A Future FOR THE Sport

HARDNESS RESEARCH REPORT

2020

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Overview

USBC continued its research of bowling ball hardness at the 2020 World Series of Bowling in advance of the 2020 USBC Masters.

As the National Governing Body for bowling, USBC is responsible for governing the rules and specifications of the sport. Based on findings in the hardness research conducted at the 2020 U.S. Open, USBC felt it appropriate to not only continue to check the hardness of urethane balls, but also to investigate the hardness of used reactive balls.

Because of the larger field size at the USBC Masters, compared with the U.S. Open, it was necessary to begin testing earlier. Since a large portion of the Masters' field also was bowling at the 2020 World Series of Bowling, USBC staff conducted field testing at the South Point Bowling Plaza in Las Vegas.

The task was to measure all bowling balls (except for plastic) that would be used at the upcoming Masters. Players could wait to submit their equipment until they were eliminated from competition at the World Series of Bowling. However, if they chose so, they could submit equipment earlier.

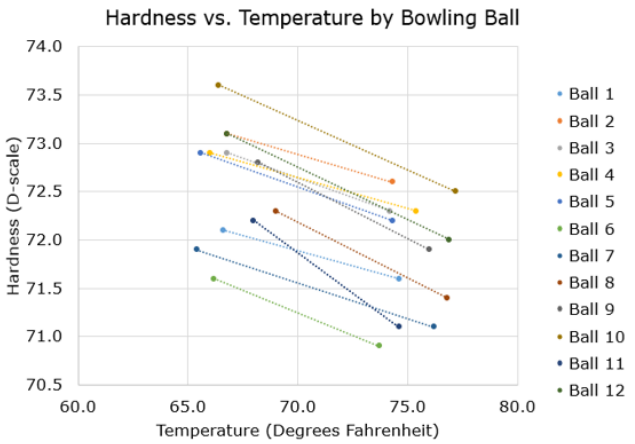
At a midpoint within the testing, enough reactive data had been gathered to show the reactive balls were not going to fail the hardness field test specifications. However, six urethane balls were found to fail the field specifications and were confiscated.

The 2020 USBC Masters was suspended indefinitely because of the public health concerns relating to COVID-19. In the interim, USBC staff analyzed the research in order for the Equipment Specifications Committee to consider next steps.

Bowling ball hardness field testing

USBC research showed temperature affects the hardness results for bowling balls, and, last December, the temperature range used for USBC's testing was adjusted to 70-77 degrees Fahrenheit to coincide with the ASTM requirement.

Hardness Temperature Dependency (in field)



Ball	Cover	Slope	R-SQ
Ball 1	Reactive	-0.063	*
Ball 2	Reactive	-0.067	*
Ball 3	Reactive	-0.081	*
Ball 4	Reactive	-0.064	*
Ball 5	Reactive	-0.080	*
Ball 6	Reactive	-0.093	*
Ball 7	Reactive	-0.074	*
Ball 8	Reactive	-0.115	*
Ball 9	Reactive	-0.115	*
Ball 10	Reactive	-0.102	*
Ball 11	Reactive	-0.167	*
Ball 12	Reactive	-0.109	*
Average		**-0.094**	

Temperature and humidity are two factors that can impact a bowling ball's coverstock. For the field tests conducted at the U.S. Open in Lincoln, Nebraska, and World Series of Bowling in Las Vegas, bowling balls were subject to different temperatures and humidity before they were submitted for testing.

In Lincoln, the average temperature was 41 degrees with 63 percent humidity. In Las Vegas, the average temperature was 57.5 degrees with 69 percent humidity.

Environment Differences

Lincoln Testing

Time	Temperature (° F)			Dew Point (° F)			Humidity (%)			Wind Speed (mph)			Pressure (Hg)			Precipitation (in)
Feb.	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Total
16	55	42.3	30	33	24.4	22	72	52.3	28	20	8.5	3	28.8	28.7	28.6	0
17	55	39.1	28	41	30.8	20	97	73.4	52	29	13.2	0	28.9	28.7	28.5	0
Mean	**55.0**	**40.7**	**29.0**	**37.0**	**27.6**	**21.0**	**84.5**	**62.9**	**40.0**	**24.5**	**10.9**	**1.5**	**28.9**	**28.7**	**28.6**	**0**

Las Vegas Testing

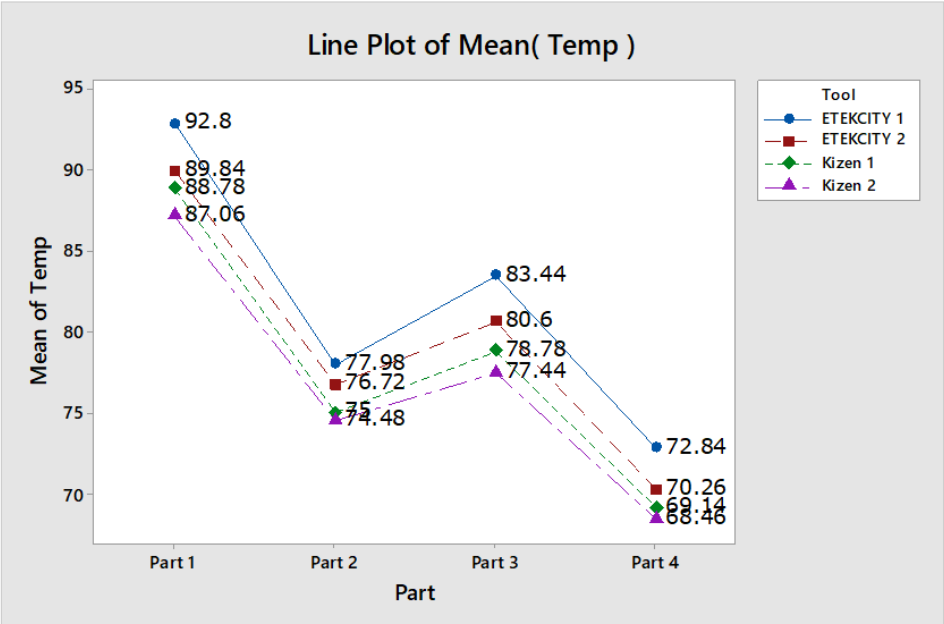
Time	Temperature (° F)			Dew Point (° F)			Humidity (%)			Wind Speed (mph)			Pressure (Hg)			Precipitation (in)
Mar.	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Total
10	60	56.8	53	51	44	28	86	64.7	30	10	5.2	0	27.9	27.8	27.8	0
11	67	57.4	54	52	50.2	46	94	78.4	47	8	3.6	0	27.8	27.7	27.6	0.6
12	71	60.1	53	52	46.1	39	80	62.2	31	13	7.1	0	27.7	27.5	27.4	0
13	61	55.5	52	49	45.6	39	88	71.2	44	22	9.1	0	27.6	27.4	27.4	1.8
Mean	**64.8**	**57.5**	**53.0**	**51.0**	**46.5**	**38.0**	**87.0**	**69.1**	**38.0**	**13.3**	**6.3**	**0**	**27.8**	**27.6**	**27.6**	**0.6**
Δ	**9.8**	**16.8**	**24**	**14**	**18.9**	**17.0**	**2.5**	**6.2**	**-2.0**	**-11.2**	**-4.6**	**-1.5**	**-1.1**	**-1.1**	**-1.0**	**0.6**

Bowling balls submitted for testing had to be placed aside and allowed to reach a temperature of 70-77 degrees Fahrenheit prior to testing. USBC used heaters to get balls to the proper temperature.

Depending on the outside temperature, and the length of time the bowling balls are subjected to outside temperature, impacts the time needed to have bowling balls reach testing temperature.

Devices used for the field tests showed variances. USBC used four infrared temperature measurement guns, two manufactured by Etekcity and two by Kizen, to measure a bowling ball's temperature prior to testing and noted a difference of three to five degrees in readings at different testing intervals.

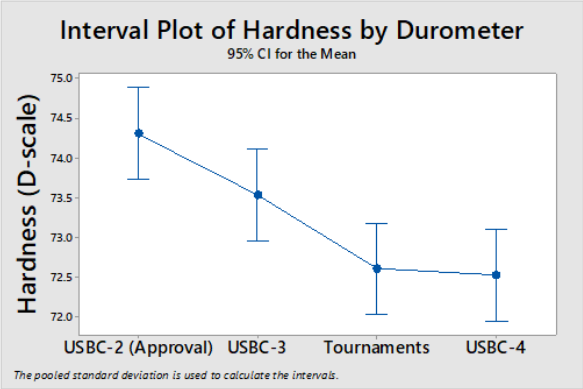
Temperature Gauge Differences (in field)



The calibrated durometers, devices used to measure the hardness of a material, also showed slight variances, as USBC was advised by the manufacturer to expect.

Durometers did impact the field test, measuring 0.8 to 1.8 points lower than the USBC approval durometer. (See charts below; approval durometer is USBC-2.) This accounts for some balls in the field test measuring below 72 and further illustrates another variance challenge in conducting field tests.

Durometer Differences (in lab)



Durometer	N	Mean	Difference	StDev	95% CI
USBC-2 (Approval)	10	74.3	0.0	0.943	(73.735, 74.891)
USBC-3	10	73.5	-0.8	0.890	(72.965, 74.121)
Tournaments	10	72.6	-1.7	0.854	(72.036, 73.192)
USBC-4	10	72.5	-1.8	0.918	(71.954, 73.111)

USBC also determined balls tested for hardness during USBC competitions must be cleaned to remove oil, so the oil does not affect the hardness results.

Since there is up to a four-point variation between properly calibrated durometers, the field test would allow for the variation. A ball is only subject to being removed from competition as determined by the competition, if the subject ball hardness averages below 68D.

USBC now has conducted two bowling ball hardness field tests and each field test provided variance challenges including:

- Temperature control
- Temperature gauges
- Durometer gauges
- Operators

Testing at World Series of Bowling

A total of 484 unique bowling balls – 330 reactive, 153 urethane, one rubber – were tested on the backend of qualifying at the 2020 World Series of Bowling at the South Point Bowling Plaza in Las Vegas.

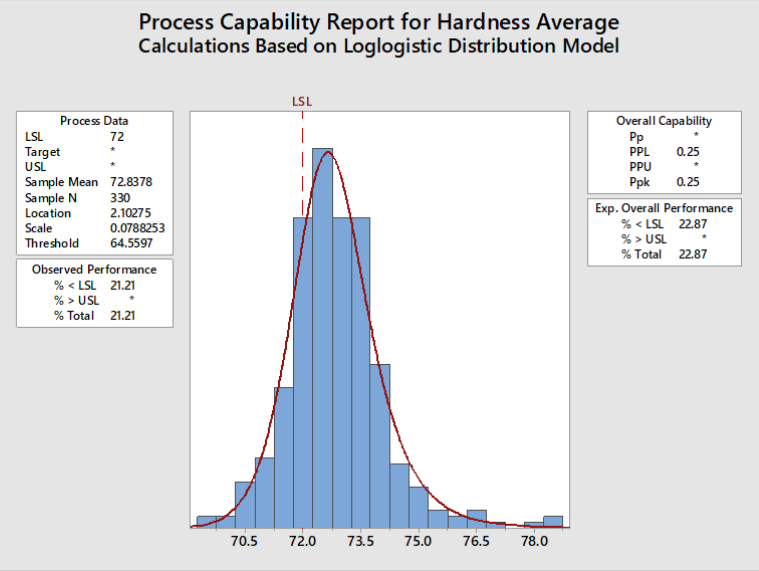
Reactive balls

While balls continue to be approved with no samples falling below 72D during the ball approval in the laboratory, 70 out of 330 (21.2%) of reactive balls measured below 72D in the field.

Please note that finding some reactive balls under the approval specification may be expected because of durometer variance. (Durometers were found to measure 0.8-1.8 points less than the official approval durometer, even when all are calibrated.) The lowest field measurement on a reactive ball was 69.4D.

Reactive Ball Summary

- 330 Reactive Balls were measured
- The data followed a log-logistic distribution
- We observed 21.2% below 72D on the field test durometers
- Amount below limit is within durometer variance ranges

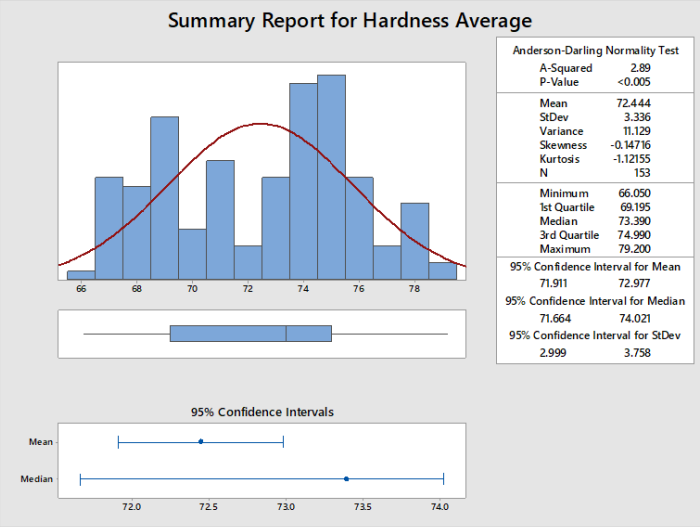


Urethane balls

Once again, though urethane balls were not below 72D when approved by USBC, 67 out of 153 (43.8%) of urethane balls in the field measured below 72D. The lowest measurement on a urethane ball was 66.1D and six urethane balls were shown to test below the field specification of 68D.

Urethane Ball Summary

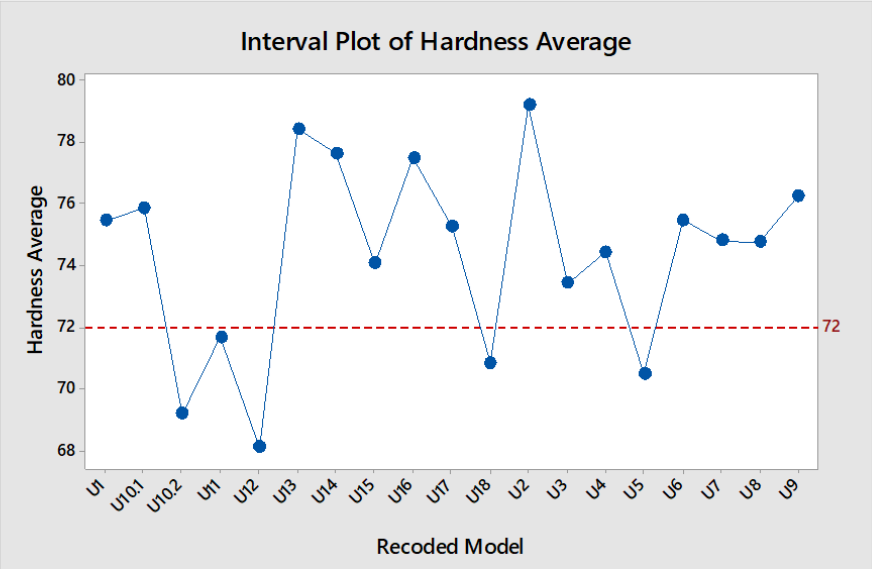
- Measured 153 urethane balls
- Observed 67 balls under 72 (43.8%)
- Distribution was again bi-model like at the U.S. Open



Of the urethane balls, five of the models tested, on average, less than 72D during the field test.

Urethane Summary by Model

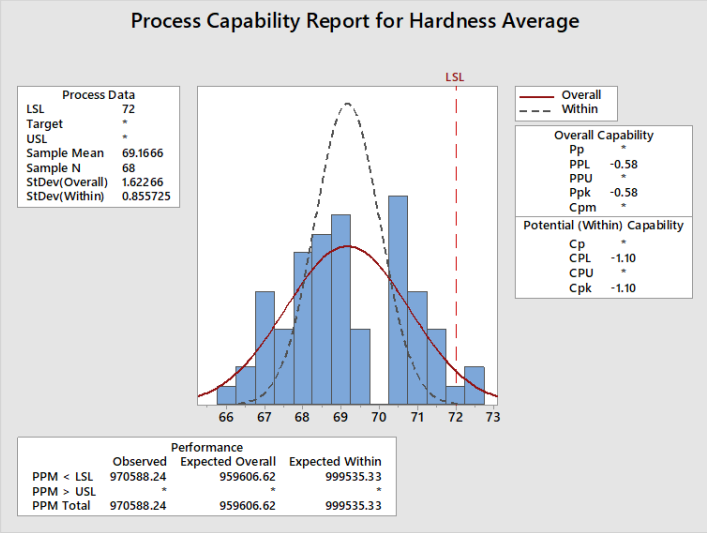
Five urethane ball models averaged less than 72 in the field.



The five models comprised 68 of the 153 urethane balls tested. The field test showed 96 percent of these "soft" urethane balls tested less than 72D.

Soft Urethanes

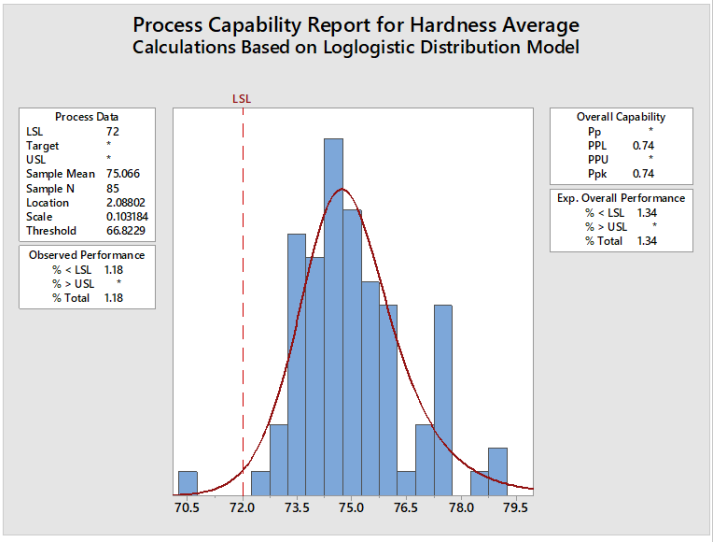
- 68 Urethane balls belonged to the 5 softer urethane models.
- The results show that 96% of these balls measured less than 72D in the field



The other 85 urethane balls tested were considered "hard" urethane balls and just over one percent of these balls tested less than 72D.

Hard Urethanes

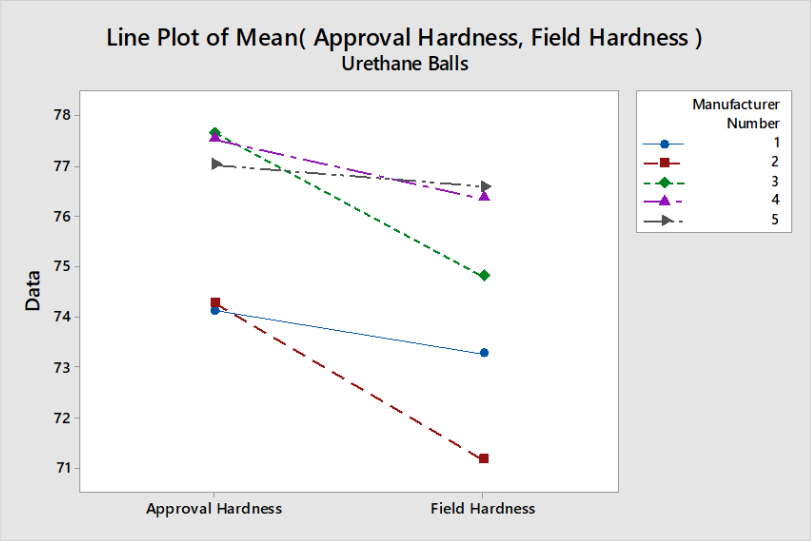
- 85 balls belonged to the harder urethane ball models
- The results show that just over 1% of these balls measured less than 72D



The field test also showed when comparing the hardness of a urethane ball at the time of approval and to its hardness in the field after use shows the hardness of the balls decrease.

Urethane Hardness drops with use

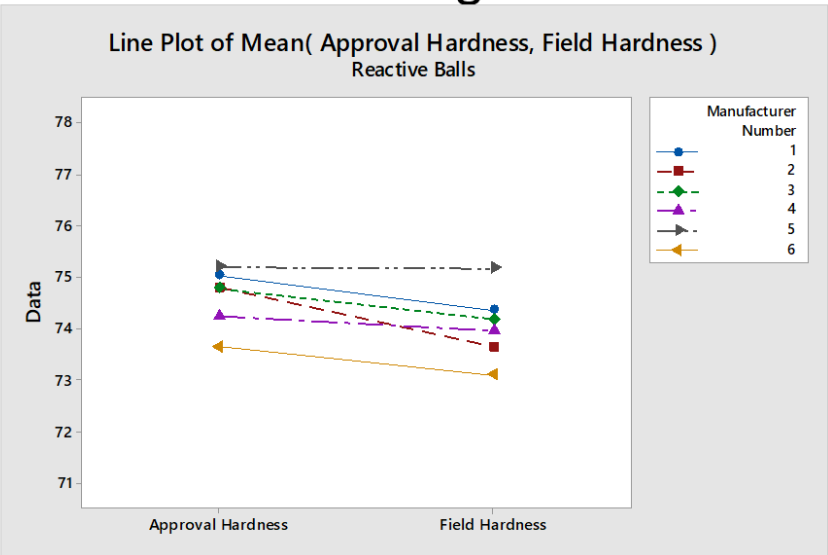
- Urethane hardness drops in the field compared to the hardness the models were approved at.
- The size of the differences change by manufacturer.



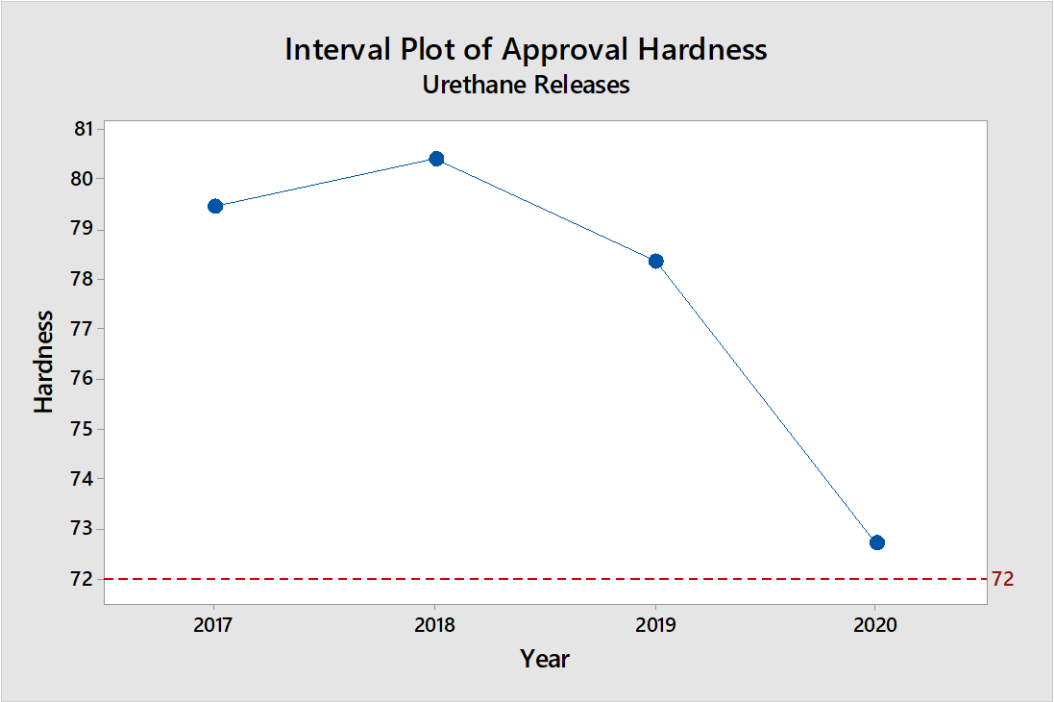
Reactive balls, however, show little variation in hardness from time of approval to when tested in the field.

Reactive balls show little to no change

- Reactive balls do not exhibit the same behavior
- Their hardness values were within measurement system variances from approval to field measurement.



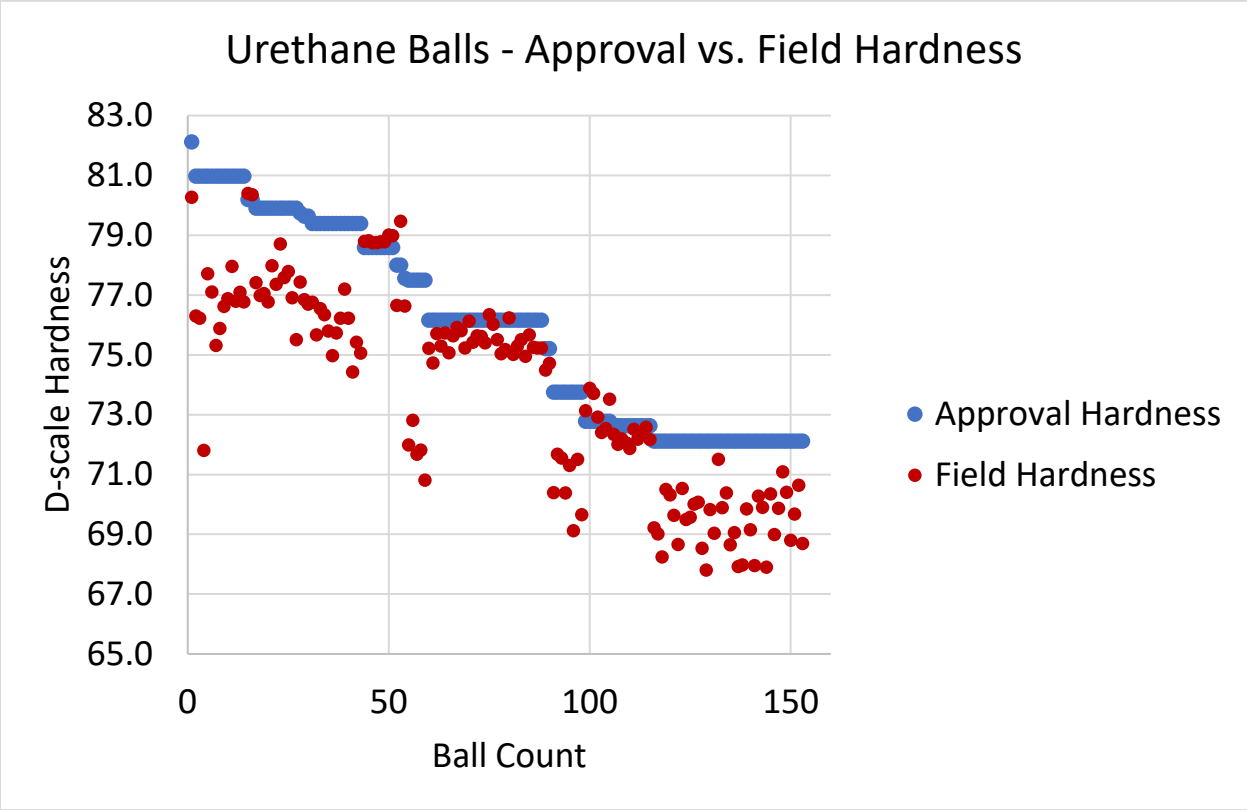
USBC monitors the hardness of approval samples and, while the data shows reactive balls have been approved at a stable level of hardness, the manufacturing target for urethane has been on a downward trajectory over the past couple of years.



Reactive ball hardness - Approval versus field test

By adjusting for measured differences between the durometers used for field testing, USBC was able to compare the measurement for each bowling ball to the average value recorded when the ball was first approved.

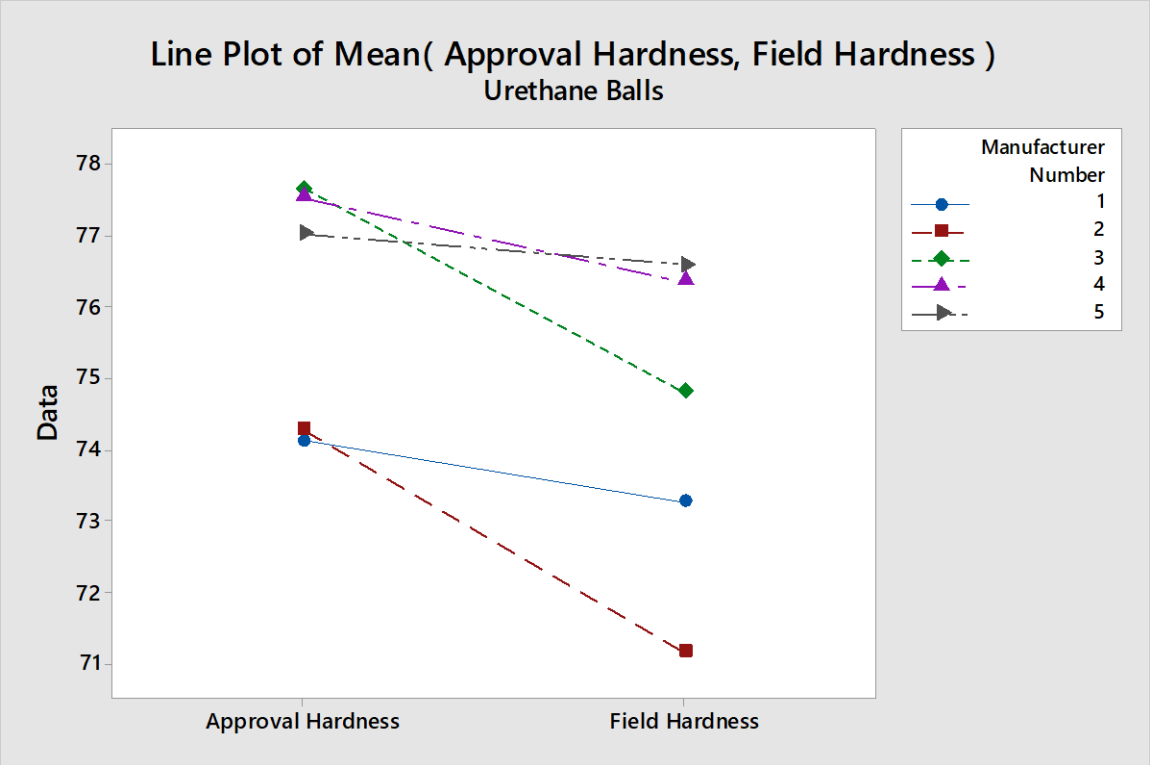
When applied to the 154 urethane balls measured, there was an average drop of 2.1 points on the hardness D-scale. The following chart shows field measurements as red dots, and approval measurements as blue dots. A change in the blue dot height corresponds to a change in ball model.



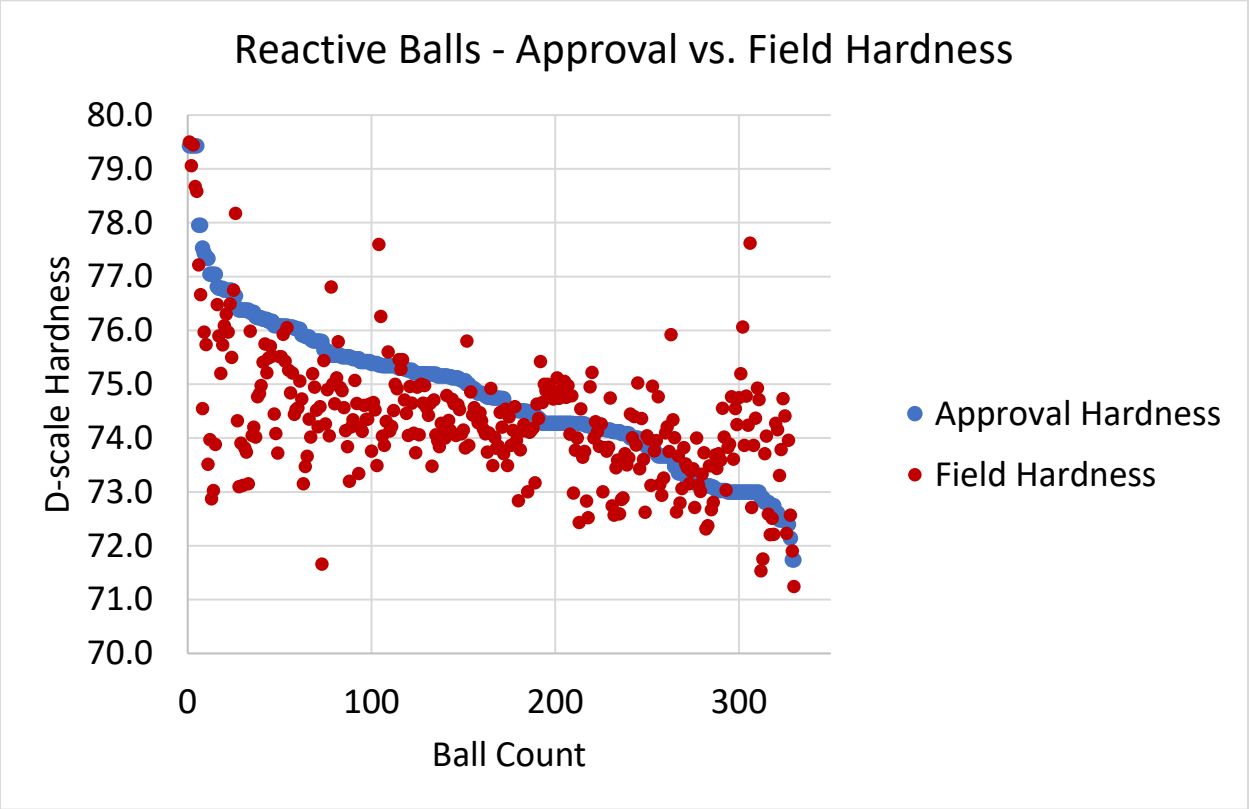
Most urethane balls drop significantly from their approval hardness, but two or three models seem to stay relatively close. Reviewing the approval data shows the models that matched closer to their approval numbers had oil absorption times of less than one hour. The fact the balls absorb oil is an indicator these balls are more of a weak reactive design, rather than a pure urethane.

In order to ensure balls remain within field test specification, targeting a higher approval hardness appears to do the job. The balls failing the field specification are balls near to the 72D specification at the time of approval.

When breaking down the hardness changes by manufacturer, all five manufacturers had a decrease in hardness from approval to the field testing, though two of the five showed a larger difference.

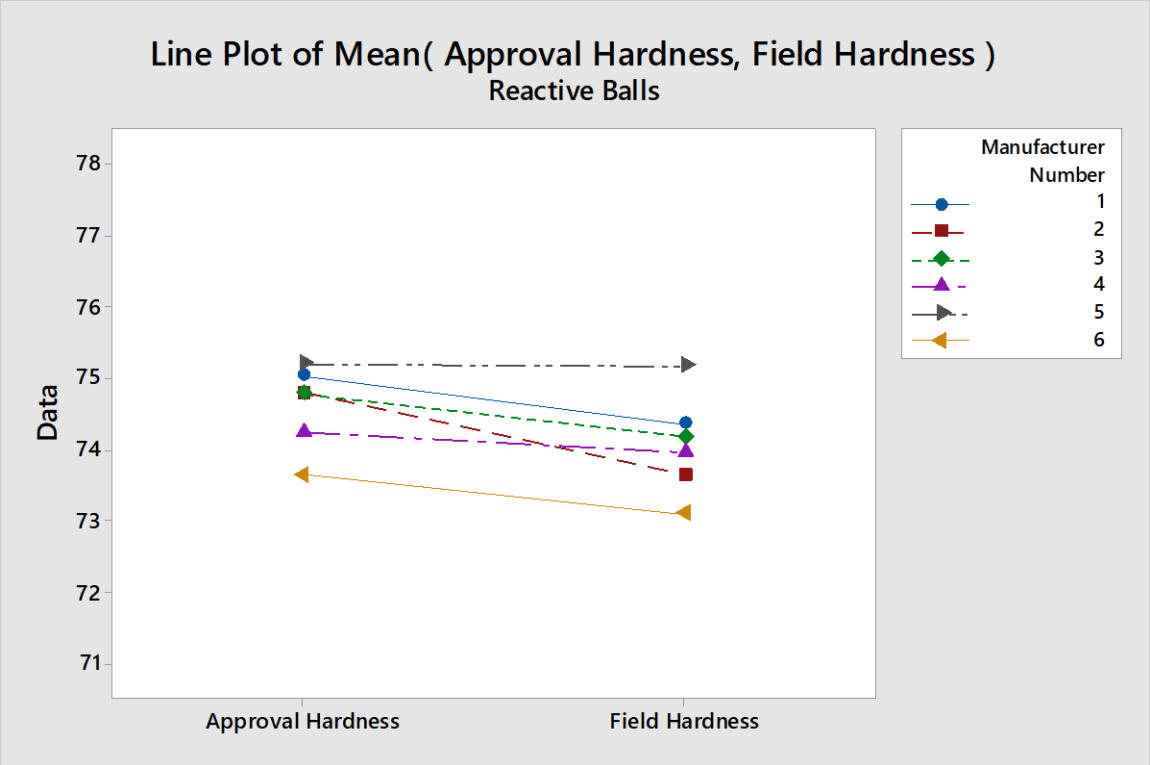


Applying the same method to reactive balls showed different results, as seen in the chart below:



Here, it is more difficult to distinguish between the approval models. In today's market, there are more models (versions) of reactive balls, resulting in a small sample size per reactive model. While there are some extreme cases of balls being as much as four points softer than the approval hardness, there also are cases where the balls in the field were as much as four points harder than the approval average. Overall, there was an average difference from approval of 0.45D softer, which was not large enough to constitute a meaningful difference.

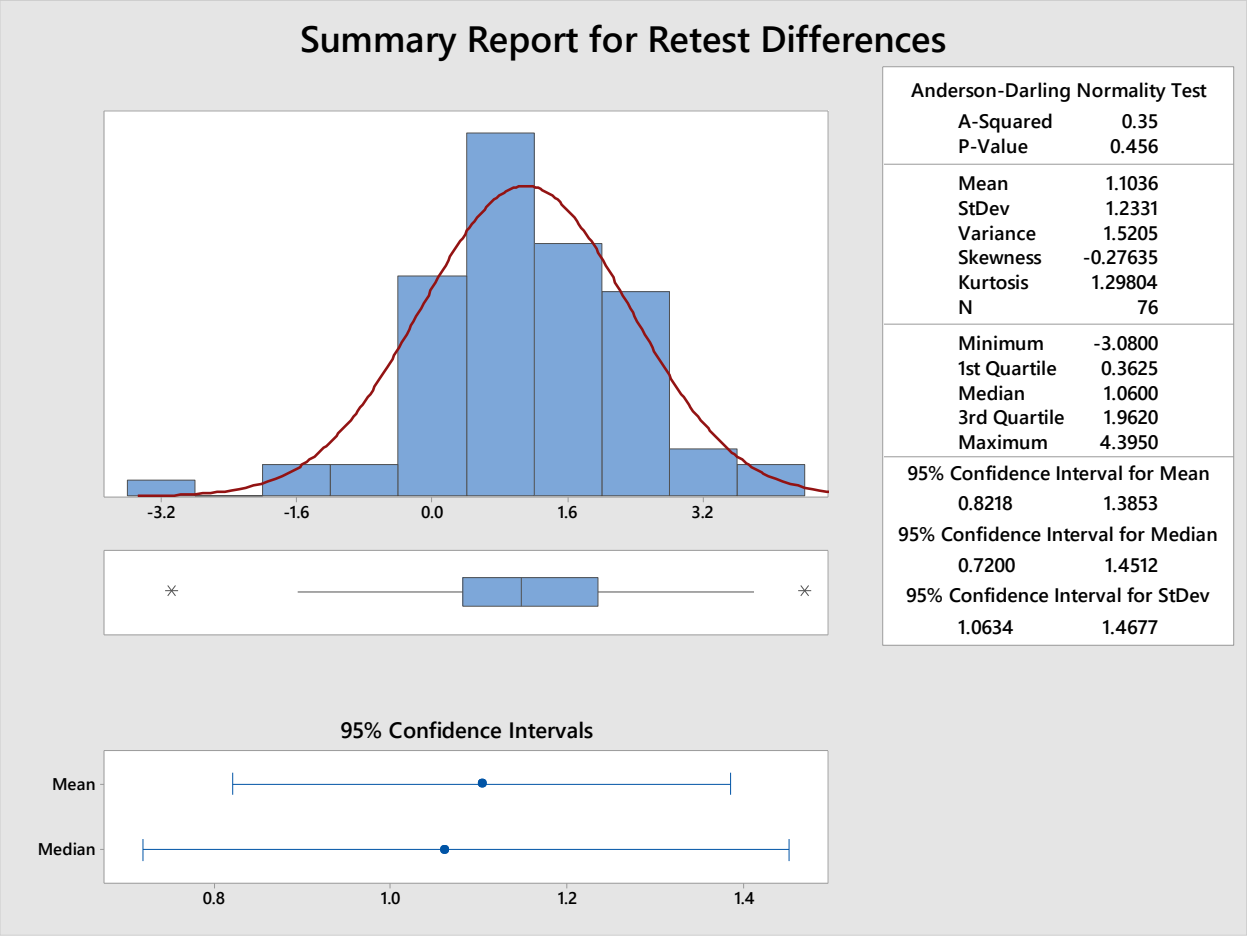
Breaking down the differences by manufacturer, the data shows that regardless of manufacturer there is little change from the approval hardness to the hardness of used reactive balls in the field.



The largest difference was 1.2 points softer for manufacturer No. 2, and the smallest difference was 0.0 points different for manufacturer No. 5.

U.S. Open balls retested at World Series of Bowling

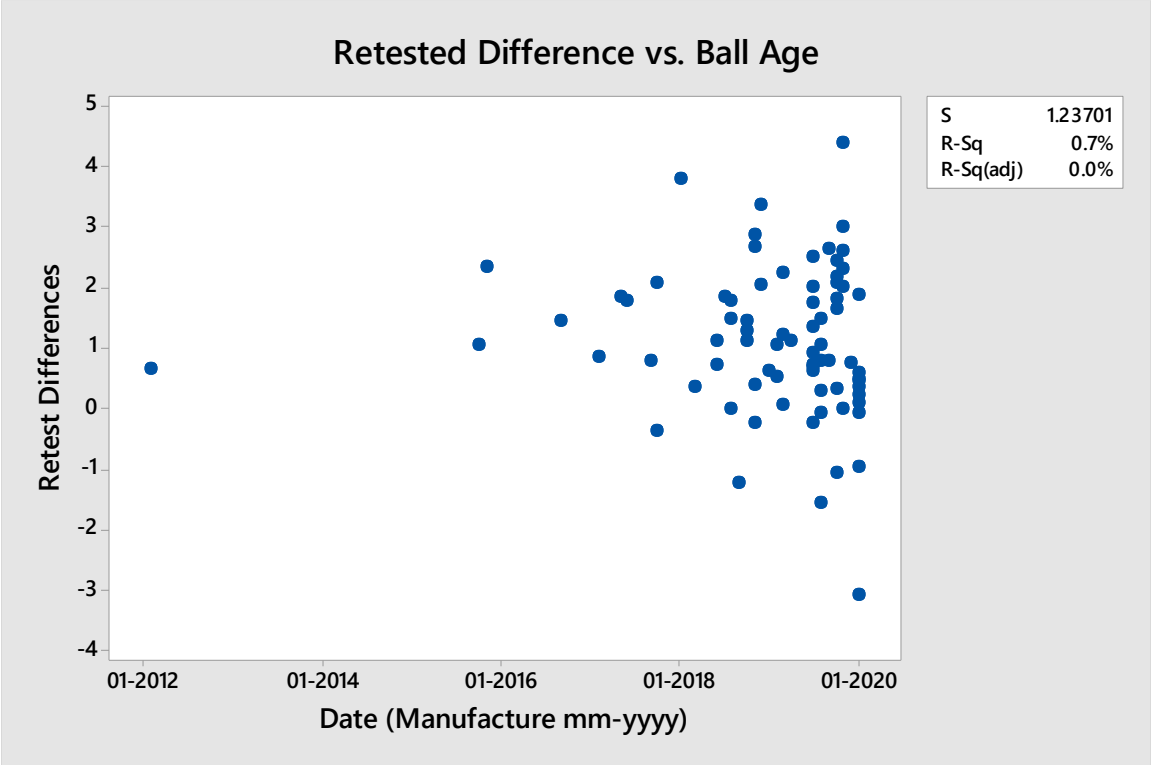
During data collection at the 2020 World Series of Bowling, 76 of the urethane balls tested at the 2020 U.S. Open were resubmitted for testing. The data shows an average (mean) paired hardness difference of 1.1 points softer on the second check. The root cause of this paired difference is under investigation. (Paired hardness means a ball's test result from the U.S. Open was compared to the same ball's test result at the WSOB). At this time, USBC staff believes the difference is related to the location of the testing and the variance of temperature gauges used to ensure the balls are within the appropriate temperature window. The following chart takes the difference in hardness measurement for each ball tested at both events and summarizes them into groups based on difference ranges.



Note: Negative differences mean the ball measured harder on the second test, and positive differences mean the ball measured softer on the second test.

The data indicates balls measured anywhere from 3.1 points harder to 4.4 points softer, with a mean difference of 1.1 points.

When these paired differences are broken down by date of manufacture, based on the serial numbers, the large fluctuations in the differences appear to be from balls made in the last two to three years, which supports the idea the overall change will settle down over time.



Key Findings

- Reactive shells showed little change when tested in the field, averaging 0.45 points softer compared to when approved
- Urethane shells showed more change when tested in the field, averaging 2.1 points softer compared to when approved
- The results vary in magnitude by manufacturer, but the trends are the same. For the reactive balls, the hardness changes little to none for all manufacturers; with urethane, the balls get softer for all manufacturers
- Duplicating the USBC field test would be extremely difficult for a tournament operator because of the time and manpower required, the number of variables, and the cost

Conclusion

The USBC Equipment Specifications Committee has proposed adjusting the approval specification for ball hardness to 73D for all models when manufactured and eliminated the field test because of challenges related to workability, temperature control and variances in testing devices.

Manufacturers will be asked to discontinue additional production of models previously approved below 73D by July 31, 2021.

All previously approved balls can continue to be used in competition.

USBC is inviting a comment period for manufacturers through June 1, 2020, on the proposed changes.

The research showed reactive balls do not get significantly softer over time and use, averaging 0.45 points softer when tested in the field compared to when approved. An increase to 73D at the time of approval allows for normal softening.

Research also has shown urethane balls get softer with use over time, averaging 2.1 points softer compared to when approved. Raising the specification to a minimum of 73D ensures reactive shell balls, which have higher hook potential than urethane, will stay above 72D hardness at all times.

USBC does not feel having urethane balls naturally fall below the hardness specification is a competition concern, since reactive balls have more hook potential than urethane.

USBC will maintain the requirement preventing bowlers from altering ball hardness as listed in the Equipment Specifications manual and in the USBC Rulebook (Rule 17a. Unfair Tactics):

> The use of chemicals, or other methods, to change the hardness of the surface of the ball after it is manufactured is prohibited.

Again, natural softening with use over time is expected and allowed. Artificial softening by tampering with a ball is prohibited.

APPENDIX – Field Test Data