A Future FOR THE Sport

COR SUSPENSION RESEARCH REPORT

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OVERVIEW

The USBC Equipment and Specifications staff has been working on developing a new and more accurate measurement device for coefficient of restitution (COR) testing. That project has been successful. However, during the course of the research, we started questioning the relevance of COR as a certification standard. Based upon data from recent USBC scoring studies, we do not believe COR impacts scoring in a way that requires regulation.

USBC conducted Bowlscore testing and found COR values minimally influence strike percentages, and we can infer it will not impact bowler averages based upon our learnings from other scoring tests.

Key findings in this study:

- USBC has developed a new COR testing device that provides more accurate and repeatable measurements.
- Bowlscore testing shows COR values minimally impact strike percentages compared to what was observed with string pinsetter testing.
- Therefore, because larger string pinsetter differences turned out to be no difference for bowler averages in real conditions, we can infer that COR would also have minimal impact on bowler averages.

Therefore, as next steps:

- Effective immediately, USBC is indefinitely suspending COR testing from the ball approval testing process.
- USBC Equipment Specifications will continue to monitor advances in equipment COR and research alternative testing methods.

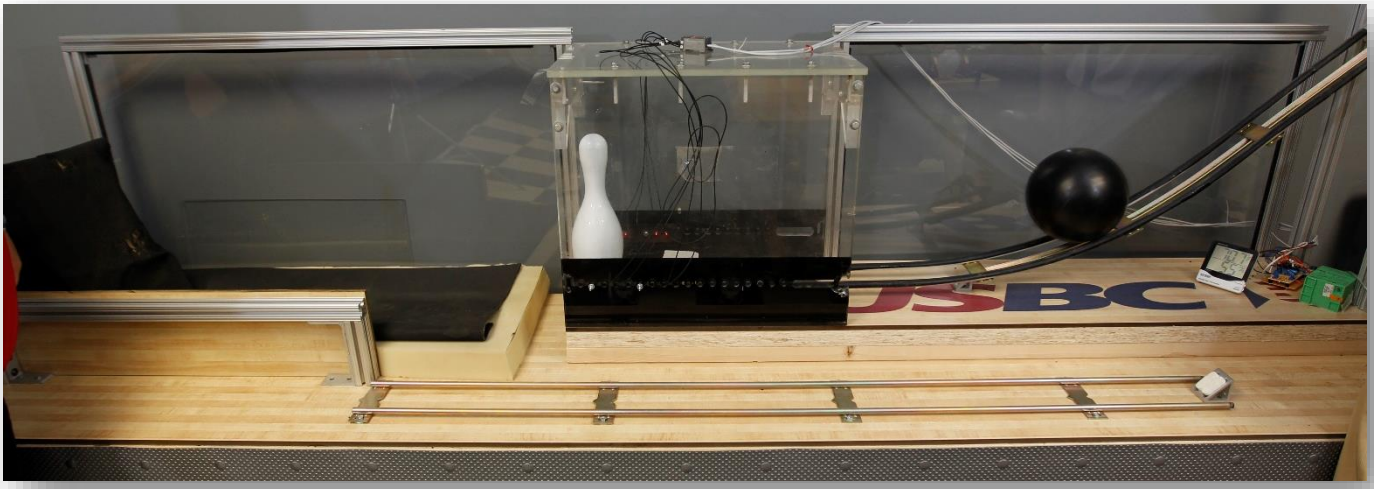
DESIGNS: OLD VS. NEW

Current COR Device

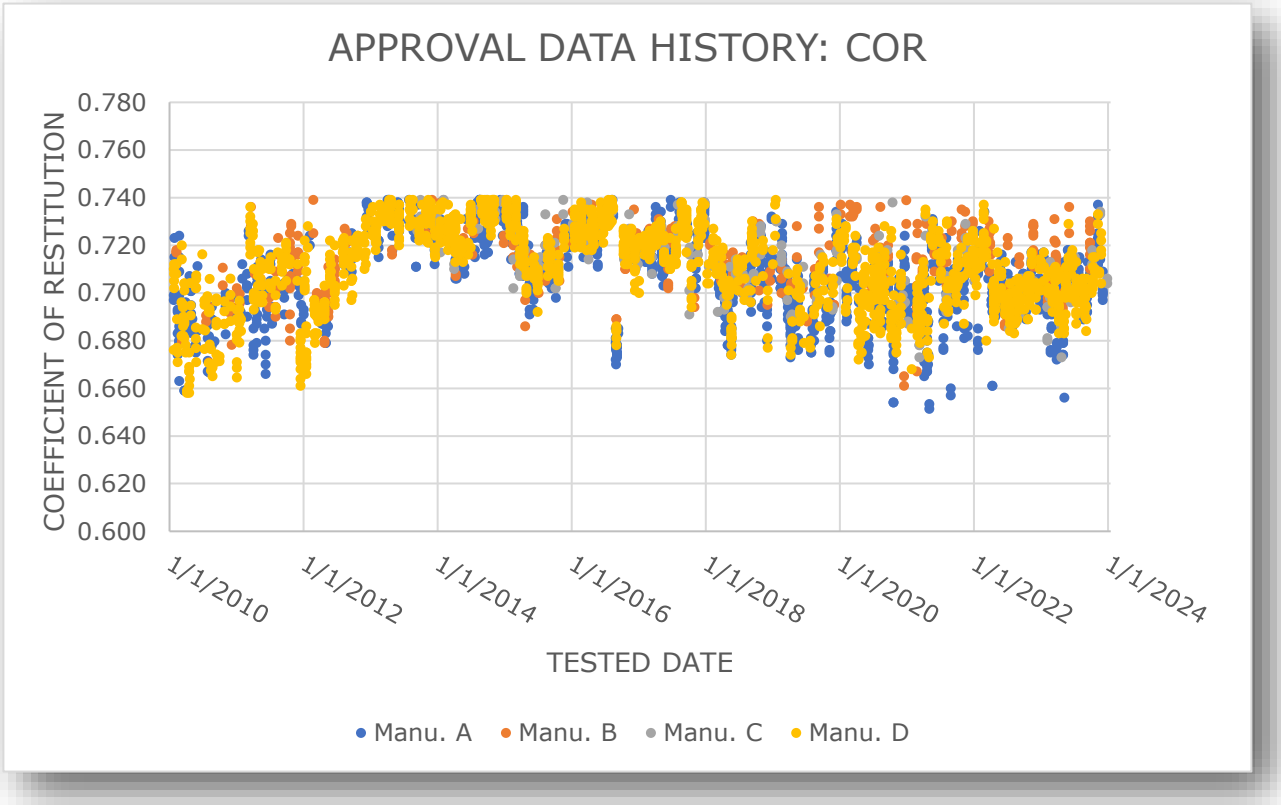
The current COR device used for USBC approval testing has been in use for 13 years and is modeled to simulate a ball-pin collision at approximately 6 miles per hour. This device uses a four-beam-break system that measures the times that each beam is broken and unbroken to calculate the entering speed of the ball before collision, exiting speed of the pin after collision and exiting speed of the ball after collision. The coefficient of restitution (COR) is calculated from the ratio from the starting and ending velocities of both the pin and the bowling ball with the following formula:

$$C.O.R. = \frac{(pin\ velocity(after)) - (ball\ velocity\ (after))}{(ball\ velocity\ before)}$$

For approval testing, each ball sample is rolled down the rails into the pin 10 times and an average result is reported. The standard pin is rotated for each collision to simulate the conditions of normal bowling and to spread the wear from the collisions equally around the pin. The following is an image of the current testing apparatus.



Reviewing the approval data history, we have found that the results from the system have not been consistent over the years. The graph below shows the history of COR approval data with the existing device, with the colors representing different manufacturers. The overall group of results trend up and down over time in a parallel manner for all manufacturers.

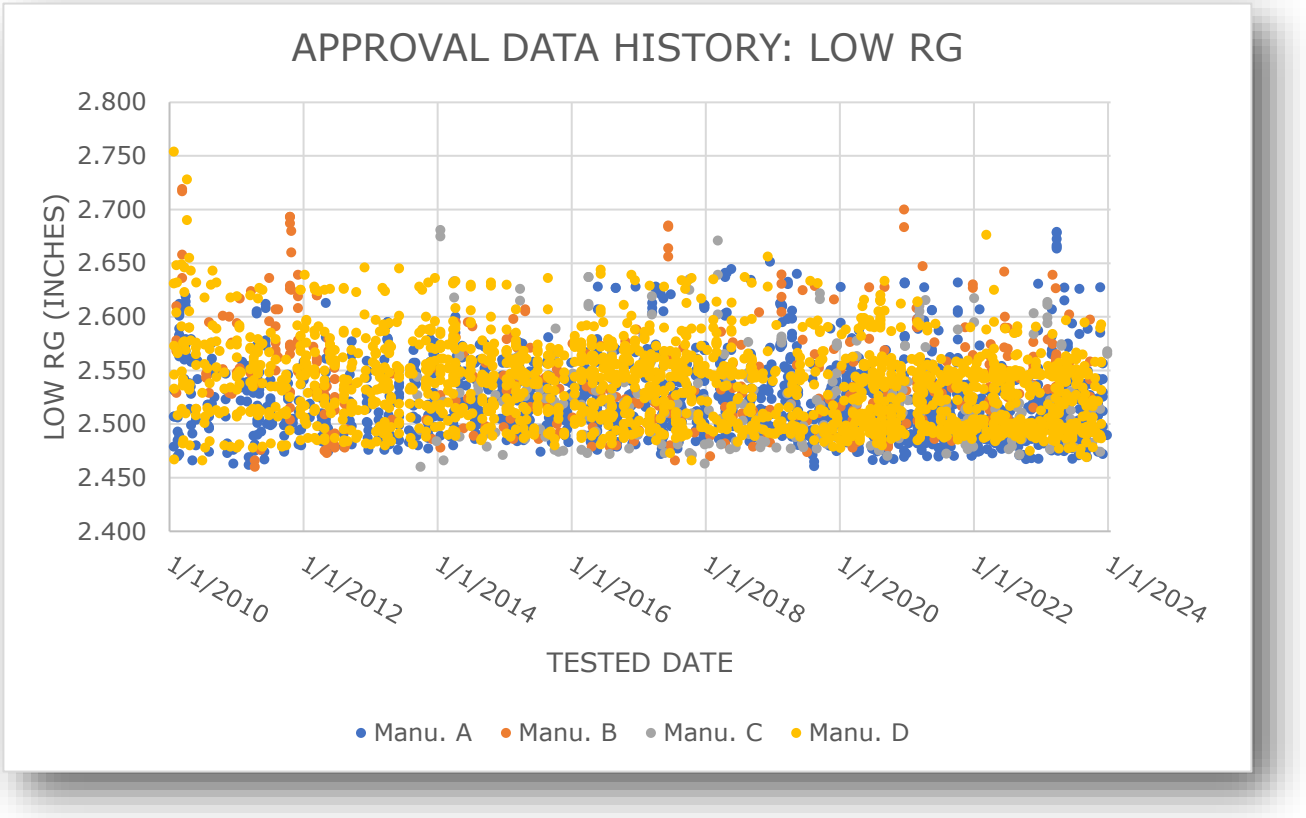


We apply Gage Repeatability and Reproducibility (Gage R&R) studies to all our testing devices at USBC Equipment Specifications. What we find is that the COR device passes a Gage R&R when all of the data is gathered in the same time frame but lacks repeatability in the long-term. Some known causes to the long-term variation include:

- Damage to the standard pins over time
- Wearing on the base plate
- Calibration challenges

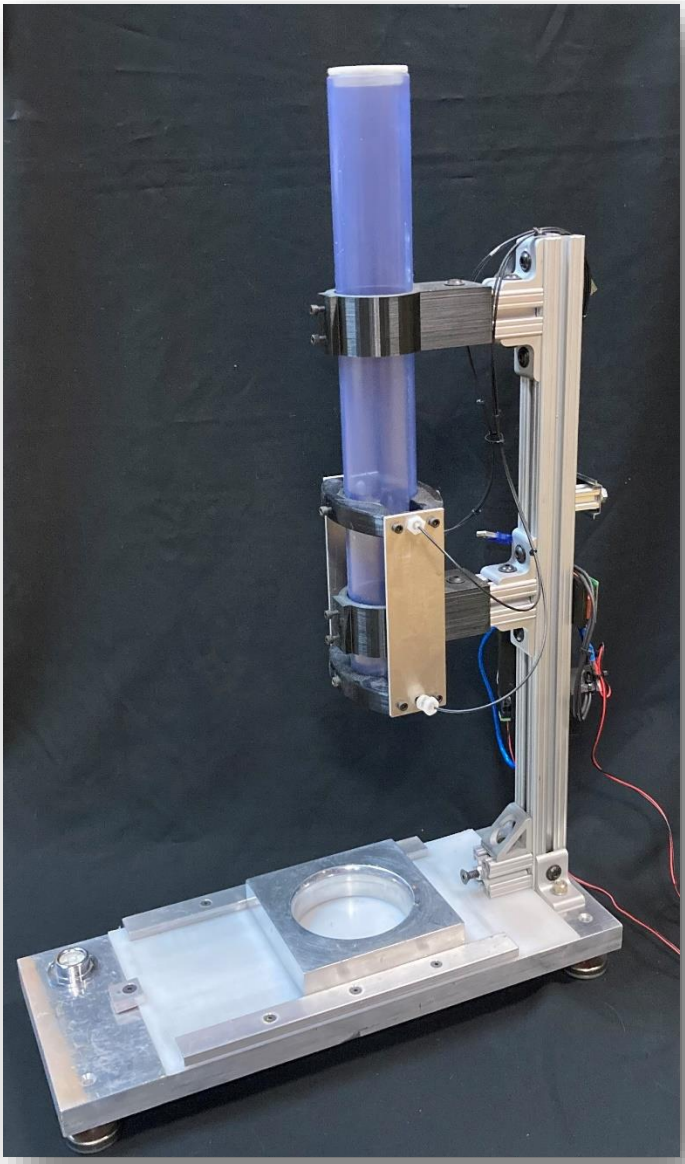
For all these reasons, USBC decided to research alternative methods of testing COR to develop a more repeatable process with a long-term calibration plan to produce stable results.

In comparison, the following graph shows the history of Low RG, another one of USBC's regulated specifications. Again, the different colors represent different manufacturers. RG has results that are consistent, and the manufacturers produce varied products within the specification ranges.



New COR Device

In 2020, USBC started designing and constructing a new type of COR device that would withstand wear, provide more consistent data over time and have a reliable calibration procedure. The resulting new COR device uses a three-beam-break system but trades the real-world ball-pin collision for a more compact, vertical design. It came to our attention that some manufacturers were measuring COR by measuring the rebound of a steel ball when dropped onto a bowling ball. We decided to design a similar system to evaluate the method. For this system, a 1 7/8" steel ball is dropped down a 2" internal diameter clear plastic tube directly onto the top of the bowling ball. The COR is calculated using the ratio of velocity of the steel ball before colliding with the ball and the velocity after collision. The reported COR values are determined by averaging 10 measurements from different locations around the bowling ball. Another advantage to this design is ease of operation by only one operator.

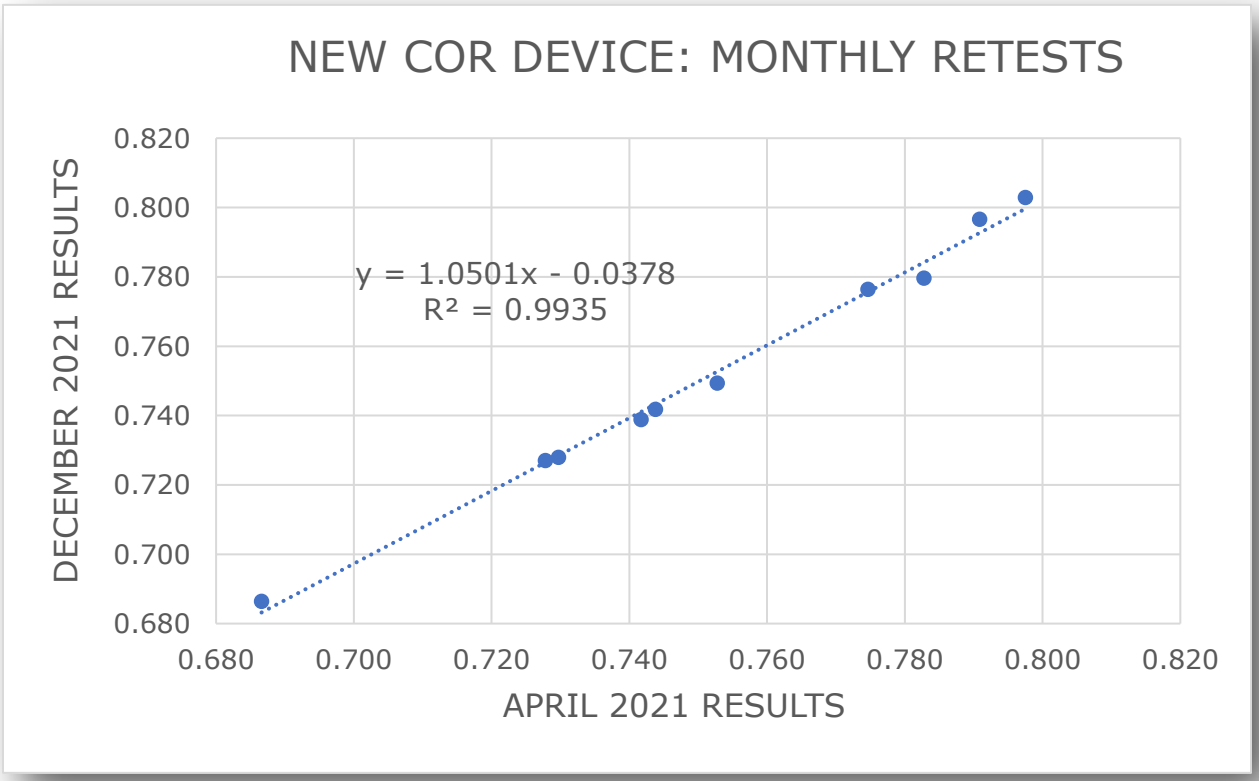


This image shows the new COR device design: an 18-inch-long clear PVC tubing with fiber-optic beam break sensors spaced six inches apart with a precision milled aluminum plate. The framing is made from 1.5” aluminum slotted framing and connected to a 1” thick aluminum base plate. A custom aluminum ball cup slides back and forth along a sheet of low friction plastic allowing for the bowling ball samples to easily be positioned directly under the tubing.

DATA COLLECTION

New Device Repeatability

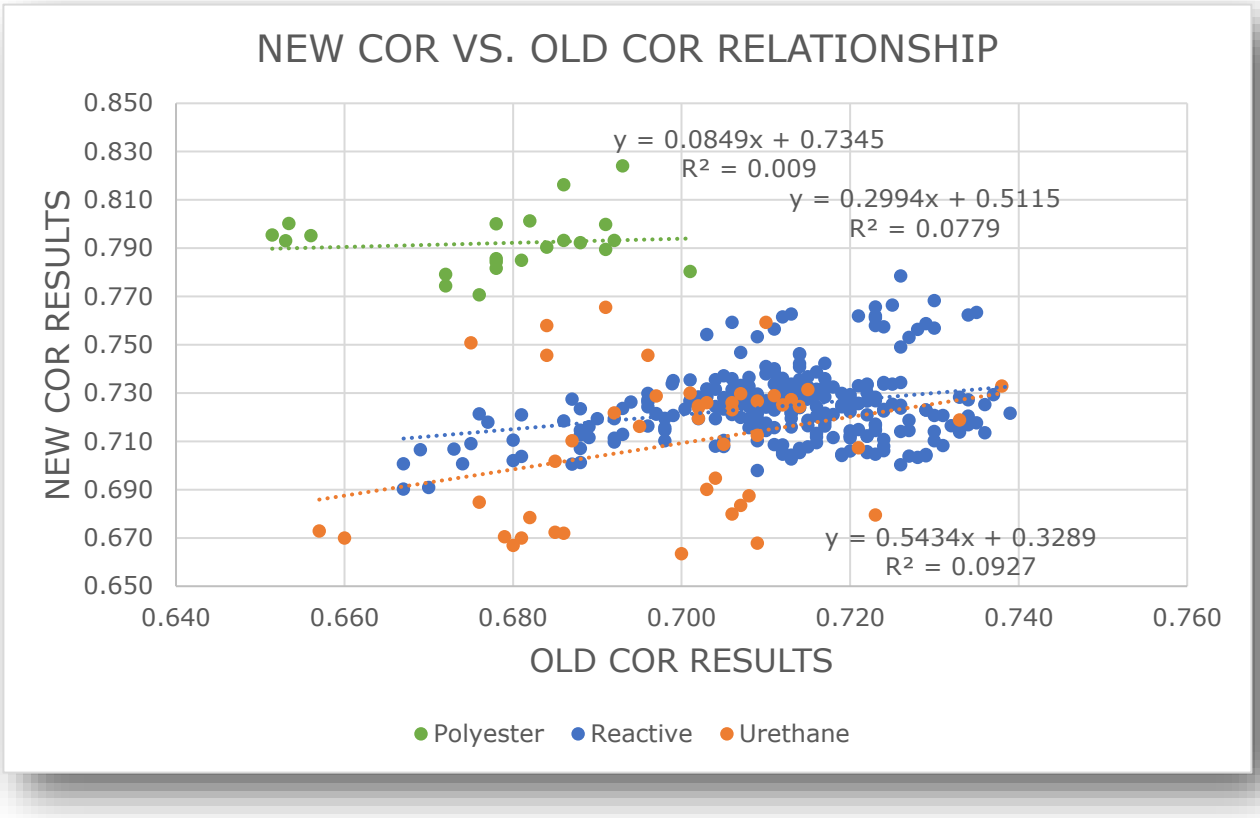
The new COR device repeatability test included 10 approved test sample balls that also spanned a large range of COR values and represented three manufacturers. This set of balls was tested first in April 2021, and then tested again monthly for comparison. The graph below shows a strong correlation between the results on the same balls tested in April on the horizontal axis and in December on the vertical axis. This shows that the new COR device is capable of supplying consistent results over large stretches of time.



Approval Sample COR Comparison Testing

Over the course of 2021, balls submitted for USBC approval testing went through COR testing twice, once with the existing COR device and again post-approval testing with the new device. Comparison data was collected for 503 bowling ball samples from 10 different manufacturers.

When the data from both devices are plotted against each other and the three major coverstock types are designated, as shown in the graph below, there is an obvious lack of correlation between the two systems. The main discrepancy is that polyester balls go from the low end of the COR range on the current device up to the high end on the new device. In addition, some urethanes perform lower on the new system and others are mixed in with the reactive balls. Having two different devices designed to measure the same physical property and not getting results is problematic. As it would require a shift in the specification range to implement the tool, it begs the question: "If the results are different, which device is producing results more relevant to bowling?"



Bowlscore Testing

To best answer that question, we used our main pin action test: Bowlscore. Bowlscore is an automated ramp system that can roll bowling balls directly into the pin deck at various entry angles and offsets. We define offset as the horizontal distance between the ball center and the pin center at the time of collision. Entry angle is the angle between the ball's line of action and the "down-lane" direction with respect to the pin deck.

A standard Bowlscore test rolls 10 shots at 23 different offsets (0 to 5.5 inches in 0.25-inch increments) and 11 different entry angles (0 to 10 degrees in increments of 1 degree) for a total of 2,530 shots.

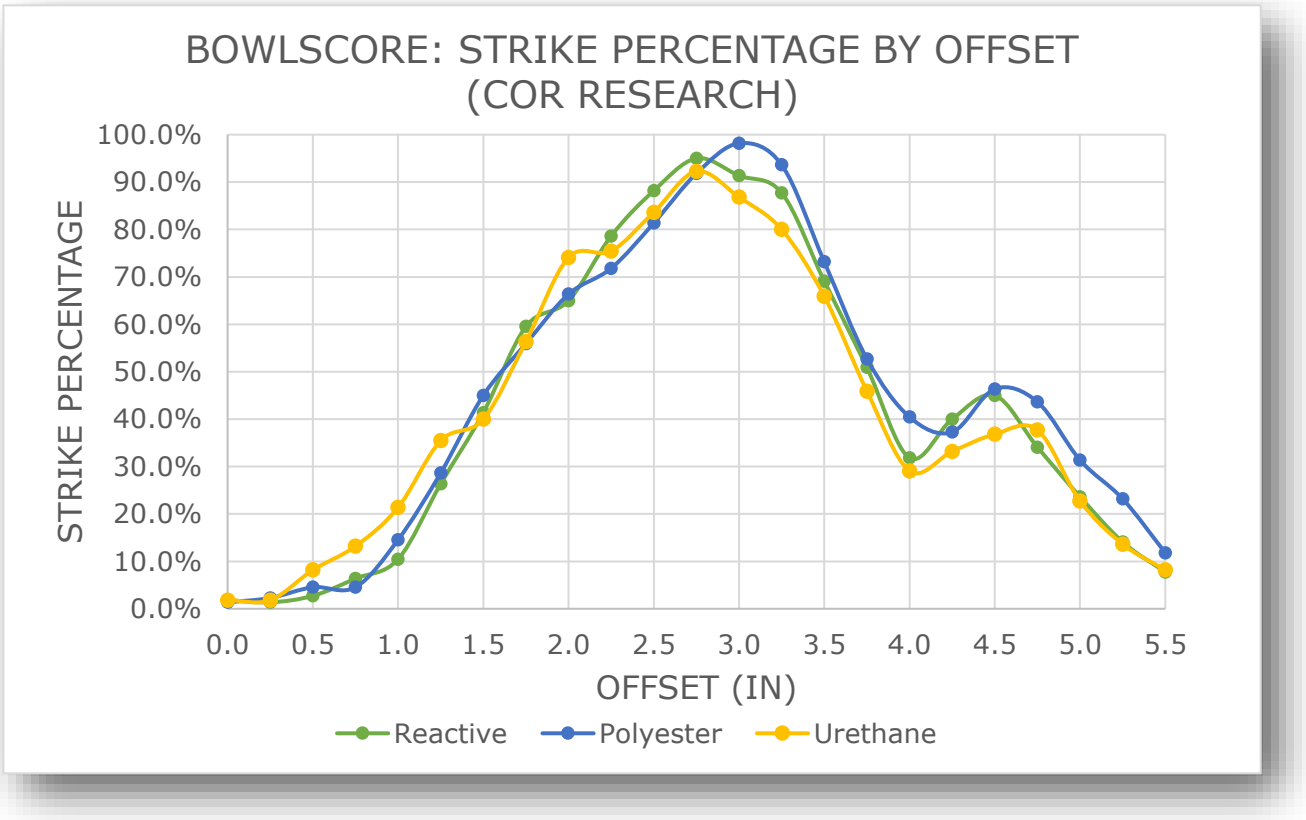
A series of Bowlscore tests were conducted by dropping four different bowling balls that span the COR specification. The balls were selected to demonstrate the highest COR we have measured, the lowest COR we have measured and another option in the middle. Each ball was tested through two full Bowlscore runs for a total of 5,060 shots each.

New Device COR and Ball Type

- 0.668 – Urethane
- 0.701 – Reactive
- 0.750 – Zero-Balance
- 0.800 – Polyester

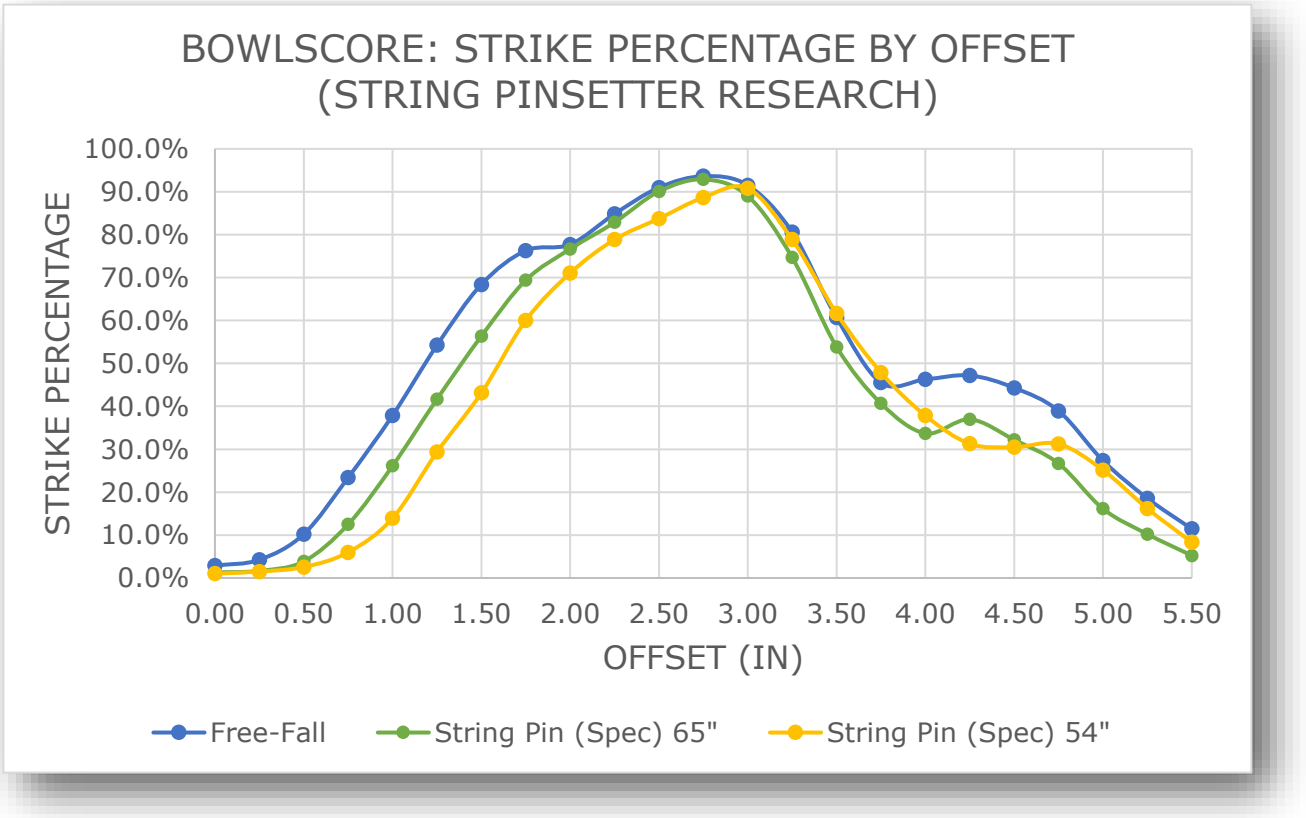
The graph shows the strike percentage averaged across all angles per offset for each ball with a different COR used in the Bowlscore testing. The results show that the strike percentages relate to the measurements obtained by the new COR device, with the largest striker percentages coming from the polyester ball and zero-balance ball, 0.800 and 0.750 COR, respectfully, with the balls with

lower COR striking a bit less.



If we look at the difference between the two most drastic cases, the polyester and urethane samples, we find a total difference in strike percentage of 2,244 strikes / 5,060 shots (44.3%) for the polyester ball down to 2,120 strikes / 5,060 shots (41.9%) for the urethane ball, a difference of 2.5%

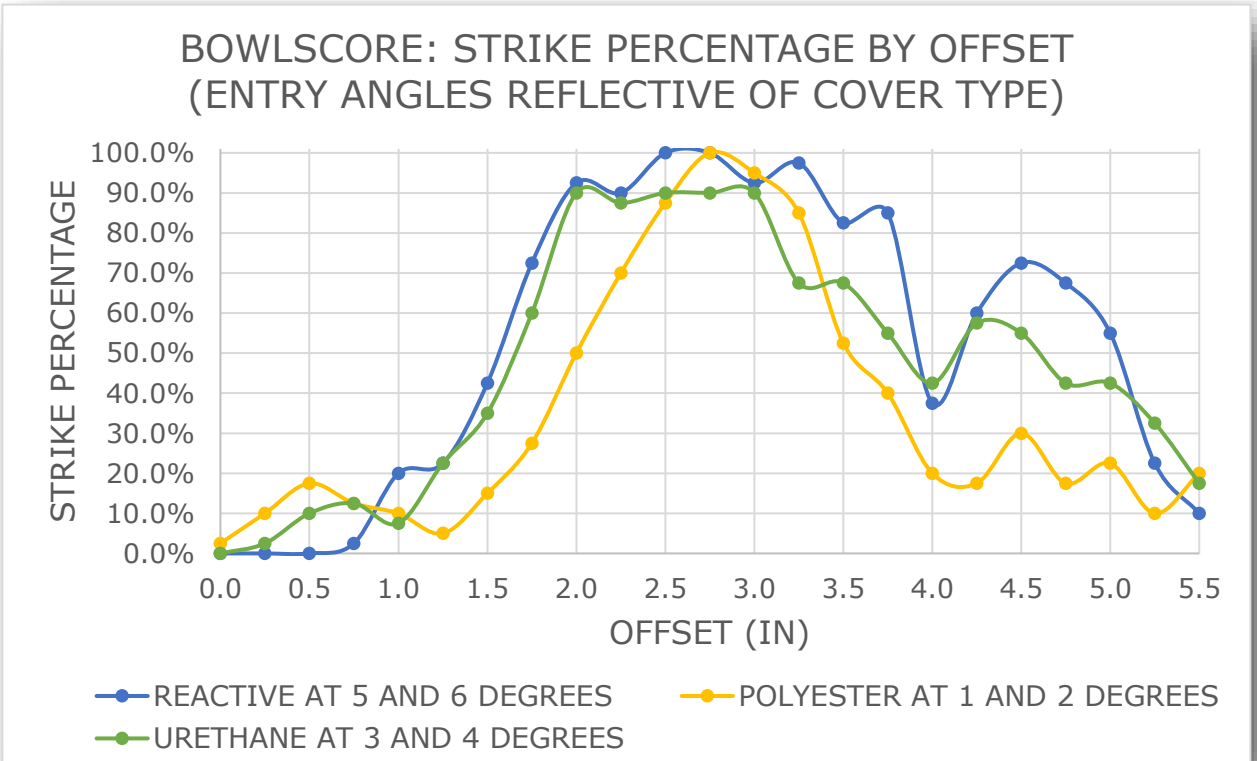
If we contrast that with the differences we observed in our string pinsetter testing:



We observed an 8.6% difference in the difference in strike percentage between machines with 54” strings and free-fall pinsetters. However, a thorough scoring study conducted over the summer of 2023 showed that there was no significant or meaningful difference in scoring between free-fall and string pinsetters.

From this, we can infer that there is no meaningful difference in bowlers’ scores due to COR.

It may seem counter intuitive that a polyester ball with a higher COR would strike 2.5% more than a urethane or reactive ball. If that’s the truth, why doesn’t everyone throw their polyester ball for strikes? The answer is entry angle. Using a ball that enters the pins with more entry angle allows for more offsets where the ball will strike. Taking a closer look at the Bowlscore data, we can isolate the entry angles reflective of how much each of these materials perform on the lane. If we look at the polyester Bowlscore results for 1-2 degrees of entry angle, the urethane Bowlscore results with 3-4 degrees of entry angle and the reactive results with 5-6 degrees of entry angle, the results align with what we would expect: reactive balls striking the most, followed by urethane, with polyester bringing up the rear.



SUMMARY

The Equipment Specifications staff has been developing a new measurement device for coefficient of restitution (COR) testing. The new measurement device reproduces data at a higher level over longer periods of time. However, research has shown that the extremes of COR values we measure with the tool have little to no impact on strike percentages in Bowlscore. Based on the findings of this research, the Equipment Specifications committee has moved to suspend the COR testing for bowling ball approval.

Key findings in this study:

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- Bowlscore testing shows COR values minimally impact strike percentages compared to what was observed with string pinsetter testing.
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