Bottle filling process

Group 9

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EXECUTIVE SUMMARY

The project is focused in analyzing a bottle filling process in order to better understand the performance of the process and to stablish adequate control charts. The process is based in a supply line of four bottles being filled at a time. The sampling data was gathered by a technician who was able to supervise the first 8 hours of production. It was sampled a total of 24 hours of data which generated a dataset of 144 samples.

The goal of the project is to determine the process' ability to fulfill the requirements of a bottle being filled with 16 ounces of liquid to avoid problems in operations and to please customers. For the present analysis, each filling line was considered as a different process. In order to achieve the goal, it was also separately calculated the adequate control limits and specification limits for each line. In the control charts plotted was evident that the process is not in statistical control and needs to be improved to avoid scrap and rework.

In order to eliminate waste and to implement Statistical Process Control in the company, recommendations have been made including the usage of specific tools to make the process be in control. The sampling process needs to be performed again according to recommendations to guarantee accurate data for future analysis.

1.INTRODUCTION

In order to analyze the performance of the filling process it was used the provided data to establish control charts for the process distribution. The study focus on phase I of control chart usage, gathering and analyzing the given data to determine if the process was in control when data were collected, to determine reliable control limits to monitor the process and assisting the filling company to bring the process into a statistical control state.

During the filling process each row can be affected by several variables that will impact in the final quality of the product. For example, each row uses separate nozzles and pipes, the pipes may have different length and different diameter, each nozzle may cause different friction on the liquid and the filling pressure for each position may be different. These variables will impact filling's flow which can also be a cause of variability between them. Based on those reasons, it was noted that each bottle filling can be impacted in a different way since they are in different positions, so on this study each row of filling was analyzed as a separate process and in a separate chart in order to provide information regarding variability between them.

2. ANALYSIS

2.1 PROBABILITY PLOT

As the analysis was based on filling process of each bottle separately, a moving range chart was chosen due to the fact that the data provided for each bottle is based on individual measurements (n=1). After this decision, it was considered to make a distribution plot in order to identify if the data follows a normal distribution (Figure 1). Analyzing the distribution plots shown on Figure 1 it can be concluded that the data is normally distributed because all four p-values are higher than 0.05.

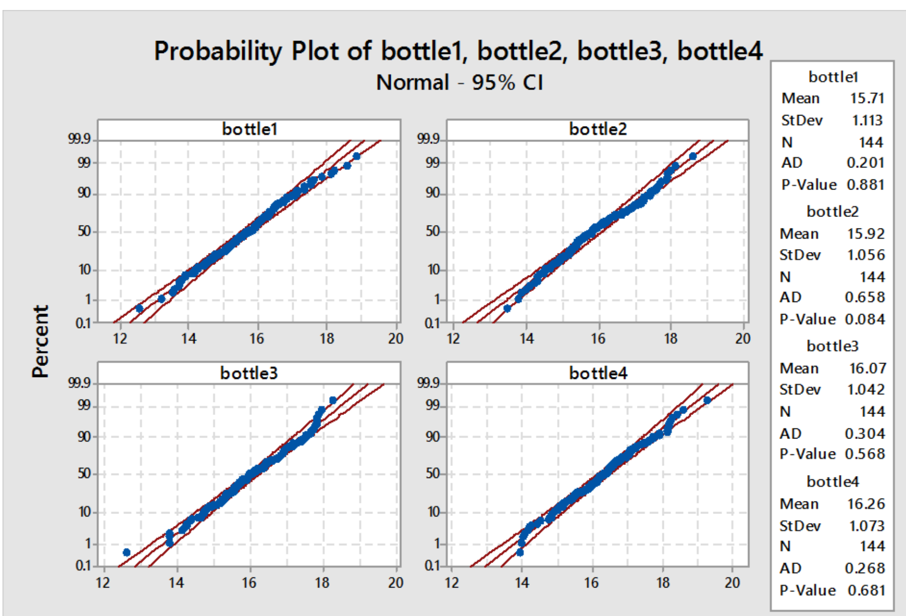

Figure 1

2.2. CONTROL CHARTS

After identifying the distribution, trial control limits were calculated using only the 48^{th} first samples because these measurements were supervised by technician and the process was supposedly running as intended. The control limits calculated were used to plot I-MR control charts to verify possible observations out-of-control.

According to the results obtained in control charts, some points were considered out-of-control and should be revised. In both moving range and individual value charts for bottle 1 (Figure 2), the observation 28 was more than 3.00 standard deviations from center line, so it was marked as out of control. For bottle 3 (Figure 4), in the individual value chart the observation 47 was marked for being more than 3.00 standard deviations from center line and in the moving range chart, the observation 48 was marked based on the same reason. In the control charts for bottle 2 (Figure3) and bottle 4 (Figure 5), there was no points out of control.

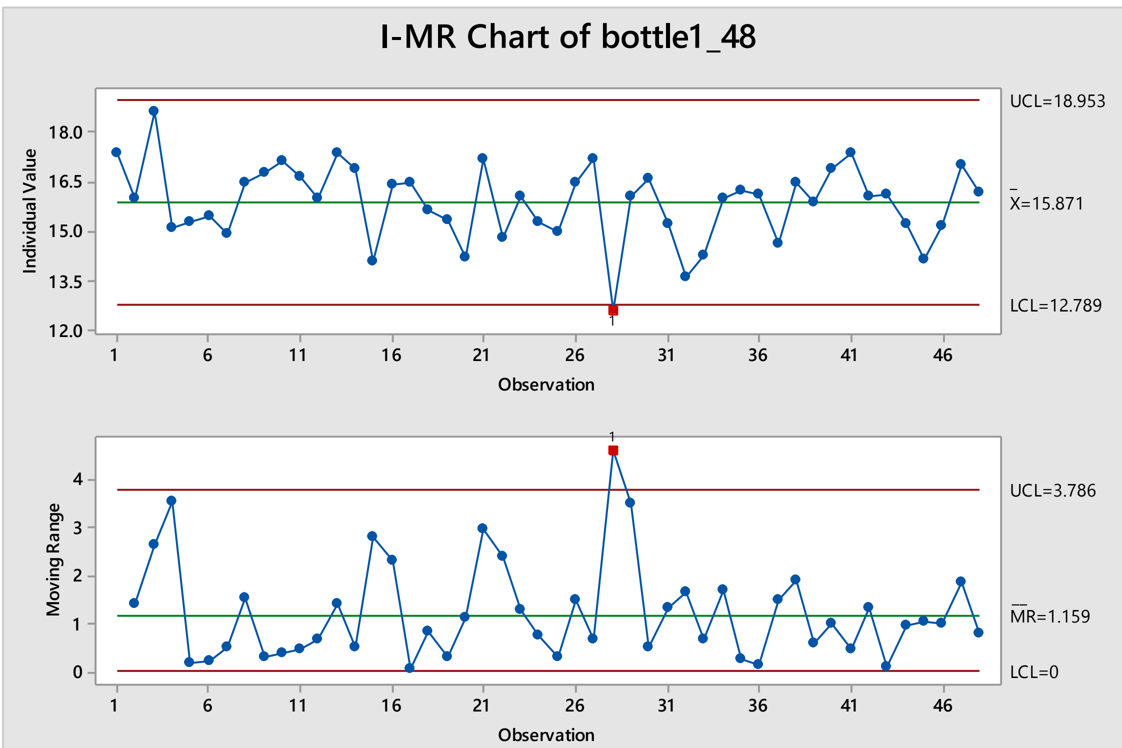

Figure 2

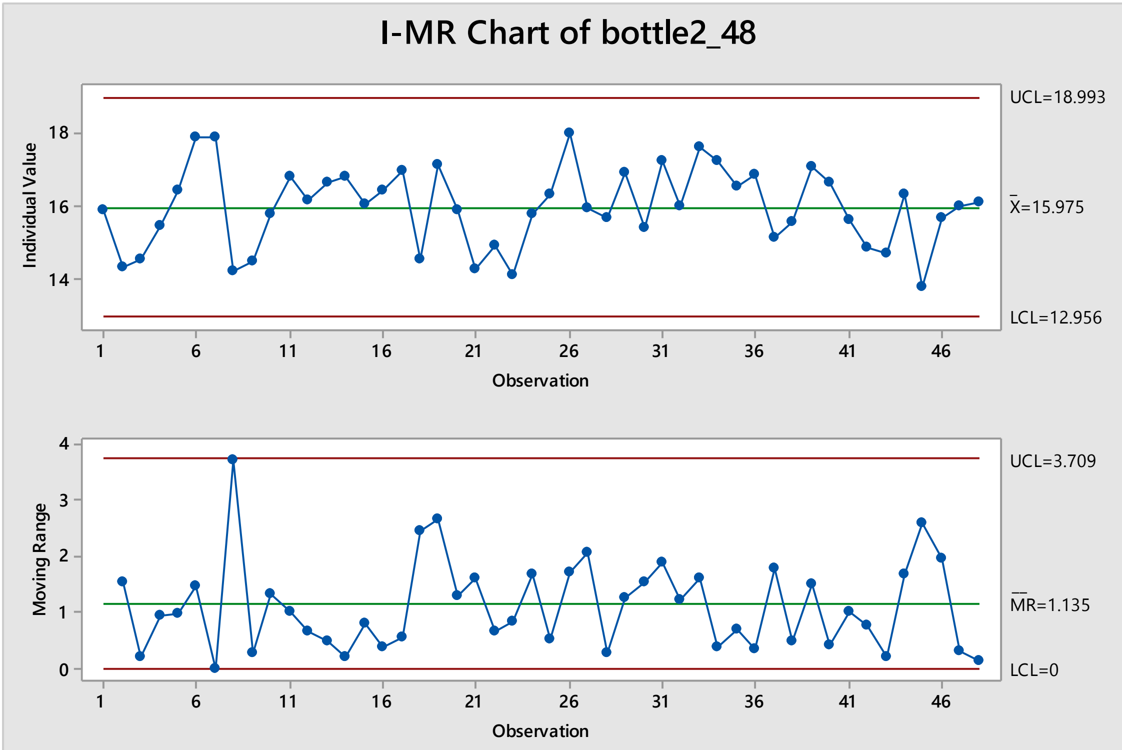

Figure 3

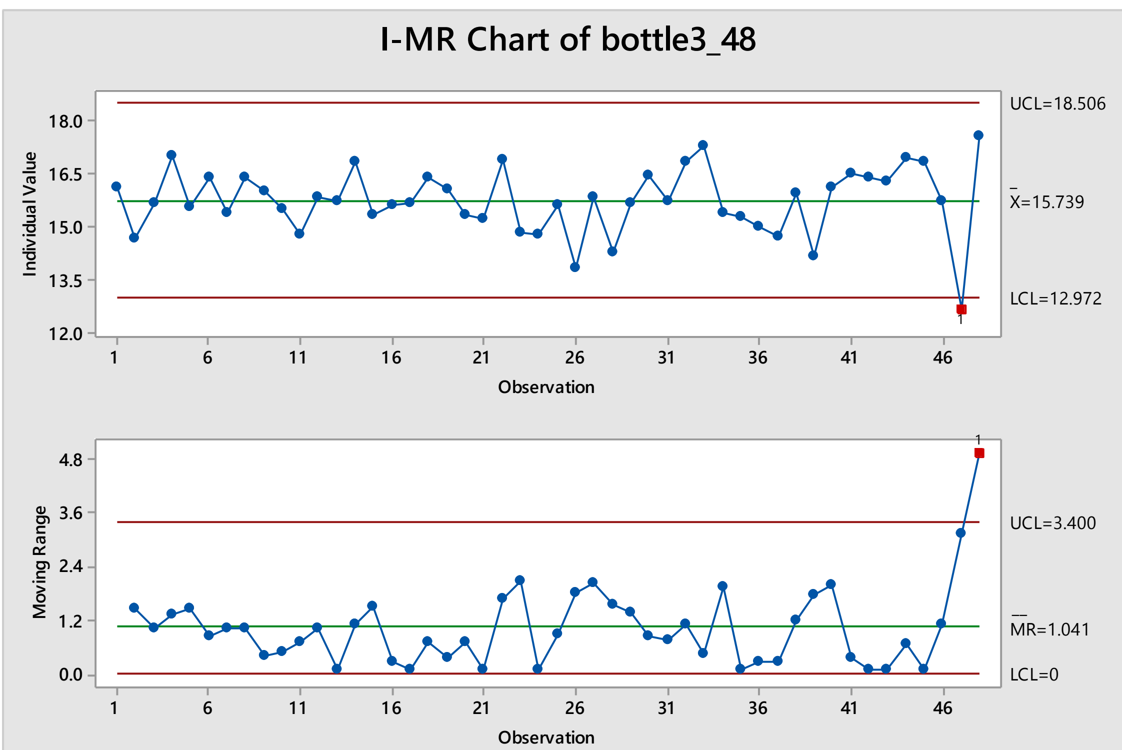

Figure 4

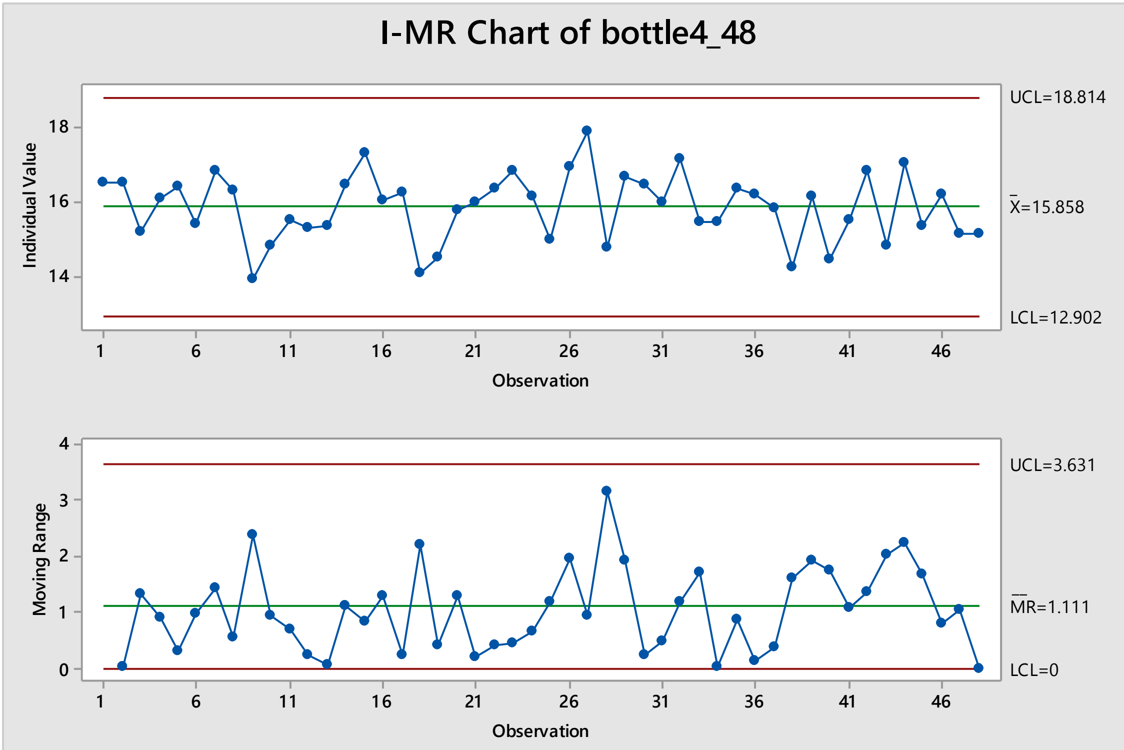

Figure 5

In order to obtain more adequate control limits, it is recommendable to use an in control process, in other words to have no points out of control. After determining the presence of some points out of control in previous charts, it was decided that control limits needed to be recalculated after omitting marked observations. After points out of control were omitted from calculations, new control charts were plotted for all four processes. According to Figure 6, Figure 7, Figure 8 and Figure 9 it is possible to notice that no new points turned up to be out of control in the new control charts.

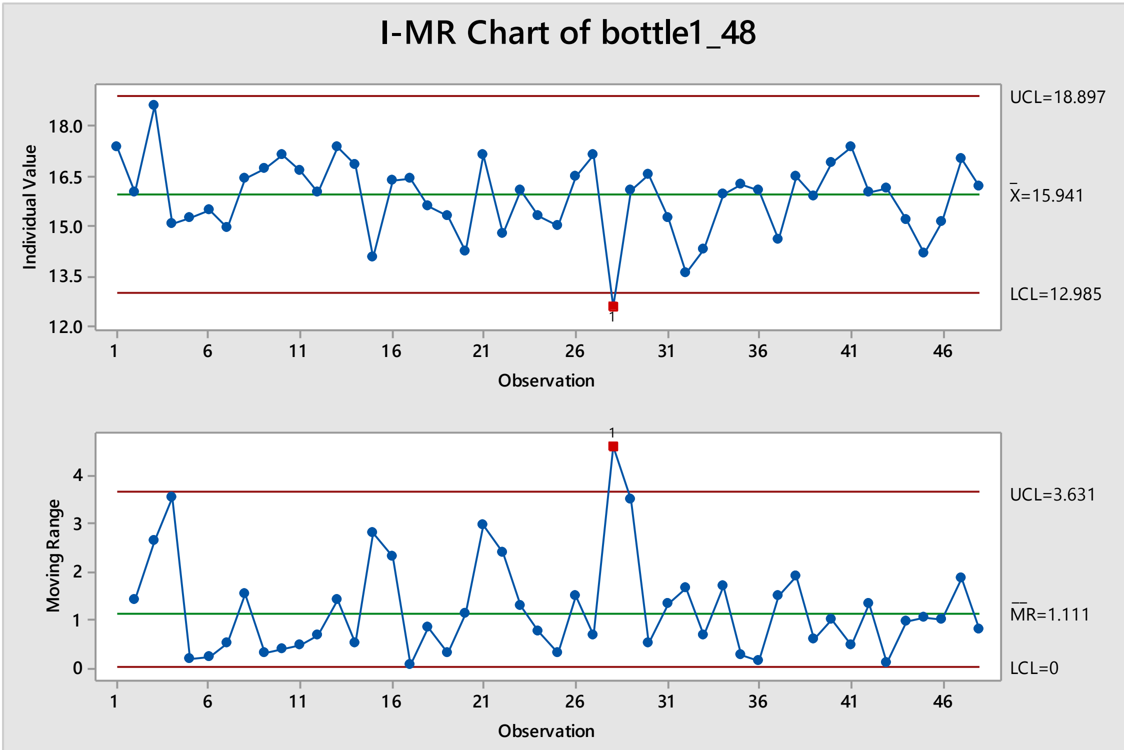

Figure 6

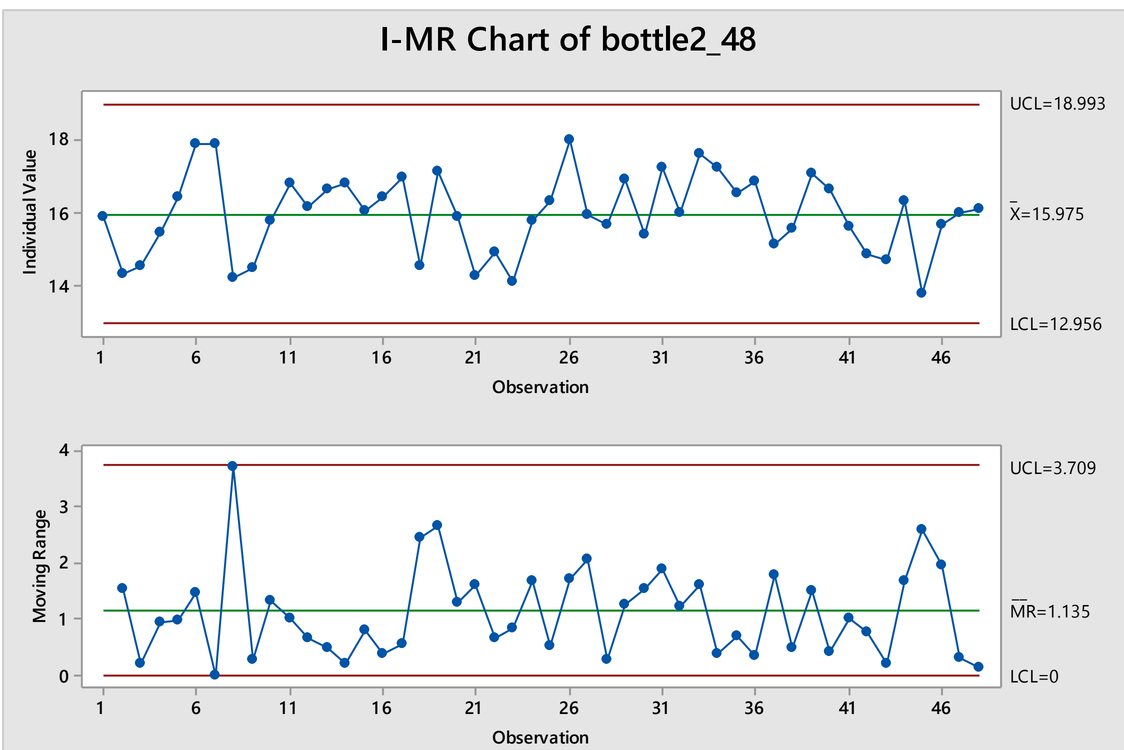

Figure 7

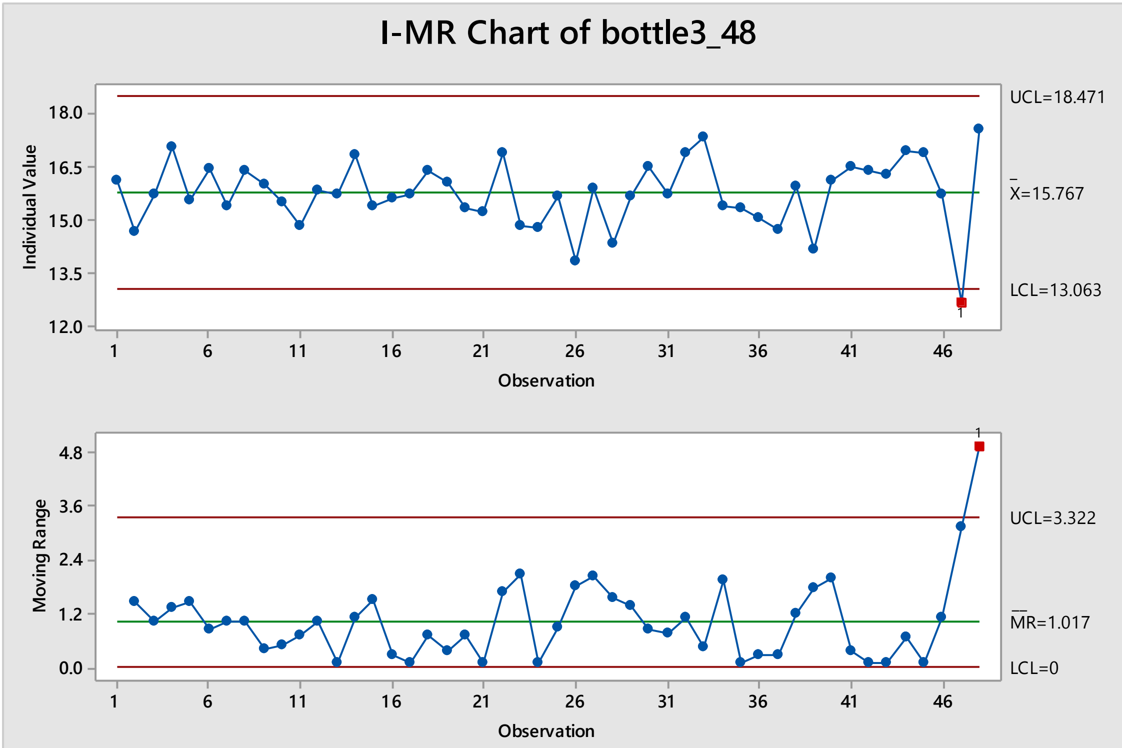

Figure 8

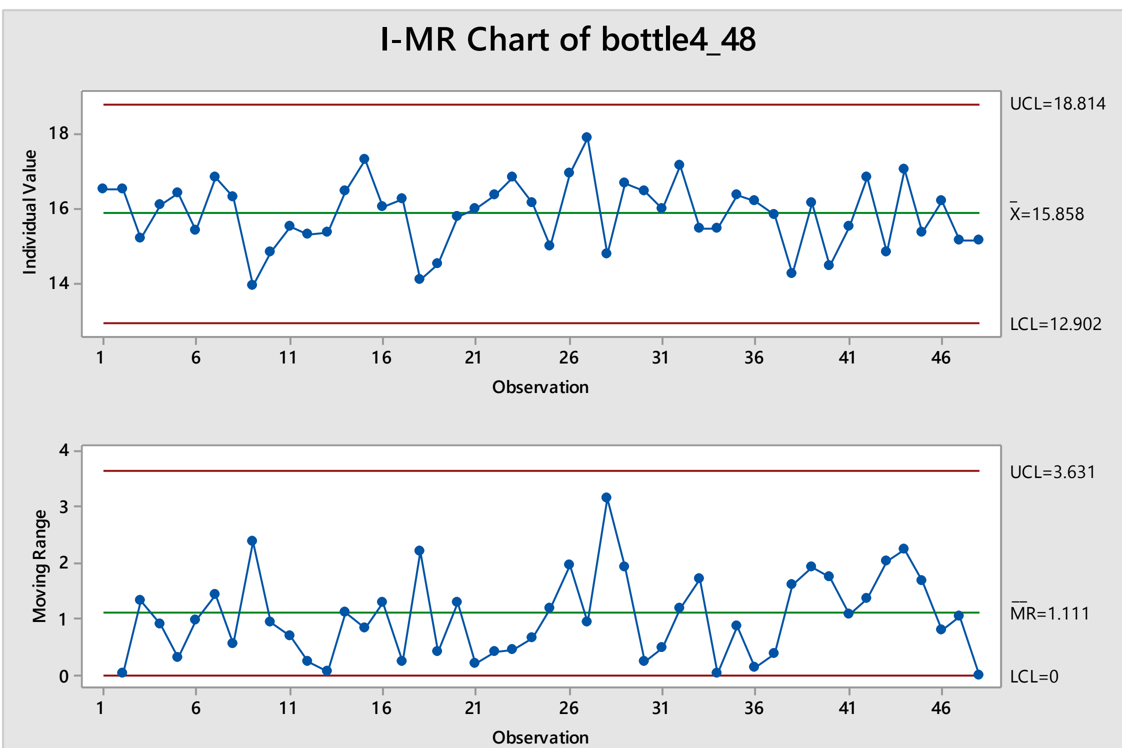

Figure 9

The next step was to create new control charts for all 144 samples using the limits previous calculated from the first eight hours, after omitting points out of control, in order to detect the stability of each of the four processes.

The results obtained are shown in Figures 10, 11, 12 and 13. The process that is in statistical control is from bottle 2. The other three processes have points outside of control limits that need to be further evaluated to determine their assignable causes.

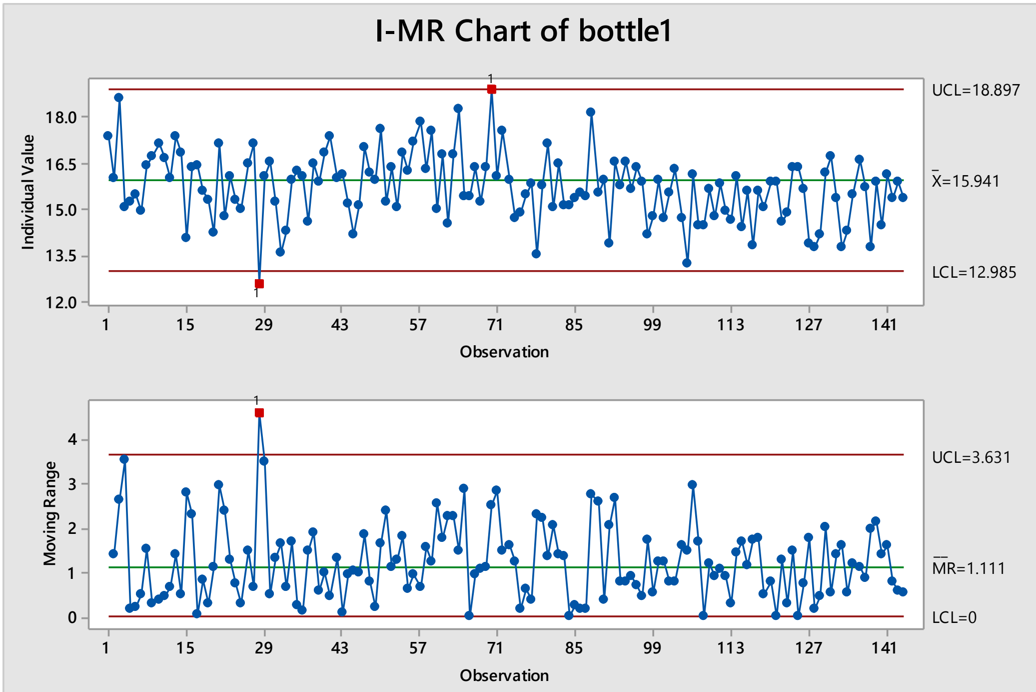

Figure 10

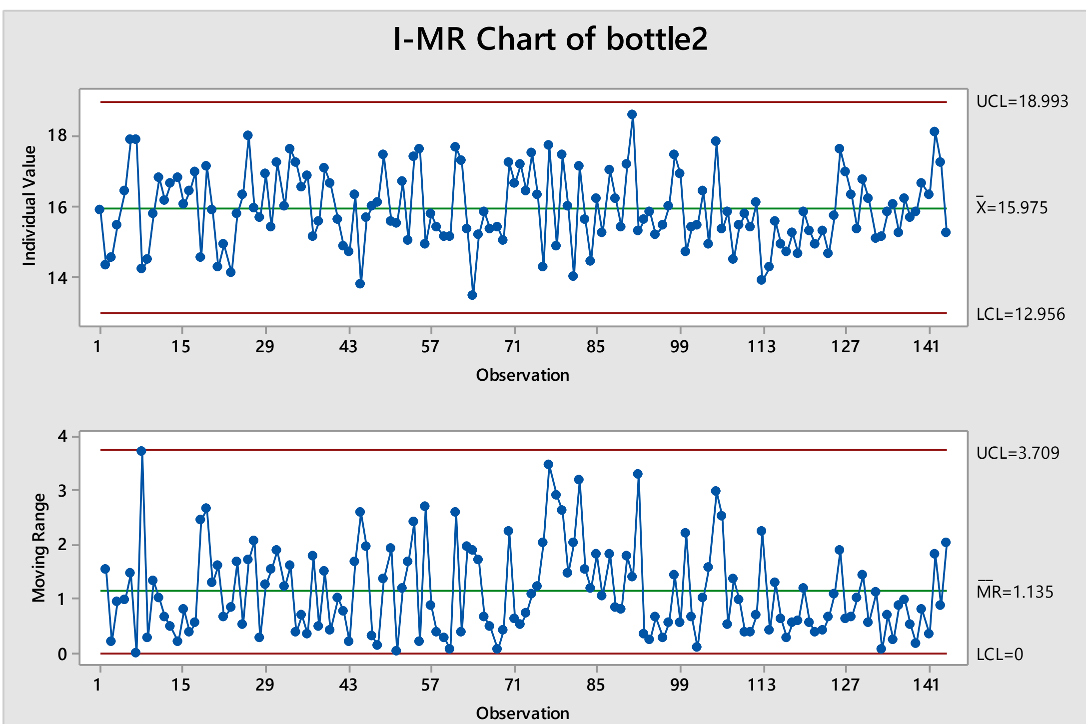

Figure 11

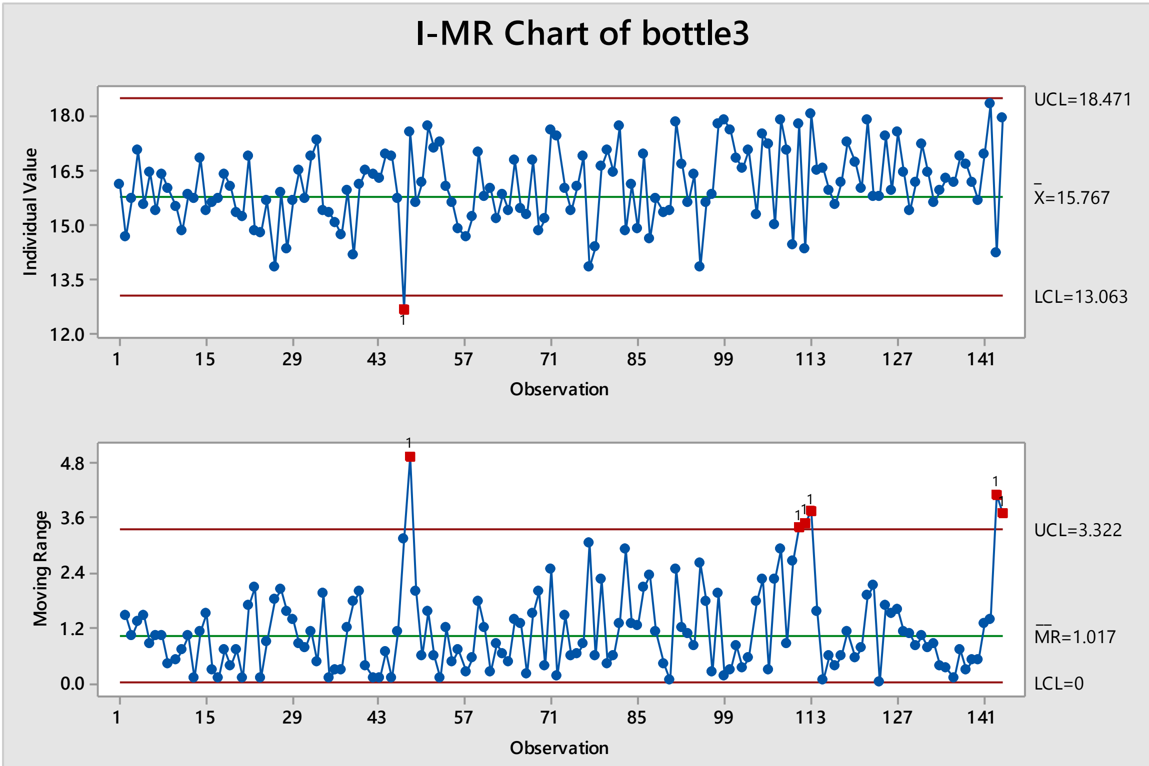

Figure 12

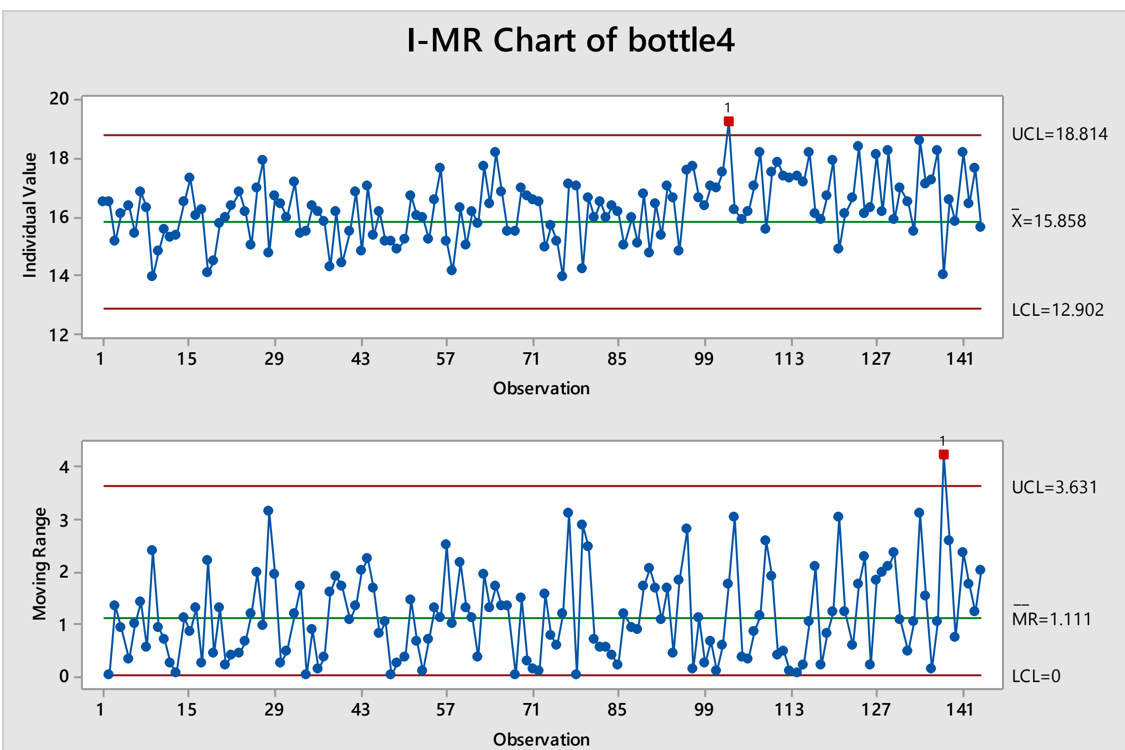

Figure 13

2.3. ESTIMATING σ

In order to reduce the bias in estimating σ, it was used as a base of the estimator the median of the moving ranges of span two. Formula 1 was used in the calculations and the results are in Table 1.

$$\hat{\sigma} = 1.047\overline{MR} \quad \text{(Formula 1)}$$

Variable	Bottle 1	Bottle 2	Bottle 3	Bottle 4
$\overline{MR}$	0.9800	1.0979	0.8800	0.9400
$\hat{\sigma}$	1.0261	1.0051	0.9214	0.9842

Table 1

2.4. PROBABILITY OF REACHING SPECIFICATION LIMITS

Considering that customers notice when bottles are filled with less than 14 ounces and that if a bottle is filled with more than 18 ounces it becomes problematic for operations, it was considered as a lower specification limit 14 ounces and as an upper specification limit 18 ounces. Table 2 shows the variables used to calculated the probability of a bottle being outside specification limits. The probability was calculated according to the formula below:

$$\Pr\{x < 14\} + \Pr\{x > 18\} = \Phi\left(\frac{\mu - LSL}{\sigma}\right) + \Phi\left(\frac{USL - \mu}{\sigma}\right) \quad \text{(Formula 2)}$$

According to the results obtained in Table 2, it is possible to notice that the filling process of bottle 1 has the highest risk of being outside the specification limits.

Variable	Bottle 1	Bottle 2	Bottle 3	Bottle 4
σ	1.0261	1.0051	0.9214	0.9842
μ	15.7131	15.9163	16.0651	16.2617
LSL	14	14	14	14
USL	18	18	18	18
ϕ (LSL)	1.66955	1.90649	2.24140	2.29802
ϕ (USL)	2.22886	2.07314	2.10001	1.76628
Z (LSL)	0.04750	0.02829	0.01250	0.01078
Z (USL)	0.01291	0.01908	0.01786	0.03867
Pr{x<14}+Pr{x>18}	6.04%	4.74%	3.04%	4.95%

Table 2

2.5. PROCESS CAPABILITY

Based on the specification limits and the mean calculated for each process, it was calculated C_p. In order to calculate C_{pkm} it was used a target of 16. The results are shown in Table 3.

Variable	Bottle 1	Bottle 2	Bottle 3	Bottle 4
$\overline{X}$	15.7131	15.9163	16.0651	16.2617
$\hat{\sigma}$	1.0261	1.0051	0.9214	0.9842
C_p	0.6497	0.6633	0.7236	0.6774
C_{pk}	0.5565	0.6355	0.7000	0.5888
C_{pkm}	0.5360	0.6333	0.6983	0.5690

Table 3

According to the C_p results in Table 3, it can be concluded that all four processes are not capable of reaching specifications limits. The C_{pk} values found are smaller than the corresponding C_p values, so they are all off-centered. It can be concluded from the results of C_{pkm} that the process mean is not able of reaching target.

3. CONCLUSIONS

Analyzing all the tables it can be seen that bottle 1 has the highest standard deviation and it is the most off-centered distribution, ratifying the highest probability of being out specification as demonstrated before. In the same way, bottle 2 has the lowest standard deviation and it is the most centered distribution, evidencing the lowest probability of being out specification.

There is a significant variation affecting the process for all four bottles, so the entire process should be reviewed in order to understand and eliminate the main causes of the problems identified. Maybe the positions where the bottles are being filled could be changed to allow a smoother filling process and reduce variability. After changes, employees must be retrained to better understand what is happening during manufacturing process and to be able to identify when the process is out of control.

4. FINAL RECOMMENDATIONS

- We remind that the use of control chart increase the ability of identifying assignable causes that might affect the process. Although a further analysis needs to be made in order to identify the root causes of these variations.
- Bottle 1, as demonstrated by results, has the worst performance distribution, so it needs to be prioritized for further evaluation in order to determine the causes of variations and assignable causes. Each one of the points out of control in all I-MR charts also needs to be analyzed to identify possible causes that are responsible for process' variations.
- For a further analysis of the causes of the assignable causes, we first recommend the use of Check Sheets to identify all types of problems that might impact the process capability.
- A Pareto Chart should be developed with the data from the Check Sheets to identify which problems are more frequent. This identification can better guide towards a solution that will positively impact process capability, focusing on the vital problems.
- A cause-and-effect diagram should also be used to identify root causes of each problem prioritized by the Pareto Chart regarding the variability and assignable causes detected in the process by the control charts.
- If feasible, it is recommended choosing bigger sample sizes every 10 minutes instead of 1 sample every 10 minutes for the implementation of statistical process control to maximize the occurrence of assignable causes between subgroups and minimize it within subgroups. By doing that, it will be possible to use an Xbar-R chart instead of I-MR chart. As we know, the ability of an I-MR chart to identify small shifts is very poor, compared to the Xbar-R charts. Control limits should be revised and adjusted after taking new samples in order to verify the three-sigma limit boundary.