Improving Efficiency of the Filling Line in a Dairy Industry

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Abstract — *In the dairy manufacturing company the efficiency of the juice filler line is around 53%. We are trying to improve it to around 70% or more. In this project we used the DMAIC methodology for process improvement. Through the first week of data observation a clear tendency is seen throughout the process. Those bottlenecks of the process are the full refrigerator, slow bottles flow and caser mechanism. A cause and effect and pareto charts were developed after a brainstorming with the operators and the mechanics. After those analyses it was found the root causes of the problems. A visual aid by the machines was proposed to increase communication between operator and mechanics. After the implementation the operators, mechanics and internal suppliers should receive continuous training using that new mechanism to report failures. It is also important to keep the process within the specifications to avoid the possibility of muda (waste).*

Key Terms — *Dairy, DMAIC, Filler, Production.*

INTRODUCTION

In the dairy (milk/juice) manufacturing company the efficiency of the juice filler (Figure 1) line is around 53%. Figure 1 shows the actual operation of a particular filler machine. The goal is to improve the efficiency of the filler machines. The current efficiency is around 53% of its capacity. We are trying to improve it to around 70% or more. That problem is caused by downtime in the process. Due to that downtime the final output of the process per shift is lower than the desired goal. Those downtimes are caused by non-programed stops. The specific goal is to find causes of the non-programmed stops and develop a mechanism to reduce it.

Figure 1
Filler Line No. 1

It is important to determine the efficiency of any manufacturing process because it is a measure of how much product and time is wasted. That waste represents economic loses to the company.

This study is useful for the company that I'm working because it improves the efficiency of the manufacturing process specifically in the filler machines. Before the execution of this project the production of the filler machines had a 47% of loses. Those loses can be determined by observation of the process. In this study those observations will be quantified and analyzed in order to improve and control the process.

PROCESS IMPROVEMENT THEORY AND TOOLS

There are ten filler machines in the plant. Each machine has a different task and specification. The production and specification for each filler machine are described in the Table 1.

The brands of those filler machines are: Federal, Elopak (Machine No. 6), Enhance (Machines No. 8 and 9). The casers brands are: Cannon, Conveyos Speciality System (Machines No. 5 and 6), Hamrick Manufacturing Service (Machines No. 7 and 10), Dupont (Machines No. 8 and 9). The Stackers brands are Cannon (Machines

No. 1 and 2), Conveyor Specialty System (Machines No. 3 to 10).

Table 1
Filler Line Machine Specifications

Filler Machine	Output	Products Per basket	Speed (Output per minute)
1	Half gallons	9	100
2	Half gallons	9	90
3	Gallons	4	55
4	Half gallons	9	84
5	Gallons and 85 ounces	4 for gallons and 6 for 85oz.	55
6	Liter	16	90
7	14 ounces	20	50
8	Pouches	64	85
9	Pouches	64	85
10	8 and 16 ounces	50 (or 20 if premium) for 8oz. and 20 for 16oz.	85

In this project will be used the DMAIC methodology for process improvement. That is the core problem solving methodology used by many lean six sigma companies [1]. The term refers to the steps Define-Measure-Analyze-Improve-Control and it is defined as follow:

Problem Definition

To define any problem or issue that is affecting the productivity in any particular area it is essential to understand and be capable to describe the process in detail. There are many definitions tools such as affinity diagrams, cause-and-effect diagrams, pareto diagrams that must be applied on common problem definitions [2].

The voice of the customer is also critical in order to define a problem in the process. Translate customers' feedback such as Critical to Quality (CTQ) trees and Kano analysis into opportunities for improvement.

It is important to define a problem that does not represent the tip of the iceberg. For that reason to understand the root causes of that problem it is critical to measure the parameters that cause the defined problem [3].

Measure

There are different types of data that can be measured in a project. The first objective for data collection is to recognize and differentiate between variable, attribute and locational data. Describe how attribute data can be converted to variable data.

For the data collection methods, describe how data form, data coding, and check sheets are utilized for data collection.

In measurement scales, describe and apply the four major measurements scales: nominal, ordinal, interval, and ratio.

Finally, recognize data accuracy considerations and describe the importance of random sampling [3].

Analyze

To understand the analyze techniques it is important to know about the seven classical wastes. Recognize and analyze the familiar forms of muda (waste) in the workplace: overproduction, excess inventory, rejects, wasted motion, additional processing, unnecessary transport and waiting.

It is important to determine the relationship between variables (muda, time, operator, shift, etc.). One technique used to define that connection is the hypothesis test. It is fundamental to recognize hypothesis test concepts such as the null hypothesis, test statistic, types of error, one-tail and two-tail tests, practical versus statistical significance and adequate sample size [3].

Also, it is essential to recognize the importance of root cause analysis. Differential between subjective tools and analytical tools.

Improve

To improve any process is necessary to eliminate wastes. There many different waste reductions methods. The first one is to apply the 5S (Sort, Set, Shine, Standardize and Sustain –a sixth S for Safety is added in some companies-). Recognize how the kanban system (pull) is used to minimize in process inventories and contribute to just-in-time manufacturing. Identify a variety of poka-yoke mechanism to mistake proof products and processes [4]. Describe how setup reduction expands production capacities, reduces inventories and minimizes wastes. Understand the role of continuous flow manufacturing and other flow improvements. Identify and understand the quick response strategy.

Once the changes are implemented it must be measured again in order to determine if there are any improvement in the process.

Control

Describe the function of quality controls such as written procedures and work instructions in directing product and process performance.

Define how control plans are developed and understand how they helped hold the gains from improvement activities. Identify who creates these plans and maintains their uses and effectiveness.

Describe the benefits of Statistical Process Control charts (SPC) in controlling process performance. Identify common and special causes. Construct and interpret various types of control charts. Understand the pre-control technique.

Describe how total productive maintenance (TPM) can be utilized to minimize the major negative loses to equipment effectiveness. Use TPM metrics to evaluate performance efficiency, operating rates, and overall equipment effectiveness (OEE) [4].

Distinguish how visual displays can be effectively used to make problems apparent, clarify targets for future improvement, and influence and direct employee behavior.

Identify how standards and standard work techniques can be used to minimize wastes and ensure more consistent performance.

Recognize the importance of employee training as both a preventive and control technique. Identify the importance of management support; training needs assessments, necessary resources and other training fundamentals.

METHOD (DMAIC)

The method for the efficiency improvement used for this project is the DMAIC (Define Measure Analyze Improve Control). Once the problem is defined the data must be measured before and after the improvement process. Before any improvement the data before must be analyzed first. There are different methods of analysis for the data in order to find problems that must be solved for any improvement in the process delivery.

The defined problem is the production. In order to improve the efficiency of the filler line a problem must be identified. By measuring the production percentage a problem can be identified and it is defined. The problem defined is the low productivity in the filler line. That productivity is around 53% and the goal is 70%. The manufacturer knows that there is a problem that must be discovered prior to make any improvement in the process. Those problems can be determined by observation of the process. Once the process is detected and data is acquired, the spotted problems must be measured to find any particular tendency.

The problems observed are the downtime due to non-programed stops, which are tabulated in the filler production shed. That data determines how many minutes a certain filler machine is stopped. There are many causes that can make a filler machine to have a non-programmed stop. Those causes are: product approval, Control In Place (CIP) failure, Neva labeling problem, upstaker failure, basket pusher failure, Video jet adjustment/regulation, ink/solvent change, label adjustment/regulation, table top adjustment/regulation, caser mechanism, stacker mechanism, case pusher binding, full refrigerator, refrigerator conveyor problem, cardboard defects, product in process, equipment failure, slow bottles, full baskets, unsold time capacity.

The data to be measured is the filler output in one month. The data for the 15 days before and 15 days after the improvement techniques implementation must be tabulated in a spreadsheet and make a chart in order to find problem tendencies and make any comparison of this project.

By collecting the data the first thing noticed is a regular tendency in many particular problems [5]. So giving special attention on those particular areas can start the analysis the process improvement. Once the data is collected and measured, a cause and effect analysis is performed using the pareto chart. The Pareto chart determines that the 80% of the problems is caused by the 20% of the failures. To analyze the root-causes of the problems and find a way to fix it a fishbone chart is used to trace the origin of the problems that causes those particular non-programmed stops. Once the root cause of the problem is found a “what if” methodology must be used to determine how to apply the improve part of this project [6]. Another tool that will be used to analyze the tendencies of the failures is the Hypothesis Test.

The filler production shed has the information of the possible problems that affect the efficiency of the machines. Those problems are tabulated as stoppage. Those stoppages are divided in programmed and non-programmed stoppages. The main idea of this project is to reduce those non-programmed stoppages. It is crucial to determine the main cause of those stoppages in order to improve.

Many changes must be made to improve the process. When the changes in the process are performed it must be measured again in order to determine if there is any improvement in the area. In order to keep with those improvements the process must be controlled. Create procedures and work aids that help people do their jobs better. The company must transfer the new methodology to the process owner and ensure that everyone working on the process is trained appropriately. During the Control phase the company personnel will document the new improved process, train everyone, set up procedures for tracking key “vital signs,” hand-off ongoing management to the process owner, and complete project documentation.

To improve the process, a Total Production Management (TPM) is developed in order to reduce the non-programmed failures in the machines. It consists on a weekly failure report that the operator’s management must send to the mechanics team. That report contains a list of possible failures in the filling line.

To create a failure report the data must be submitted via software. In that software the operator’s manager put the information of the failure. The software is the SAP (system for application of product).

There are two proposals to improve the efficiency of the line by refining the communication between the machine operators, the mechanics and the material suppliers. The first proposal is to put an intercom device near the manufacturing line. With that the operator can call the supplier for materials and/or the mechanic for maintenance. The other proposes device is a board with a number that the operator must change with the bottle count in the filler machine. If that number is below the target line the operator must call the supervisor and do the failures report. The mechanic performs a preventive maintenance in that machine prior the other machines. By doing that it prevents to wait when the machine is fully stopped or damaged in order to perform maintenance. Also it set a priority on those machines that really needs preventive maintenance.

RESULTS

The results are displayed in the DMAIC format:

Define

The project charter is illustrated in the Table 2. It summarizes a schedule to complete the project.

Measure

Through the first week of data observation a clear tendency is seen throughout the process. Those bottlenecks of the process are the full refrigerator, slow bottles flow and caser mechanism. The bottle flow and the caser mechanism are a problem, which are not related directly with the filler line but affects the production in that area. Also is notable the labeling adjustment especially in the premium bottles. Figure 2 shows the difference between the normal and premium bottles.

A SIPOC (Supplier-Input-Process-Output-Customer) diagram shows the most important suppliers of the company for the evaluated process [7]. It is a tool used by a process improvement team to identify all relevant elements of a process improvement project before work begins.

Table 2
Project Charter

Project Name	Improving efficiency of the filling line in a dairy industry.			
Process Impacted	Filling Line			
Project Leaders	Eduardo Moró Pérez, E.I.T.		Telephone 787-237-4197	
Sponsor	Ervin Coss Borges, P.E.		Telephone 787-622-8000	
Coach	José A. Morales, Ph.D., P.E.		Telephone 787-622-8000	
Team	Ervin Coss, P.E. (Manufacturing Engineering), Gladys Marrero (Engineering Assistant)			
Start Date	April 1, 2013	Target Completion Date	May, 2013	
Project Description	Identify reasons and roots causes for defects in order to improve productivity in the filling line. Identify the major offenders in the process to reduce the defects.			
Project Scope	The scope of this project is to increase productivity, improve requirements to 70%, focus in eliminating the non programmed stops.			
Project Goals & Measures	Project Goals:			
	Metric	Current (Baseline)	Entitlement	Goal
	1. Output	53.0%		70.0%
Expected Business Results	To reduce cost and increase productivity.			

Project Schedule

Phase	Start Date	Completion Date
Define	01/Apr./2013	01/Apr./2013
Measure	01/Apr./2013	15/Apr./2013
Analyze	15/Apr./2013	15/Apr./2013
Improve	16/Apr./2013	30/Apr./2013
Control	01/May/2013	07/May/2013

Approvals:
Project Leaders : Eduardo Moró Pérez, E.I.T. Date: __________
Project Coach: Ervin Coss Borges, P.E. Date: __________
Project Sponsor: José A. Morales, Ph.D., P.E. Date: __________

Figure 2
Normal (Suiza Fruit) and Premium Products

Table 3
SIPOC Diagram

Supplier	Input	Process	Output	Customer
Ranchers	Milk	Filler Line	Suiza Dairy	General Public
Farmers	Juice		Suiza Fruit	General Public
Plastic supplier	Bottles		Suiza Products	Filler Line Crew
Plastic supplier	Pouches		Suiza Products	Filler Line Crew
Plastic supplier	Caps		Suiza Products	Filler Line Crew
Mechanics	Tools		Maintenance	Filler lines Crew

The production shed (Figure 3) represents the actual production of the filler machines output in the plant. Every Wednesday the data is tabulated and then is determined if the data is under the desired parameters and which action must take in order to avoid any uncertainty, which may happen.

Analyze

A cause and effect (fishbone) chart (Figure 4) is developed after a brainstorming with the operators and the mechanics. In that brainstorming it was found that a proper communication between operator's manager and the mechanics team was not very successful. In that brainstorming with the operator the five whys were answered as follow:

- There is a low efficiency in the bottle lines.
  - ➢ Why?
- Because the machines are experiencing non programmed stops.
  - ➢ Why?
- Because the machines fails too much.
  - ➢ Why?
- Because there is no proper preventive maintenance.
  - ➢ Why?
- Because there is a lack of accurate communication between operators and mechanics.
  - ➢ Why?
- The communications have many steps between actual operator and mechanics.

After that brainstorming and the data analyzed, the mechanics urged the operator's management to send a weekly failure report. In that weekly report it is details of the failure tendencies of the particular machine.

A t-test was performed on the data for the quantity of non-programed stops (Figure 5) with the following results:

- Test of Mu = 0.05 vs not 0.05
- The assumed standard deviation = 28.5
- Variable N: Quantiy 20
- Mean: 21.45
- Standard Deviation: 29.2043
- Standard Error Mean: 6.3728
- 95% Confidence Interval: (8.9596, 33.9404)
- Z: 3.36
- P-Value: 0.01

With a P-value of less than 0.05 it indicates that the process is statistically significant. Therefore, any change on the non-programmed stops may impact the productivity of the filler line. Figure 6 represents the data of downtime in minutes.

	Indicador	Unidad de medida	Periodo	Fecha de corte	Período Base	Objetivo Modelo de Configuración	Mensual 1/Abril-30/Abril	Resultado de la semana 14	Responsable
3	**Productividad de Planta San Juan**	Lts/persona							Director de Operaciones
	Producción San Juan								Director de Manufactura
3.2	**Eficiencia de Envasado (TVC)**	%	semanal	miércoles	45%	53%	43%	42%	Gerente de Producción
3.2.1	Tiempo (T)	%	semanal	miércoles	55%	64%	63%	63%	Gerente de Producción
3.2.2	Velocidad (V)	%	semanal	miércoles	80%	85%	69%	66%	Gerente de Producción
3.2.3	Calidad (.C)	%	semanal	miércoles	100%	100%	100%	100%	Gerente de Producción
3.3	**Eficiencia de Envasado (TVC)**	%	semanal	miércoles	45%	53%	43%	42%	Gerente de Producción
	Línea 1 (1/2 Galón) *Impacto de producción: 60%*	%	semanal	miércoles	45%	63%	41%	40%	Gerente de Producción
	Línea 2 (1/2 Galón) *Impacto de producción: 60%*	%	semanal	miércoles	46%	57%	50%	44%	Gerente de Producción
	Línea 3 (1 Galón) *Impacto de producción: 30%*	%	semanal	miércoles	40%	33%	41%	36%	Gerente de Producción
	Línea 4 (1/2 Galón) *Impacto de producción: 10%*	%	semanal	miércoles	35%	52%	34%	37%	Gerente de Producción
	Línea 5 (1 Galón) *Impacto de producción: 30%*	%	semanal	miércoles	45%	33%	39%	36%	Gerente de Producción
	Línea 6 (Cartón) *Impacto de producción: 6%*	%	semanal	miércoles	44%	58%	69%	64%	Gerente de Producción
	Línea 7 (14 Oz) *Impacto de producción: 3%*	%	semanal	miércoles	24%	30%	32%	30%	Gerente de Producción
	Línea 8 (Pouch) *Impacto de producción: 3%*	%	semanal	miércoles	61%	51%	47%	45%	Gerente de Producción
	Línea 9 (Pouch) *Impacto de producción: 1%*	%	semanal	miércoles	65%	50%	50%	55%	Gerente de Producción
	Línea 10 (8 Oz) *Impacto de producción: 3%*	%	semanal	miércoles	30%	56%	36%	37%	Gerente de Producción

Figure 3
Production Shed

Improve

In order to improve the communication between operators and mechanics a visual aid (Figure 7) must be placed by the machines. That facilitates the information flow between team members and also the operator does not left the machine unattended. Also with that visual aid the mechanic can establish priority on those machines that begins to failing. While the mechanic is informed via visual aid the lines supervisor starts the failure report. The pareto chart illustrated in Figure 8 represents the desired data for the most recurrent
non programmed stops. With that data the efficiency of the lines increase up to 71%. Figure 9 is the proposed loop to attend any failure or need that some particular filler machine on some specific moment. With that mechanism the operator never leaves the machine unattended, the supervisor fills the failure report (Figure 11) while the mechanics gives attention to that particular machine or the supplier brings the necessary material for the optimal operation.

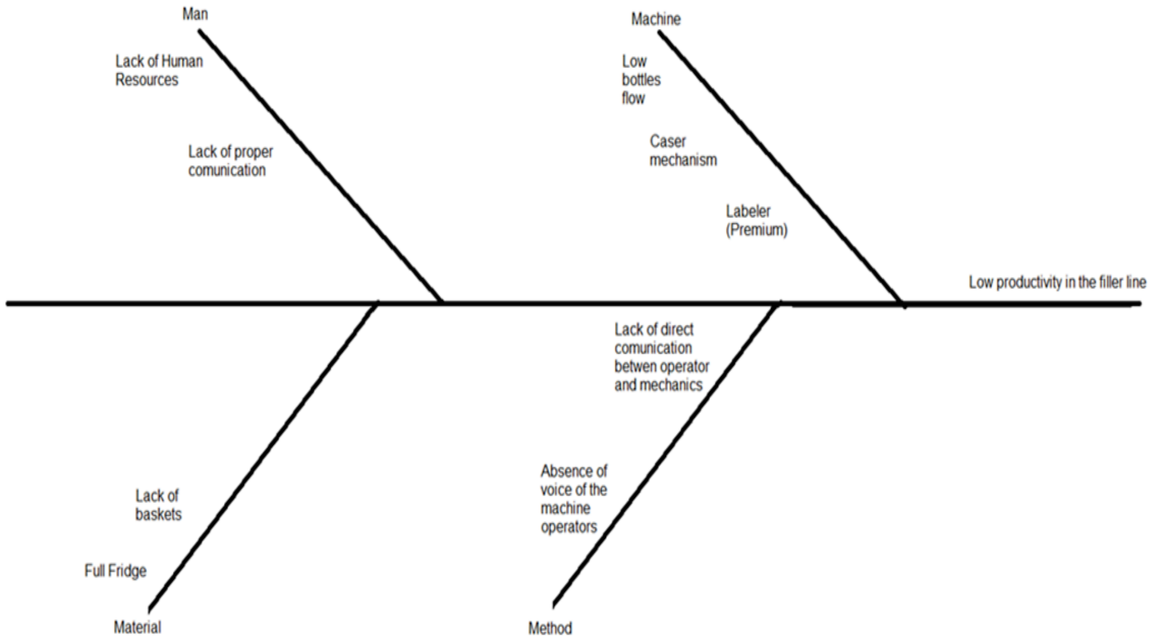

Figure 4
Cause and Effect Diagram (Fishbone)

Control

The purpose of this step is to sustain the gains. Monitor the improvements to ensure continued and sustainable success. Create a control plan. Update documents, business process and training records as required. A Control chart can be useful during the control stage to assess the stability of the improvements over time.

The monitoring control system that will be used is the visual aid. That aid will turn red when and an alarm will sound if the actual output runs out of specification. The specifications are given in the control limit table (Table 4). In order to develop that table the lower limit is chosen by the number which represents the 70% of output for each filler machine. The upper limit is the default output which represents the 100%. It is important to maintain the process between those control limits in order to reduce muda (waste).

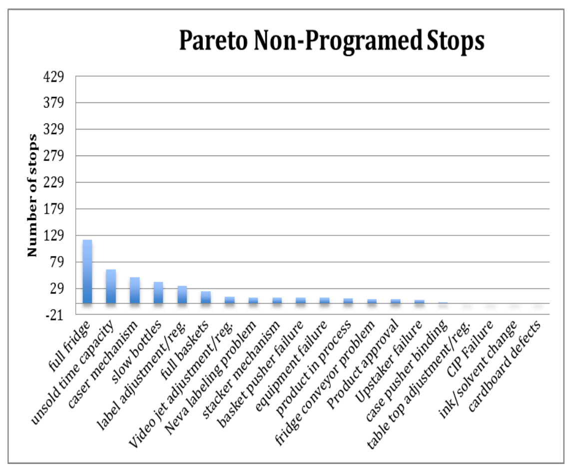

Figure 5
Pareto for Quantity of Non-Programmed Stops

Anytime were the output is less than the normal output for that specific machine a warning is send to the mechanics. With that warning the mechanics should prioritize that machine in the preventive maintenance.

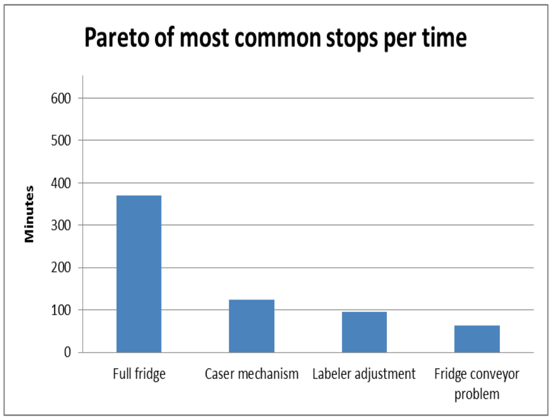

Figure 6
Pareto of Minutes for Most Recurrent Stops

The operators, mechanics and internal suppliers should receive continuous training using that new mechanism to report failures. It is important to keep the process within the specifications. That ensures a proper productivity and less economic losses due to downtime.

Figure 7
Visual Aid Model

The process capability (Cpk) will be constantly monitored. The goal is to maintain the process with a long term Cpk value near of 0.17. That value guarantees a yield near the desired 70% (Figure 10).

In order to maintain this process in control the manufacturing crew must have knowledge of the new mechanism to report failures by promoting it (Figure 10). New operators should be trained only with the new mechanism in order to obligate the older operator to upgrade its methodology to report any issue with the filler line. Also for older operator, a continuous education (2 hour every 3 months or 8 hours per year) must be taken in order to keep up to date with the mechanism of failure reports.

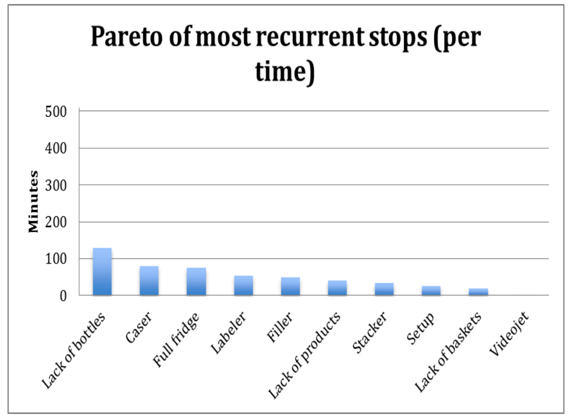

Figure 8
Pareto of Most Recurrent Stops (per time)

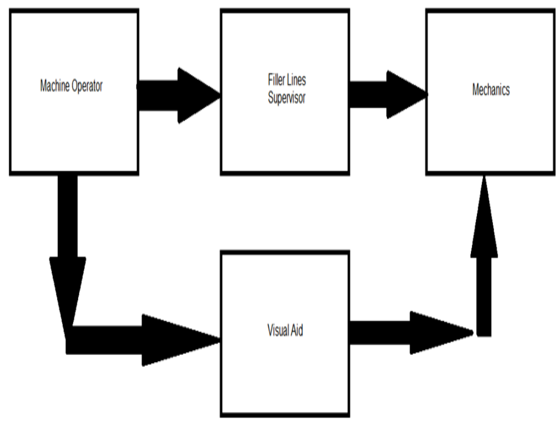

Figure 9
Maintenance Loop with Visual Aid

Sigma level	DPMO	Percent defective	Percentage yield	Short-term C_{pk}	Long-term C_{pk}
1	697,700	69%	31%	0.33	−0.17
2	308,700	31%	69%	0.67	0.17
3	66,810	6.7%	93.3%	1.00	0.5
4	6,210	0.62%	99.3790%	1.33	0.83
5	233	0.023%	99.97670%	1.67	1.17
6	3.4	0.00034%	99.999660%	2.00	1.5
7	0.019	0.0000019%	99.9999981%	2.33	1.83

Figure 10
Sigma Level and Cpk

Table 4
Filler Line Control Limits

Machine (Line)	Upper Limit	Lower Limit
1	100	70
2	90	63
3	55	39
4	84	59
5	55	39
6	90	63
7	50	35
8	85	60
9	85	60
10	85	60

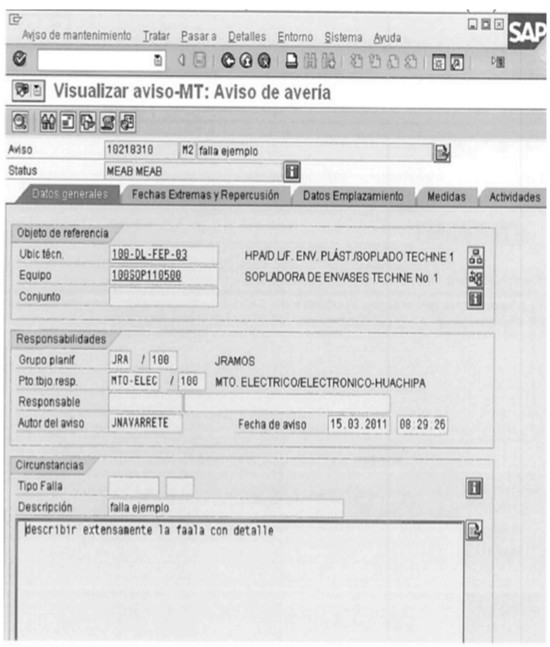

Figure 11
Failure Warning

CONCLUSION/RECOMMENDATIONS

Many companies have their process improvement mechanism on the paper and did not execute it properly. It is important to maintain a good and proper communication between teams of the same company in order to make a higher quality final product. Also is imperative to give the machine operators decisional power on their machine. The fact is that is only the operator that works the entire shift on the specific machine and knows better than anyone how the machine must work properly.

Another recommendation is that safety is the most important thing in any working place. If the layout represents a safety issue a future project must be developed in order to reduce any safety issue that the employees are exposed daily.

There is also a recurrent problem with the fridges, which are full and represents a bottleneck in the process. That problem can be worse if the outputs of the filler lines are improved. Another project must be performed for the fridges to determine a possible optimized layout or the possibility to buy more fridge space.

It is important to avoid overproduction due to the actual size of the fridges. The full fridge bottleneck was reduced but its actual size should not be increased. Therefore once this project is fully developed it is important to report any overproduction in order to fix that before it possibly blocks the fridge again. Another recommendation for this project is a continuous improvement in the process.

The method for the efficiency improvement used for this project is the DMAIC (Define Measure Analyze Improve Control). Once the problem is defined the data must be measured before and after the improvement process. Before any improvement the data before must be analyzed first. There are different methods of analysis for the data in order to find problems that must be solved for any improvement in the process delivery.

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