BOWLING TECHNOLOGY STUDY

AN EXAMINATION AND DISCUSSION
ON TECHNOLOGY'S IMPACT IN
THE SPORT OF BOWLING

A Future FOR THE Sport

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SECTION I:
A BRIEF EXAMINATION OF TECHNOLOGY IN BOWLING

The United States Bowling Congress Equipment Specifications and Certifications team spent more than two years doing in-depth research, specifically looking at bowling balls and their effect on the bowling environment.

Why? In a world that is constantly advancing and changing, USBC and bowling are no different. The bowling ball, and its position in the hand of a bowler and its contact with the lane, is something USBC always will need to research. The manufacturers do their job in continuing to deliver products to make the sport easier for the bowler, and the bowlers also continue to evolve in incredible ways.

As the National Governing Body for the sport of bowling, USBC constantly needs to measure the effects on the sport of every variable.

The ball, the lanes, and oil conditions have impacted the sport during the last several decades, spurring discussions about technology advancements. Do the advancements help or hinder the sport? Has the technology lowered the skill level required for bowlers to compete at higher levels?

Those with a history in bowling understand technology has changed the sport, but to what degree? There are several factors to consider, but it is important to look at the history of bowling to see how it has evolved.

Ever heard of a dodo ball? Back in the early 1900s, bowlers were known to use balls that were 20 or even 22 pounds to gain an advantage. Then, someone figured out a way to make an unbalanced bowling ball.

During the same time frame, bowlers would take half of a 19-pound ball and cement it to half of a 17-pound ball — it also was called a 7-9 combination — to create what was called a dodo ball. If controlled properly, which was not easy, a dodo ball provided a decided advantage on the lanes.

Many bowlers at that time used balls with two gripping holes, for a finger and a thumb. With a dodo ball, they would have to keep their fingers perfectly straight during delivery or the ball quickly would end up in the channel. And, any kind of follow-through would produce a similar poor result.

What is now called a washout originally was called a dodo split because it was a common leave when a dodo ball was thrown too fast. Chicago, Cleveland and Louisville were the areas you could find many dodo ball users until 1913.

At the 1913 convention of the American Bowling Congress, which oversaw organized men's bowling through the 2004-2005 season, ABC delegates outlawed the dodo ball. While the rule did receive stiff opposition, enforcement of the rule and the desire to produce a more balanced playing field saw the dodo ball gradually disappear.

But that did not stop the desire of the bowlers to use everything in their power to score higher and with more consistency.

Whether technology has made it easier to build and maintain lanes that remain more level, lane machines that allow for a consistent distribution of oil on the lanes, or the development of bowling balls (see timelines 1 and 2) that provide the hook needed for just the right entry angle into the pins, these factors helped contribute to the meteoric rise in perfect games.

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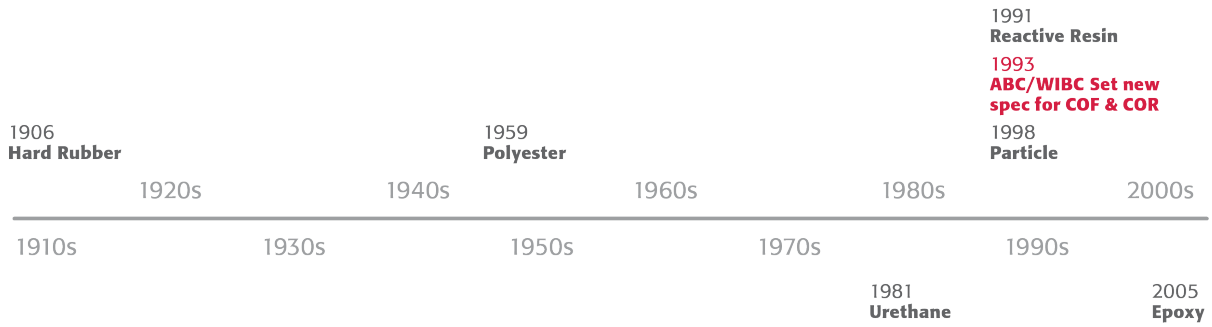
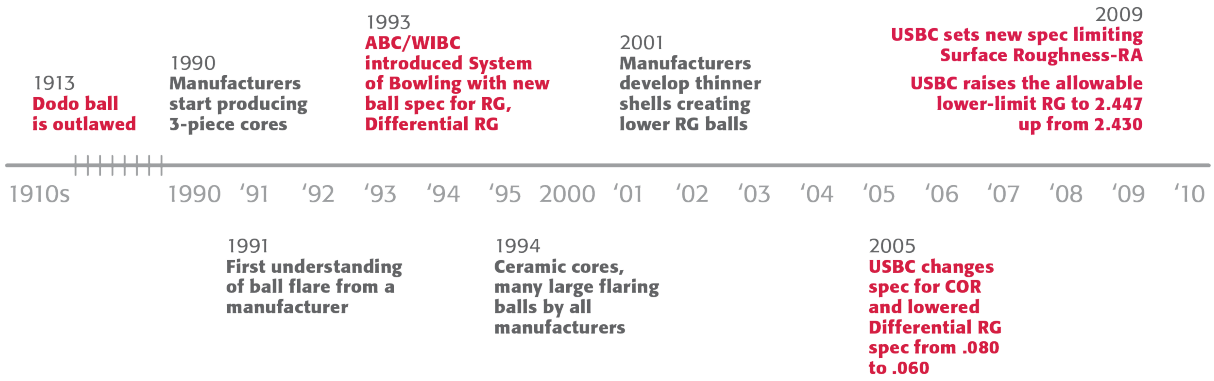


Coverstock technology timeline 1



Core technology timeline 2

The 1990s would see an explosion of 300 games. ABC recognized 41,303 perfect games during the 2000-2001 season and the number continued to rise all the way to ABC's final year, when there were 48,674 perfect games in 2004-2005.

Yet, during this time, the industry saw the number of certified bowling centers decrease from about 9,300 to just fewer than 6,000. Fewer lanes, yet more 300 games.

It's easy to understand why, in bowling's history, the 300 game was such a celebrated accomplishment. That's not to say the perfect game is any less of an accomplishment in today's game; it simply is to point out the occurrence of such a feat is more common today.

Many suggested the bowling ball was the reason for the dramatic rise in perfect games and USBC has performed extensive studies of the bowling ball.

In 2005, a task force was formed to address bowling ball performance issues and its impact on the credibility and integrity of the sport. The USBC Chief Executive Officer at the time stated USBC "will manage — but not stop or control — new technology."

That led to a two-year, joint study of bowling ball motion by USBC and representatives from the major domestic bowling ball companies[1]. The data gathered from the **Ball Motion Study** validated what properties of bowling balls significantly influenced their motion, resulting in new manufacturing specifications that placed limits on the **surface roughness** of new bowling balls.

1 Representatives were from Brunswick, Columbia 300, Ebonite and Storm

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The research was started because technological advancements in bowling ball **coverstocks** and **cores**, combined with improved lane surfaces and lane oiling patterns, had contributed to the increasing rate of honor scores and overall scoring pace.

USBC stated as part of its Ball Motion Study that those factors possibly were jeopardizing the credibility of the sport to the point where technology — and not player skill — was having too great an impact.

Every manufacturer, including those in the world of sports, will push the limits to produce superior products that will put their business on the map and make it the go-to company for every team or individual. Athletes also seek the next, greatest product that will push their performances to the highest level possible.

What's wrong with this mentality? Not a single thing, because pushing the limits is the reason we no longer play football in leather helmets[2], or tennis and golf with wooden rackets[3] and clubs[4].

Would the pole vault[5] world record be more than 20 feet if athletes still used the same type of poles they did back in the 1950s?

Speedskating, which has been an organized sport for as long as bowling, has seen its 1,500-meter record drop almost a full minute over the course of its history. Is that simply because we have better-trained athletes or did the advancements in ice skate design[6] and how ice surfaces are constructed and maintained[7] play a role?

In bowling, competitors no longer roll a hard, rubber ball on wooden lanes.

Bowling ball coverstocks went from rubber to polyester to urethane to reactive resin. Weight blocks inside a ball also saw changes that gave bowlers a much more powerful tool. The wood lanes now are mostly made of advanced synthetic materials.

The way the lanes are maintained, and the lane oil used have seen many advancements. But what many bowlers might not know is how the amount of oil used on lanes has changed during the last few decades because of the advancement of materials[8] used in the coverstocks of bowling balls.

Today's balls can absorb more lane oil, which helps to move the oil on the lane and/or pick up the oil to create a drier lane surface. When oil is pushed aside or simply absorbed by a bowling ball, that allows more of the surface of the ball to contact the lane surface and inevitably create more hook.

USBC asked oil manufacturers[9] about how the use of lane oil has evolved over the last few decades.

Both manufacturers noted the amount of oil on a lane when setting a standard league pattern, otherwise known as a house condition[10], was about 8 milliliters during the 1980s. The amount nearly doubled from the 1980s to the 1990s, and the amount of oil needed has continued to rise at nearly the same level.

Now, centers are averaging about 24 milliliters of oil per lane, which is an astonishing 16 milliliters more — three times the amount — than was used just a few decades ago.

2 **History** of the football helmet
3 Racquet **technology** in tennis
4 Golf equipment innovations **timeline**
5 Pole vault **technology**
6 How ice skates are **made**
7 Ice skating **history**
8 Mica, particles, other additives and the overall chemistry of the coverstock has pushed the levels of performance
9 Kegel and Brunswick
10 A house condition refers to when more units of oil are used in the middle part of the lane and less on the outside, thus creating an easier playing environment for bowlers

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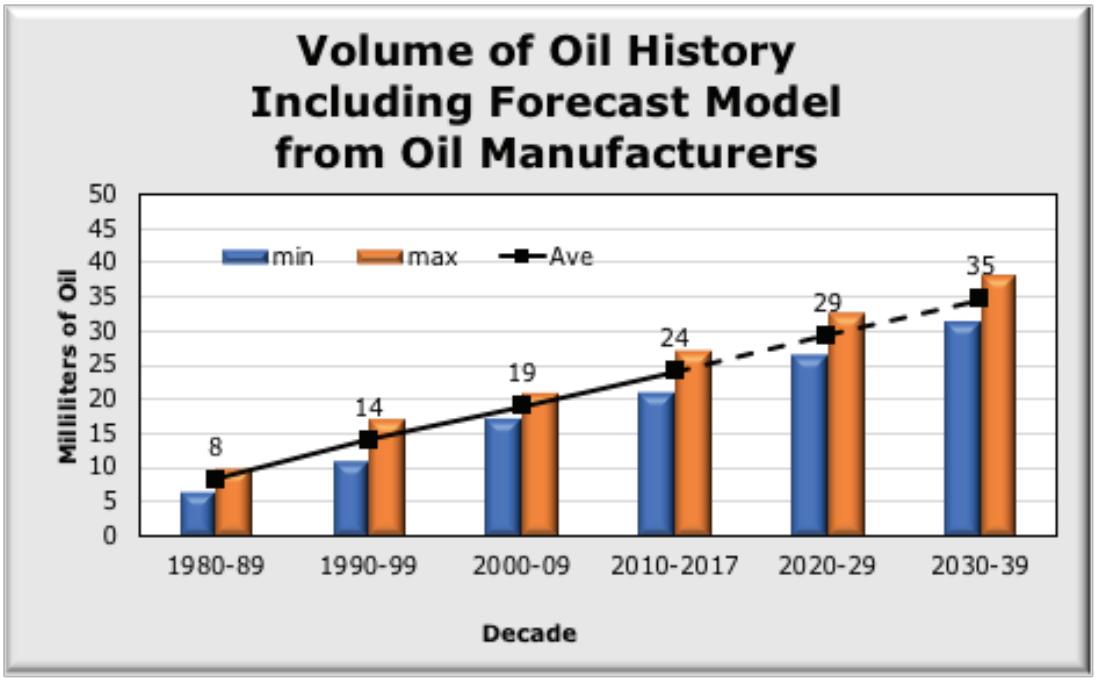

chart 1

Based on oil volume data for the past four decades provided by oil manufacturers, it is within reason to forecast the amount simply will continue to increase each decade to maintain the house condition for a typical league.

Oil volume — more specifically, **oil depletion** — is an important area of study for USBC. The need for more oil means an increased cost to centers over time which can also have an adverse effect on lane maintenance and all the moving pieces such as pinsetters and ball returns. And when oil is depleted, lanes lose the protection and are more likely to see added wear and tear.

In response to USBC's **Facebook polls**, most respondents said the most influential component of bowling well in today's conditions is having the right ball in your hand. While they also cited figuring out lane transition and quality shot-making as influential, 42 percent said having the right ball in your hand was the key.

As shown in chart 1, more oil is applied on lanes today. Yet, bowlers continue to see the lanes transition at a fast rate. With balls removing oil from the lanes, the lanes transition faster.

And what do bowlers need to do when lanes transition? While making the correct moves might be an answer, finding the right ball to match the condition seemingly has become the answer for most bowlers.

The environment of the sport is being changed by technology, and it's important to determine if such changes are lessening the skill level of the bowler.

It is the role of a sport's National Governing Body to stay abreast of changes in technology to ensure the equipment used in competition remains within certain specifications and that competitions are decided by the skill of the players, not who has the latest, most technologically savvy equipment. The equipment should evolve but specification changes also must be considered.

That's the role of the organizations that oversee each sport. These groups must be vigilant in monitoring, examining — and sometimes re-examining the effects of technology.

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Back in the 1980s, the United States Golf Association (USGA) and Professional Golfers Association (PGA) ran into issues with grooves[11] used on the clubface of PING golf irons. PING began turning out golf clubs with square grooves after the technology was approved.

The company continued working on the product but as golf's governing body investigated, it found revisions to the clubface went beyond approved specifications, making newer PING clubs illegal for competition. A lawsuit followed but, eventually, **the USGA agreed to grandfather in PING clubs** made before March 31, 1990. A decade later, PING reached an agreement with the PGA Tour to **waive its grandfather clause**.

The case shows neither party did anything wrong — PING wanted to make better golf clubs for its customers and the USGA stepped in when the technology was pushed to the point where it could significantly impact the skills required to compete.

Golf also saw the advent of titanium drivers — and those big clubheads that look like toasters on a stick — and once again restrictions had to be developed because of the new technology.

For the sport of bowling, technology has more than transformed the sport. We no longer need pin boys to reset the pins, most lanes no longer are made of wood, and we don't need a pencil (or grease pencil) to score games.

While bowling balls have seen tremendous technological advancements in the last 30 years, the lanes we bowl on and how they are oiled also have been factors when looking at how the sport has evolved.

Bowling lanes used to be constructed of different types of wood[12], however, lane manufacturers turned to synthetic materials in the 1970s. The new lanes are easier to maintain, more durable and provide a more consistent playing field.

The materials used in synthetic lanes have the look of a wood surface, but centers no longer need to resurface the lanes each season. USBC set specifications for the synthetic lanes, including a **specification** related to the hardness of the surface, in 2007.

The lane conditioner[13], the oil-based liquid that nowadays is applied with a machine to the lane surface, is another factor that has come into play in more recent years.

In 1987, after two years of testing, ABC introduced an ultraviolet additive in the lane oil, along with the take-up device and reader, to record and read the amount of oil present on a lane surface.

USBC introduced lane oil **specifications** for the first time in 2007, setting a range of viscosities for the oil.

Summary

The bowling ball, the pins, the lanes and the lane conditions all are part of the playing field in bowling and influence the sport.

Everyone involved in the manufacturing of the products that are part of this environment will continue to explore ways to make better products for their consumers. The USBC Equipment Specifications and Certifications team's ongoing commitment is to stay informed and analyze changing products, and thoroughly test new products that could impact the sport.

The goal of this ***Bowling Technology Study*** is to figure out what the sport looks like today in these areas and then decide what's in the best interest of the sport for tomorrow.

11 **Grooves** common questions
12 Pine, a softer wood, was used for most of the middle section of the lane while harder, more durable, maple wood was used on the three areas that take the most wear — the approach, the early portion of the lane called the heads, and the pin deck.
13 Lane conditioners were first developed to protect the wood lanes and have evolved to also affect the difficulty level of the sport, when applied in a specific pattern on the lane.

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SECTION II:
A STUDY OF RG AND DIFFERENTIAL RG

Starting in July 2015, the USBC Specifications and Certifications team spent more than two years doing in-depth research on today's bowling balls.

In-depth research meant looking at every aspect of the bowling ball. Most of today's balls have two notable elements — the core and the coverstock. The core is the guts of a bowling ball, with either a heavy shape in the middle and a lighter density outer core (three-piece) or just a heavy shape in the middle (two-piece). The coverstock is the outer shell of the ball. Most bowling balls since the early 1990s are constructed in this manner (image 1).

image 1

A variety of shapes are used for cores — **symmetrical** and **asymmetrical** — and can have varying densities to provide different reactions when the ball is rolled.

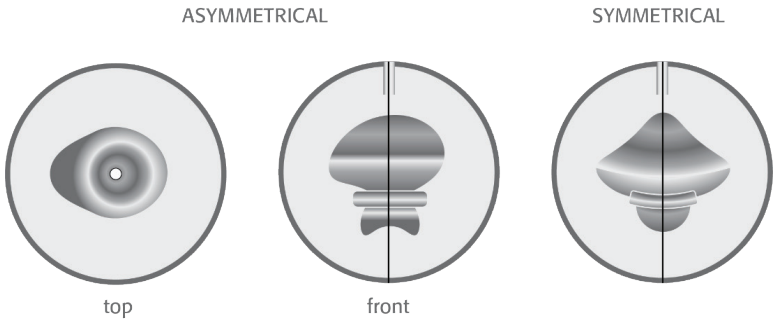

image 2

Coverstocks are made with a wide variety of materials but generally are polyester (plastic), urethane and reactive urethane (also called resin). Not only does the material of the coverstock have an impact on the ball's reaction, but the finish of the coverstocks can be manipulated through sanding and polishing to produce different reactions on the lane.

While it might seem the options for cores and coverstocks are not overwhelming, the number of combinations of the two does provide many choices when constructing a ball. The USBC Equipment Specifications and Certifications team approves over 300 new ball models every year.

In 2005, USBC announced a **specification change** regarding the **Coefficient of Restitution** (COR) for bowling balls. Higher COR equates to more deflection, while lower COR equates to less deflection. It is the "bounce" or the elasticity of the collision, or as the United States Golf Association refers to COR, the "spring-like" effect[14].

COR values normally range from 0 to 1, where 1 is perfect elasticity, i.e. provides the most "bounce." For bowling, the new specification moved the upper limit from 0.78 to 0.75.

14 USGA reference to spring effect

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The COR change came on the heels of USBC establishing a maximum density specification for bowling ball materials and changes to the **Coefficient of Friction** and Radius of gyration.

Radius of gyration (RG) specifications were first implemented in 1993, when the American Bowling Congress set the limits at 2.430 to 2.800. A decade later, in 2005, USBC changed the **specification**, reducing the maximum **differential RG** from 0.080 to 0.060. USBC stated the change was an effort to control **flare** and entry angle. In 2010, the lower RG **specification** was changed from 2.430 to 2.447 and set the minimum model average at 2.460.

The USBC Director of Sport stated, at the time, that USBC was "implementing changes as deemed necessary to ensure the integrity and protect the future of the sport."

The same reasons led the USBC Specifications and Certifications team to again look at properties of the bowling ball.

Let's start by looking at radius of gyration. The technical explanation will mention **moment of inertia** about an axis and include the properties of mass and radius. A former USBC research engineer explained the radius of gyration determines how easy it is for a bowling ball of particular weight to rotate about a given axis and is a measurement of where the weight is located inside the ball, relative to the center.

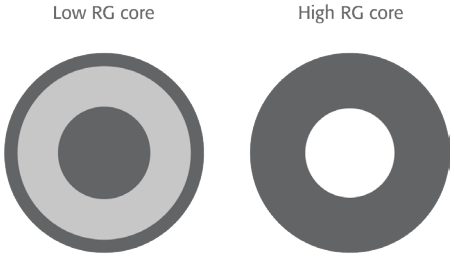

image 3

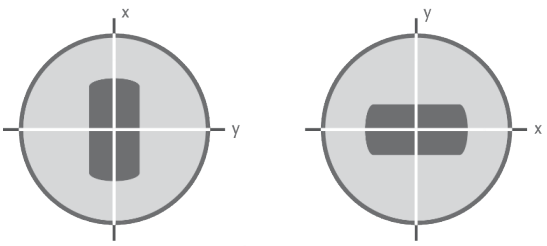

image 4

For a given core shape, the denser[15](heavier) the inner core becomes, the more the bowling ball will rev up, or rotate on its axis, in a quick manner. The less dense (lighter) the inner core, it will take longer for the ball to rev up as it travels down the lane, thus, having a higher RG (image 3).

So why is low RG or high RG important? Because a low RG ball allows friction with the lane to add to rotation for a sooner[16] and more arcing breakpoint. The high RG ball resists rotation longer, and it becomes harder for friction to add to the ball's rotation, resulting in a ball that slides further down lane before hooking.

The shape of the core will change the differential RG, which is the difference in the RG results when the ball is measured along the low RG x-axis (pin) and high RG y-axis (6-3/4" from pin).

For example, if you had a high density cylindrical shape (image 4) and tested it for RG through the axis of the cylinder, the weight would be close to the axis and have a low RG.

Then, if you laid the shape on its side, the weight would move out and the RG would be higher. The differential RG is the difference in these two RG values along the lowest and highest RG axis in the same ball (image 5).

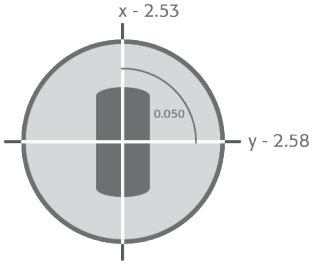

image 5

While the way the ball is delivered, and the number of revolutions imparted by the bowler plays a role, balls with a higher difference between maximum RG and minimum RG values — the Differential Radius of Gyration — can be seen by looking at the oil rings on the ball. The rings show the flare of the bowling ball and balls with a higher differential will have greater separation between the rings (image 6).

15 The darker color in image 3 represents a denser material
16 Moment of Inertia video

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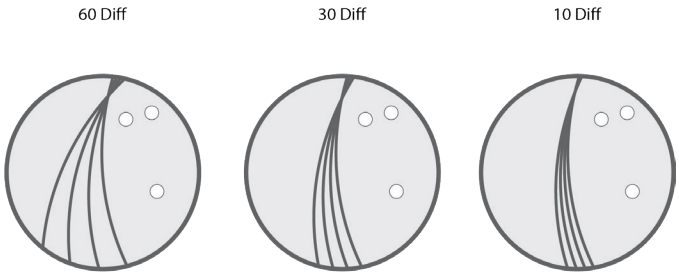

image 6

But what does flare mean? Well, a flaring ball allows a dry area of the coverstock to be in contact with the oiled lane, which increases the friction, as opposed to a non-flaring or small flaring ball where the same area of the coverstock that has picked up lane oil repeatedly contacts the oiled lane.

The USBC Specifications and Certifications team determined differential RG was an important factor, and it was among the many factors that were part of the research of today's bowling ball.

Testing consisted of many different **phases**, including:

- Vary the differential RG property
- Vary both RG and differential RG properties
- Flat oil patterns vs. house patterns
- Vary bowler properties (speed, revolutions and axis rotation angle)
- Simulate five-person team to dry up the track
- Bowlers' rotation versus RG
- Production balls with same core that varied RG and differential RG
- Comparing different weight balls

The two following interval plots are for balls thrown with the same RPM rate. From there we questioned the results leading to the RG vs RPM study.

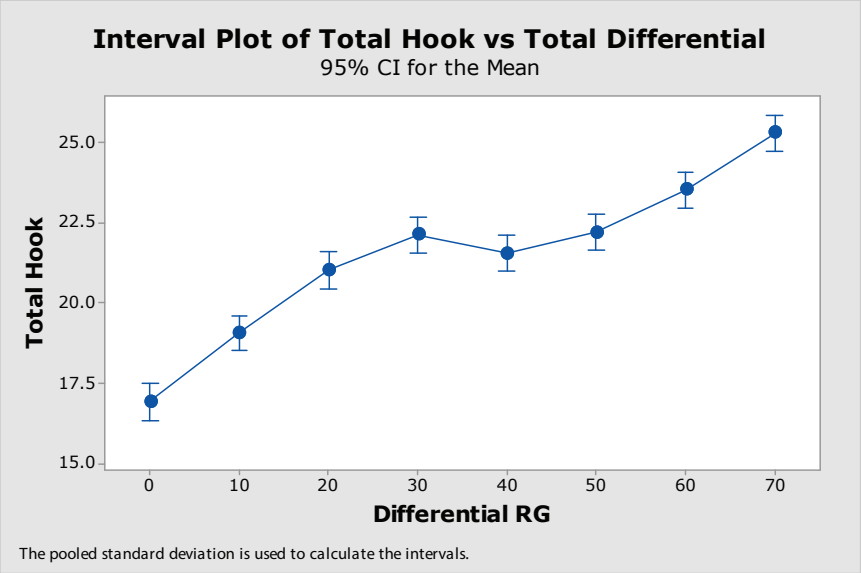

chart 2

After the first test, when varying the differential RG, hook increased as the differential RG was increased.

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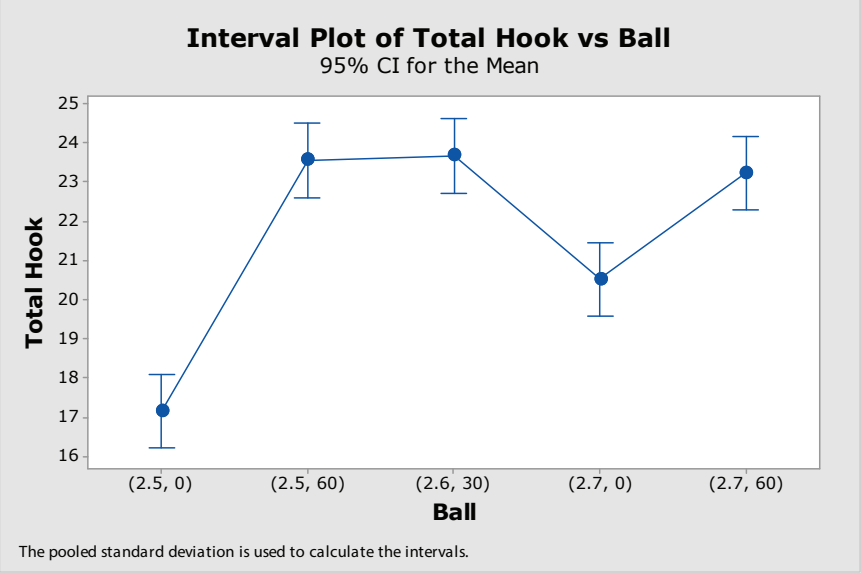

chart 3

When the RG and differential RG both were varied, balls with zero differential would hook less while those medium to high differential RG (.030 and .060) balls hooked about the same.

But what effect does RG have on the bowler's revolutions per minute **(RPM)** when rolling a ball?

The USBC team questioned the initial results when the high RG ball had higher hook ratings. Therefore, it decided to go to the definition of moment of inertia, which is a force resistant to rotating motion.

That led USBC to investigate if a difference is measurable in the RPM rate when bowlers throw different moment of inertia balls (different RG balls), to see if the team had missed something.

Using a high-speed camera, the team analyzed 37 bowlers with a full range of RPM rates (chart 4).

The results proved the RG of the ball does alter the RPM rate a bowler can impart on a ball.

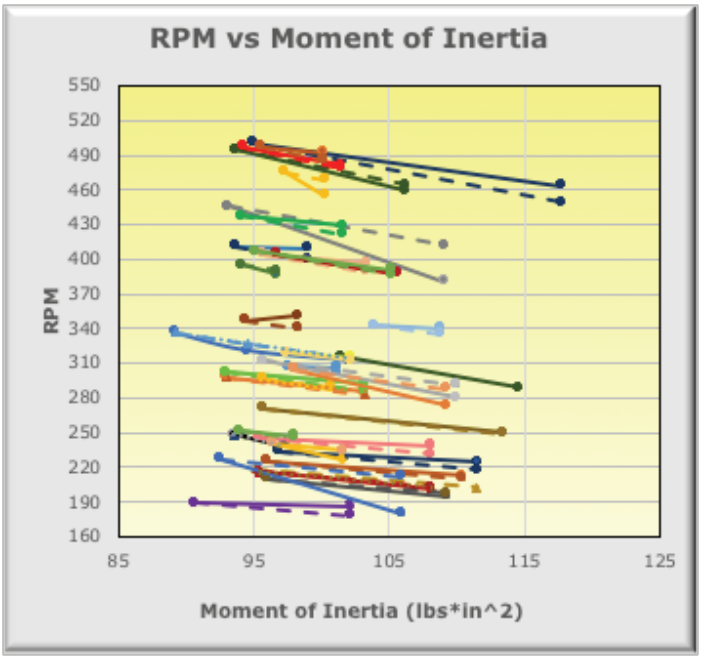

chart 4

The findings were an extremely important discovery, changing what the Ball Motion Study found in 2008 when looking at RG. The Ball Motion Study was correct but expanding the analysis by incorporating RPM provided more data which delivered new results.

But it also meant the team would have to go back to the start of the test, so it could consider this new factor.

The RG of the ball affects the RPM rate a bowler can impart on the ball. The RPM study determined a typical 300-RPM bowler can get about a 37-RPM difference between extremely low versus extremely high RG balls of the same weight (chart 5). That is quite a large difference.

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A mathematical model was developed, based on maintaining the same rotation energy for any ball a bowler throws.

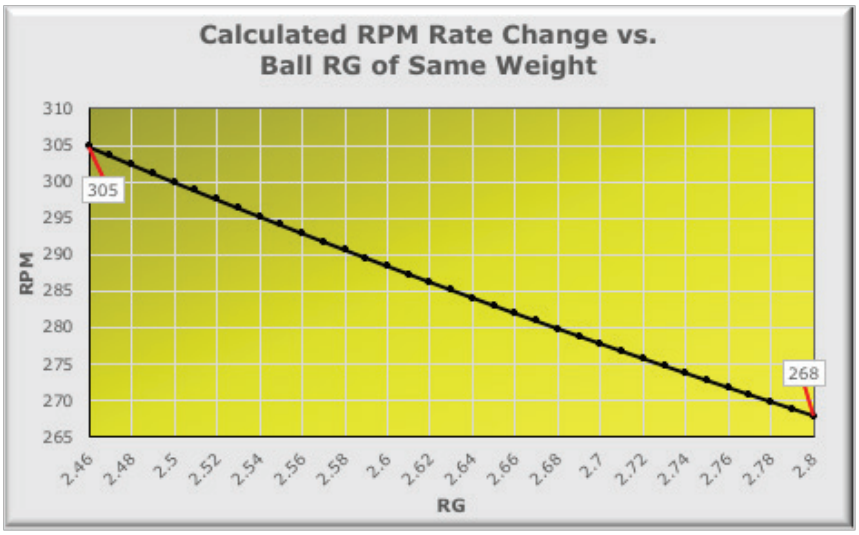

chart 5

The next test was to repeat the previous test but vary the RPM rate as the RG of the ball was changed.

Bowlers, normally, do not throw a ball rotating around the low RG axis, which is located at the pin. Therefore, the RG at the bowler's **Positive Axis Point** (PAP) had to be measured and the RPM rate adjusted accordingly.

For this test, the low RG ball was thrown with 282 RPM, a medium RG ball was throw with 275 RPM and the high RG ball was thrown with 262 RPM. This changed the results to be in line with popular belief that flaring, lower RG balls are the normal high-performance balls.

Matching the RPM rate to the ball RG became part of all future testing.

The next test incorporated the RPM difference based on RG value and consisted of 20 shots on a flat oil pattern (chart 6). The flaring balls with .030 and .060 differential RG hooked more than non-flaring balls with minus -.002 and .000 differential RG. The low RG ball with the high differential hooked the most.

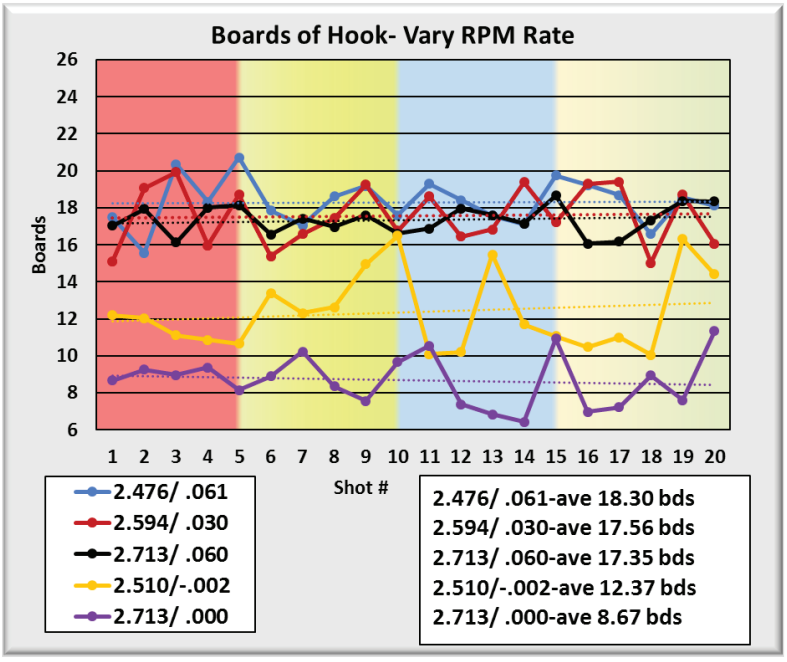

chart 6

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A look at the average ball paths with a low RG high differential ball, a medium RG medium differential ball, and a high RG high differential ball reaction on their first five shots (chart 7).

The ball paths show that the lower the RG, the more hook for a ball. Some might say the overall difference in the ball paths is small, but the amounts are the difference between throwing a solid strike and hitting the pocket light.

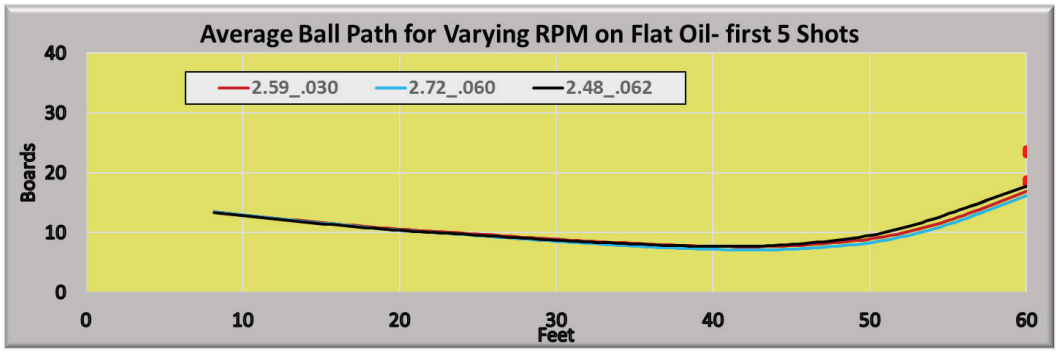

chart 7

A statistical review of this data determined differential RG had the most impact (chart 8) with RG and interaction between the RG and differential RG also are important factors, though to a lesser degree.

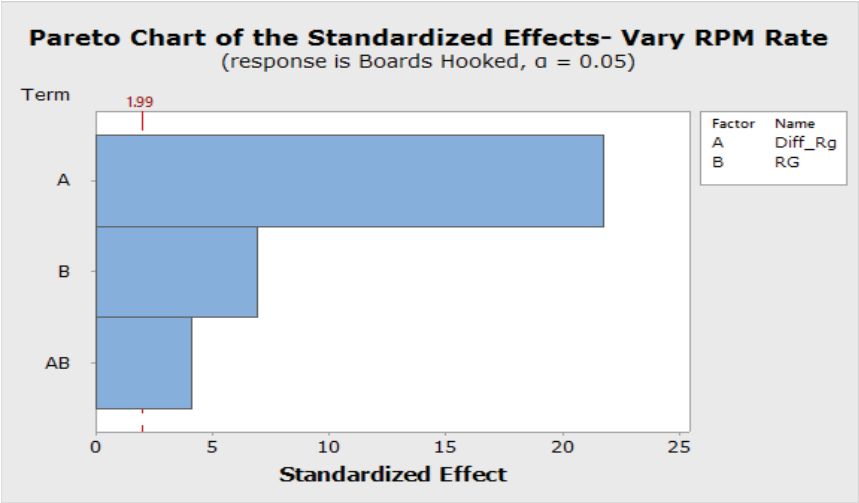

chart 8

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The next test looked at changing the pattern from a flat pattern to a house shot. The pattern change brought the results closer together, since the balls that hooked less were thrown farther outside on the lane where there was less oil, creating more hook for these balls.

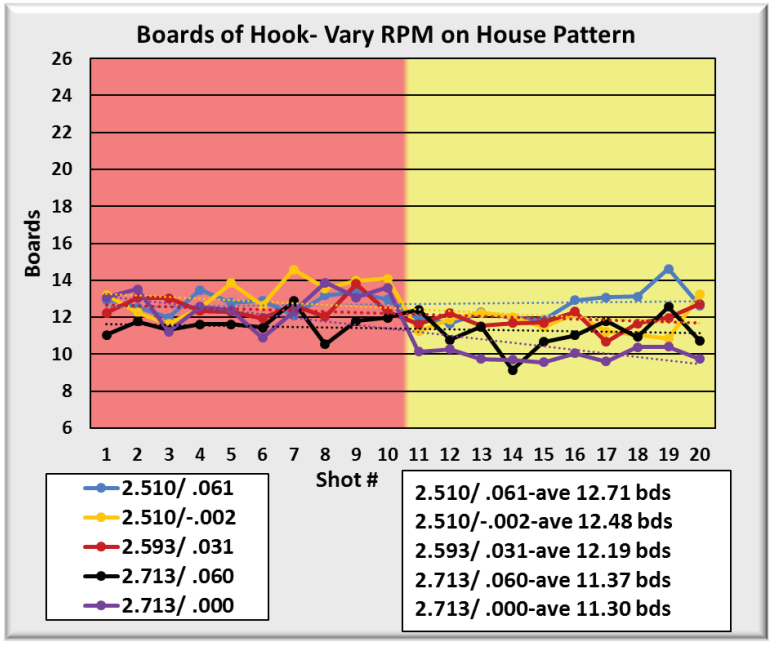

chart 9

The test balls, which used different weight slugs to vary the RG and differential RG, began to develop problems, so USBC enlisted a manufacturer to build specific test balls.

The manufacturer provided balls with RG of 2.5, 2.6 and 2.7, along with differential RG of .030, .060 and .080 for testing. At this point, we stopped testing ball with .000 RG differential since the result always determined they had much straighter ball paths.

From all these test balls, the two balls to hook the most were the high differential balls — 2.6 RG with .060 differential RG and 2.7 RG with .080 differential RG (chart 10). These hooked about one board more than the average ball path.

The two balls to hook the least were the low differential balls — 2.5 RG with .030 differential RG and 2.7 RG with .030 differential RG — that saw a hook about one to two boards less than the average ball path.

The total difference in hook between the balls was about three boards.

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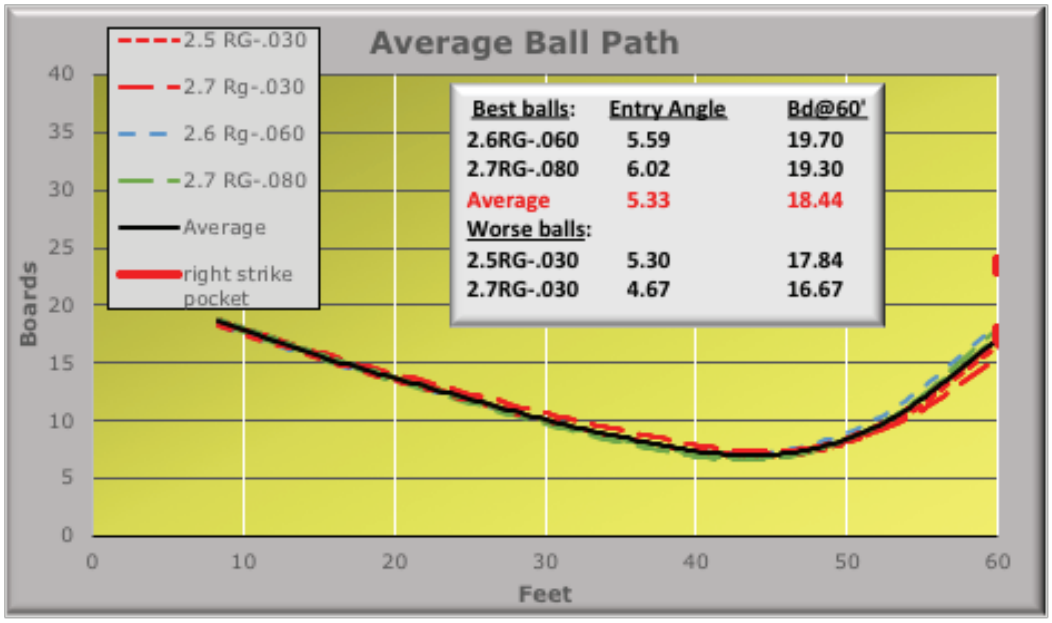
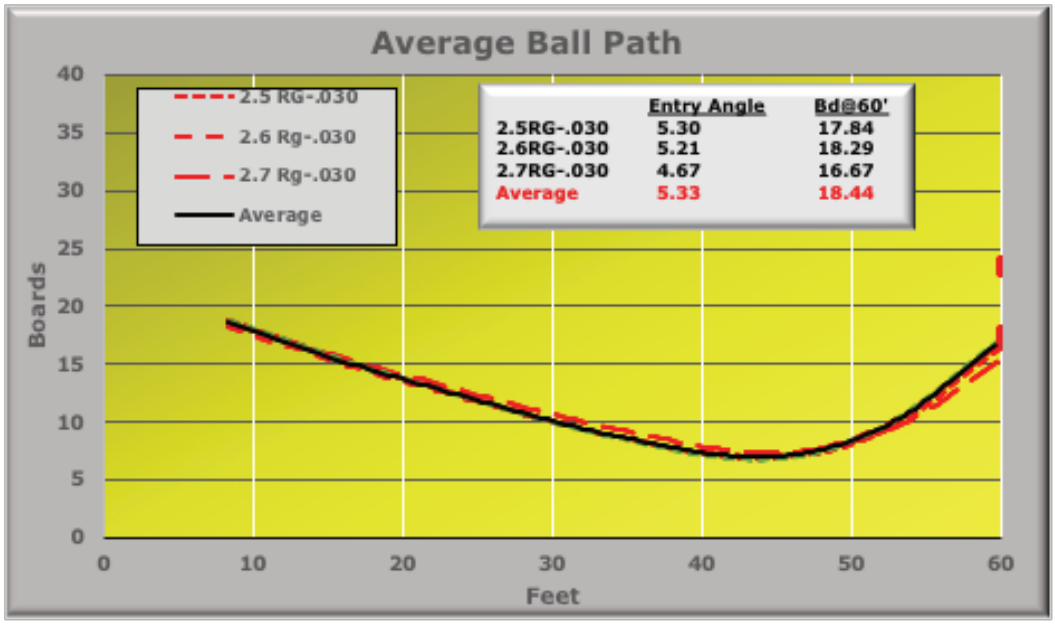


chart 10

A look at the ball paths based on the differential RG found the following:



.030 RG diff – Hooked the same or less than the average, with the 2.6 RG hooking the most and the 2.7 RG hooking the least. This would be the only property that consistently hooked less than the average.

chart 11

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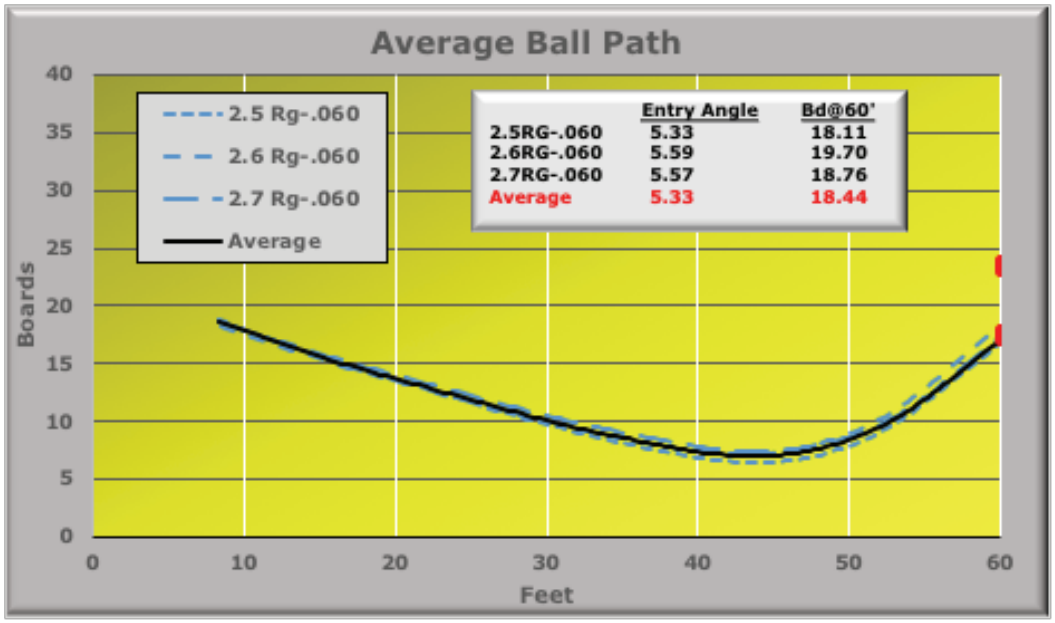

chart 12

.060 RG diff – Hooked the same or more than the average, with the 2.6 RG hooking the most and the 2.5 RG hooking the least.

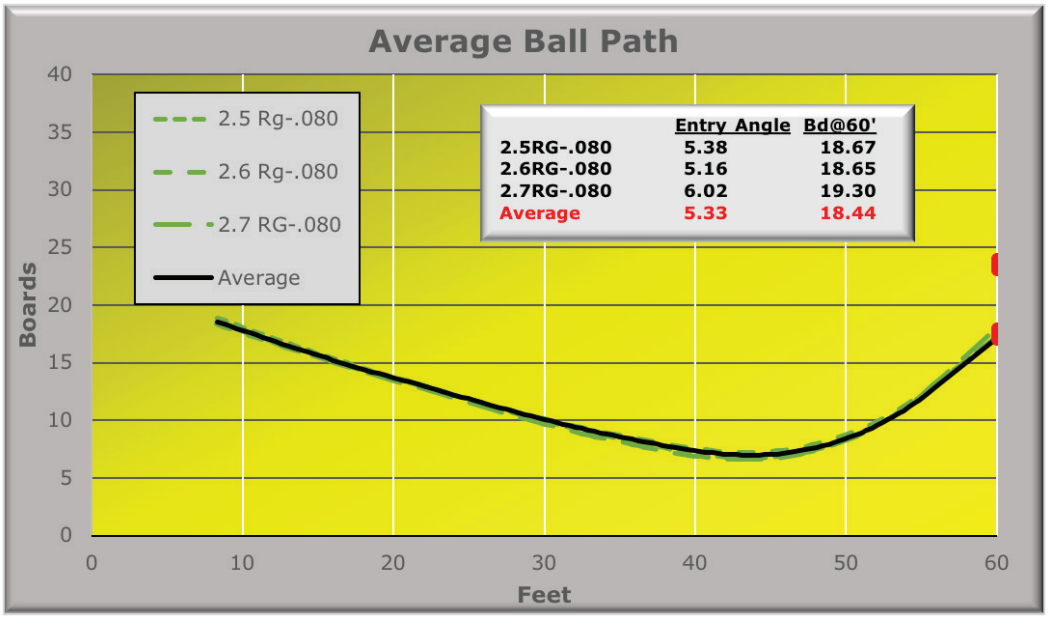

chart 13

.080 RG diff – Hooked more than the average, with the 2.7 RG hooking the most and the 2.6 RG hooking the least.

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Looking at the ball paths based on RG found the following:

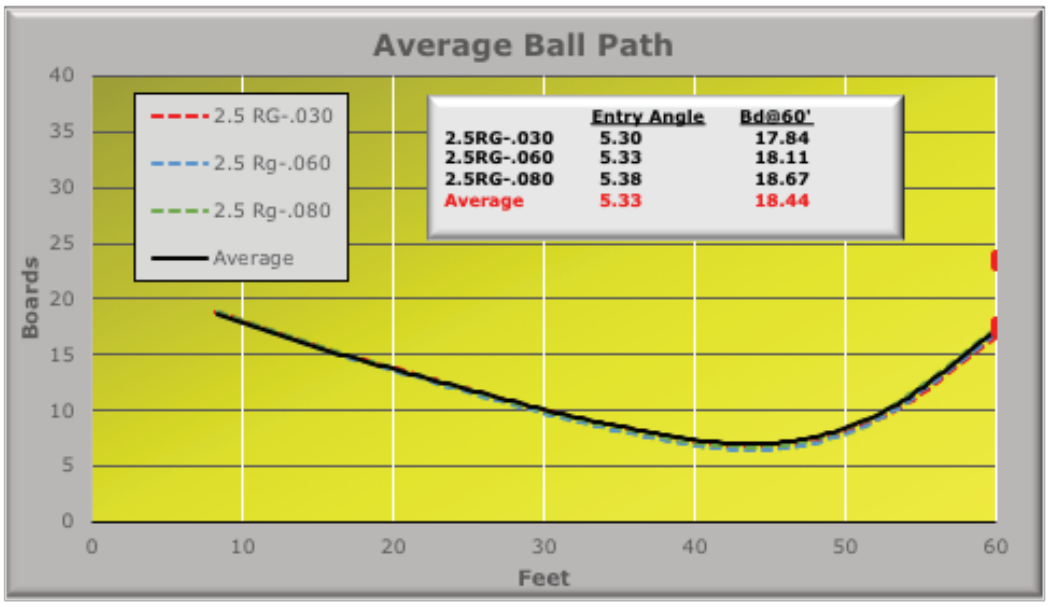

chart 14

2.5 RG – Hooked about the same as the average; differential had little effect on hook or angle.

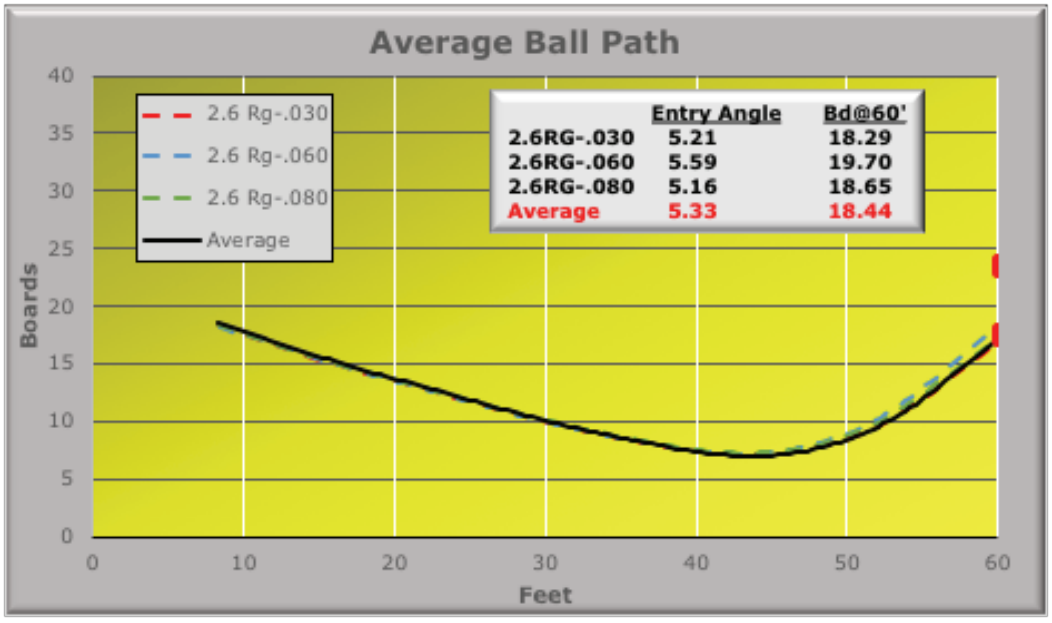

chart 15

2.6 RG – Hooked about the same or more than the average; .060 differential hooked the most with more entry angle.

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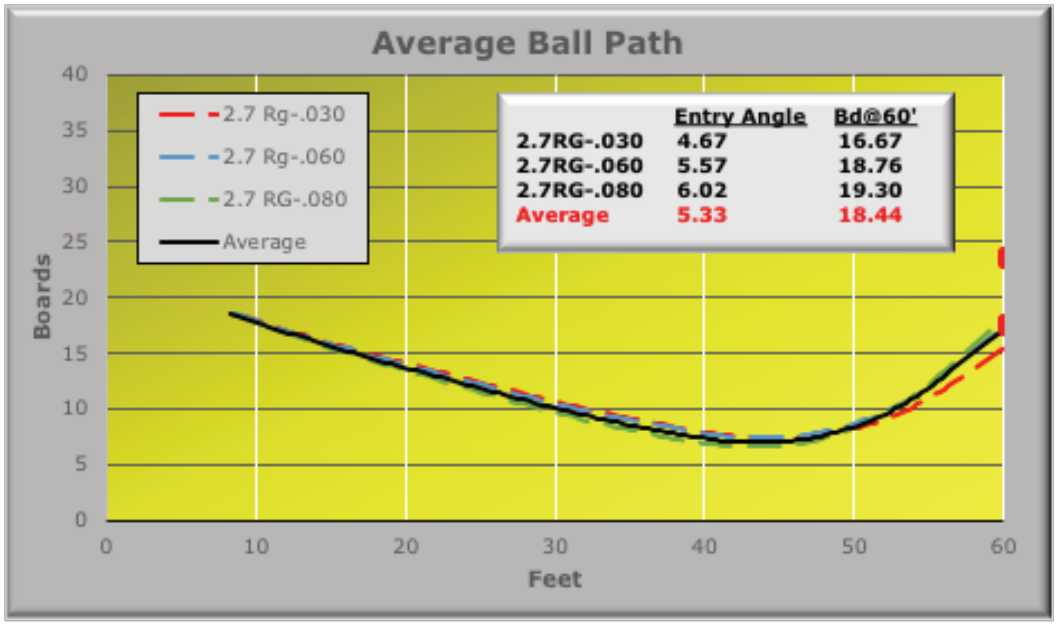

chart 16

2.7 RG – Had the largest range in ball paths, hooking from less than average to more than average; .080 differential hooked the most with more entry angle.

The entry angle data is an important factor to consider.

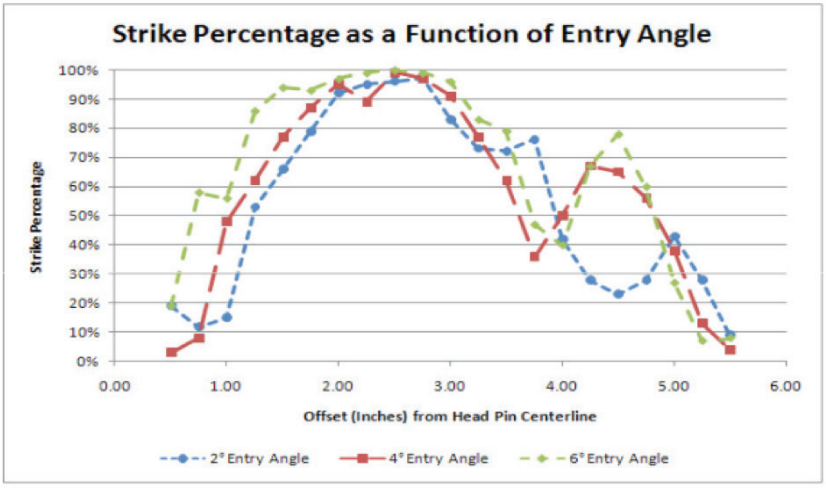

chart 17

Previous **USBC studies** have shown an increased entry angle into the pins significantly improves carry of the corner pins (chart 17). A higher carry percentage means the bowler will strike more, as shown in previous studies.

Board change — how many boards difference when the ball enters the pins — also is an important factor to consider.

If you examine the different RG charts 10-16, you will see more than a three-board difference between a 2.6 RG ball with 0.060 differential (at board 19.30) and a 2.7 RG ball with 0.030 differential (at 16.67) — a difference of 2.63 boards.

A bowling lane has 39 boards, so three boards might not seem to be much of a difference.

Yet, if you examine the ball paths in charts 10-16, you will see the bowling ball does not use the entire lane of 39 boards; it uses about half that number. So, when you see a change of nearly three boards over 18-20 boards,

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that is quite a bit of difference.

And when looking at league situations, where a high volume of oil is used, the total number of boards used on a lane could be less than 10. With players hugging the oil line. That would make nearly a three-board difference much more significant.

What the data did show was 2.7 RG balls had the largest range, hooking from less than average to more than average, and that 0.080 differential RG for a 2.7 RG ball hooked the most with more entry angle.

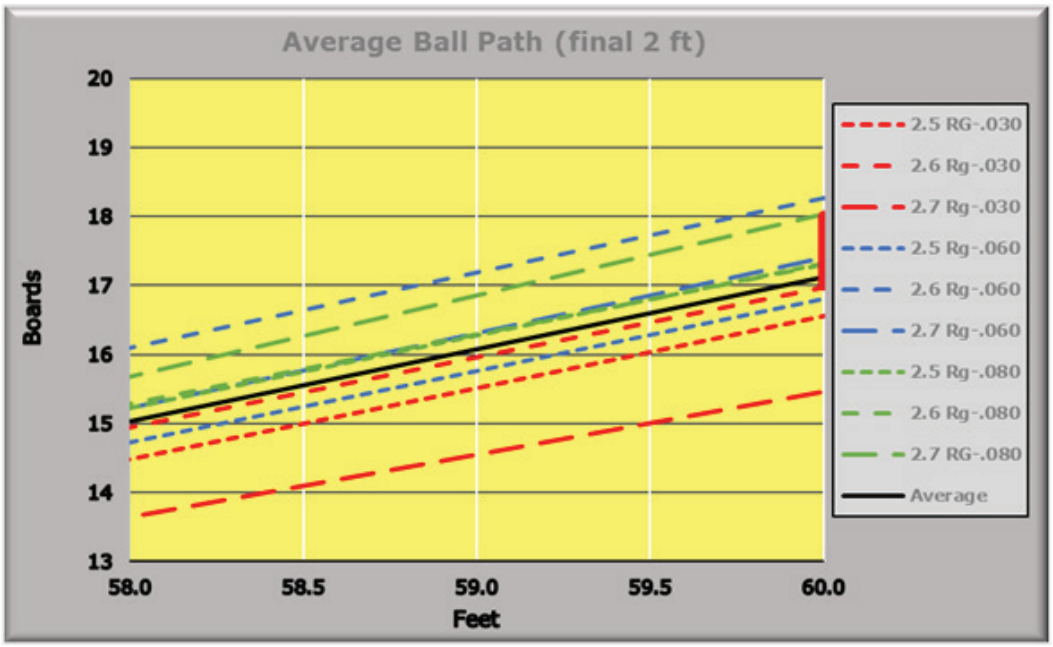

chart 18

Key Takeaways

The RG of the ball affects the RPM rate a bowler can impart on the ball. The RPM study determined a typical 300-RPM bowler can get about a 19-RPM difference between 2.46 RG and 2.62 RG balls of the same weight.

The 2008 Ball Motion Study clearly stated RG was a more dominant factor than differential RG, however, it was determined in this ***Bowling Technology Study***, since the RPM rate is linked to the RG of the bowling ball used, the differential RG IS the more significant factor on a ball's ability to hook. It is especially more noticeable on a flat pattern. When we tested bowling balls on a house condition, the differential RG effect compared to just the RG was less noticeable.

The data shows a bowling ball with 2.7 RG has a significantly different reaction in its ball path (a nearly three-board difference) and entry angle (1.35 difference) when the differential RG was set at .030 and then at .080.

The team also noted the only property that hooked the same or less than the average was bowling balls with the .030 differential.

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SECTION III:
THE IMPACT OF BALANCE HOLES

There is a growing concern that the design intent of bowling balls is being manipulated with the use of a balance hole. The USBC team needed to determine how any holes altered the ball dynamics; specifically, if different size and location of balance holes affect the RG or differential RG.

A balance hole for a bowling ball is intended to remove static imbalance but more recently they are being strategically placed to change a ball's dynamics.

The **USBC team's test** consisted of drilling balance holes of several different sizes — 3/4-inch, 1-inch and 1 1/4-inch diameter holes — into bowling balls of varying RG to determine if balance holes can impact the RG and the differential RG.

All balance holes during these tests were located to have maximum effect on the ball dynamics and all were 3" deep.

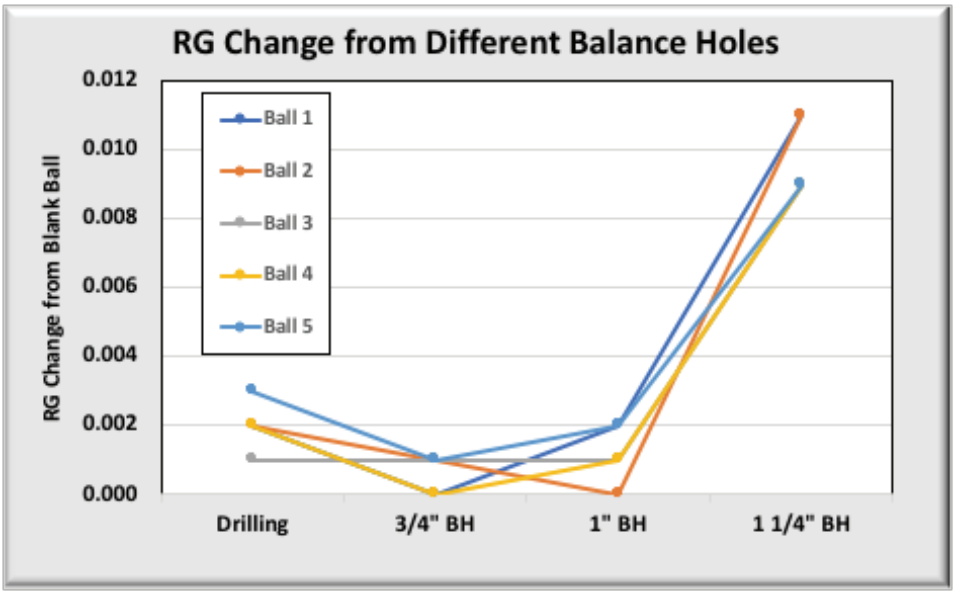

chart 19

The test found the largest diameter balance hole (1 1/4-inch) did add .009-.011 to the RG.

The change in differential RG was more pronounced. While the gripping holes did have up to .003 change in the differential RG, the balance holes added between .005 and .021 depending on the balance hole's size.

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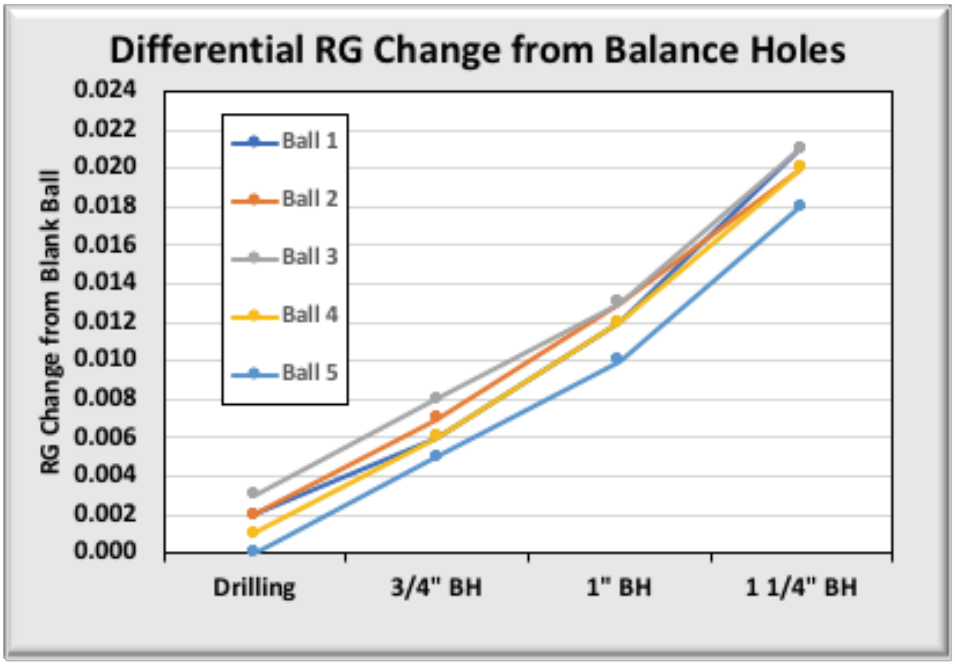

chart 20

The testing showed that gripping holes (finger and thumb holes) can have a very small effect on RG and differential RG compared to the undrilled ball, but balance holes can affect the dynamic properties of a bowling ball depending on the balance hole's size and location.

Strategically located, a 1 1/4-inch diameter balance hole that is three inches deep can alter differential RG by as much as .020. Smaller diameter balance holes, however, have much less effect.

Key Takeaways

Today, bowling ball manufacturers, through a variety of platforms[17], are communicating ways for pro shops to enhance their products for customers through balance-hole drilling techniques. These techniques can have an impact by increasing the overall flare and hook potential of products beyond the level of the original design intent.

USBC's research shows balance holes can have a significant impact on various properties of the bowling ball, particularly differential RG. Balance holes will be an area of continued research and regulation given their demonstrable affect of the overall dynamics and therefore performance of bowling balls.

17 Technical video demonstrations, ball drilling/layout documents and pro shop seminars

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SECTION IV:
BOWLING BALL OIL ABSORPTION STUDY

In its examination of the bowling ball, the USBC Equipment Specifications and Certifications team took a closer look at the oil absorption rates of bowling ball coverstocks, which is the outer surface of the balls.

Why is it important to understand the rate of oil absorption for bowling balls? Because it needs to be determined how the movement and removal of oil on a lane impacts the game.

The data from oil companies in **Section I** illustrated much more oil is being used on today's lanes, an issue that directly relates to the integrity of the environment in the sport.

Currently, there is no specification for the amount of lane oil that coverstocks are allowed to absorb, so initially the team would need to determine the best method to test oil absorption properties of a bowling ball.

As the national governing body, USBC is charged with regulating the sporting environment — the pins, the ball, and the lanes — and in turn this impacts the entire industry and bowlers. If the equipment and conditions on the lane cause deterioration of the lanes, that needs to be addressed in a balanced manner to ensure a sustainable, affordable, and accessible sport.

While a bowling ball's core, and the way a ball is drilled, does have a significant impact in the way a ball rolls, the coverstock plays the more important role[18] in how a bowling ball interacts with the lane.

There are three main types of coverstocks today, based on the material used to create the ball: polyester (plastic), urethane and reactive resin.

Plastic coverstocks are found on low-cost, entry-level balls that first came onto the market in the late 1950s. Today's competitive bowlers will use a plastic ball for their spare shots because it has less hook, providing a straighter ball path.

Urethane balls started in the early 1980s and, compared to plastic, offered more hook by providing added friction through the oil on the lane.

Reactive resin coverstocks started being produced in the early 1990s. They start with urethane as the base chemistry and then have an added component that makes the coverstocks more **porous**. This allows the ball to absorb lane oil, so the ball's surface would remain dry.

In the last two decades, the most significant advancement in ball technology has been the use of **particles** in the base material, designed to create a rougher surface and add more friction through the lane oil, like how snow tires can help a car have better traction in winter weather (image 6).

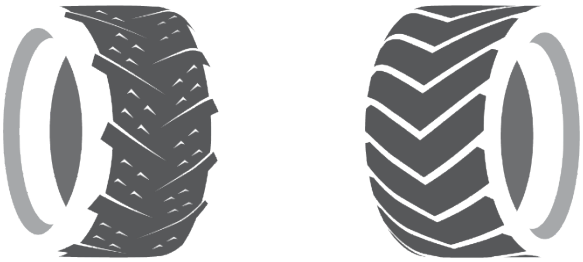

image 6

As part of its examination of bowling balls, the USBC Equipment Specifications and Certifications team examined new balls sent in for approval — just over 400 balls (during the time frame of this Bowling Technology Study) — with a 3D confocal scanning microscope[19]. The team looked at the balls right out of the box and then sanded the balls with 500-grit Abralon.

The **Sa values** below show the difference in surface roughness over an area for reactive, particle, urethane and polyester balls. The higher the Sa value, the larger the difference between the peaks and valleys — which basically means the higher Sa, the rougher the surface. A bowling ball with a rough surface will create more friction on the lanes.

18 As stated in the **2008 Ball Motion Study**
19 Confocal scanning microscope **definition**

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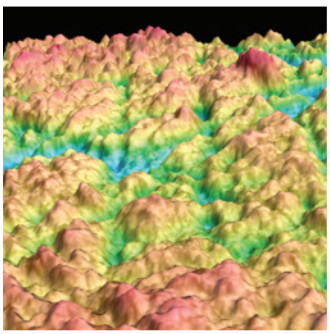
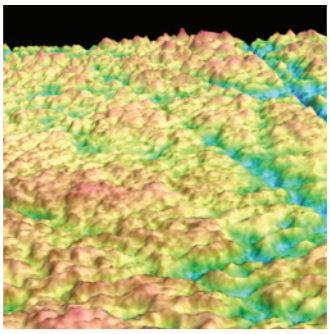
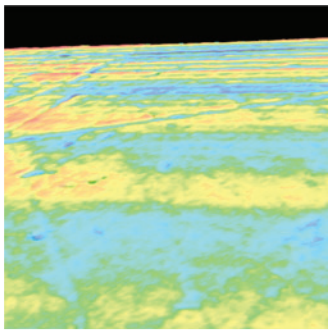


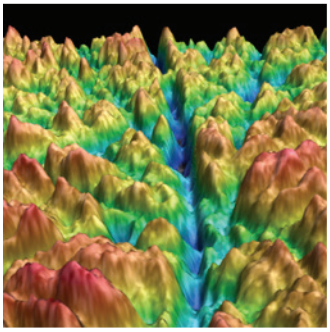
Solid Reactive Box



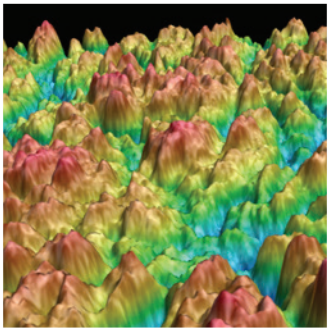
Solid Urethane Box



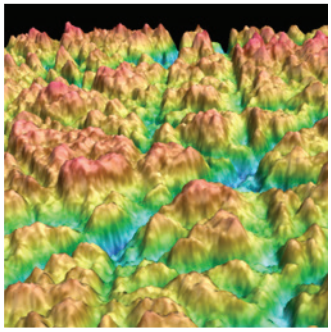
Polyester Box



Solid Reactive 500 grit



Solid Urethane 500 grit



Polyester 500 grit

Examinations on new balls showed the surface of reactive balls were about 1.5 times rougher than polyester balls.

Chemistry	# balls	Average of Sa
Reactive	215	44.02
Particle	4	40.64
Urethane	9	37.05
Polyester	4	31.96
Grand Total	**232**	**43.48**

While the rougher balls do create more friction, there are some who believe the ball's ability to pick up more lane oil could shorten the true lifespan of the ball. Think of a bowling ball as a sponge; a sponge only can absorb so much water before it needs to be rung out. A bowling ball is similar in that its coverstock can absorb only so much oil. Without the ability to absorb oil, it loses its ability to hook, as the lane oil now stays on the lane and acts as a lubricant.

But unless every ball being used has reached full absorption, leagues and competitions must use much more lane oil, as previously shown by the oil manufacturing companies forecast in **Section I**. This was also confirmed when we held the **proprietor focus group**.

What is the value of having a more porous bowling ball? There are two advantages — it removes the oil from the lane and it creates a dry ball surface to contact the lane to increase friction.

Basically, removing oil from the lane helps to change a ball's reaction. When there is less oil on the lane, the hook potential of the ball will increase. This can significantly help a bowler on "fresh" conditions, when oil has just been applied to the lanes, though the bowler likely will need to make adjustments, or possibly change bowling balls, as the oil becomes less and less with each shot.

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But how fast does a bowling ball absorb lane oil? The first step was to find a test that would show how fast oil is absorbed by a bowling ball.

Since this was a new test for the sport, the USBC Equipment Certifications and Specifications team's goal was to determine the best test method for conducting oil absorption. Two different oil absorption methods were tested along with a number of other test **phases**:

- Test pieces of shell placed in oil and measure weight gain (with and without a vacuum on sample)
- Place a drop of oil on ball and measure oil absorption time

For the weight-gain test, USBC used shell samples from bowling balls to determine the percentage of weight gain for a ball when soaked in oil. USBC learned it could soak the shell samples in mineral oil and get a good indication of total percentage of weight gain during a 20-hour test.

The next oil absorption test method involved using a metering syringe to apply a small drop of oil onto a bowling ball's shell and measure the time for the oil to totally soak into the shell. A camera recorded the microscopic video, so a tester did not have to monitor every minute of the test.

Each of the oil absorption tests — soaking shells vs. applying a drop of oil to a ball — provided similar results but the repeatability of the testing process was an inherent issue with the weight-gain test method. Plus, cutting shell samples for every ball seeking approval would be time-prohibitive as it would take 1-1 ½ hours to cut shell samples from each ball.

For the droplet test, the testing station was built to handle one bowling ball and then was expanded once the testing procedures were verified and ready for use. The test uses a syringe to place a droplet of oil on the surface of a bowling ball and cameras record the elapsed time for the ball to absorb the oil.

Below is a look at USBC's oil absorption setup for eight bowling balls, using eight cameras and a DVR monitor.

USBC would test more than 500 balls for oil absorption. There were three drops in each color and the ball's oil absorption time was determined by the average for the fastest color.

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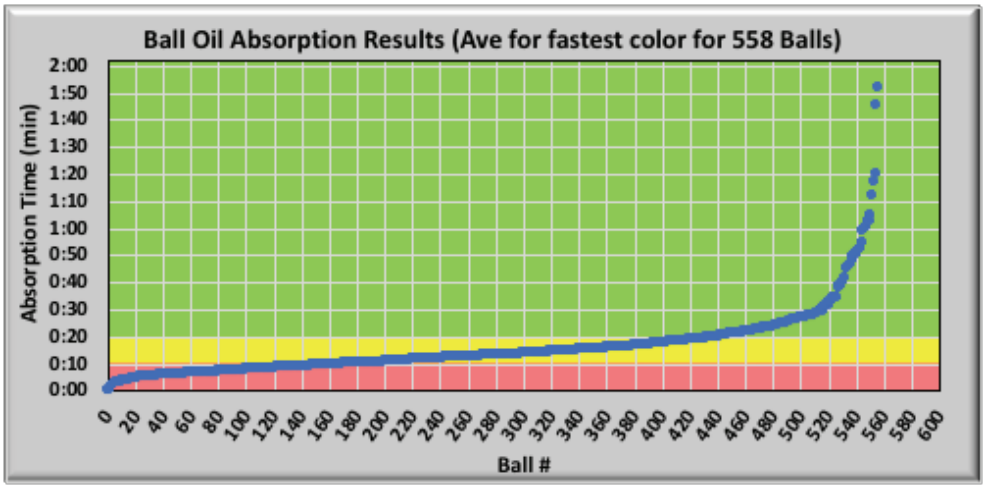

chart 21

As seen in chart 21, 29% absorbed the oil in less than 10 minutes, 49% in 10-19 minutes, and 22% of the balls tested absorbed the oil in 21 minutes or longer.

To ensure ball manufacturers could repeat the tests as conducted by USBC, they were provided a list of the equipment along with the **Standard Operating Procedure** (SOP) used by USBC so they would be able to repeat the tests in their facilities.

After the information was shared with manufacturers, USBC did receive questions such as:

- What can be done to speed the test for each ball?
- How does sanding equipment affect the results?
- Does dirty rinse water in the sanding process affect results?
- How does temperature of the ball affect the test?
- Does the time lapse between surface preparation and testing affect the results?

Each was a question that needed to be addressed. The first, to speed the ball test, was solved by increasing the number of cameras to three, instead of one, for each ball.

To look at the sanding process, USBC tested the same ball using a Surface Factory[20] equipment and also tested the ball after using a Cook Sphere Machine[21]. The differences in oil absorption between a ball that was placed in a Cook Sphere Machine versus a ball with the Surface Factory equipment was less than one minute and the average was less than 40 seconds.

The rate of oil absorption then was checked to see if having dirty water versus clean water in the sanding machine made a difference. Testing showed the water did not affect oil absorption times.

To determine if time between surface preparation and testing was a factor in oil absorption, USBC tested bowling balls at different intervals, re-sanded the balls and then tested again at different intervals. The tests did reveal the ball absorbed oil slower over time but that sanding returned the ball's absorption rate to close to its original rate. With this new information, the test method was adjusted to requiring the ball to be sanded within 24 hours of being tested.

20 Manufactured by Storm, used to adjust the surface of bowling balls
21 Manufactured by Jayhawk, used to adjust the surface of bowling balls

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To confirm the validity of the testing process, USBC consulted with an independent engineering and process expert with top credentials in manufacturing quality assurance. In assessing the acceptability of measurement uncertainty of the test, he specifically looked at Gauge Discrimination[22] and Percent Contribution.

Gauge Discrimination is a calculation that is a direct measure of gauge uncertainty and is reported in the same units as the measurement itself. Ideally, the value for this measure should be less than 10% of the tolerance; however, values as high as 20% are considered acceptable. The test procedure's gauge discrimination was 1.77 minutes. The gage R&R was conducted on balls with colors having oil absorption times between approximately four minutes and 14 minutes.

Percent Contribution is a calculation that is a direct ratio of gauge variance to total variance. The ideal value for this measure is less than 1%; however, values as high as 9% are very acceptable in manufacturing industries. Percent contribution was calculated and used, since the range of the study (approximately 10 minutes) nearly matches the range of the measurement of interest. The percent contribution was calculated as 5.25%, which is very acceptable.

The independent expert concluded USBC had shown through a scientific and statistical study that oil absorption of a coverstock can be measured with acceptable repeatability and reproducibility. Using a well-defined standard operating procedure and signal averaging were the pillars to success.

Key Takeaways

One of the more important items to consider is the fact a specification related to the oil absorption of a bowling ball has never been established. The USBC team will provide the data from this study to the USBC Equipment Specifications Committee, which is charged with making decisions regarding specifications.

That is not to say coverstocks have never been studied by USBC.

The coverstocks of bowling balls have been studied and the ability of a ball's coverstock to absorb lane oil is known to be crucial to ball reaction when compared to shells that do not absorb lane oil. When a ball absorbs the lane oil as it goes down the lane, and continues to absorb the oil between shots, it allows the surface of the ball to remain dry. And a dry ball, when contacting the lane, will provide more friction (and more hook) than a ball that has a lubricated surface because it cannot absorb oil.

As mentioned, USBC engineers did examine soaking balls to check the absorption rate but determined the better method was to calculate the rate of absorption by placing drops of oil on the bowling ball.

The oil absorption test will continue to progress over the next few months, and in coming years, because the lane and how it is oiled is such an important factor in the playing field of the sport.

As the process is adopted in manufacturing facilities, more education and data will come to light and USBC will continue to monitor and communicate with all stakeholders about what needs to happen moving forward.

22 Measurement System Analysis examples one and two.

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SECTION V:
LEAGUE SIMULATION STUDY

To have a better understanding of oil depletion and ball reaction for bowlers during competition, USBC conducted a **league simulation study** by having 10 right-handed bowlers — two teams of five bowlers — compete using a variety of equipment. The bowlers had averages between 188 and 229 in standard leagues during the 2016-2017 season.

The study took place over four days. Each day, the bowlers would bowl three games and were provided balls drilled with the same layout. Also, the coverstocks of the balls were sanded at the start of each day's test with 2000-grit Abralon.

The league simulation study was conducted on the same pair of lanes each day at the International Training and Research Center in Arlington, Texas. The same oil pattern also was used each day except for Day 4, when the oil volume was reduced 20 percent.

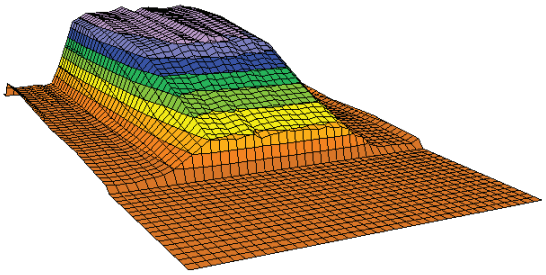
A day-by-day look at the league simulation study:

Day 1

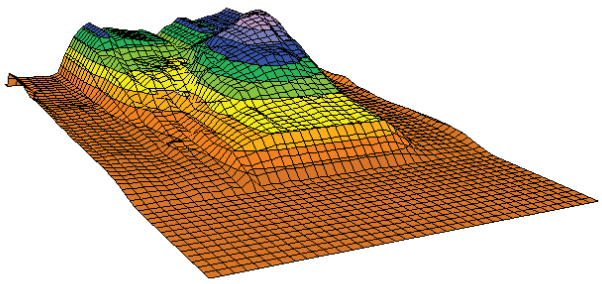
Bowlers were provided with a reactive ball used by today's bowlers. The ball had a high differential RG (between .050 and .060) and had a coverstock that had fast oil absorption.

Test parameters	Starting position on approach	Starting target at arrows	Finish position on approach	Finish target at arrows	Moves with feet	Moves at target
Day 1 (today's reactive)	20.7	12.4	30.1	18.5	9.4	6.1

To track oil depletion, tapes were taken before bowling and in between each game to view how the pattern was deteriorating over time.



Day 1 — Fresh pattern



Day 1 — Breakdown

The above graphics show significant changes to the pattern after bowling.

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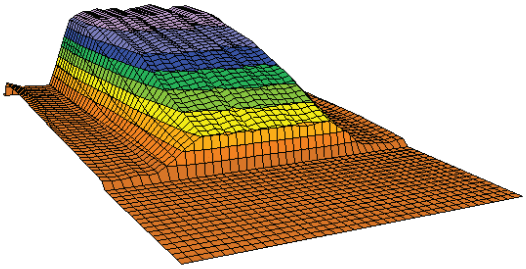
Day 2

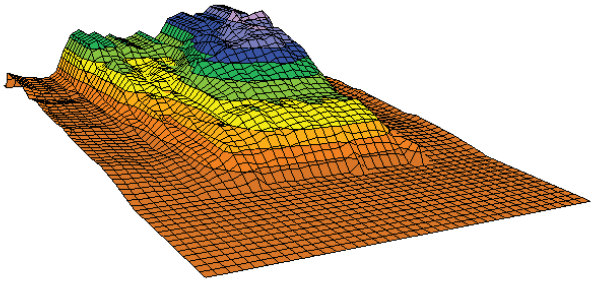
Bowlers were provided a reduced reactive ball that had a lower differential RG (between .040 and .045) and a coverstock with a slower oil absorption rate. A look at the bowlers' changes from Day 1 to Day 2:

Test parameters	Starting position on approach	Starting target at arrows	Finish position on approach	Finish target at arrows	Moves with feet	Moves at target
Day 1 (today's reactive)	20.7	12.4	30.1	18.5	9.4	6.1
Day 2 (reduced reactive)	19.1	11.5	24.9	15.4	5.8	3.9

Once again oil depletion was tracked and showed how the pattern deteriorated:



Day 2 — Fresh



Day 2 — Breakdown

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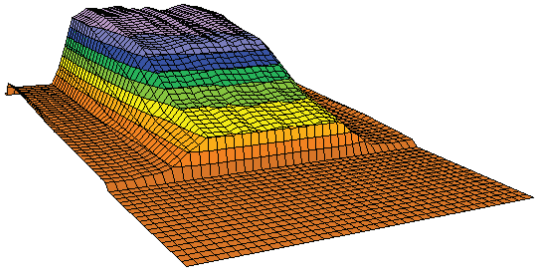
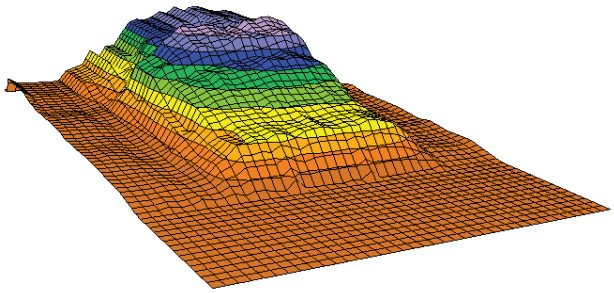
Day 3

Bowlers were provided a urethane bowling ball. A comparison from each of the three days and a graphical look at the breakdown of the oil pattern:

Test parameters	Starting position on approach	Starting target at arrows	Finish position on approach	Finish target at arrows	Moves with feet	Moves at target
Day 1 (today's reactive)	20.7	12.4	30.1	18.5	9.4	6.1
Day 2 (reduced reactive)	19.1	11.5	24.9	15.4	5.8	3.9
Day 3 (urethane)	14.2	6.3	16.7	8.6	2.5	2.3



Day 3 — Fresh



Day 3 — Breakdown

While it was more difficult to see the difference in oil depletion from Day 1 to Day 2, as it appeared the patterns were equally damaged, it is apparent the urethane balls used on Day 3 did drastically less damage to the lane condition.

To quantify the oil on the lane, USBC examined tapes at five positions down the lane — at 8, 22, 31, 40, and 44 feet. The 44-feet tape only was done after bowling to quantify if oil was being carried down the lane. The oil volume was given a value by adding up all the units of oil on each board, both, before and after bowling.

The values provided the following overviews:

Test Day	Balls	Before Bowling	After Game 1	After Game 2	After Game 3	Total Depletion	Depletion Per Game	Pct.
Day 1	Modern Reactive	5002	4582	4294	3519	1483	494.3	100%
Day 2	Reduced Reactive	5119	4789	4235	3698	1421	473.9	96%
Day 3	Urethane	4969	4755	4223	4052	917	305.8	62%

The data shows reduced reactive balls remove 96% as much oil as modern reactive balls, and urethane balls remove 62% of the oil removed by modern reactive balls. Reducing the properties of bowling ball as determined may not be a dramatic improvement in reducing the amount of oil removed from the lanes but it is a step in the right direction.

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Day 4

Bowlers were provided a reduced reactive ball, as they were on Day 2, but 80% oil volume was used for the pattern.

A look at the lane tapes, taken at 22 feet, to compare the oil patterns from Day 2 and Day 4.

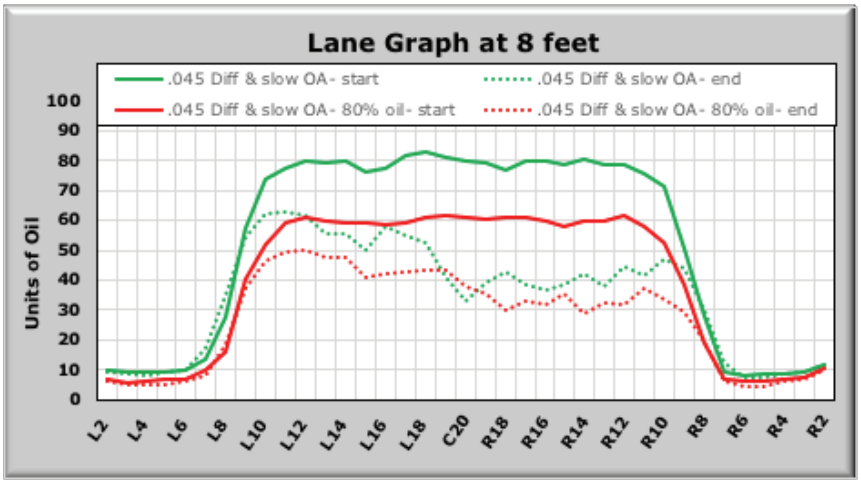

chart 22

Day 2 lines – Solid Green before bowling, dotted green is after
Day 4 lines – Orange is before bowling, Light green is after

Using today's reactive balls on Day 1 required the most moves in the front of the lane (9.4 boards with feet and 6.1 boards at target) while the Day 4 reduced reactive equipment and reduced oil conditions were similar to the moves made on Day 1.

Test parameters	Starting position on approach	Starting target at arrows	Finish position on approach	Finish target at arrows	Moves with feet	Moves at target
Day 1 (today's reactive)	20.7	12.4	30.1	18.5	9.4	6.1
Day 4 (reduced reactive, less oil)	20.4	11.6	27.5	15.4	7.1	3.8

Also, worth noting is the scoring pace of the teams in league simulation study.

Remember, the test took place on the same pair of lanes, with the same oil condition each day except for Day 4. The only changes made were the balls being used except for Day 4, when the oil volume was reduced 20 percent with the same pattern.

In chart 23, the difference in total pins for each test parameter was based on the total number of pins from Day 1, when using today's reactive resin ball was used. For example, when the only change was to go from today's reactive ball to a reduced reactive ball, the teams knocked down 345 fewer pins. When going from today's reactive ball to a reduced reactive ball with 80 percent oil volume on the lanes, the teams knocked down 89 more pins.

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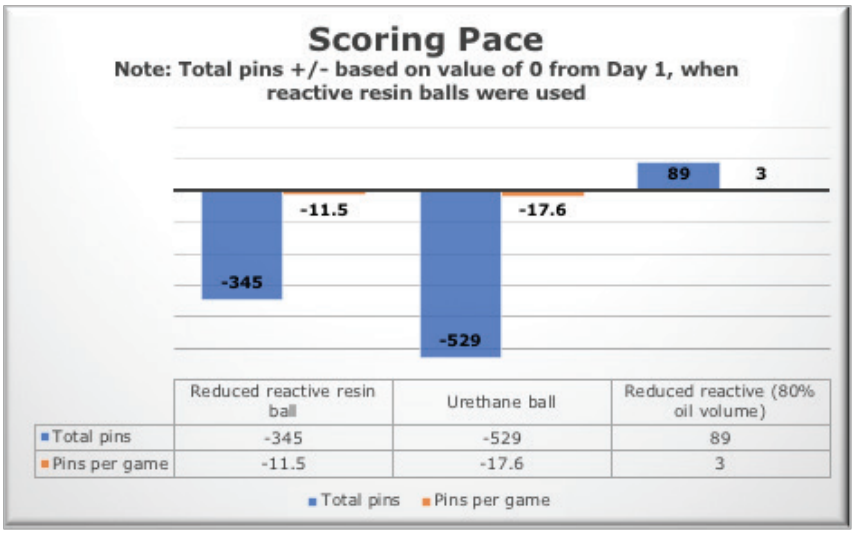

chart 23

Key Takeaways

When bowlers were provided with today's reactive resin bowling balls that had a high differential RG and fast oil absorption, the results are what bowlers are seeing in leagues and tournaments every week — bowlers and teammates having to constantly move to keep up with the transition of the lanes.

The key was to see what would happen if certain specification changes were made to the equipment. The Day 2 results showed a reduced reactive bowling ball — differential RG between .040 and .045, and with slower oil absorption — hooked less and required fewer moves, resulting in bowlers being able to play further outside, especially at the end of three games.

Urethane also was interesting as the bowlers had to play further outside. By the end of the third game, there was a dry area of almost five boards from the arrows to the end of the oil pattern as the bowlers only moved two boards over the three games.

But the key takeaway was to see the difference between Day 1 and Day 4. USBC wanted to see if the lane condition could be adjusted, yet still match how today's bowling balls perform on today's lane conditions and how it impacted scoring.

By using bowling balls with reduced oil absorption properties, which go straighter, it was possible to use 20 percent less oil on the lane but still allow the bowlers to start in the same location when competing. And despite having less oil on the lanes to start, with the use of slower-absorbing balls the bowlers had to make fewer moves — moves with feet went from 9.4 boards to 7.1 and moves at target went from 6.1 boards to 3.8.

In addition, scoring remained nearly the same — it actually showed an increase of about three pins per game — with the reduced oil absorption ball on 20% less oil.

The table below shows that the amount of oil pulled up from the lanes was about two-thirds of the oil depleted when using today's bowling balls in the heavier oil pattern. So, while the amount of oil removed from the lanes was more in line with the amount removed by a urethane ball, the bowlers still were able to hook the ball similar to the reactive balls used on today's conditions and score like they do today.

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A look at how the oil was placed on the lane each day and the effect on the lane oil by the bowlers each day:

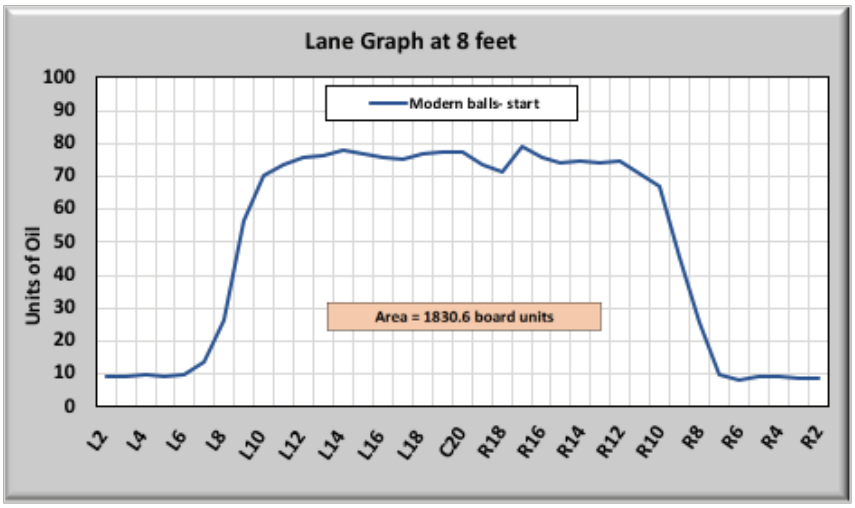

chart 24

Ball	Oil Before Bowling	Oil After Bowling	Oil Removed	Percent Removed	Comparative Oil Removed
High flare & fast oil absorbing balls	5002	3519	1483	29.6%	Baseline
Reduced flare & slow oil absorbing balls	5119	3698	1421	27.8%	4.2% less
High flare urethane balls	4969	4052	917	18.5%	38.2% less
Reduced flare & slow oil absorbing balls on 80% oil volume	4247	3195	1052	24.8%	29.1% less

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SECTION VI:
FACEBOOK POLLS

Discussions of technology's effect in sports have been ongoing since competitive sports began, and bowling has been asking many of the same questions: Should bowling continue to support advancements in technology that might negatively impact the sport? Should tougher limits be placed to prevent further advances? Do specifications need to change to reduce technology's impact on the sport?

In March of 2017 — as part of its ongoing research study — USBC posted a series of quick polls on its Facebook page[23], to see how bowlers and bowling fans viewed today's technology in the sport. USBC, as part of that study, also started asking questions at all levels of bowling through industry **focus groups**.

The Facebook polls were conducted knowing those who follow USBC on Facebook are bowling's most avid fans, the sport's most engaged participants and that they would respond to the polls. The polls were not meant to be scientific, but an exercise to get people thinking about bowling technology and to create conversations, which it certainly did.

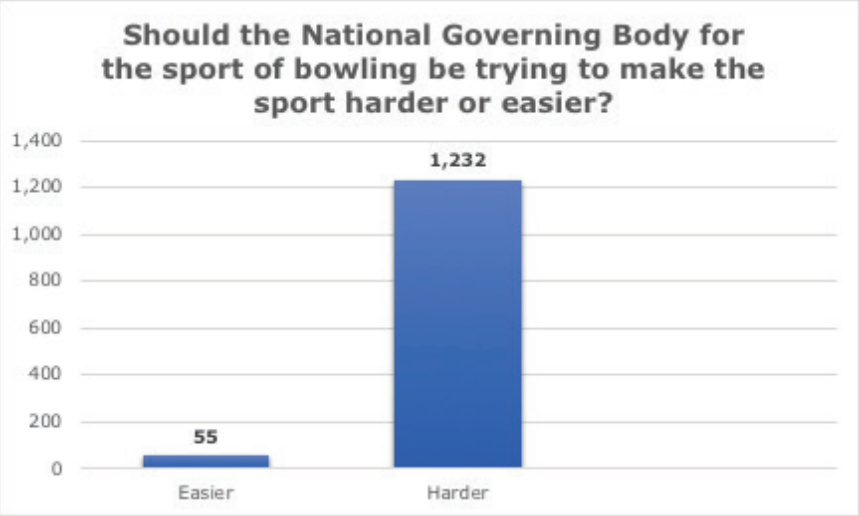
The information learned from the Facebook polls is a perspective of a certain group, not a data point. The posts for the series of questions informed those who viewed the post that USBC was conducting research into the sport, specifically technology, as well as certain elements that affect the sport.

It also stated USBC has made efforts during the last few years to make its tournaments more challenging by limiting the number of balls for competition, changing the rule on surface adjustments, and altering its stance on revealing the lane patterns ahead of time. These efforts were made with the goal being to provide fair competitions, a higher level of integrity and simple adjustments that, in theory, make the sport more challenging.

The posts asked participants to simply provide one-word answers to the post; to ensure respondents did not influence others, USBC selected to remove responses that provided additional comments.

The questions and the results of the Facebook polls:

Facebook Poll No. 1
Date: March 8-9, 2017
Total responses: 1,287



23 **www.facebook.com/usbc** has approximately 275k followers

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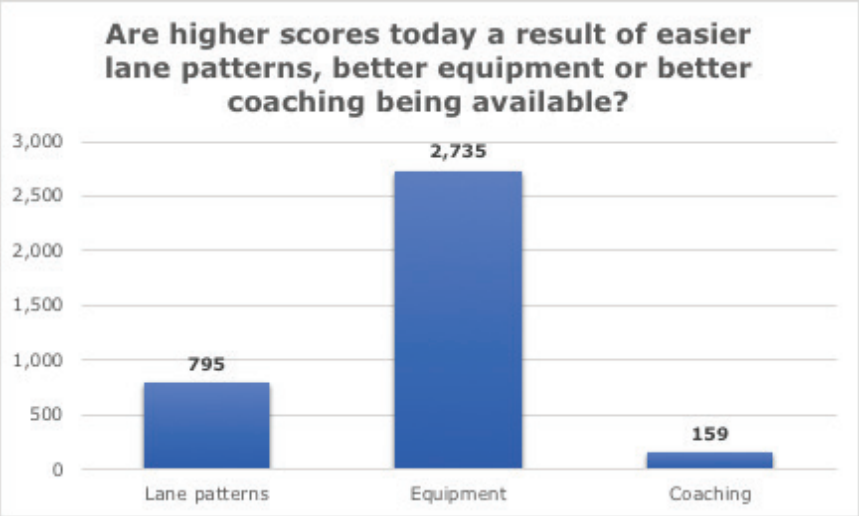
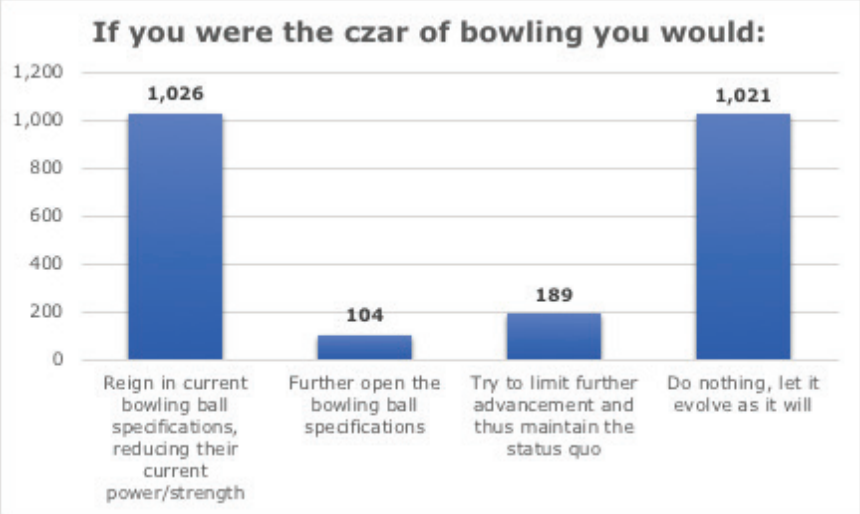
Facebook Poll No. 2
Date: March 15-16, 2017
Total responses: 3,689



Facebook Poll No. 3
Date: April 5-6, 2017
Total responses: 2,340



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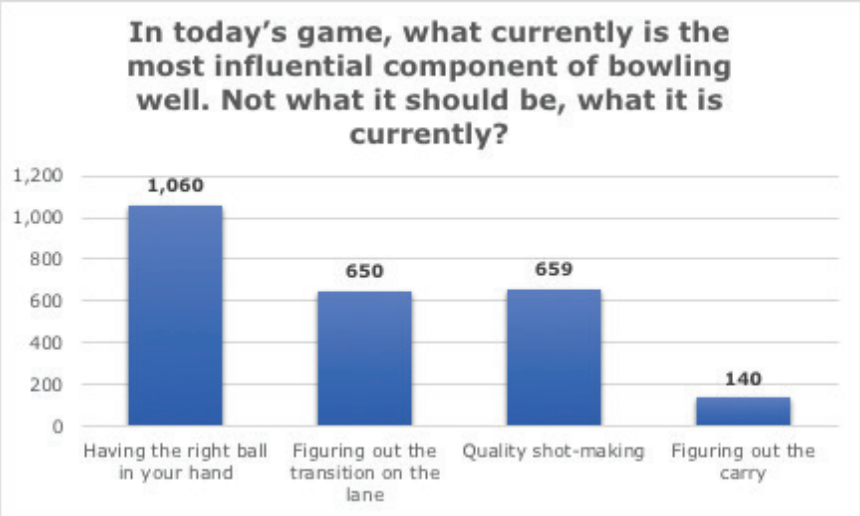
Facebook Poll No. 4
Date: April 12-13, 2017
Total responses: 2,509



Key Takeaways

Most respondents felt USBC should make the sport harder (96%) and that the equipment was the main factor of higher scores (74%). The group was split on whether they would reign in current ball specifications (44%) or do nothing and let technology evolve as it will (also 44%).

And while figuring out lane transition and quality shot-making were ranked as influential (each was 26%), the majority said the most influential component of bowling well in today's conditions is having the right ball in your hand (42%).

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SECTION VII:
INDEPENDENT SURVEYS

While USBC continuously studies the technology, it also seeks input from those who bowl, those who run the bowling centers and those who work with the equipment bowlers use.

USBC received an independent, objective and research-based analysis on the effects of technology in the sport through surveys to members of the Bowling Proprietors' Association of America (BPAA), International Bowling Pro Shop and Instructors Association (IBPSIA) and to USBC members.

The online surveys were distributed via the BPAA, IBPSIA and USBC databases between April and August of 2017.

Group	Survey population	Total survey responses	Survey response rate
BPAA members	2,719	287	11%
IBPSIA members	458	92	20%
USBC members	728,937	18,844	3%
Total	732,114	19,223	3%

Theoretical margin of error — BPAA +/-5.5%; IBPSIA +/-9.1%; USBC +/-0.7%
(based on a 95% confidence interval on questions where opinion is evenly split)

Before examining the survey results, we first need to understand the people who responded to the survey.

Let's start with a breakdown of the USBC members who submitted their opinions and highlight the key numbers:

USBC Respondents

Age and experience

- 74% male
- 90% are 30 or older with 27% age 30-49
- ***85% have bowled for at least six years***, 63% for 21 or more years
- 54% bowl in a league one time a week, 29% twice each week
- 55% bowl in 1-5 tournaments each year

Equipment and average

- 42% say they are average bowlers, 45% are above average
- ***64% use 1-2 balls when bowling***
- 47% own 2-4 balls
- ***28% average 151-180***
- 26% average 181-200
- 22% average 201-220

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Knowledge of equipment and lanes

- 59% rated their knowledge of bowling technology as basic or fair
- 24% rate themselves as knowledgeable of bowling technology
- ***72% rated their knowledge of lane conditions as basic or fair***
- 51% say they notice lane conditions changes each game
- 77% rated their knowledge about overall flatness of lanes and its importance as minimal, basic or fair

Based on responses, we can see the average USBC respondent has bowled for at least six years, competes in a weekly league, and bowls the occasional tournament.

It also is interesting to note that 64 percent of these USBC members use only 1-2 bowling balls when competing, the majority average 180 or less, and about three-quarters of the respondents have an OK understanding of lane conditions and flatness of lanes.

Next, a breakdown of IBPSIA members who responded, once again highlighting key numbers:

IBPSIA Respondents

Age and experience

- 95% male
- 74% age 50-plus; 23% age 30-49
- ***91% have bowled for 21 or more years***
- 70% bowl league more than once a week
- 95% bowled in at least one tournament each year

Equipment and average

- 79% say they are above-average bowlers, 17% are elite bowlers
- ***71% use 1-4 balls when bowling***
- 90% own 5 or more balls
- 53% average between 201-220
- 25% average more than 220

Knowledge of equipment and lanes

- 55% say they are knowledgeable about bowling technology
- 41% rate themselves as experts in bowling technology
- ***69% rate themselves as knowledgeable on lane conditions***
- 48% notice changes to lane conditions each game
- 50% notice changes to lane conditions shot to shot
- 64% rated their knowledge about overall flatness of lanes and its importance as knowledgeable, 26% as expert

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The average IBPSIA respondent is a high-average bowler who competes in a couple of leagues each week, bowls in tournaments, owns several bowling balls, and is knowledgeable about lane conditions.

Of course, this is what one would expect from a pro shop operator. IBPSIA members are invested in the sport; it is their livelihood and, because they also are competitors, they need to understand all aspects to the sport. You also would expect they would own more bowling balls than the average bowler — 90 percent own five or more — yet they use four or less balls when they compete.

Last, a breakdown of the BPAA members who responded, again highlighting key numbers:

BPAA Respondents

Age and experience

- 84% male
- 66% age 50-plus; 30% age 30-49
- 25.9 average numbers of lanes in center (24 median)
- 18.7 average number of certified leagues that center hosts each week (9 median)
- 7.3 average number of tournaments center hosts each year (4 median)

Knowledge of equipment and lanes

- 68% own 2-8 bowling balls
- ***95% use 4 or less balls when bowling***
- 49% say they are knowledgeable or expert about bowling ball technology
- ***66% rate themselves as knowledgeable or expert on lane conditions***
- 22% rate their knowledge as fair on lane conditions
- 59% notice changes to lane conditions each game
- 18% notice changes to lane conditions shot to shot
- 52% rated their knowledge about overall flatness of lanes and its importance as knowledgeable, 10% as expert

The median was noted for league and tournament data because several centers are much busier, which skewed the averages higher.

For BPAA members, bowling is their business, so it is expected a high majority (88%) rated their knowledge of lane conditions between fair and expert. Regarding the overall flatness of the lanes and its importance, 62% said they were knowledgeable or experts with another 22% saying their knowledge in this area was fair.

Survey Responses — By Affiliation

To start, let's look at responses to questions about bowling technology. Those taking the survey were asked to rate their overall satisfaction level with the quality of bowling technology on a scale of 1-5, with 5 being very satisfied.

Each group's response showed an above-average satisfaction with the overall quality of bowling technology, with all three groups coming in between 60 to 63 percent. Seven percent of USBC members, 10 percent of IBPSIA members and 13 percent of BPAA members had a below-average satisfaction rating.

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To further understand each group's opinion about bowling technology, they were presented with several statements related to lanes and bowling balls. Again, respondents were given a scale of 1-5, with 5 meaning they strongly agree with the statement and 1 that they strongly disagree.

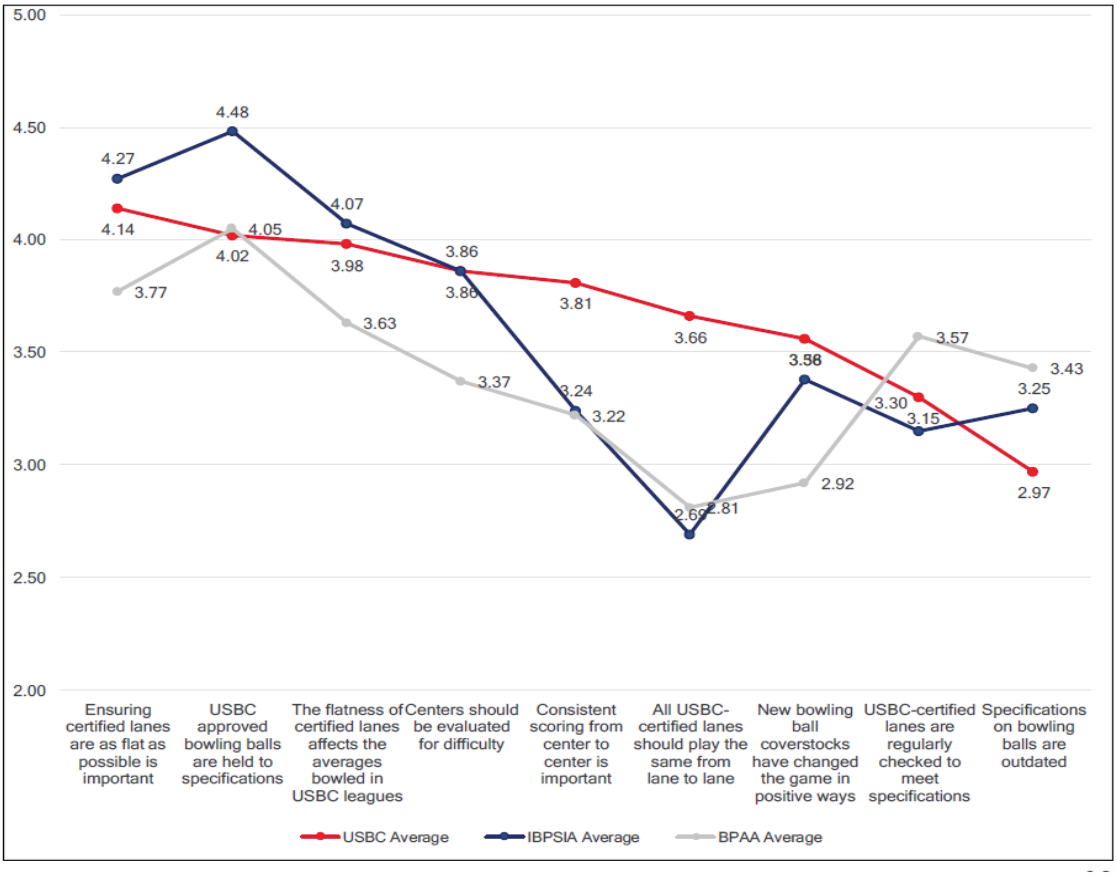
All groups agreed ensuring certified lanes are as flat as possible and that USBC approved bowling balls are held to specifications were important factors.

Again, with a 5.0 rating meaning they strongly agree, IBPSIA members averaged 4.27, USBC members were at 4.14 and BPAA members at 3.77 on the importance of flat lanes. Bowling balls being held to specifications averaged a 4.48 response from IBPSIA members while USBC and BPAA members were at 4.02 and 4.05, respectively.

The groups also agreed the flatness of certified lanes affects averages bowled in USBC leagues (BPAA 3.63, USBC 3.98, IBPSIA 4.07) and that centers should be evaluated for difficulty (BPAA 3.37, both USBC and IBPSIA at 3.86).

The one statement that drew the largest difference in response was that all USBC-certified lanes should play the same from lane to lane. USBC members leaned more to agreement of that statement at 3.66, but IBPSIA and BPAA members leaned toward disagreeing at 2.69 and 2.81, respectively.

Three additional questions drew a more neutral response from the groups: New bowling ball coverstocks have changed the game in positive ways, USBC-certified lanes are regularly checked to meet specifications, and specifications on bowling balls are outdated.



When more specific statements about lane conditions were presented, the majority agreed lane machine technology has had a positive impact on bowling. But the groups were a little more divided as to the type of lane conditions on which they should compete.

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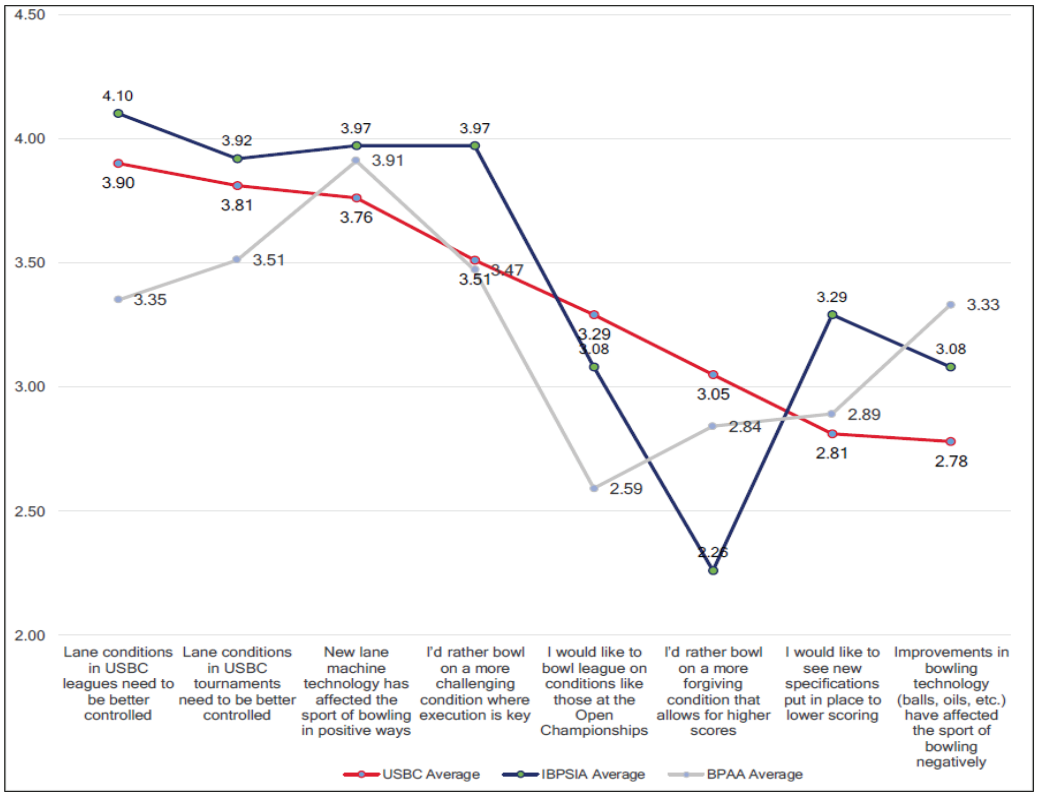
IBPSIA respondents, who we have determined are bowlers with higher averages, said they would not want to bowl on easier conditions that would allow for higher scores (2.26) and leaned more toward the statement that they would rather bowl on a more challenging condition where execution is key (3.97). BPAA and USBC members were more neutral about bowling on more forgiving conditions (2.84 BPAA, 3.05 USBC) or on more challenging conditions (3.51 USBC, 3.47 BPAA).

As for whether they would like to see specifications put into place to lower the scoring pace, BPAA and IBPSIA members leaned slightly against the idea (2.81 IBPSIA, 2.89 BPAA) while USBC members were more neutral (3.29).

Neither group felt strongly, either in agreement or disagreement, that bowling balls, oil and other technological advancements had negatively affected the sport.



The response to the statements show each group felt positive regarding the improvements in bowling technology during the last three decades. Overall, the attitude of USBC respondents was 75 percent positive or very positive while IBPSIA were at 67 percent and BPAA at 57 percent.

Those holding a negative attitude were rated at nine percent for USBC, and that number was more than double for IBPSIA (20 percent) and BPAA (22 percent) members.

So, what did the groups say the biggest factors are that contribute to the higher scoring pace?

All groups agreed the biggest factors were lane conditions and bowling balls. While the groups were almost dead even in agreement about bowling balls being a factor (38 percent BPAA, 37 percent USBC, 36 percent for IBPSIA), lane conditions were listed by more than half of the IBPSIA members (55 percent), 49 percent by BPAA members and 44 percent of USBC members as the greatest factor.

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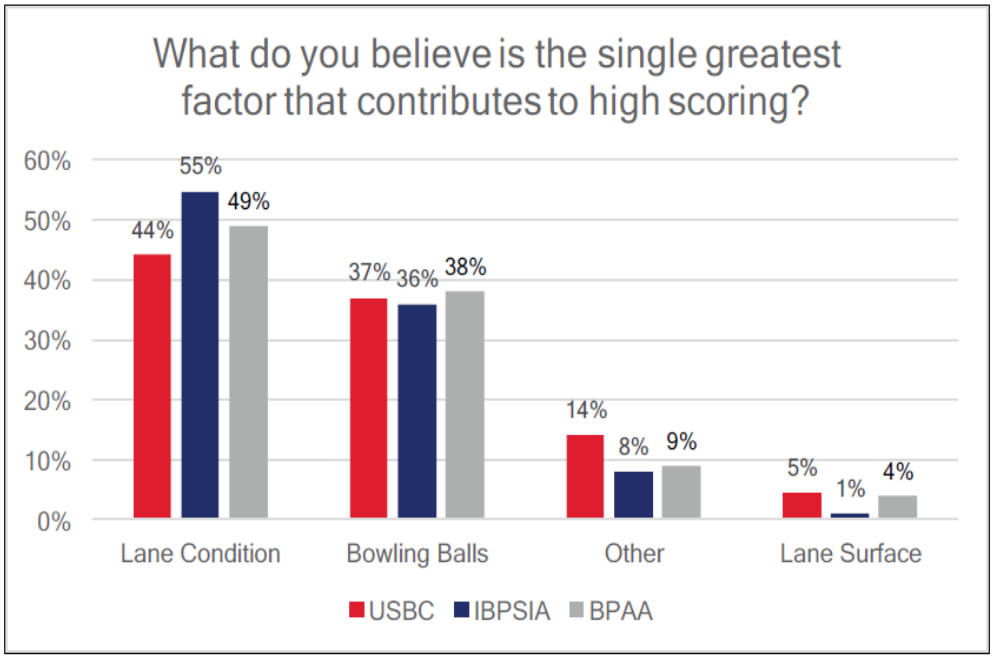
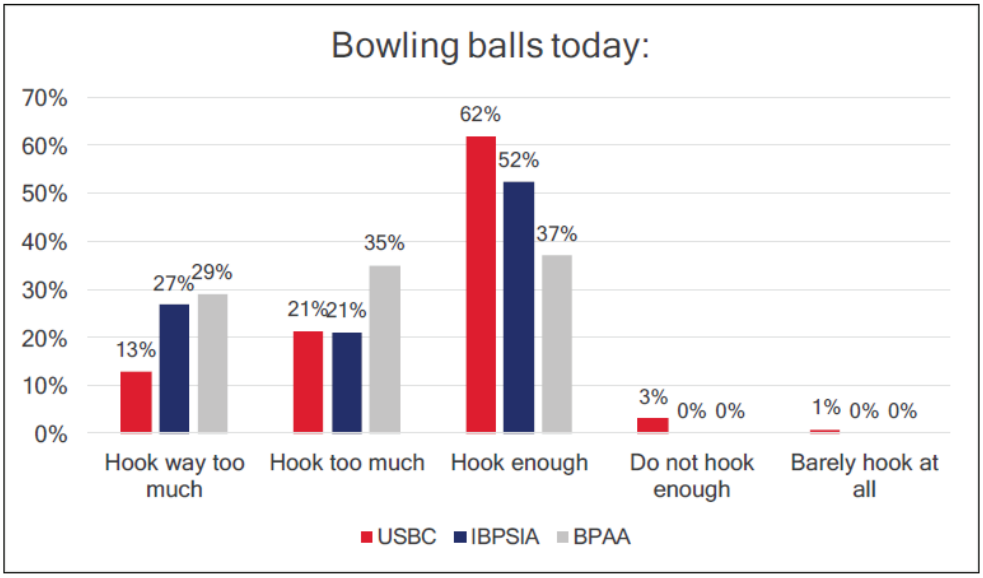


The majority of USBC (62 percent) and IBPSIA (52 percent) members agreed today's bowling balls hook just enough while only 37 percent of BPAA members agreed. A much larger percentage of BPAA members (64 percent) said bowling balls either hook too much or way too much, with 48 percent of IBPSIA members and 34 percent of USBC members in agreement.



What also is important to note is that every IBPSIA and BPAA respondent, and 96 percent of USBC members, agree today's bowling balls hook enough, hook too much or hook way too much.

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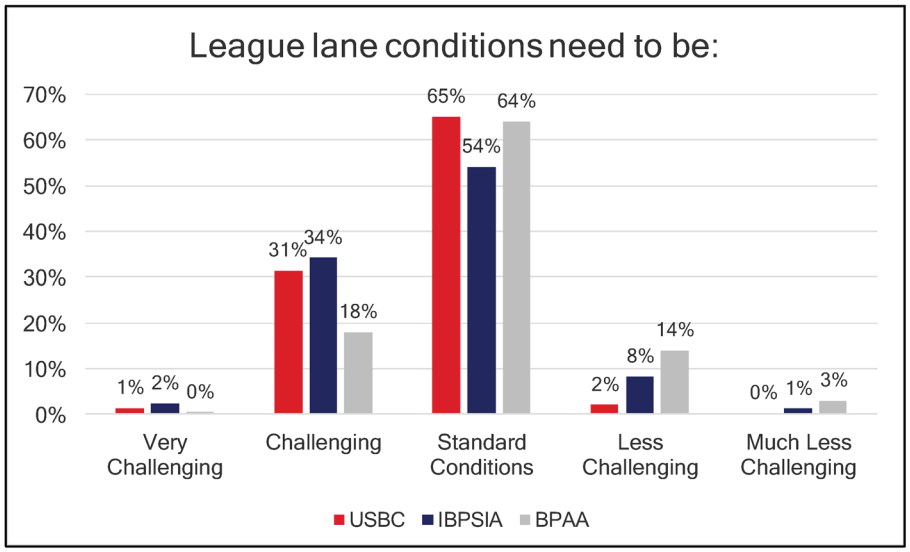
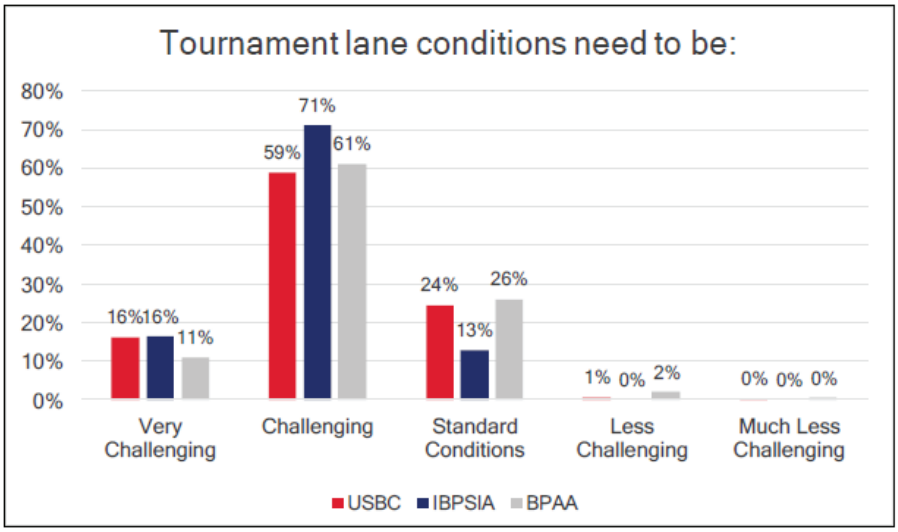
Each group also had strong opinions about the lane conditions that should be used for tournaments. But first, a look at the reason the members of each group bowl.

We mention again that IBPSIA members are highly engaged in the sport, so it is expected that 67 percent said the reason they bowl is the competition. While 36 percent of USBC members and 31 percent of BPAA members also say competition is the reason they bowl, half of USBC respondents and 51 percent of BPAA respondents cite recreation or social purposes as the reason they head to the lanes.

No matter the reason for bowling, the majority in each group agreed standard conditions are OK for league play, but 75 percent of USBC members, 72 percent of BPAA members and 87 percent of IBPSIA members stated challenging or very challenging lane conditions should be used for tournaments.





USBC and BPAA members shot down the idea bowlers want to compete on easier conditions when they bowl league. Only two percent of USBC respondents and 14 percent from BPAA said they would like to see less challenging conditions in league competition; 65 percent of USBC and 64 percent of BPAA respondents said standard conditions are fine for leagues.

USBC already has started to address issues about lane conditions by instituting a new designation for leagues competing on conditions that fall between Standard and Sport. Based on research from leagues that competed

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under a Sport/Challenge designation, the Challenge lane condition designation and conversion chart was established starting with the 2017-2018 season. Visit **BOWL.com/SportBowling** to see the **study** and the **Sport** and **Challenge** conversion charts.

As for the flatness of lanes, USBC has announced new requirements for lane inspections and will adjust specifications for new installations for the 2019-2020 season based on research conducted by the USBC Equipment Specifications and Certifications team. The research included analysis of the lane certification paperwork submitted by 323 centers, and an examination of more than 1,000 lanes throughout the country. Read the full study **here**.

The changes are part of an ongoing process as USBC continues to seek ways to ensure reported averages are a true reflection of a bowler's abilities.

One other piece of information worth noting is how the bowlers look at those who use a two-handed style. Two-handed bowling has become more commonplace in the last 10-15 years, popularized by pro bowlers such as Jason Belmonte and Osku Palermaa.

But is two-handed bowling good for the sport? Forty-one percent of IBPSIA respondents say yes, while 23 percent of USBC respondents and 27 percent of BPAA respondents felt two-handers are good for the sport. A larger percentage of USBC respondents (49 percent) were indifferent about two-handed bowlers, while 36 percent of IBPSIA and 40 percent of BPAA respondents were indifferent about two-handers in the sport.

The majority in each group did say they prefer today's bowling equipment (USBC 60 percent, IBPSIA 45 percent, BPAA 34 percent) and lane surfaces (BPAA 59 percent, USBC 55 percent, IBPSIA 52 percent).

When it comes to the lane conditions, most USBC (49 percent) and BPAA (38 percent) respondents also prefer today's conditions but 29 percent of the IBPSIA group prefer lane conditions from the 1990s.

The groups did agree the 1970s (BPAA 43 percent, IBPSIA 36 percent, USBC 25 percent) and the 2010s (USBC 33 percent, IBPSIA 29 percent, BPAA 17 percent) are the decades that produced the most skilled bowlers over the last five decades.

Survey Responses — By Bowler Averages

Having categorized the survey results based on affiliation — BPAA, IBPSIA or USBC member — looking at how bowlers responded based on their skill level also offers insight.

Bowlers were put into five average categories — those with an average of less than 150, averages of 151-180, 181-200, 201-220, and an average of 220 and over. Answers to some questions did provide a much different result, depending on the bowler's average.

They once again were provided statements and asked to rate on a scale of 1 to 5 with 5 being that they strongly agree.

When asked if all USBC-certified lanes should play the same from lane to lane, results show the higher the average of a bowler, the more likely they would disagree with the statement. Bowlers with the highest averages disagreed (2.98 average) while bowlers with a 150-and-under average agreed with the statement (3.98).

Opinions were almost equally separated on the statement that consistent scoring from center to center is important — high-average bowlers disagreed, lower-average bowlers agreed.

No matter the average, all groups agreed ensuring certified lanes are as flat as possible is important, and the flatness of lanes affects averages in certified leagues.

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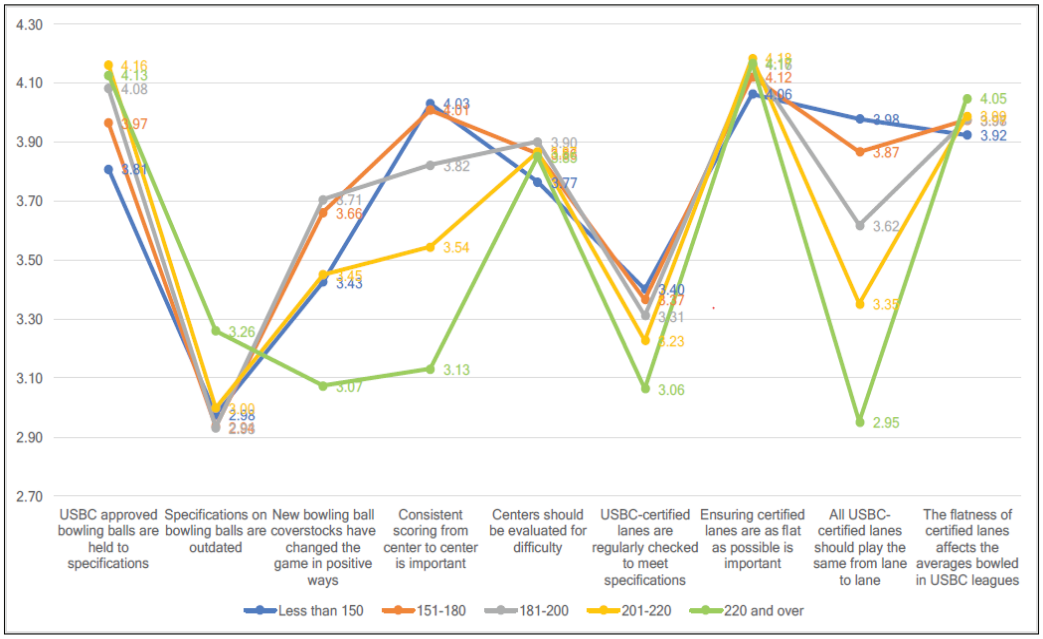
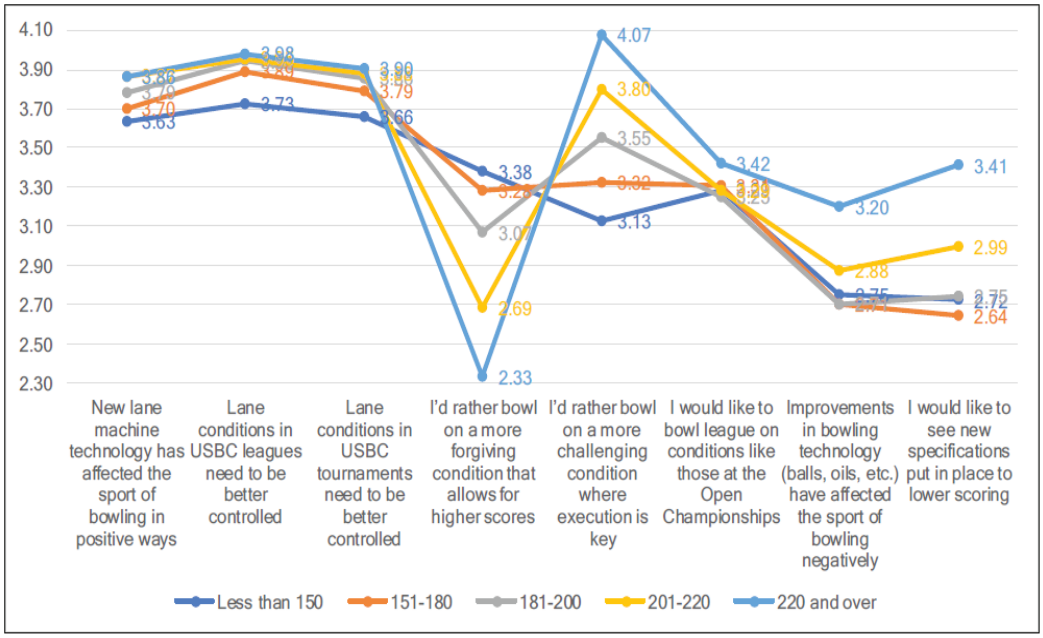


A bowler's average also had a direct correlation on the lane conditions they would like to bowl on. While lower-average bowlers would like to compete on more forgiving conditions that allows for higher scores, high-average bowlers want more challenging conditions where execution is the key.

No matter the average, all agreed new lane machines have affected bowling in positive ways and lane conditions in USBC leagues and tournaments need to be better controlled.



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Key Takeaways

The surveys provided data about the people who compete and those who are involved in the day-to-day operation of the sport. Some of the key items to note about the people who responded to the surveys:

How long they have bowled

- 85% of USBC respondents have bowled for at least six years
- 91% of IBPSIA members have bowled for 21 or more years

Number of bowling balls used when competing:

- 64% of USBC bowlers use 1-2 balls
- 71% of IBPSIA members use 1-4 balls
- 95% of BPAA members use 1-4 balls

Bowling averages:

- 54% of USBC bowlers average less than 200, 28% average 151-180
- 79% of IBPSIA members rate themselves as above-average bowlers

Knowledge of lane conditions:

- 72% of USBC bowlers rate their knowledge as basic or fair
- 69% of IBPSIA members rate themselves as knowledgeable
- 66% of BPAA members rate themselves as knowledgeable or expert

While they approach the sport from different perspectives, the three groups — bowling proprietors, pro shop operators, and league bowlers — agree on several items:

- Lane conditions and bowling balls are the biggest factors affecting scoring
- USBC-approved bowling balls must be held to specifications
- Ensuring the flatness of lanes is important and it affects averages
- Lane machine technology has had a positive impact on bowling
- Above-average satisfaction with the overall quality of bowling technology
- Standard lane conditions are OK for league play, but tournaments should provide more challenging lane conditions
- Lane conditions in USBC leagues and tournaments need to be better controlled
- Every IBPSIA and BPAA respondent, and 96 percent of USBC members agree that today's bowling balls hook enough, hook too much or hook way too much.

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SECTION VIII:
FOCUS GROUPS

The surveys did provide a great deal of information but USBC also wanted to bring together people in the industry to discuss the future of bowli

Setting up focus groups would provide an opportunity for those invested in the sport to exchange ideas and opinions about technology in bowling, and to also have them consider how they would respond if they were responsible for the specifications for bowlin

Focus groups of proprietors and pro shop owners were invited to visit the International Bowling Campus in March and April of 2017, and a summit of bowling leaders was held a few months later to further discuss the sport of bowling.

Each group went through a series of exercises that would culminate in answering seven questions about the state of bowling, including where they saw the sport in the future and the sport's technology. The questions to answer were:

- What is the current state of the sport?
- Where do we see the sport in the future?
- Define what we believe to be the most influential factors within the technology?
- Do we want to see a rollback in technology?
- Would our customers support a rollback in technology without leaving?
- If a rollback, how would we do it?
- What does the group believe to be the most influential marketing area bowling should invest in?

A group exercise kicked off the sessions for the proprietors and pro shop operators. Each was asked: What would you like to accomplish during the next two days? and were tasked with collectively delivering a statement to serve as a guideline for their focus group. Because of a shorter timeframe, the summit of bowling leaders bypassed this part of the exercise.

The next step was to pose a series of questions to generate an exchange of ideas. The questions were crafted for topics that would be discussed toward the end, with the most important topics having multiple questions. Additional questions on a given topic were designed to be similar but with different outcomes, so they would confirm or deny the groups findings.

The questions were meant to spur discussion, promote ideas and have each group work toward a consensus. A look at the questions provided:

1.) The sport of bowling is currently

a) Headed in the right direction

b) A complete disaster

c) In a good place, set to evolve into the future

d) An industry in need of a lot of fine-tuning

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2. Bowling is on the decline because

a) Game got too easy

b) Time commitment is too long

c) Social factors

d) Business factors

3.) Bowling ball technology has been:

a) Good for the game/sport

b) Bad for the game/sport

c) Good for the game, bad for the sport

d) Bad for the game, good for the sport

4.) If you were the czar of bowling you would

a) Reign in the ball specifications

b) Open up the specifications

c) Try to limit further advancement and maintain the status quo

d) Do nothing, let it evolve

5.) Did scoring advance because

a) The balls got out of control?

b) The patterns were made to easy?

c) Bowler education advances?

d) Lane machine technology advances?

6.) If bowling technology was taken backward and league scores were reduced by 20 or more pins would your bowlers

a) Celebrate the change?

b) Quit soon after?

c) Think of it as a non-issue, they would bowl regardless?

d) Become outraged, disenfranchised then less interest?

7.) If you made a change to the balls

a) Slow oil absorption (making the balls last longer and hook less)

b) Reduce the coefficient of friction

c) Raise the RG/Lower the differential RG

d) Eliminate resin balls completely

8.) The best bowlers came from what era?

a) 1970s

b) 1980s

c) 1990s

d) 2000s

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9.) Two-handed bowling is good for the sport

a) Yes

b) Indifferent

c) No

d) Absolutely not

10.) Having a certified lane inspection process is

a) No longer important

b) Important

c) Never going to work long term, centers can't afford it

d) Essential to the long-term viability of the sport

11.) What should be the most influential component of bowling well

a) Having the right ball in your hand

b) Figuring out the transition on the lane

c) Quality shot-making

d) Figuring out the carry

12.) What would be the best improvement for bowling?

a) A return to the past in terms of the specifics of the sport

b) Continued advancement in all areas

c) The easier the better, we should figure out new ways for new bowlers to do better sooner

d) A slight, gradual roll back of the bowling balls

13.) Bowling has declined over the years because

a) Nobody cared to do the right thing in regards to technology

b) The world evolved and bowling got left behind

c) People lost the drive to practice and get better at it

d) Financial concerns such as lower availability to discretionary income

14.) Bowling balls have evolved over the years both inside and out. I would say

a) The game is too complicated now

b) The strategy necessary to be good at the sport has been a positive outcome from it

c) I love it, gives me more options to sell the aspects of the sport

d) It really is just what it is, and I support it

15.) If the game evolved in a way that made it harder, my customers would

a) Practice more

b) Do exactly what they do now

c) Become more interested in it

d) Would not at all be interested in that

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16.) From a marketing perspective, the best way to build bowling is

a) From the top, invest in the pros

b) From the bottom, youth bowling is the most important now

c) We need to get back to the common bowler, my core customer; what's in it for them?

d) Top of mind awareness spends

17.) Bowling is as cool as it's ever been because

a) Family entertainment Centers (FECs) and the nightclub scene

b) Pop culture uses it more than ever in commercials, TV shows, etc.

c) It's not

d) We have shifted priorities at national from sport to recreation

18. My customers

a) They just want to strike, and they don't care how easy it is

b) They just want to have a good time; their score doesn't really matter

c) They believe bowling is hard enough and would like them easier

d) They would like a return to lower scores and an emphasis on shot-making

19.) The No. 1 "event" that has impacted scoring the most

a) Resin balls

b) Fresh backend of the lane being possible with each run down the lane

c) Core dynamic enhancements

d) Short oil/3-unit rule/pattern development

20.) I believe

a) Bowling is poised for a comeback

b) Bowling will continue to decline over the next three decades

c) Bowling is what it is and that's a good thing; it will continue to evolve and that's a good thing

d) Bowling is still the best way that exists to be competitive and social at the same time

Following a discussion period that went between two and four hours, each of the groups were divided into smaller groups. For the breakout session, the groups are provided the ball specifications out of the manual and were asked to be the USBC Equipment Specifications and Certifications team.

In the role of the USBC Equipment Specifications and Certifications team, the groups were asked: What would you do? They were given an hour and a half to discuss options and then made presentations to their collective group.

A summary discussion closed the meeting.

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Pro Shop Operators

Pro shop operators visited the IBC in March of 2017.

Assembling a diverse group — keeping number of shops operated and geography in mind — was the goal, making sure to have at least one operator with only one store in ownership, at least one with more than one but no more than five shops, and one with more than 10 shops, and to have representation from throughout the country.

Twelve invitations were sent and all 12 accepted. Ownership ranged from one shop to nearly 50; overall, 125 shops and two online businesses were represented with total revenue of about $18 million combined.

The statement, in response to the question of what they wanted to accomplish during the summit, was that they wanted to understand where the governance of bowling is headed, and they wanted to work together to provide the best possible information to shape the future in a positive way. They said they have been looking to have a voice and can provide insight, and they want to see all groups work together to shape the sport's future.

The majority believes the state of the game is good, but does need fine-tuning, and that social and business factors are the reason for the decline. A very small faction did find scoring to be a reason for decline. While they were somewhat split on the sport's future, six believe bowling remains the best way to be social and competitive at the same time.

While the ball, lane oil, lane machines and lane pattern were discussed, 10 of the 12 pro shop operators say the ball is the most influential technology factor in bowling; one said the oil patterns and another said lane machines. Placement of weight holes for bowling balls also was a concern for some.

In discussing rollbacks in technology, the majority was in favor of modifications and believe it would not significantly affect the customer. All want to see a specification for oil absorption and said any rollout would need to occur in three or four years to allow manufacturers time to react and that current balls needed to be grandfathered in.

Pro shop operators stated the recent decline in league bowling is related more to social and business factors, but that bowling also is the best way for people to be social and competitive at the same time.

As for what is the most influential marketing area, the pro shop operators stated a balance in all areas — pro, youth, league, recreational, and top-of-mind awareness — was needed and are all important aspects.

Bowling is not only a passion for pro shop operators, it is their business. Their investment in the sport goes beyond just equipment, they have seen the effects of technology and they also see that making gradual improvements to specifications would be in the best interests of the sport. As the ones who sell, drill and discuss bowling balls with customers each day, they felt their customers would be willing to accept changes that are reasonable.

The results from the group:

- 10 of the 12 think the ball is the most influential factor in bowling's technology
- Most of the group is in favor of a roll back in technology
- Each group said they would like to see a specification for oil absorption
- One group wanted to see total differential reduced 25 percent
- One group wanted to see coefficient of friction reduced 25 percent
- All groups said a rollout of specification changes would need to be over 3-4 years

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Proprietors

The summit for proprietors took place in April 2017. Once again, a diverse group in ownership — a single-center owner to an owner of more than 10 centers — with representation from across the country was sought.

Seven proprietors accepted the invitation. Among the group was the owner of a 14-lane center that annually has 700 league bowlers, a proprietor who operates 10 centers that include traditional and recreation centers, an owner of eight centers who has been in the business for more than 40 years, and a family-owned business operating a couple of centers. Overall, 32 bowling centers and a distributor were represented with a total revenue of $74 million.

For their statement on what they wanted to accomplish during the summit, proprietors said league bowling was important to them, and also important to the business and the sport. They want to provide some vision to USBC to help reduce the wear and tear on the lanes, using data and not emotion to make the decisions. As to what should be the future of our business, regarding league bowling, proprietors said fairness for all bowlers should be one of the goals.

They stated the bowling ball was the most influential factor in bowling technology, and six members believe a rollback in technology is necessary while one suggested an adjustment. They also believe customers would either not notice the difference or adjust to the environment.

Proprietors discussed the increased cost of oil and the wear and tear of the lanes because of oil absorption rate of the balls and added a rollback should not "nibble around the edges" and that any rollbacks should be based on data collected. They stated oil absorption and coefficient of friction should be looked at.

As for the areas where bowling should invest to have the most influence, most proprietors simply felt marketing efforts should be focused locally and delivered in all areas as noted above.

The proprietors in the focus group are, first and foremost, business people. Bowling is their livelihood. While they might have been a little wary of discussing their business, several did express concern about the way bowling balls affect their lanes, the amount of oil needed for the lanes, and how these factors affect their equipment because it does impact them both short- and long-term.

One interesting note concerned questions related to consumers. After the first day, three of the proprietors strongly believed equipment changes would negatively impact their business, yet at the end of Day 2, all were agreeable to seeking to implement a measured reduction of some kind.

They also showed they were open to possible adjustments, but those adjustments should be decided by the experts through research and data.

The results from the group:

- Proprietors stated the bowling ball is the most influential factor in bowling's technology
- Six out of seven proprietors believe a rollback in technology is necessary
- Five were concerned what today's ball does to the lanes and how it will affect costs
- Increased cost of oil, and to offset wear and tear on lanes is a reason for a rollback
- Possible changes must be based on data collected

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Bowling Leaders' Summit

In October of 2017, USBC held an industry leaders summit to further discuss the sport of bowling. Among the group was a second-generation proprietor, a lifelong bowler with a professional background in sales and marketing who had been involved in the sport for more than 50 years, a center owner with 30 years of bowling knowledge and a lifelong bowler who grew up working in a center.

The initial discussion was whether the sport of bowling is headed in the right direction. Is the sport in disarray, maybe needs some fine-tuning or perhaps needs a complete overhaul? The majority believed bowling is in a good place but could use some fine-tuning.

There were varying opinions about evolving technology, from the fact some felt most bowlers don't really understand lane patterns or ball specifications, to the continuing cycle of manufacturers making balls that hook more while tournament managers continue to put more oil on the lanes to negate the dynamics of the balls.

An overwhelming majority believed lane machine technology and lane patterns are the most influential factors, more than the bowling ball itself.

If there was a dramatic move that would reduce league scores by 20 or more pins, the group was asked how they thought bowlers would react. The majority said bowlers would become outraged and several added bowlers would soon quit.

Asked what change they would make to bowling balls, most of the group said they would lean to having bowling balls with slow oil absorption that would make balls last longer, though offer less hook.

Most of the group felt quality shot-making remains the most influential component to bowling well, and the reason bowling has declined over the years is because the world evolved but bowling did not. They see customers who are not influenced by lane conditions or bowling balls, but recreational bowlers who just want to strike and have fun, and scores really don't matter. They also see the best way to market bowling today is to get top-of-mind awareness.

Yet the group sees bowling as the best sport because it can be competitive and social at the same time. While they struggle with how to proceed, they want the league experience to be solid. One mentioned ball limits might be appropriate because of advancing technology while another said changes need to be for the right reason.

Segments of the group in the sport — those charged with overseeing the sport's technology and those who operate the centers — looked at technology and how they thought technology should be addressed. Both said the main purpose of any change needs to be about the consumer, to provide a positive experience.

The group, overall, agreed with previous discussion groups that they would like to see changes to help the sport.

The results from the group:

- Coverstocks should be the focus for specifications, not the core
- Any changes should focus on the consumer, providing a positive experience
- Quality shot-making remains the most influential component to bowling well
- Bowling has declined because the world evolved, and bowling did not
- Goal should be to stop things from escalating, to hold things in check

Key Takeaways

The focus groups had lively discussions and provided valuable insight into how those who work with the bowlers think about technology advancements in the sport. USBC understands it will need to continue to talk with the bowling industry so standards and specifications are in place to ensure the sport remains in the bowler's hands and is not impacted simply because of advanced technology.

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But it is important to note key points from the groups:

- 10 of 12 pro shop operators said the ball is the most influential technology factor
- Proprietors also said the ball was the most influential factor
- Majority of bowling leaders said lane machine technology and lane patterns are the most influential factors
- A group of proprietors said a rollback should not "nibble around the edges" and be based on data collected
- Six of the seven proprietors believe a rollback in technology is necessary
- Majority of pro shop operators were in favor of modifications and a specification for oil absorption
- The rollout of any specification changes would need to occur over 3-4 years, pro shop operators said
- Majority of bowling leaders said bowling ball coverstocks should be the area of focus

That does not necessarily mean new technology will be limited or that accepted technology won't be re-examined.

In 2014, USBC modified the **specifications on bowling ball gripping holes** because of no-thumb and two-handed bowlers. Not using a thumb during the delivery, plus having a balance hole, effectively created two balance holes and affected the dynamics of a ball. USBC studied the situation and determined a new specification was needed. As we saw in the focus group, the balance hole continues to spark discussion.

The recent additions of the Challenge designation and new requirements for lane inspections will help to create a more level playing field.

But the most important takeaway from these exercises is that research must always be ongoing because, so many factors can affect the bowling environment.

These factors and others will continue to draw USBC's attention to ensure bowlers know that when they step on the lanes, their skill will determine their success.

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SECTION IX:
SUMMARY OF BOWLING TECHNOLOGY STUDY

The bowling technology study, poll, surveys and focus groups are dedicated to the idea USBC needs to continually explore all facets in bowling while thinking about the future of the sport and the integrity of the competitions conducted in the sport.

In addition to the pages of research from the study of today's bowling ball, the information shows there are varied opinions about the state of bowling. USBC believes the engagement of all stakeholders in these topics is extremely important to build a brighter future for the sport and a better USBC everyone can be proud to be a part of.

The interaction of the oil pattern, ball technology and the playing surface has progressively become out of balance creating an integrity issue for the sport.

Lane conditions today feature an increasing volume of oil that combined with the advancing ball technology and higher revolution bowling style is breaking the oil pattern down quicker.

This is leading to the lanes transitioning must faster, with less consistency and greater manipulation than we have ever seen before. All of this threatens the integrity of the sport.

The sustainability and integrity of the current environment long-term is the chief concern.

For example, the levels of oil applied to the lane are increasing to the point of being unmanageable within our competitions and cost prohibitive to bowling's stakeholders.

In addition, equipment degradation and customer dissatisfaction are very real sustainability concerns and a growing problem recognized widely in the bowling industry.

The technology of the bowling ball in the hands of the consumer dictates how much oil is on the lane. Now, with more history and years of research data in this area, USBC can regulate with more specificity - becoming more proactive than reactive.

For the good of the sport, emerging technologies should be further understood, and regulation continually considered.

The next steps will include an ongoing dialogue with the manufacturers concerning what the future of the sport should look like, and USBC then will proceed responsibly toward it.

Decisions may be determined in the short term, and regardless of any decisions, USBC will continue to research all areas of the sport moving forward. USBC has been and always will be committed to fulfilling its role as the National Governing Body for the sport of bowling.

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TIMELINE OF STUDY

The USBC Equipment Specifications and Certifications team spent more than two years doing in-depth research on bowling balls to determine the impact of ongoing technological advancements on the sport's environment. USBC also discussed bowling technology with several groups involved in bowling through surveys and group discussions.

A brief look at the timeline of the studies:

July 2015

- **CORE Part 1:** Differential RG Study
  To understand effect from varying the differential RG within the current USBC spec range
- Purchased laser microscope

Aug. 2015

- **CORE Part 2:** Differential RG Study- Retest
  Repeat Phase I of differential RG study.
- Began testing laser microscope to setup proper calibration

Sept. 2015

- **CORE Part 3:** RG and Differential RG Study- Quantify Ball Motion Effects
  To quantify the ball motion effects of varying both RG and total differential
- **CORE Part 4:** RG and Differential RG Study- Bowler Properties
  Study Phase 1 and 2 when incorporating additional bowling ball and bowler properties to see how they affect hook
- **CORE Part 5:** RG and Differential RG Study- Retest
  Repeat the RG and differential RG study phase 2 test to confirm results

Oct. 2015

- **CORE Part 6:** RPM vs. Ball MOI- Bowlers Rotation Study
  Determine if bowlers generate different rotation when they use balls with different moment of inertias (MOI)
  Does ball moment of inertia affect E.A.R.L.'s initial release values

Dec. 2015

- **CORE Part 7:** Adjusting RPM Rate Vs. Ball MOI
  Repeat Phase 2 RG and differential RG study but adjust the rotation rate based on using same rotational energy for each ball on a flat oil pattern
- **CORE Part 8:** Vary RPM vs. Ball MOI on House Pattern
  Repeat phase 4 RG and differential RG study varying rotation rate to maintain the same rotational energy for each ball on house pattern

Jan. 2016

- Developed surface roughness database by measuring most balls submitted for USBC approval
- **CORE Part 9:** Summary of all Tests and Area at Pocket
- **CORE Part 10:** Area at the Pins- Retest
  Repeat the phase 5 RG and differential RG study, which varied the rotation rate to maintain the same rotational energy for each ball on a house pattern

Feb. 2016

- **CORE Part 11:** Simulate League with E.A.R.L. on House Pattern
  Run RG and differential RG study a using combination of high and low RG with high and low differential RG balls to simulate three games of bowling with five bowlers each using one of the five ball combinations and varying rotation rates to maintain the same rotational energy for each ball on a house oil pattern
- **CORE Part 12:** Comparing Different Weight Balls on House Pattern
  Repeat the Phase 5 RG and differential RG ball study varying rotation rate to maintain the same rotational energy for each ball on a house oil pattern.

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Dec. 2016

- **COVER Part 1:** Initial Oil Absorption Results
  This report summarizes the initial oil absorption testing for bowling ball shells

March 2017

- Recognized Sa results vs. the existing profilometer results for Ra are similar
- **COVER Part 2:** Oil Analysis for Oil Absorption Test
  Evaluate different mineral oils for potential candidates as the oil for the oil absorption test
- Pro shop operators summit held at International Bowling Campus
- First two of four Facebook surveys are posted

April 2017

- **CORE Part 13:** Bowler Test Results
  Test balls with different RG and differential RG values to measure ball path changes
- Proprietors summit held at International Bowling Campus
- An independent research company was engaged by USBC to conduct an independent, objective, and research-based analysis of the effects of technology in bowling
- Starting in April, and running through August, online surveys distributed to BPAA, IBPSIA and USBC email databases
- Final two questions of four Facebook surveys are posted

May 2017

- **COVER Part 3:** Surface Roughness effect on Oil Absorption
  Test to compare oil absorption results on the same ball when it is sanded with different grit Abralon pads

June 2017

- **COVER Part 4:** Oil Depletion Study vs. Ball Oil Absorption Rate
  Study to see how fast and slow oil absorbing ball with the same RG and differential RG affects the oil pattern
- Meet with individual manufacturers so they could learn the new oil absorption test procedures

July 2017

- **COVER Part 5:** Repeatability of Oil Absorption in Same Location
  Study of oil absorption in the same location several times to determine repeatability and consistency for rechecking data
- **COVER Part 6:** Clean vs. Dirty Surface Preparation Water Effect on Oil Absorption
  Study to determine if oil absorption times are affected by using dirty water, as opposed to clean water, when prepping ball surface for testing

Oct. 2017

- Bowling leaders' summit held
- **CORE Part 14:** The Effects of Balance Holes

Nov. 2017

- **COVER Part 7:** Five-Person Team League Simulation
  Study oil depletion and ball reaction with different types of bowling balls (varying differential RG and varying oil absorption rates) for five-person teams

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GLOSSARY

Asymmetrical Core (undrilled)—A ball where the RG (radius of gyration) values of the Y (high RG) and Z (intermediate RG) axes of the ball differ by more than 5% of the total differential of the ball.

Coefficient of friction (COF)—The ratio of the force opposing the relative motion of two surfaces and the normal force acting perpendicular opposing force. In bowling, this term usually defines the interaction between the coverstock, lane conditioner, and lane.

Coefficient of restitution (COR)—The ratio of the energy of two objects after impact to the energy before impact. In the case of a ball striking a pin, this is the percentage of energy transfer from the ball to the pin.

Core–The interior of the bowling ball; depending upon the construction of the ball, the core may consist of the inner core (weight block) and/or the outer core (light filler material).

Coverstock—The exterior or outer shell of the bowling ball.

Flare—The ball track progression due to axis migration.

Moment of Inertia—Resistance to change in rotation.

Particle—Any solid additive mixed into the coverstock to change the interaction between the bowling ball, lane conditioner and the lane.

Porous—Having miniature spaces or holes through which liquid or air may pass.

Positive Axis Point (PAP)–The point on a ball which the ball rotates initially upon release. A bowler's Axis Point is unique to them and has the potential to change depending on how that bowler releases the bowling ball. The Axis Point includes both a horizontal and vertical measurement from the center of grip.

Radius of Gyration (RG)—Measured in inches, radius of gyration is the distance from the axis of rotation at which the total mass of a body might be concentrated without changing its moment of inertia.

Revolutions Per Minute (RPM)—A measure of the frequency of rotation, specifically the number of rotations around a fixed axis in one minute.

Surface Roughness (Ra)—The arithmetic mean of the peak to valley distances over an evaluation distance.

Surface Roughness (Rs)—The arithmetic mean of peak to peak distances of the local peaks in the evaluation distance.

Surface Roughness (Sa)—The arithmetic mean height of the surface of the evaluation area.

Symmetrical Core (undrilled)—A ball where the RG (radius of gyration) values of the Y (high RG) and Z (intermediate RG) axes of the ball do not differ by more than 5% of the total differential of the ball.

Differential RG–The difference between the X (low RG) and Y (high RG) axes values of any bowling ball. This determines the flare optional for the ball.

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