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DEPARTMENT OF STATISTICS

Statistical Quality Control

Assignment 2: Project on simulated data

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Abstract

This report focuses on using statistical process control methods to analyze the production process at a cookie manufacturing plant. Specifically, it looks at how consistent the weight of the cookies is. We will use various control charts like X-bar, S, CUSUM, and EWMA to identify any significant changes, or shifts, in production. By simulating production data, the report will show how to tell the difference between normal variations and significant shifts that could indicate a problem. These shifts might be due to changes in the production process. The results will demonstrate how quickly and effectively each type of control chart can detect these shifts, offering valuable insights for the company to monitor and enhance its manufacturing process.

1.Introduction

We work at a cookie manufacturing company where we want to keep an eye on how the cookies are made. The cookies we are focusing on should weigh 12.9 grams each. To check this, we collect a sample of 7 cookies every hour, and we analyze data from 30 such samples. This monitoring helps the company quickly spot any big changes in the production process, faster than usual methods would. Catching even small variations can improve how efficiently we make cookies and boost the overall quality of our products. This can save money, enhance the company's reputation, and make us a better partner for business deals. Statistically, we will use various control charts and examine shifts to evaluate how effective our monitoring is.

2.X-bar charts

We begin by creating the X-chart using the first 30 samples, each containing 7 cookies, in phase 1. We assume the data are normally distributed with a mean weight of 12.9 grams and a standard deviation of 0.1 grams. Below is the chart that illustrates our experiment:

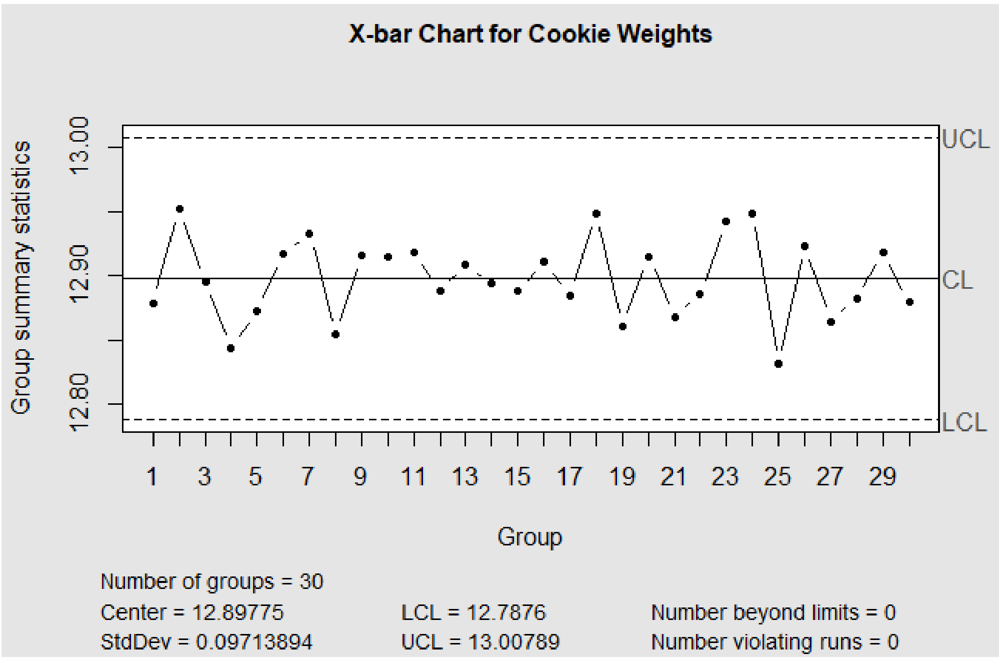

Figure 1:Original X-bar chart

This X-bar chart for Cookie Weights displays the mean weights of cookies in 30 groups. The process appears to be in control, as all points lie between the Upper Control Limit (UCL) and Lower Control Limit (LCL), and there are no obvious patterns or runs. The Center Line (CL) shows the overall process mean. However, variability within groups suggests room for improvement. No points beyond limits or violating runs indicate the process consistency, yet the spread implies potential optimization of the cookie weight consistency could be beneficial.

Assuming there is a slight upward adjustment in the mean by 0.5 grams, which is equivalent to half a standard deviation, we want to explore whether the X-bar chart would detect this change. The chart depicted below is an X-bar Control Chart that has been updated to reflect this minor shift in the average weights.

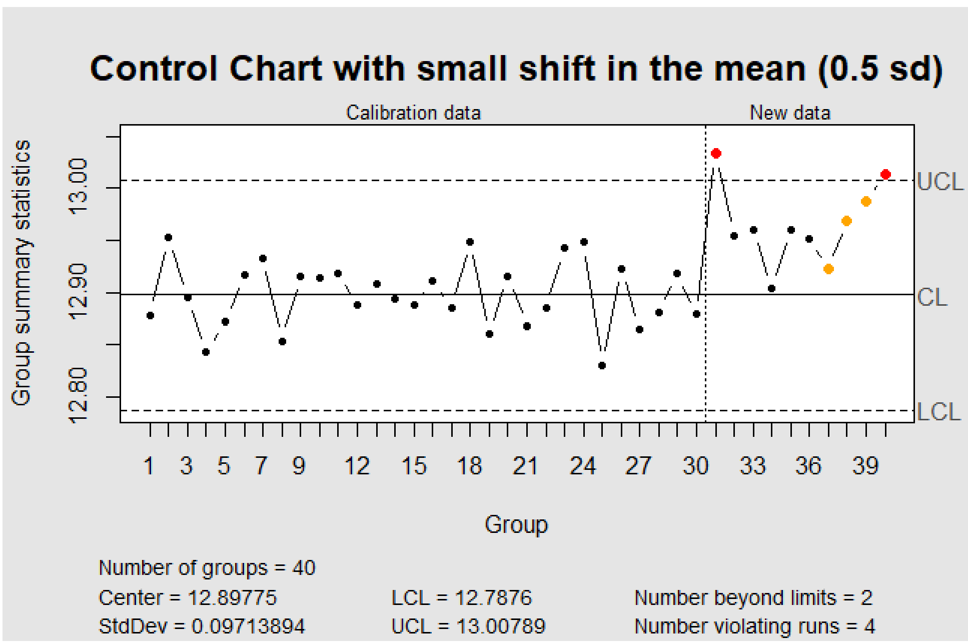

Figure 2:X-bar chart after small shift

The updated X-bar chart illustrates a slight upward shift in the process mean by half a standard deviation. The 'New data' section highlights this change, distinguished from the 'Calibration data.' Two points exceed the Upper Control Limit (UCL), and there are four runs that breach the expected randomness, indicating a potential loss of process control. This suggests the process may be experiencing a significant shift, warranting investigation into the causes behind this movement in mean cookie weights.

Now let's consider a scenario where there is a notable increase in the mean by 2 grams, corresponding to two standard deviations. We aim to determine if the X-bar chart will capture this adjustment. Below, the X-bar Control Chart presented has been modified to include this considerable shift in the average weights.

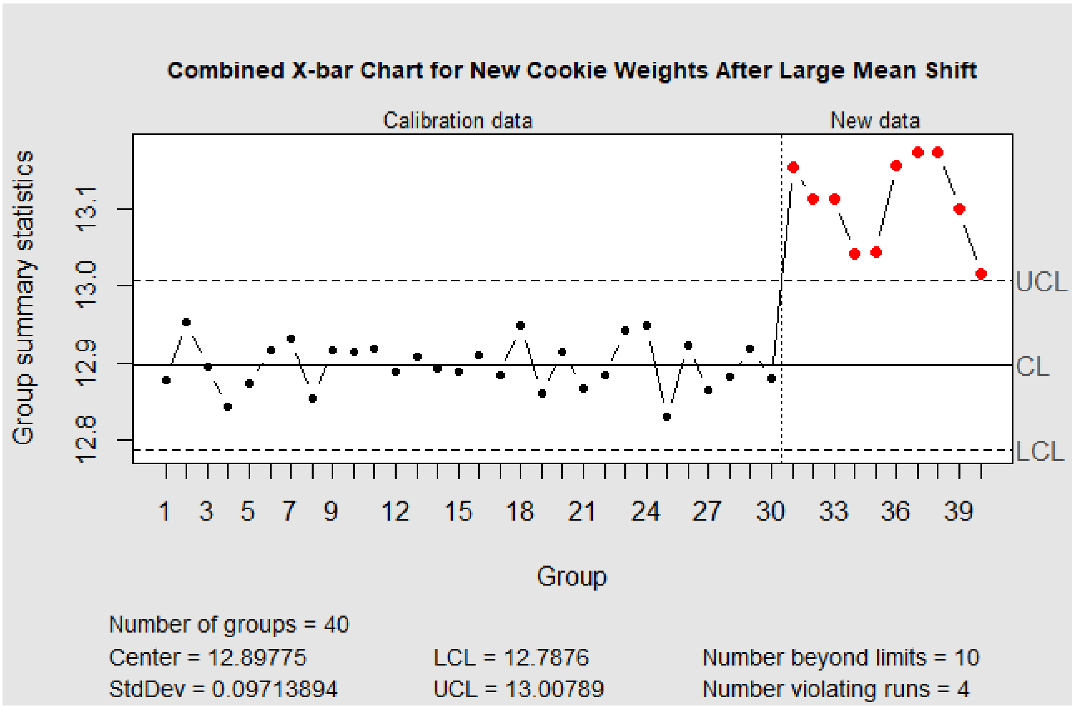

Figure 3:X-bar chart after Large shift

This X-bar chart represents a pronounced shift in the average cookie weights by 2 grams, equating to two standard deviations. The 'New data' points, marked in red, show a clear departure from the 'Calibration data.' With 10 points surpassing the Upper Control Limit (UCL) and four runs indicating non-randomness, the chart suggests a substantial change in the process mean. This marked deviation signals a need for immediate investigation and potential process adjustment to rectify the shift and return the process to a state of control.

3.S charts

For our experiment, we're shifting focus to process variability, employing a phase 1 S-chart based on the original data set. The S-chart's purpose is to monitor fluctuations in process variation over time. Displayed below is the S control chart reflecting our process's variability without incorporating any shifts.

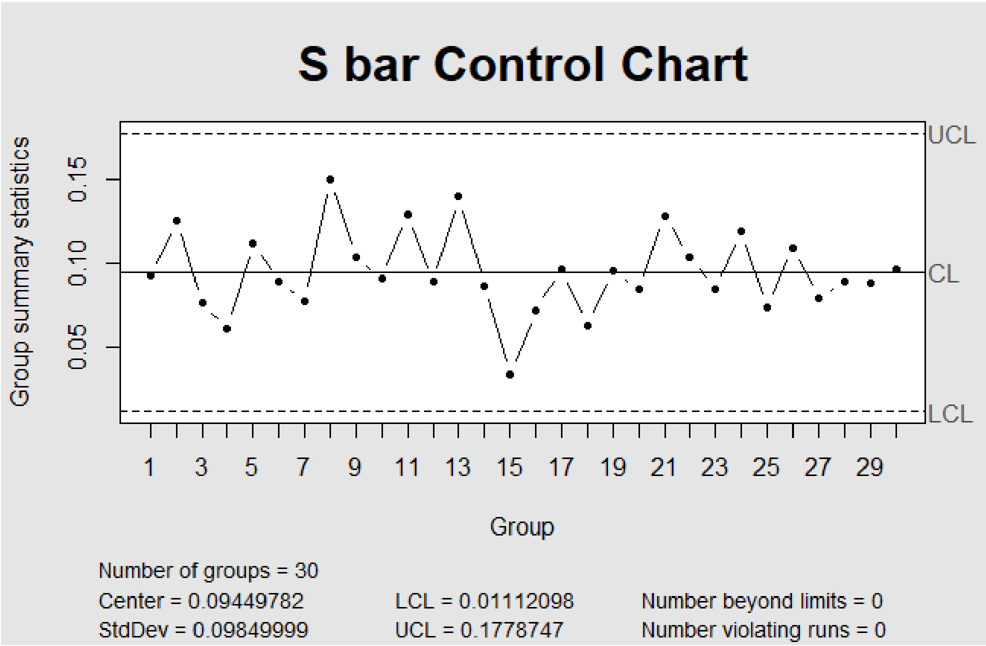

Figure 4:Original data S chart

Presented here is the S-bar Control Chart, a tool designed to track the variability of a process. In this instance, the chart is constructed using 30 groups from the original data, with no introduced shift. All data points lie within the Upper and Lower Control Limits (UCL and LCL), signifying consistent variability. The Center Line (CL) reflects the average of the sample standard deviations, providing a baseline for evaluating process stability. The absence of points beyond limits or runs violating expected randomness suggests the process variability is under control.

Then we perform a small sift in the standard deviation from 0.1 to 0.15.The new S chart is presented below.

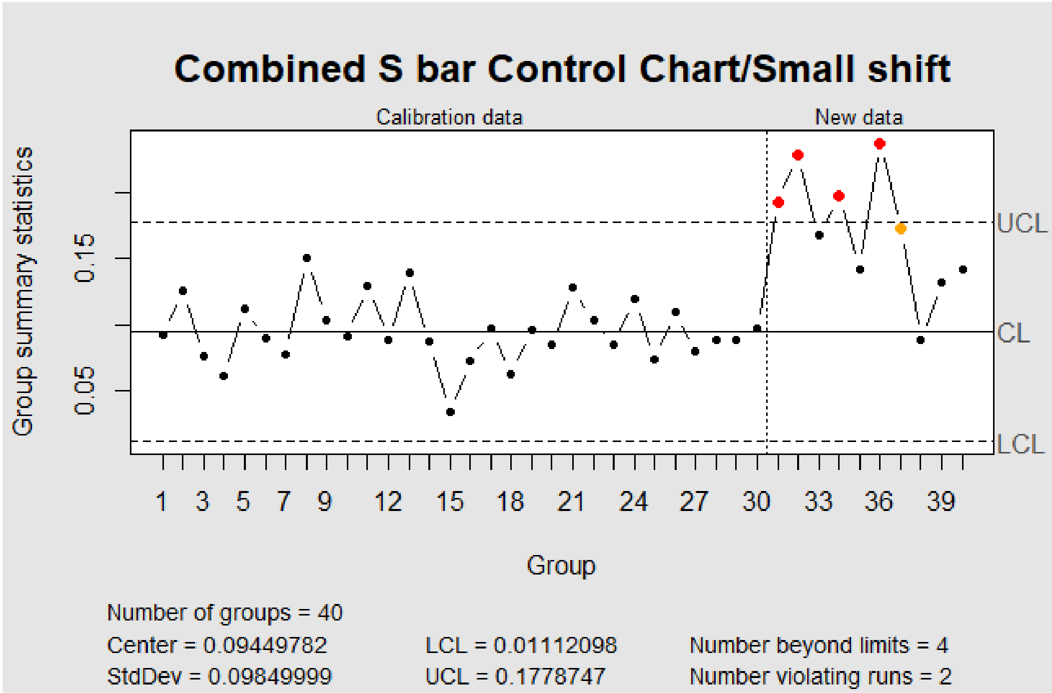

Figure 5:S control chart after small shift

This Combined S-bar Control Chart illustrates the process variability with a minor increase in the standard deviation. The 'Calibration data' shows consistent variability within control limits. In contrast, the 'New data'—marked in red—indicates a shift with points above the Upper Control Limit (UCL). With four points beyond the limits and two runs violating the expected pattern, this suggests an increase in process dispersion. This new variability should be examined to maintain quality control, as consistent variability is key to process predictability and quality.

Then we perform a large shift in the variance of our data,presented in the chart below.

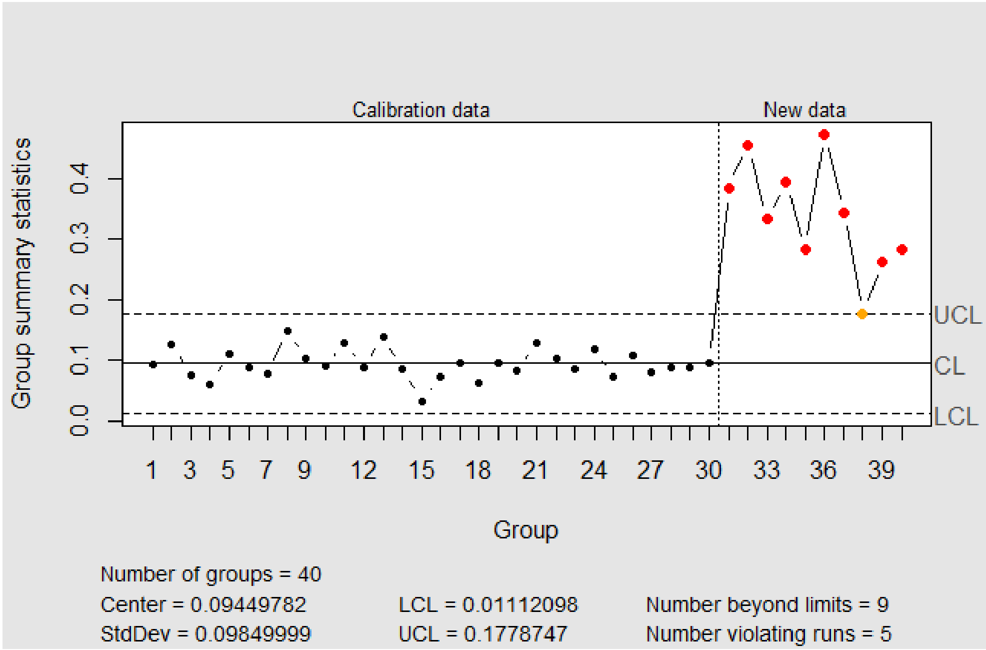

Figure 6:S chart after Large shift

The S-bar Control Chart here represents a more pronounced shift in process variability. The 'Calibration data' portion, depicted in black, demonstrates a stable process with all points within the control limits. However, the 'New data,' highlighted in red, exhibits a clear surge in variation, with nine points exceeding the Upper Control Limit (UCL) and five runs breaking the expected randomness. This substantial increase in variability, signifying a potential change in the process or system, necessitates immediate investigation to identify the cause and implement corrective measures.

4.EWMA control charts

The EWMA chart is really good at spotting small changes in a process that normal charts might miss. It uses a special factor to pay more attention to the latest data, which helps it catch tiny differences quickly. This way, we can fix issues fast and keep the process running smoothly. Since this chart is great for small changes, we'll use it just for that, since the previous used charts successfully handled the large changes.

Below is the ewma chart for the small change in the mean.

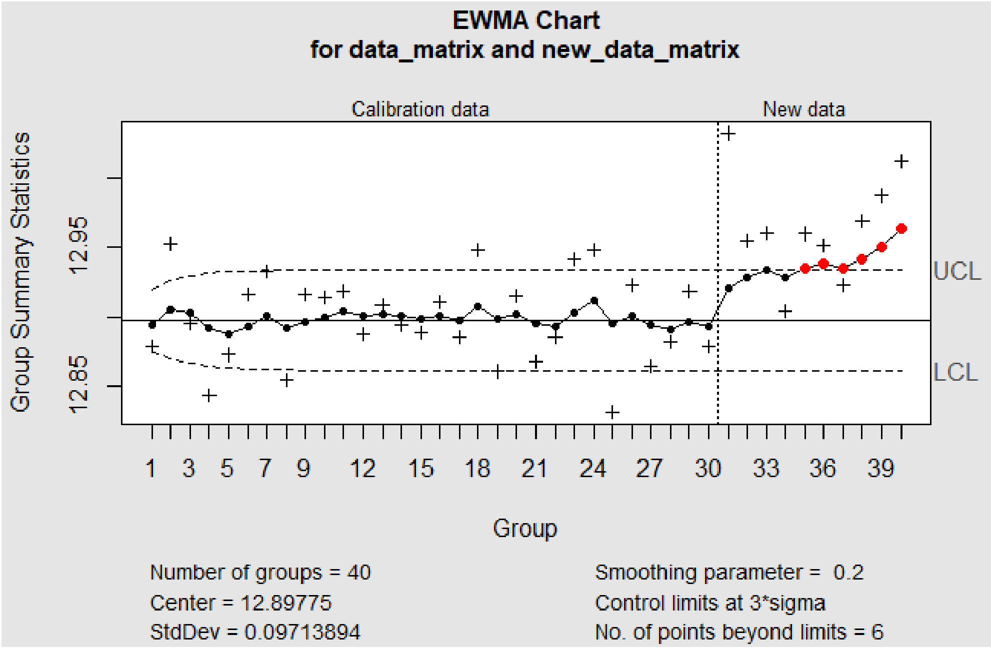

Figure 7:EWMA chart after small shift in mean

This EWMA chart compares 'Calibration data' and 'New data.' The chart's latter portion, marked by red points, shows a trend moving towards the Upper Control Limit (UCL). With six points surpassing the control limits, the chart signals a shift in the process. This upward trend, especially in the new data, indicates a process shift or drift that may require intervention to maintain process stability. The EWMA chart's sensitivity to small changes is key to detecting this potential shift.

5.CUSUM control charts

A CUSUM chart is ideal for spotting small, ongoing shifts because it keeps a running total of any little differences from what's expected, making those differences stand out more over time. By focusing on the gradual buildup of these tiny changes, the chart acts like a sensitive alarm, catching shifts that might slip by unnoticed with other methods. This sensitivity ensures that if something starts to stray from the norm, we can step in quickly to correct it, keeping the process consistent and controlled.

The chart below represents the CUSUM Control Chart including the small shift.

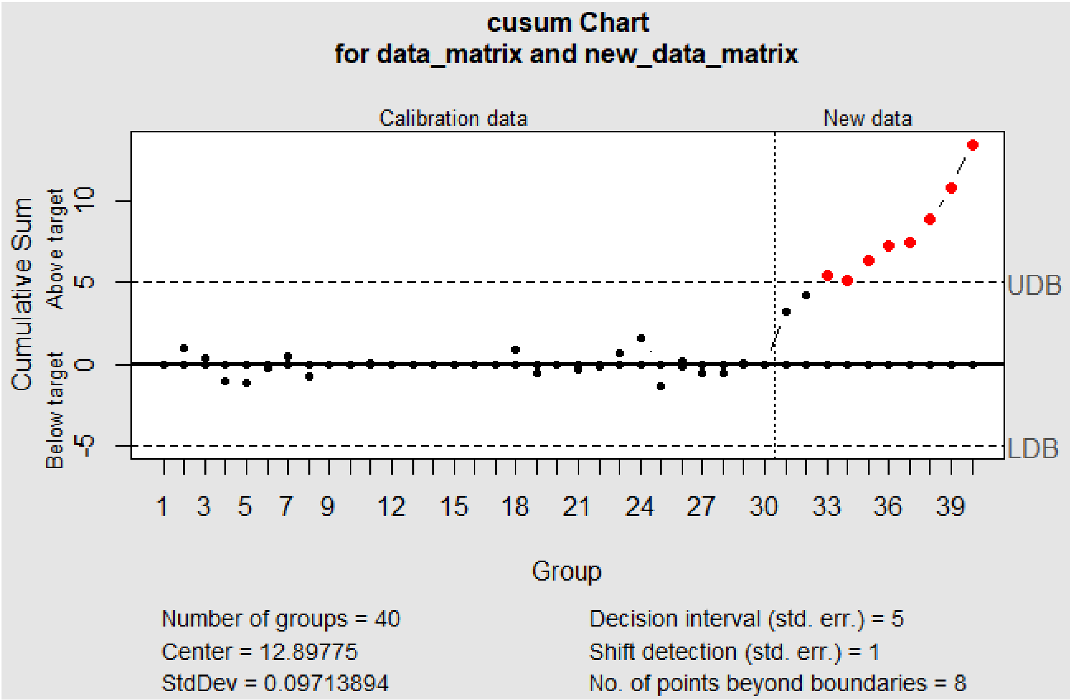

Figure 8:CUSUM chart after small shift in mean

The CUSUM chart here shows 'Calibration data' consistent within control, but a distinct upward trend in the 'New data' section suggests a shift. With eight points crossing the Upper Decision Boundary (UDB), it signals a potential small shift in the process mean. This chart excels at identifying and confirming changes over time, as evidenced by the new data's deviation from the established baseline, highlighting the need for further investigation into the process changes that might have caused this shift.

6.Conclusions

In our detailed review, we used different control charts to check for large and small changes in how our products are made. The X and S charts quickly spotted the big changes, which is really important for keeping an eye on product weight. For smaller, trickier changes, like those half a unit in size, EWMA and CUSUM charts were better at finding these by the fifth check, showing they're good at catching these small differences. Especially worth mentioning is the CUSUM chart, which was even better than EWMA at noticing one more unusual reading and showed us which way things were shifting. This insight is super helpful for making timely fixes. Using these charts in the right way helps us make sure our manufacturing stays on point, catching and fixing even tiny mistakes, which means our products stay reliable and work like they should.