White Paper: An Introduction To Successful Deployment of Radio Frequency Identification in the Petroleum Industry

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This whitepaper is the 1st document of a part three (3) part series on Radio Frequency Identification (RFID) in the Petroleum Industry. It is intended for end-users within this vertical-space looking to evaluate RFID/Wireless Sensor Network technologies for particular application areas.

The intial document in the series will introduce RFID and evaluate models used for the successful deployment of the technology both within the Petroleum Industry and other markets. It will conclude with a macro-level roadmap to successfully undertake the adoption and evaluation of the technology for petroleum exploration, drilling, production, refining, and field product manufacturing.

INTRO

RFID has surfaced as a technology that can provide an automatic and wireless method of identifying drill collar, drill pipe, conductor pipe, surface casing, production casing, tubing, and even drill bits, on the derrick floor, immediately prior to tripping down pipe, or, in the case of pipe, also immediately after tripping it out.

The challenges are abundant and by no means inconsequential. How do you design a RFID system that does not jeopardize the integrity of the field product, does not interfere with equipment and operations, survives the down hole environment, is readable at adequate distances, and is cost effective enough to justify its return on investment.

The reality is, when the technology first surfaced within the market space, it did not address all these issues. Those systems that worked were unimaginably expensive and those that were cost effective were undeniably problematic. So how do you deliver on a technology that has both intrigued and frustrated?

You take a top-down approach by breaking up the market space and the technology into subsystems and understanding both the development of the technology and that of the market space and how the two can successfully coincide. Then develop a bottom-up roadmap to enabling this technology to succeed. This seems like rather conventionalized model for an RFID system that needs to work under extreme pressures, in inflammable environments, with temperature ranges that put the surface of Mars to shame, but yet in its simplicity helps breakdown the fundamental components of not only creating a successful system but taking the right steps in order to create that system.

STEP 1 Look at Parallel Market Space that Has Already Seen Significant Market Adoption

TLogistics and Manufacturing markets have seen solid value delivered through the implementation of RFID technologies.

Companies such as Wal-Mart, Target, Boeing, Pratt & Whitney, BMW, Ford, and General Motors have all deployed automatic identification systems using RFID. The most public of these success stories has been the retail giant Wal-Mart that requested that its suppliers attach ultra-high-frequency (UHF) passive (battery-less) tags to merchandise being shipped to their stores and to distribution centers. Alternatively, many of the aforemetioned aerospace and automotive corporations used RFID technology as part of the traceabitlity, quality-control, and assembly processes during manufacturing.

> *Both apply the technology primarily at source / manufacturer level and extract benefits of its data collection capacity across their supply chains.*

> *Wal-Mart progressive adoption approach has allowed suppliers to prepare for and adequately support this mandate; however the Wal-Mart supplier network has lagged in adopting the technology within their own operations and this has slowed and limited the value that Wal-Mart can extract through this mandate.*

> *The automotive industry has implemented a variety of different control systems to help both improve and automate assembly, as well as streamline targeted recalls and improve the customer experience.*

The question that may come to mind now, is why do we care about a market space that at first-glance has no similarity to our own. Well, while field products like casing and pipe don't come with 6 speed transmission or leaking fuel lines, they, just like transmissions and fuel lines, require an extensive range of machining steps and controls as part of their manufacturing process.

So, at heart of this first glance into different market spaces, we leave with 2 lessons.

1 *Source/Manufacturing level tagging brings benefits to everyone downstream and has proven successful in other supply chains.*

2 *Mandates requiring suppliers to adopt RFID have had mixed results, the goal of dominant entities in any supply-chain should encourage adoption by clearly defining the value of the technology and it's ROI at various levels within the market space and support its adoption.*

STEP 2 Understand your own market space

This isn't so much a question of knowing your own business as it is a question of knowing the business of those upstream and downstream from you. If you produce oil field products, where do they go, why are they used? If you use oil field products, where do they come from, how are they produced?

To further refine these questions:

- *Not only where do they go next, but where do they travel throughout their lifetime.*
- *Not just how they are used functionally, but what is their purpose in the global scheme of things.*
- *Not only where do they come from, but how do they get there?*
- *Not only how are they produced, but what are the quality controls that assure their production?*

Case Study (Part 1)

So lets take an example of casing, the purpose of which is preventing sediments from caving into the well, protecting fresh water reservoirs from contamination, and serving as a route for drilling mud. An oil field product manufacturer produces pipe in accordance with API specifications based on outer diameter, wall thickness, steel grade, weight / unit length, and type of coupling. These variables depend on the requirements outlined in the case program, which depend on the inherent characteristics of the well and the objectives set forth by completion team. Further to that those objectives are outlined by oil companies, driven by their own objectives, defined by global demand, political stability, and a multiplicity of other factors. Now although on a macro-level this water-fall approach to procurement may seem realistic, the fact of the matter is on micro level the sheer dynamics of completion don't allow it. Even with the advents of seismic exploration and well loggers wells still get abandoned (1 in 5), and some of those that don't, require a progressive acquisition of knowledge to define a casing program as depth increases and more information is known about porosity, lithology, and potential depth of the reservoir. This leads to stockpiling to prevent completion delays, which from a procurement point of view is a very inefficient method of delivering product, yet it is necessary to continue operation. So, manufacturers produce casing that is stockpiled at the distribution level and delivered to the rig site as per demand.

On a more macro-level, wells are completed to transport oil and/or gas to the surface so that it may be refined and sold to the consumer (commercial or end-user). Casing is component of a system that enables the extraction of oil/gas. If this component has either malfunctioned and/or is not available then production is jeopardized and immediate repair or procurement is required to continue operations.

What are our lessons from our own market space?

1 *One way to streamline procurement is to streamline data exchange. Information flow can help the entire supply chain to gain a better understanding of product and process. There is a need for the streamlining of information.*

2

In order to have information you first need to collect it. Automatic identification technologies such as RFID are what is called the "edge" of the enterprise, the hands and feet that collect raw data, that is then analyzed and presented in various forms within application systems and exchanged with collaboration partners (organizations in your supply-chain). Bottom line is that you want to know what goes on upstream and downstream from you so that you can better run your own operations. Data enables you to do that. Technologies such as RFID enable you to do that quickly and cost-effectively.

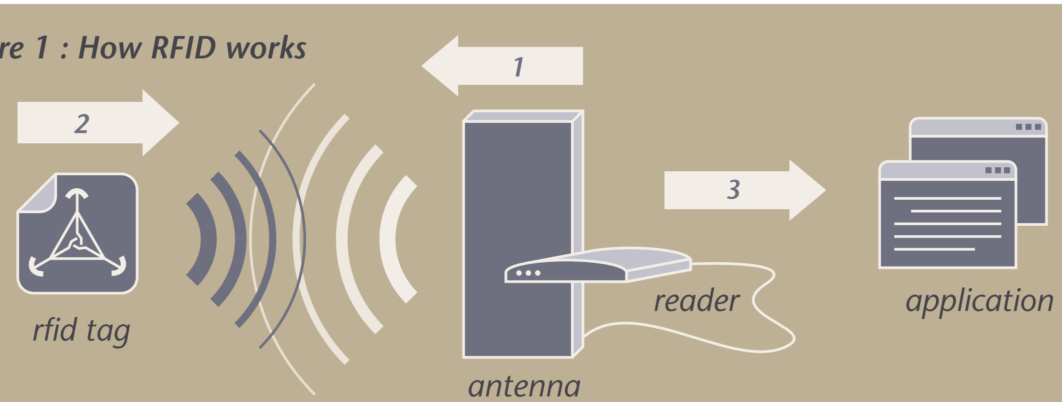
STEP 3 Understanding RFID

The technology has variety of different application areas with the oil & gas industry and corresponding tag designs, protocols and system frameworks to match.

The technology space can be separated into active tags, semi-passive tags, and passive tags. Where active tags have an internal battery source and continuously transpond, semi-passive tag have an internal battery source that supports the outgoing signal, but still require an external energy source to transmit, and passive tags that do not have a battery and require an external energy source to transpond/transmit.

These tags transmit signals to receiving antennas and reader systems that interpret and translate this signal to data.

figure 1 : How RFID works



Read range and computing capacity is directly proportional to the price. Such that active tags can have megabytes of onboard storage with read ranges that can be in the hundreds or even thousands of feet and range in price between $20-$100, where as passive tags have data capacities that can be up to 1024 bits with read ranges to a maximum 40-50 feet and prices between 0.05-$5.00.

The technology does have its limitations and although some of these limitations have evolved to levels where they are no longer obstacles to implementations, others are inherent to the unassailable rules of physics.

- *The technology requires special attention around metal surfaces as they tend to provide interference in the form of radio signal reflection. Certain frequencies have historically worked better on metal surfaces than others (ex: Low Frequency (LF), High Frequency (HF)), however some newer tag designs now take into account the detuning effects of metal and perform extremely well in these conditions (ex: UHF metal-tuned tags).*

- *Water and/or Liquids have a similar affect on the tag signals, they tend to absorb RF energy and decrease read range. Advancements in tag designs have significantly improved the capacity of tags to work in these environments.*

- *Inherent to the transmitting and receiving bandwidths of LF, HF, UHF, and others, is the fact that all these cannot transmit through metal objects. Despite this, the very reflective properties that, in the past, created issues with reading RFID tags actually help to propagate that signal to receiver antennas without the need for line of sight. Improvements in communications protocols have allowed a once distorted signal to remain intact through such environments.*

The fundamental benefits of RFID technology are:

- *In many cases, it does not require a line-of-sight view of that tag to retrieve information.*

- *Can be rewritten to. Which means that the data on the tag can actually be reprogrammed with new information.*

- *It is automated. The fact that these are RF waves propagating through space means that in many business processes this "wireless" capacity enables a hands-free ability to record objects that are tagged.*

- *In certain conditions, several hundred different tags can be read in less than 1 second. This allows multiple items to be simultaneously, or rather almost simultaneously, to be scanned and record. A feat that is not possible with todays digital imagers and barcode scanners.*

- *An RFID tag can be a mobile data base serving multiple entities across its journey.*

What should be our lessons from understanding more about RFID?

1 *Although the field products are predominantly metal, and many are exposed to liquids, next generation RFID technologies have advanced to levels where many applications that were once problematic are now possible.*

2

Being able to write to the tag means being able to provide onboard product life-cycle information even when you don't have access to an application system. Disconnected or Partially Connected situations are very common across the oil & gas space and so the capacity of this type of onboard storage is, in some cases, very important.

3

Being able to scan assets through liquids or mud and being able to scan multiple items at the same time, means that the technology can do more than a barcode system. Capture data in the most challenging environments is something not achievable with legacy barcode systems.

STEP 4 *Understand RFID in your market space*

Supporting growth and innovation is priority for the Oil & Gas market space. A recent Gartner market report on Information Technology (IT) within the industry had 60% of respondants ranking these two factors as the primary catalyst for IT investment.

RFID technology can support a growing market space through its underlying capability to provide traceability and control.

- *It can complement existing application systems and data collection devices.*
- *It can disrupt the existing status quo by introducing completely new processes and application areas.*

Application areas include:

1. *Casing & Drill Pipe Control and Traceability*
2. *Zonal Isolation Valve Actuation*

3 *Perforating Gun Actuation*

4 *Geo-fencing (Derrick Floor, Manufacturing Yard, Refinery)*

5 *Sensor Networks (Derrick Floor, Manufacturing Yard, Refinery, Transportation)*

6 *Supply Chain Visibility (procurement, across-production, transportation)*

Case Study (Part 2)

Coming back to our production casing example. The value of enabling a casing product with the capacity to be traced wirelessly across its manufacturing, storage, and transportation product work-flow provides both implicit and explicit benefits across the supply-chain.

Product Manufacturer

Having the ability to uniquely identify a case as it is running through its production process using an RFID infrastructure delivers an unprecedented level of data about product movement. Being able to "fuse" this data with production equipment sensors provides an even deeper level of knowledge about a particular item.

Data fusion is done at the application layer and is essentially the ability to combine different data sources to deliver a consolidated and value-added view of, in this case, operations.

In the case of manufacturing oil field product there are multiple locations where sensor and machining data can be consolidated with product identification to provide a valuable view into operations

Heat Treatment | **Temper** | **Quench**

Heat Treating *casing involves heating the carbon-steel to temperatures that increase the energy levels of the chemical bonds to levels where the microstructure and carbon content of the carbon-steel changes. By doing so, the carbon steel physical properties, things like yield and tensile, are changed. This process incorporates temperature sensors to assure that the furnaces are heating the carbon-steel to levels that are in accordance with the desired resulting specification and take into consideration the original casing steel grade, wall thickness, and other variables that affect the undergoing heat treatment.*

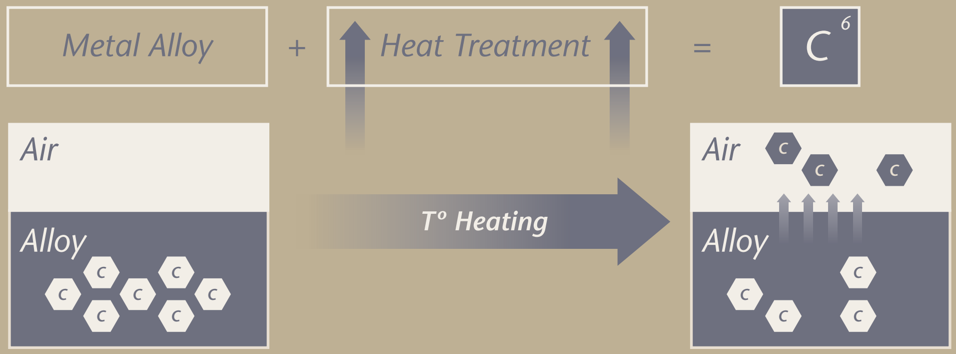
This is followed by a rapid cooling called ***quenching*** *which is intended to rapidly lower the temperature of the steel through undesirable phase transformations and create martensite, a microstructure with inherently "strong" physical properties.*

Since it is difficult to control the abundance of martensite created during quenching, a secondary heating step called ***tempering*** *is intended to reduce the excessive martensite gradually and render the product more ductile.*

Controlling temperature, product exposure time, water pressure valves, are important mechanisms to validating product quality.

picture 1: Heat Treatment

figure 2 : Carbon Diffusion



*Where **Carbon Content** is a Function of **Hardness** + **Carbon** % <=> + **Hardness***

figure 3: Phase Transformations

Temperature	*Structure*
Room (72 °F)	*Body Centererd Cubic Structure*
Austenitic Phase (approx. 700 -+ 1450 °F)	*Face Centered Cubic Structure (Austenite)*

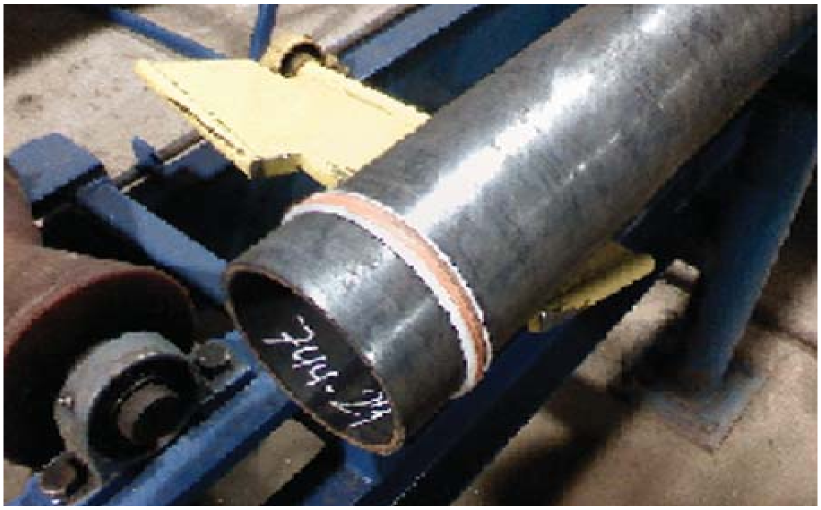
Hot Sizing ***Straightening*** ***Cooling Table***

***Hot sizing** is basically a machining process that assures rotational symmetry (makes the casing perfectly circular, or near to it). **Straightening** assure that the product itself is straight, and the **Cooling table** enables an even cooling surface for the casing so that any additional changes in the microstructure during the cooling process occur evenly across the surface of the product.*

These post-heating manufacturing work-flow steps also require levels of control that can include temperature, in addition to machining lifecycle and maintenance data.

Since this entire workflow is sequential FIFO (first-in-first-out) it is sufficient to "RFID enable" the products on the outgoing end of these process steps.

When we "RFID Enable" the individual products we've created a link, a data fusion, between the product and all the sensory equipment outlined above, in addition to the work order of the underlying production run. The application matches the identification number on the product (RFID tag) to the temperatures, exposure times, and maintenance activities performed on the machines and the desired specifications and original characteristics of the product, as well as any additional visual inspections that will be performed. We've enabled the floor-worker to now interact with the casing product on an individual basis, or the RFID infrastructure to automatically record the casing through particular locations.



picture 2: Heat Treatment

Special-End-Area Inspection & Electro-Magnetic Inspection
(or Alternatively Ultrasonic Inspections)

These quality control steps verify product integrity through a series of visual and sensory systems.

Special-End-Area Inspection *magnetizes the casing and using magnetic fluorescent particle that expose defects when viewed under an ultra-violet light. The magnetic-field is altered around the defects and the particles around this defect align themselves differently than they would along a non-defective surface area.*

Electromagnetic Inspection *involves running the casing product through a set of coils that measure transverse, longitudinal, grade, and wall thickness characteristics of the casing. Using electromagnetic, gamma-ray, and eddy current techniques to extract product data and match it against threshold requirements of the work order.*

picture 3: Special-End-Area Inspection

picture 4: Electromagnetic Inspection

The RFID tagged products run through Special-End-Area and Electromagnetic Inspection and are scanned through each inspection stage.

Once again, a fusion of information occurs between the object (casing product) and the data collected during the inspections.

picture 5: Outgoing Electro-Magnetic Inspection (RFID Read)

Hydrostatic Test	***End Finishing***	***Thread Inspection***

Hydrostatic Testing *involves passing pressurized water through the casing to assure that it can support pressure levels in accordance with its downhole use.*

End Finishing *is creating threads on the ends of the pipe in accordance with torque and related requirements when joining casing together.*

Thread inspection *verifies variables such as lead (distance a thread screws in one turn), taper (diameter change across the threads), and other thread features to assure that they are meeting specification.*

picture 6: Hydrostatic Test

picture 7: End Finishing & Thread Inspection

Picture 8: Reading Casing Through these Stations

Once again, through data collection, in this case using touch screen systems in picture 7, we've gathered assembly and quality control data about each individual casing running through these stations. We've then associated/fused this data to each unique casing tag.

We've now covered all the explicit internal benefits of using an RFID system within the 4-walls of a product manufacturer.

Additional implicit benefits lie in the data fusion. Metric analysis of production stations that can provide real-time data about things like throughput, productivity, down-time, yields, and a variety of other statistics are also results of continuously recording RFID tagged products as they move through production.

figure 4: Software Dashboard

Supply-Chain Collaboration

The now "finished-product" will ship to distribution sites and subsequently to onshore and offshore rig locations for use. It will also, in some instances, ship directly to the rigs. Now however this RFID enabled casing will hold a historical record of all the manufacturing and quality control steps that it has moved through.

This tagged casing will enable the distributors and the casing teams to, given an RFID infrastructure of their own, streamline the data exchange and casing validation. The casing now has the capacity to be validated against the casing program specifications onsite, in real-time, in an automated fashion.

In addition, irrespective of the fact if the rig itself has an RFID system implemented or not, the "RFID enabled" pipe has, at the manufacturing level, gone through a more regimented and granular quality control system and so is, statistically speaking at least, a better quality product. This improved process control infrastructure clearly falls with Six-Sigma and Kaizen philosophies and business management strategies that, among other objectives, are centered to deliver better quality product more efficiently.

Also, given visibility into the production process and across the supply-chain means that procurement and, more broadly, drilling and completion has been rendered more efficient and reactive to the dynamics associated to it.

STEP 5 Making this all work

So now that we've broken down the market and the technology from a top-down approach where do we begin the process of bridging theory with practice.

i. Drive industry adoption of RFID technology

There is already a considerable level of interest amongst oil & gas companies surrounding the technology. There is publicly available case studies on deployments across various application areas. Nevertheless many of these deployments are pilots and those that have reached beyond this stage are truly early adopters.

A consolidated effort of industry professionals and end-users needs to drive a unified effort to support successful adoption. Recently, a solution group within the space was formed to accelerate and execute on these very activities.

Named the "Oil & Gas RFID Solution Group", this group consists of Texas A&M University, University of Houston, Merlin Concepts & Technology, Shipcom Wireless, Motorola, and Avery Dennison. The group is working in collaboration with other standard bodies including EPC Global, as well as some end-users, to define industry wide roadmaps for successful adoption of RFID Technology.

ii. Establish RFID-Oil standard

Collaborative Commerce & Data Exchange needs to allow individuals up-stream, mid-stream, and down-stream to exchange information between each other seamlessly. This involves defining data structure, communication, and processes that are consistent, and more importantly, accepted and supported, by the community as a whole.

Building a universally accepted data-schema for RFID tags, means being able to add/remove/modify information on the tag itself as it moves through the supply-chain. It also means being able to extract specific fields of information about particular data without prior knowledge of the asset at hand. These data schemas could be product *specifications, as in our case study example, or sensor networks that output temperature, vibration, and other related telemetry information, or other RFID systems. As RFID assets move through the supply-chain and move in and out of the "4-walls" of a corporation and enter a new location they need to still provide data, a standard will enable that.*

This standard would not just be limited to data-schema, but software architecture, data-exchange formats, air-protocols, safety requirements, and best-practice frameworks. Building the standard would not only drive collaboration between supply-chain partners but would drive the technology within the market space. As integrators and hardware developers could now build equipment and systems based on an established set of models that have been tested and approved by the industry.

iii. Conduct proof-of-concept projects (POC) for industry

Nothing works better than "proving your concept" through successful implementations. Projects such as the Tejas Casing system (discussed above) deployed by one of the members of the solution group, Merlin Concepts & Technology, or an RFID asset management system for Qatar Petroleum, deployed by Shipcom Wireless, yet another member of the solution group, serve as repeatable success stories for further adoption of the technology. Channeled through Texas A&M, which offers a think thank and support infrastructure to deploy these "POC's" cost-effectively, while supporting and directing the end-user so that their POC investment is scalable, successful, and inline with industry development.
Next-Generation RFID technologies are evolving everyday and are redefining how the Oil & Gas market space does business. Understanding the value they bring to the industry and the direction that they are evolving in should be a priority for everyone's Information Technology department.

BIOS

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Konrad Konarski is Vice-President of Merlin Concepts & Technology. He holds a Bachelor of Software Engineering from the University of Concordia and carries over 12+ years of experience in industrial automation, radio frequency identification, and wireless mobility technologies and application systems. Konarski has been engaged throughout his career with a variety of advisory councils and strategic initiatives with the petroleum, mining, and aerospace market space. He has served as the managing principal for the successful delivery of information technology systems for Federal Organizations and Fortune 500 companies worldwide. Konarski also participates as an active advocate of RFID technology and its application uses within the supply chain, having partaken in multiple national and international television interviews, magazine features, and round table discussions, he like the other members of the Oil & Gas Solution Group, serves as an ambassador to the technology.

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Sam Falsafi, Sr. Director of Business Solutions at Shipcom Wireless: is a 10 year veteran of the IT industry and an expert in the field of assessing the Impacts of RFID Technology in a multilayer supply chain, working mainly with large and medium sized companies developing RFID strategies, planning and implementing process improvements. Sam has several years of progressive end-to-end supply chain management, information technology management, business development and management consulting leadership for innovative solutions to improve business. He has led teams in the delivery of more than 50 international RFID projects. He is a frequent speaker on topics such as RFID and supply chain re-engineering. Sam is currently the lead RFID and supply chain customer advocate for Shipcom's Oil & Gas practice. He sits on the advisory committee of Microsoft Global RFID advisory council, CompTIA RFID Cornerstone Committee and EPC Global Canada strategic advisory committee and their strategy and R&D sub-committees.