

Application of RFID Technology to Construction of High-reliability Nuclear Power Plants

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OVERVIEW: As regards construction of nuclear power plants, the requirements covering an enormous number of various kinds of product lines in the order of millions of units must be satisfied and rigorous traceability concerning products and manufacturing and inspection operations must be assured. Focusing on the functionality and versatility of RFID technologies that have been gaining much attention over recent years, Hitachi has started development and testing for application of RFID as a solution for three key targets: (1) improving efficiency of management of work operations and goods used in construction of nuclear power plants, (2) assuring high reliability of information traceability, and (3) preventing human errors while improving work efficiency.

INTRODUCTION

IN regard to construction of nuclear power plants, it is necessary not only to handle various kinds of components, products, and tools in large volumes exceeding millions of units, but also to rigorously ensure “information traceability” concerning materials composing each manufactured article, manufacturing processes, and installation-work history. Moreover, with the continuing deregulation of power generation, initial investments such as construction costs are being

kept down; consequently, even more improvement of operation efficiency is needed.

In the meantime, as regards the industry concerned with mass-production systems, technologies applying RFID (radio-frequency identification)—one fundamental technology underpinning the trend from now onwards towards the “ubiquitous information society”—are becoming more widespread at an increasing pace thanks to their functionality and versatility.

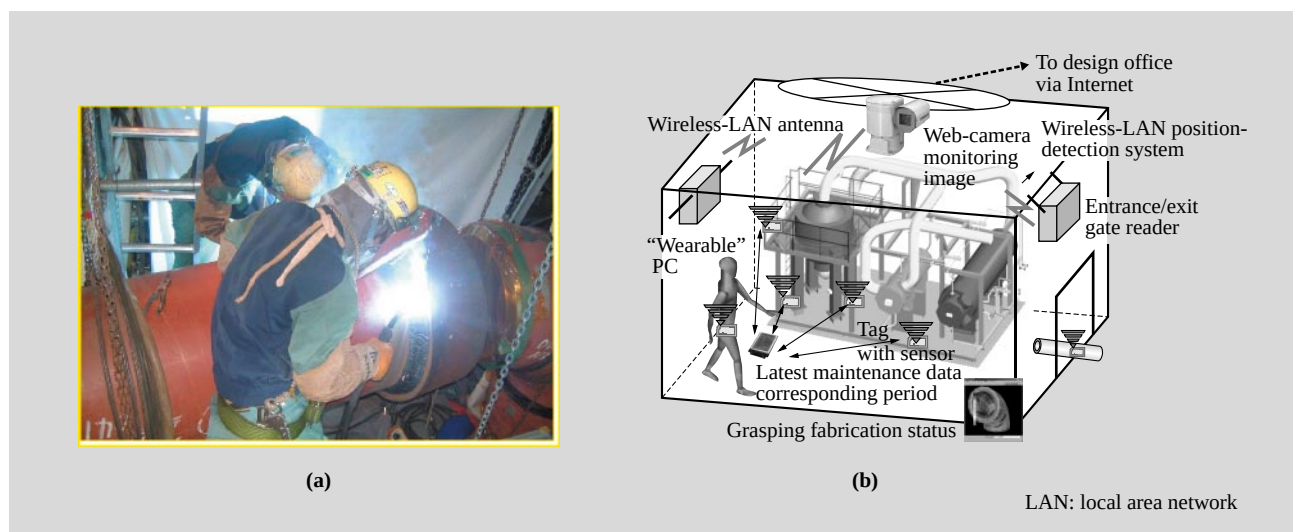


Fig. 1—Expected Nuclear-plant Construction by Application of RFID Technology.
Shown are image of on-site welding work at a nuclear plant (a) and next-generation concept (b). Hitachi is aiming for highly dynamic control of people, materials, and operations, work-streamlining support, and improved safety and reliability by applying RFID (radio-frequency identification) technologies.

With this background in mind, Hitachi has procured orders from a large number of manufacturers concerned with non-mass production systems. Moreover, to handle the massive amount of products concerning many design, fabrication, and inspection departments, we have started development of construction technology applying RFID to construction of nuclear power plants, to which systematic application of RFID technology has been considered difficult up till now (see Fig. 1).

The rest of this paper describes the development of RFID-applied construction technologies, and the underlying basic technologies, and current activities for high-reliability nuclear power plants.

NUCLEAR-POWER-PLANT CONSTRUCTION AND RFID TECHNOLOGY

In the case of nuclear power plants, a massive amount of materials, including a total length of 120 km of piping with accompanying components at more than 50,000 points, must be treated. Hitachi is applying IT in order to strengthen the quality-management systems for handling these parts. In particular, we are applying two kinds of systems.

(1) In regard to fabrication plants, “production systems” for consistently supporting and controlling production processes (from arrival of materials up to product dispatch), and

(2) In regard to construction sites, we are applying “total construction management systems” for consistently supporting and controlling construction work, from delivery management of manufactured articles up to transfer of equipment control aimed at commissioning.

These systems were developed and implemented in association with integrated CAE (computer-aided engineering) systems developed by Hitachi, and while not only quality assurance but also improved efficiency of various indirect operations is realized, accurate work planning and performance control has been made possible. However, starting with work record keeping accompanying fabrication and installation of vast amounts of products, input of data into the systems (e.g. data such as inspection-operation details and information on measurement devices used for inspections) needs a lot of work by hand.

RFID is not just a way of creating an in-built ID (identification) in the manner of a bar-code; it can solve the problems with applying product IDs in factories (such as weathering resistance and dust) by means of external-package processing and by improving the

efficiency of the reading operation via wireless sending and receiving of data over a distance. In consequence, by means of attaching RFIDs to products and workers—as well as tools and various measuring devices—it is possible to assure high-quality traceability of information (from planning stage up to on-site installation) and gain various benefits such as construction of even higher quality-assurance systems and elimination of human errors.

Being currently under investigation, an example of our activities regarding application of RFID technology to plant construction is described in the following section.

ACTIVITIES REGARDING PIPING FABRICATION AND ON-SITE FITTING

On-site Working Environment Virtual Testing

Giving much cause for during assembly of piping is the environmental resistance of RFID. Accordingly, experimental testing under simulated environments covering materials receipt up to actual-site construction (including surrounding-equipment noise from welding heat, welding equipment, and high-frequency pipe-bending equipment; work-environment conditions such as dust concentration; weather conditions such as temperature, rainfall, and snowfall during pipe storage; and loading during transportation) was done repeatedly. As a result of these tests, it was confirmed that RFID can cover the ration methods used in the case of any of the testing items, and the environmental resistance of RFID can adequately satisfy the demands during actual applications (see Fig. 2).

Application to Piping Fabrication and Installation Work

RFID tags are attached to products targeted for control from the initial stage of factory manufacturing and applied to piping fabrication and installation work. This process is summarized in the following three steps:



Fig. 2—Scene of Experiment on RFID Tags for Withstanding Welding Heat. By attaching an RFID tag and thermocouple to the piping, the influence of welding heat on the RFID tags was confirmed.

(1) Manufacturing control

In the material-receipt stage, an RFID tag is attached to each material, and an ID is created for each product. By combining and reading off the product ID created at time of receipt with the ID of the worker performing each operation at each control point for handling processing work in a fabrication plant (such as bending and welding of pipes), a record that was previously created temporarily by the worker by hand is created; subsequently, labor saving by inputting data into the control system is possible. Moreover, by applying RFID technology, it is possible to not only certify products at the work site but also material utilization and operator competency. In addition, RFID technology will also make huge contributions to ensuring high-reliability traceability and establishing high-quality management systems that will enable, for example, reduction of the potential for mistaking operating instructions, prevention of human error (such as transcription and inputting errors), and reduction of the latent cost losses accompanying these factors.

(2) Dispatch and receival control system

At the times of dispatch from the fabrication plant and of delivery of manufactured products to the actual site, the ID tag attached to the product is authenticated by remote transmission/reception of data, and by cross-checking the both sets of information via the RFID system, the receiving process can be made simpler and more efficient. Moreover, appropriating the tags consistently in an actual fabrication plant leads to

assurance of high traceability and reduction of tag resources.

(3) Fitting-sequence control

By certifying the product ID confirmed at the time of receipt at the control points for operations within an actual site in a similar fashion to that done during manufacturing control, it is possible to improve efficiency (such as direct input of on-site handwritten records into the system) and task-progress management of work in real-time is possible. Moreover, by applying RFID to worker certification as well, it is possible to improve efficiency of safety management on-site. Similarly, by applying RFID to machine tools and measurement devices, it is possible to improve the efficiency of management of loaned tools and calibration-control time limits (see Fig. 3).

ACTIVITIES REGARDING ELECTRICAL WORK

Background

In the case of setting-up of the control panel and replacement work, without a doubt, work for connecting a great number of cables to the control-panel terminal blocks will be created. To prevent connection mistakes, up till now, various methods, such as attaching number tags (called Delrin* marks) beforehand to the center wire of cables and color-coding the center wire to make it easy to identify, have been used (see Fig. 4).

On repeating meticulous operations in limited time periods, however, it can hardly be said that human error will not occur. Accordingly, ways of eradicating errors, like performing multiple work confirmation by several people, are continually being tried out.

Applying RFID to this kind of work has reduced

* Delrin is a DuPont registered trademark.

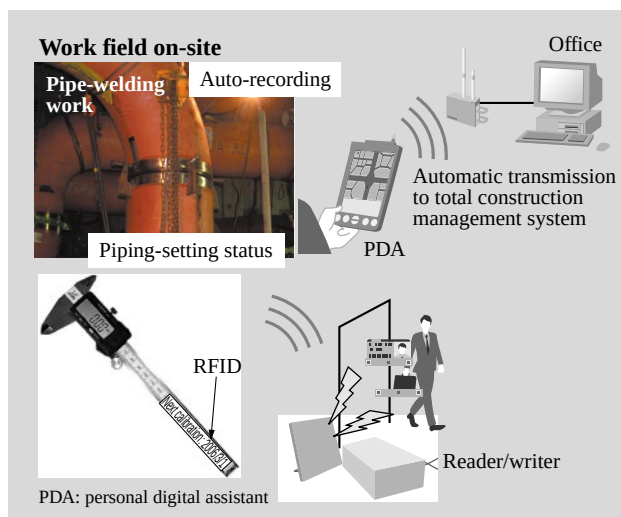


Fig. 3—Overview of Construction Sequence System.

Work information (such as data set from on-site, tools used, and operation requirements) is automatically transmitted, and the “total construction management system” is used to manage that information.



Fig. 4—Example of Wiring of Control Panel.

In the central control room of a power plant, before testing of local equipment, cables are temporarily disconnected and dealt with. Moreover, on the local-equipment side, the same work is generated.

the task of worker verification, affirmed the potential application of RFID to determining wrong connections, and pushed forward the development of a wiring-connection navigation system.

Wiring-navigation System

A “wiring-navigation system”—which automatically assists a worker in joining electric cables to terminals on the control panel—is presently under development. The configuration of this system is shown schematically in Fig. 5. In this system RFID tags are attached to both the terminal side and the wiring side, and this set up realizes a function for determining whether a butt connection is correct or not as well as enables confirmation of the wiring condition used in the circuit design drawing. The system imports circuit CAD (computer-aided design) data of upstream design, the terminal number required for wiring work, and displays the center-wire number of the cable by LED (light-emitting diode). Confirmation from PC or PDA (personal digital assistant) is possible, and automatically confirming that the wiring work was completed according to the design plan, even after it has been completed, is being developed. Technical challenges that remain include devising methods for mounting RFID tags on terminal blocks and electric-cable center of wire as well as developing directional antennas⁽¹⁾.

Development of Electrical Cable Fitted with RFID

One more benefit of discriminating electrical cable, other than the above-described work for connecting terminals, is the ability to know to which terminals cables that have become bunched together are connected. Consequently, for discriminating such cables, prototype production of cable fitted with RFID tags has started. To specify the placement of RFID tags in the case that radiowave reception and transmission becomes long distance, radiowave simulation has been implemented and is continuing. From now onwards, we aim to commercially launch this prototype cable at the earliest time possible.

DEVELOPMENT OF RFID CIRCUIT-BOARD TECHNOLOGY

RFID Mounting Technology for Precision Devices

Among precision mechanical devices, test manufacture of RFID-mounted prototypes of various kinds of PCB (printed circuit board) has been

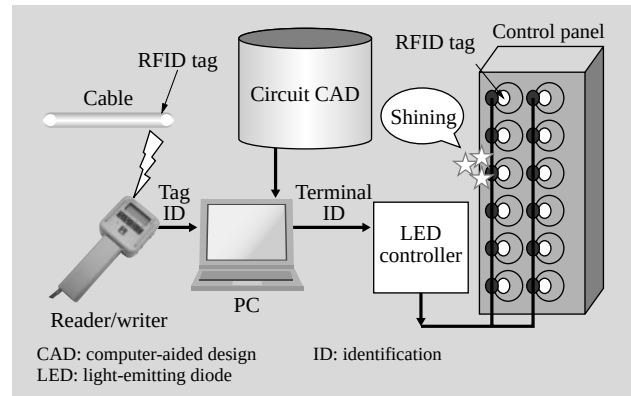


Fig. 5—Configuration of Wire-connection Navigation System. As for the wiring navigation system, an RFID tag attached to the target cable is read by the reader/writer, connected information from a database is obtained, and it is possible to show the connection location to the worker.

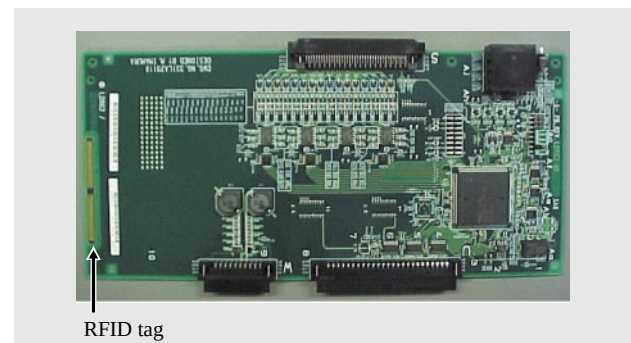


Fig. 6—External View of RFID-packaged Printed Circuit Board and RFID-tag Fixing Point.

To avoid reflection of electromagnetic waves, without ground composed of metal, the RFID tag is attached to the edge of the board.

performed. A PCB is usually configured with its under part ground (which is an earthed surface) composed of metal. This means that if an RFID is mounted on a PCB, metallic reflection occurs and radiowaves cannot reach the RFID. To solve this problem, the RFID tag is mounted at the edge of the PCB, where there is no ground metal.

Moreover, with the aim of extending the radiowave transmission/reception range, a radiowave simulation for pinpointing the mounting position for the RFID tag was carried out (see Fig. 7). The results of this simulation show that it was possible to optimize the width clearance and position of the RFID tag. In regards to this prototype product, it was supposed that radiowaves would not be transmitted or received by the reader/writer during operation of the PCB. During PCB operation, however, transmitted or received

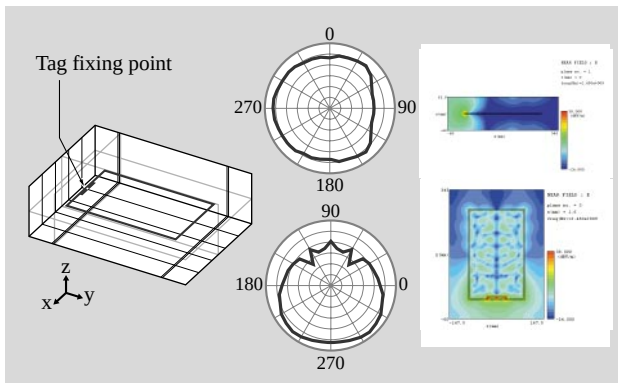


Fig. 7—Radio wave Simulation Results Obtaining Maximum-length Radio wave Reception Distance.

From the simulation results, it is shown that there is enough clearance width between the ground and RFID and that optimization of the fixing point of the RFID tag is possible.

radiowaves become noise, so an investigation to determine whether RFID has any influence on a PCB is being conducted in parallel with the above-mentioned tests.

Development of Patch Antenna for Handling Metals

Since components that make up a power-generating plant consist of many kinds of metals, it is necessary that RFID tags can be attached directly to metal parts. In general, an RFID device reflects radiowaves transmitted from a reader/writer in a 360°.

On receiving these reflected radiowaves, the reader/writer can obtain the information stored on the RFID

tag. As a consequence, when an RFID tag is mounted directly on a metal part, radiowaves from the back side (connected to the metal) are reflected by the metal, and these reflected waves interfere with the radiowaves at the front side. As a result, the radiowaves cannot be received by the reader/writer. To address this problem, a prototype RFID tag was constructed in a configuration (size: 25 × 27 mm) that does not transmit radiowaves from its back side.

CONCLUSIONS

This paper described our efforts and developments in regards to the fundamental RFID technology used in construction for high-reliability nuclear power plants. Over recent years development of RFID technology has been remarkable, and this technology will certainly play a key role in the realization of the “ubiquitous information society.” Hitachi has started application of RFID technology to construction of high-reliability nuclear power plants, and by utilizing technologies and system infrastructure we have accumulated up till now, on top of assuring safety and high-quality, we are targeting even higher reliability and operation efficiency, thereby contributing to the establishment of construction technologies for the next-generation of high-reliability nuclear power plants.

REFERENCE

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