Cost Reduction in the Accumulator Process in Welding Operations

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Abstract *— For the last few weeks, the heating, ventilation, and air conditioning manufacturing company Thermo King Arecibo has been increasing the operational cost due to leak problems on the accumulator area in the welding department. The purpose of this project is to find the root cause of the problem causing this increase in defects in order to reduce budgeted cost while maintaining compliance with ISO regulation. Under this panorama the welding department of Thermo King Arecibo determines to look into the process using concept that combined Lean manufacturing techniques and Six Sigma tools and strategies. This Lean Six Sigma Methodology focused on business and process improvements based on decrease of process variation, waste elimination, process improvement and customer satisfaction. This project has been developed under the Lean Six Sigma principles and using DMAIC five-step approach, in order to identify opportunities to enable the company to reduce overall cost and gain efficiencies and breakthrough the welding department operation cost. The plan implementation helped reduce waste by 6.0%, resulting in a saving of more than $3,259.64 per month. As part of the implementation sustainability, a sheet maintenance schedule (SMS) for the robot was created in order to minimize leaks defects due to poor maintenance of the robot.*

Key words*: Accumulator, Lean, Waste, Welding.*

PROBLEM STATEMENT

Through the last weeks, the amount of defect on accumulator's welds has significantly increased over 200% comparing with normal production. This situation affects the budgeted cost due to rework and scraps and affects the assembly line if the prognostic number of accumulator doesn't meet the demand of the line. The company seeks to improve quality and reduce cost in the manufacturing process in order to maintain superiority in the trailer heating, ventilating, and air conditioning (HVAC) units while maintaining compliance with the International Organization for Standardization (ISO) requirements. The purpose of this project is to find the root cause of the problem causing this increase in defects in order to reduce budgeted cost while maintaining compliance with ISO regulation. The area that is going to be impact is the welding cell of accumulator in TK3 building of Thermo King Arecibo. This area has 4 stations (manual welding, robot welding, brazing, and leak test) necessary for the manufacture of an accumulator but the project is going to be focus on the first 2. Some possible causes that are making those defects are: quality of the Argon used for robot's welding, maintenance of the robot and other equipment, the quality of assembling parts, operator procedure among others.

The objectives of this research work are: Improve quality by reducing the leak defects by 50%, Cost reduction by eliminating scraps and rework hours and Improve delivering time to the assembly line. With the project implementation, TK3 building of Thermo King Arecibo will improve product's quality and reduce operational cost by eliminating waste due to rework, scraps and overtime payments. Also, by finding and knowing the problem's causes, a maintenance prevention plan can be created to maintain the percent of manufacturing cost due to leaks defect under 7%.

LITERATURE REVIEW

The heating, ventilation, and air conditioning system, also known as HVAC, is the technology of indoor and vehicular environmental comfort. Its goal is to provide thermal comfort and acceptable indoor air quality. HVAC system design is a subdiscipline of mechanical engineering, based on the principles of thermodynamics, fluid mechanics, and heat transfer. The basic components of a HVAC system (Figure 1) include a condenser, an expansion valve, evaporator, accumulator and a compressor. [1]

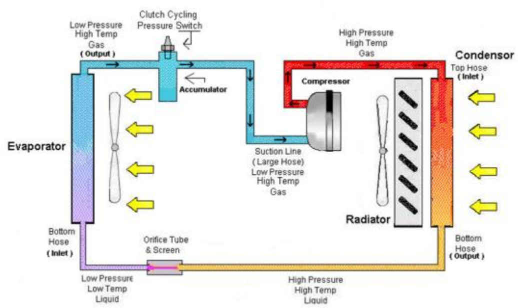

Figure 1
HVAC System Diagram

The accumulator is the component of the HVAC unit that is going to be study and analyzed in this article. An accumulator is a small, cylindrical structure containing a system of pipes. An input pipe connects the accumulator to the evaporator of an air conditioning unit. An output pipe connects the accumulator to the compressor of the air conditioner. Evaporators exist as part of an air conditioner's low-pressure system, while compressors comprise part of the high-pressure system. Accumulators serve as a transition between these two systems, converting refrigerant from its low-pressure form to its high-pressure form. The chief role of the accumulator is to isolate the compressor from any damaging liquid refrigerant. Liquid is not compressible and would destroy the compressor if allowed to enter. For that reason, accumulators are placed at the evaporator outlet and are used to separate liquid refrigerant from vaporized refrigerant, as well as remove any moisture contained in the refrigerant. Refrigerant enters the accumulator as it leaves the evaporator. Any liquid refrigerant is trapped in the accumulator, while vaporized refrigerant and refrigerant oil is allowed to pass on to the compressor. [2]

One factor that can affect the performance of a HVAC unit is its ability to withstand high pressure throughout the system. That is way a good weld is crucial for the operation and reliability of a unit. Welding is a fabrication or sculptural process that joins materials, usually metals or thermoplastics, by causing coalescence. This is often done by melting the workpieces and adding a filler material to form a pool of molten material (the weld pool) that cools to become a strong joint, with pressure sometimes used in conjunction with heat, or by itself, to produce the weld. This is in contrast with soldering and brazing, which involve melting a lower-melting-point material between the workpieces to form a bond between them, without melting the work pieces. Some of the best known welding methods include: Shielded metal arc welding (SMAW), Gas tungsten arc welding (GTAW), Gas metal arc welding (GMAW), Flux-cored arc welding (FCAW), Submerged arc welding (SAW) and Electroslag welding (ESW). [3]

This project is going to focus on the Gas Metal Arc Welding process of accumulators. The main goal is to investigate the root cause problem, finding a propel solution to eliminate this new increase in leaks and sustaining the implementation to keep control of the process. In order to meet the proposed objectives, will be used Lean Six Sigma methodology.

PROJECT METHODOLOGY

In order to achieve and comply with the project objectives, this section provides an overview of procedure and methodology that will be applied in the design project. The project methodology to be used is DMAIC improvement strategy coming from Six Sigma principles. DMAIC is an acronym that has five phases: Define Measure, Analyze, Improvement and Control.

Define Phase: This phase consists in defining the scope, goals and project statement. It will use a project charter in order to describe the process and identify the possible opportunities of improvement.

Measure Phase: The objective of this phase is the collection of the key aspects of current process and relevant data. As well as the identification of potential factors that may affect the process. It will use data collection and detailed process flow diagram. The tools to be used to show visual representations of the current state are graphs, charts, flowcharts and Supplier-Input-Process-Output-Customer (SIPOC) diagram.

Analyze Phase: This phase consists on identifying deep causes with the objective of validate them with relevant data. The key components of this phase include cause-effect, root cause and value- non value added analysis. It will used Value stream map and cause-effect diagram.

Improvement Phase: The objective of this phase is optimizing the current process based on data analysis. The key components for this phase include lean manufacturing tools, optimized process parameter settings and standardized work.

Control Phase: This phase includes designing and documenting the new controls and procedures, in order to hold the gains. Key components to this phase are visual workplaces, periodic audit exercises and training process to monitor the success.

The following graph (Figure 2) proposes the schedule of the activities to complete the project. It also includes the estimated duration of each activity.

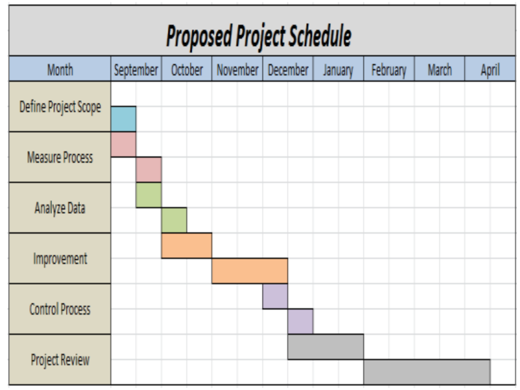

Figure 2
Project Schedule

Results and Discussion

In order to identify the relation between the suppliers, input product, process, output and customers, a SIPOC Diagram (Figure 3) was created.

Suppliers

E-COAT is in charge of supplying all metal components that requires the cleaning process, Tubing department supply all copper materials and Stock Department supply the brackets.

Input

Kanban - Place all the accumulator parts in bins and cars, to be available for the operator.

Process

1. Spud (M13) – The first step of the robot is the weld of the spud in the Top Cap.
2. Manual Welding – The operator welds manually the internal components (Flute) and tacks the two caps to the cylindrical shell.

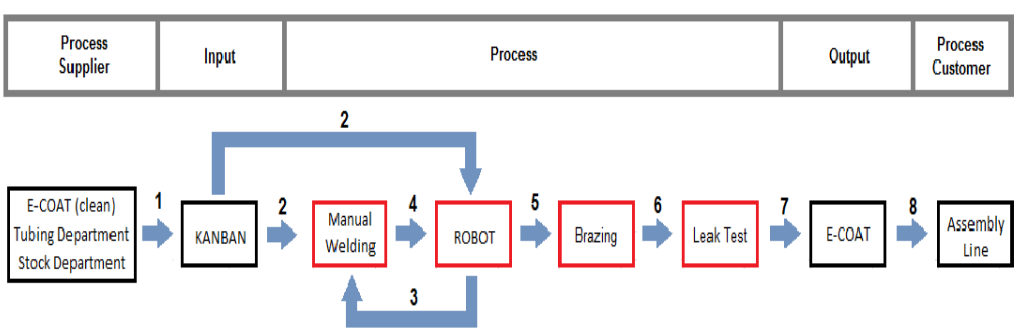

Figure 3
SIPOC Diagram

3. Caps (M3, M4) –The operator puts the preassembly in a spindle to start the robot's program that welds the caps to the shell.
4. Brackets (M6, M7, M8, M9) –The operator then place the accumulator in another fixture to welds the brackets to the shell.
5. Spud (M12) –The last step of the robot is the weld of the spud.
6. Brazing (72, 213) –After the robot finished, the accumulator is passed to brazing.
7. Leak test (Helium Test) –The last step of the process is a Helium Leak Test to verifying there are no leaks through the welding.

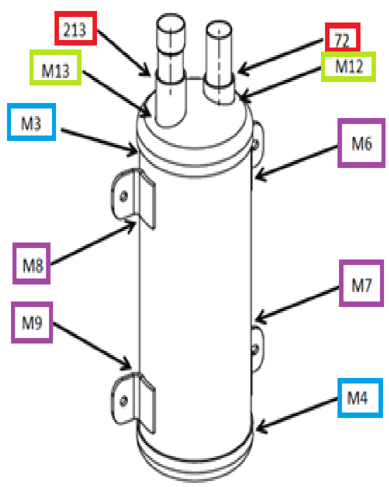

Figure 4
Accumulator Welds

Output

E-COAT - Paints the accumulator.

Customer

Assembly line of Precedent units.

A leak form was created to collect data concerning the operation of the process. The form supply information to the team related to: when it occurred, how many were, the location on the accumulator and the types of leak. This data was used to create a Pareto Chart (Figure 5) to identify the event with the most failures.

The data collected on the form was used to compute the increase cost due the leak problem. An existing operational cost report established that the manufacturing cost is $55.87 per accumulator and $3.25 of manpower per accumulator due overtime. The following table 1 shows approximately the manufacturing cost on accumulator through the month of October 2014.

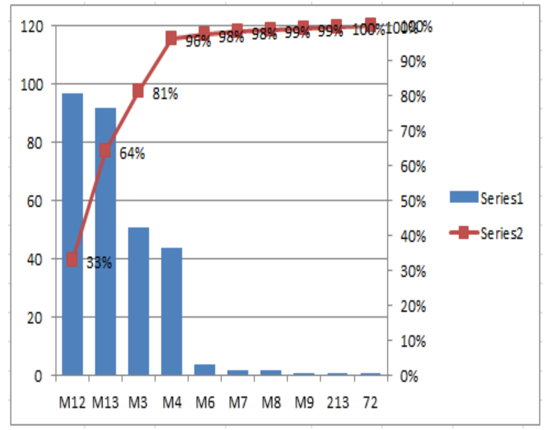

Figure 5
Pareto Chart

Table 1
Accumulator Manufacturing Cost

	Quantity	Cost/Accum.	Total
Ideal	940 Accum.	$55.87	$52,517.80
Additional	85 Accum.	$55.87	$4,748.95
Overtime	295 Accum.	$3.25	$958.75
Total Cost			$58,225.50

The table # 1 indicates that 295 from 940 accumulator needed rework and 85 of those rework finished in scrap. Because of those scraps, 85 new accumulators were manufacture to compensate the need of the assembly line. The total cost cause by the leak problem that month was $5,707.70, equal to 9.8% of the manufacturing accumulator cost represented in the following pie-chart (Figure 6).

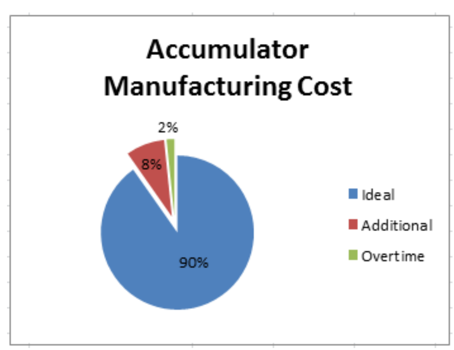

Figure 6
Pie Chart

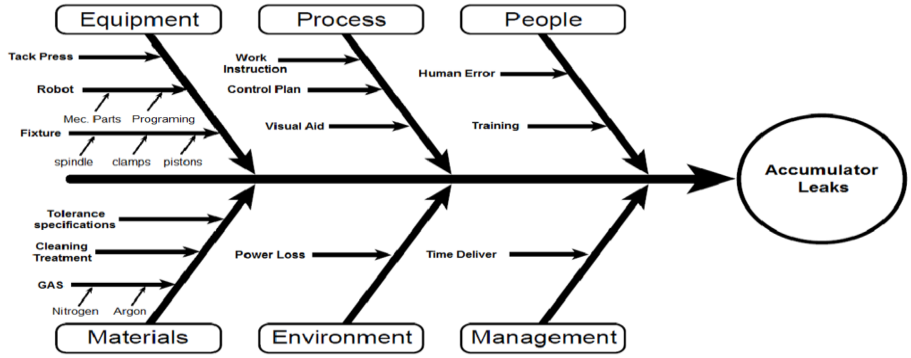

Figure 7
Fishbone Diagram

The focus in this analyzed phase is about finding opportunities for improvement within the welding process. The first step is to analyze all measured data. Then understand all feasible causes that affect welding by performing a Fishbone analysis and set priorities among them discovered causes. For this part, every member of the team gave their opinion based on their own expertise. With that information a cause-effect analysis was performed shown in figure 7, in order to find the possible causes.

The main possible causes identify in the fishbone diagram that affects calibration cost were selected to be evaluated and categorize under the fallowing 4 categories:

- High Impact– Low Difficultly
- High Impact – High Difficult
- Low Impact – Low Difficultly
- Low Impact – High Difficult

The High/ Low Impact factors were defined in terms of the effect productivity and operation cost. As well, the High/ Low Difficultly factor were defined in term of the investment cost and time/effort to implement, and quality risk. The figure 8 shows the analysis performed and the selected causes following the previous approach.

After a discussing with the team members, there were nine primarily aspects selected and categorized as shown in figure 8. The primarily focus in the selection pursues the initiative that are considered to have low difficulty and provide high impact. Therefore, reprograming and changing the quality of the Argon gas were selected as process causes that can achieve great revenue with minimal investment and less implementation time/effort required.

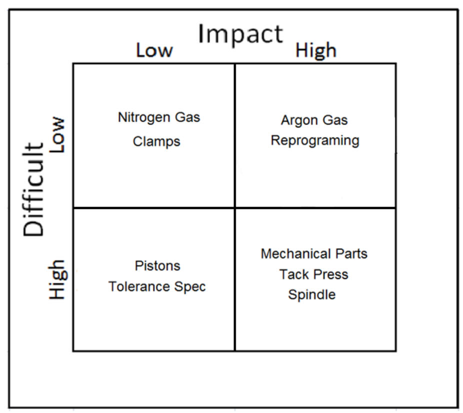

Figure 8
Categorized Analysis

In the improvement phase the first aspect taken in consideration was the Argon gas used to isolate and protects the weld area from atmospheric contamination. After changing the Argon principal line to individual tanks, the leaks were reduced by 4.86%. The next step was reprograming the robot to its reference position. The change in settings creates an increase in leaks by 2.56%. By analyzing this new data, the team decides that a mechanical part that holds the welding gun called torch, could be responsible for the increment of leaks. The torch was changed and the robot reprogramed. Those new changes decreased the leaks by 16.95% in special the ones related with spuds.

At this point of the implementation the M12 and M13 weren't the biggest detractors. For that reason the focus turn to the leaks related to shell and caps. The next aspect to be studied was the tack press and later the spindle. Those changes produced a decrease of 3.49% in special those related to the weld between shell and caps like M3 and M4. The last step was to create a maintenance schedule to keep the robot and fixture in optimum conditions. This will be explaining in detail in the control phase. A second cost projection was performed after plan implementation to illustrated the saving the company gain with the implementation on the accumulators cell units.

Table 2
Accumulator Manufacturing Cost After Implementation

	Quantity	Cost/Accum.	Total
Ideal	1005 Accum.	$55.87	$61,736.35
Additional	38 Accum.	$55.87	$2,123.06
Overtime	100 Accum.	$3.25	$325
Total Cost			$64,184.41

The table 2 indicates that only 100 from 1005 accumulator needed rework and 38 of those rework finished in scrap. Of those scraps, 35 new accumulators were manufacture to compensate the need of the assembly line. The total cost cause by the leaks problem in the month of December was $2,448.06, equal to 3.8% of the manufacturing accumulator cost represented in the following pie-chart (Figure 9).

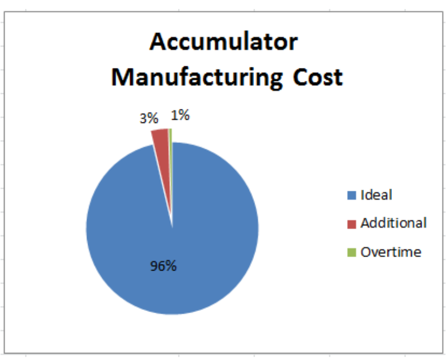

Figure 9
Pie Chart After Implementation

At the beginning of the project, the company's waste due to re-work and scraps on the accumulator area was 9.8%. However, after plan implementation the waste was reduce to 3.8%. The plan implementation helped reduce waste by 6.0%, resulting in a saving of more than $3,259.64 per month. Without the plan implementation the company would have incurred in approximately $39,116 annually.

The purpose of DMAIC control phase is to provide a control plan to prevent the counter measures and solutions in place that can be controlled to prevent future problems and provide a sustainable financial benefit. As mention in the improve phase, a sheet maintenance schedule (SMS) for the robot was created. This SMS contains the date of the maintenance, the parts of the robot that needed maintenance and the parts that needed to be replaced; either for normal wear condition or broken accidentally. This SMS was created with the objective of maintain the robot in its optimal condition to prevent another increase in leakage, to sustain the improvement made by the plan implementation and to maintain stock inventory updated. This form will be part of the new maintenance record. In addition, a successful implementation includes constant monitoring from the operator of the robot, the manufacturing technician, the programmer and the leak tester.

Conclusion and Recommendations

At the end of the plan implementation, the three main objectives of this project were accomplished. The first objective was to improve quality by reducing the leak defects by 50%. Before the implementation the percent on defects were 31.38% and by the time the implementation reach the control phase the percent on defects were 9.95%. That means a reduction on leaks defects by 68.29% of the initial leak percent. The second main objective was to reduce cost due to rework and scraps to maintain the percent of manufacturing cost due to leaks defect under 7%. At the beginning of the project, the company's waste due to re-work and scraps on the accumulator area was 9.8%. However, after plan implementation the waste was reduce to 3.8%. The plan implementation helped reduce waste by 6.0%, resulting in a saving of more than $3,259.64 per month. Without the plan implementation the company would have incurred in approximately $39,116 annually.

As part of the implementation sustainability, a sheet maintenance schedule (SMS) for the robot was created in order to minimize leaks defects due to poor maintenance of the robot. This SMS contains the parts of the robot that needed maintenance and the parts that needed to be replaced; either for normal wear condition or broken accidentally. This SMS was created with the objective of maintain the robot in its optimal condition to prevent another increase in leakage, to sustain the improvement made by the plan implementation and to maintain stock inventory updated.

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