# Development and Validation of an RFID-based Surveillance System on a Flow-shop Overhaul Line

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## ABSTRACT

A number of military departments have installed barcode systems to enhance the efficiency of overhaul, parts stock, and replenishment management. Barcode systems can be contaminated or damaged easily and are likely to break down due to incorrect operation procedures that downgrade efficiency. This study attempted to implement a real-time surveillance system using the radio frequency identification (RFID) system with tags, reading devices, middleware, and a wireless network. The purpose for implementing the system was to upgrade the efficiency of production, quality, and supplies control. This process enhanced the overhaul managerial efficiency, accuracy of stock level, and overhaul surveillance status of the production process. It also enhanced the transparency and traceability of parts. This study validated the RFID performance of tags against metal interference and certified the reading rate, which facilitates the further applications of RFID technology.

**Keywords:** RFID, real-time surveillance, overhaul management, tags reading rate

# 發展及驗證以 RFID 為基礎之流程式翻修線監控系統

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## 摘　要

近年來軍方翻修管理、物料存貨及撥補系統，多借助條碼系統增加效率，但該系統易受環境污染、破壞及人工作業錯誤等因素，影響作業效率。本研究透過架設無線射頻辨識（RFID）標籤、讀取器、中介軟體及無線網路系統，建立一套「即時監控」系統，有效提升生產、品質及物料管理效能，達到提升翻修管理效率及物料存貨準確性，並有效監控翻修現況、加強料件透明化及可追蹤性等。同時驗證 RFID 標籤對抗金屬干擾情形及讀取率，以利後續 RFID 技術的應用。

**關鍵詞：**無線射頻識別技術，即時監控，翻修管理，標籤讀取率

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# I. INTRODUCTION

The timely and flawless maintenance and administration of military parts is extremely important for logistics support. All logistic procedures influence one another. All enterprises have to monitor the increase and decrease of parts accurately. The radio frequency identification (RFID) system uses intellectual e-tags on the parts, cartons, and pallets to transmit and trace the data related to the objects by RFID wireless transmission and reading capability. RFID is a far-sighted and effective solution but entails excessive costs and dramatic changes for the operation procedures. Modern enterprises spare no effort to reduce their operation costs by using technological applications. This study upgraded the efficiency of human resource and parts management. It enhanced the performance of the existing system in order to reduce management costs by using non-contact reading, data digitization, real-time transmission, and the encryption/decryption of RFID. The study helped military factories and private enterprises upgrade their managerial efficiency.

The RFID system incorporated the production control, supplies control, and warehousing system. The RFID reduced the redundant labor, materials, and time with a secure computer network that replaced the conventional barcode system.

The RFID system minimizes redundant labor, resources, and time. The system consolidates production control, logistics flow, and information flow. This study gathered real-time overhaul data together with storage information and transmitted the data to the database system wirelessly by RFID technology. The system developed real-time production surveillance system software in order to analyze data and to control the maintenance resource pulse related to overhaul information. The system enhanced administration capabilities.

Radio waves are often absorbed or disturbed by metals. This study attempted to validate the resistance of the tags against the disturbance imposed by the metals. The researchers attempted to determine the influence of metals on the reading rate of the tags.

## 1.1 Overhaul procedures

The object is a military engine overhaul depot that adopts a flow shop in which overhaul services are contained in 10 stations: disassemble and clean, cylinder and accessories repair, crankshaft assemble, cylinder assemble, timing and fuel pump, electricity system, visual inspection, dynamometer test, final inspection, and outsourcing repair. Figure 1 shows the main steps in the overhaul line:

(1).Disassemble engine: the engines are disassembled into electrical and mechanic parts and accessories.

(2).Clean accessories: workers remove all grease and stains from the metal surface.

(3).Wait until repair and/or change parts completed: the repair area included the cylinder and accessory repair area. Workers determined whether the accessories were usable or not, and replaced all unusable accessories. Workers overhauled all usable accessories and delivered them to the sub-areas for assembly.

(4).Assemble: the assembly area comprises crankshaft, cylinders assemble, timing and fuel pump, and electricity system areas. The quality control staff at the sub-areas recorded the repair quality of the accessories, completed the reception procedure, and prepared an assembly list. The workers in the final inspection area required the assembly list.

(5).Visual inspection and deficiency correction: lubricant system and electricity system were tested in order to find out whether both systems were functioning normally. Then, quality control staffs recorded the data obtained from the tests.

(6).Dynamometer test: the workers placed the engines in the dynamometer machine. They connected the machine to a sensor. Quality control staffs recorded the data obtained from the dynamometer cell, and included the data on a performance list. The engines were delivered to the final inspection area if the dynamometer test results were acceptable.

(7).Final inspection: the workers checked the engines to make sure if all engines have been repaired thoroughly and were integrated with the repaired gear boxes. Meanwhile, quality control staffs delivered an accessory overhaul, an assembly, and a performance list to this area. The engines were shipped on schedule if approved by the final inspectors. The inspectors returned any defective engine to the visual inspection area for further analysis, diagnosis, and correction by a trouble-shooting taskforce, which comprised staffs from all areas.

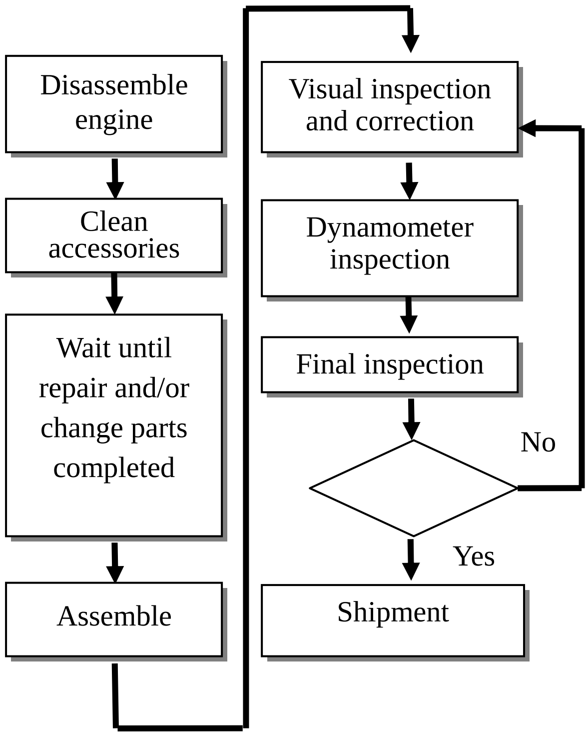



Figure 1. Engine overhaul procedures.

## 1.2 Description of issues

The operators at the object factory trace and record the data manually. The production control staffs do not have any real-time information on hand. This study has analyzed the overhaul line and found three issues:

(1).The overhaul line does not provide a recognizable operation procedure.

The staffs record control procedures manually on paper. They have a difficult time obtaining the information punctually. Not all staff members can record the overhaul procedures precisely and it is difficult to determine who is responsible for any mistakes.

(2).The overhaul line does not provide for a procedure to control the operation progress.

The staffs record the movements of the work-in-process (WIP) and parts on paper. It is impossible to record WIP quantity, movement, and the quantity of finished products precisely. There is no way to monitor the repair quality and to identify the deficiency instantly. The manufacturing costs are increasing and the quality is deteriorating.

(3).Staff workers record procedures on paper, which makes verification extremely difficult.

The overhaul line requires 45 quality control reports. The staffs compile these reports on paper and archive them. They do not update the overhaul information and parts data on a regular basis. The control procedure is not efficient enough to consolidate all the information and data.

## 1.3 The purpose of this study

The purpose of this study is fivefold:

(1).Develop a real-time surveillance software system to gather overhaul line and information about supplies in order to facilitate production, quality, and supplies control by RFID, an information platform.

(2).Gather the engine overhaul line and information about the supplies by PDA and store RFID signals in the database. The goal is that operators will have all data and graphic information displayed on the system.

(3).Gather, organize, analyze, and monitor real-time information using the RFID tags affixed on the parts, PDA, and middleware. The purpose of the study is to digitize and synchronize production management and parts stock information to facilitate the production of output reports.

(4).Serve as an important reference with respect to the development of RFID systems in the future.

(5).Validate the RFID reading rate in a real setting in order to provide real information to facilitate the decision-making process for RFID installation.

Chapter II of this paper reviews the literature on RFID. Chapter III discusses the development and implementation of the real-time overhaul management and parts stock surveillance system. Chapter IV concentrates on the validation reading rates of the various tags. Chapter V outlines the conclusions.

# II. LITERATURE REVIEW

## 2.1 RFID

### 2.1.1 The RFID composition

RFID identifies a single item by radio waves. The majority of identification systems comprise a reader and electronic tags. RFID tags comprise 2 components, an antenna, and a chip [1]. The RFID saves data in the tag and assigns a unique serial number to the data. RFID tags are either passive (without battery) or active (with battery). The active tags cost more than the passive ones. The active tags are capable of reading data within 10-100 meters. The passive tags detect objects within ten centimeters to five meters only [2]. An RFID system is more efficient than a barcode system with respect to its data-processing capability. An RFID tag can store more data than required by identification needs. The data can be written repeatedly at users' discretion [3]. The RFID allows organizations to obtain real-time information instantly, including the locations and characteristics of the objects affixed with tags, i.e. human beings and products [4].

### 2.1.2 RFID applications

Hallwirth and Kogelnig [5] believe that RFID has the optimal potential for supply chain management. Manufacturers stress the coordination between costs, standards, and supply chain partners. Kambil et al. [6] began with the supply chain and studied the applications and benefits of RFID. They have thoroughly reviewed all topics related to RFID deployment and described the deployment paths from the standpoint of suppliers, manufacturers, logistics service providers, and retailers. Their study is valuable for supply chain members who desire to apply RFID to their daily operation.

Sudarshan et al. [7] believe that the workloads of data administrators have increased to such an extent that they have to resort to RFID middleware. They conclude that the data structure itself has to be capable of deleting, sorting, and processing data to ensure effective data administration.

RFID automates the tracing of pallets, containers, products, and all other properties. RFID has the capability to gather real-time data from products. The barcode system lacks the same capability [4]. RFID enhances the efficiency of daily operations, i.e. warehousing procedures, parts processing, and inventory control in supply chain [8]. Ngai et al. designed an RFID system for integrated mobile commerce. They designed wireless equipment, wireless accessible portals, and SMS gateways. These designs solved many of the problems of customer service, purchase-order administration, cargo administration, real-time warning, and monitoring at the cargo loading and unloading stations [9].

## 2.2 Real-time monitor and tracing

Real-time signals are effective and sufficient to influence real-time knowledge-based systems. The RFID-based traceability system is a practical tool to monitor the real-time logistics and activities [10]. Supply chain managers welcome the RFID system, which helps them trace objects throughout the entire process on a real-time basis, from manufacturing to warehousing [11]. Managers are eager to see that RFID produce a timetable, of the actual time consumed by the production line [12]. RFID is an outstanding solution as compared to all other real-time surveillance techniques. RFID gathers real-time information and detects real-time events automatically [13]. Web sites are so powerful that they can gather all data effectively and efficiently. Information integration devices, such as RFID, digital-input device, and PDA, enhance the effectiveness and efficiency of the information needed by quality control staffs [14]. RFID improves the tracing competence of production line and enhances product-tracing and supplies-processing efficiency. Toyota has automated its cargo reception process by RFID and diminished its soaring production costs [15].

RFID shortens the redundant period of the equipment and reduces maintenance costs with its regulated surveillance equipment [16]. RFID is more efficient than the barcode for record-maintenance and data-retrieval. RFID allows users to trace items and assets within the internal system and thereby facilitates production surveillance, quality control, equipment maintenance, asset tracing, and the after-sales services needed by the warranty [4]. This study adopts PDA, which provides: (1) a calendar, address book, notes, and lists; (2) internet-browsing; (3) access to the internet by a modem, host phone or wireless network; (4) synchronization between PDA and PC; and (5) a platform provided with software [17, 18].

### 2.3 Latest application and development of RFID systems

Several factories have applied RFID to their production control and warehousing management. This study reviewed the literature and summarized the highlights related to the movement tracing of parts and monitoring throughout the assembly and inventory control process [19]. It also reviewed literature on the supply chain management of retailers [20]. The researchers examined the study made by Brewer, Sloan, and Landers et al. regarding WIP of the electronic manufacturing industry and inventory control [21]. The study reviewed the research of Karaer and Lee and Ngai et al. regarding tracing, administration, and utilization of products returned for repair [22, 23]. Shu-Jen Wang et al. established an RFID-based supply chain simulator in accordance with the replenishment model adopted by a TFT-LCD factory in Taiwan. The simulation showed that the manufacturing process and parts flow improved significantly following installation of the RFID. They found that inventory costs dropped, inventory turnover rates increased, and the supply chain increased in efficiency [24].

### 2.4 Readability of RFID tags

There is no way to guarantee 100% readability when an RFID-based system covers more than one factory, mainly due to the different directions of tags and different types of products. The readability of the tags was 25% when cartons contain nothing but bottles. The empty cartons and metal containers cannot assure 100% readability [25, 26, 27, 28]. The uncertainty imposes a critical challenge to RFID [23, 29, 30, 31]. The parameters of the tests play an important role with respect to the readability of RFID in addition to the varied tag directions and different types of products. The wind, rain, motors, and machines in the surrounding areas obstruct the electromagnetic waves transmitted between tags and readers [26]. There is no international standard for the validation of RFID readability. Researchers conduct their experiments in different environments and different laboratories. The software, hardware, and antennas differ. The readability varies from case to case.

This study developed a PDA and RFID-based production management and parts stock surveillance system in order to transmit information from the field of object factory to the manager's office. The administrators, production administrators, parts stock staffs, and maintenance staffs can obtain all information related to the overhaul status and parts stock quickly.

## III. DEVELOPMENT AND IMPLEMENTATION OF SURVEILLANCE SYSTEM

### 3.1 The concepts of system development

This study gathered the information related to overhaul procedures by RFID technology on an engine overhaul factory. The overhaul process included the overhaul and parts stock phase. The overhaul phase included the engine admittance, disassembly and cleaning, repair, assembly, inspection, and final inspection phases. The parts stock phase handled various materials and parts needed by the overhaul procedure. The overhaul progress and inventory control data and the parts required by the overhaul, are included in the real-time surveillance system. Figure 2 shows the operation procedures.

The system summarized the data stored in the database and presented the information to the administrators. The system included the Microsoft® SQL Server® database retrieval software, Internet Information Service (IIS)-supported network services, and Active Server Page (ASP)-outputted XML data. The terminal contained Adobe® Flash® to integrate numerals and output real-time dynamic graphics and charts. This study utilized the multi-layer and cross-platform techniques to develop an RFID-based surveillance system. The details of the both technologies were explained as follows.

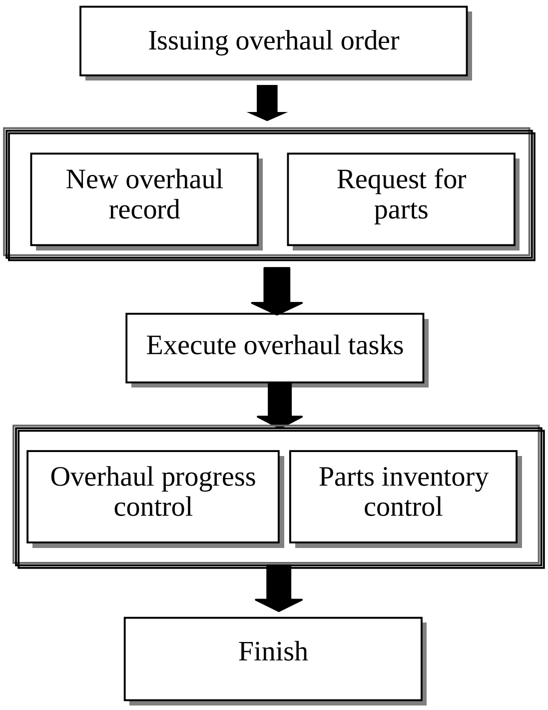



Figure 2. Real-time surveillance system flowchart.

### 3.2 The planning and features of real-time surveillance system

(1). Cross-platform

Cross-platform enables operating systems and hardware frameworks to allow various program languages, software, and hardware to function. The system contains Adobe® Flash® that serves as the system display core in which Adobe® Flash® Player serves as a cross-platform browser. This system display core contained an effect-enhancement module that allowed a new experience for Internet surfers. More than 60% of Internet-connected computers include an Adobe® Flash® Player according to its official web site. The managerial staffs could observe the activity in the factory anytime from all computer systems (Microsoft Window, Linux®, and Mac®). Table 1 shows the software and hardware specifications of the real-time surveillance system.

This study used multi-layer technology to link the PDA input data, RFID data access, data storage, data integration, and the information report layer. Figure 3 shows the Input-Process-Output relationship between the PDA, RFID, Server, and the User.

Table 1. Software and hardware specifications of the real-time surveillance system

| | | |
|---|---|---|
| Server | Software | · Microsoft® Windows Server 2003® (SP1) operating system or above<br>· Microsoft® SQL Server 2005® database system or above<br>· Internet Information Server (ASP Support) |
| Server | Hardware | · Intel® Xeon Processor 2.80- GHz/ 533MHz computer or above with Server<br>· 1GB DDR／SD RAM or higher<br>· 72GB hard disk (Wide Ultra320 SCSI) or higher, or SATA 100GB hard disk or higher |
| User | Software | · Abode® Flash® Player 7 or above<br>· Mozilla FireFox Browser 5 or other Browsers |
| | Hardware | · 256MB DDR／SD RAM or above<br>· Intel® Pentium III PC/notebook or above<br>· 1M/256KB Bandwidth |

(2). Real-time surveillance

Real-time surveillance is monitoring by real-time information technology. Real-time information technology requires a software framework to transmit and process data within a short period. The system comprises Microsoft Window® Internet Information Service (IIS) that outputs XML documents to Adobe® Flash® to display graphics and texts as opposed to the static information displayed by the database. RFID allows users to gather field data instantly. RFID-based real-time surveillance is highly beneficial to the day-to-day administration, parts replenishment, and labor dispatch of a company.

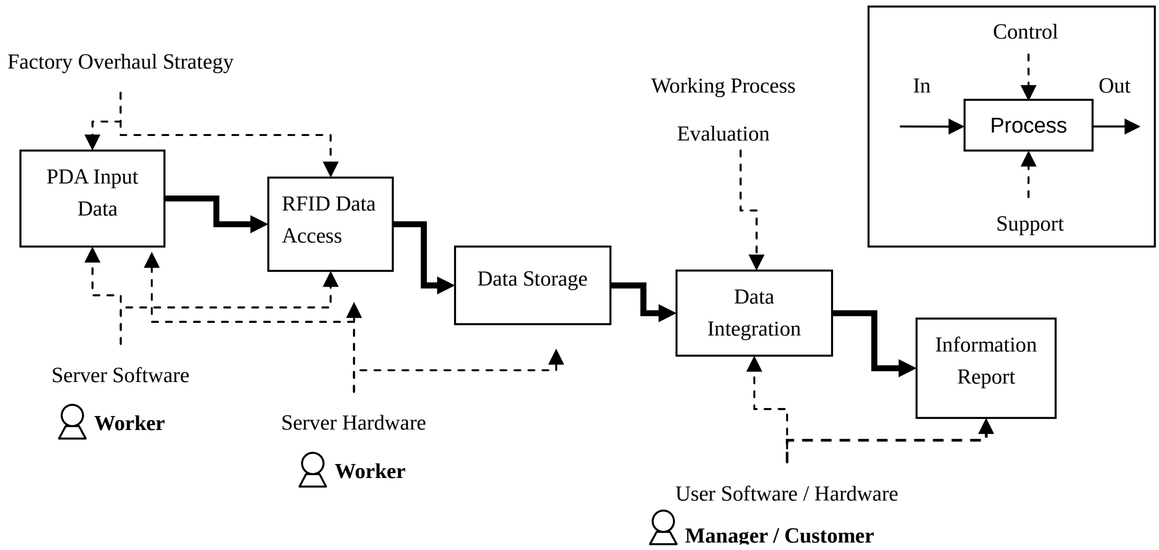



Figure 3. The Input-Process-Output relationship between the PDA, RFID, Server and the User.

(3). Data integration, inquiry, and outputting

The system generates the data related to the efficiency, movement timing, and material allocations of the overhaul line. The system uses four criteria to generate the data, arrival, departure, waiting parts, and parts arrival. It uses the inventory-counting mechanism and online support model to display the below-safety stock and waiting parts status in accordance with the inventory records, the quantities on hand, and the quantities requested. The system displays the item names, tag codes, and order of the serial numbers saved in the database for fuzzy-query. The operators can output the attendance of the staff, the delay counts of the documents, the parts transferable efficiency, the efficiency of the test, and re-overhaul rate statistics.

(4). Hardware implementation

The object factory was set up as a flow shop. Its overhaul, assembly, and inspection areas were adjacent to each other. Each area occupies approximately 5x8 meters. They sent the repairable and the WIP items to the repair areas. According to the physical inspection, if RFID comprises ultra high frequency (UHF, 860-960MHz), the reader is likely to misread the tags affixed to the parts in the nearby area due to the excessive distance. If RFID comprises high frequency (HF, 13.56MHz), the RFID system has a better chance of reading the data accurately in a distance shorter than 10 centimeters.

The overhaul line does not have to read objects rapidly and continually because the workers infrequently transfer parts. They affix UHF tags on the logistics boxes or cartons. The UHF reading-device validated the boxes or cartons when the workers sent the parts to the repair areas or to the warehouse. The workers used the HF-RFID prototype system in the overhaul line and warehouses.

The system operators installed a Compact Flash Card in the PDA (HP iPAQ hx2490), which served as the reception platform for HF tag readers. Wi-Fi served as the interface for the wireless transmission. The operator installed an antenna to enhance the signal intensity.

The system used MIFARE-series HF tags, which comply with EPC standard specifications. The system also used a CSL ULTF portable reader (Model CS 101) to read UHF tags. Figure 4 shows the implementation of the real-time surveillance system.

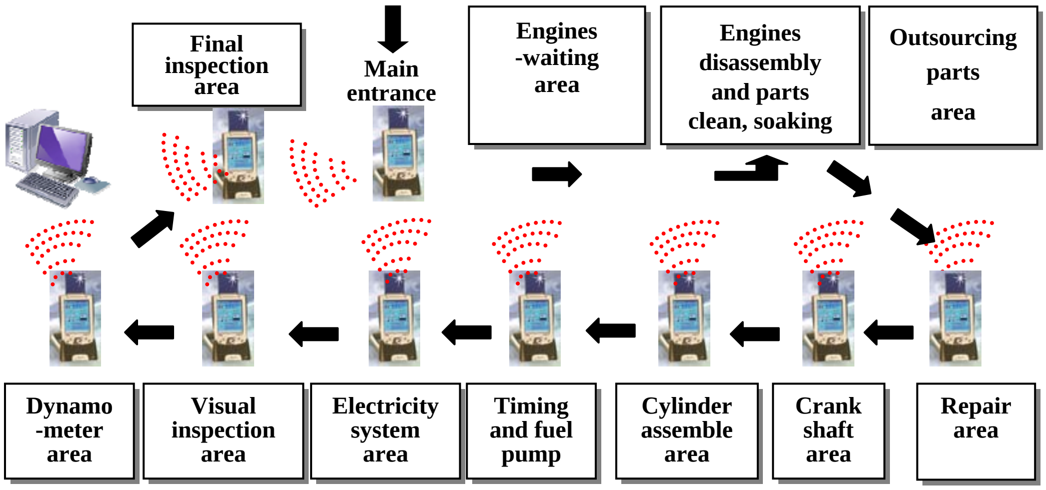



Figure 4. Real-time surveillance system implementation.

### 3.3 System framework

The system utilized PDA operating system application programs to gather parts information, overhaul line and parts stock data, and transmit (save) data within the database. The system comprised an overhaul line surveillance module as well as a stock surveillance module to integrate and output all information pertinent to the progress and parts stock facilities. The system displayed graphics and charts on the system interface. Figure 5 shows the framework.

### 3.4 Real-time surveillance system module

(1). Factory overview and overhaul line's dynamic data

Figure 6 shows the workplace allocation of the object factory. Station 1 through station 10 denoted the sequence numbers of the overhaul process designated in the same manner as the real-time surveillance system process shown in Figure 4.

Figure 7 contains the names of the workstation along with detailed information including the quantity of engines and their serial numbers, the quantities of WIP, and the number of items to be replenished. The "Total below safety" column indicated that the supplies fell below safety stock wherein the latest number of items (in the left blank) and total quantity (in the right blank) are marked. The "Total shortage" column indicated the quantity and items to be replenished (as shown on the left blank) as well as the total quantity (as shown on the right blank). Figure 6 shows the control screen to assist the administrators control of the real-time production progress and identify the status of the bottleneck.

The overhaul line presented graphics and texts containing dynamic data and thereby allowed users to browse the factory works. All information and digits are contained in Figure 6 and Figure7.

(2). Progress analysis

The system displayed the progress in accordance with the status of the engine. The interface displayed a Progress Bar that allowed the staff to identify the system status at one glance. The system provided the completion percentages and the number of days before deadline to facilitate progress control. Figure 8 displays the progress of two engines. The blue lines denote the overhaul progress and the orange line denotes the hours of parts shortage. The length of line shows the progress percentages as well as the number of days before deadline.

(3). Job order list / transferal job order list

The workshops communicated with each other by written notices called job orders. Job orders contained various information including the estimated arrival time of parts, estimated completion time, and job numbers. The operators designed job orders to help users identify the latest progress, the quantity of overhauled engines together with the quantity of accessories transferred to other factories for repair. Job orders were the basis for WIP control and tracing.

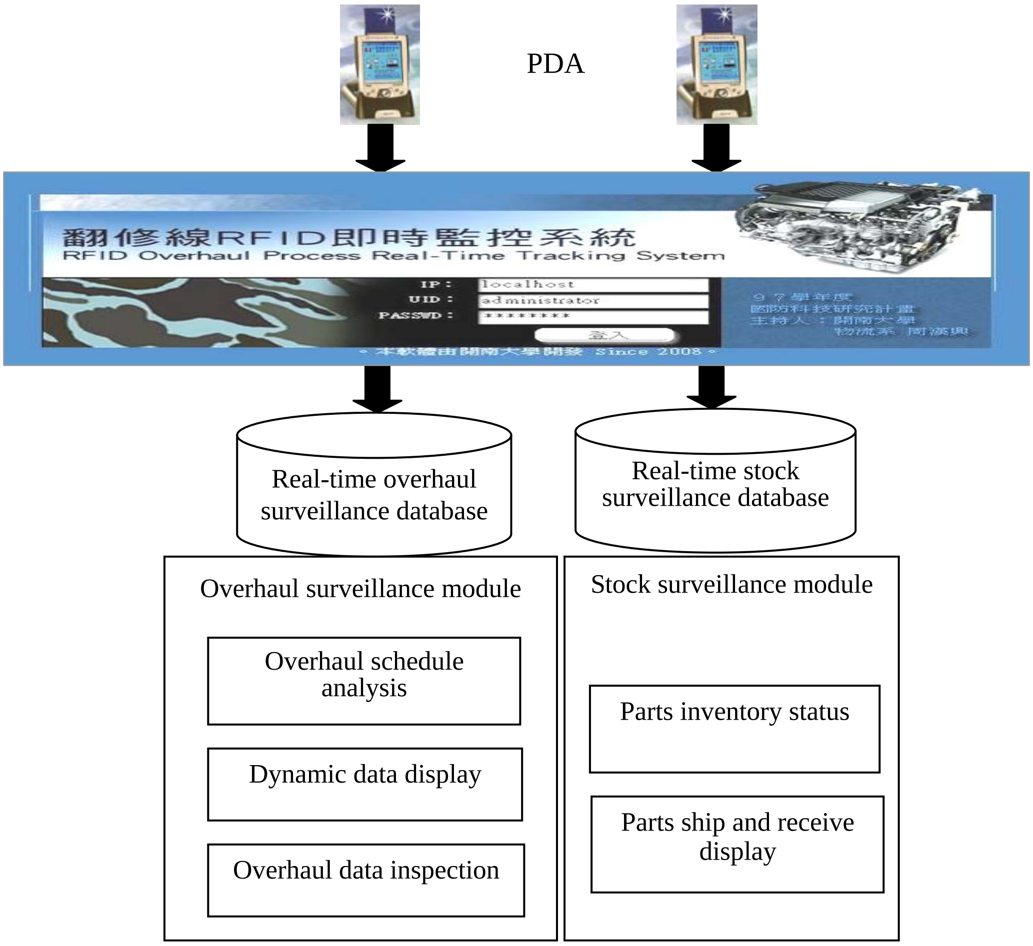



Figure 5. Real-time surveillance system framework

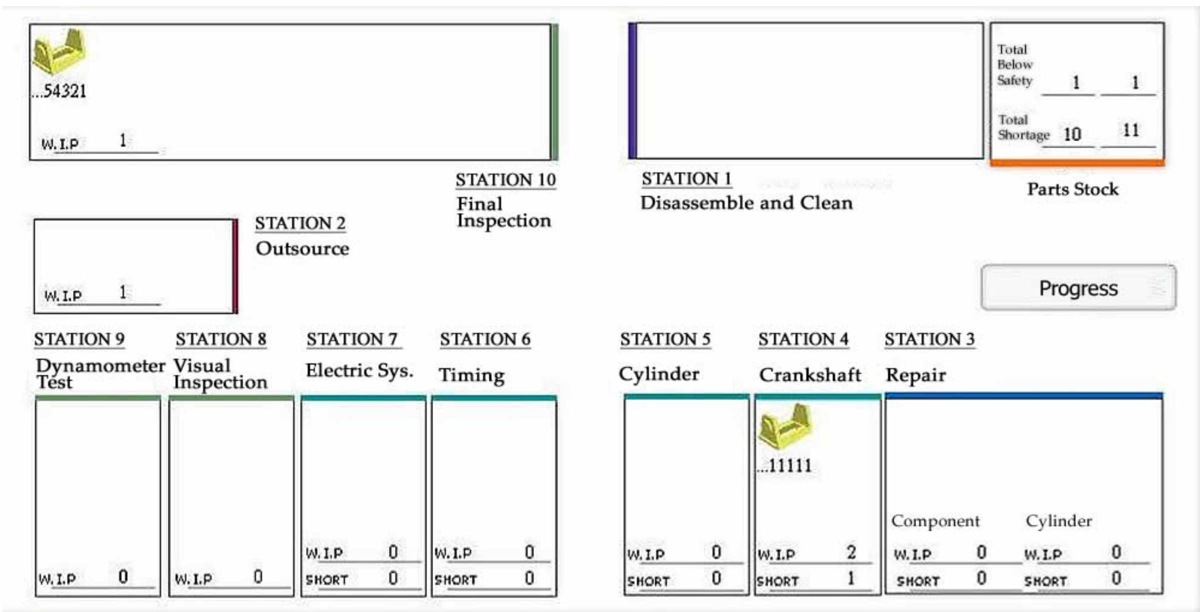



Figure 6. Factory overview.

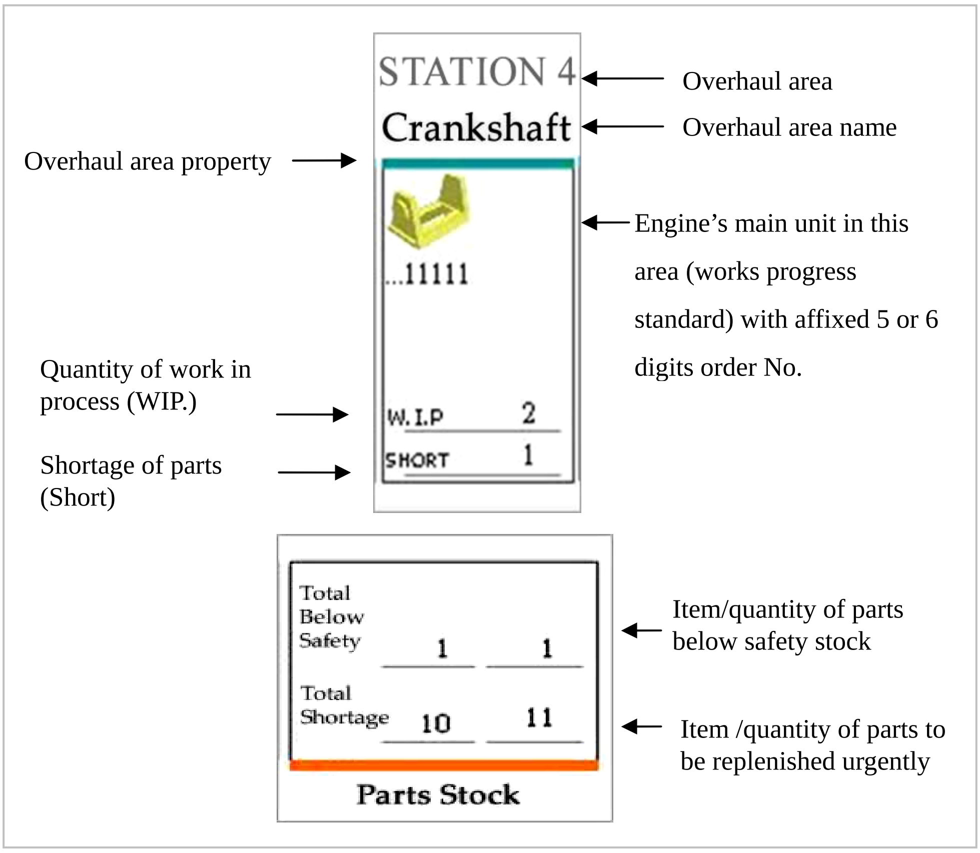



Figure 7. Factory station overview.

The job order contained the order number, engine number, the name of department, which owned the engine, overhaul history of the engine, admittance date, job order completion date, shipment date. Figure 9 shows the job order list.

4. Factory repair records

The overhaul information contained data reception hour, tag number, job order number, engine number, item name, parts number, overhaul station, overhaul status, progress status, abnormal damage, inspection status, recorders, as shown in Figure 10. Factory repair records helped administrators check and summarize the reports based upon job orders, parts numbers, and RFID tags.

5. Real-time parts tracing and factory repair records

Both real-time parts positions and repair records refer to the movement of RFID tags within the factory. The movement record contained the location of the supplies, the time in which area, for what purpose, and who recorded it. All events were recorded in chronological order. The system required the real-time tracing and factory repair records as the core data. The staff used the data to analyze all supplies. Real-time supplies information comprised basic data, job order number, engine number, tag number, item name, parts codes, tags issuance date, and the tear-down date of the tag. The information also included the current locations of supplies, the status of progress, abnormal damages, and the status of inspection as shown in Figure 11.

6. Parts inventory administration

The supplies administration module displayed the basic data of all parts stored within the warehouse. The data included name, parts number, and unit price. It also included the quantity recorded in the books, the quantity on hand, the safety stock and the requested quantity.

The interface contained all records pertinent to incoming parts together with applications for supplies. The interface also recorded all outgoing supplies in chronological order, including the movements of supplies, the applications for supplies, and the staff who recorded the movement of supplies. The warehouse parts table contained the following information: materials property, item name, parts number, suitable main unit, quantity stated in the books, quantity on hand, requested quantity, safety stock, storage level, unit prices, source of goods, and replacement rates. Different colors identified the status of the inventory. There were five statuses representing the different levels of inventory, normal, application for supplies, short quantity of supplies, below the safety stock level (yellow), and shortage urgent (red). Stock staff used the status of the inventory to facilitate their inspection. Figure 12 shows the parts inventory list.

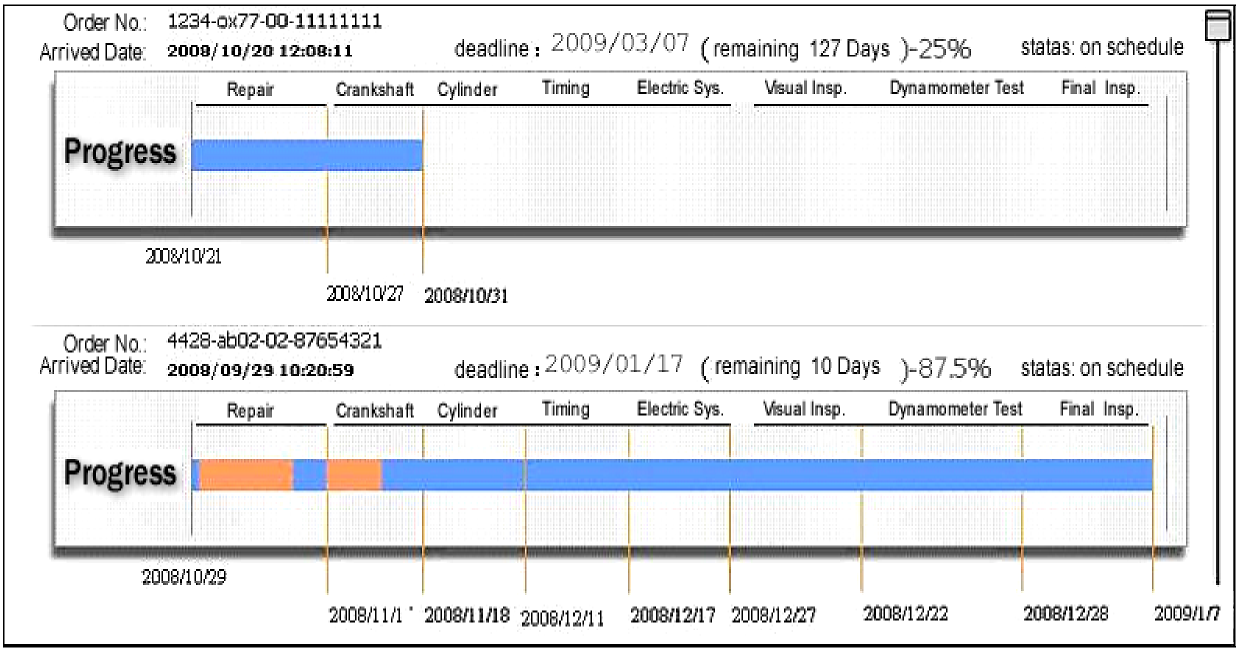



Figure 8. Works progress chart.

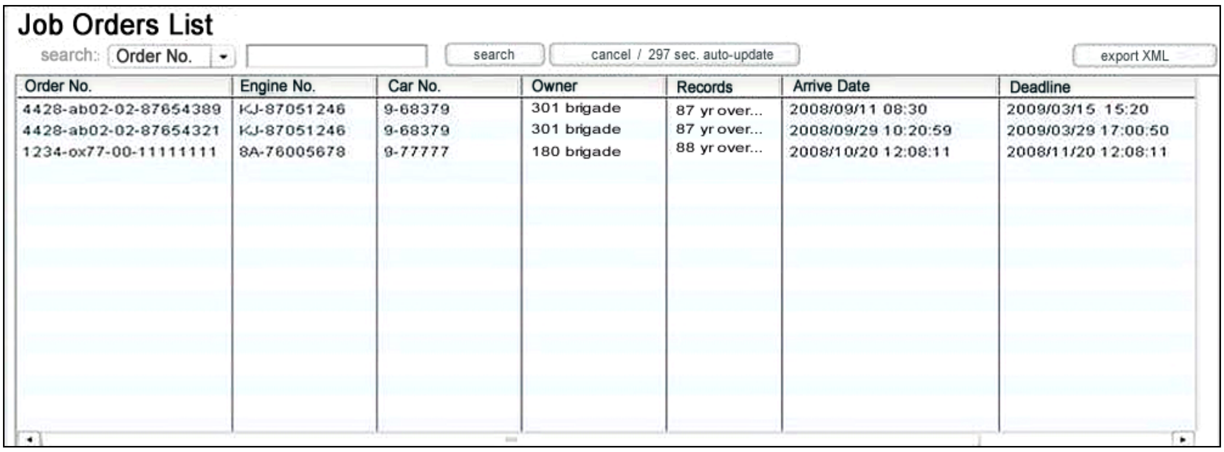



Figure 9. Job order list.

| Time | Tag No. | Order No. | Name | Part Number | Engine No. | Station |
|---|---|---|---|---|---|---|
| 2008/12/07 17:11:18 | 5C24528E | 4428-ab02-02-87654321 | engine main unit | 7531-67-473-1689 | KJ-87051246 | Crankshaft |
| 2007/12/01 21:30:32 | 5C24528E | 4428-ab02-02-87654321 | engine main unit | 7531-67-473-1689 | KJ-87051246 | Crankshaft |
| 2008/11/30 18:11:50 | 5C24528E | 4428-ab02-02-87654321 | engine main unit | 7531-67-473-1689 | KJ-87051246 | Crankshaft |
| 2008/11/29 15:36:09 | 5C24528E | 4428-ab02-02-87654321 | engine main unit | 7531-67-473-1689 | KJ-87051246 | Crankshaft |
| 2008/11/18 17:48:51 | 5C24528E | 4428-ab02-02-87654321 | engine main unit | 7531-67-473-1689 | KJ-87051246 | Crankshaft |
| 2008/11/18 07:52:34 | 5C24528E | 4428-ab02-02-87654321 | engine main unit | 7531-67-473-1689 | KJ-87051246 | Crankshaft |
| 2008/12/11 17:57:00 | 5C24528E | 4428-ab02-02-87654321 | engine main unit | 7531-67-473-1689 | KJ-87051246 | Cylinder |
| 2008/12/22 18:50:25 | 5C24528E | 4428-ab02-02-87654321 | engine main unit | 7531-67-473-1689 | KJ-87051246 | Visual Insp. |
| 2008/12/25 18:57:24 | 5C24528E | 4428-ab02-02-87654321 | engine main unit | 7531-67-473-1689 | KJ-87051246 | Visual Insp. |
| 2008/12/27 16:32:07 | 5C24528E | 4428-ab02-02-87654321 | engine main unit | 7531-67-473-1689 | KJ-87051246 | Electric Sys. |
| 2008/12/28 18:56:11 | 5C24528E | 4428-ab02-02-87654321 | engine main unit | 7531-67-473-1689 | KJ-87051246 | Dynamometer |
| 2008/12/31 15:32:11 | 5C24528E | 4428-ab02-02-87654321 | engine main unit | 7531-67-473-1689 | KJ-87051246 | Dynamometer |
| 2008/11/13 18:00:35 | 5C24528E | 4428-ab02-02-87654321 | engine main unit | 7531-67-473-1689 | KJ-87051246 | Cylinder |
| 2008/11/02 15:28:31 | 5C24528E | 4428-ab02-02-87654321 | engine main unit | 7531-67-473-1689 | KJ-87051246 | Cylinder |
| 2008/11/17 00:52:24 | 5C24528E | 4428-ab02-02-87654321 | engine main unit | 7531-67-473-1689 | KJ-87051246 | Cylinder |
| 2008/11/01 23:33:40 | 5C24528E | 4428-ab02-02-87654321 | engine main unit | 7531-67-473-1689 | KJ-87051246 | Cylinder |

Figure 10. Factory repair records.

**Real-time Parts Tracking**

search: Order No. ▾ | search | cancel / 287 sec. auto-update | export XML

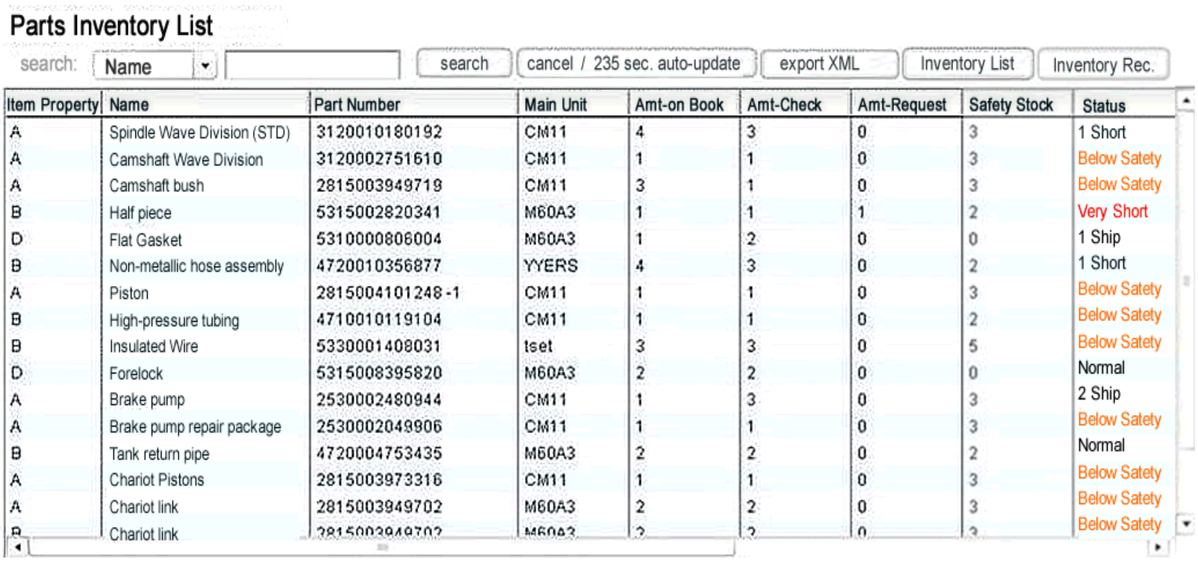
| Tag No. | Order No. | Name | Part No. | Current Position | Issue Date | Dispose |
|---|---|---|---|---|---|---|
| 5C23BE3E | 1234-ox77-00-11111111 | Engine | 7531-67-473-1689 | Crankshaft (2008/10/31 10:43:56) | 2008/10/31 | - |
| 5C24528E | 4428-ab02-02-87654321 | Engine | 7531-67-473-1689 | Final Detection (2009/01/07 17:06:58) | 2008/10/29 | - |
| 5C1EC7DE | 1234-ox77-00-11111111 | Crankshaft | 2815-01-040-7642 | Crankshaft (2009/01/07 17:06:58) | 2008/10/31 | - |
| 5C23BF2E | 1234-ox77-00-11111111 | Cylinder | 2815-00-150-7405 | Cylinder Overhaul (2008/10/31 10:45:3 | 2008/10/31 | - |
| 5C21CC5E | 1234-ox77-00-11111111 | Generator | 2920-00-441-8137 | Cylinder Overhaul (2008/10/29 23:53:5 | 2008/10/31 | - |
| 5C235CEE | 1234-ox77-00-11111111 | Intake Manifold | 2815-01-146-9005 | Outsource (2008/10/31 10:45:08) | 2008/10/31 | - |

Figure 11. Real-time parts tracing.

(7). Parts stock management records

Supplies records contained the dates of the records, type of records, RFID tag numbers, parts properties, item names, parts number, job order numbers, quantity of receiving/shipping goods, requested quantity and units, storage position and requestors. Figure 13 shows the parts stock management records. This module allowed the administrators to search, trace, and create reports for administration.

The operators gathered all messages related to engine overhaul and parts by their PDA. The system was audited by real-time information technology. Real-time information technology is capable of transmitting and processing all information related to the progress, factory information, supplies utilized in the overhaul areas and inadequate supplies as well as the information pertinent to the supplies stored in the warehouse for overhaul. The real-time information technology is capable of integrating and outputting information, and displaying graphics and tables on the system interfaces. This study showed that the system is executable.

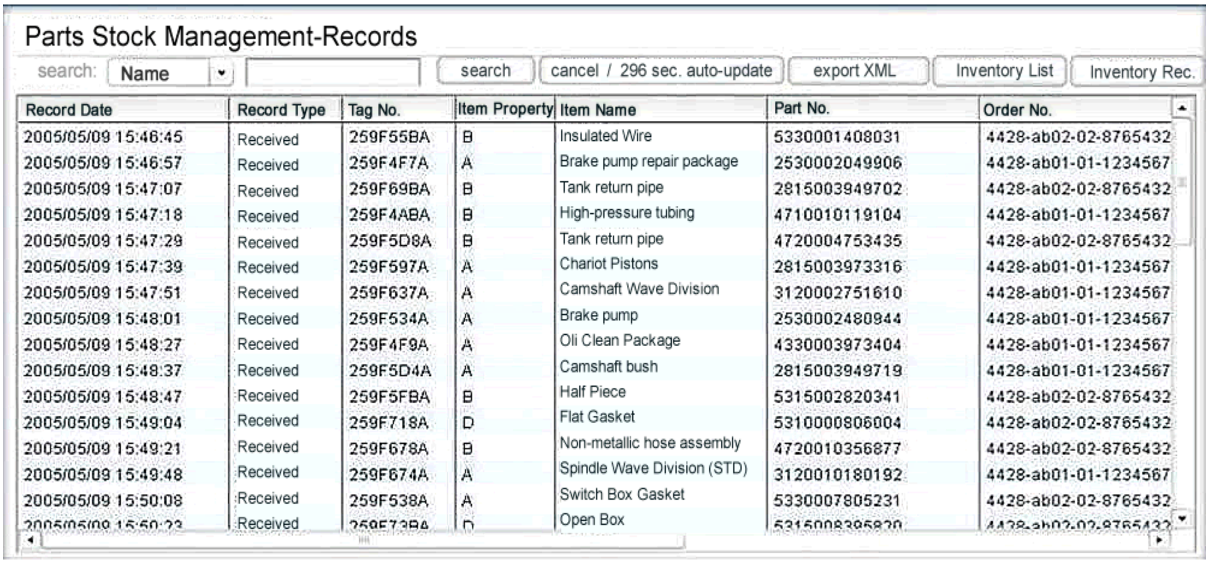


Parts Inventory List

search: Name | search | cancel / 235 sec. auto-update | export XML | Inventory List | Inventory Rec.

| Item Property | Name | Part Number | Main Unit | Amt-on Book | Amt-Check | Amt-Request | Safety Stock | Status |
|---|---|---|---|---|---|---|---|---|
| A | Spindle Wave Division (STD) | 3120010180192 | CM11 | 4 | 3 | 0 | 3 | 1 Short |
| A | Camshaft Wave Division | 3120002751610 | CM11 | 1 | 1 | 0 | 3 | Below Satety |
| A | Camshaft bush | 2815003949719 | CM11 | 3 | 1 | 0 | 3 | Below Satety |
| B | Half piece | 5315002820341 | M60A3 | 1 | 1 | 1 | 2 | Very Short |
| D | Flat Gasket | 5310000806004 | M60A3 | 1 | 2 | 0 | 0 | 1 Ship |
| B | Non-metallic hose assembly | 4720010356877 | YYERS | 4 | 3 | 0 | 2 | 1 Short |
| A | Piston | 2815004101248-1 | CM11 | 1 | 1 | 0 | 3 | Below Satety |
| B | High-pressure tubing | 4710010119104 | CM11 | 1 | 1 | 0 | 2 | Below Satety |
| B | Insulated Wire | 5330001408031 | tset | 3 | 3 | 0 | 5 | Below Satety |
| D | Forelock | 5315008395820 | M60A3 | 2 | 2 | 0 | 0 | Normal |
| A | Brake pump | 2530002480944 | CM11 | 1 | 3 | 0 | 3 | 2 Ship |
| A | Brake pump repair package | 2530002049906 | CM11 | 1 | 1 | 0 | 3 | Below Satety |
| B | Tank return pipe | 4720004753435 | M60A3 | 2 | 2 | 0 | 2 | Normal |
| A | Chariot Pistons | 2815003973316 | CM11 | 1 | 1 | 0 | 3 | Below Satety |
| A | Chariot link | 2815003949702 | M60A3 | 2 | 2 | 0 | 3 | Below Satety |
| B | Chariot link | 2815003949702 | M60A3 | 2 | 2 | 0 | 3 | Below Satety |

Figure 12. Parts list on warehouse inventory administration.



Parts Stock Management-Records

search: Name | search | cancel / 296 sec. auto-update | export XML | Inventory List | Inventory Rec.

| Record Date | Record Type | Tag No. | Item Property | Item Name | Part No. | Order No. |
|---|---|---|---|---|---|---|
| 2005/05/09 15:46:45 | Received | 259F55BA | B | Insulated Wire | 5330001408031 | 4428-ab02-02-8765432 |
| 2005/05/09 15:46:57 | Received | 259F4F7A | A | Brake pump repair package | 2530002049906 | 4428-ab01-01-1234567 |
| 2005/05/09 15:47:07 | Received | 259F69BA | B | Tank return pipe | 2815003949702 | 4428-ab02-02-8765432 |
| 2005/05/09 15:47:18 | Received | 259F4ABA | B | High-pressure tubing | 4710010119104 | 4428-ab01-01-1234567 |
| 2005/05/09 15:47:29 | Received | 259F5D8A | B | Tank return pipe | 4720004753435 | 4428-ab02-02-8765432 |
| 2005/05/09 15:47:39 | Received | 259F597A | A | Chariot Pistons | 2815003973316 | 4428-ab01-01-1234567 |
| 2005/05/09 15:47:51 | Received | 259F637A | A | Camshaft Wave Division | 3120002751610 | 4428-ab01-01-1234567 |
| 2005/05/09 15:48:01 | Received | 259F534A | A | Brake pump | 2530002480944 | 4428-ab01-01-1234567 |
| 2005/05/09 15:48:27 | Received | 259F4F9A | A | Oli Clean Package | 4330003973404 | 4428-ab01-01-1234567 |
| 2005/05/09 15:48:37 | Received | 259F5D4A | A | Camshaft bush | 2815003949719 | 4428-ab01-01-1234567 |
| 2005/05/09 15:48:47 | Received | 259F5FBA | B | Half Piece | 5315002820341 | 4428-ab02-02-8765432 |
| 2005/05/09 15:49:04 | Received | 259F718A | D | Flat Gasket | 5310000806004 | 4428-ab02-02-8765432 |
| 2005/05/09 15:49:21 | Received | 259F678A | B | Non-metallic hose assembly | 4720010356877 | 4428-ab02-02-8765432 |
| 2005/05/09 15:49:48 | Received | 259F674A | A | Spindle Wave Division (STD) | 3120010180192 | 4428-ab01-01-1234567 |
| 2005/05/09 15:50:08 | Received | 259F538A | A | Switch Box Gasket | 5330007805231 | 4428-ab02-02-8765432 |
| 2005/05/09 15:50:23 | Received | 259F73BA | D | Open Box | 5315008395820 | 4428-ab02-02-8765432 |

Figure 13. Parts stock management records.

## IV. VALIDATION OF THE RFID-BASED SURVEILLANCE SYSTEM

A number of researchers [30, 32, 33, 34] attempted to increase the readability of the RFID system by increasing the number of dock-door readers, upgrading the antenna power, and adjusting tag directions. The object factory produced many types of products and in small amounts through a lengthy overhaul process. The warehouse of the factory was relatively small. More than 98% of the items stored in the warehouse were metal products. This study adopted the user-friendly PDA and portable reader to protect the tags from the interference imposed by metals. The study validated the readability of tags by the use of different types of tags, various tags attachment methods, and improvement of the directions of the readers. It identified the RFID system implementation criteria for the small & medium factories with the emphasis being on minimum costs and maximum benefits, 100% readability.

This study validated UHF and HF tags, including metal-proof tags, adhesive tags, and hanged tags. The radio waves are often absorbed and disturbed by metal when radio waves are transmitted and received by the chips provided on the tags. This study placed all tags on the metal surface to find out the maximum disturbance on the tags and validated on the reading rates of RFID tags.

(1). Validation of the reading rates when tags are placed on the metal parts

The average reading rate of metal-proof tags reached 75% when UHF tags were placed one meter away from the reader. The average reading rate decreased when the distance increased. The average reading rate dropped to 25% when UHF tags were three meters away from the reader. The electromagnetic waves diminish when the distance from the reader is increased [26, 30]. The average reading rate of the metal proof HF tags reached 100% with HF tags five centimeters away from the reader. The average reading rate of the UHF and HF tags dropped to zero at five centimeters away from the reader. Table 2 shows the reading rates for tags placed on the surface of metal parts.

This study found that metal-proof tags outperform other tags with respect to the resistance against the disturbance imposed by metals. They found that they needed to use metal-proof tags if they needed to place the tags on the metal surface. The anti-metal tag requires Telfon-spacer material provided between tags and metals and thus isolated the electromagnetic interference. This conclusion coincided with the results acquired by previous researchers [35]. However, the metal-proof tags require higher costs.

(2). Validation of the reading rates when tags were placed on shelves

The designers of UHF tags created them to read cartons placed on shelves and read unwrapped items. The researchers glued the adhesive tags on the surface of the cartons. The metal parts contained in the cartons were 0.5 meters vertically away from the reader. The study found that the optimal electromagnetic wave resolution when the reader is placed vertically to the antenna [27]. The researchers piled six cartons on top of each other and as a result, the average reading rate reached 93.2 %. They hanged the tags on five pieces of metal parts irregularly placed at 0.5 meters away from the shelves vertically. The angles between the tags and reader varied randomly. The average reading rate reached 100%. Table 3 shows the reading rates for tags placed on shelves.

The electromagnetic waves decrease due to the disturbance imposed on the metal parts. This study found that adhesive tags could not ensure 100% accuracy when the parts were located on shelves. The hanged tags produce 100% accuracy. The RFID provided with hanged tags obtained the most desired reading rate.

HF tags ensure a 100% reading rate. Metals and water have less affect on electromagnetic waves generated by HF. This conclusion coincides with the results acquired by previous researchers [23, 36]. The reading rate increases when objects are closer to the readers. The researchers had to place the readers closer to the objects and the motion has to be longer when HF tags were read. These drawbacks may not be overlooked when HF tags are adopted.

(3). Validation of the reading rates for pallets loaded with parts

Companies ship large amount of parts using pallets. The researchers glued UHF adhesive tags on the cartons. They loaded the pallets with eight empty cartons and validated by readers 1.5 meters from the tags vertically. The validation showed that the average reading rate reached 50%. The average reading rate reached 100% when the operator placed readers around the pallets (360 degrees). Different reading methods resulted in different reading rates as shown in Table 4.

The researchers glued metal-proof UHF tags on five cartons containing metal parts. They placed the cartons on pallets and validated by readers 1.5 meter away from the tags vertically. The validation showed that the average reading rate reached 35%. The reading rate is far from practicability. When readers are placed around the pallets, the average reading rate reaches 100% as shown in Table 4.

According to the results of Table 4, the reading rates decreased when the researchers placed the metal parts inside the cartons. The metal-proof tags cannot resist disturbance sufficiently. However, this study achieved the highest reading rate when the researchers placed the readers around the pallets. The researchers adjusted the angle between the reader and tags nearly vertical and acquired optimal readability.

Table 2. Reading rates for tags placed on the surface of metal parts

| Frequency of the tags | Type of tags | Distance to the object | Test No. | Parts being read (pieces) | Parts to be read (pieces) | Average reading rate (%) |
|---|---|---|---|---|---|---|
| UHF | Metal-proof tags | 1 meter | 1 | 4 | 4 | 75% |
| | | | 2 | 2 | 4 | |
| | | | 3 | 3 | 4 | |
| | | | 4 | 3 | 4 | |
| | | 2 meters | 1 | 3 | 4 | 66.7% |
| | | | 2 | 2 | 4 | |
| | | | 3 | 3 | 4 | |
| | | 3 meters | 1 | 1 | 4 | 25% |
| | | | 2 | 1 | 4 | |
| | Adhesive tags | 1 meter | 1 | 0 | 4 | 0% |
| | | | 2 | 0 | 4 | |
| | | | 3 | 0 | 4 | |
| | | | 4 | 0 | 4 | |
| UHF | Hanged tags | 1 meter | 1 | 0 | 4 | 0% |
| | | | 2 | 0 | 4 | |
| | | | 3 | 0 | 4 | |
| | | | 4 | 0 | 4 | |
| HF | Metal-proof tags | 5 centimeters | 1 | 4 | 4 | 100% |
| | | | 2 | 4 | 4 | |
| | | | 3 | 4 | 4 | |
| | | | 4 | 4 | 4 | |
| | Adhesive tags | 5 centimeters | 1 | 0 | 4 | 0% |
| | | | 2 | 0 | 4 | |
| | | | 3 | 0 | 4 | |
| | | | 4 | 0 | 4 | |
| | Hanged tags | 5 centimeters | 1 | 0 | 4 | 0% |
| | | | 2 | 0 | 4 | |
| | | | 3 | 0 | 4 | |
| | | | 4 | 0 | 4 | |

Table 3. Reading rates for tags placed on shelves

| Type of tags | How to use tags | How to use readers | Test No. | Parts being read (pieces) | Parts to be read (pieces) | Average reading rate (%) |
|---|---|---|---|---|---|---|
| UHF adhesive tags | Adhesive tags glued on cartons with metal parts inside | To read 0.5 meters away from tags vertically | 1 | 6 | 6 | 93.2% |
| | | | 2 | 5 | 6 | |
| | | | 3 | 6 | 6 | |
| | | | 4 | 6 | 6 | |
| | | | 5 | 5 | 6 | |
| UHF hanged tags | Tags hanged on metal parts | To read 0.5 meters away from shelves vertically | 1 | 5 | 5 | 100% |
| | | | 2 | 5 | 5 | |
| | | | 3 | 5 | 5 | |
| | | | 4 | 5 | 5 | |
| | | | 5 | 5 | 5 | |
| HF adhesive tags | Adhesive tags glued on cartons with metal parts inside | To read 0.05 meters away from tags vertically | 1 | 5 | 5 | 100% |
| | | | 2 | 5 | 5 | |
| | | | 3 | 5 | 5 | |
| | | | 4 | 5 | 5 | |
| HF hanged tags | Tags hanged on metal parts | To read 0.05 meters away from shelves vertically | 1 | 5 | 5 | 100% |
| | | | 2 | 5 | 5 | |
| | | | 3 | 5 | 5 | |
| | | | 4 | 5 | 5 | |

Table 4. Reading rates for UHF tags placed on pallets

| How to use tags | How to use the readers | Test No. | Parts being read (pieces) | Parts to be read (pieces) | Average reading rate (%) |
|---|---|---|---|---|---|
| Adhesive tags glued on empty cartons | To read 1.5 meters away from pallets vertically | 1 | 4 | 8 | 50% |
| | | 2 | 4 | 8 | |
| | | 3 | 4 | 8 | |
| | | 4 | 4 | 8 | |
| | To read by the readers placed around the pallets | 1 | 8 | 8 | 100% |
| | | 2 | 8 | 8 | |
| | | 3 | 8 | 8 | |
| | | 4 | 8 | 8 | |

| How to use tags | How to use the readers | Test No. | Parts being read (pieces) | Parts to be read (pieces) | Average reading rate (%) |
|---|---|---|---|---|---|
| Metal-proof tags affixed to cartons with metal parts inside | To read 1.5 meters away from pallets vertically | 1 | 2 | 5 | 35% |
| | | 2 | 1 | 5 | |
| | | 3 | 2 | 5 | |
| | | 4 | 2 | 5 | |
| | To read by the readers placed around the pallets | 1 | 5 | 5 | 100% |
| | | 2 | 5 | 5 | |
| | | 3 | 5 | 5 | |
| | | 4 | 5 | 5 | |

## V. CONCLUSIONS

The majority of conventional factories adopt barcode-devices to gather the information pertinent to their commodities. They rely on manual scanning to process information. RFID gathers real-time information automatically. RFID minimizes mistakes, facilitates automation, and creates a paperless environment. This technology enhances the visibility and safety of logistics. Users have access to the movement of parts with a RFID reader and efficiently control the overhaul supplies.

This study made the following contributions: (1) surveillance and real-time tracing of the WIP and stock of the factory, (2) demonstrated the real-time surveillance over quality control, identified the deficiencies, and minimized redundant workload, (3) demonstrated how RFID could update overhaul progress, gather stock information, and digitalize data, and (5) validated the reading rates of UHF and HF tags.

Technological development will continue to upgrade the readability of RFID tags. The variations in the operating environment and the manufacturing-process play a critical role in this upgrading process of the reading rates of tags [23].

A RFID-based surveillance system is an ideal tool to visualize information and thereby allows the administrators to monitor the overhaul production lines. It facilitates the progress administration, logistics administration, and personnel dispatch.

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