ENGINEERING REPORT

Subject: Summary of all Tests and Area at Pocket

Date: 1/6/16

Place: International Training & Research Center

Present: Danny Speranza

Purpose:

This report gives an overall summary of the different tests in the RG and differential RG study.

Summary:

The RG and differential RG Study was to determine the impact on ball reaction from these two ball properties. Major findings:

- If the bowler's properties are held the same and only the ball properties of RG and differential RG change, then the high RG, high differential RG ball performed best
- Discovered that bowler's RPM rate is naturally altered if the moment of inertia of the ball changes. This drastically affects the on-lane test results.
- If the RPM rate is adjusted depending on the moment of inertia of the ball, then the low RG, high differential RG ball performs best
- On a house oil pattern, the ball performance difference is smaller when the RG and differential RG are changed due to the varying lane friction created by the oil pattern
- This report investigates the "area at the pocket" and finds on a house pattern the low RG, high differential RG ball achieves a smaller area at the pocket which improves potential scoring

Data:

This report summarizes the findings from the different tests for the RG and differential RG ball property study.

Test parameters in the order of testing:

The following tests were conducted using balls with varying RG and differential RG values:

1. Vary RG and differential RG of the ball with same bowler properties on a flat oil pattern. Throw all balls from the same starting location and direction and move every five shots. Test on flat oil.

2. Vary the RPM rate depending on the moment of inertia to maintain same rotational energy and line up each ball to hit the same location at the end of the oil pattern plus hit the pocket. Test on a flat oi pattern.

3. Same as previous test but test on a walled-up house condition.

ENGINEERING REPORT

Summary table:

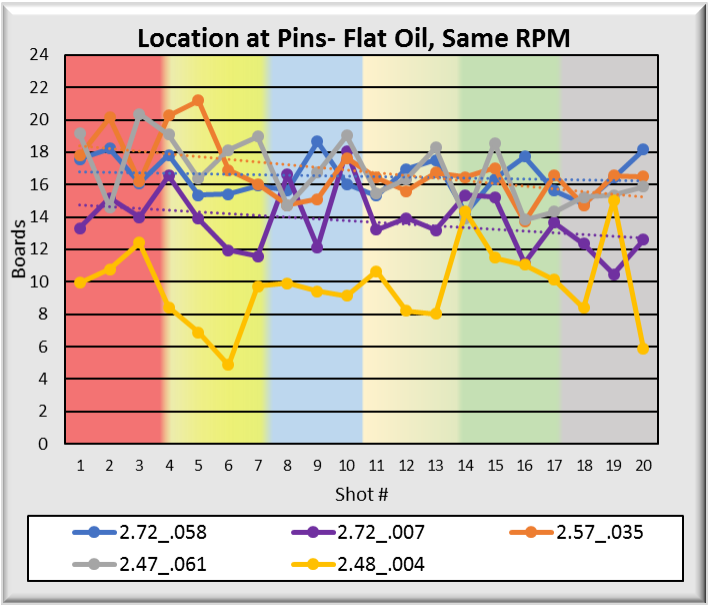
	Flat pattern with same RPM			Flat pattern with adjusted RPM			House with adjusted RPM		
Test Parameters	**Original RG_ diff Rg test**	**Value**	**Comments**	**Adjusted RPM, flat**	**Value**	**Comments**	**Adjust RPM, house**	**Value**	**Comments**
Overall test setup	Same RPM rate for all balls			Vary RPM vs MOI for each ball			Vary RPM vs MOI for each ball		
- RPM for low MOI	275			282			282		
- RPM for high MOI	275			262			262		
oil pattern	flat			flat			house condition		
Ball path	All same ball path			hit pocket, adjust every 5 shots			hit pocket, adjust after shot 10		
Overall test summary	**Follows math prediction that High RG performs better- high RG_ high diff had the most boards of hook and total angle**			**Follows bowlers opinion that low RG performs better- low RG_ high diff had most boards of hook and earliest break point**			**House condition brings ball reactions closer together- low RG_high diff had most boards of hook, low RG_low diff had the most total angle**		
Boards of Hook (bds)	High Rg hooked more than low RG with all diff RG			Diff Rg has a greater impact on boards of hook than RG			RG had greater impact on boards of hook than Diff RG		
- most	**high RG_ high diff**	**21.8**		**low RG _ high diff**	**18.3**		**low RG_ high diff**	**12.7**	house oil pattern greatly affected boards of hook
- 2nd most	high RG_ low diff	20.8		center pt	17.6		low RG_ low diff	12.5	
- 3rd most	low RG_ high diff	20.7		high RG_ high diff	17.4		center pt	12.2	
- least	low RG_ low diff	16.9		high RG_ low diff	8.7		high RG_ low diff	11.3	
Total Angle (degrees)	high RG had more angle with any diff RG			Diff Rg has a greater impact on total angle than RG			house pattern greatly affected angle RG & diff Rg have same impact		
- most	**high RG_ high diff**	**7.5**		**high RG_ high diff**	**6.8**		**low RG_ low diff**	**5.5**	Low RG has more total angle
- 2nd most	center pt	6.9		center pt	6.5		low RG_ high diff	5.4	
- 3rd most	high RG_ low diff	6.8		low RG _ high diff	6.0		center pt	5	
- least	low RG_ low diff	6.2		high RG_ low diff	3.9		high RG_ low diff	4.4	
Break point (ft)	Break point about the same for all flaring balls			throw out early hooking balls due to playing straighter line			throw out early hooking balls due to playing straighter line		
- earliest	**low RG_ high diff**	**43.1**		**low RG_ high diff**	**42.4**	not a large change in break point location if thrown with the same ball path	**high RG_high diff**	**40.8**	results might be affected by small changes in launch angle and lay down pt
- 2nd earliest	high RG_ high diff	43.2		high RG_ high diff	43.2		center pt	41.3	
- 3rd ealiest	high RG_ low diff	43.2		center pt	43.4		low RG_ high diff	42.0	
- latest	low RG_ low diff	45.8							

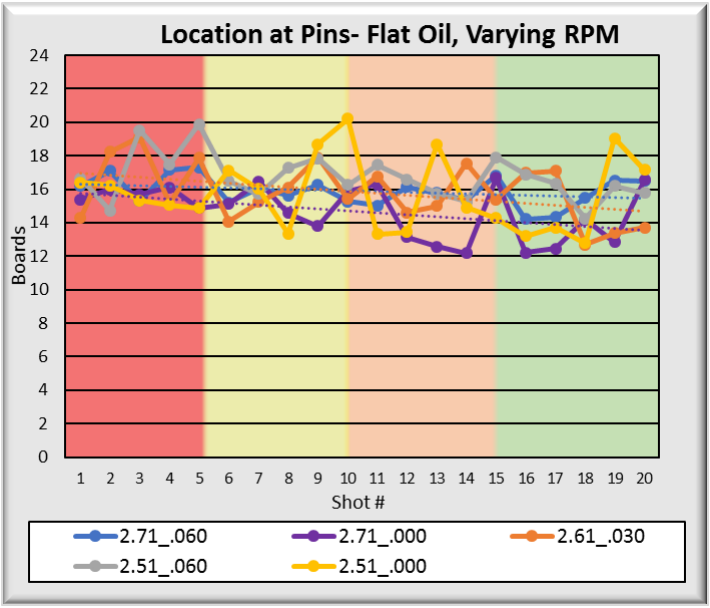
ENGINEERING REPORT

ENGINEERING REPORT

Area at the pocket:

A good ball reaction is a ball that wants to hit the strike pocket the most. Therefore, a ball reaction that ends up hitting a smaller area at the pocket is desirable; and the data present here is an attempt to evaluate that objective. The graphs below show the ball location at the pins.

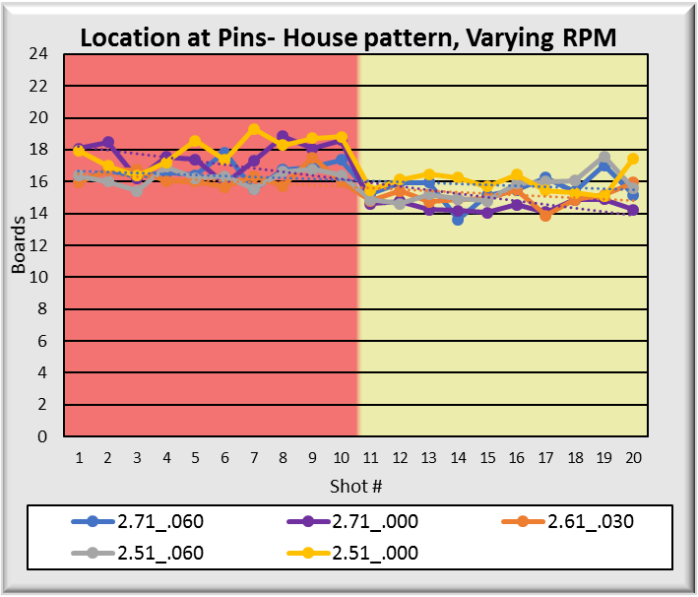




The first 2 tests (above), when varying both the RG and differential RG (above), were on a flat oil pattern. The first graph above played the same line with all balls with the same RPM rate and did not try to hit the pocket. But, it still shows the repeatability from each ball over 20 shots. The 2nd graph above also was tested on the same flat pattern but started out hitting the pocket. For both tests, the ball path was moved in towards the center of the lane after every five shots by 1.5 boards at the foul line and 1 board at the arrows. The background chart color shows when the launch conditions changed.

For the most part, the final position stayed close to the same location throughout the 20-shot test. Therefore, the 1.5-by-1 move worked well.

ENGINEERING REPORT



Above is a chart where we adjusted the RPM rate to match the moment of inertia of the ball and tested on a house pattern. Only one move was made after shot 10 by the same 1.5-by-1 move. It is obvious that after the move on shot 11, all final locations were hooking a little less. Therefore, the move was too large.

Comparing this chart on a house pattern to the first two charts on a flat pattern, the final locations were in a smaller range on the house pattern. The walled-up oil pattern reduced the area at the pins. This makes sense to bowlers.

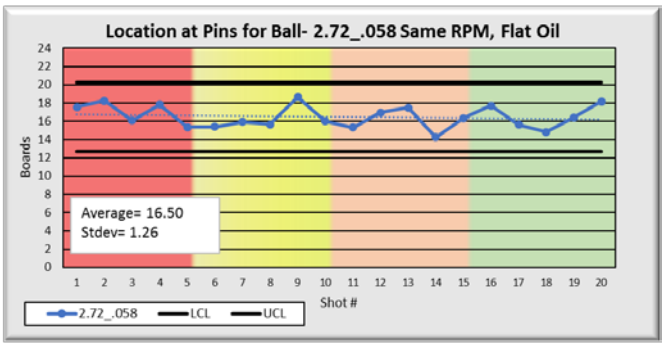
Below is the same data graphed as separate control charts:

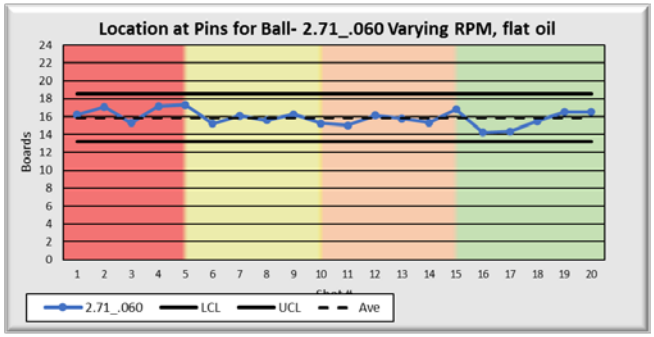
- The upper and lower control limits indicate the area at the pocket. The limits are equal to ±3 times the standard deviation. The closer together the limits, the better that ball is at hitting a given target.
- Remember the first 2 tests were done of flat oil patterns, which will create a larger gap between the upper and lower limits.
    - The last test was on a house condition which create a smaller gap between limits

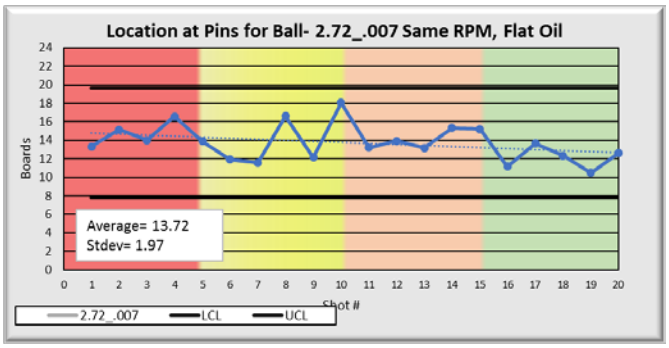
ENGINEERING REPORT

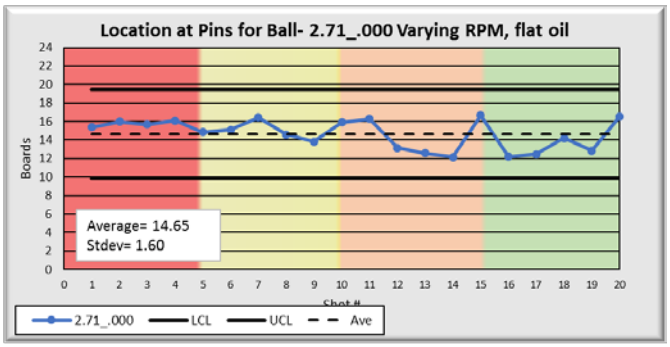
Same RPM rate on flat pattern

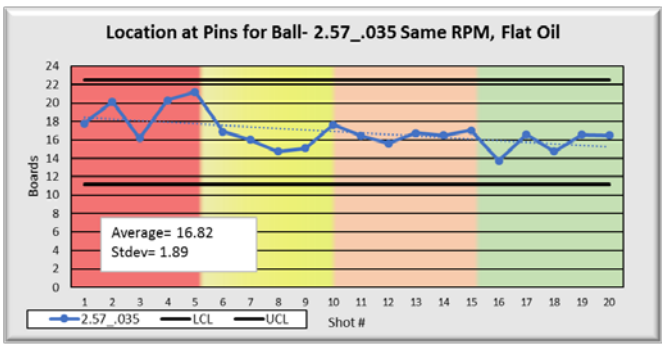
Varying RPM on flat pattern

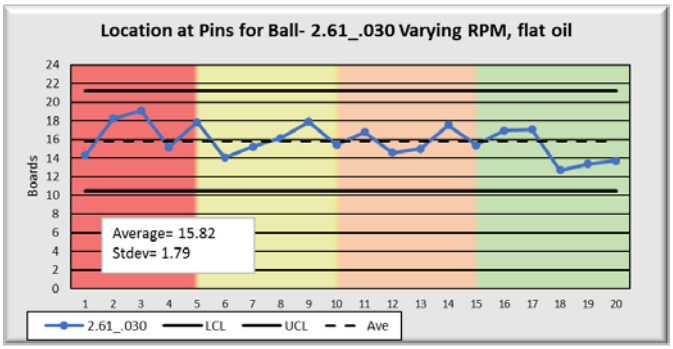


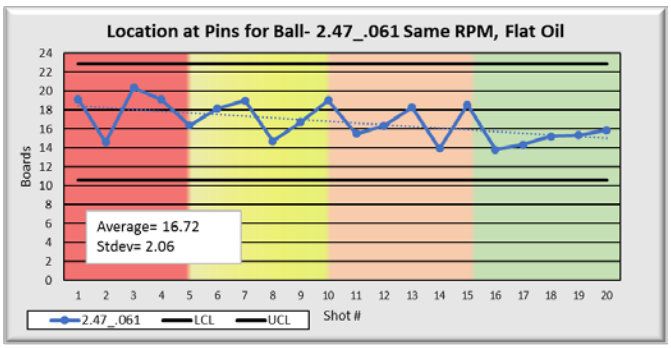


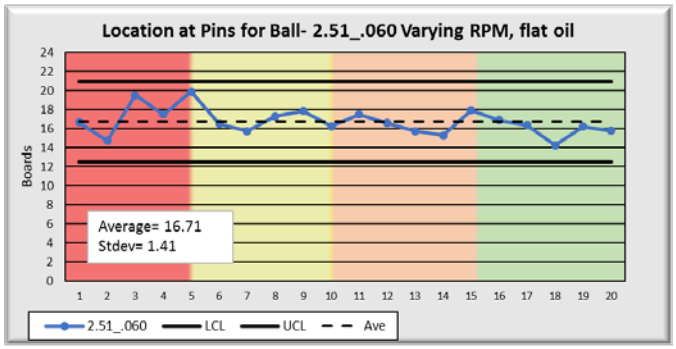




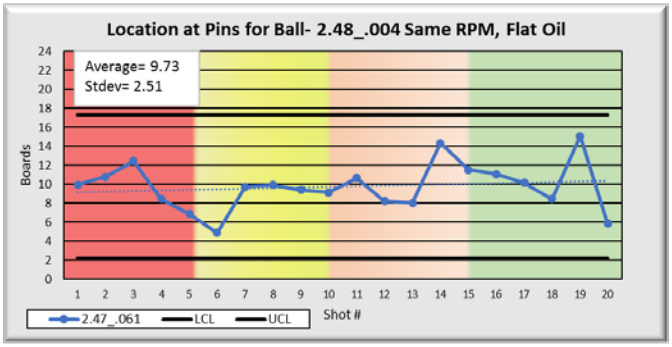


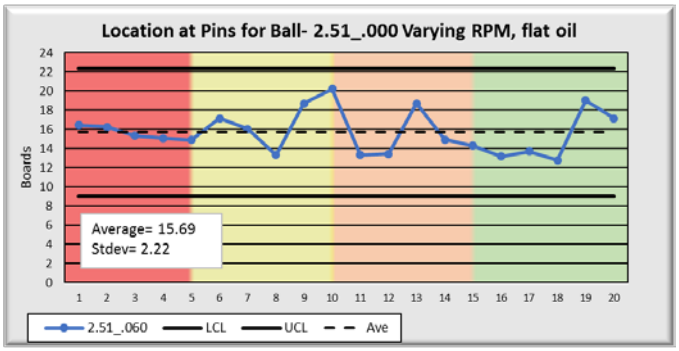






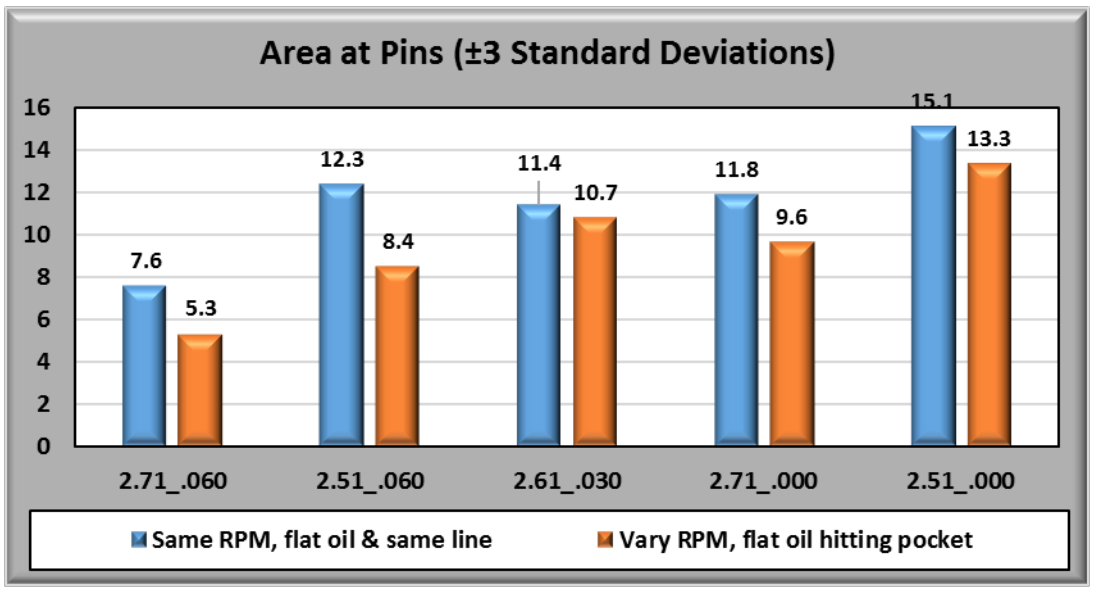
ENGINEERING REPORT





For the first test which was on a flat oil pattern and same rotation for all balls, the smallest area at the pocket was with the high RG, high differential RG ball (2.72 / .058). From the test with varying RPM rate and flat oil pattern, the smallest area still came from the high RG, high differential RG ball.

The graph below is another way to see the area at the pins.



Smaller bars equate to a smaller area at the pocket and is a preferred reaction.

ENGINEERING REPORT

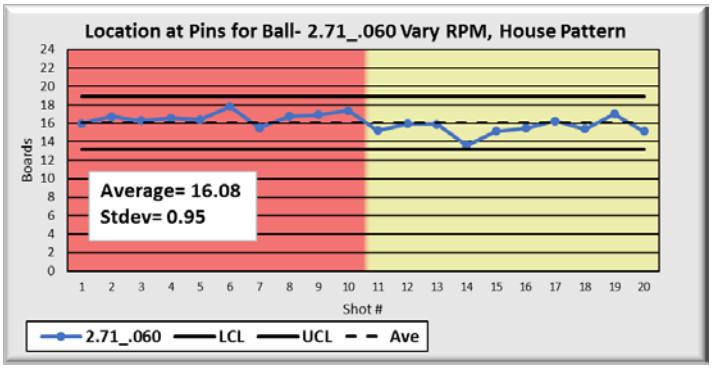
Area at Pins

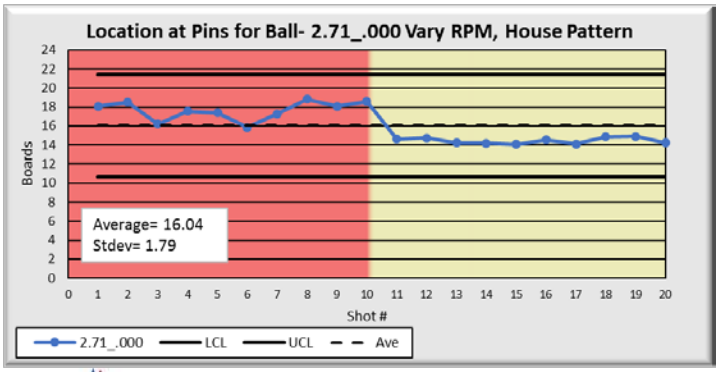
	Ball	2.71_.060	2.51_.060	2.61_.030	2.71_.000	2.51_.000
Same RPM, flat oil, same line	Average	16.50	16.72	16.82	13.72	9.73
	St. dev.	1.26	2.06	1.89	1.97	2.51
	total area (± 3 stdev)	7.6	12.3	11.4	11.8	15.1
	ranking (smallest area to largest)	1	4	2	3	5
Vary RPM, flat oil, hitting pocket	Average	15.89	16.71	15.82	14.65	15.69
	St. dev.	0.88	1.41	1.79	1.60	2.22
	total area (± 3 stdev)	5.3	8.4	10.7	9.6	13.3
	ranking (smallest area to largest)	1	2	4	3	5

Varying RPM on flat oil hitting pocket is what a bowler should see when they bowl on a flat oil pattern that hooks a lot. The bowler would natural achieve more rotation from balls with lower moment of inertias. So, on a flat oil pattern that hooks a lot, the best performing ball as far as area at the pocket was the high RG, high differential ball. Second best was the low RG, high differential RG ball.

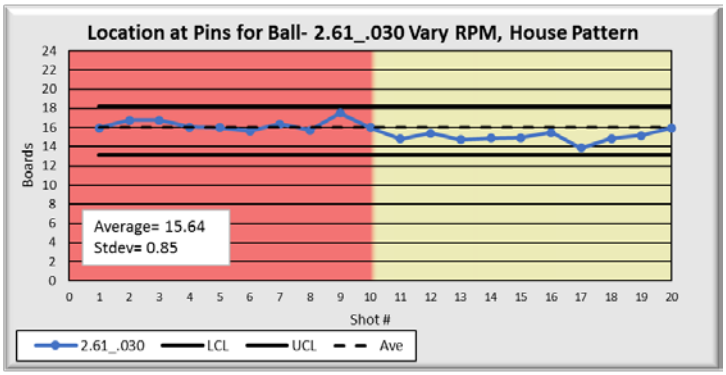
Below are the control charts for the different balls with varying RPM rate on a house condition:

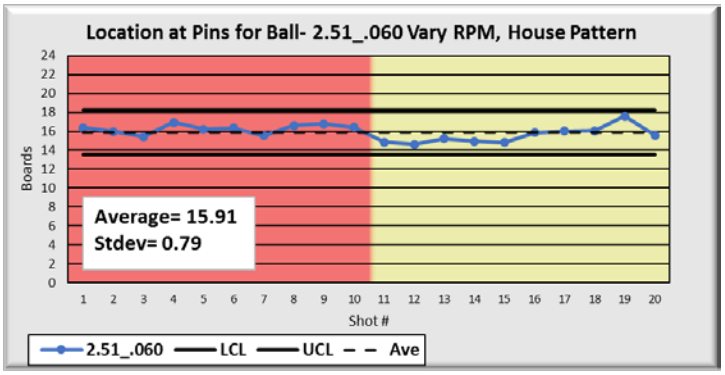
Vary RPM rate on house pattern

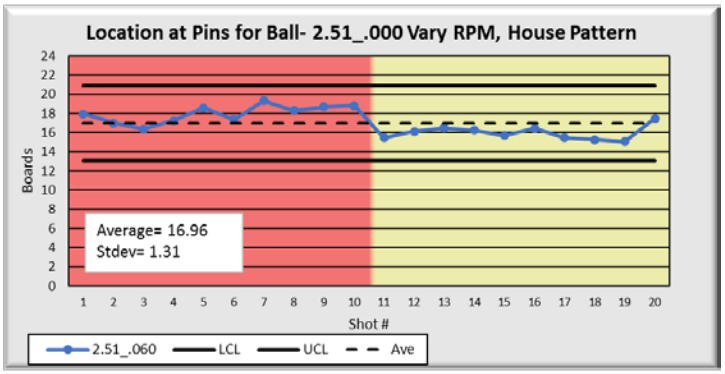




ENGINEERING REPORT



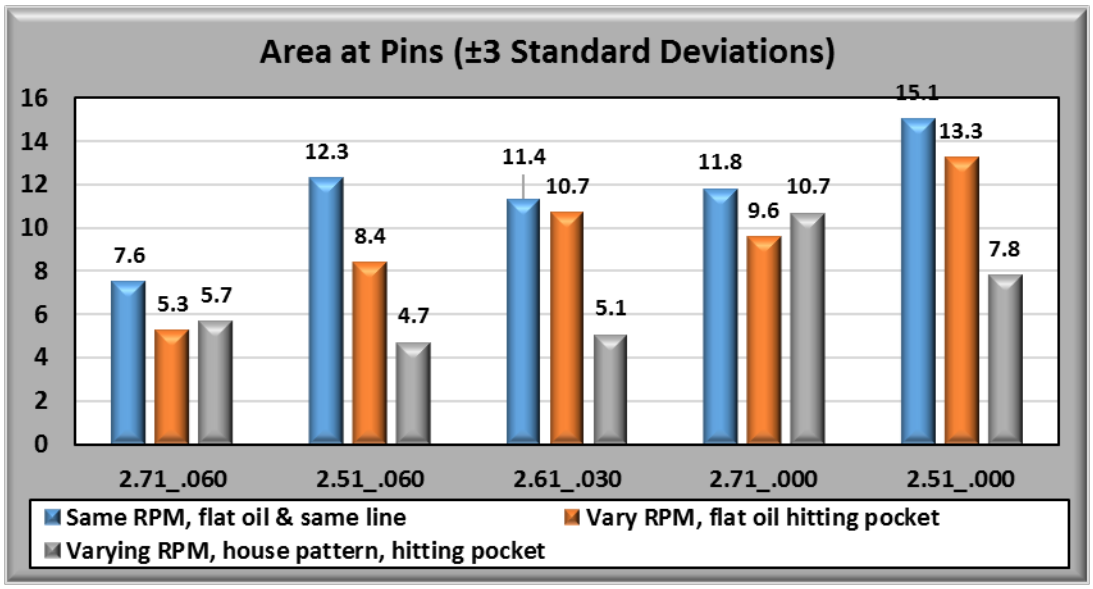




The upper and lower control limits are closer together, as they should be on a house pattern. And, it is very obvious that there was drifting in the control chart for shots 11-20 after moving the ball path. Many control charts have eight or more data points in a row below the average, which indicates drifting. If we rerun this test and not make any moves after shot 10, the area at the pins should get even smaller on the house condition.

The chart below shows the area at the pins for the different balls throughout the tests.

ENGINEERING REPORT



The grey bars for the area at the pins on the house pattern are mostly shorter, indicating a smaller area at the pins on the house pattern. The best ball for the house pattern is the low RG, high differential ball (2.51 / .060) with the smallest area (or smallest standard deviation). All three flaring balls had smaller areas at the pins then the non-flaring balls on the house condition. Many grey bars represent about half the area at the pins as the same ball on a flat oil pattern (blue and orange bars), indicating the ball path being steered by the oil pattern on the house condition.

This area at the pins is probably the most important factor in ball selection for a given oil pattern.