



Working on the railroad

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When people learn that over one million railcars in North America are equipped with two radio-frequency identification (RFID) tags, they are surprised. When they are also told that the railcars have been equipped with RF tags for over 20 years, they are shocked. Most people's perception of the railroads is that it is an old industry that is slow to adopt new technology. This is far from the truth.

Fifty years ago, railroads in North America began searching for a system that would allow them to automatically identify railcars. In the late 1960s, the Association of American Railroads (AAR) adopted an optical identification system that used color-coded labels. These labels were mounted on each side of the railcar. This system was called Automatic Car Identification or ACI. All railcar owners were required by the AAR to install these labels on their cars. This requirement led to the full-scale implementation of the ACI system in the early 1970s. Unfortunately, because dirt accumulated on the labels and the labels began to deteriorate with age, the system's accuracy was much less than expected, and ACI was eventually abandoned



IMAGE LICENSED BY INGRAM PUBLISHING

Digital Object Identifier 10.1109/MPOT.2015.2410372
Date of publication: 8 September 2015

in the late 1970s. Due to this failure, railroads did not seriously search for another system to identify railcars until 1986 when they believed new technologies could meet their requirements.

There were a couple of other issues that stimulated this renewed search. In the late 1980s, there was a derailment in Ohio. According to the railroad's train list, the railcars

that derailed were carrying hazardous commodities. Fortunately, the train list was wrong, and the railcars carrying the hazardous commodities were in another part of the train and did not derail. But what would have been the implications if it had been the other way around with the derailed railcars actually containing hazardous commodities when the railroad thought that they did not?

According to a study by one railroad during this same period, 80% of its train lists were wrong. The train lists would have extra railcars that were not in the actual trains, the trains would have railcars that were not in the list, and the actual positions of the railcars in the trains would not correspond to the list.

ing read would always be the same. This fixed distance would allow the readers to be positioned so they would always be close enough to the tag for the reader's RF signal to power-up the tag's internal electronics, thus eliminating the need for a battery.

It was important that data encoded into the RF tag could be entered and changed in the field. Railcars are constantly moving. To equip over one million railcars, railroad employees in the field had to be able to encode the railcar data into the tag and install it on the railcar during the short time the railcar is at their location.

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The railroads searched for a system in which railcar-mounted equipment (for example, an RF tag) would possess the following attributes:

- 99.99% read reliability at speeds up to 70 mi/h
- maintenance free for a period of 15 years
- operational in the railroad environment with a failure rate no greater than 5% per year.

At the time, only an RFID system could meet the speed and reliability issues in an all-weather environment. However, most RFID systems required batteries, which meant that they could not be maintenance free for 15 years.

The railroads had one major advantage; the system they were searching for would not require a long RF read range. Since railcars are confined to a track, the distance from a reader to the tag be-

ing read would always be the same. This fixed distance would allow the readers to be positioned so they would always be close enough to the tag for the reader's RF signal to power-up the tag's internal electronics, thus eliminating the need for a battery.

They are not owned by railroads. They are owned by holding companies that lease the railcars to railroads and shippers. When a railcar lease is transferred to another railroad or shipper, the reporting marks on the railcar (equipment initial and number) are usually changed to accommodate the new lessee. This requires the data encoded into the RF tags to be changed to the new reporting marks.

Survival of the fittest

A major concern was the tags' ability to survive for 15 years in a variety of environments including a wide range of temperature, humidity, moisture, altitude, sunlight (ultraviolet light will deteriorate the case material), vibration, and impact extremes. In addition, a large portion of the railcar fleet is used to transport coal and goes through thaw sheds in the



winter. Thaw sheds heat the railcar to extremely high temperatures to unfreeze coal prior to it being unloaded. Thaw sheds use open flame or radiated heat to warm up the railcars. Temperatures exceeding 450 °F have been measured on the

ers looked to mount the tags beneath the railcar.

RF tag systems work quite well whether the tags are mounted on the sides of the railcars or underneath. The cost of installing the tags on the sides is much less than mounting

to the railcars' sides and to bolt or rivet the tags to the brackets was probably three to four times more than the cost of the tags.

In 1990, after four years of testing several manufacturers' RFID systems, the AAR adopted Amtech's RFID system (Amtech later became part of TransCore) that used a proprietary communication protocol and called it Automatic Equipment Identification or AEI. It was quite unusual for the railroads to adopt a standard that was proprietary, but very few, if any, open RFID communication protocol standards existed at the time.

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sides of railcars when they are in a thaw shed.

Surprisingly, most electronics can survive these high temperatures. However, most cases made from plastic will not. The problem with plastic is that the higher the melting point, the lower its impact resistance. The great fear was that if the impact resistance was too low, a person with a hammer could easily destroy a large number of tags on a passing train.

After years of testing, a combination of high-temperature plastic and aluminum paint solved the issue. Thaw sheds using radiated heat generated a higher temperature on the side of a railcar than open flame. Aluminum paint reflected the radiated heat away from the tag and allowed for the use of a plastic with a lower melting point and higher impact resistance.

Another issue was where to place the RF tags on the railcars. Most railroads wanted to mount two tags, one on each side of each railcar. Oth-

ers looked to mount the tags beneath the railcar. However, there is a problem with side mounting when two tracks are close together.

When tags are mounted on the sides, a reader that is installed between two tracks will sometimes read tags on both tracks and not be able to identify which track the railcar is on. This is because the reader's signal can bounce off the railcar in front of it and read the tag mounted on the railcar behind it.

On the other hand, when tags are mounted underneath, it is highly unlikely that a reader's antenna mounted between two rails on one track pointed up at the railcar would read a tag mounted underneath a railcar on an adjacent track. Due to the cost and time it would take to install tags on over one million railcars, it was decided to mount the tags on both sides of the railcar.

Even with mounting the tags on the sides, the cost of the RF tags themselves was a small part of the price of implementing this system. The cost to weld mounting brackets

Mandates and installation

In 1991 the AAR mandated that all railcars that are interchanged (handled by more than one railroad) be equipped with two AEI RF tags within a three-year implementation period ending on 31 December 1994. The selection of a three-year implementation period was based on the fact that 98% of the railcars would be in a repair shop one time during a three-year period. Amtech delivered over three million tags to the railroads by the end of 1994 (see Fig. 1).

The Amtech tag transmits 120 b of data in approximately 12.5 ms (approximately 9,600 baud). It operates in the 900–928 MHz band. The tag contains the following information:

- equipment initial
- car number
- side indicator code (left or right side of the car)
- length (in decimeters)
- number of axles



FIG1 An AEI tag.

- bearing type code
- platform identifier code.

The full tag specification can be found in the AAR standard S9203, which is available from the AAR at www.aar.org.

Initially there were thoughts of including data about the railcar's destination and cargo in the tag. But it was decided that this information was needed at the next terminal or yard well in advance of the railcar arriving and could be easily sent to that facility over a computer network. There was also concern that unauthorized personnel could read the tag and obtain sensitive information about the railcar's destination and cargo.

The railroads immediately started installing reader sites along their mainline tracks. No one knows for sure, but it is estimated that there are now between 6,000 and 10,000 railroad reader sites in North America (see Fig. 2). These exist not only on the railroads but also within the facilities and at the gates of railcar shippers.

One of the weaknesses of the original AEI tags was the need for a programming port on the back of the tag. To encode data into an AEI tag, a tag-encoding device called a tag programmer had to have physical electrical contact with the printed circuit board inside the case. A hole or programming port was designed into the case to allow for this contact. Once the tag was encoded, the port would be sealed with a push plug that had an O-ring.

For a multitude of reasons, the push plugs were not always properly inserted. Often the O-ring would twist when the plug was inserted, causing a bad seal. When the tag heated up during the day, it would force air out through the bad seal, and when it cooled down at night it would suck moisture in, which would at first degrade the tag's performance and eventually cause a failure. Even though there was an issue with the programming port, tag read reliability and a low failure percentage greatly exceeded the railroads' expectations.



FIG2 A wayside reader.

In 2005 TransCore developed a new AEI tag without a programming port to replace the original tag. The new tag's printed circuit board was completely sealed inside the case. When the tag was inserted into a tag programmer, the programmer would send an RF signal through the case to encode the data. The elimination

of positive identification of the railcar, it is almost impossible for these detectors to collect measurement data on a particular railcar, axle, or wheel to do any trending analyses.

There are currently few defect detectors that incorporate AEI readers. Until recently the railroads have placed very little emphasis

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of the programming port greatly increased the read reliability and reduced the failure rate of the tags.

The railroads' AEI program has been a great success in tracking railcars on the railroad mainlines. It is also heavily used with scales to associate the railcar's weight with its ID. Unfortunately, there are still many areas in the rail industry where AEI is underutilized.

The railroads have many different types of defect detectors along the tracks. Twenty years ago, when the AEI standard was developed, fields such as bearing type code, number of axles, car length, and side of the car were included in the tag's data to assist these detectors in identifying the railcar and the axle or wheel on the railcar having the defect. With-

out incorporating AEI readers into these defect detectors. Why it has taken so long to incorporate the AEI readers into these systems is somewhat of a mystery.

There is a great potential for the utilization of AEI by shippers to identify the locations of railcars within their facility, but a very small percentage of shippers have installed AEI readers for this purpose. There are a number of reasons for this underutilization.

A railroad AEI reader system does much more than just reading the tags. The AEI reader system must build a clean train list and send it off to another computer system. These systems not only must read the AEI tags, but they must be able to detect when a train is present, the direction



FIG3 A portable reader.

the railcars are moving, if the train is moving back and forth in front of the reader, if there are railcars with missing or nonworking tags, and when the train has finished passing the site. Track circuits or presence loops are often used to determine train presence. Wheel detectors are usually used to determine direction and when there are railcars with no functioning tags. Some companies are now using various radar configurations instead of wheel detectors and other on-track sensors to provide this information.

It is a complex process to coordinate data from all of the different sensors to create a clean train list, and there are only a small group of companies that have experience in developing these systems. This process gets even more complex in a yard where tracks are close together, and the possibility of reading tags on an adjacent track is a major issue.

The price of purchasing, installing, and maintaining an AEI reader system in a yard environment is often prohibitive. In many cases it becomes difficult to justify the expense, and railroad customers often opt to use a single stationary AEI reader at their rail gate to know when and what railcars have arrived or departed their facility and a portable AEI or vehicle-mounted reader to know what railcars are on each track.

Portable AEI tag readers have been available for close to 20 years but have not been widely used. They are typically too big, heavy, and expensive and also have a short read

range of approximately 5 ft. Some facilities use portable readers to read tags on railcars from a vehicle. However, this is difficult due to their short read range.

Vehicle-mounted readers have a much longer read range because they get their power from the vehicle and have a larger antenna. These are not widely used because few vehicle-mounted systems are offered.

Portable readers are also used to associate barcoded information from seals, products, parts, and loading/unloading positions with a railcar. By having an AEI reader and a barcode reader in a single unit, the accuracy and speed of collecting this data greatly increases. Again, their size and cost has greatly reduced the use of portable readers for this purpose.

RF evolution

Unlike barcode readers, there has not been much improvement in the design of AEI RF readers for the railroad market in 20 years. Almost all of the stationary and portable readers in service have been provided by a single company.

One of the problems of early adopters of RF identification is that the systems that were available at the time did not use an open communication protocol. When the AAR adopted the Amtech identification system, it was agreed that Amtech would be required to license its communication protocol to other manufacturers who could then manufacture compatible tags and readers. Unfortunately, no other manufacturer had an interest in acquiring a license to manufacture compatible equipment.

It the early 2000s Amtech's communication protocol patents expired. After they expired, several other companies started manufacturing stationary RF readers that could read the AEI tags on the railcars. Some of these newer readers have many advanced features that the current AEI RF readers lacked. These include direct network connections and the ability to internally run user-written scripts (programs) that provide a great deal more infor-

mation about the RF signal than the reader receives from the AEI tag.

These advanced features have the ability to greatly reduce the cost of installation and maintenance of the AEI reader systems, while helping to solve some of the problems, such as reading AEI tags on an adjacent track. I call these *smart readers* because their advanced features are analogous to the features that differentiate a smartphone from a regular cellular phone.

Unfortunately, the companies that manufactured AEI-compatible readers did not target the railroad industry. They primarily targeted the toll and access control markets and almost totally ignored the railroads.

In the last couple of years, some AEI reader system developers and railroads have started installing these advanced RF readers. These newer RF readers have significant advantages over what is currently being used, and they have the ability to realize the enormous potential that AEI has for the rail industry.

Recently, a mobile computer manufacturer integrated an RF reader that can read AEI tags into one of its mobile computers. This mobile computer also has a built-in two-dimensional imager. This unit is small, lightweight, and less expensive than the current portable reader (see Fig. 3).

There is a great need and many opportunities for expanding the use of AEI RF systems in the railroad industry. Hopefully more manufacturers and system integrators will develop RF readers and reader systems. Their participation would be a tremendous benefit to the industry.

About the author

Tom Levine (tomlevine@signalcc.com) has over 40 years of experience in the railroad industry and has worked on classification yard, train dispatching, and AEI reader systems. He has a B.S. in electrical engineering from Carnegie Mellon University and served in the U.S. Marine Corps and the U.S. Army.

