RFID SOLUTIONS FOR THE UPSTREAM OIL & GAS SUPPLY CHAIN

WHITE PAPER

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1. ABSTRACT

In this whitepaper, we describe the Oil and Gas supply chain, placing particular emphasis on the upstream portion of that chain, that is, the operations up to and including the production of oil or gas at a rig or well. We outline several opportunities for deployment of RFID in that area, and discuss potential challenges and solutions.

2. INTRODUCTION

Opportunities for RFID based solutions in the Oil and Natural Gas industry are extensive, yet the application of such technology in the field is still in its early adoption stage. The areas in which RFID has proven to be a convenient solution, including traditional asset tracking, higher inspection efficiencies, and accurate (and reliable) real time information, are also major concerns in the Oil and Gas business.

However, the adoption of RFID technology to improve supply chain efficiency and visibility in this industry is fairly recent. In numerous discussions with industry experts, two major reasons have been identified for such lag: first, the benefits have not been clearly understood and quantified; second, RFID interoperable standards for proper technical performance across stages in the oil and gas supply chain have not yet been defined. This whitepaper is intended to serve as a first step towards addressing both of these reasons for the lack of adoption of RFID in oil and gas.

This paper focuses on the potential applications of RFID in the upstream portion of the Oil and Gas supply chain. A future whitepaper by the RFID Oil & Gas Consortium will address the downstream supply chain portion. Consequently, this paper explores the impact of RFID, and its implementation challenges, in two particular stages: drilling equipment manufacturing and transportation, and down-hole rig operations.

3. RFID BASICS

Radio Frequency Identification (RFID) is a wireless (contactless) identification technology for objects. Through radiofrequency waves, a reading device accesses information stored on a transponder, which, in order to be read, needs to be within a defined reading range. Information storage capacity and read-write capable transponders are major advantages of RFID compared to its competitor technologies.

RIFD technology has three major components: the RFID transponder, the RFID interrogator device and the backend IT system. A transponder (or tag) is a silicon microchip with an attached radio antenna generally embedded in a glass or plastic case. Through its antenna, the tag sends and receives information by means of radiofrequency waves from the interrogator (reader) device. This happens, of course, only if the reader device location is within the reading range of the tag. The retrieved information is then transferred to the backend IT system for proper data cross-referencing with the corresponding records on existing databases.

The two main types of RFID tags are passive and active tags. Passive tags do not have their own energy source, and therefore need to be activated by the reading device signal to reflect the corresponding response signal. On the other hand, active tags have an embedded battery that allows them to broadcast a stronger response signal, therefore improving the tags overall performance by an increased reading range. Tags also differ in the operational frequency ranges for which they are designed: low (125-134 kHz), high (13.56 MHz) and ultra high frequency (860-960 MHz). Higher frequency tags provide longer reading ranges and faster communication speed, but are more costly and their performance might be affected in moist environments.

There are important advantages of RFID compared to other automatic identification technologies, especially with barcoding. First, RFID allows greater information storage capability, even when compared to advanced (2-D) barcodes. As a result, much more detail about the identified object can be stored and tracked. Additional benefits include faster reading rates due to multiple parallel readings possible, and greater operational efficiencies as RFID tags, again compared to barcode systems, do not require neither a line of sight (i.e. tags can be read through packaging) nor significant alignment with the reader to have their information retrieved. Finally, RFID reader devices might have the capability to modify information on tags, which is not possible with barcoding.

For a more detailed overview of RFID and its application in supply chains, please refer, for example, to [1].

4. APPLYING RFID IN THE UPSTREAM OIL AND GAS SUPPLY CHAIN

This paper focuses on the potential applications of RFID in the upstream portion of the Oil and Gas supply chain, with particular emphasis on drilling equipment manufacturing and transportation, and down-hole rig operations.

The Oil and Natural Gas supply chain is illustrated in Figure 1.

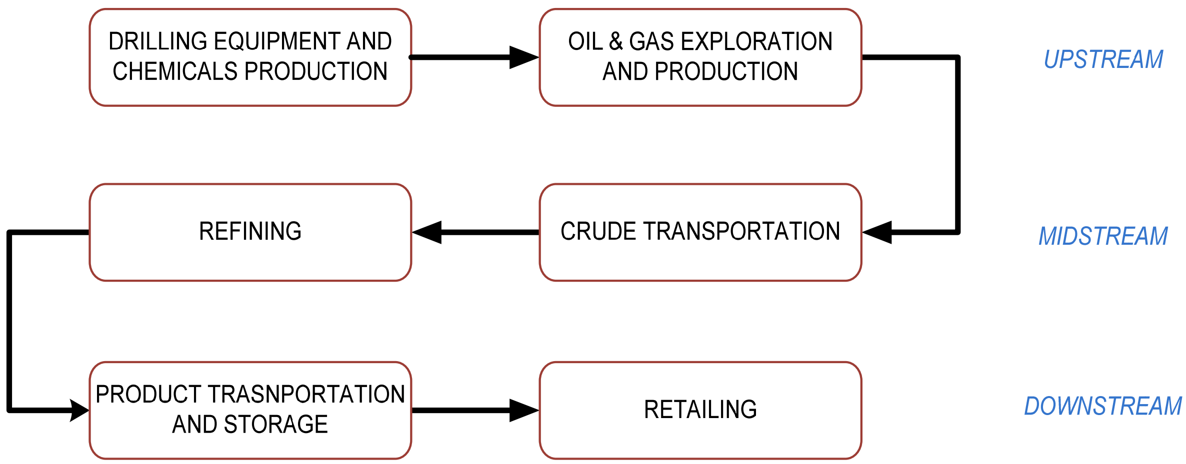

Figure 1. Oil & Natural Gas supply chain at different levels. Graphic taken from [2].

4.1. Drilling Equipment Manufacturing, Transportation and Storage

Manufacturing:

The various operations involved in manufacturing drill pipe (as one example of down-hole drilling equipment) are as follows:

- Forging – process of shaping by heating it to a very high temperature and applying localized compressive forces. Here, metal preheated to about 2250 F is compressed in a press to obtain the desired shape – a joint blank.
- Bar or Tubing – cutting/shaping metals to form a cylindrical section and then cut to he desired length
- Blanking and Boring – Blanking is a method of cutting holes in a metal piece and boring – the act of smoothening the holes thus drilled.
- Austenitizing the metal piece with an integrated oil quench to increase its strength followed by tempering to eliminate small amounts of brittleness if any in the metal piece.
- Finishing and Threading – Finally a quality check is made, required threads are cut on the joint and coated with a layer of phosphate to prevent corrosion.
- Deburring and Facing – Checks for burs on pipes and eliminate them by using an abrasive material. Joints get a clean smooth finish after facing.
- Upsetting – to increase diameter of pipe by compressing its length and austenitized again but water quenched this time followed by tempering.
- Welding finished pipes to get the required length.

Drilling equipment transportation and storage:

Pipes and other drilling equipment are pre-ordered and stored at the rig. Based on inputs from geologists pre-ordered pipes – drill and casing - are stored in racks on the rig. Unique paint or scribe markings on pipes help in identifying the right pipe of the right length, diameter. A rotating arm or a crane picks up the required pipe. The pipe thus picked up is then hoisted and used for drilling.

The Scope for RFID

The manufacturing process of pipes provides ample opportunities for RFID implementation. Tags can be embedded into these pipes during manufacturing to prevent rework during later stages. To do this, a small section of pipe can be cut to place the tag. Alternatively, tags can be attached to the outside of pipes using adhesives or plastic collars.

Tagging drill pipe, casing or collars can be beneficial not only to the manufacturer, but to every member of the supply chain who uses the pipe - from manufacturer to logistics provider to operating personnel on the rig. Some common benefits shared by all members include effective inventory management, storage and handling improvements, keeping track of age and usage of the pipe and preventing fatigue failure. For additional discussion, we refer to [3].

a. Effective inventory management and visibility:

RFID may help in better drilling equipment inventory management by keeping track of real time information on inventory. Since the requirements and usage of equipment can be updated in real-time on all IT systems across the supply chain, replenishment activities become timelier and easier.

RFID also helps in achieving a high degree of inventory accuracy. Inventory accuracy is defined as the degree of consistency between physical and logical inventory (in the IT system). In Oil & Gas, as well as in virtually any other industry, there is rarely a perfect agreement between actual inventory (e.g. of drill pipes, casing pipes) and inventory in the computer system. Oversight in inspection, loss due to shrinkage, misplacement, etc., are some of the reasons for this imbalance.

By using RFID, human intervention in inventory management (e.g. cycle counts) can be almost entirely eliminated and accurate levels of inventory are maintained. Furthermore, with RFID it is possible to determine the exact location of the material in the supply chain in real time. Latest advancements in technology have enabled the usage of RFID with tracking devices like GPS to give an accurate pin point location of where inventory is located. Knowing what is in the replenishment pipeline and when it is expected to arrive, potentially allows safety stocks to be reduced, while maintaining or increasing rig operations.

b. Storage and handling improvements:

Fairly crude methods are currently used to keep track of pipes at the rig. Unique markings on pipes usually help in differentiating pipes with respect to diameter, length and other specifications. Markings become illegible over time as a result of dirt accumulation and wear.

Use of RFID can help eliminate the tedious process of marking pipes, as well as the time-consuming and error-prone process of manually locating pipes by their markings on the racks. A reader placed in the crane used to lift pipes to the drilling platform can be used to read tags on the pipes to pull out necessary data.

c. Predicting drill pipe fatigue failures:

An important phenomenon concerning drill pipes is fatigue failure. As drill pipe is used and re-used, small hairline cracks may develop. These cracks may cause the pipe to break down-hole, leading to a lengthy stop in drilling activity and costly retrieval operations.

Currently, pipes are carefully inspected before they are re-used; however, cracks may occur spontaneously and without prior warning. Hence, inspection cannot be 100% reliable. RFID may help considerably by keeping track of the exact history of each pipe: when it has been used, at what position in the drill string, for how many hours, under what conditions etc. All this information is available essentially for free, if an RFID reader captures every pipe as it is lowered into the hole.

This information provided by RFID can be used to establish better predictions of the expected useful remaining lifetime of a given drill pipe, thus helping to prevent both drill string failures, as well as optimizing the number of times a given drill pipe is re-used before reconditioning.

4.2. Down-Hole Rig Operations

A drilling rig is the collection of equipment used to drill a borehole. A rotary drilling rig is the most common type of rig used in all kinds of drilling operations. It consists of a rotating bit that scrapes, gouges and cuts rock fragments to make a well. Sufficient load or weight is applied on the bit by using large sections of thick walled pipes called *drill collars*. These provide the required force for the drill bit. Several drill collars are used depending on how much weight needs to be exerted and how fast one wants to drill. Another set of pipes called *subs* of relatively smaller length, are placed just above the bit in order to absorb all the stress. Long sections of pipe called *drill pipes* are joined together in a drill string and assist in connecting the surface equipment to the well. The rig crew add sections of drill pipe as and when the depth of the borehole increases. The pipes are assembled separately and then inserted into the hole 2 or 3 at a time.

The Scope for RFID

a. Ensuring Correct Drill String Composition

Ensuring correct drill string composition, that is, assembling the correct drill pipe with the right couplings at the right bolt tension, using the correct collars, etc, is particularly critical due to the high operational and environmental costs associated with drill string failures. As of now, identifying the correct parts of a drill string is an error-prone manual process relying on paper based information systems (i.e. hand written labels and paper drawings). To facilitate the identification process, spray-painted codes on the pipes are sometimes used; however, if the painting has faded or if it is not easily visible, identifying pipes remains cumbersome. Any error (e.g., assembling the wrong component or using a close to failing equipment) could lead to expensive operational and environmental consequences. If a drill string component breaks, it is necessary to remove the whole string, which is, of course, an undesired cost. Furthermore, the environmental impact of such a breakage can be severe [4].

RFID tags can be used to effectively know the correct drill string configuration. By reading the transponder on each drill pipe, operators can (1) prevent a wrong piece opf pipe or equipment from being assembled into the drill string, and (2) cross-reference tag information with string specifications and know exactly which other components need to be used. Efficiently indentifying the required components is greatly facilitated with RFID. Consequently, the likelihood of an error in drill string composition is drastically reduced.

b. Dimensional Information Storage

Accurate dimensional information of pipes is critical for the drilling process. Borehole depth determination, for example, one of the most important aspects of the rig operations, considerably relies on drill pipe string lengths. Hence, precise information on equipment dimensions is vital. Often, though, this is still a manual process in which operators tape measure drill pipes. Moreover, pipe storage racks and atmospheric conditions like wind increase the difficultly of the measuring process. The information flow consists of measures being written down on a piece of paper and then entered into a computerized system. The entire process is subject to human errors and a small mistake in pipe specifications can result in considerable offsets of subsequent operations.

RFID makes this procedure very simple. RFID tags can be used to store dimensional information. Then, as required, tags can be read automatically by an interrogator device obtaining precise specifications about each drill pipe or drill string component. Therefore, there is no further need for inefficient and error-prone pipe measurement operations. In addition, the information flow is unbroken as data goes from the tag to the reader to the computer system without human intervention in the information content. Both greater operational efficiencies in obtaining drill pipe measurements, as well as accurate dimensional information have a considerable impact in the overall performance of down-hole rig operations.

c. Inspection and Recertification

Currently, manual, and mostly visual methods are being utilized to inspect drill pipes and strings. The operators manually inspect the pipe for surface cracks, pits, measure wall thickness, OD and calculate cross sectional area. Recent surveys and statistics suggest that a large portion of failures occur in and around the upset runout or in the slip area [4]. A pipe that has been inspected and cleared may develop cracks and fail after deployment. Hence, the industry is in need of methods to better focus on issues such as crack identification, or if possible, crack prediction.

Two applications of RFID in the upstream Oil and Gas supply chain, monitoring corrosion likelihood and predicting lifetime on drill pipes, are suggested to improve the overall inspection process. By keeping track of historical use data, RFID tags can help predict the remaining lifetime of a drill pipe or its associated usage risks. Visual inspection activities will likely still be required; however, a more reliable inspection can be achieved with the proposed RFID technology.

d. Monitoring Drill-Fluid Based Corrosion Likelihood

Drilling fluids are used primarily to clean and lubricate the bit and to carry rock fragments to the surface. Also, they apply necessary hydrostatic pressure on the formations to prevent mud from entering the well and overall fluid control. In addition, drilling fluids act as a support until the casing is cemented and protect the borehole walls.

Drilling fluids can be broadly classified as: liquids (water-based and oil-based muds), liquid and gas mixtures (foam, aerated water) and gases (air, natural gas). Important factors influencing fluid selection include the type of formation being drilled, temperature range, strength, permeability, formation pore fluid pressure, evaluation procedure of the formation, water quality and ecological environmental factors. Muds are the most frequent drill fluid used [5].

Despite being necessary for the drilling process, muds generate drill pipe corrosion, one of the most common roots for drill pipe crack. Corrosion can be defined as the loss of strength of a material due to wear. Environmental factors cause the metal to alter and degrade over time, eventually resulting in breakdown. The most important factors influencing corrosion rates are:

- *Temperature:* corrosion rates increase with temperature.
- *Flow rate velocity:* corrosion rates also increase with higher flow rates. *Heterogeneity:* localized variations in composition or microstructure may increase

corrosion rates. (e.g., ringworm corrosion caused by non uniform grain structure results due to improper or insufficient heat treatment after upsetting).

- *High stresses:* in general, corrosion increases with high stress concentration.
- *pH*: low pH values (less than) raise the rate of corrosion. For aluminum alloys, this is also true for high (more than 10.5) values.

In addition, the primary corrosive agents affecting a drill stem in an environment of water-based drilling fluids are: dissolved gases (oxygen, carbon dioxide and hydrogen sulfide), salts (chlorides, sulphates and carbonates) and organic acids [6, 7].

Detecting the amount of corrosion caused by a drilling fluid (*corrosivity*) is not trivial due to the complex reactions involving various corrosive agents and several other factors that control corrosion rates. However, RFID along with other sensors can help to accurately monitor corrosion related information of the above mentioned factors. 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.

e. Predicting Potential Fatigue Related Failures

Corrosion takes several forms but is most dangerous when it combines with other kinds of damage. Many types of corrosion occur at the same time. However, one form usually predominates. An interesting type of corrosion from an RFID deployment perspective is fatigue failure, a result of accumulated cyclic stresses, and a fairly common cause/reason for drill string breakages.

Metals subjected to cyclic stresses of sufficient magnitude will develop fatigue cracks that may grow until complete failure occurs. RFID tags can be used to keep track of the life/age of a pipe which will help in more accurate prediction of fatigue.

Currently, there is no automated process in place to track the age of the pipe which is a critical factor in fatigue failure. RFID readers can help capture this data automatically, 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.

5. RFID Challenges

Despite having clear advantages over traditional methods, many factors impede the adoption and implementation of RFID. Technological, economical and environmental challenges have hindered the proliferation of RFID on a large scale in the petroleum industry. Here we discuss some of the salient problems/challenges.

5.1. Economic

For first time users, RFID seems costly. It involves the price of tags, readers and the necessary IT infrastructure. Tags used for pallets and consumer packaged goods applications (CPG) are relatively cheap and readily available. High pressure/temperature/corrosion tags are neither readily available nor cheap.

We argue that RFID tags may be costlier than barcodes or other purely manual solutions but, in the long run, for many applications RFID will prove to be more efficient and effective.

In particular for down-hole applications in Oil & Gas, the advantages that come with RFID seem to outweigh the associated costs. In addition, once applied to drilling equipment, RFID can open a plethora of cost-cutting opportunities both in upstream and downstream supply chains.

5.2. Technical

The RFID tag and reader communicate with each other through middleware, which in this sense forms the heart of RFID. Middleware refers to the software that is responsible for proper data entry into the system. The reader transmits data to an application which collects, filters, and then processes it as per requirements.

Several inroads have been made in RFID hardware, but uniform standards for hardware and software have not been established yet for the Oil & Gas industry. Physical challenges like tag interference, reader interference, inconsistent data must be addressed by standards as well. The rugged and harsh conditions of this industry make it extremely difficult to implement a new technology like RFID. Tags have to withstand extremely high pressure temperature, corrosion, sulfide stress cracking etc. Regular RFID tags cannot be used under these conditions. Currently, there are very few tags available in the market that can be readily used. Hence customization of RFID tag enclosures or casings is likely necessary for down-hole operations.

The RFID Oil & Gas Consortium is committed to developing a standard for RFID hard- and software – specifically for the oil and gas sector.

6. RFID EQUIPMENT SAFETY REQUIREMENTS - THE ATEX DIRECTIVE

Any equipment intended for use in potentially explosive atmospheres and for trade within the European Community, must comply with the 94/9/EC Directive. The Directive, commonly known as, ATEX, lays down essential equipment health and safety requirements. The purpose is to have a standardized mechanism of risk assessment and therefore enhance the free trade of equipment within the EU by removing the need of several local testing and regulations. The directive does not provide technical specifications; these are given by the European Harmonized Standards.

In the case of RFID technology, as equipment are mostly electrical, the applicable standards are provided by the European Committee for Electrotechnical Standardization (CENELEC). Manufacturers are not required to adopt such standards, however, if they do so, their products benefit from a presumption of conformity to the Directive [8]. In industry, those standards are extensively utilized, and research suggests their use simplifies the Directive compliance process.

Equipment must satisfy three pre-conditions to be in the scope of the ATEX Directive: have its own source of ignition; be intended for use in a potentially explosive atmosphere; and be under normal atmospheric conditions. The Directive defines an *explosive atmosphere* as: a mixture with air, under atmospheric conditions, of flammable substances in the form of gases, vapors, mists or dusts in which, after ignition has occurred, combustion spreads to the entire unburned mixture. *Potentially explosive atmospheres (PEA)* are those which could become explosive due to local and operational conditions [9]. Oil rigs and wells are PEA, hence, RIFD equipment for rig operations needs to comply with ATEX

The Directive establishes two broad groups to classify equipment. Group I includes all equipment intended for use in the undergrounds or surface installation parts of mines (i.e. atmospheres where firedamp and coal dust are present)[10]. Group II considers all equipment not included in Group I. Based on the proposed applications of RFID in oil and gas industry, such technology should be classified as Group II. Within this group, the directive specifies 3 categories depending upon the likelihood of occurrence of explosives atmospheres and their duration.

RFID equipment manufacturers are required to conduct a risk assessment process to identify, estimate and evaluate the equipment potential hazards to could lead to the formation of explosive atmospheres (e.g. electric sparks, electrostatic discharges); and analyze the alternatives to prevent their occurrence or limit their effect. Moreover, based on the above mentioned categorization, manufacturers need to define the appropriate specific requirements, typical protective systems, and conformity assessment procedure applicable to their equipment.

The CE Mark is the proof that the equipment complies with the applicable directive. As the CE Mark applies to all directives, the EX Mark is used to specify that it is ATEX. Together with those two marks, additional information like the group, category and type of protection system used must be included in the RFID equipment label. If the equipment falls within the scope of two or more directives, they all should be applied. In particular, RFID equipment is also within the scope of the Electromagnetic Compatibility 89/336/EEC (EMC) Directive [11].

7. CONCLUSION

This whitepaper describes the Oil and Gas supply chain, placing particular emphasis on the upstream portion of that chain. That upstream portion includes the operations up to and including the production of oil or gas at a rig or well. For this upstream supply chain, we outline several opportunities for deploying RFID technology.

Applications of RFID at the rig include tracking drill pipe and drilling equipment topside to make inventory management more effective, improve storage and handling, and aid in predicting drill pipe fatigue failure. Down-hole RFID opportunities are in ensuring correct drill string composition, storing dimensional and other information, improving inspection and recertification processes and predicting potential fatigue-related failures by providing drill pipe usage history information, and monitoring drill-fluid based corrosion during down hole operations.

8. REFERENCES

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9. ABOUT THE AUTHORS

Gary M. Gaukler is an assistant professor in the Department of Industrial and Systems Engineering at Texas A&M University, where he also directs the RFID and Supply Chain Systems Lab. He is a founding board member of the Oil & Gas RFID Consortium and advises the consortium's standards setting efforts.

Dr. Gaukler teaches undergraduate and graduate courses in production and inventory control, logistics, and operations. His research interests center around systems engineering concepts applied to operations. He is particularly interested in the impact of automatic identification and sensor technologies such as RFID on supply chains. Dr. Gaukler has project leadership experience as the Systems Analysis team lead for a $7.5 million multi-disciplinary research project funded jointly by NSF and the Department of Homeland Security. He has published in academic and business journals on the topics of retail operations, inventory control, supply chain management, and manufacturing.

He holds a BSc (1998) in engineering and management science from Universitat Karlsruhe, an MS (2000) in industrial and systems engineering from Georgia Institute of Technology, an MS (2003) in operations research from Stanford University, and a PhD (2005) in management science and engineering from Stanford University.

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10. ABOUT THE OIL & GAS RFID CONSORTIUM

The Oil & Gas RFID (OGR) Solution Group brings together select industry subject matter experts, academic researchers and technology service providers to identify, define, develop, and deploy cutting edge solutions for Exploration, Production, Drilling, and Product Manufacturing in the Oil & Gas market. By educating and refining the customers understanding of what the technology can do for them, and developing systems with the help of a consolidated effort of Oil & Gas professionals, the solutions group is creating scalable application systems and data standards, and helping to generate a better understanding and increased adoption of Radio Frequency Identification within the Oil & Gas Industry.