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RFID for Oil and Gas Industry: Applications and Challenges

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Abstract*—Oil and Gas industry is a multi-billion dollar industry with many mission critical operations. RFID systems development organizations have designed a plethora of applications specifically for the oil and gas industry in order to enhance its operational efficiency and increase production and safety. We surveyed existing literature and profiles of oil and gas companies. In this paper, we list RFID systems used in oil and gas industry. Additionally, we have outlined the major challenges facing RFID systems in this mission-critical applications domain.

***Index Terms*—Applications and Challenges, Oil and Gas, RFID, Survivability and Security**

I. INTRODUCTION

Cyber-Physical Systems [1] are emerging technology that enables and improves the link between computational and physical infrastructure and elements. Usually, CPS is enabled by sensors and mobile technologies using wireless technologies and interconnectivity. The concept of Internet of Things (IoT) [2] integrated perfectly with the Cyber-Physical System where the physical elements "things" become active participants in business, social and information processes. Things will be interconnected through the future Internet infrastructure to provide full integration between physical objects and the cyber space. They will be enabled to communicate and interact among themselves and with the environment to exchange data and information, and to make decisions even without human interaction and intervention. Many technologies will enable CPS and IoT systems including wireless sensor networks, mobile communication and miniature electronics and MEMS. One of the main commercially available technologies is the RFID technology which is being used in many industry domains including medical, retail, aviation, military and oil and gas industry. RFID has been used as a smart replacement for the bar code and has been used mainly in asset management. The RFID tags simplicity and mobility have contributed heavily in creating innovative usages of this technology many domain. Oil and gas industry is a multibillion dollar industry that is considered the economical vessel for many countries. This industry has many phases in its supply chain including exploration and drilling, crude transportation, refining, product transportation and finally retailing to end customers as shown in Fig 1: Oil and Gas Supply Chain. During all phases of the supply chain, millions of assets are used and moved from one place to another with lots of human interaction and involvement of large machinery.

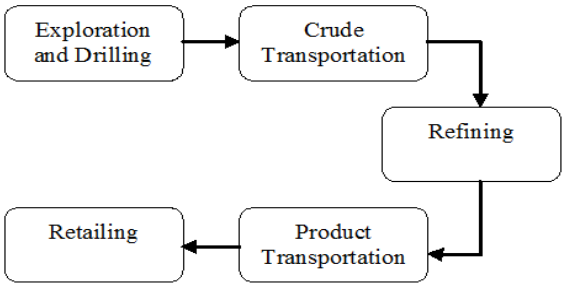

Fig 1: Oil and Gas Supply Chain

RFID adoption in oil and gas industry has proven to provide

- Greater and faster quality control
- Optimized production scheduling
- Increase in production yields and throughput
- Reduced production overhead
- Optimized information flow to and from field worker
- Reduced human errors during inspection, production, and order processing,
- Improved customer service
- More informative corporate decision making
- Accelerated auditing
- Access to real-time inventory status

In this paper, we surveyed the literature and company profiles to list out RFID's applications in the oil and gas industry. In addition to asset management, RFID has been used in many other innovative applications in this industry such as oil rig sites managements, subsea pipeline inspection and personal safety and security. Moreover, we list out the challenges facing the RFID technology in this mission-critical industry. The paper is organized as follows. In Section II, a brief background on RFID is introduced. Then, the surveyed list of RFID applications for oil and gas industry is introduced in Section III. In Section IV, three main challenges with discussion on how to target them are presented. Finally, the paper is concluded in Section V.

II. RADIO FREQUENCY IDENTIFICATION (RFID)

Radio Frequency Identification (RFID) technology [2]-[3] proved itself as an essential technology used for automation and the transformation to the Internet of Things concept. RFID system is being used mainly as an asset management tool that provides efficiency management and control over assets in different application spaces. Any RFID system consists of two components, a reader and a tag. The reader

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sends an interrogation signal as an RF signal to scan all available tags. The tag receives the RF signal and reply with its stored ID. More advanced tags available that uses battery can send more information than just the ID. They can sense the merchandise they are tagging, send more stored information or can store new data in their memory. The RFID tag can be considered as a radio bare code that could be scanned from a distance. Moreover, multiple tags could be scanned and read at the same time. Using this combination of reader(s) and tags, the tagged item/person can be tracked as they move from one place to another. Many consider RFID as the natural successor of bar code technology, however price and tag cost still remains a major issue in RFID adoption as IoT enabling technology.

Table 1: Comparison of Bar Code Labels and RFID Tags

Operations	Barcode/UPC Labels	RFID EPC Tags
Efficiency	• Reads one tag at a time • Line of sight required • Action required by scanner operator	• Reads multiple tags simultaneously • No line of sight required • Action not required by operator – but does accommodates on-demand identification with a handheld reader
Durability	• Paper labels are easily damaged or obscured by oil and/or dirt	• RFID tags can be matched to the application needs, providing the right level of durability for specific environments
Data Capacity	• Limited amount of data	• Significantly greater capacity enabling the storage and capture of more detailed and relevant information
Flexibility	• Static information – Write once • Tags are not re-usable	• Dynamic information – Ongoing read/write capacity enables creation of continual records • Tags are re-usable
Security	• Information is usually printed on the label with the bar code	• Information is encoded
Uniqueness	• Bar code can only identify a class of goods	• RFID tags and their associated serial identification number provide unique serialization

RFID systems usually creates massive amount of data that are simple and contains spatial temporal information. Table 1: Comparison of Bar Code Labels and RFID Tags summarizes the differences between bar codes and RFID tags.

III. RFID APPLICATIONS IN OIL AND GAS INDUSTRY

RFID systems are being used in oil and gas industry in all phases of the supply chain from exploration and drilling to delivery [5]. Based on the study we carried out, we have identified 4 classes or domains in the oil and gas industry where RFIDs are being used. These are summarized in Error! Reference source not found..

Domain	Uses
Operations	• Estimating drill lengths • Drill pipe health • Drilling risers • Laydown yards
Safety and Security	• Search and rescue • Mandatory checklist equipment • Worker tracking • Unauthorized personal detection • Mustering headcounts • Detecting a falling worker • Incidence investigation
Asset Management	• Equipment identification • Identifying unreachable pipes, flanges, etc. • Subsea applications • Maintenance • Workflow tracking • On-site critical information
Administration	• Identification • Employee time logs and attendance • Activity logs • Parking facilities • Document tracking • Vehicle tracking

A. Operations

Below is a summary of uses of RFID tags in the field of operations.

1) Estimating Drill Lengths

During exploration and drilling, drill pipes are added to existing drills as the drill head goes deeper and deeper. RFID tags are attached to each drill pipe. RFID readers on the drill collars maintain a log of number of drill pipes inserted into a site to track its depth.

2) Drill Pipe Health and Pipe health

RFID tags on the drill pipes are updated with critical information. Historic data of drill pipe use conditions such as temperature, flow rate velocity, stress, pH, and mud composition can be easily stored and accessed using RFID transponders and reader devices.

RFID readers access critical information about the pipe every time a piece of drilling equipment is lowered down-hole. This data can be further used to estimate failure by comparing it with the historic data available from previous manual examinations of the pipes. This procedure will prevent the usage of pipes that are on the verge of failure.

3) Drilling Risers

A drilling riser is a conduit that provides a temporary extension of a subsea oil well to a surface drilling facility. RFID tags on various lengths of each riser segment assist in controlling the extension depth. Readers on the sides read RFID tags to estimate depths and number of risers used.

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4) Laydown Yards

Pipes and drills as kept in laydown yards from where they are rented by oil drilling companies. These pipes are tagged with RFIDs containing information such as pipe's identification number, age, length, number of times used for drilling, recent job ID, etc. RFID readers are used to extract this information before re-using.

B. Safety and Security

Below is a summary of use of RFID tags in the field of search and rescue.

1) Search and Rescue

On the oil rig, RFIDs are used in combination with other sensors such as GPS, water presence, etc. For example, if a worker falls into the sea, the water sensor detects presence of saltwater and assists the rescuers to carry out search and rescue operation. Similarly, missing persons can be tracked using RFID badges with GPS.

2) Mandatory Checklist Equipment

In facilities/rigs where there is a set of mandatory safety equipment that must be worn by a worker, RFID tags on the equipment provide an automated checklist. When a worker passes through gates equipped with RFID readers, the reader verifies whether the worker is wearing all the mandatory safety equipment or not.

3) Worker Tracking

RFID readers are installed throughout the facility. When a person with the RFID badge moves around the facility, the RFID readers installed in the facility log his location and time.

4) Unauthorized Personal Detection

Cameras installed in the facility are used to identify moving objects. These cameras coupled with object identification systems recognize if there is a person in the facility. The RFID readers read the ID of the person using his/her badge. If this person is in the facility without a badge the system will raise an alarm and/or notify concerned authorities. In this way, unauthorized person on the premises can be detected.

5) Detecting a Falling Worker

RFID badges are being used in combination with other sensors such as accelerometers, GPS, etc. to achieve multiple applications. For example, if a worker falls through the stairs, the accelerometer detects rapid decent and RFID helps identify and localize the possibly injured worker.

6) Mustering Headcounts

In case of activities such as a fire drill, headcounts are carried out and workers not present are identified. RFID readers detect all persons who reached the mustering area. Who have not reached can be identified and localized.

7) Incidence Investigation

In case of an incidence, activity logs and worker tracking is used to identify the steps leading to the incidence and finding the root cause.

C. Asset Management

Human error is inevitable, but when it comes to a crucial process as ensuring that customers receive their shipment on time, much less, the correct shipment. Finding the right pipe in a field and ensuring product meets API specifications based on outer diameter, wall thickness, steel grade, weight/unit length, and type of coupling is a common scenario in the oil and gas industry, and errors could cost more than money. Being able to RFID tag assets and determine their location and status in real time as they travel from manufacturing floors to on-site delivery is extremely important for oil and gas businesses.

1) Equipment Identification

Pipelines, flanges and other equipment that is used in hostile environments face corrosion, abrasion, rust and other factors that make it hard for conventional tags to help identify them. Paint wears off, other tags get rubbed off. RFID tags can be welded, mounted using epoxy, attached using bands, etc. to pipelines and other equipment. Workers use RFID readers to identify them.

2) Identifying Unreachable Pipes Flanges, etc.

Identifying high objects or objects in complex structures is a challenge. Using conventional identification methodologies fail in place where the objects are unreachable or out of line-of-sight of workers. RFID tags attached to such assets assist workers in identifying them from long distances using powerful RFID readers.

3) Subsea Applications

Underwater pipelines that carry oil from rig to land require regular health inspection. Moss, algae, rust and other factors make it impossible to identify pipeline segments for inspection. RFID tags are attached to underwater pipeline segments for identification as well as other critical information. Divers or remotely operated underwater vehicles navigate to these pipelines and use underwater RFID readers to identify particular pipeline segments.

Saving pipeline segment geographical position in the pipeline segment itself in its RFID is useful for maintenance purposes. Sometimes due to current dynamics or other geohazards, pipelines on the seabed tend to shift their location. In this case, when a diver or remotely operated underwater vehicles search and identify the pipeline segment, they update its location on the RFID tag.

4) Maintenance

As equipment used in oil drilling, exploration and transportation goes through rugged environment, conventional identification methodologies fail. Barcodes get erased; paint gets rubbed off; etc. RFIDs are designed to work on metal surfaces. Therefore, all equipment that requires maintenance is labeled with an RFID tag. A database is maintained at the workshop containing all maintenance log entries of particular equipment. The database is indexed using RFID tags of the equipment. Part number, number of previous maintenance cycles, maintenance history, health of the equipment, date of arrival, date of service, technician assigned, date of dispatch, etc. is kept in the database. When a piece of equipment arrives at the workshop, its history can be retrieved using the database and its RFID tag.

5) Workflow Tracking

Throughout the maintenance cycle, the equipment goes

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through various stages in the workshop. At each stage, RFID is used to identify the equipment. Moreover, as RFID tags can be rewritten, each stage updates the RFID tag on the equipment until it reaches its final stage. Hence, the stage in which the equipment is during the maintenance cycle can be determined just by reading the RFID tag.

6) On-site Critical Information

Information other than identification can also be stored on RFID tag such as critical information that must be read by RFID readers on-site where there is no database connectivity available. For example in the laydown yard, a worker can check the health statistics before using a pipe.

D. Administration

The uses of RFID tags in the field of administration are summarized in this sub-section.

1) Identification

It is mandatory for each worker on the facility to wear an RFID badge. Only persons with authorized badges can enter a particular location inside the facility.

2) Employee Time Logs and Attendance

Employees are provided with RFID based badges for access to facilities. When a badge passes through the entry-exit gates, attendances are marked with time stamps.

3) Activity Logs

Equipment such as computers, control systems, etc. cannot be used until a user uses his/her RFID badge to login. All critical activity on such systems is logged with user ID and time.

4) Parking Facilities

Transportation-based RFID transponders are being used for wireless access control at the entry and exit points of parking facilities. They help in automating authorization and logging entry and exit times.

5) Document Tracking

Handheld RFID reader integrated to PDA can read RFID tags attached to documents. This automates document inventory and tracking application. RFIDs assist desktop document management systems as document issue history available in document itself. This improves document inventory visibility causing reduction in misplaced documents and reduced efforts in tracking classified documents.

6) Vehicle Tracking

RFID-based real-time location system (RTLS) platform provide fully integrated solution that includes all RFID software and hardware, such as tags, receivers, exciters and repeaters, necessary for an RFID implementation. RTLS are used to automatically identify and track the location of objects or people in real time, usually within a building or other contained area. RFID tags fitted to each vehicle that assist in automated identification and tracking at entry, parking lot, detail shop, run lines and exit. Other applications of vehicle tracking through RFID include metrics collection on vehicle use and cycle times, status reports and dashboard information, and verification of driver ID and vehicle ID at entry/exit points using readers installed at gates. This helps in ensuring complete up to date inventory, automatic billing, enhanced security and logging use.

7) Miscellaneous

Other uses of RFIDs in oil and gas industry are tracking rail cars, tanker trucks, wireless flow meters, bolts for flanges, cargo containers, oil drums, etc. They are also used for controlling vessel bay loading, hazardous emission sensing, scaffolding management, and with smart sensors in refineries and production facilities.

IV. RFID CHALLENGES IN THE OIL AND GAS INDUSTRY

Full adoption of RFID systems in oil and gas industry has many challenges to be solved and tackled. In this section, we will shed some light on major challenges that might affect the adoption rate of this technology in oil and gas industry.

A. Lack of Standardization

A major problem with current RFID Systems is the lack of industrial standardization in data formats, interoperability and interference problems between RFID readers and tags from different vendors. There are two main advantages of developing an international standard for RFID systems. Firstly, standardization will enable interoperability between different RFID systems developed by different vendors which in turn will reduce complexity and cost [6]-[7]. Secondly, standardization will facilitate the growth of RFID market in many different industries [8]. Another major challenge for RFID systems is the lack of a global and consistent Radio frequency spectrum allocation for RFID usage among different countries. As big portion of the radio spectrum is licensed to cellular phone companies, this makes standardizing the RFID radio frequency for a global RFID system very complicated. For example, USA and Canada use the frequency band from 902 to 928 MHz while in Europe the band 865.6-867.6MHz is used for UHF RFID and in Japan the band 953 MHz to 954MHz is used [7].

B. Survivability, Security and Reliability

Oil and Gas industry is a mission-critical industry. A single operational mistake might result in a catastrophic, economic, environmental and/or life loss. A major challenge of designing RFID systems for Oil and Gas industry is to design survivable systems. A survivable system [9] is defined as a system that can fulfills its mission in a timely manner even in the presence of malicious attacks and/or system failures. RFID systems designed for this industry should be highly survivable to sustain mal functioning and system failures. Security defines all features and techniques to protect the system from outside vulnerabilities and attacks. Security is considered as a subset of survivability. Since tags are very vulnerable, physical security is crucial. Moreover, since wireless communication is used communication security is another major focal point. To design survivable RFID system more efforts should be spent on designing efficient hardware and software authentication components to enhance security.

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More research should be done on building adaptive and resilience RFID systems as well. Another major challenge for RFID systems in mission critical applications is the open wireless communication part. The operational environment of this industry is very highly metal based. Attenuation and interference from metal components and other devices might affect the quality of communication affecting the whole system. A site survey to detect interferences from other wireless systems or noise from large machinery is very essential. The survey should give recommendation on reader locations and antenna orientation. The survey also will identify specific equipment requirements.

C. Energy

Energy consumption is a major factor when it comes to deploying millions of tags, readers and sensors all over the environment. Battery replenishment will be a daunting task when using millions of active RFID tags. Adding more capabilities to tags such as sensors and more memories will increase the energy consumption. Solutions to this problem include designing efficient green hardware, efficient communication protocols, utilizing renewable energy sources and utilizing energy harvesting techniques.

D. Forced Changes in Business Processes

For established industries, RFID deployment requires fundamental transformation of business processes. This also incurs a high initial investment. Of course, the benefits are far greater. Cost of changes in existing infrastructure and manual business processes are hard to estimate. These changes to physical assets, people and processes cause an obstacle in acceptance of technologies such as RFID. Comparing ones business to case studies can help in identifying the pros and cons. For example, McCarran International Airport in Las Vegas initiated a $125M project to RFID-enable its baggage-tracking system with the goal of reducing baggage mishandling by 15-30%. The typical cost of re-routing a misrouted bag is over $100. The potential savings on the 70,000 bags handled daily at McCarran was significant [10]. There are a large number of successful case studies available to provide benchmarks. Some more examples are available in various articles of RFID Journals [11]–[14].

V. CONCLUSION

Oil and gas industry is benefiting from advancements in RFID systems and applications on fronts such as optimized operations, lower running cost, increased human safety and better asset management control. This paper listed the most important applications of RFID systems in this industry. Furthermore, this paper provides a list of major challenges that affect the adoption rate of RFID technology in such mission critical application and their possible solutions.

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