Total Productive Maintenance (TPM) to Improve Laboratory Performance

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Abstract *— Total Productive Maintenance is a methodology focused on the improvement of equipment performance. Is a concept mainly employed in the manufacturing operations in which the equipment performance is constantly monitored to reduce the impact in the yield. This research records the implementation of Total Productive Maintenance into the laboratory operation and how the equipment performance improved. The implementation consisted in the identification of equipment losses, performance indicator identification, the assessment of the preventive maintenance program and in the implementation of 5S tools. The focus relied in a reduction of equipment issues and malfunctions increasing the availability of the equipment issues and malfunctions increasing the availability of the equipment and improving the laboratory performance.*

Key Terms *— Improvement, Laboratories, Performance, Total Productive Maintenance.*

INTRODUCTION

At industries Total Productive Maintenance (TPM) is a concept mainly employed at the manufacturing operations as an improvement tool focus in equipment performance. Many studies shown the results of the implementation of TPM concepts in manufacturing operations such as the automobile industry [1][2]. Results demonstrated improvements in Overall Equipment Efficiency (OEE) and in defects reduction [2][3]. This mean that the application of TPM tools improved the equipment performance. Is TPM a concept that will be applied to other operations such as laboratories?

In previous years quality control laboratories have implemented improvement concepts pursuing be more efficient and agile. Concepts of lean laboratory was one example of the tools employed in order to improve the laboratory performance. Deployment of standard work, visual management, shift huddles were some the activities related to lean implementation in the laboratory. Nonetheless, TPM was a concept never applied before at laboratories.

The approach used in the laboratories was one focused in the improvement of testing methods and human error reduction. However, the equipment performance was not a focus area for laboratories even though the analytical testing requires equipment usage. Equipment issues such as unplanned stops, system suitability failures or malfunctions were only assessed if was related to a laboratory investigation. The inclusion of TPM at the laboratory operation added a new scope into the improvement loop. Equipment is a key element inside the laboratory operation along with the analyst performance and testing methods.

Reference [4] indicates that TPM is a methodology that follow the increase of equipment performance and availability improving the planned maintenance program and implementing preventive maintenance programs. The approach relies on identify the main equipment losses, define corrective and preventive actions. Additionally, involve the operators in the maintenance program giving them capabilities and skills to sustain the equipment in optimal conditions [4]. Based on that, the purpose of this study was found how the application of TPM will improve the laboratory performance. As well as, determining major offenders of equipment failure in the laboratory. Also, found out areas of improvement such as the reviewed of the preventive maintenance program, developed job aids for the analysts and defined metrics to measure the equipment performance in the laboratory. The application demonstrated that performance should improve and supported the strategy of including other elements never considered before in the organization scope.

METHODOLOGY

The methodology employed in this study was a similar approach employed at the manufacturing and automobile industry. In overall the methodology replicated the deployment model used by these industries. The model included: the data collection of a period of one previous year, the identification of the performance indicators and major offenders. Based on the data, an equipment be selected as pilot for the implementation. The scope included the identification of main losses of the equipment, the application of 5S and the review of the preventive maintenance program. Additionally, training of the analysts is part of the study scope. The team was a multidisciplinary team of analysts, instrumentation experts and laboratory leaders. At the end of the implementation the equipment performance was monitoring using the performance indicator identified.

RESULTS

The TPM Model previously explained in the methodology section was applied in the laboratory operation of a manufacturing industry. The equipment layout of the laboratory consists two main equipment, the High Liquid Performance Chromatography (HPLC) and the Inductively Couple Plasma (ICP). The gross of the analysis was performed on these two main equipments. The initial scope of the project implementation was the study of the data systems to identify which data would be used for the data collection. There were two systems that collect information regarding equipment: the laboratory investigations report (LIR's) and the service request (workorders) report.

A laboratory investigation query was performed to gather the data from one year (2019-2020). The report of the query contained only the investigations related to instrument malfunction and instrument failures. Figure 1 shows the investigation report query resulting of 40 investigations related to equipment: 16 of equipment malfunction and 24 of system suitability failure in one year.

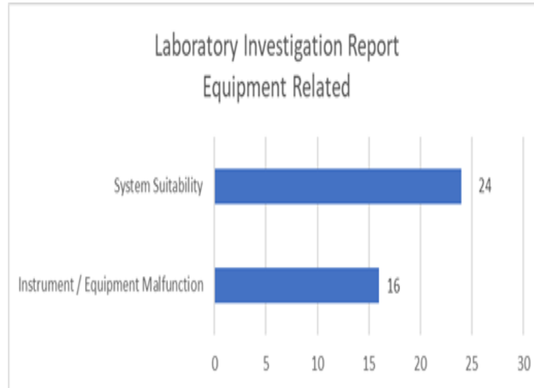

Figure 1
Laboratory Investigation Report Related to Equipment

To identify which equipment was related to these investigations the data was stratified and showed that the ICP had caused more investigations with a total of 23 investigations. (Figure 2). Basically, twice the number of investigations were related to system suitability failures and others by equipment malfunction. Additionally, another data source used for the data collection was the service request (work order) information. The service request query collected the work requests related to instrument service.

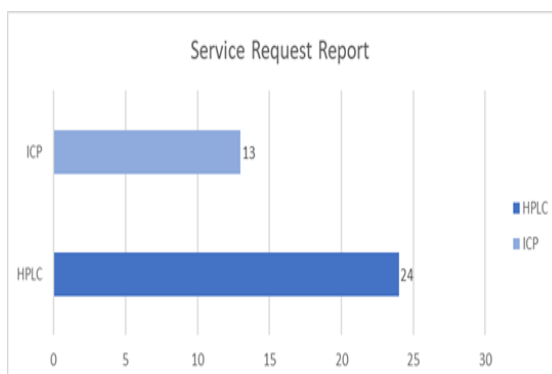

Figure 2
Service Request Report

Figure 3 provides the summary of the query in which 37 work requests were generated within a year specifically addressed to equipment support, 24 for HPLC and 13 for ICP. To understand the rationale of the requests two pareto analysis were conducted in order to identify the main causes of work requests for the HPLC and ICP. The Pareto of the HPLC request showed that most of the service request were regarding equipment malfunction followed by out of specification results (OOS) and atypical chromatography. (Figure 4).

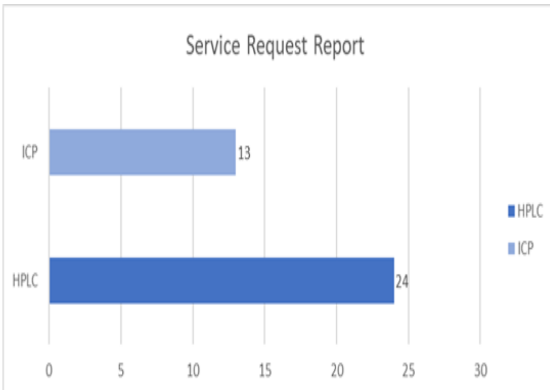

Figure 3
Service Request Report

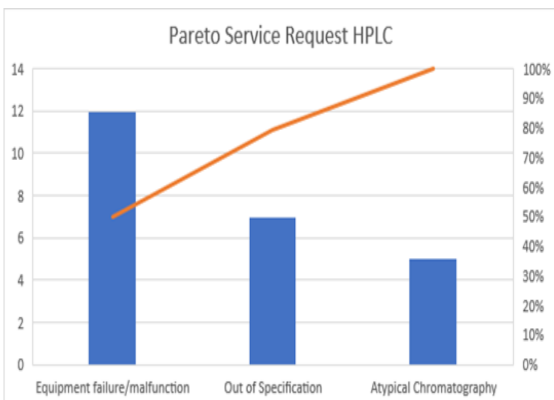

Figure 4
Pareto Service Request

For the ICP, the second pareto (Figure 5) the data showed that the main cause of service request was to address equipment malfunction followed by system suitability failures. Based on the data, the equipment with more issues regarding malfunction and failures was the ICP. The historical data identified the ICP as the major offender in terms of equipment performance.

The ICP was identified as the pilot for the TPM implementation. The next step consisted in understanding the losses of the ICP. What were the issues with the ICP? Which were the opportunities? The data previously presented in the Figure 1 showed issues related to equipment malfunction and system suitability failures.

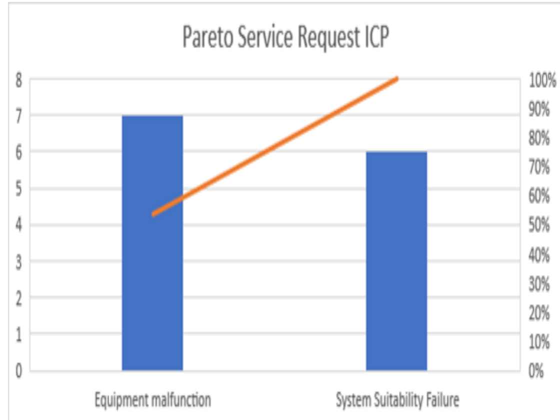

Figure 5
Pareto Service Request ICP

Analyzing the root cause of the ICP investigations the pareto showed that the causes were related to malfunction of equipment parts such as injector, pump tubing, and other causes such as standard response. After reviewing the pareto of losses shown below, (Figure 6) the major offender was related to the equipment malfunction specifically malfunction of equipment parts such as the injector and pump tubing.

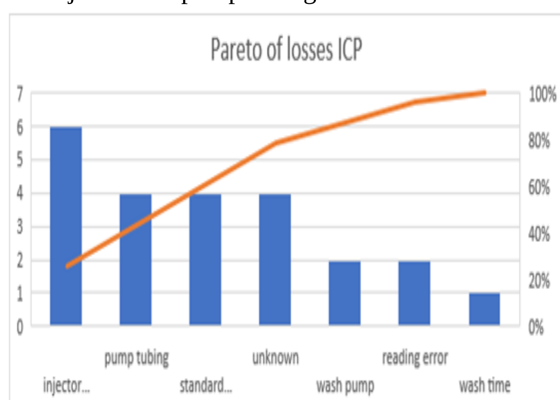

Figure 6
Pareto Losses ICP

The Pareto highlights equipment issues that impact the laboratory performance. These issues caused delays in the testing process and increase the unavailability of the equipment. Which indicators would have been used to measure the equipment performance? Reviewing the metrics used at the laboratory operation, lead time and downtime were indicators used to measure performance. Lead time was an indicator influenced by many factors such as investigations, manufacturing delivery, materials availability, data acquisition system and equipment. The scope was very wide to be used as a metric into the project. Downtime was a metric focus in measure the time of unavailability of the equipment and in addition triggers the action regards of time. For TPM purpose, the downtime metric was chosen as an indicator of performance and improvement. This allowed the monitoring of one variable within the process: specifically, the equipment variable.

The data analysis was discussed with the laboratory team prior to move to the next phase. The team understood the data collected, new opportunities found and the plan of the next phases for the TPM implementation. The analysts were responsible in the assessment of the ICP area and applied the 5S tool in the area. On the other hand, the instrumentation contractors were assigned to make a full assessment of the equipment, executing the Planned Maintenance Program (PM). The purpose of the Planned Maintenance was to optimize the equipment reducing unplanned stops and failures. The team, instrumentation colleagues and analysts identified the list of spare parts need it to sustain an inventory of parts that would reduce the wait time when the parts are not available. The 5s activities were conducted in the ICP workbench area. At the sort step the team reviewed the area and identified the necessary and unnecessary tools of the workspace. The tools identified as unnecessary were removed from the area and the necessary tools were set in order. The area was clean and tidy as part of the shine step. To standardize, all colleagues were trained in the concepts of 5S and the layout of the area was explained. To ensure the sustainability of the tool an audit process was defined by the team on where each week a leader or colleague from other area inspect the ICP area and give a score based on the findings and a checklist used for the inspection and actions.

The review of the preventive program was the next stage of the project. At this stage a gap was identified; the only program in place regarding to equipment was the planned maintenance program. The standard operating procedures (SOP's) were the only guidelines available for the analyst to perform the activities of setting and cleaning of the equipment. The Planned Maintenance Program was conducted twice a year. Meanwhile, the analysts highlighted the need of a program that provides guidelines to setup, troubleshoot, and inspect the equipment align to the SOP's. The availability of another preventive program would provide additional support to the colleagues providing the tools and capabilities required to manage the equipment correctly. With the support of the instrumentation contractors and training department a program was developed to attend the needs of the area. The program was led to develop visual job aids with training for the analysts. The job aids included visual inspection, execution of critical steps, safety warnings aligned to the standard operating procedures. The application of the job aids were before and after the testing process ensuring the readiness of the equipment after each test. The training design included the theorical part on which the job aid was explained step-by-step to the analyst and a second part of on-the-job training on where the analyst executed the job aid, practicing the critical steps, and troubleshooting the equipment.

Figures 7 and 8 demonstrate the job aids of the ICP specifically the injector and pump parts. These parts of the ICP were identified as the major contributors of malfunction of equipment in the data analysis phase. The job aid was a visual guide designed to explain in detail the tasks required to be performed on each used. The job aid design style was a check list format with images on each task. That format helped the analysts go step-by-step through the tasks, have the images as support and standard operating procedures as references. The job aids were located in the ICP area near to the equipment ensuring the availability for all users.

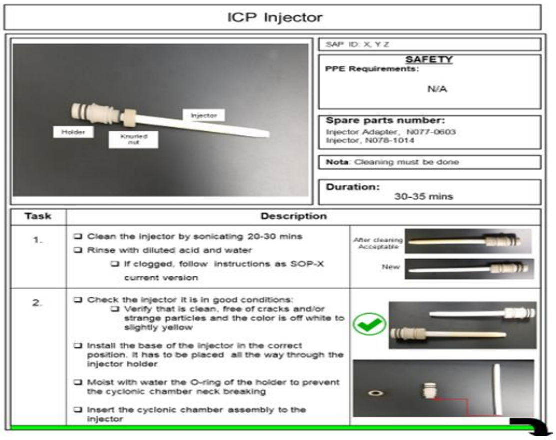

Figure 7
Job Aid Injector

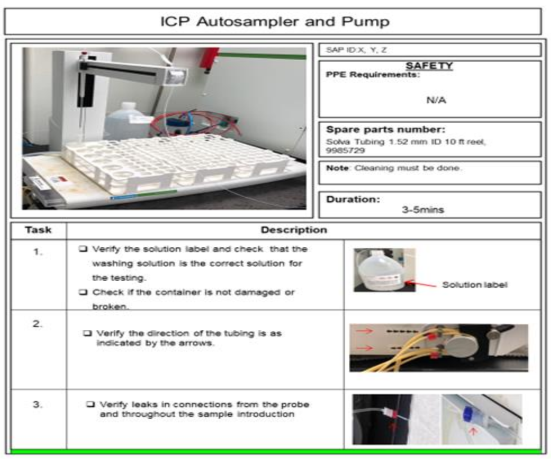

Figure 8
Job Aid Pump

At this point, the elements of Total Productive Maintenance were deployed into the laboratory operation. The data collection, losses identification, and pilot for implementation were completed. The 5S tool and plan maintenance activities were performed. An additional preventive program was developed, and all the analysts were trained in the new activities. All the phases were deployed, and change is visible at the workplace. The ICP area was cleaner, better organized and with the availability of spare parts. The job aids were available at the ICP area facilitating the setting and cleaning tasks. Analysts performed the tasks following the jobs aids and executed troubleshooting when required. After the implementation of TPM, the next step consisted in monitoring. Downtime was the performance indicator identified at the beginning of the project. Downtime was the period of time that the equipment was off; unavailable to use. Monitoring downtime in the laboratory operation allowed to track the equipment availability and the reasons for the unavailability. Equipment issues such as inadvertent stops and system suitability failures during the testing process was measure in the downtime metric. At the beginning of the project the downtime concept was explain to the team and the plan was included the downtime metric as part of the shift huddle of every day. Each day the analyst gathered all the lost time due to ICP equipment issues. The lost time in hours was graphed in the downtime metric available at the visual management board. At the daily meeting the supervisor discusses the metric with the team and the actions that should proceed. After, the TPM implementation downtime was used to continue measuring the equipment lost time. Monitoring the downtime helped to have more information available of equipment performance and pushed forward to a continuous improvement loop in the operation.

Figure 9 portrays the ICP downtime data of thirty days. The tendency for the first days had higher values of downtime. Values over five hours per day were related to downtime each shift. The difference in the tendency was visible through the implementation of TPM. A change was observed around the middle of the month in which the hours of downtime decreased. Downtime values of less than five hours per day were present after the implementation of the TPM tools. Additionally, a reduction of the variability in the downtime values were achieved through the implementation of TPM. The initial state of the project showed a value of eight hours of downtime for the ICP. After the implementation, a value of two hours of downtime was achieved. The availability of the equipment increased by six hours, which meant an increase of availability of seventy-five percent in contrast to the initial state. The current state showed an improvement of seventy-five percent of equipment performance compared with the initial state without the implementation of TPM.

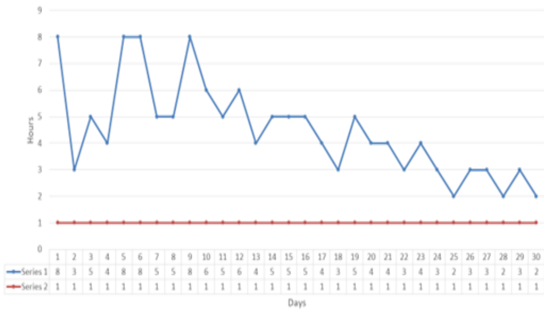

Figure 9
Equipment Downtime Metric

DISCUSSION

The problem stated in Chapter 1 has been solved: the implementation of Total Productive Maintenance into the laboratory operations improved the equipment performance. This changed the approach used in the past by the laboratories regarding laboratory performance. The inclusion of equipment into the laboratory approach allowed to assess and monitor the equipment performance finding areas of improvement that would impact the performance. Improvement such as five S, downtime reduction and capabilities of the analysts were implemented in the project.

Findings and limitations encountered during the process were the unavailability of a preventive program for the equipment. The only program in place regarding to equipment was the planned maintenance but an additional program was not in place. One of the objectives was the review of the preventive program to find out areas of improvement. The unavailability of a program limited the objective; to accomplish this objective the preventive program was developed in the project scope. The preventive program came as a plan to attend the needs of a proactive program that created the culture to evaluate and perform activities that sustained the availability of the equipment. Other limitations were the selection of the performance indicators for the TPM implementation. The laboratory operation was different as the manufacturing operation and the concepts of Overall Equipment Effectiveness, Mean time between failure, Mean time between Repair were not applied. Finding an indicator that fit into the laboratory operation measuring the equipment performance was downtime.

The implementation of the TPM concepts into the laboratory contributed into the organization, demonstrating how Total Productive Maintenance works in the laboratory operation. Developing a Preventive Maintenance Program for the ICP. Training the analyst in the preventive program. Increasing the capabilities and skills of the analysts. Defining a performance indicator to measure equipment performance. Promoting a teamwork environment.

Future Research will need to apply the Total Productive Maintenance into organizations such as laboratories and replicate the implementation in other areas. Also, the scope of the TPM could be expanded through all the laboratory operations including other equipment in the TPM program. The application of performance indicators such as Overall Equipment Efficiency would need to be assessed in order to be included into the laboratory performance.

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