# A Temperature-Managed Traceability System Using RFID Tags with Embedded Temperature Sensors

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**Abstract**

The recent rise in social needs for the "safety" of various products and services have made precise quality control necessary in various fields such as for: medical care, logistics, trade and equipment management as well as for the food industry.

One of the most important parameters of quality control is the temperature. In the case of products that require temperature management, the storage temperatures have long been managed using specialized thermometers located in the storage facilities. Nevertheless, there have often been cases in which damage to the products was found only after they were delivered to consumers via various distributors and it has been difficult in such cases to precisely identify the cause of the quality degradation.

This paper introduces a solution to the above problem that uses "RFID tags with embedded temperature sensors." It will also introduce the "Temperature-Managed Traceability Starter Kit" that contributes to effective risk management by easily enabling consistent temperature management throughout transportation processes.

**Keywords**

traceability, temperature management, risk management, RFID sensor, ZigBee, middleware

## 1. Introduction

### 1.1 Traceability of Foodstuffs

Until very recently, very few people have cared about "how a product delivered to me was manufactured" or "how it was transported to me." Many problems and accidents have lately occurred with foodstuffs, which are among our most familiar products. As a result, the awareness of consumers with regard to "food safety" has suddenly begun to rise and many questionnaires conducted by administrations and consumer organizations show the statistical results that "80% of consumers are interested in this issue." The consumers who need "reliability on safety and quality with regard to foodstuffs" now demand that the food-related businesses introduce "traceability systems" as a means of risk management to forestall emergencies.

What is basically required when building a traceability system is to manage product lots from the most upstream to the most downstream locations. When you find a problem with a specific product, it is impossible to trace it back to past accidents and identify the precise cause without effective lot management, even if a large amount of related product information is available. All the manufacturer can do under the circumstances is to recall and refund on all of the manufactured products in the batch. Such a burden is critical, both for the manufacturer and also for other businesses that did not manufacture the product. How could they avoid bearing both the cost and the consequent decline in their corporate images? An ideal solution would be to build a traceability system based on cooperation by the various businesses involved in covering the entire supply chain.

However, it is not so easy to promote the actual building of a traceability system due to problems related to cost sharing. There are also additional problems such as the definition of correspondence between the codes used by the existing systems of the different businesses and their methods of standardization. **Fig. 1** shows the types of businesses that are involved in the

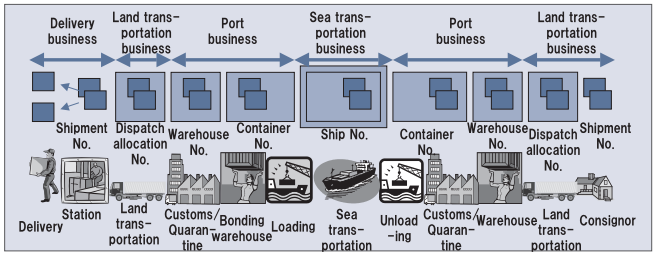


Fig. 1 Various types of businesses involved in the context of global logistics.

global logistics of the supply chain. When there are a large number of businesses involved as shown in this example, it is not instantly possible to build a new traceability system that spans all of the businesses. Instead, what is required in the beginning from the viewpoint of risk management is to implement a traceability system within the range of responsibility of each firm.

### 1.2 Foodstuffs Freshness Management

Once the traceability of the entire foodstuffs supply chain is completed, quick and accurate product recall becomes possible in the event of an incident occurring within certain product lots. However, the traceability system is still far from being ready for dissemination due to the many issues yet to be solved, as described above. It is also difficult for the present to clarify if an abnormality in a production lot was produced during production or during transport. As the management of freshness is a very important function for fresh foods, it is desirable that the quality conditions during transport are clearly understood. If, for example, changes in temperature during transport can be identified, it is at least possible to determine if there has been a problem in the temperature management during transport, even when an abnormality occurs within the product lot. Food manufacturers generally receive certain types of complaints from their customers. But if the cause of the problem is unclear, an explanation cannot be persuasive and a decision cannot be made whether or not the products are to be recalled. In this context we realized that sensing devices can offer a means of effectively dealing with this problem.

## 2. Technology for Sensing the Status of Objects

### 2.1 Market Needs

As described in the previous section, consumer awareness of the product quality is currently at a very high level, as also is interest in the "traceability of quality assurance." There are various factors that degrade the quality, and one of the most important among these is the temperature. It is therefore important to develop mechanisms that can detect products that have their quality degraded due to inappropriate temperature management in order to prevent their shipment.

### 2.2 Requirements for Temperature Management

Traditionally temperature management has been applied using thermometers installed in trucks and warehouses and recently some businesses have employed compact temperature loggers for temperature management. Businesses that are either now using or intending to use temperature management systems must satisfy the following requirements.

**(1) Ease of Introduction**

In many cases, merchandise necessitating quality management is distributed among more than one distributor. As temperature management in the distribution path often necessitates the cooperation of several businesses, it tends to be difficult to effectively apply a management system among all of them.

**(2) Ease of Data Collection**

When thermometers installed in warehouses and trucks are used for the management, periodical temperature checks are required. In the case of management systems that also use temperature loggers, each logger should be connected physically to a PC and the data collection becomes a manual operation.

**(3) Individually Applied Temperature Management**

Conventionally management has been done by sampling individual packages on a per-warehouse basis. However, temperatures at the entrances and deep inside warehouses tend to vary greatly because there is a wide variation in the temperature at the entrance due to the opening and closing of the doors. Therefore, the thermometers installed in the warehouses or trucks are sometimes incapable of recording the correct temperatures of the products.

**(4) Low Temperature Management Costs**

In the past, the system construction costs and the high labor costs of the operations have been obstacles to the introduction and deployment of temperature management systems.

### 2.3 RFID Sensor Tags

An RFID sensor tag incorporates temperature, humidity, illuminance, and/or shock sensors. Usually, it also incorporates memory, a battery and a clock to record sensor data in memory at constant intervals. The history of "when" a tag was "in which status" can then be accessed later by reading tag memory.

The properties of RFID sensor tags are suitable for meeting the requirements of the temperature management system users (**Fig. 2**).

An RFID sensor tag with embedded memory can measure and record temperatures by itself. This means that a business can perform temperature management across multiple businesses by starting/stopping the measurement and collecting the data independently, without requiring other businesses to perform the work required for the temperature management.

Since RFID sensor tags collect data using wireless communication, it is not required for any work to be done to connect

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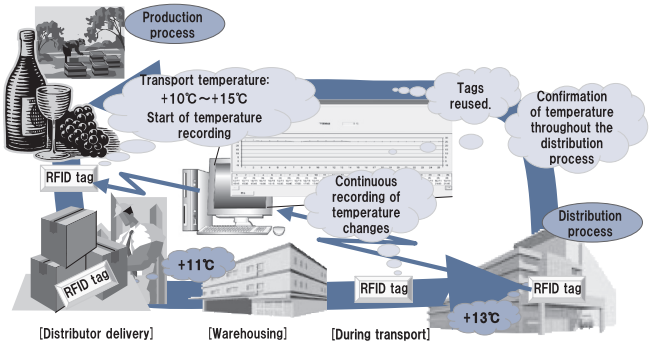


Fig. 2 Utilization of RFID sensor.

to a PC. This not only means that there is a reduction in the required connection work but also that there is the added benefit of automated data collection. The data collection is thus facilitated because automatic data collection becomes possible provided that the RFID tag is located within the read range of the RFID reader.

The fact that each tag has a unique ID can also be used for the temperature management of individual items by combining temperature management with the inspection function.

From the viewpoint of price, too, the cost of using RFID sensor tags is lower than for the temperature loggers, so the system can be constructed at a relatively low price.

### 2.4 Another Wireless Sensing Device

The ZigBee module with built-in sensor is another type of wireless sensing device to the RFID sensor tags.

The RFID tag was originally developed to enable individual identification, and RFID tags are attached to each product or on a per-palette basis for use in tracing distribution paths, improvements in inspection job efficiency and automation of the inventory checking function. Since using the RFID tags in temperature management makes it possible to manage the temperature of each product or on a per palette basis, the system is suitable for use in temperature tracing throughout the period of delivery of products.

The ZigBee is a device that targets the networking of modules and its use started in the observation and management of buildings and environments. In temperature management, it is possible to install ZigBee modules with a built-in sensor in a warehouse to replace the existing thermometers and to collect the temperature data in the warehouse automatically. This does away with the need for human labor to be increased, because the multiple ZigBee modules can be networked automatically for the collection of data at a single location. Due to these advantages, the ZigBee modules are suitable for use in the fixed-point observation of a warehouse or truck.

In the future, it will be possible to create temperature management systems by combining devices that feature different properties.

### 2.5 Sensing Middleware

Since the fields of applications of sensing devices vary depending on their types and models, it is essential to select and use a device according to its prescribed application. This means that a framework should be created so that any device can be handled in the same way from the optimum perspective of the application.

For this purpose, our RFID middleware "RFID Manager" incorporates a plug in device interface for absorbing differences between devices. By incorporating the framework for sensors in this interface, it is possible to construct a sensing system with a device selecting capability. A sensing system constructed in this way can deal with any system in which sensors of various types and tags of different standards are mixed by arranging data and transferring it to the higher-level application (**Fig. 3**).

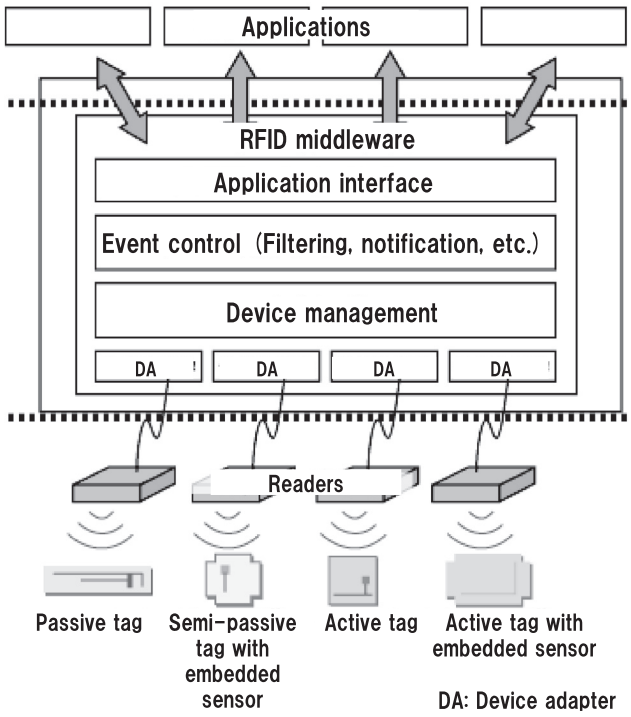


Fig. 3 RFID middleware system configuration.

The system using the RFID Manager has an event control function that can select desired information from multiple tag IDs or from a large volume of tag temperature data and notify its application. This makes it possible for example to notify the application only of the data indicating quality abnormalities.

Due to the still small number of types and absence of standards, the utilization procedures and setting parameters of RFID sensor tags vary widely depending on the source. The parameters related to the sensing operations themselves are also so complicated that it is extremely difficult for end users to synchronize them properly, with a clear understanding of their diverse features. The RFID deals with this problem by providing an interface that may be easily utilized by end users. It is one of the important roles of middleware to improve the usability in this way.

## 3. Temperature-Managed Traceability System

### 3.1 Simple Risk Management Technique

If the status of objects can be identified as data, the expression of unexpected events can be improved. The traceability of the entire chain is important, but the market also needs a simple risk management technique for use in cause analysis as a prior step to fault tracing. For instance, temperature management is applied not only in the food industry but it is also needed in various aspects of various businesses handling products that have a temperature management requirement, such as in medical care, warehousing and the trading industries. Simple risk management in these applications is possible by transporting product lots while integrating the sensing devices together with them.

### 3.2 Starter Kit

Unlike traditional loggers, RFID sensor tags are suitable for integrating batch management with an application system. However, some users might be wary of beginning construction of a system without knowing if it can withstand the actual operations. In order to meet such hesitant opinions, we released the "Temperature-Managed Traceability Starter Kit" for users who want to adopt step by step approach.

The Starter Kit is provided as a package that contains temperature RFID sensor tags and an application program to avoid giving trouble to the user. As the installation and RFID tuning operations are performed by specialized engineers before delivery, the system may be used immediately after delivery and installation by connecting the cables and supplying power. The basic operating procedure is as follows.

(1) Launch the application to recognize the tags in the proximity of the RFID read/write devices (All of the tag control operations can be executed from the application without the need of tag registration in advance).

(2) Start the setup by entering temperature measuring intervals and basic information on the product and send instructions to the designated tags (multiple tags are possible) by means of wireless communication, in order to begin recording the temperatures.

(3) Arrange for the transportation of the tags together with the product lots.

(4) Collect the tags at the delivery destination (this can also be done by collecting from the returned container).

(5) Launch the application to recognize the tags in the proximity of the RFID read/write devices and obtain the temperature history data of the designated tags (multiple tags are possible) by means of wireless communication.

(6) Check abnormal temperatures. If a problem is found, the details can be checked on a reference graph. The data can also be output in file format.

## 4. Conclusion

**Fig. 4** shows the actual data obtained using the Starter Kit.

We introduced the solution using the RFID temperature sensor as a means of a simple implementation of continuous temperature management throughout the process of transportation. However, in the real world in which a large number of lots are distributed daily, an abnormality may frequently be discovered "afterwards." What is required in the future is the "real-time management" of abnormalities and their instant recovery in the event of a problem. Such a process will necessitate a system that can send the status of "objects" in transportation to the management center via a communication circuit. Since a communication circuit is not always online, it is also necessary to take the requisite measures for the period in which it is offline. In addition, the service will not be limited to Japan, so the radio regulations in other countries should also be considered.

We are conscious of many problems to overcome, and we will make every endeavor to provide solutions that are deserving of the Ubiquitous society.

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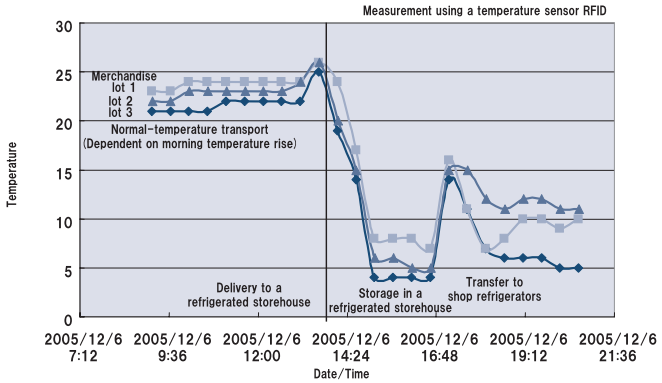


Fig. 4 Temperature changes during an actual delivery of merchandise.

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