ENGINEERING REPORT

Subject: Five-Person Team League Simulation Study

Date: 11/10/17

Place: International Training & Research Center

Present: Danny Speranza, Tom Frenzel and Test Bowlers

Purpose:

Test oil depletion and ball reaction with three types of balls:

- Modern Reactive – High total differential balls with fast oil absorption rates
- Reduced Reactive – Reduced total differential balls with slow oil absorption rates
- Modern Urethane – High total differential urethane balls, which do not absorb oil

Summary:

- Modern reactive balls hooked the most and forced the bowlers to move the most
- Reduced reactive balls hooked less and forced the bowlers to move less
- Modern urethane balls hooked the least and forced the bowlers to move the least

Discussion:

This test was initiated to combine the results from the oil absorption study with the RG, differential RG study and determine how adjusting certain variables will affect:

- Oil depletion from the lane
- Required movement by the bowlers
- Impact on scoring

Ten bowlers were selected to bowl on four different days with different balls each day.

- Day 1- modern reactive ball
- Day 2- reactive balls with reduced flare and slower oil absorption time
- Day 3- modern, flaring urethane balls
- Day 4- the reduced reactive balls from day 2 were used again on a lower volume of lane oil.

The pattern was altered by reducing the pump setting from 50 to 40 microliters per revolution which is a 20 percent reduction in oil volume.

Data:

Bowling Balls

Thirty bowling balls were selected to be used in this study. Each bowler was selected to be given one of each type of bowling ball.

Type	Differential RG	Oil Absorption Rate
Modern Reactive	Greater than or equal to 0.055”	Faster than 7 minutes
Reduced Reactive	Between 0.040 and 0.045	Slower than 19 minutes
Modern Urethane	Maximum available	Do not absorb oil

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Ball	Type	Weight	Shell	Total Differential	Oil Absorption Time
Ball 1	Modern Reactive	14	Solid Reactive	0.055	6.35
Ball 2	Modern Reactive	14	Hybrid Reactive	0.056	6.95
Ball 3	Modern Reactive	14	Hybrid Reactive	0.055	6.40
Ball 4	Modern Reactive	15	Solid Reactive	0.054	6.13
Ball 5	Modern Reactive	15	Hybrid Reactive	0.056	6.70
Ball 6	Modern Reactive	15	Solid Reactive	0.060	6.17
Ball 7	Modern Reactive	15	Hybrid Reactive	0.055	6.40
Ball 8	Modern Reactive	15	Pearl Reactive	0.056	6.27
Ball 9	Modern Reactive	15	Pearl Reactive	0.059	5.53
Ball 10	Modern Reactive	15	Solid Reactive	0.057	4.72
Ball 11	Reduced Reactive	14	Pearl Reactive	0.041	24.43
Ball 12	Reduced Reactive	14	Pearl Resin	0.045	24.95
Ball 13	Reduced Reactive	14	Solid Reactive	0.045	22.28
Ball 14	Reduced Reactive	15	Pearl Reactive	0.045	24.43
Ball 15	Reduced Reactive	15	Pearl Reactive	0.042	22.38
Ball 16	Reduced Reactive	15	Pearl Reactive	0.042	21.17
Ball 17	Reduced Reactive	15	Pearl Resin	0.043	24.95
Ball 18	Reduced Reactive	15	Pearl Reactive	0.043	20.22
Ball 19	Reduced Reactive	15	Hybrid Reactive	0.040	19.10
Ball 20	Reduced Reactive	15	Solid Reactive	0.045	20.03
Ball 21	Modern Urethane	14	Solid Urethane	0.051	Does not absorb oil
Ball 22	Modern Urethane	14	Solid Urethane	0.050	Does not absorb oil
Ball 23	Modern Urethane	14	Solid Urethane	0.047	Does not absorb oil
Ball 24	Modern Urethane	15	Solid Urethane	0.032	Does not absorb oil
Ball 25	Modern Urethane	15	Solid Urethane	0.053	Does not absorb oil
Ball 26	Modern Urethane	15	Solid Urethane	0.050	Does not absorb oil
Ball 27	Modern Urethane	15	Solid Urethane	0.047	Does not absorb oil
Ball 28	Modern Urethane	15	Solid Urethane	0.047	Does not absorb oil
Ball 29	Modern Urethane	15	Solid Urethane	0.046	Does not absorb oil
Ball 30	Modern Urethane	15	Solid Urethane	0.052	Does not absorb oil

Moves by the Bowlers

The bowlers filled out a worksheet about their moves throughout the test. Below is a summary:

Test parameters	Track rings	Flare width	Starting approach board	Starting target board	Finish approach board	Finish target board	Moves with feet	Moves at target
High differential RG & fast oil absorption balls	5.0	1.6	20.7	12.4	30.1	18.5	**9.4**	**6.1**
Reduced differential RG & slow oil absorption rate balls	6.3	1.4	19.1	11.5	24.9	15.4	**5.8**	**3.9**
High differential RG urethane balls	8.0	2.5	14.2	6.3	16.7	8.6	**2.5**	**2.3**
Reduced differential RG slow oil absorption balls on lower oil volume	6.3	1.4	20.4	11.6	27.5	15.4	**7.1**	**3.8**

The bowlers were asked to track where they were lining up on the approach and where their target was at the arrows. Each time the bowlers made a move, they documented it and continued bowling how they would in a standard league. The results showed:

- The balls with high differential RG and fast oil absorption rates caused bowlers to move the most. They moved an average of **9.4 left with their feet and 6.1 left with their eyes** over the course of three games bowled by 10 bowlers on two lanes.
- The balls with reduced differential RG and slow oil absorption rates reduced the amount the bowlers had to move. They moved an average of **5.8 left with their feet and 3.9 left with their eyes** with the same amount of bowling.
- The urethane balls with high total differential RG caused the bowlers to move very little. They moved an average of **2.5 left with their feet, 2.3 left with their eyes**, again with the same amount of bowling.
- On lower oil volume, the reduced differential RG, slow oil absorption balls behaved similarly to high differential RG and fast oil absorption balls on heavier oil volume. On the reduced oil volume, the reduced reactive balls caused the bowlers to move an average of **7.1 left with their feet and 3.8 left with their eyes.** Compared to the test with the same balls on higher oil volume, this showed the bowlers getting further left with their feet, while keeping their eyes in the same position.

The track ring measurements further illustrated the effects of oil absorption. Urethane balls, which do not absorb oil, showed the most amount of flare rings when the balls returned to the bowlers. The slower absorption balls showed less rings than the urethane balls. Oil was absorbed in the time it takes for the balls to return to the bowlers. The fast oil absorption rate balls showed even less track rings when they returned. Even more oil was absorbed in the time it took for the balls to return to the bowlers. The rate at which balls are absorbing oil is increasing the amount of the balls surface which is dry. Dry surface directly relates to the friction the ball experiences while traveling down the lane.

SPECTO Results

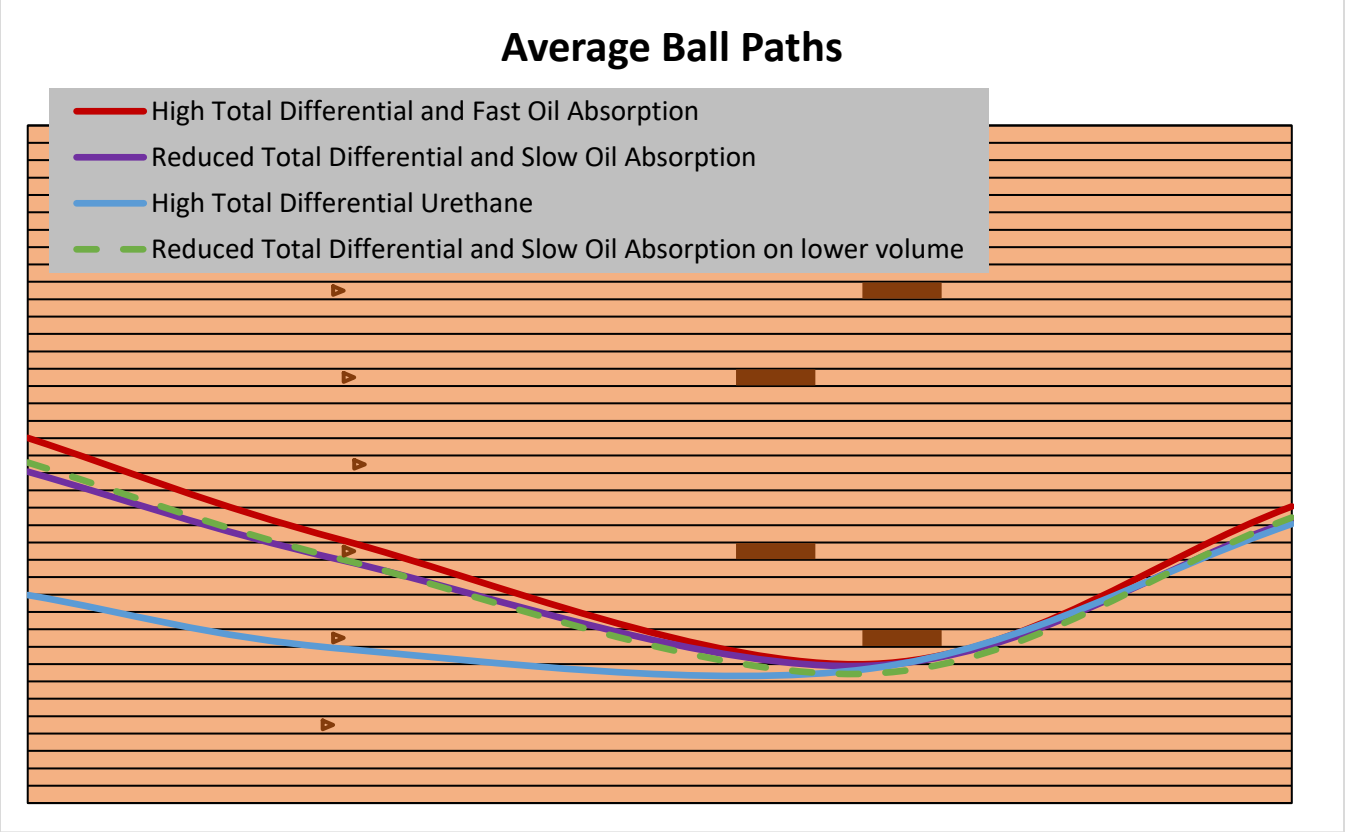
For all three types of bowling balls, Kegel's SPECTO tracking software was used to track the ball paths. The average ball paths for each type of ball are shown on the next page. The results show that:

- Reduced differential RG with slow oil absorption balls play 2 and 1 right of high differential RG, fast oil absorption balls
- High total differential urethane balls play 9 and 6 right of high differential RG, fast oil absorption balls
- On lower volume, the reduced differential RG with slow oil absorption balls play 1.5 and 1 right of high differential RG, fast oil absorption balls

Furthermore, the data shows that the bowlers had to adapt how they bowl when the equipment changes. As the ball's strength decreased, the bowlers naturally reduced ball speed and straightened their lines to preserve entry angle into the pocket.

Test parameters	Launch Speed	Launch Angle	Entry Angle	Total Angle
High differential RG & fast oil absorption balls	17.463	-2.012	3.636	5.648
Reduced differential RG & slow oil absorption balls	17.153	-1.746	3.286	5.032
High differential RG urethane balls	16.994	-1.065	2.697	3.762
Reduced differential RG & slow oil absorption balls on lower volume.	17.471	-1.911	3.552	5.463

- Balls with reduced differential RG and slow oil absorption caused the bowlers to reduce speed by 0.31 MPH and straighten their angles by 0.266 degrees. Even with these adjustments, bowlers lost 0.35 degrees of entry angle.
- High differential RG urethane equipment caused bowlers to reduce speed by 0.47 MPH and straighten their angles by 0.95 degrees. Despite the adjustment, bowlers still lost 0.94 degrees of entry angle.
- On lower oil volume, the reduced differential RG with slow oil absorption balls were able to be thrown with equivalent speed to the high differential RG fast oil absorption balls with 0.10 degrees straighter launch angles. They only saw a 0.08 degrees reduction in entry angle.



Note: The solid ball paths were bowled on 23 mL of oil, the green dashed ball path was bowled on the same pattern with 18 mL of oil.

Scoring Pace

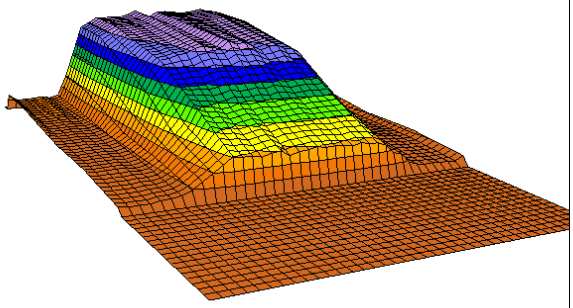
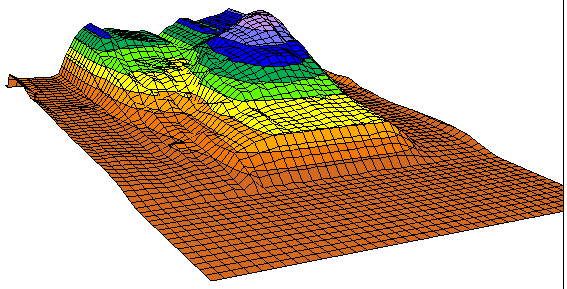
Scores were tracked for each ball type for the two teams of five bowlers. The results are as follows:

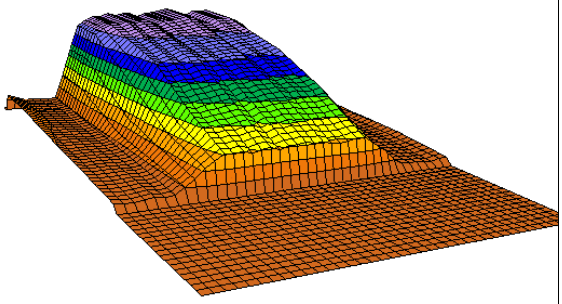
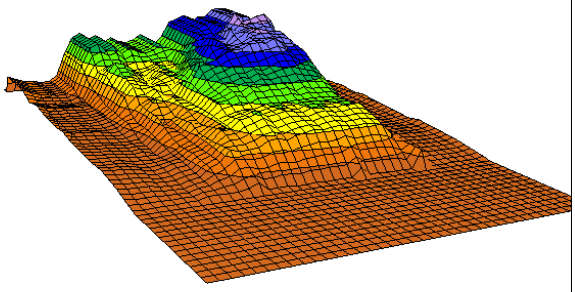
Test parameters	Team 1	Team 2	Total	Comparison
High differential RG & fast oil absorption rate balls	3215	3103	6318	+0
Reduced differential RG & slow oil absorption balls	3140	2833	5973	-345
High differential RG urethane balls	2901	2888	5789	-529
Reduced differential RG & slow oil absorption balls on lower volume.	3425	2982	6407	+89

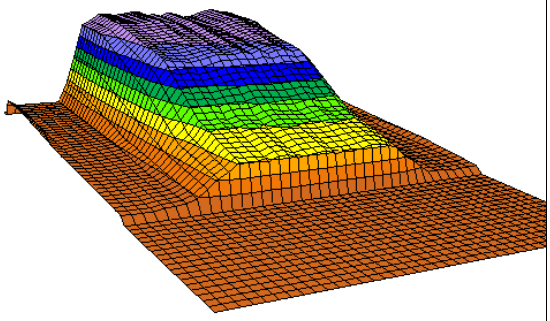
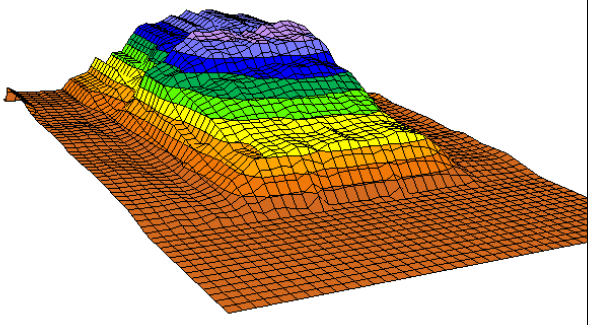
- Reduced total differential slow oil absorption balls scored 345 pins lower than high total differential fast oil absorption balls (11 pins per game less).
- High total differential urethane balls scored 529 pins lower than high total differential fast oil absorption balls (17 pins per game less).
- On lower volume, the reduced total differential slow oil absorption balls scored 89 pins higher than the high differential fast oil absorption balls (3 pins per game more).

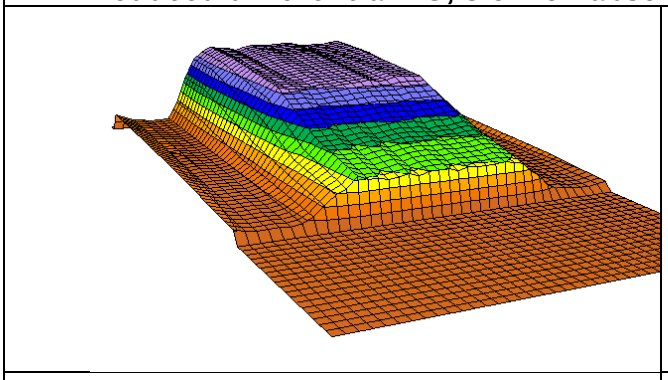
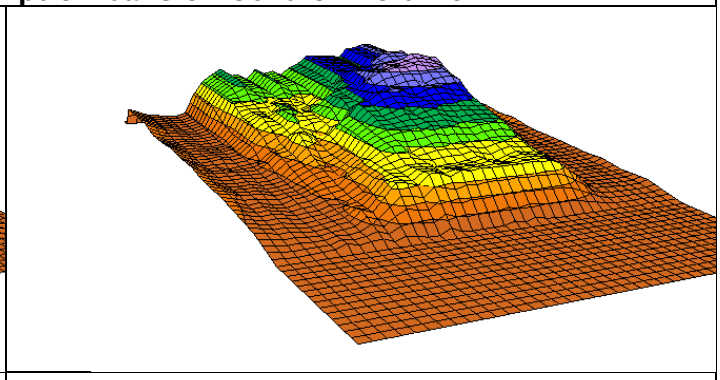
Oil Depletion

To track oil depletion, tapes were taken before bowling and in between each game to view how the pattern was deteriorating over time. The following are 3D graphics of the pattern before and after bowling.

High differential RG, fast oil absorption balls.	
	
Fresh	Breakdown

Reduced differential RG, slow oil absorption balls.	
	
Fresh	Breakdown

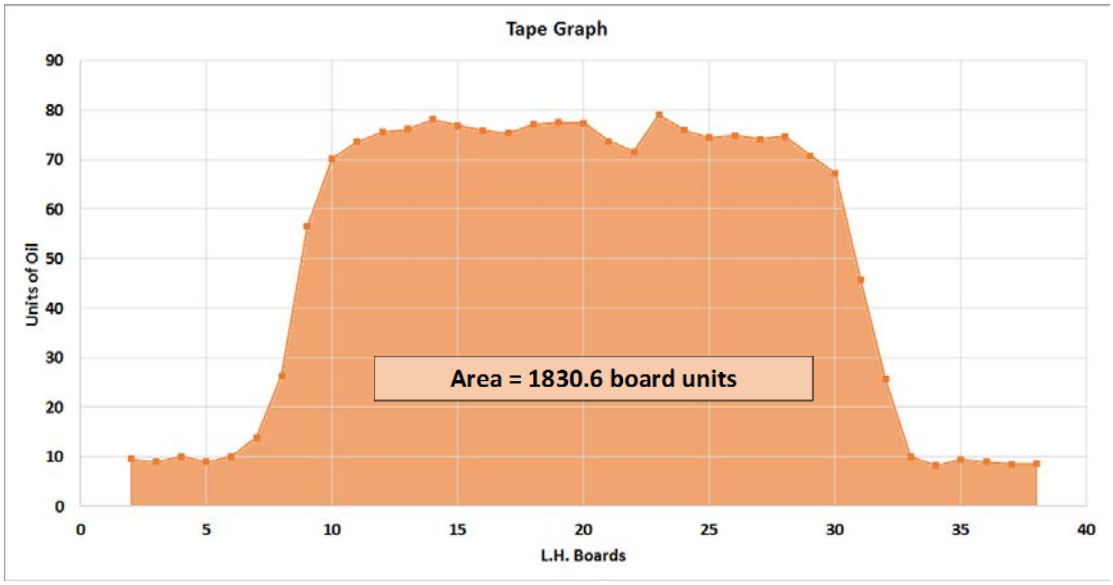
High differential RG urethane balls.	
	
Fresh	Breakdown

Reduced differential RG, slow oil absorption balls on 80% oil volume.	
	
Fresh	Breakdown

These graphics show that the modern reactive balls depleted the entire peak of the pattern in the heads. This was due to the bowlers needing to continually move left to keep the balls in the pocket. The reduced reactive balls only removed oil towards the right-hand side of the pattern. In fact, some oil in the purple range of the graph (the color associated with the maximum oil volume) is still visible on the left side of the pattern. The bowlers were able to stay right longer without having to move as far left, and the differences were clear.

The modern urethane equipment only removed a small portion of oil in the heads on the right side of the pattern. For the urethane balls, the oil left of the 20th board remained untouched because the bowlers never had to move that far left. When the reduced reactive balls were revisited on the lower oil volume, the breakdown was still focused on the right side of the lane condition. This time, the bowlers were still able to stay right longer, though at the end of bowling they were another board further left than before with their laydowns as we saw earlier. There is still a small purple area in the heads that the modern reactive balls completely depleted.

The amount of oil was quantified by calculating the area under a lane tape. This is an example of one of the tapes we took at eight feet down the lane prior to bowling:



The area is calculated by determining the lines from point to point for each data point then using integration to calculate the area under each line. By adding the areas under the eight feet, 22 feet, 31 feet and 40 feet tapes we can get a value that represents how much oil is on the lane.

Test parameters	Oil Before Bowling	Oil After Bowling	Oil Removed	Percent Removed	Comparative Oil Removed
High differential RG & fast oil absorption rate balls	5002	3519	1483	29.6%	Baseline
Reduced differential RG & slow oil absorption rate balls	5119	3698	1421	27.8%	4.2% less
High differential RG urethane balls	4969	4052	917	18.5%	38.2% less
Reduced differential RG & slow oil absorption balls on lower volume.	4247	3195	1052	24.8%	29.1% less

Based on this data:

- Reduced differential RG, slow oil absorption balls removed 4.2% less oil than their high differential RG, fast oil absorption counterparts.
- The high differential RG urethane balls removed 38.2% less oil than the high differential RG, fast oil absorption bowling balls.
- When thrown on lower volume, the reduced differential RG slow oil absorption equipment removed 29.1% less oil than the oil that was removed by the high differential RG fast oil absorption equipment on high volume. There appears to be a correlation between the initial volume of a pattern and how quickly the oil is removed from the lane.

Carry Down

Using the same method on tapes taken 2 feet past the pattern, we can evaluate the carry down.

Test parameters	Carry Down after game 1	Carry Down after game 2	Carry Down after game 3
High differential RG & fast oil absorption rate balls	39.9	41.4	33.5
Reduced differential RG & slow oil absorption rate balls	33.2	63.0	37.0
High differential RG urethane balls	23.1	54.7	46.5
Reduced differential RG & slow oil absorption balls on lower volume	21.4	32.5	40.7

This data showed that the greatest amount of carry down was detected after Game 2 with the reduced differential RG slow oil absorption balls with high oil volume. The second-highest was the high differential RG urethane balls after Game 2. This suggests that both oil absorption and differential RG play a role in controlling how much oil is carried down the lane.

Conclusion

In this study, we have seen that the reduced differential RG ball with slower oil absorption rates minimize the amount bowlers move over the course of a league night. We also saw that bowlers will compensate for the equipment by adjusting their ball speed and launch angles. In addition, we have seen that a reduction in lane oil volume has the potential to keep scoring to the level of modern balls on more oil, while keeping the bowlers further right. Lastly, we have seen that balls with higher absorption rates have shown to reduce the amount of oil that is being removed from the lane. All this needs to be considered in maintaining the integrity of the sport by ensuring technology never outweighs the skill of the bowlers.