A Future FOR THE Sport

HARDNESS RESEARCH REPORT

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Table of Contents

OVERVIEW

Research conducted by the United States Bowling Congress (USBC) Equipment Specifications staff shows environmental factors, especially temperature, can change the hardness measurement of bowling balls. Urethane shell balls are the most prone to variance, although reactive shell balls had variance as well.

USBC found urethane balls will pass the USBC specification for minimum hardness at manufacture, but then may measure below specification when heated. Balls measured immediately after use may also have measurements under specification. This decrease in hardness based on environmental factors occurred for urethane shell balls across multiple brands.

The USBC Physical Specification for ball hardness at the time of manufacture is:

> *"The average surface hardness of a bowling ball shall not be less than 72 durometer D at any time when measured at 68-78 degrees Fahrenheit."*

A durometer is a hardness testing tool that measures the depth of an indentation in the ball created by a given force on a standardized presser. USBC has a published standard operating procedure (SOP) to test ball hardness that calls for using a Type D Digital Durometer in a stand and taking measurements in 10 different locations. In order to receive USBC approval, the average measurement of a ball must not be less than 72D. All tests following the SOP are conducted by USBC staff, on UBSC's equipment at USBC's testing facility, and of balls at time of manufacture.

USBC conducted a series of tests after a question was raised in the field related to approved urethane balls allegedly measuring below specification.

Test Example #1 – Hot Car Trunk

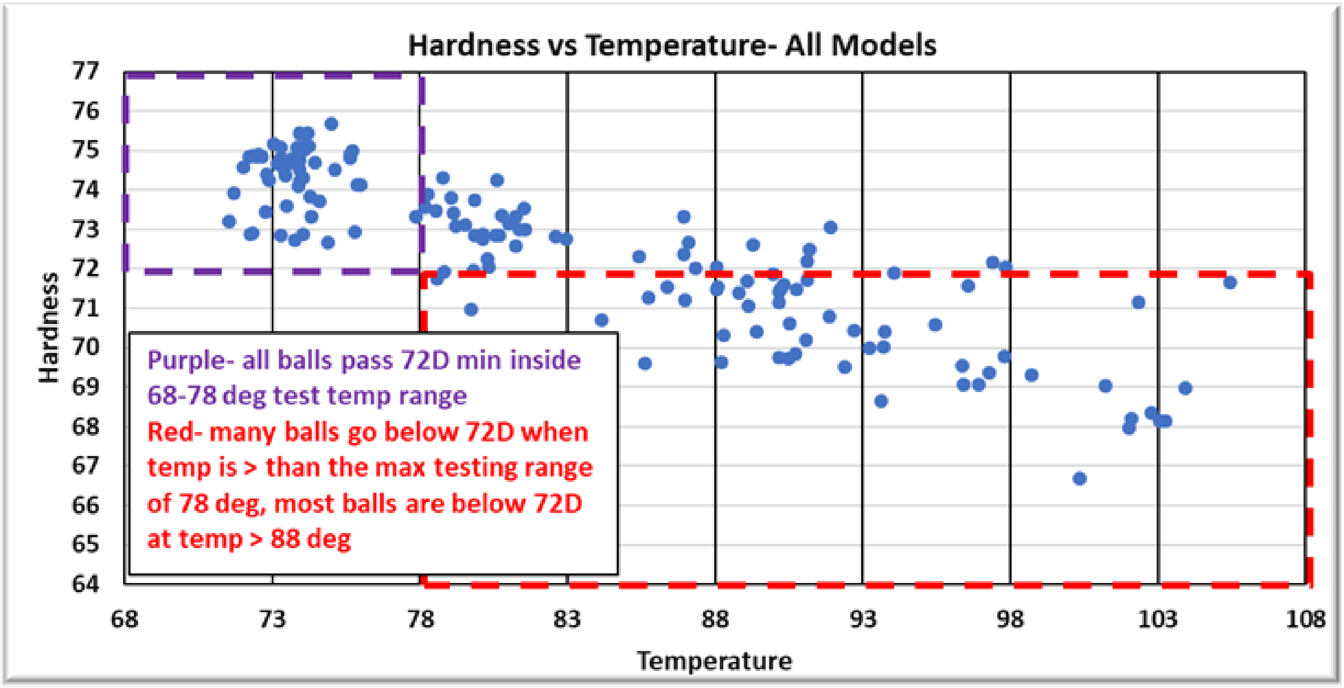
In order to better understand how temperature affects the hardness measurement, USBC tested 10 balls. Seven balls in the test were urethane shells, three were reactive. The test simulated the effect of balls being stored in a hot car trunk for several hours and then being moved to room temperature. Test parameters included:

- Baseline measurement of balls in lab at room temperature
- Balls placed in hot car trunk (119-130 degrees) for approximately five hours and then measured immediately
- Balls remeasured at room temperature two hours after being moved from hot car trunk to lab

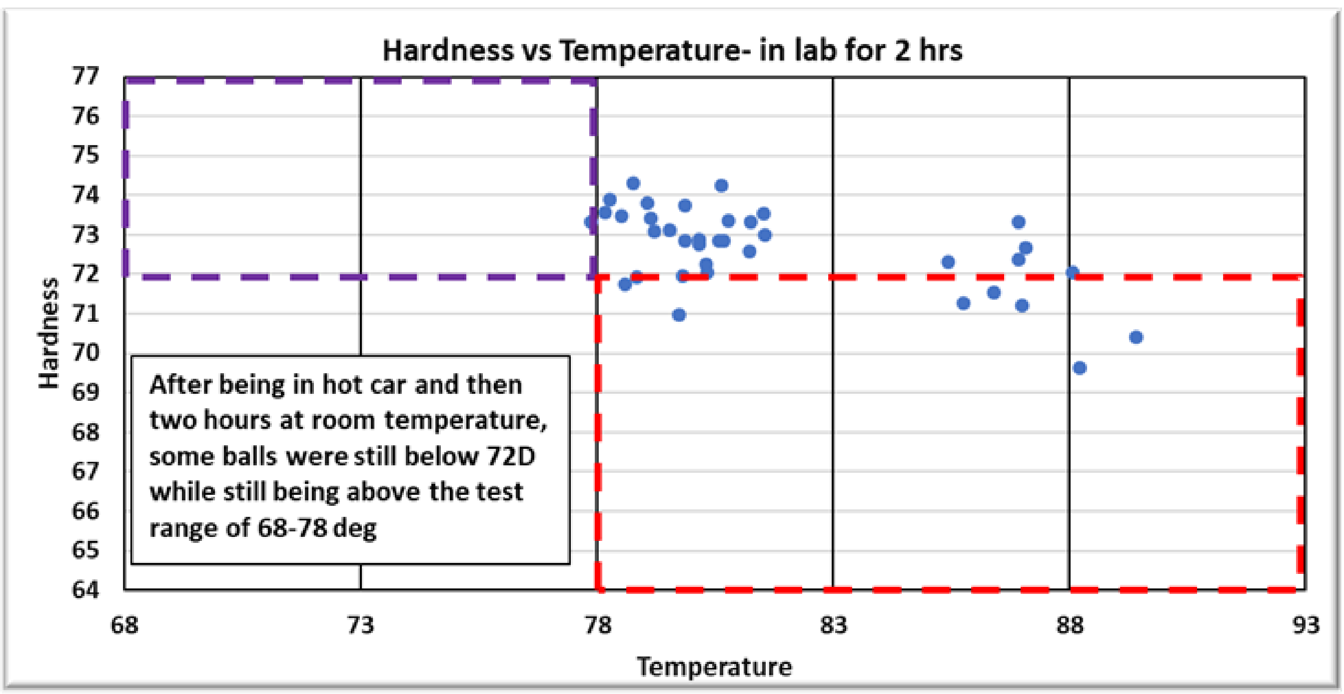
Result:

There is a direct correlation showing that as temperature increases, ball hardness decreases. Common environmental factors can cause a ball to measure outside of specification.

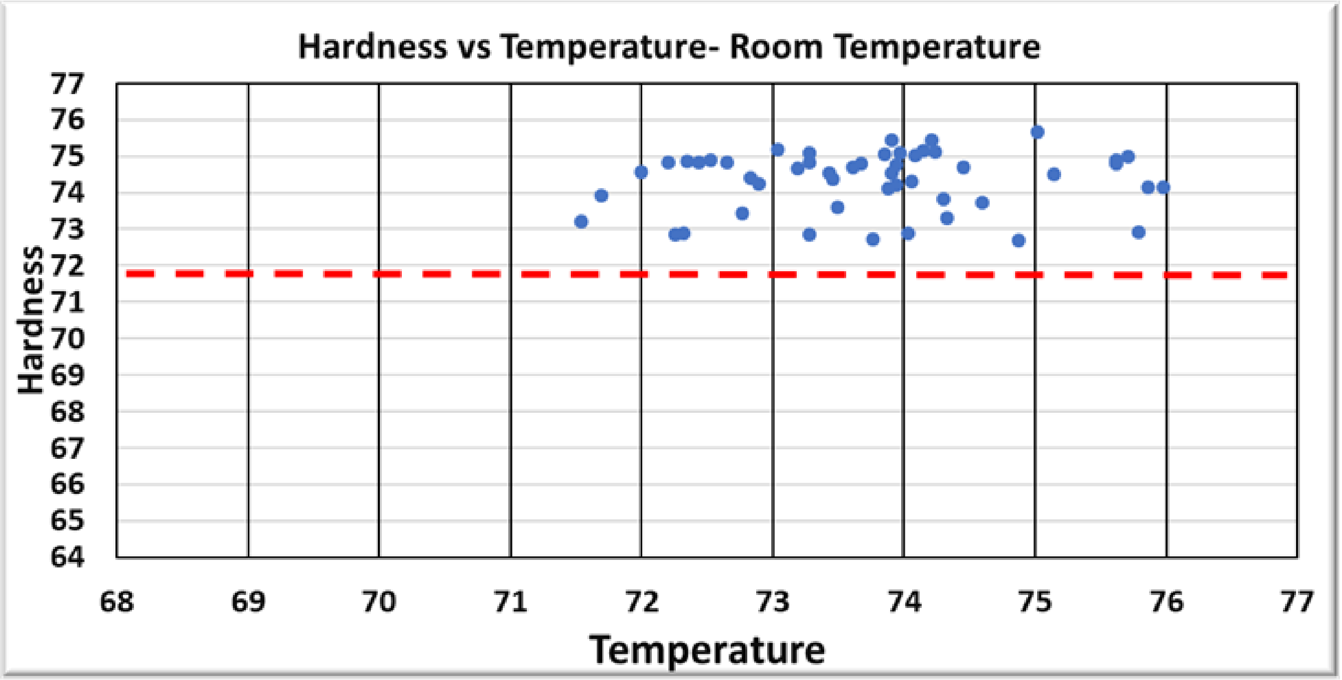
- All balls were confirmed to measure above the 72D hardness specification at room temperature (68-78 degrees) to start.
- Ball Surface temperature rose as high as 105 degrees in the car trunk
- All balls softened to measure below 72D when ball surface temperature exceeded 98 degrees
- Even after two hours at room temperature, a significant number of balls measured below 72D when removed from car trunk
- Temperature change affects urethane shells more than reactive ones, but the effect is clear with both



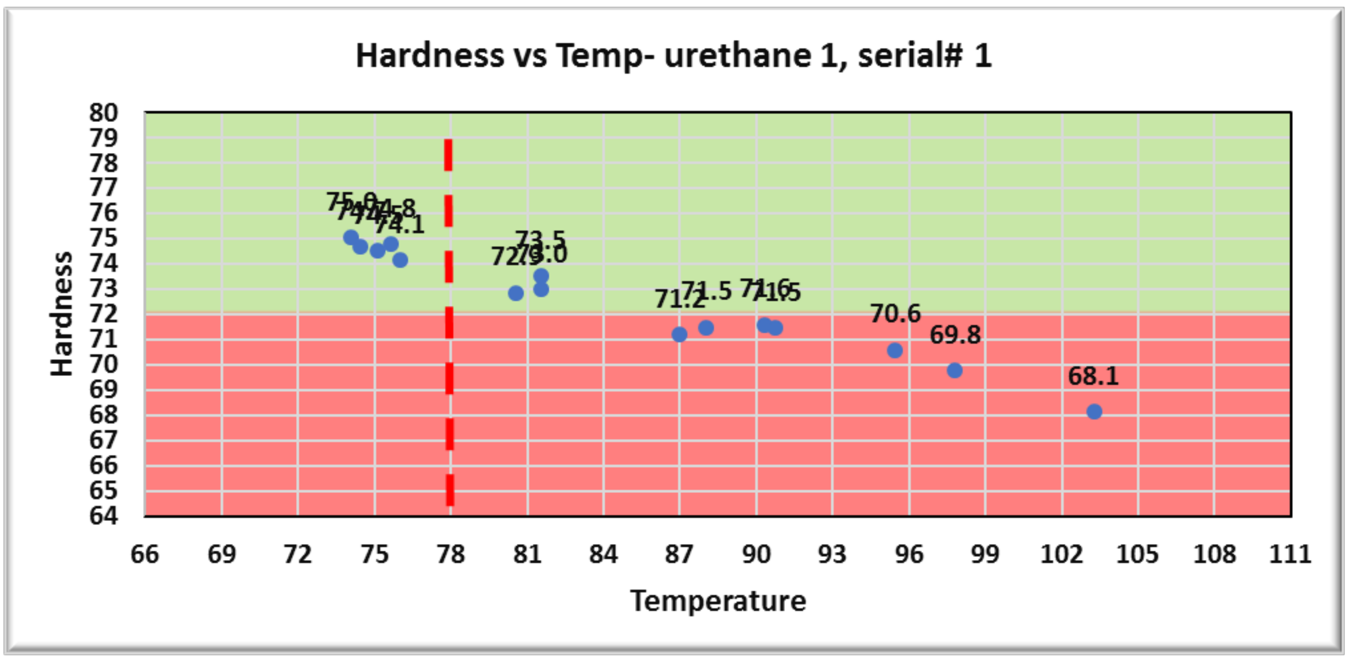
Results after two hours at room temperature after being in a hot car trunk:

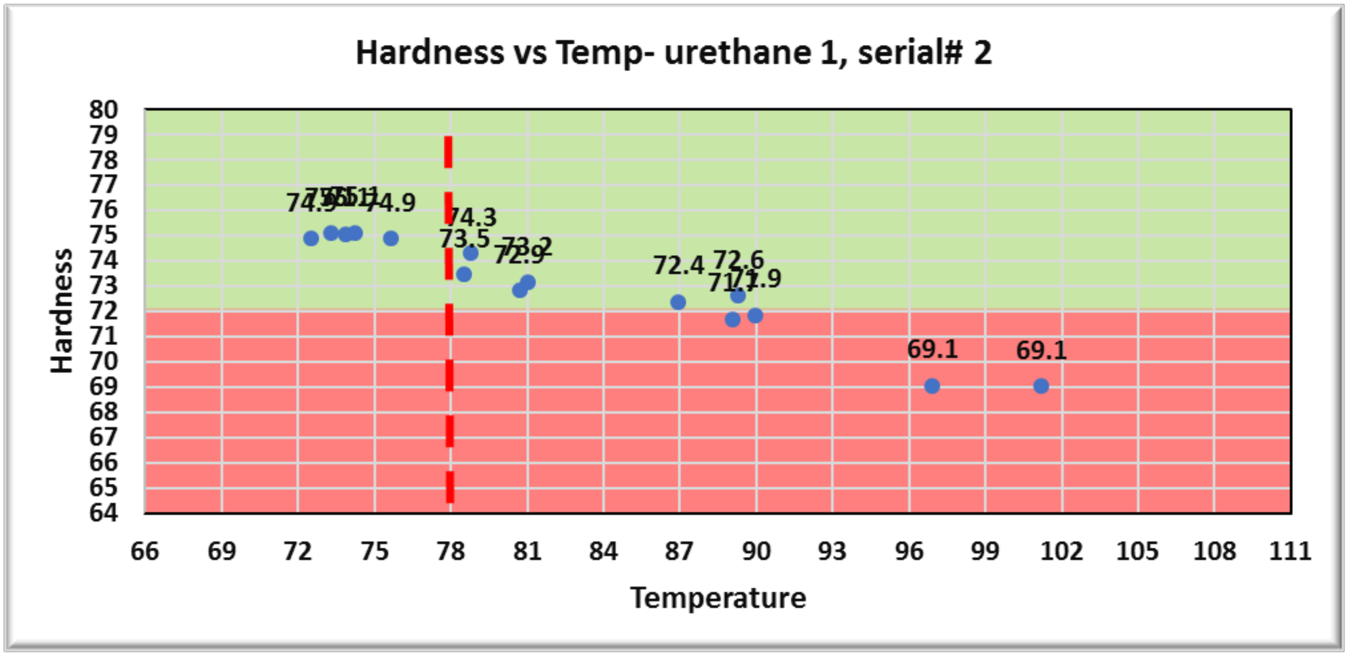


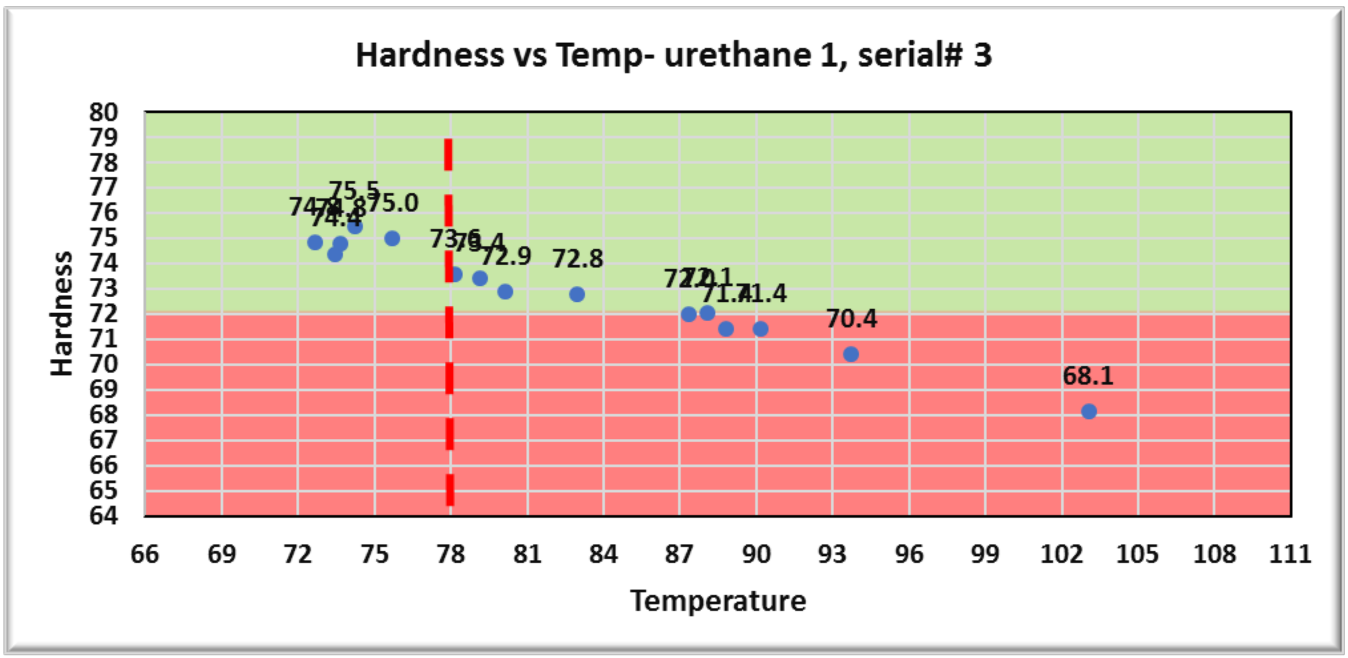
All balls returned to the hardness specification (greater than 72D) when the ball temperature returned to room temperature at any point during the test:

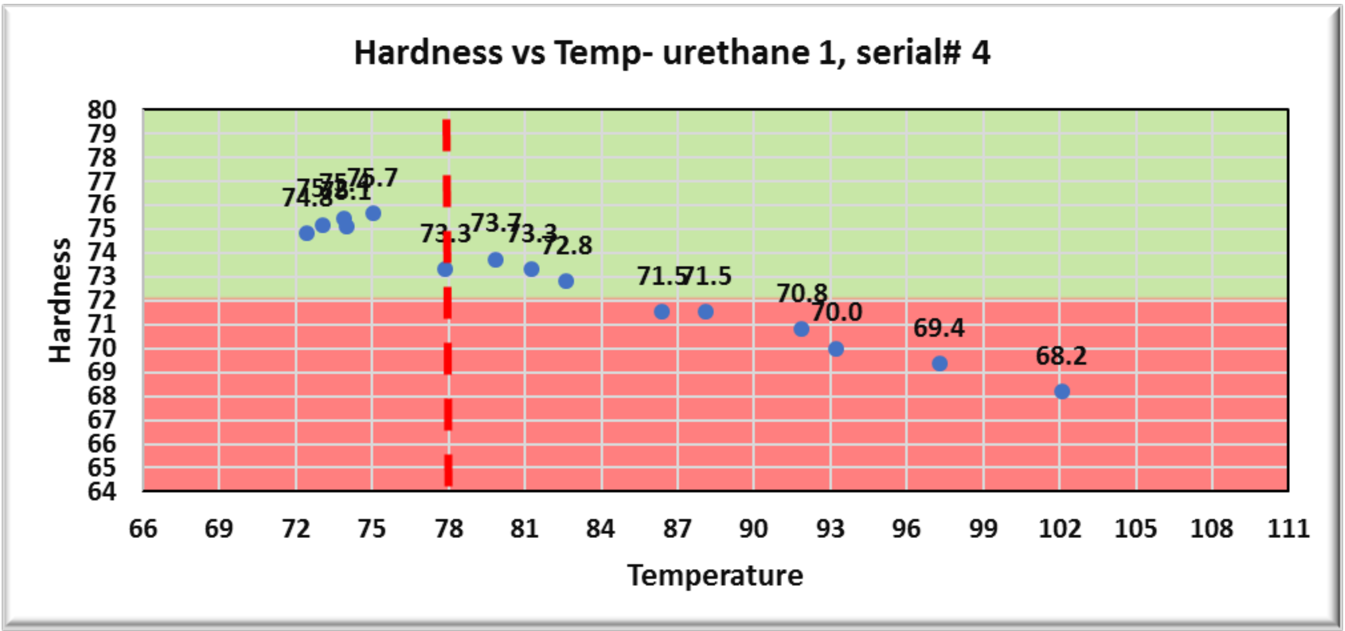


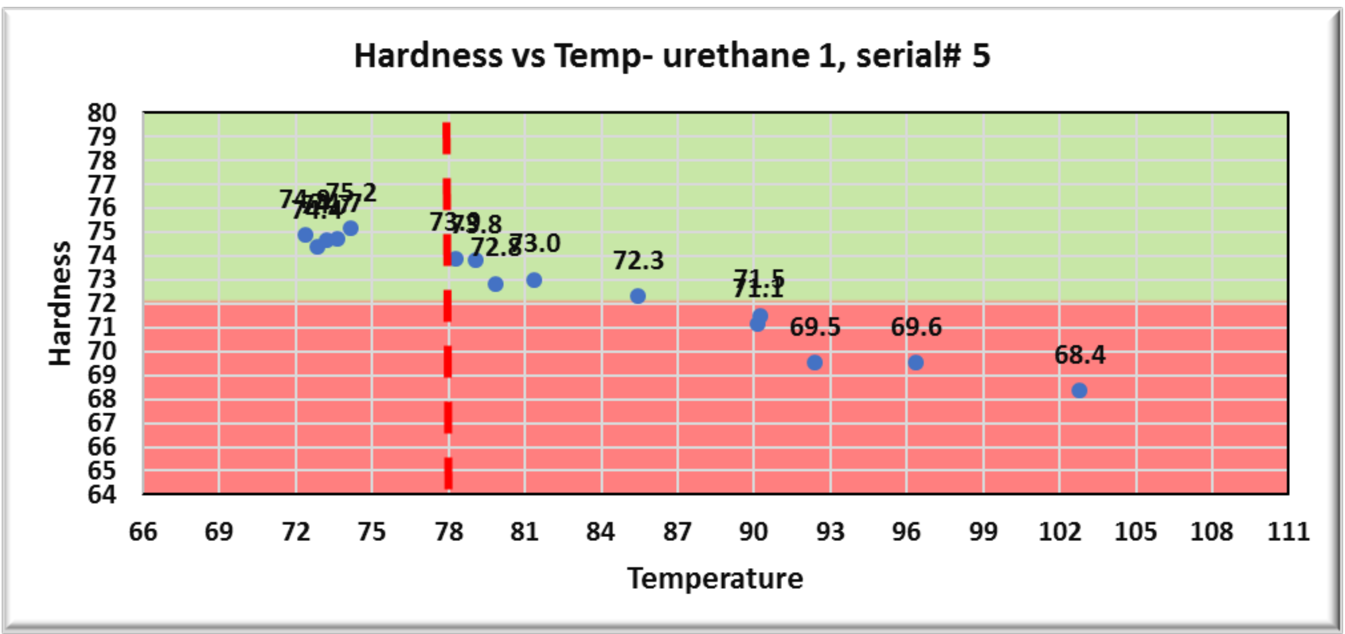
Individual ball hardness results:



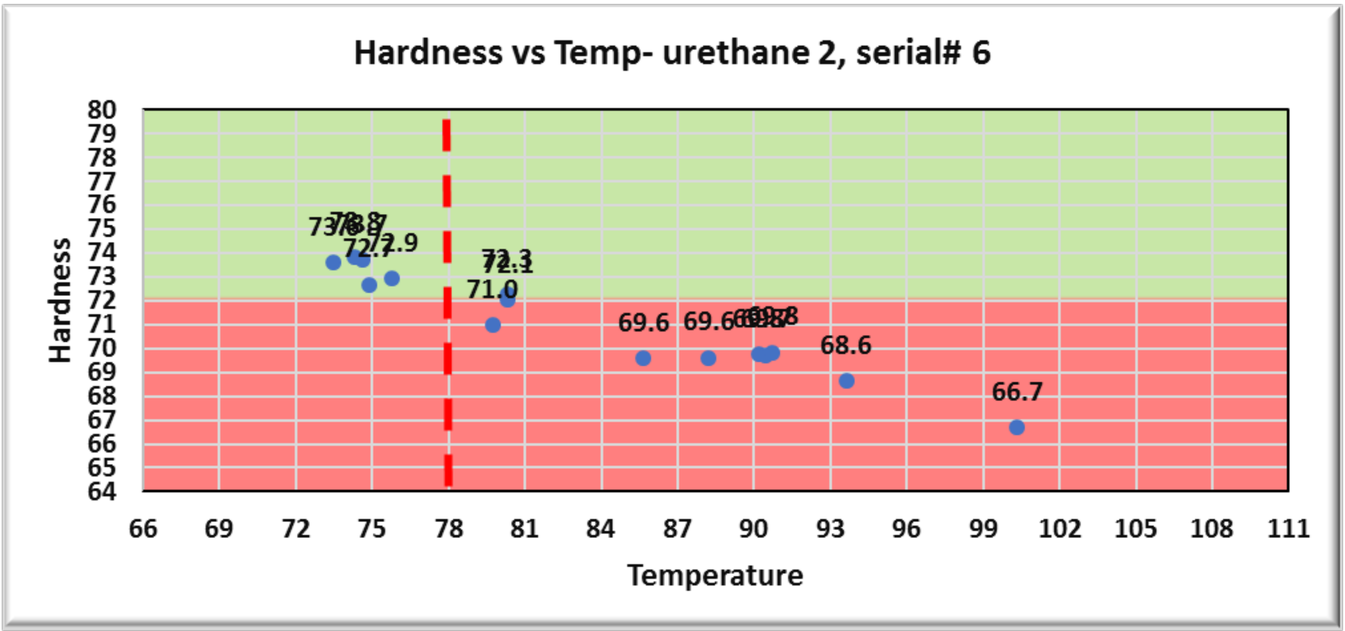

Hardness vs Temp- urethane 1, serial# 2
Hardness
Temperature
80
79
78
77
76
75
74
73
72
71
70
69
68
67
66
65
64
66
69
72
75
78
81
84
87
90
93
96
99
102
105
108
111
74.9
74.3
73.5
72.4
72.6
69.1
69.1

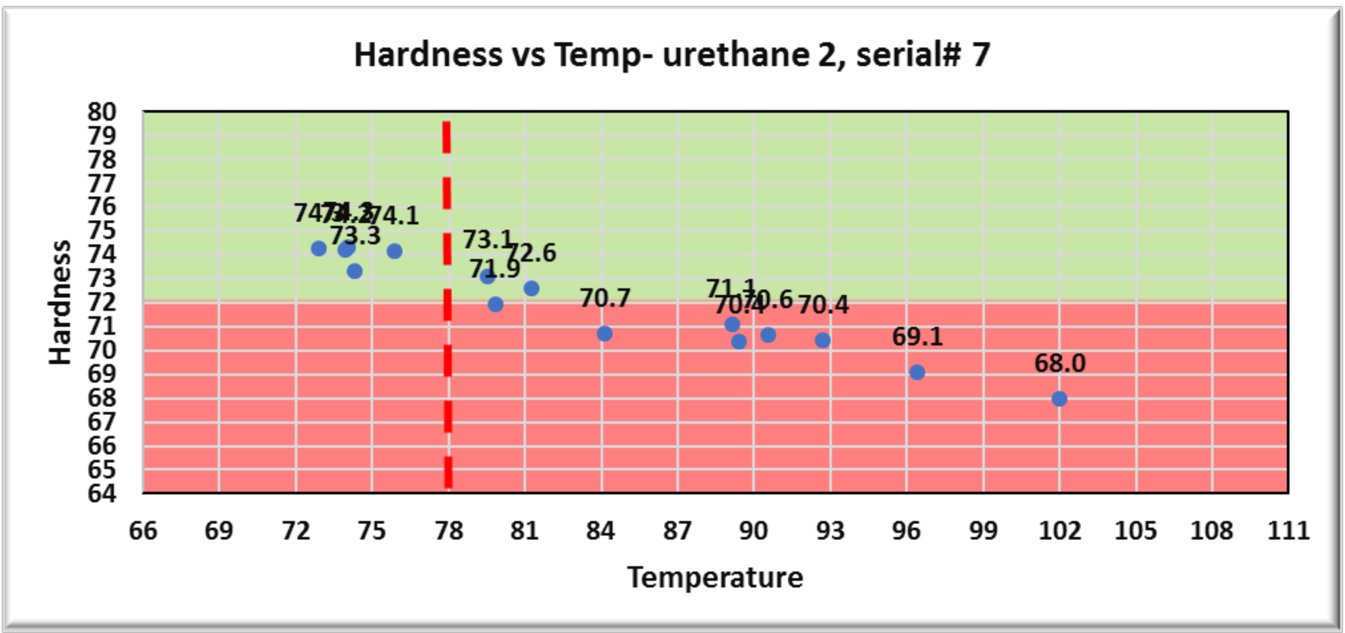

Hardness vs Temp- urethane 1, serial# 3
Hardness
Temperature
80
79
78
77
76
75
74
73
72
71
70
69
68
67
66
65
64
66
69
72
75
78
81
84
87
90
93
96
99
102
105
108
111
75.5
75.0
72.9
72.8
70.4
68.1



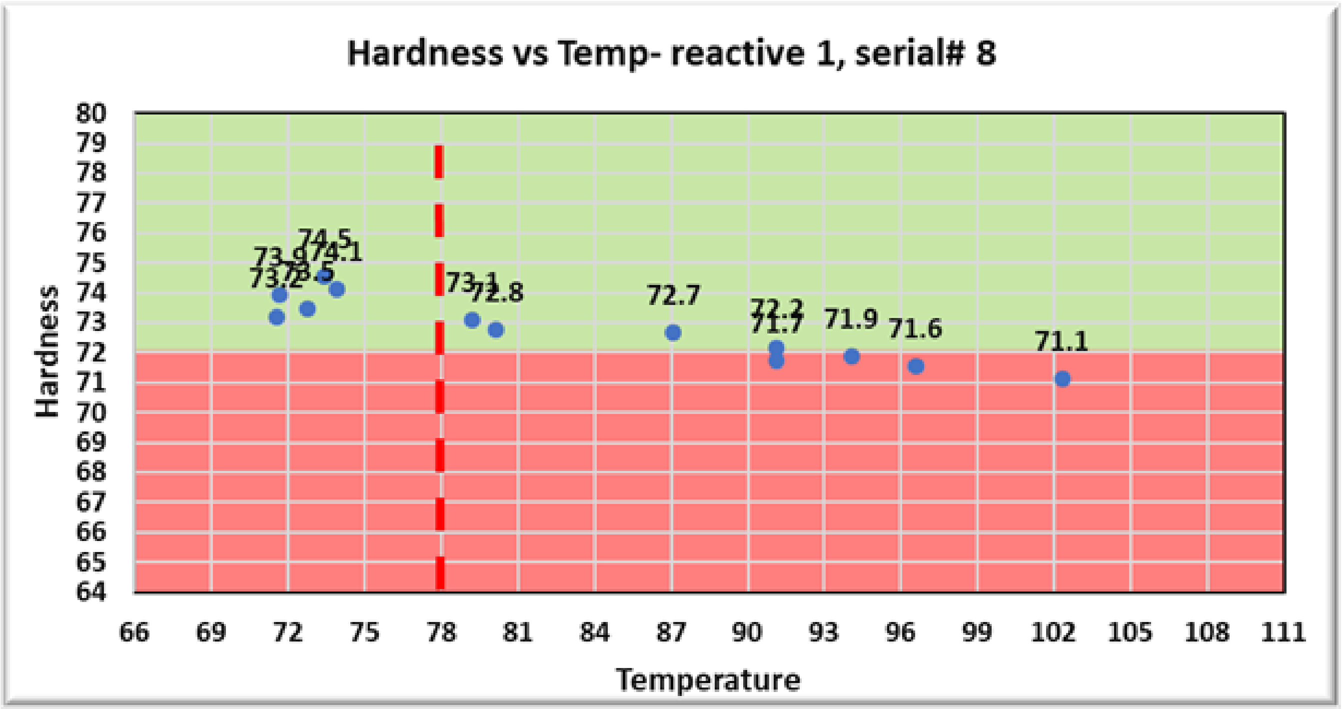


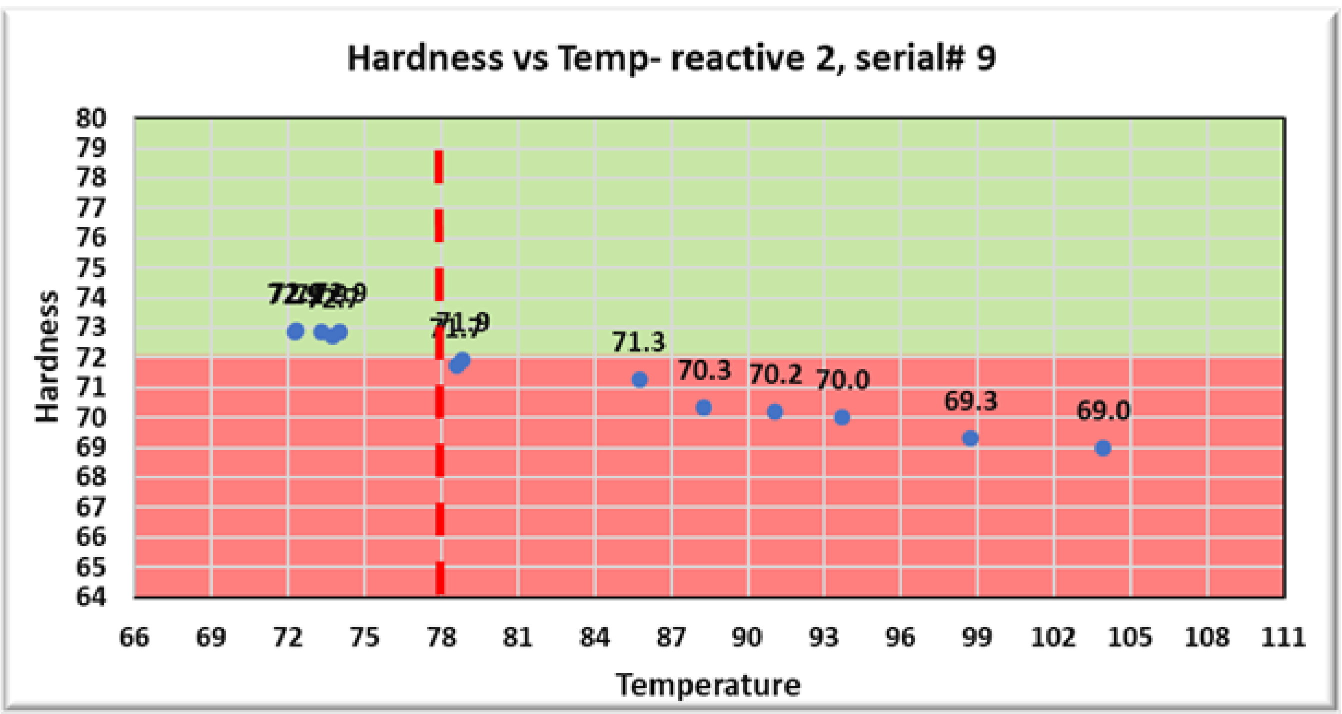
Different urethane #2 balls:

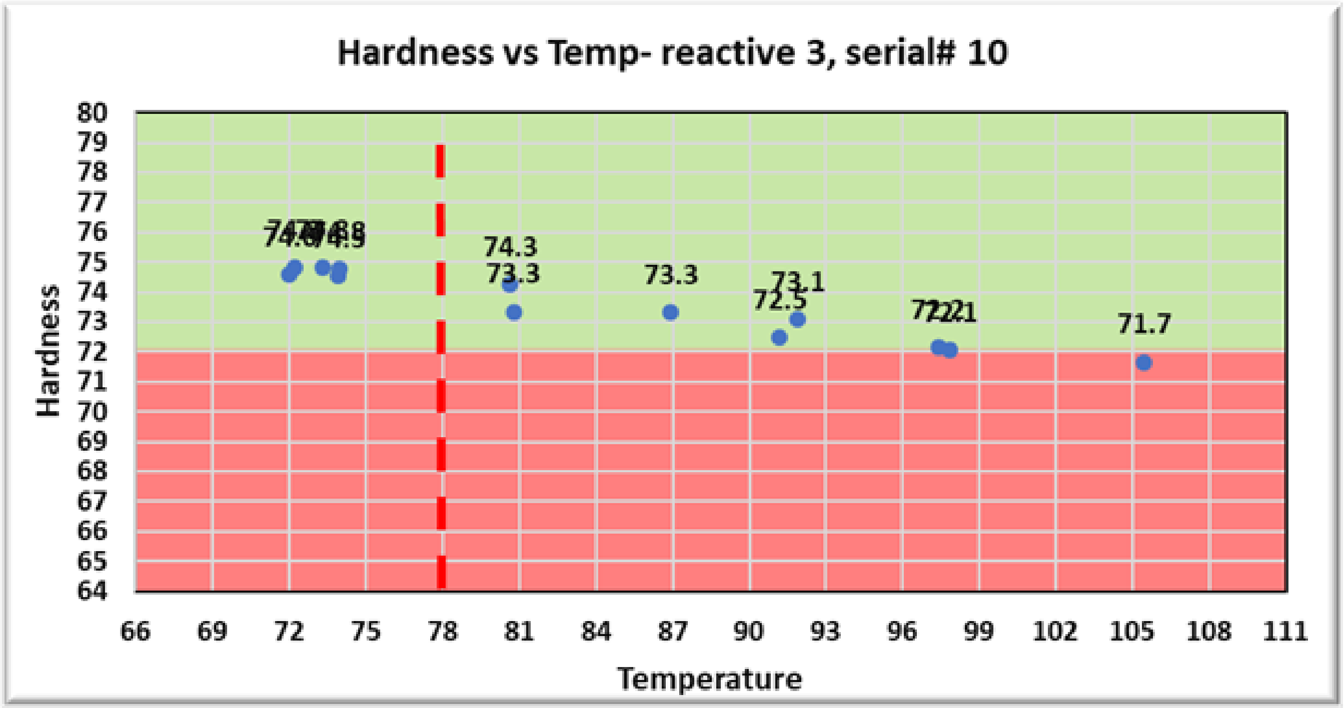

Hardness vs Temp- urethane 2, serial# 6
Hardness
Temperature
72.9
71.0
69.6
69.6
68.6
66.7


Hardness vs Temp- urethane 2, serial# 7
Hardness
Temperature
74.1
73.3
73.1
72.6
71.9
70.7
70.6
70.4
69.1
68.0

Reactive shells:







Test Example #2 – Effects from Use

In order to look at how use affects the hardness measurement, USBC tested a mix of urethane and reactive shell balls. The test involved USBC's test robot E.A.R.L. throwing each ball 60 times with the same delivery. After a baseline measurement in the lab, balls were then measured every 10 shots to see how hardness measurements changed.

The same balls were then:

- Re-measured the next day
- Cleaned with isopropyl alcohol and re-measured
- Cleaned with Kegel Ball Revivor for another measurement

The test was conducted throwing the ball at 17MPH, 60 degrees axis rotation, 400 RPM with 5 degrees tilt. **Reactive shells did not show a meaningful change.**

Result for urethane shells:

- After 30 shots, the urethane shell balls measured a hardness decrease of between 1D and 5D. Each of the urethane balls tested (across multiple brands) measured below the 72D limit after 30 shots
- When re-measured the next day, hardness moved back up at least 1D for each sample and progressed to within 2D of the starting hardness
- When cleaned with isopropyl alcohol, hardness measurement again moved closer to the starting hardness, although less than 1D
- When cleaned with Kegel Ball Revivor, hardness measurement moved even closer to the starting hardness

Given that it appears oil on the ball was effecting hardness measurements, USBC conducted an additional test of taking a baseline ball measuring 75D and applying a 3" diameter circle of oil in an isolated location on the ball.

Result for urethane shells:

- Measurements within the oil circle were 4.2D lower than baseline
- Measurements outside the oil circle taken immediately with the same durometer that still had oil on the indicator needle were about 2D lower than baseline
    - After about five measurements, the oil wore off the indicator needle and the results returned to baseline

Preliminary conclusions:

Conducting a hardness measurement immediately following use of a urethane ball will yield variable results from the ball's approved manufactured measurement. Currently, USBC does not have enough data to determine causation.

USBC further investigated issues related to durometer variability. ASTM spec #D2240-15 gives full details of how a durometer operates. Every .001" movement of the indicator (penetrating needle) equates to 1 hardness point called a duro. The durometer is built with the indicator extending 0.098" +/- 0.002". Since the indicator length can vary slightly, there can be a built-in tolerance of +/- 2 points for a total range of 4 points between durometers as built. There is also a tolerance within each durometer that, according to the ASTM spec, can be as large as 2.16 points. This provides insight into differences and variance of results using different durometers.

Summary and Next Steps

Following our research on variables in hardness testing results, USBC is modifying the hardness specification. The USBC ball hardness specification is a manufacturing standard. The durometer measurements gathered by USBC in our testing facility is the standard for compliance. USBC knows temperature affects the hardness results for bowling balls. The temperature range used for USBC's testing will be adjusted slightly to 70-77 degrees Fahrenheit to coincide with the ASTM requirement.

Additionally, balls tested for hardness during USBC competitions will have a new specification. Balls must be tested consistent with USBC's standard operating procedures. They must be cleaned to remove oil, so the oil does not affect the hardness results by lubricating the durometer indicator needle. Since there is up to a 4-point variation between properly calibrated durometers, the field test will allow for this variation. A ball is only subject to being removed from competition as determined by the Competition, if the subject ball hardness averages below 68D.