Development of Digital Photo System Using RFID Technology In Plant Construction Management

Hatori Fumio[1], Yoshimura Yasushi[2] and Ebata Shinichi[3]

1:Hitachi Plant Technologies,Ltd. Business Development Div. 5-2 Higashi-Ikebukuro 4-chome,Toshima-ku,Tokyo,170-8466 Japan, e-mail:fumio.hatori.zq@hitachi-pt.com
2:Hitachi Plant Technologies,Ltd. Matsudo Research Laboratory
3:Hitachi Plant Technologies,Ltd. Energy Systems Div.

Abstract

We have studied the applicability of RFID tags and developed systems to provide clear work traceability to streamline administrative task in the construction work of a plant. Our test results indicate that RFID tags can be used effectively for these purposes. We have developed a method for effectively proving whether a digital photo is authentic or not in order to obtain clear work traceability, along with a system to reduce the time spent filing digital photographs and associated information correctly in a short time.

Keywords: Material management, progress management, IC tag, digital camera

1. Introduction

The rationalization of construction costs is strongly urged. On the other hand, quality control and the safety management of the construction become very important, too. But, the labor productivity of construction industry is low in comparison with the other manufacturing industry. In order to solve these problems, construction management system using information technology becomes more important. RFID (Radio Frequency Identification) is attracting increasing attention as a basic technology for the incoming ubiquitous society. Various experiments are being performed to apply this technology to commodity distribution businesses and production plants. For the practical use of an information system, there is also the need to develop underlying hardware as well as useful applications.

The construction of a large-scale plant requires a great number of equipment, materials, workers and temporarily stored products. In order to assure the construction quality, the traceability of work history, from factory production up to an installation inspection in a destination site is required so that people can find who did particular works when and how, which involves enormous amounts of manpower management. In this report, we study the environmental resistance of RFID in a plant construction site, and work traceability as the key control item to view the applicability of RFID, and describe the development of RFID-used applications.

2. Plant construction Management and study of RFID applications

2.1 Traceability of work

To assure the quality of construction work, a work history is kept to see when and who did which task, as well as recording working conditions and inspection results. This operation is called work traceability, providing a work quality assurance record and the means of finding the root cause if a defect is found after a plant starts operation.

Fig. 1 shows the flow of example installation work of pipe grooves matching and work records. Pipes delivered to a building interior are temporarily suspended near their installation site. An inspection is performed to check that no foreign matter is contained in the pipe interiors, and photos are taken to prove it. Subsequently matching of pipe grooves is performed. During this stage, when the work was carried out and by whom is recorded, according to the instructions for grooves matching work. Upon completion of this work, a witness inspection is conducted to see and record whether the work has been done as instructed. If the work passes the inspection, welding work is performed. In addition to the next welding and piping

works, other works are also recorded to ensure work quality and provide traceability for the same. These control subjects can be identified by RFID and their information can be input by RFID, helping to improve recording efficiency and quality control.

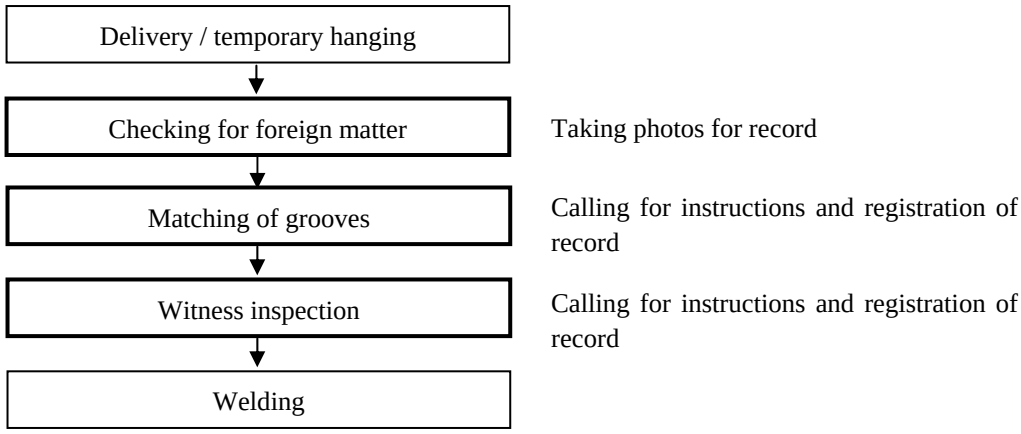


Fig. 1 Piping work and recording

3. Problems for RFID applications and study method

3.1 Assessment of environmental resistance

Assuming the use of RFID in construction sites, we have selected the assessment items of RFID environmental resistance, which are indicated in **Table 1**, along with the assumed conditions. We have conducted tests to check that RFIDs can perform reading without being damaged and to see whether an RFID can be used for construction work without any problem. In addition, low cost is a prerequisite because a huge quantity of RFIDs may be used for material control. Out of the RFIDs available when we performed assessment, we selected widely-used low-cost RFIDs and tested them. **Fig. 2** shows the conditions of the test conducted to assess the influence of welding heat on RFIDs. The RFID tags were exposed to the simulated environmental conditions of construction sites in order to test them for the respective assessment items and check whether an RFID reader can read the IDs recorded in the tags.

The attaching of RFID tags at equal intervals from the weld line: Measurement of temperature with a thermocouple

Table 1 Assessment items of RFID environmental resistance and assumed conditions

No.	Environment of the construction site		Assumed conditions
1	Temperature	At high temperature	Welding is performed near RFIDs
		At low temperature	Stored outdoor in winter (-20°C)
2	Noise influence		Use of RFIDs near a welding machine
3	Transportation of products		Shocks are given when products are transported and unloaded.
4	Hydric environment	Rain	When it is raining
		Snow	When it is snowing
5	Contamination	Iron powder	Iron powders are adhered to an RFID in a building under construction.
		Paint	Paint is adhered to an RFID.

Fig. 2 Assessment test of welding heat

3.2 Problem in work traceability

Documentary photography is vital as evidence for construction work traceability. However, the present documentary photography has the problems shown in **Table 2**.

There are many similar-looking inspection subjects such as pipes, and so the picture of a subject is taken together with a board on which the necessary information is written so that the subject can be identified. If no such board is photographed, a documentary photo cannot specify which product is shown. However, this method cannot prove the information given by a photo is the same as that given by a board. Furthermore, when organizing many photographs, photo files must be opened one by one to check the board information, which is a time-consuming operation.

To solve the above problems, we have studied methods to prove whether a photo is authentic or not and reduce the time required to organize photos and search them, and developed an effective RFID-applied photography control system.

Table 2 Present problems for photography control

Item	Present status	Problems
To prove whether a photo is authentic or not	Information of a subject is indicated on a board and photographed.	It is difficult to prove whether the board information is really for a taken photo.
Efficiency for organizing photos	Screen images should be checked to see photo images.	A person should see a screen image and judge.
Efficiency for searching a photo	Photos are placed in work record control files.	It takes time to find a specified photo.

4. Results of RFID applicability assessment and development of a new application

4.1 Results of the environmental resistance assessment

Table 3 shows the environmental resistance test results of RFID. ○ indicates that the RFID tag was not destroyed and could be read quite normally. △ indicates that the reading distance was shortened and × indicates that no reading could be made.

In most test items, not all the tags were destroyed and some could still be read. However, if they were remained wet or in direct contact with metal, reading could not be made, although when tags are used outdoors in rain or snow, the results show that they can be read without any problem if moisture is removed. Likewise, if an isolation material is used to separate a tag from a metal by 2~5mm, readings can be made. In a test for the transportation of products, 2.45GHz and 950MHz tags with a dipole antenna were found to be readable provided their chips were not destroyed even if their antennas were cut. However, the 13.56MHz coil-shaped tag could not be read if its antenna was cut. The antenna of the 2.45GHz tag is smaller than that of the 13.56MHz tag, and so the 2.45GHz tag is less vulnerable to an impact. In particular, when a tag is

attached to a heavy material such as a pipe, a bigger tag is more likely to be subjected to impact and damaged due to its size.

Table 3 Assessment results of RFID environmental resistance

No.	Test environment		Type（Frequency）			Remarks
			13.6 MHz	2.45 GHz	950 MHz	
1	Temperature	At high temperature	○	○	○	Temperature near RFID: 283°C
		At low temperature	○	○	○	Reading can be made at - 20°C
2	Noise influence		○	○	○	Welding machine
3	Transportation of products		×	△	△	Capability is reduced when the antenna is cut.
4	Hydric environment	Rain	○	○	○	Usable with an additional measure
		Snow	○	○	○	Same as above
5	Contamination	Iron powder	○	○	○	Usable with an additional measure
		Paint	○	○	○	

The RFID communication distance is also influenced by the output of an RFID reader. In a simulation for practical use, we used a low-output handy reader. The results indicated that the reading distance was shorter than that shown in the catalog, even under normal conditions. It was 50mm for the 13.6MHz tag, 30mm for the 2.45MHz tag and 100mm for the 950MHz tag. The difference between the actual values and catalog values is excessive, meaning the communication distance should be slightly longer for practical use.

The above results indicate that RFID can be used for a plant construction if an improved operation method is devised for a problem such as that caused by metal contact. And, we have found that an RFID may be damaged during product transportation and that a tag with a dipole antenna has higher damage resistance.

4.2 Development of a photography control system

Fig. 3 shows the outline of the RFID-applied photography control system. The RFID of a subject product such as a pipe is read by an operator in a construction site and the RFID information is sent to a digital camera. Subsequently the information transferred by the RFID reader is embedded into the photo file taken by the digital camera and the photo can be proven to be authentic. After returning to the office, an operator registers the photo files taken together with the RFID files into the database and can organize the photos and search for them by using the RFID codes. The following describes the detailed respective functions:

(1) Proof of photo authenticity

Fig. 4 shows the procedures used to record the photos. An operator for inspection and recording uses a computer system equipped with an RFID reader to read the RFID tag attached on their helmet and thus identify themselves. Subsequently the test results are recorded into the computer system, and the RFID tags used to identify the inspection subjects are read. The time (t_0) when the RFID is read is recorded in the computer system, whereupon the subsequent elapsed time is monitored. The time (t_1) when a photo is taken is checked, while the computer system also checks the time having elapsed since the RFID tag was read until a photo was taken (t_1-t_0) and judges whether the photo was taken within the allowable time (t_a) for taking photos. If a photo is not taken within (t_a), the read RFID tag information used to identify a product is deleted and the photo taken becomes invalid. If a photo is taken within (t_a), the RFID tag information is embedded into the photo information and recorded. The allowable time (t_a) should be the time during which

it is impossible for an operator to move elsewhere to take a photo of other subjects. If a piece of RFID information is one and only and it is impossible to take a photo of a product other than the particular product in question, the RFID information of which has been read, we can prevent a mismatch between the RFID information and the subject in the recorded photo and prove the authenticity of the photo taken.

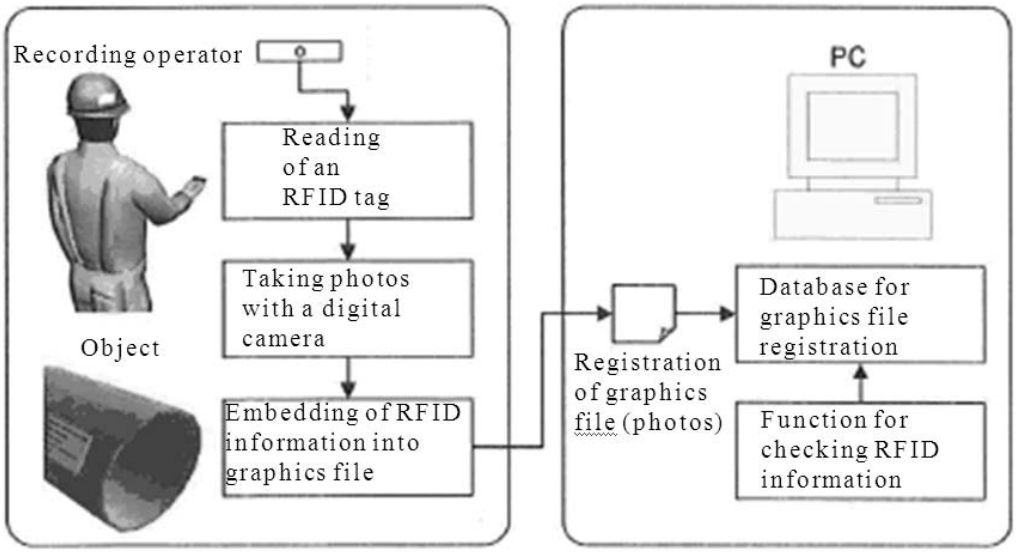
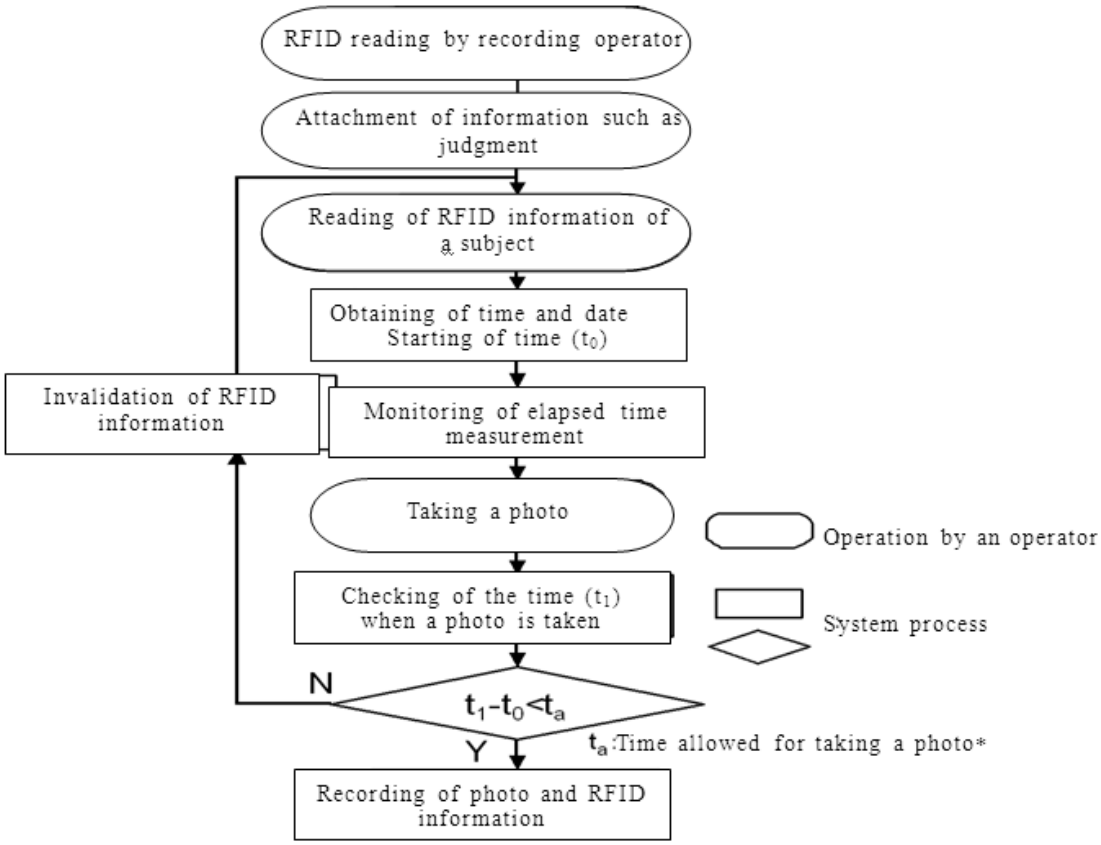


Fig. 3 Outline of an RFID-applied photography control system



*Time allowed for taking a photo: Allowable time for taking a photo after reading an RFID tag to prevent an operator from moving elsewhere or taking a photo of another subject.

Fig. 4 Procedures for RFID-used photo recording

(2) Filing of photos and searching function

We have studied methods for embedding an RFID code into a photo file to prove a taken photo is authentic and automatically judge a subject in a photo. The format of photos taken by a digital camera is standardized. The standard, known as EXIF (EXchangeable Image File format) specifies the types of information registered in a photo file and the storage location. As for the types of information, these include image size, resolution, photographing condition, maker name, camera model number, latitude, longitude and optional conditions, etc., while storage areas for writable information are specified for the respective types. A storage area for user information is also included in the same, and we have decided to use that area to write the read-in RFID code information.

Information written in EXIF can be referenced and checked in the application. Using the image database software, we have constructed a system where by referencing an RFID code recorded in the user information area of EXIF, an operator can check information associated with the RFID codes for subject items such as a recording operator and piping. This system enables an operator to search for the photos registered in it without opening files if the recording operator name or product name is given.

Fig. 5 shows the configuration of the RFID-applied photography control system. This system consists of a PDA and digital camera, both of which have the Bluetooth function, a short-distance radio communication standard. The PDA performs the input of an inspection record and reading of an RFID tag, and the data are transferred to the digital camera by Bluetooth communication in real time. RFID information is always transferred if a photo is taken within the allowable time. However, if no photo is taken within the allowable time, empty RFID information is transferred and the RFID information that has been transferred up to that point is deleted. The digital camera has a function to write RFID information sent by the PDA into the EXIF user information area.

For software to register and control the photos embedded with RFID codes, we have used the software for image control. This software is used to check the RFID code embedded in the EXIF user information area for photo files, search for specific photos and create a file sheet based on the RFID codes and information associated with the subjects.

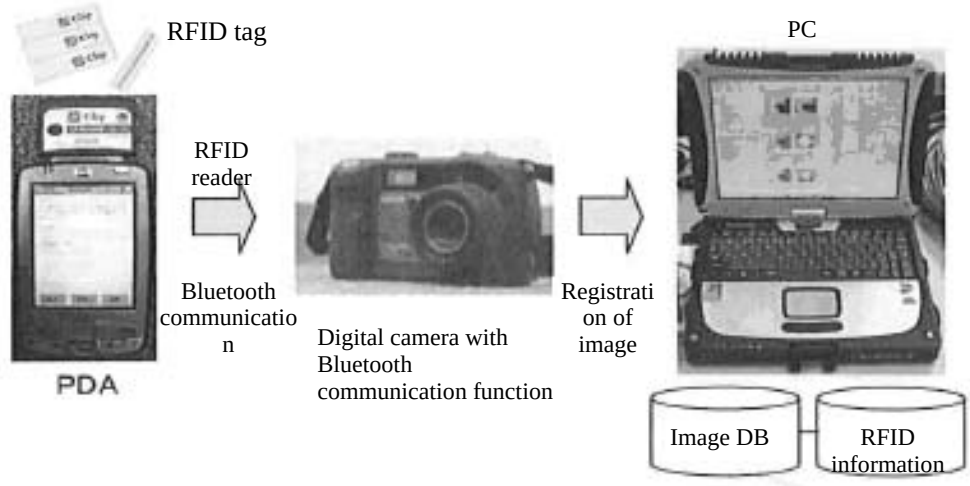


Fig. 5 Configuration of the photography control system

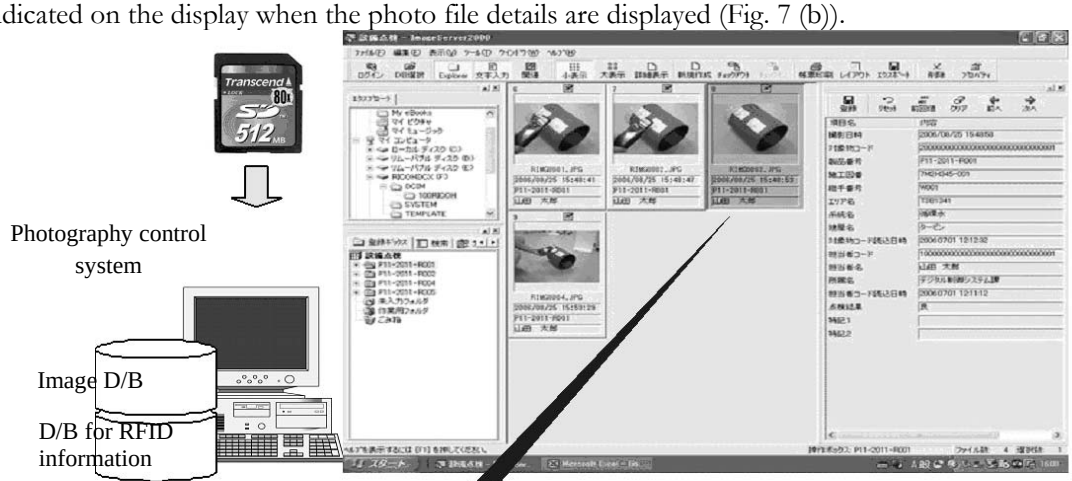
Fig. 6 shows the RFID-applied photography control system's screen transition. When the software is started, the user authentication screen is displayed to prompt an operator to read an RFID tag. The operator reads the RFID tag for self-recognition, which is attached to his helmet **(a)**. Subsequently a pass/fail judgment is performed in the inspection result input screen **(b)**. When the photographing-ready button is pressed, the RFID reader enters the state where reading can be performed. The reader reads the RFID tag attached on a subject pipe and transfers the RFID code and inspection result to the digital camera while keeping the read-in time of the tag as shown in the data transferring screen **(c)**. The transferred RFID code is displayed on the liquid crystal screen of the digital camera so that an operator can check the data transfer

status. When a photo is taken in this state, the RFID code and inspection result are embedded into the EXIF user information area within the photo file.

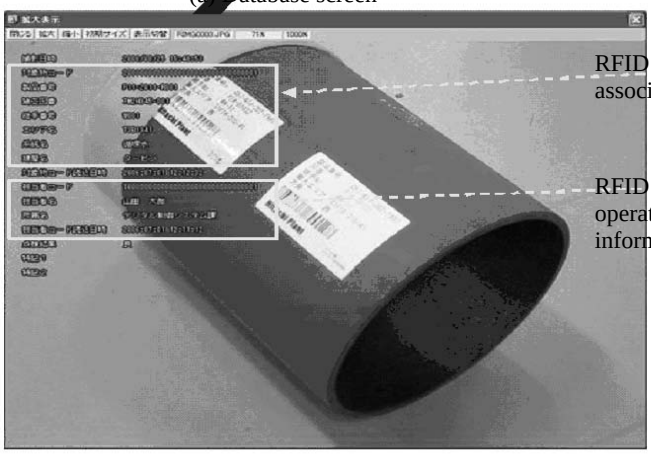
(a)User authentication screen (b)Inspection result input screen (c)Data transfer screen

Fig. 6 Diagram showing transition of PAD screens

A database software screen for photography control is shown in Fig. 7. The photos taken are recorded in a memory card, while the photo files recorded in the latter are registered in the image database. The belonging section, the operator's name for the operator RFID code and the drawing number, welding point number, system name and similar for the piping RFID code are recorded in an orderly manner within the database software in advance. The photo file is registered and at the same time the RFID information is called from the EXIF user information area to display the associated information. This information is indicated on the display when the photo file details are displayed (Fig. 7 (b)).



(a) Database screen



(b) Display of the photo file details

Fig. 7 Database software screen for photography control

c) Checking of the effects

A RFID code is issued on a one and only basis, meaning a subject pipe can be uniquely identified provided no human error is made when attaching the RFID tag to a pipe. Therefore, if the RFID code for the subject item is embedded into the photo without fail, the photo's authenticity can be proven. Only provided a photo is taken within the specified time, can this system allow registration of the RFID for the photo in order to definitely associate the photographic subject with the RFID code. We did set this allowable time for photographing at 30 seconds and tested photography accordingly. Under the circumstances simulating a construction site, an operator was well able to take a photo of a subject item within 30 seconds. However, it was impossible for an operator to move elsewhere to take photos of other subject items. For the construction of a plant in which bulky products are used and the photographic subjects are located over a wide area, the reliability of this system to prove whether or not a taken photo is authentic can be increased by restricting the time allowed for transferring RFID information. For small-diameter pipes, however, it was impossible to prove 100% correctly whether the photos for all the subject items were authentic or not. We will study the range of valid authenticity as well as the practical use of the system.

By using this system instead of the traditional method for writing RFID information on a board in a construction site, an operator need only read information from the RFID tags attached to the operator and product and take photos, meaning the work can be simplified and the working time reduced. Traditionally an operator had to spend as long as 2 to 3 hours checking photos and filing those taken for the purposes of product inspection work, which took half a day. We have confirmed that this system enables an operator to search for photos and file them automatically in an orderly manner within about 30 minutes.

5. Conclusions

We have studied the applicability of RFID technology to streamline the control work in plant construction, developed an RFID-applied application and obtained the following conclusions:

- We have conducted environmental resistance tests for RFID under the circumstances whereby a construction site is simulated It has since been confirmed that the RFID system could be used practically without a problem.
- We have proposed methods to embed RFID information into a photo file and restrict the time allowed to transfer RFID information
- By using a database system for photography control, we have developed a system enabling us to automatically call a subject item from RFID information and create a file sheet.

We have already started using our developed system, and confirming the application effect. We think the RFID technology progresses still more. We will also continuously check new products to improve it and study the application of this technology.

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