UACJ INVESTIGACIÓN

Título del Proyecto de Investigación a que corresponde el Reporte Técnico:

RFID APPLICATION FOR TRACEABILITY AND COLD CHAIN MONITORING OF ADHESIVE DURING LOGISTICS PROCESS

Tipo de financiamiento

Sin financiamiento

TÍTULO DEL REPORTE TÉCNICO

RFID APPLICATION FOR TRACEABILITY AND COLD CHAIN MONITORING OF ADHESIVE DURING LOGISTICS PROCESS

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Ciudad Juarez Chihuahua a Noviembre 07 del 2019

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Por medio de la presente se hace CONSTAR que **Griselle Samantha Santos Castellanos**, matrícula **153288**, alumna del Programa de la Maestría en Ingeniería Industrial de la UACJ, realizó en esta empresa el siguiente proyecto: **RFID Cold chain** con la asesoría del: **David Atayde** en un periodo comprendido del **31 de agosto del 2019 al 22 de noviembre de 2019.**

Se extiende la presente para los fines que al interesado convenga.

Sin más por el momento, quedo a sus órdenes para cualquier duda o aclaración.

Saludos cordiales,

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TÍTULO DEL REPORTE TÉCNICO

Resumen del reporte técnico en español (mínimo 600 palabras):

La introducción de tecnología de identificación con radio frecuencia para los materiales sensibles a temperatura durante su cadena de suministro es una de las tendencias con mayor importancia y es considerada una mejor practica en la industria manufacturera. El uso de etiquetas de identificación con radio frecuencia ayuda a identificar desviaciones de temperatura durante las diferentes etapas del proceso logístico esto con la finalidad de tener una mayor trazabilidad de los materiales durante el proceso.

Resumen del reporte técnico en inglés (mínimo 600 palabras):

The introduction of RFID technology in the supply cold chain is one of the most significant trends and best practice for the monitoring of the temperature deviations. The usage of RFID tags during process can help the different stages of the logistics process to increase the traceability of the materials and identify any deviation in the temperature.

Palabras clave: RFID, cold chain, outbound, inbound, shelf life, middleware, RFID antenna, industry 4.0

Usuarios potenciales (del proyecto de investigación**):**
Mainly manufacturing companies using perishable materials and cold chain materials that are temperature sensible, even though this report is focused in one specific type of material (adhesive) the RFID application can be use according to the needs of the company that want to be implemented.

Reconocimientos (agradecimientos a la institución, estudiantes que colaboraron, instituciones que apoyaron a la realización del proyecto, etc.**):**
This report is dedicated to all the Bosch departments involved in the implementation and planning of the Project.

1. INTRODUCTION

Industry 4.0 emerges from the combined effect of the availability of innovative digital technology and the constant demand by manufacturing companies for automated processes assuring the quality in their products and faster reactions to any deviations in their production developments. This encouraged the use of RFID (Radio Frequency Identification) technology during the last decade due to the boom of the industry 4.0 solutions offered in the manufacturing market. These solutions include several options as tags, readers, conveyors and antennas that facilitate the continuous movement of goods and raw material in the supply chain.

Even though the concept of industry 4.0 started mainly in manufacturing process, its usage in the all the activities in the value stream increased its share since the hardware can be implemented as a standard solution also for logistics processes. Machines, finished goods and transportation can communicate one to another with a single RFID tag containing crucial information.

Using RFID technology can help not only business owners but also shareholders to develop lean supply chains nevertheless the most important benefit is the paper-less and real time data that can be track and manipulate as fast as you can imagine.

The main purpose of this document is to present RFID solution for not only logistics but also its impact on the quality aspects of the materials. The usage of RFID tags in the containers of certain materials can help to the deviation management of the temperature behavior of “cold chain materials”. This last term refers to the network of refrigerators, cold stores, freezers and cold boxes that maintain materials at the right temperature during transportation, storage and distribution from factory to the point of use. These temperature sensitive materials are critical because their wrong expiration date can cause supplier claims and material losses. Both subjects (cold chain and RFID) will be treated deep dive to understand the major benefits of the introduction of new technologies into established processes.

2. BACKGROUND & PROBLEM STATEMENT

In 2019, the supplier claims of adhesive material caused the company Robert Bosch to lose around 80,000 USD in negative inventory adjustments and scrap movements in the system. This was one of the top 10 of scrap material in the plant. Even though the supplier was responsible of these claims, the importance of the incoterm placed in the sales agreement mislead the responsibility to the plant instead of attributing to the supplier. Not only the scrap cost but also the incorrect shelf life (expiration date) of the batches caused concern in all the departments involved in this issue.

Planning, warehouse, quality and production invested their efforts to find a temporary solution to avoid more scrap in the short term. Reaction plans were implemented and more control in the temperature management was applied. The temporary solution was to install a data logger in each container batch of the shipment of this material. This means that for example if a shipment has 3 different batches, 3 data logger will be placed in one of the containers, not all the containers will have its own data logger since the price of implementing a 1:1 relation will be expensive. The price of each logger is around 34 USD dollars and they are not re-usable since the device has no capacity of "re-write" any information in the logger. After this contention action the receiving process didn't change since the data logger was take off from the container by warehouse point leader assuring this part as logistics being the process owner for this implementation. However if any deviations in temperature were found in the data logger (See picture 1.1 from the annex) warehouse department was in charge in notifying to the entire value stream. After this mail notification, incoming (quality department) proceed with the supplier claim and deep dive investigation about the root cause of the deviation in the temperature and starts the necessary actions with the specific batch.

Since the design of the packaging was in the scope of the customer's responsibility, Bosch absorbed the price of the data logger. This means that procurement department (inside the logistics group) was in charge of paying the fee of the devices to the supplier. Especially since the transportation, incidents (delays) were increasing from one per month to two per month. In addition, transportation mode and carrier was the

customer decision, so every delay or lag in the carrier that affected the temperature of the batches carried was also Bosch's responsibility.

For the case explained in this document, the material in discussion is transport in a dedicated truck conditioned with special features because of the technical conditions of the material. Temperature sensitive material are not always easy to handle especially for the ones that have transportation times between 4-5 days and are traveling overseas, to give an idea: from Germany to USA and the import to Mexico). So every small deviation in the ETA's (estimated arrival time) of the shipment can cause a mishandling of the adhesive material in matter of bad control of the temperature or temperature out of specifications. This action can incur into a material full rejection, imagine entire containers rejected due to incorrect temperature or material already expired before arriving to the warehouse.

Another force majeure cause related to transportation can be the common airport strikes placed in Europe. It is important to clarify that 2018 was the year of aviation strikes not only passengers (over 1.8 million passengers were affected according to Aerotime News HUB) but also cargo freight was affected because of the lack of personnel to operate the air carriers as Lufthansa, DHL, Panalpina and UPS just to mentioned some of the companies dedicated to cargo base freights.

Any complications presented during transportation will have big impact in the cold chain materials especially when the human element and the environmental conditions are not that easy to predict nevertheless what is useful to learn is how to mitigate this risk. In logistics, it is the rule to expect the worst and have faster reactions to handle high-value shipments ensuring the correct attention to the shipment and always a contingency in place or reaction plan to diminish these unexpected risks.

After explaining the risks during transportation, it is important to focus on the properties of the cold chain material that for this case is a type of adhesive used in one of the high-cost finished good in the plant (rear view camera). Therefore, any scrap movement or material rejection can cause from a raw material shortage to a production line down due to material rejected because of temperature out of control.

The main purpose of implementing the data loggers in the containers was also to avoid out of temperature adhesive to be supply to production as certified material because

before the data logger there was no visual aid or technical information of the temperature behavior of the shipment during its transportation. This means that for example if a batch had several deviations, peaks of temperature out of specifications in the transportation process neither warehouse personnel, or incoming were able to identify this material conditions. One disadvantage of the data loggers was that the device was inside the contained (cooler) so this means that if a batch had the data logger this cooler requires to be open to take out the data logger and see the flashing light either green or red depending in the material status. The action of opening the cooler was the most critical one because after one of the containers was opened the responsibility of the whole shipment was rely in the customer (Bosch). Consequently, this made harder to conduct any supplier claims or return to vendor process because the coolers were already opened.

That is the main reason of why exploring new technologies and options to close these gaps in the supply chain that affects directly the daily operation not only for logistics but also for production causing deviations in the complete value stream. The risks during transportation, the missing data of the temperature deviations during logistics process and the restriction of the data loggers where the main reasons of why looking to a new device that can fulfill all these open points. Even though the data loggers was a short-term solution and faster reaction from the whole team to the problem. The team had more expectations of how to solve this problem so after analyzing if to keep to data loggers or move forward to RFID tags, this last one was the best option to implement this technology under an established budget expecting costs reductions and improvement in quality process building a stronger supplier- customer supply chain.

General objective (Purpose of the document)

The purpose of introducing RFID technology into the adhesive material process is to have a clear overview of the temperature behavior during its transportation and logistics management. Even though the temperature deviations are control and follow up by the actual data logger, there is an opportunity area for continuous improvement. Since the material is temperature sensible the risk of supplier claims are bigger due to its physical properties and the cost of blocked material is higher. Continue with the actual process is not a sustainable solution because the shelf life will not change according to the expiration of each batch.

The shelf life refers to the length of time that a material may be stored without becoming not useful for use or production. It's like an expiration date or best before date of a product in matter that its properties are still maintain and can be use into the production process. Giving an incorrect shelf life can cause that bad material enter to the production process and detecting its bad condition once already processed can be more expensive in comparison if the material is scrapped at the moment that is identified with bad conditions. This is another cause why the RFID label will be give more benefits to the actual scenario due to its data analysis according to the temperature behavior during transport can assign a new shelf life instead of doing the manual calculations counting the days backwards. A very important fact is that the adhesive shelf life is dependent on the adhesive system and the storage conditions, in particular, the temperature.

There are several conditions that can help to the material to maintain its manufacturing original shelf life, for example in cases where the adhesive shelf life can be extended through correct storage at low temperatures, also it should be indicated on the packaging. Nevertheless it must be considered that there are deviations that even with the perfect packaging and temperature control devices cannot be control at first instance. One of the main reasons of the introduction RFID into logistics process is to take advantage of the data analysis and writing information that can be store in the RFID tag since it leads to a lean management where nonconformities and deviations are more visible to identify and investigate deep dive in order to avoid any bad material into production process and also making precise quality claims and scrap charges to supplier.

Specific objectives (Activities to develop)

In order to implement the use of RFID tags in cold chain materials it must be done the next activities:

- Mapping of actual process with no use of RFID. When implementing a new process the first activity that all departments involved must do is go to *gemba* (is a Japanese term meaning "the actual place") which is basically go to the warehouse and observe the actual process, compare with the ideal scenario with the RFID data loggers and compare if there are any gaps between the two process and look for improvement areas and ideas to avoid any waste during and after

implementation. Create a process flow where all the activities involving the actual process are consider and where the new technology will be value added to the process itself.

- Evaluation of existing RFID hardware in the Juarez warehouse and compatibility with other projects in logistics area. The warehouse has already RFID infrastructure in each dock in the which consists of 2 types of installation:
    - For outbound process (shipments to El Paso or shipments for Mexican customers) the RFID installation consists of 1 RFID reader with internal antenna and 3 RFID UHF antennas. Since the internal antenna of the RFID reader has less power in comparison with the external antennas and taking in consideration that the process of how the trucks are being load from Juarez side to El Paso & other locations, this is the most convenient hardware to use since the process owner is in the sending system.
    - For inbound process (raw material received coming from the cross dock in El Paso) the RFID installation consists of 1 RFID reader with no internal antenna and 4 external antennas. Since the inbound trucks are loaded with not standardize process or in certain way where it can be manipulate to the most convenient, the requirement of having more powerful and extent reading of the labels was very important for this case. For this use case it is important to remember that logistics process of the inbound materials presented in the below chart.

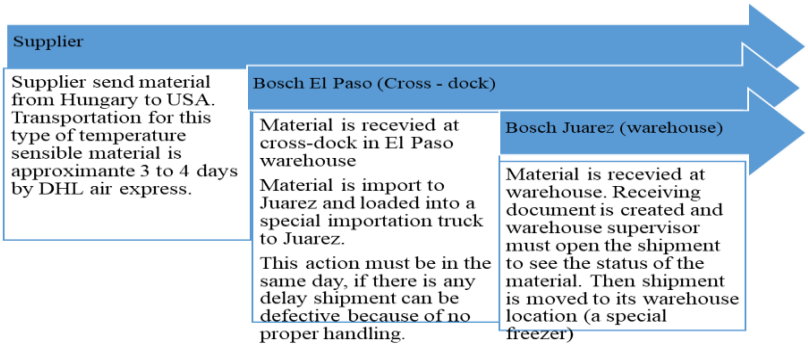


Table 1- Inbound process

Subsequently for the implementation of the use of RFID into the cold chain material was imperative to evaluate the existing hardware already in place to benefit from the investment. The RFID installation at the inbound docks was helpful to create the first time stamp in the background. Therefore no new gates must be in placed only the use of the RFID handheld terminals (similar to scanners).

- RFID hardware testing and positioning of the labels in the shipment. Even though we are using different types of RFID hardware in the process is very important to validate the one that has less flexibility. This will be the RFID gates in the inbound docks which were tested with different tags and positions of the pallets placed in the forklift used to unload the shipments. Meanwhile the inbound shipments are handled by the cross-dock operations and they don't have any standardize process of how the trucks must be load, the validation of the RFID gates was perform at the power reading level of the antennas, interacting with different positions since the data logger will be inside the boxes and not in the same positions every time.
- Implementation of an automated process using the time stamp of the reading information with the RFID readers and the tags of the shipment. This means that after application of this technology all employees handling this material will have access to a more detail time stamp of the logistics process behind. The RFID tag will contain the next time stamps:
    1. First time stamp will be create when material is shipped by supplier. This means that after writing the information into the tag there is no option of returning the shipment or assign an incorrect date. Also this will help to avoid any incorrect or aleatory shipping date of the material since there will be no option of fraud this information. In the past it was pretty common that shipping date in the invoices or in the bill of ladings where manually assign within 2 or 3 days of breach and for cold chain materials these lead time can be very sensible in matter of transportation or shelf life in the warehouse.
    2. Second time stamp is created when material passing through RFID gates installed at Robert Bosch Juarez warehouse. Even though this type of

material is handled carefully and with extreme care in some cases with the day by day priorities, this material was physically received but not stored in the freezers as soon as shipment arrived. This gap can cause into defective material specially if the batches were not arriving in perfect conditions (melting ice, missing enough amount of ice or already expired)

3. Third time stamp is created when batch is read by RFID handheld terminal by warehouse supervisor. This time stamp is the last one and the most important one because is the one that detects if material comes in bad conditions and analyze previous time stamp to derivate a new shelf life.

Restrictions of the project

The introduction of the RFID label into the adhesive material will improve the detection of temperature deviations during its transportation and material handling, additionally it will assign a new shelf life date according to the temperature analysis based in the data stored in the RFID tag. Taking in consideration the previous general benefits it is important to identify and explore deep dive into the complete solution and how there are gaps that this project will also cover and improve. For example the actual data logger used is stored inside the packaging cooler. This means that in order to take out the data logger and start with the temperature behavior analysis, warehouse supervisor must open the container and break down the pallet. The action of the container inspection means that after the cooler is open all the material shipment is responsibility of the customer so all claims are not valid or can be more difficult to defeat if bad material is identify after the material is handle already in the warehouse. Even though deviations can occur with the introduction of the RFID tag for example that in sporadic cases can be that the tag comes defective. This happens at the moment when supplier is writing the information into the RFID tag, perhaps the tag comes faulty and incur into a process failure. It is important that to avoid these types of deviations all tags must be validated at first instance after its procurement due to the fact that there are no actual *pokayokes* (Japanese term that means "mistake-proofing") at supplier to detect RFID tags with no information written. As there is no information of the historical deviations of miswritten tags from other manufacturing plants with same process one solution is the introduction

of a standard RFID readers to perform a process confirmation at supplier location where the shipment or batch has the correct codification (writing information) in the label.

Although the process will not change at the moment of receiving the shipments at warehouse additional activities must be add to the process to maintain the same functionality. In the actual scenario the data logger is take out of the cooler by warehouse operator and by the lights (green or red) escalation mails are sent to the whole supply chain. From logistics to quality the mail must be distributed to keep all informed about the material status, this type of escalations are only done when the light is turning red which means that the complete batch of the shipment arrived in bad conditions. The same procedure must take place with the RFID logger, since it contains the information if the material is in good or bad conditions, nevertheless this status will be given by the RFID scanner that will read the re-usable tag before the package is opened.

Even though mail escalations will be maintain the same which is not the ideal scenario to an automated process in the background, warehouse operators will inform to incoming (supplier quality department) about any bad shipment or bad conditions material at the moment that is identify. However they will be able to access to more detailed deep dive data and historical analysis of the shipment and decide whenever the material can be use or be scrap or even assign a new shelf life. Here we can find an opportunity area to introduce a middleware between the status of the RFID tag and the mail service using (Mainly Microsoft outlook) instead of relying in manual confirmations by mail, connecting the database of the tag and the mail interface can be a solution in the future to skip any human interaction or dependency in the process.

Another existing gap for this process is that the new shelf life date given by the data analysis made by the RFID software is not linked automatically to SAP (systems applications and products) which is the company software that integrates several departments' modules. Even though it is very important to change or compare this date in the system to the one that the SAP is assigning the fact that needs to be change manually in SAP can also incur into misleading or deviations of the process. The assignation of certain shelf life by SAP is very ambiguous since it only takes in consideration one field in the master data of the part number and it's receiving document date. For example if the shelf life of the part number of the adhesive in discussion is 70 days after receiving, the

logical operation of the system is the addition of 70 days to the its receiving date. Consequently if material is received by November 4th, the shelf life in SAP will be January 13th 2020 so the calculation is not reliable because SAP doesn't go deep dive into the temperature deviations or detailed time stamps of the logistics process of the part numbers. Nevertheless the missing connection between the two applications relied into human interaction to input information into one system which is the manual error that it must be avoided with industry 4.0 projects. Above is shown the IT infrastructure to understand the connection between the systems. Systems used are:

- ANTRA software: application that measures the deviations of the temperature of the batch. This is integrated in the RFID reader from supplier.
- SICK software: application of the RFID reader from customer, this is used to validate and test the physical hardware and the RFID tag position in the package.
- SAP: ERP (Enterprise resource planning) system used in the company for the material handling and consumption.
- Crosstalk middleware: links the SICK reader and the SAP system, however there is direct actual connection from ANTRA to SAP. Here is the gap is in matter of the lack of automatic update of the shelf life of each batch in SAP.

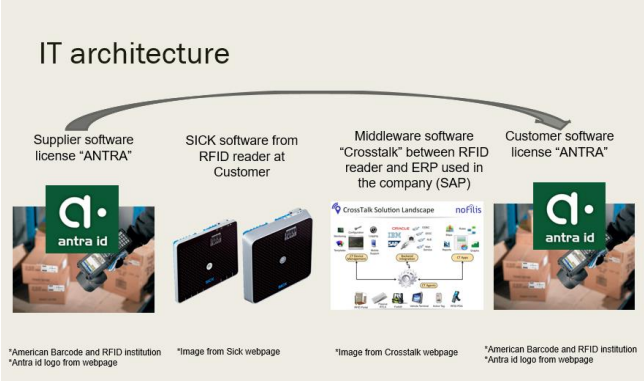


Figure 1. IT infrastructure mapping

Even though the warehouse personnel has experience with RFID projects and are familiar with the IT infrastructure and the hardware itself, this project will not only benefit the warehouse operation but also quality department so for this aspect its crucial to take into consideration the learning curve for this new scope. Nevertheless, the actual process will not change it material flow and communication standards some activities

will be add to the quality's department scope. For example at the moment the incoming team (quality's group who is in charge of supplier's claim and damage material at receiving area) is in charge of blocking the material in SAP when it comes damage or out of specifications. The investigation and deep dive of the reasons for this matter is done in the long term causing more delays within the supplier and issuing more orders to suppliers for replace this material which in some cases the lead time for replenishment is too long for the production requirements. Also the frozen zones established in the supplier's contract doesn't allow to issue more orders within this time frame which can incur into a production shortage even though the claim can be the supplier's fault. Another important aspect to consider is the inventory blocked and its replacement, the orders that raw material group issue into the ERP system (SAP) increase the TCT (total coverage target) in inventory which is a very important KPI for the plant. So after the RFID implementation in cold chain material, the supplier's claim can be addressed immediately to the root cause and identify if this can be charge to the supplier and faster replenishment from their side must be done. Here incoming team will have faster reaction times since all the data information to make the supplier claim will be as soon as they receive the material and read the RFID data logger in the package.

In matter of investment, it is very important to evaluate the cost-benefit of the project and mainly the payback period. Evaluating the business case it will be consider the inventory adjustments made in 2018 and until the third quarter of 2019. These adjustments can be done due to two mainly reasons: scrap, or negative inventory adjustments due to quality issue. Even though the budget allocated for this project was sharp in matter of the hardware needed any extra charge or budget deviations can affect the hardware procurement. The main purpose is the flexibility of the hardware already installed and the one specialized for this project. That's why the RFID testing in the gates installed in dock is crucial to see if the tag location inside the package is going to be possible to read and information can be track since material is crossing the inbound docks.

Figures are YTD & SAP data		
Adhesive material	Receipts	Negative scrap movements not charge to supplier
Amount USD	$ 55,996,461.00	$ 79,073.76
Quantity (gr)	376,155	52,383.10

Figure 2. Material receipts & adjustments in 2019

Therefore after analyzing all the previous restrictions mentioned, there is a need to have the acknowledge that these factors can be consider as "showstoppers" in a matter of time if there are no countermeasures proposed after the project implementation. That's why a reaction plan for these aspects is presented above:

Restriction presented	Will affect at short term (6 months)	Counter measures
Missing ***pokayokes*** at supplier	Yes	Supplier will need to install a RFID reader in the dock of shipping to identify if the package has its RFID activated or written. This will increase the cost of the project to $5,406.00. The plan will be to check the tendency of the packages with no RFID activation from supplier, if the cases are more than 1 in 6 months a quality gate at supplier must be implemented. This is based in the information that supplier has from 1-2 shipments per month.
Email communication	No	One of the purposes of industry 4.0 projects is to replace human interaction in the implemented system, this is due to the information transmitted between the system, nevertheless as this implementation is at its first phase in matter of the interconnected systems the mail communication will be necessarily to inform about the defective shipments from supplier.

		The true north for this project will be to develop an option of send an automatic signal (or mail) to quality department that communicates the packages arrived and their current status. This can be link to the supplier software that does the temperature analysis (ANTRA).
Missing connection between software applications	No	When the ANTRA software assigns the batch a new shelf life, this date is not automatic transfer to the SAP batch documentation. So quality department must update SAP system, this update is very important for the FIFO consumption because even though all the materials are consumption based on FIFO, for cold chain materials the consumptions is based in the expiration dates. If SAP is not update in correct manner the purpose of having a more accurate shelf life will be in vain.
Learning curve from personnel	Yes	For every project the training of the personnel is very important since all the troubleshooting will be part of their daily activities if failures happen. For RFID projects the warehouse and quality department will be trained since the basics of this new technology, nevertheless the learning curve will depend in each team capabilities and willingness.
Investment	No	RFID projects first investment are lower cost based in comparison with other logistics investment projects that are more than 20,000 USD. The return on investment will be different for each project, however for this business case the savings are easy to identify since the purpose

		is to avoid any scrap charge to the company's cost. Other RFID projects will involve more quality based benefits or the most common case: increase productivity. For our business case the investment will be sustained by the scrap amount and the scrap caused by incorrect shelf life date assigned.

Table 1. Counter measures of the project restrictions

Basic RFID introduction and training for the warehouse and quality personnel

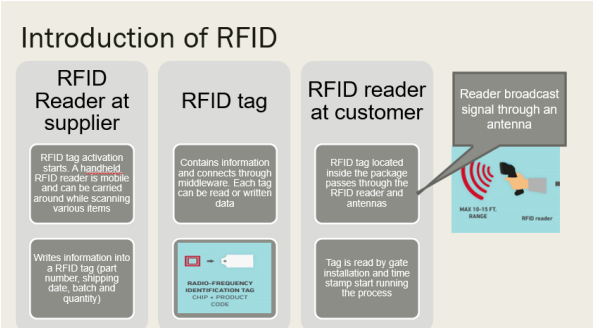


Figure 3. Basic RFID data

Justification- Impact and importance

Like all supply chains, cold chain operators must continually upgrade technology to ensure efficiency, integrity, and safety. This includes both back-end IT infrastructure and front-end devices to gather and report key shipment data in real time. One of the logistics pillars in the company Robert Bosch is innovation at the current processes. Mainly this feature derivate from several projects that enable digitalization in the supply chain. This means that the objective of having leaner processes and communicated interfaces is very important to follow in order to go with the true north of the company. RFID technology enables part of this objective since it is one of the simplest and most accessible industry 4.0 solutions that can be flexible to any logistics process. For our project not only logistics will be improve but also quality department will be have data with more quality and detailed information in one RFID tag at the moment. The importance of having a control cold chain supply chain can help the companies to maintain their stocks turnover in a good condition and avoid any bullwhip effect due to scrap issues. Cold chain materials with its capital-intensive equipment, strict temperature

requirements, and energy dependence, has always been a demanding logistics segment. Now the sector is grappling with additional challenges—from increases in the sensitivity, quality standards, and volume of many of its goods, to continually mounting regulations.

Below you can see a chart explaining why it is important to improve the quality of the cold chain supply chain.

Trend	Impact/ Cause
Cold chains are becoming more global.	Due to high demand shippers are concerned about maintaining control of products in transit
An increasing focus on quality and product sensitivity	Another fast-growing transportation process is controlled room temperature. These adhesive materials are safe at room temperature, but must be maintained there during transport using temperature-assured containers, such as reefers, to avoid the spikes that can come in ambient containers.
Regulation is on the rise	Establishing preventive measures and harmonizing regulations are major issues for the cold chain material industry.
Manufacturers are outsourcing more processes to 3PLs. (Third party logistics)	Shipper demand for efficiency, visibility, and product freshness is driving cold chain 3PLs to add a wide range of value-added services.

Table 2. RFID trends for cold chain materials

1. Related literature

In matter of terminology below are the main concepts used in this document. It is very important to also include additional information of how RFID works in the background in order to have a quick overview of the process.

General concepts

Batch: A batch is a quantity of the material produced during a given production run. A batch represents a homogeneous unit with unique specifications. A Batch is a subset of

the total quantity of a material held in stock. The subset is managed from all other subsets of the same material. Depending on the plant, material and operational levels we can choose the level at which you want the batch number to be unique. The material number is unique at the client level. However, the uniqueness of the batch number can be defined at the following levels

- In combination with the material and plant
- In combination with a material number
- At the client level

Industry 4.0: is the subset of the fourth industrial revolution, industry 4.0 is the trend towards automation and data exchange in manufacturing technologies and processes which include cyber-physical systems (CPS), the internet of things (IoT), industrial internet of things , cloud computing, cognitive computing and artificial intelligence. Industry 4.0 strategy are: the strong customization of products under the conditions of highly flexible (mass-) production.

Cold chain materials: A cold chain is a temperature-controlled supply chain. An unbroken cold chain is an uninterrupted series of refrigerated production, storage and distribution activities, along with associated equipment and logistics, which maintain a desired low-temperature range. It is used to preserve and to extend and ensure the shelf life of products, such as fresh agricultural produce, seafood, frozen food, photographic film, chemicals, and pharmaceutical drugs. Such products, during transport and when in transient storage, are sometimes called cool cargo. Unlike other goods or merchandise, cold chain goods are perishable and always in route towards end use or destination, even when held temporarily in cold stores and hence commonly referred to as cargo during its entire logistics cycle.

Traceability: the quality of having an origin or course of development that may be found or followed.

Outbound & Inbound materials: Inbound logistics refers to the transport, storage and delivery of goods coming into a business. Outbound logistics refers to the same for goods going out of a business. Inbound and outbound logistics combine within the field of supply-chain management, as managers seek to maximize the reliability and efficiency of distribution networks while minimizing transport and storage costs. Understanding the

differences and correlation between inbound and outbound logistics can provide insight for developing a comprehensive supply-chain management strategy.

SAP: SAP stands for Systems Applications and Products in Data Processing.

Middleware: Computer software that connects software components or applications. It is use most often to support complex, distributed applications based on XML, SOAP, Web services and service orientated architecture (SOA). Middleware can include web servers, application servers and content management systems.

RFID concepts

RFID: Radio-frequency identification (RFID) is the wireless non-contact use of radio-frequency electromagnetic fields to transfer data for the purposes of automatically identifying and tracking tags attached to assets

RFID tags: An RFID tag, in its most simplistic form, is comprised of two parts – an antenna for transmitting and receiving signals, and an RFID chip (or integrated circuit) which stores the tag's ID and other information. RFID tags transmit data about an item through radio waves to the antenna/reader combination. RFID tags typically do not have a battery (unless specified as Active or BAP tags); instead, they receive energy from the radio waves generated by the reader. When the tag receives the transmission from the reader/antenna, the energy runs through the internal antenna to the tag's chip. The energy activates the chip, which modulates the energy with the desired information, and then transmits a signal back toward the antenna/reader. On each chip, there are four memory banks – EPC, TID, User, and Reserved. Each of these memory banks contains information about the item that is tagged or the tag itself depending on the bank and what has been specified.

dBm: The expression dBm is used to define signal strength in wires and cables at RF and AF frequencies.

RFID reader: An RFID reader is the brain of the RFID system and is necessary for any system to function. Readers, also called interrogators, are devices that transmit and receive radio waves in order to communicate with RFID tags. RFID readers are typically divided into two distinct types – Fixed RFID Readers and Mobile RFID Readers. Fixed readers stay in one location and are typically mounted on walls, on desks, into portals, or other stationary locations.

RFID Antennas: The RFID antenna gives off RFID waves along a horizontal or vertical plane, which is described as the antenna's polarity. If the RF field is a horizontal plane, is it described as horizontally linear, and the same principle applies to an RFID antenna that creates a vertical plane. An antenna's polarity can have a significant impact upon a system's read range. The key to maximizing read range is to ensure an antenna's polarity aligns with the polarity of the RFID tag. If these do not match up, for instance, a vertical linearly-polarized antenna and a tag with a horizontal linearly-polarized antenna, the read range will be severely reduced. A circularly-polarized antenna transmits waves that continually rotate between horizontal and vertical planes in order to give an application enhanced flexibility by allowing for RFID tags to be read in multiple orientations. However, because the energy is divided between two planes, a circularly-polarized antenna's read range is shorter versus a similar gain linear antenna.

RFID Cables: RFID Antenna Cables facilitate communication between the RFID reader and RFID antenna. Without the cable, the reader cannot power and send signals to the tags via the antenna. Choosing an RFID cable may seem like an easier task than choosing other components; however, cables can vary greatly in three specific ways – connector types, length, and thickness/insulation rating – so, it is important to take all three into consideration before purchasing.

RFID tag structure: the memory of a tag is split into three: the TID, EPC, and User Memory.

- Tag Identifier Memory (TID): The TID or Tag Identifier is 20 bytes or 160 bits. These means there are 1,460,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000 different possible tag IDs (1.46 * 1048). Every RFID tag has a unique TID. The TID is not editable.
- Electronic Product Code Memory (EPC): global identifier, generally 12 bytes, user editable, and meant to be written to as a UPC type replacement.
- User memory: the size of User Memory can vary from 0 bytes to 64 bytes. The cheaper the tag the fewer bytes of user memory it will likely have.

RFID LF: The LF band covers frequencies from 30 KHz to 300 KHz. Typically LF RFID systems operate at 125 KHz, although there are some that operate at 134 KHz. This

frequency band provides a short read range of 10 cm, and has slower read speed than the higher frequencies, but is not very sensitive to radio wave interference.

RFID HF: The HF band ranges from 3 to 30 MHz Most HF RFID systems operate at 13.56 MHz with read ranges between 10 cm and 1 m. HF systems experience moderate sensitivity to interference.

RFID UHF: The UHF frequency band covers the range from 300 MHz to 3 GHz. RAIN RFID systems comply with the UHF Gen2 standard and use the 860 to 960 MHz band. While there is some variance in frequency from region to region, RAIN RFID systems in most countries operate between 900 and 915 MHz

Active RFID: Active RFID systems use battery-powered RFID tags that continuously broadcast their own signal. Active RFID tags are commonly used as "beacons" to accurately track the real-time location of assets or in high-speed environments such as tolling. Active tags provide a much longer read range than passive tags, but they are also much more expensive.

Passive RFID: Passive RFID systems use tags with no internal power source and instead are powered by the electromagnetic energy transmitted from an RFID reader. Passive RFID tags are used for applications such as access control, file tracking, race timing, supply chain management, smart labels, and more. The lower price point per tag makes employing passive RFID systems economical for many industries.

Frequency: The number of repetitions of a complete wave within one second. 1 Hz equals one complete waveform in one second. 1 KHz equals 1,000 waves in a second. RFID tags use low, high, ultra-high and microwave frequencies. Each frequency has advantages and disadvantages that make them more suitable for some applications than for others

Read range: The distance from which a reader can communicate with a tag. Active tags have a longer read range than passive tags because they use a battery to transmit signals to the reader. With passive tags, the read range is influenced by frequency, reader output power, antenna design, and method of powering up the tag. Low frequency tags use inductive coupling (see above), which requires the tag to be within a few feet of the reader.

Read rate: Often used to describe the number of tags that can be read within a given period. The read rate can also mean the maximum rate at which data can be read from a tag expressed in bits or bytes per second.

Read-write tag: an RFID tag that can store new information on its microchip. These tags are often used on reusable containers and other assets. When the contents of the container are changed, new information is written to the tag. Read-write tags are more expensive than read-only tags.

Interference: Anything that prevents radio waves from traveling between a tag and reader correctly and causes the tag to be read incorrectly. Can be caused by other radio signals or by some physical objects metals and liquids that absorb or reflect the radio signals

3. METHODOLOGY

For this project, it was consider four phases in matter of planning and implementation, in each one-detailed activities will be described. Nevertheless, no specific dates were mentioned since some of them have being delayed due to external causes from hardware supplier. For methodology section planning and building phase will be explain. For results section testing and go live phase will be explain since the results were given according to the testing activities.

Planning

The planning phase of a project involves since building the business case to the agreements made between all the project members and their contribution to the project. Also involves the budget planning for the hardware procurement and the risk analysis for the planned failures, this leads to the action of making a reaction plan that helps the project implementation more consistent and transparent. Even though the cost-benefit of the project was clear since the beginning, there release and approval of the budget is the longest process for this kind of project involving new technology. In the table above you will find the one pager document that was presented to the directors and managers in order to approve the project implementation.

Making the business case:

Initial situation:	Benefits:

Adhesive material is received at warehouse. Packages are open to identify if material is in good or bad conditions with a visual inspection of a data logger placed inside the packaging. There is not historical data in the actual data logger. Warehouse personnel informs quality department to dispute the supplier claim and material is blocked in system and scrap afterwards.	Faster reaction from quality department to deviations in temperature. Supplier claims can be done after material is receiving with no opening of the package. Scrap will be charge to supplier due to incoterm agreed (FCA*) New expiration date will be assign to the adhesive material according to the historical temperature conditions.
Project description: RFID* tags will be written from supplier location with its shipping date, part number, quantity and batch number. These tags will be placed inside the packaging with the purpose of store the historical deviations in temperature of the adhesive material during its logistics process. Material lots can be blocked even if packaging is not open and new shelf life can be assign according to data mining from RFID tag	Target condition: Charge 100% of the scrap to supplier if temperature deviations are immediately after its shipping date Decrease negative inventory adjustments due to blocked material Assign more accurate shelf life base in data and not in dates calculation established by the ERP* system. **RFID: Ratio frequency identification* **FCA: free carrier* **ERP: Enterprise resource planning*

Table 3. Business case

Planning phase activities

- Define the cost- benefit and investment charts
- Release the budget for approval
- Kick-off meeting with all the departments involved
- Mapping of the actual process to identify where the new implementation will impact and what will be either remove or add to the process.

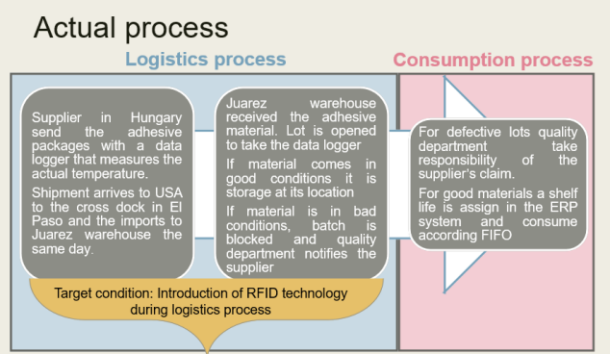


Figure 3. Actual & Proposed process

- Gemba with all the departments to have new eyes to the process
- Define new process with the technology introduced and how this will impact to the departments
- Define a champion from each department to have the project committee diversified and identified as a cross-functional team
- Hardware supplier evaluation for the materials used in the project
- Define milestones and important dates for the project implementation

Build

- List of project requirements of software and hardware

Software requirements	Hardware requirements
■ ERP system (SAP) ■ Middleware to read the tags and translate the information (Hardware supplier) ■ Data analytics program (Hardware supplier) ■ Software reader (for testing)	• 1 RFID handheld terminal reader • RFID tags • 1 RFID handheld terminal reader • RFID desktop reader • 1 RFID gate installation (Already in placed)

Table 4. Hardware requirements

- Hardware procurement
    - Buy RFID handheld terminals and RFID tags for supplier

RFID CQC Project items			
Material	Quantity	Price	Total
RFID Handheld receiving terminal	2	$3,400.00	$6,800.00
ANTRA license	2	$ 470.00	$ 940.00
RFID desktop reader	1	$ 875.00	$ 875.00
RFID tag writer application	1	$ 525.00	$ 525.00
Temperature logger (Package of 200 units)	1	$ 88.00	$ 88.00
Total			$9,228.00
RFID infrastructure in warehouse docks			
Material	Quantity	Price	Total
RFID reader & cables	1	$3,286.00	$3,286.00
UHF antennas	3	$ 240.00	$ 720.00
Installation	1	$1,400.00	$1,400.00
Total			$5,406.00

Table 5. Hardware investment

- Software configuration
    - Middleware configuration and supplier software (ANTRA) installation and configuration in warehouse and quality computers
    - RFID gates at the docks must have the correct reading configuration in the software
- Check if facilities are needed for the implementation (network nodes, electrical installations and activation of internet nodes at warehouse)
- Process confirmation of adhesive materials shipments and when arrives to the warehouse in order to have a smoother implementation
- Align reaction plan with all the departments to identify failure modes and counter measures.

Build

- Process mapping with new technology, prepare documentation identifying the list of activities that have impact during the project implementation.

List of activities:

Activity description	Responsible
1. At supplier location, scans the mater HU (per batch) part number and package	Supplier
2. Supplier places the scanner above the pallet in order to write information into the RFID tag. RFID tag is inside the cooler. Information written into the tag: Part number, Batch and quantity	Supplier
3. Supplier writes the information into the RFID tag. RFID tag keeps inside the cooler	Supplier
4. Material arrives into the plant dock in Juarez. (Material was previously imported from USA cross-dock)	Bosch (warehouse)
5. Material passes through RFID gates (No SAP link/ or gr posting) just to generate a timestamp directly to ANTRA software when material arrived physically to the warehouse	Bosch (warehouse)
6. Material passes through RFID gates and CQC data logger is detected. For this case the visual aid can be optional, the main purpose of the lights is to create a visual escalation that data logger is missing.	Bosch (warehouse)
7. Material can be split, scanner reads the label outside to confirm the part number and batch.	Bosch (warehouse)
8. Scanner is placed above the cooler to read the RFID tag (Cooler must be close, you can read the RFID tag outside the cooler for any quality claim0029	Bosch (warehouse)
9. After reading the RFID tag, you can remove the data logger inside the cooler.	Bosch (warehouse)
10. RFID data logger must be carry to the desktop reader (incoming) to have the data available to any deviation	Bosch (quality/ incoming department)
11. ANTRA software is open, you can assign new shelf life, analyze	Bosch (quality/

data or block the material according to the data given	incoming department)
12. RFID data logger is keep in a metal box to return to supplier according to min/max	Bosch (quality/ incoming department)
13. RFID data loggers are return to DELO to keep running the loop	Bosch (warehouse)

Table 6. Project activity list

4. RESULTS

Testing

For this phase, the testing activities describe the RFID testing in the dock area for the **first time-stamp creation after shipment is received.** During this testing phase the position of the label of the pallets is crucial for the reading by RFID since during this stage the RFID infrastructure is fixed.

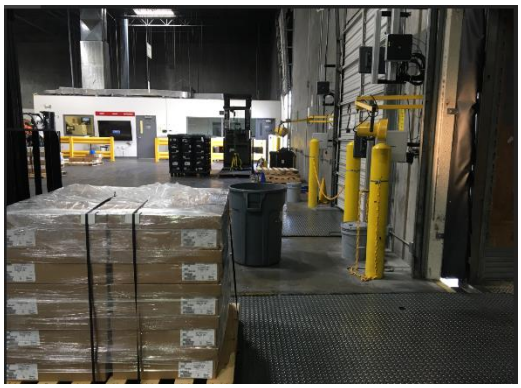
RFID infrastructure	Testing photo for reference
	

Table 7. Testing images

- For this testing, we use the software directly from the reader (SOPAS) screen is shown below and what are the parameters that we measure for this type of testing.

  For a good and effective RFID reading the average of the dBm must not vary between 30 – 50 dBm, taking in consideration that are read above 60 dBm are in risk of not be detected by the RFID UHF antennas.

  1. RSSI- closest to 0 is the better, -70 it will lose the signal and it will not good anymore
  2. dBm: unit of reading power

3. UII: the number that is program in the RFID tag -double click in the UII to see the whole information (TAG Access)

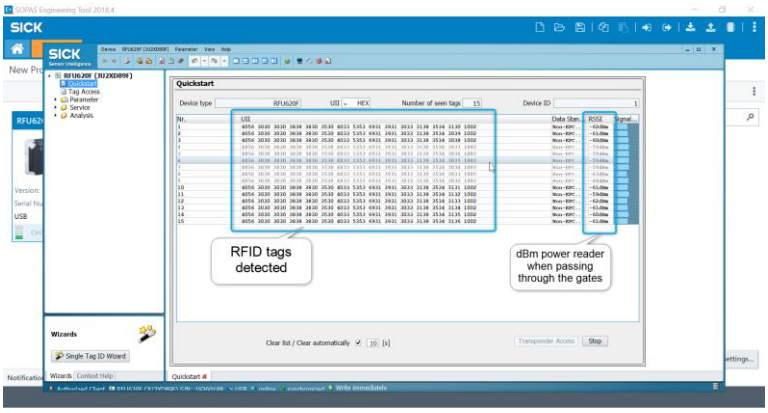


Figure 5. Sick testing image

- RFID infrastructure at warehouse dock
    1. RFID reader with internal antenna (Sick)
    2. 1 external UHF antenna (kathrein)
    3. 1 external UHF antenna (kathrein)
    4. 1 external UHF antenna (kathrein)

Figure 5. RFID infrastructure in receiving dock

First test with configuration shown as the image below

1. RFID reader with internal antenna (Sick) – Power at 35 dBm

2. 1 external UHF antenna (kathrein) – Power at 20 dBm
3. 1 external UHF antenna (kathrein) – Power at 20 dBm
4. 1 external UHF antenna (kathrein) – Power at 20 dBm

Average reading 5 RFID tags placed in the shipment: 56.8 dBm

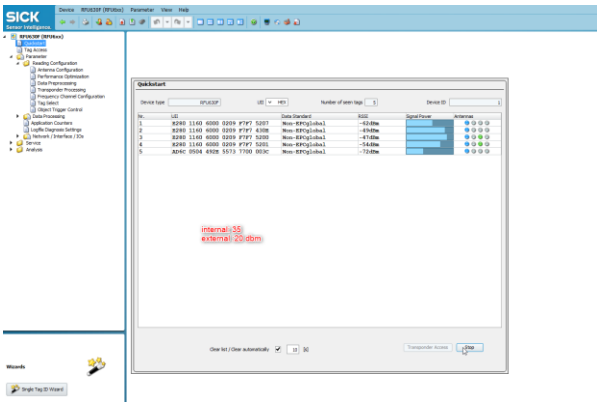


Figure 7. Sick testing image

Second test with configuration shown as the image below

1. RFID reader with internal antenna (Sick) – Power at 35 dBm
2. 1 external UHF antenna (kathrein) – Power at 25 dBm
3. 1 external UHF antenna (kathrein) – Power at 25 dBm
4. 1 external UHF antenna (kathrein) – Power at 25 dBm

Average reading 4 RFID tags placed in the shipment: 59.5 dBm

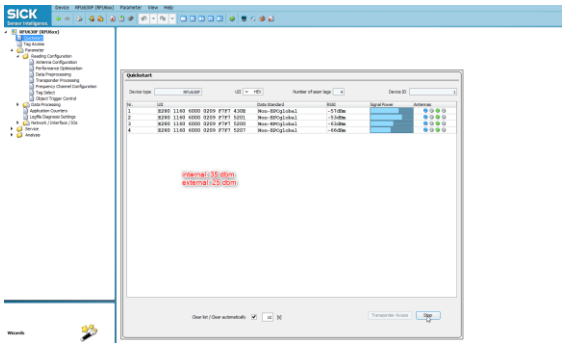


Figure 8. Sick testing image

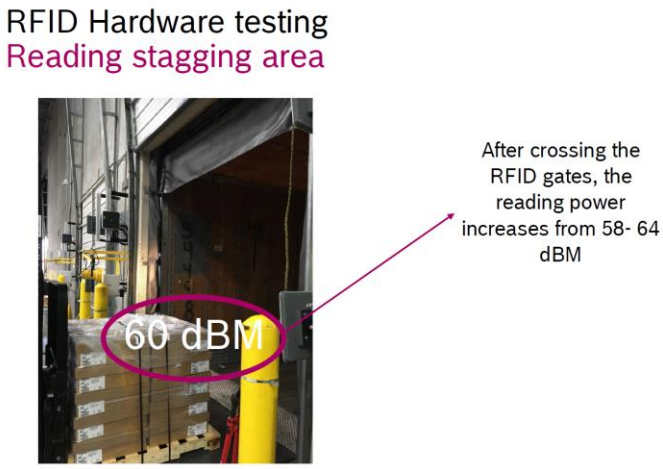


Figure 7. RFID hardware testing

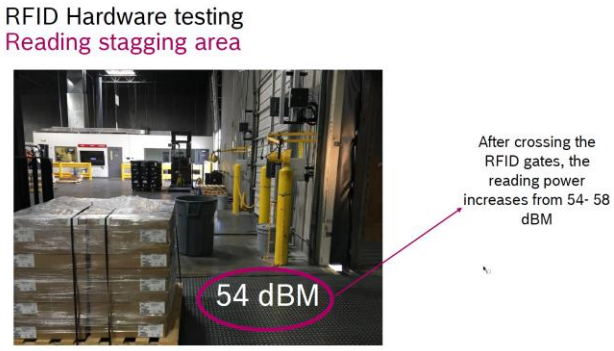
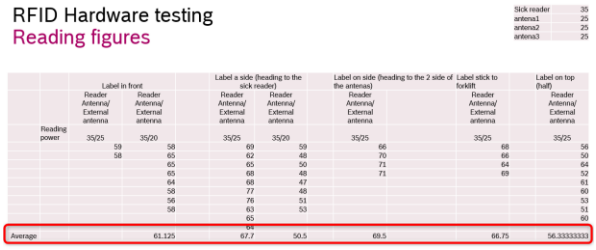


Figure 8. RFID hardware testing

- RFID testing in the receiving area after shipment is unload from the truck and is ready for put-away.

Below are the figures for the reading of the RFID tags in the dock area. Images are shown to have a reference of how the RFID infrastructure is running and the parameters of the RFID reader and the antenna configuration.



	Sick reader	35
	antena1	25
	antena2	25
	antena3	25

	Label in front		Label a side (heading to the sick reader)		Label on side (heading to the 2 side of the antenas)	Label stick to forklift	Label on top (half)
	Reader Antenna/ External antenna	Reader Antenna/ External antenna	Reader Antenna/ External antenna	Reader Antenna/ External antenna	Reader Antenna/ External antenna	Reader Antenna/ External antenna	Reader Antenna/ External antenna
Reading power	35/25	35/20	35/25	35/20	35/25	35/25	35/25
	59	58	69	59	66	68	56
	58	65	62	48	70	66	50
		65	65	50	71	64	64
		65	68	48	71	69	52
		64	68	47			61
		58	77	48			60
		56	76	51			53
		58	63	53			51
			65				60
			64				
Average		61.125	67.7	50.5	69.5	66.75	56.33333333

Table 8. RFID reading figures

For this phase, the go live activities describe the RFID implementation process when the material is unload and second **time-stamp is tracked.** During this phase, it is crucial to map the process with the introduction of RFID technology, the main purpose of the testing was to assure that the process was detailed established in matter of RFID parameters and introduction to the departments of the system. Therefore during go live you can see how the process must be implement and the pictures are showing the results of the project. Here as it is managed a RFID handheld portable reader is easier to read the information so what it is important is the content to see if the material batch is in good or bad conditions. In the table below, you can find the description of each image according to its contribution to the process.

Picture	Description
1	RFID tag activation at supplier, at this moment the information is written.
2	RFID tag information with details, information written by supplier
3	Example of unloading of the material, this can vary according to the shipments
4	RFID is read by customer (Bosch) here you see the new shelf life
5	RFID tag unique identification tag (example)

Table 9. Go live activity list

Figure 9. Go live RFID tag activation process at sending location

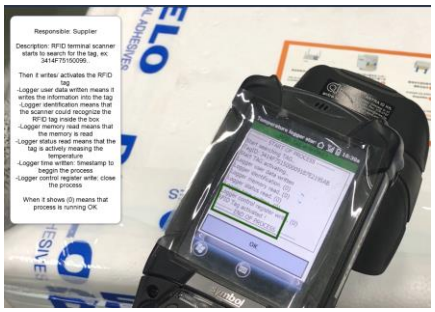


Figure 10. Go live RFID tag activation process at sending location

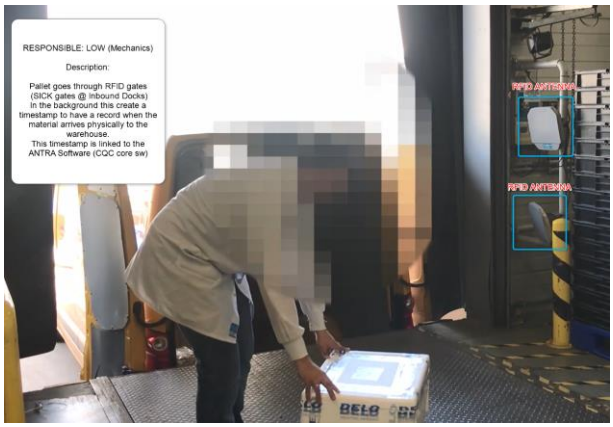


Figure 11. Go live inbound shipment received at Juarez warehouse

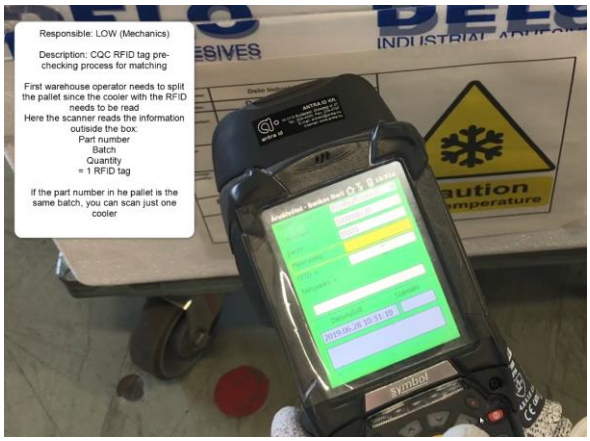


Figure 12. Go live inbound shipment received at Juarez warehouse

Figure 13. Go live inbound shipment received at Juarez warehouse

5. CONCLUSION

The cost benefit of the project is to avoid any charge from supplier to our company this due to the material rejection for any deviations of temperature status. It is well known after analyzing the mapping of the process that the purpose of introducing RFID technology into the adhesive material process is to have a clear overview of the temperature behavior during its transportation and logistics management. Not only the charge of the scrap material but also to have more reliable expiration dates in the material master data that follows the FIFO consumption during production process. This project help up to relied in new technologies that are accessible for the company and flexible in matter of the existence middleware and connected IT infrastructures. The usage and the learning curve of this project it is a clear opportunity area to increase the expertise of all the levels of the warehouse and the departments involved.

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