Protecting Assets, Protecting People: Exploring IoT Solutions to Drive Improved Asset Integrity and HSE Performance in Oil & Gas

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Abstract

Under budget constraints, oil and gas organizations are turning to technology solutions to ensure greater asset integrity and improve operational safety. Purpose-built digital equipment, like mobile devices and IoT sensors that are certified intrinsically safe for hazardous environments, can do both.

Communication of precise/timely information in hazardous environments allows teams to make the best decisions possible, ensuring personnel follow safety procedures and processes meet regulatory requirements, while also driving improved performance. Accurate, real-time communication in combustible environments is only possible with intrinsically safe (IS) communications hardware, such as tablets and IoT sensors. These bring industrial applications directly into ATEX/IECEx Zone 1 hazardous areas to capture/share real-time information, making them more efficient, productive, and safe.

Performing inspection activities onsite with digital devices or IoT sensors reporting 24/7 helps organizations create live and dynamic workflows in real-time. Thus, maintenance, repairs, or further assessments can be optimally scheduled. Further, digital records validate compliance (i.e. location, date, time, pictures) while driving efficiency. Pervasive digital connectivity is expected to result in savings and improved asset integrity, securing healthier and safer operating environments.

We explore the potential benefits to asset integrity and HSE management from intrinsically safe technologies that help oil and gas teams communicate better. We look at use cases where personnel collect, share, and analyze IoT data in Zone 1 operations (industrial areas where ignitable concentrations of flammable gases, vapors or liquids are likely to exist under normal operating conditions), using devices that are certified to not ignite combustible environments. When such IS solutions are applied broadly across a hazardous area operation over a period of time, we expect them to help save time, improve accuracy, and monitor personnel's well-being so they can do their jobs better and more safely - and drive better results for their organizations.

The paper describes just some of the ways that IS-certified technologies have the potential for changing how oil and gas teams communicate, helping them drive better results through improved health, safety, compliance and efficiency. We suggest testing methodologies with IoT devices for organizations to establish their own HSE baselines that can be used for benchmarking improvements from the implementation of those devices. We also make predictions for future oil and gas operations based on ongoing development of IoT/machine learning technologies and call for further research and testing in realistic scenarios.

Introduction

Under budget constraints, oil and gas organizations are turning to technology solutions to ensure greater asset integrity and improve operational safety (Williams, et.al. 2018). Purpose-built digital equipment, like mobile devices and IoT sensors that are certified intrinsically safe (IS) for hazardous environments, can do both.

We propose that communication of precise and timely information in hazardous environments allows teams to make the best decisions possible, ensuring personnel follow safety procedures and processes meet regulatory requirements, while also driving improved performance. Accurate, real-time communication in combustible environments has traditionally been difficult to achieve because of strict mandates that regulate electronics in hazardous areas (Olivier 2019). All communications hardware, such as tablets and IoT sensors, used in ATEX/IECEx Zone 1 hazardous areas must be certified intrinsically safe (IS), meaning they will not cause a spark that could ignite a combustible environment (Consunji 2013). Other challenges to health and safety for hazardous area operations include:

- gaining context around issues that collectively point to the potential for a larger, more serious problem
- facilitating communications and collaboration among feld workers and experts
- effectively transferring knowledge during shift changes
- accessing real-time e-learning and expert input for new workers in the field.

As more IS devices are being developed, oil and gas operators are using them to address these challenges. By bringing industrial applications directly into hazardous areas to capture and share real-time information, IS IoT technologies are making operations more efficient, more productive, and safer (Behrendt, et.al. 2017; Brandl 2017).

Statement of Theory and Definitions

Based on anonymous client case studies, plausible use cases in oil and gas operations and third-party research, we posit that pervasive digital connectivity in hazardous areas is expected to result in greater efficiency and improved asset integrity, securing healthier and safer operating environments.

- We define "greater efficiency" as reduction in time and/or operating costs from the implementation of digital technologies in a Zone 1 oil and gas operation.
- We define "improved asset integrity" as catching problematic or potentially problematic issues surrounding a piece of equipment or process before a failure occurs, or the use of IoT technologies to otherwise extend the lifespan of assets in hazardous areas.
- We define "healthier and safer operating environments" as those in which potential risks to personnel and assets are reduced following the implementation of IoT devices. This definition is related to Heinrich's Accident Pyramid which proposes that a reduction in minor accidents in the workplace will mean fewer major injuries (Heinrich 1931).

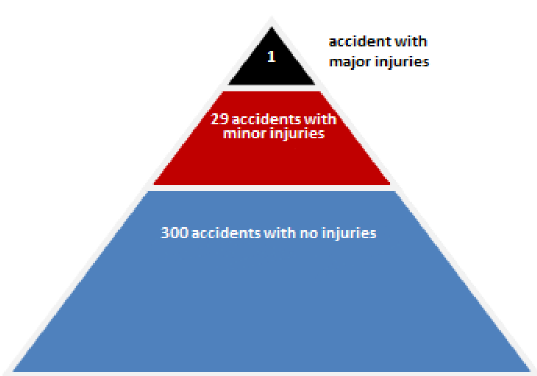

Figure 3: Heinrich's Accident Pyramid

Based on our observations from the analyzed use cases, we suggest ways in which organizations could test IoT solutions in order to establish HSE baselines surrounding their operations. This baseline data could be used to benchmark the impacts of IoT solutions on health, safety and asset integrity.

Description and Application of Equipment and Processes

To test our theory that using IoT devices in hazardous areas for pervasive communications and data management results in improved efficiency and safety, we examined a combination of seven client case studies and staged use cases using either intrinsically safe tablets or intrinsically safe IoT sensor arrays or both during 2017, 2018 and 2019. All studies were conducted as product trials that may or may not have resulted in sales. Some studies are still ongoing or confidential, thus all company names are omitted in this report. Some use cases were staged by the OEM of the products being studied and were designed to test the equipment in various scenarios. Some implications of use case results were based on previous third-party research and results.

The equipment studied included:

1) Intrinsically Safe Tablet in conjunction with various industry applications (Figure 1)
2) Wireless IoT Sensor Solution (Figure 2)

Figure 1

Figure 2

The Intrinsically Safe Tablet studied is a 10-inch, IP65-rated, Windows 10 tablet certified for ATEX/IECEx Zone 1 and Class I, II, III Division 1 hazardous areas. The purpose-built enterprise tablet operates on WiFi or LTE network communications, has front and rear intrinsically safe cameras, capacitative touch screen and up to 12 hours battery operating time. The lightweight, thin design, rugged tablet is highly customizable to run bespoke industry applications in extreme environments. Other like devices were expected to achieve similar outcomes.

The IoT Sensor Solution studied is a modular system comprised of an endpoint, battery, WiFi communicator, and a selection of more than 40 “plug-and-play” sensor nodes that are preprogrammed to be immediately operational and recognizable in the user’s cloud-connected process automation, asset management, rounds management applications or related systems. The wide variety of mix-and-match sensor nodes, including gas sensors, environmental sensors and conditional sensors, enables users to configure the system to simultaneously monitor multiple specific factors, providing multi-dimensional context for conditions and alerts based on programmable thresholds. We also integrated a universal bus that enables connections to third-party devices that utilize a 4 – 20 mA connector, effectively making legacy equipment “cloud-connected smart equipment” or “smart sensors” that are able to be monitored in conjunction with other monitored factors.

The two solutions – the Intrinsically Safe Tablet and IoT Solution - may be used together or separately to provide contextual data and share that information broadly among teams in hazardous areas. With a more detailed view of an operation and wider communication throughout, we suggest that organizations are able to make better-informed decisions, resulting in safer and healthier processes and work environments.

Use Cases Studied

The following use cases employed either the Intrinsically Safe Tablet, the IoT Sensor Solution or both:

1) Refinery operators visualizing real-time gas levels/air quality with IS IoT sensors, resulting in early leak detection, minimizing health hazards
2) Upstream operators consulting digital manuals/procedures with IS tablets, ensuring compliance
3) Maintenance completing inspection forms in Zone 1 with IS tablets, resulting in time savings/asset integrity
4) Technicians digitally capturing barcodes or NFC tags to improve data accuracy and time on tools
5) Onsite personnel/offsite consultants viewing situation with real-time VoIP application on IS tablet, saving time/improving quality
6) HSE manager monitoring workers with principle component analysis (PCA) software on IoT devices that communicate among teammates and offsite management, avoiding accidents
7) Repairmen using virtual/augmented reality apps to check equipment conditions, improving accuracy/safety

Presentation of Data and Results

The following use cases include information gathered from anonymous clients, staged trials by OEMs and third-party research. The goal was to qualitatively measure a perceived difference in safety and asset integrity in each case, or quantifiable differences where available, through the use of Intrinsically Safe Tablets and/or IoT Sensors.

Case Study #1: Refinery operators visualizing real-time gas levels/air quality

Operators of an oil refinery were given a wireless, intrinsically safe IoT Sensor Solution to set up in a Zone 1 area of the refinery. The IoT Solution was configured with the following components:

- Endpoint
- Battery
- WiFi
- CO_2 sensor
- O_2 sensor
- Environmental sensor (temperature, light, humidity)

Operators used an Intrinsically Safe Tablet to visualize the IoT sensor data. Operators were able to see when the temperature and gases changed in quantity, producing an alert based on thresholds set. They could then share those readings immediately with other team members carrying Intrinsically Safe Tablets in Zone 1 hazardous areas. This real-time reporting and notification showed that gas leaks and their potential associated risks could be detected early or almost immediately.

Other studies have shown that early notification of gas leaks correlates positively with minimizing risk and loss (Van Riemsdijk and Bosselaar; Afebu, et.al. 2015). Additionally, early detection of the factors that could align to cause accidents (the Swiss Cheese Model of Accident Causation) can aid in preventing them (Reason 1990). In this case, it was deduced that early detection would help to minimize health hazards, environmental risk and safety compliance risk, plus protect asset integrity.

Case Study #2: Upstream operators consulting digital manuals and procedures with IS tablets
An upstream oil and gas operation implemented the use of Intrinsically Safe Tablets among newly hired/trained personnel working in Zone 1 areas. When presented with a question about the safest operation of a certain piece of equipment, the workers were able to search product and procedure manuals on the tablets to find instructions.

A variety of documented industry studies have shown that the occurrence of hazard-related incidents negatively correlates with adequate training and effective communication (Parviainan, et.al. 2017; Shuen and Wahab 2016). In other studies, personnel have been found more likely to comply with strict regulatory procedures if those procedures are obviously stated in literature or other places that are easily accessible (Akhigbe, et.al. 2016). In this case study, then, proper operation of the equipment was expected to result in a safer work environment and compliance with regulatory mandates. The use of intrinsically safe tablets to verify proper procedures was expected to be the catalyst for better behaviors, which, over time, can be expected to yield better outcomes.

Case Study #3: Maintenance completing inspection forms in Zone 1 with IS tablets
Maintenance personnel inspecting equipment in a petrochemical facility used digital forms on Intrinsically Safe Tablets to complete their hot work permits and related inspection reports. They were able to use the tablet's cameras to take photographs and upload those along with the timestamped reports directly to a maintenance records database, as well as email them to managers offsite. By moving to digital forms, the duration of the hot work permit process and inspection time was reduced from an average of 4 hours to 45 minutes. The change also resulted in fewer mistakes, plus, the digital records validated compliance. Such improvements ultimately contribute to increased asset integrity and reduced risk (Barchard, K. and Pace, L. 2011; Richter, A. et.al. 2017).

Case Study #4: Technicians digitally capturing barcodes or NFC tags
Technicians managing inventory used barcode and NFC readers on Intrinsically Safe Tablets to scan equipment parts in Zone 1 hazardous areas. Previously, they wrote serial numbers with pencil and paper because certified devices were not available for their Zone 1 hazardous area. Writing the date by hand was time-intensive, and technicians had to spend additional time once back in the office to input this data into IT systems. Barcode and NFC readings via the tablets resulted in increased Time on Tools and improved integrity of information by reducing mistakes in data entry. Using digital solutions has elsewhere been shown to improve data accuracy and Time on Tools (McKinsey 2018; Richter, et.al. 2017; Fuchs, et.al. 2018).

Case Study #5: Onsite personnel and offsite consultants viewing a situation with real-time voice and video application
In the case of a complex asset integrity situation, onsite personnel used an Intrinsically Safe Tablet to converse with an offsite consultant and visually show him the problem. This real-time, multi-media communication enabled personnel to correct the problem more quickly and easily by virtually bringing an expert to the scene for assessment and advice. As a result of the quick and effective consultation, the asset was fixed before the situation worsened, extending the asset's lifespan and eliminating the need for a replacement. Optimal equipment operation has been shown to contribute to safer operating environments (Ferguson 2019).

Case Study #6: HSE manager monitoring workers with principle component analysis (PCA) software on IoT devices that communicate among teammates and offsite management

Workers in a Zone 1 hazardous location used PCA software on Intrinsically Safe Tablets to report on rounds activities, informing offsite HSE management about their performance of said activities. Managers would immediately know if any behavior was noncompliant, as indicated by incomplete or faulty reporting. This monitoring resulted in increased compliance in dangerous environments, thus reducing safety risks. Greater accountability and verifiable compliance has been associated with such types of reporting applications (Petrusich and Schwartz 2017).

Case Study #7: Repairmen alerted by alarms of a problem using virtual/augmented reality apps to check equipment conditions and plan repair

Crew were alerted of a probable leak in piping by IoT sensors that detected changes in air quality and product volume. Repairmen sent to repair the breech, which was in an undetermined and largely inaccessible location, could visualize sensor data on Intrinsically Safe Tablets and use virtual reality and augmented reality applications to locate the equipment in question, view specifications, and plan the repair strategy. The activity was perceived to result in time and cost savings, as well as the avoidance of a potentially dangerous situation. Virtual reality has been shown as a safer alternative to some types of dangerous industrial work (Shamsuzzoha, et.al. 2019).

Results

In each case, performing activities onsite with digital devices and/or viewing data from IoT sensors reporting on selected intervals helped organizations make better-informed decisions more quickly. More complete information about the larger operational context, plus the ability to solve issues rapidly before conditions worsened, was believed to contribute to more efficient and safer operating environments.

Based on these observations, we recommend the following steps for organizations wishing to evaluate the use of Intrinsically Safe Tablets and IoT sensors for managing asset integrity and improving safety in hazardous operations:

1) Select the conditions you want to monitor. Which factors, combined with certain other factors, could possibly contribute to an unsafe situation? Maybe these are levels of oxygen, methane or other gases that become a potentially dangerous mix. Or maybe these are the vibration of mechanical parts in conjunction with a rise in temperature that could indicate a pending failure. Which are the combinations of conditions you would want to receive an alert about?
2) Create thresholds for those conditions. What are the minimum and/or maximum levels of the conditions you selected that are considered safe? What sort of alarms should be set to alert when certain combinations of those conditions are met?
3) Configure intrinsically safe IoT sensors to monitor selected conditions, setting the assumed thresholds for each. You will be testing over a specific period to observe the selected factors in order to establish baselines for each.
4) Deploy the IoT sensors throughout an operation, or begin by placing them in a few key locations.
5) Begin monitoring the sensor data with analytics tools of choice. Establish baseline "normal" levels for each condition, and adjust sensor thresholds as needed.
6) Issue Intrinsically Safe Tablets to personnel in Zone 1 hazardous areas. Load industry software that they would normally use in an office setting onto the tablets.
7) Ask personnel to perform their usual jobs using the tablets in Zone 1 and other areas. Record their ease of use, speed of completion, accuracy of data entry, and other evaluation indicators.
8) Ask personnel to monitor the IoT sensor data on their IS tablets while in Zone 1 and other areas during their normal shift.
9) Manually cause an alert by changing the sensor data. Observe the alert on IS tablets.
10) Use appropriate applications on tablets to help personnel in Zone 1 locate the cause of the alert and report on their findings, including taking photos, logging data in back office systems, etc.

11) Record personnel’s comments and feedback about their user experience with the tablets and the IoT sensors, asking what may have been easier, harder, quicker or slower using these devices than their previous processes. Be sure to ask their opinions on whether the devices make them feel more/less confident, more/less safe, more/less efficient, more/less secure, etc.

Conclusions

In this paper, we explored the benefits to asset integrity and HSE management from intrinsically safe technologies that help oil and gas teams communicate better. We looked at use cases where personnel collect, share, and analyze IoT data in Zone 1 operations, using devices that are certified to be incapable of igniting combustible environments. In each of these cases, IS solutions were shown to or perceived as saving time, improving accuracy, and monitoring personnel’s well-being so they can do their jobs better and more safely - and drive better results for their organizations.

This paper describes just some of the ways that IS-certified technologies are changing how oil and gas teams communicate, helping them drive better results through improved health, safety, compliance and efficiency. The future success of oil and gas operations is expected to be based on ongoing development of IoT and machine learning technologies, and highly accurate and valid data is a necessary predecessor to artificial intelligence (AI) (World Economic Forum 2017).

With IS technologies that enable real-time insight and communications, the benefits of IoT may be extended to hazardous area operations that previously may not have had access to those types of predictive and analytical technologies. With better information, delivered and shared in real-time, oil and gas and other industries with hazardous area operations will be better equipped to make decisions that impact not only the efficiency of those operations, but also the safety of their personnel.

Further research and testing in realistic scenarios would contribute to richer understanding of the role IoT solutions play in oil and gas operations. The use cases for IoT technologies in hazardous area operations are numerous. Additional clinical trials, as well as on-the-job testing of intrinsically safe devices in multiple scenarios, would add to the mounting evidence of improved asset integrity and HSE management that results from pervasive digital connectivity via implementing IoT technologies in oil and gas operations.

Future predictive maintenance in oil and gas will be based on complex analysis of variable operating conditions; AI and IoT technologies will help to identify patterns of potential safety concerns, predict equipment failure and schedule preventative or on-time maintenance (Lee, Lee & Kim 2019). These advances will not only reduce downtime in oil and gas but also minimize the risk of accidents involved with dangerous maintenance activities. With future IoT Sensor Solutions and Intrinsically Safe Tablets helping to improve communications and insight into operations, increased worker safety, productivity and asset integrity are likely results. With IoT technologies for oil and gas, the future is now.

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