Subject:	Differential RG Study

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Place: International Training & Research Center

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Purpose:

Combination RG and Differential RG Study will start with evaluating the effect from varying just differential RG.

Summary:

The results from varying the differential RG of a ball showed that very small differential RG (below .030) reduced the hook amount significantly, along with reducing entry angle, and generated a later break point.

Differential RG in the .030 to .050 all had about the same amount of hook, entry angle and break point location.

.060 and .070 Differential RG had a little more hook, more entry angle and an earlier breakpoint than the .030 to .050 differential RG balls.

Data:

Test parameters

The "Combination RG and Differential RG" Study is a test to quantify the lane performance from these two ball properties. In this test, only, the differential RG of a ball was varied. A single ball was used for this test. To vary the differential RG of the ball, two large 1-3/8" diameter holes were drilled into the ball through the pin (which is the low RG axis) and opposite the pin (See picture below). A spreadsheet was developed to calculate the ball RG and differential RG if various density materials (i.e. steel, ball plug material and hollow spacers) were inserted into the holes at different depths. It was determined that we could manipulate these weighted slugs and create differential RG ranging from .000 to .060, which is the current specification range. At the end of the test, we added .070 differential RG since gripping holes can result in raising the final differential RG above the .060 manufacturing spec.







A 13-pound ball was used for the test knowing that weights would be added. The final measured ball varied from the calculated differential RG by less than .004:

Diff RG Target	Calculated diff RG	Measured diff RG	Difference between calculated & measured
.000	002	.002	004
.010	.010	.012	002
.020	.020	.022	002
.030	.029	.031	002
.040	.039	.040	001
.050	.050	.051	001
.060	.059	.062	003
.070	.069	.069	.000

The test lane was oiled using a standard lane conditioner. The lanes were oiled flat from gutter to gutter and tapered from the foul line to the oil line.









The test balls were thrown by E.A.R.L. The ball in the middle of the range with .030 differential RG was thrown a few times until it hit approximately the strike pocket which then established the starting trajectory for all future ball tests. A single ball test consisted of 30 shots with E.A.R.L. being adjusted left after every 5 shots by 1.5 boards at the foul line and 1 board at the arrows.



This resulted in targeting approximately the same location at the end of the oil pattern to create maximum oil depletion at the end of the pattern and play the lanes like a bowler would. A few bowlers bowled on the oil pattern to ensure it was close to a normal amount of hook.

BOLTS was used to collect the ball path data for every shot. The results are summarized below.





Test results

The following test parameters were monitored:

- Total hook
- Entry angle
- Breakpoint
- Track flare/pinfall

Total hook:

BOLTS was used to measure the total hook. A straight line was extended using E.A.R.L.'s launch settings (lay down board and trajectory) to 60 feet. The number of "boards of hook" was calculated at 60 feet, between this straight line and the ball path measured by BOLTS.







Below is a chart for the "boards of hook" for each shot for the various differential RG settings. The color zones in the chart are for the five-shot grouping before E.A.R.L was repositioned.



Also, in the text box on the above chart, is the average boards of hook for all 30 shots at each differential RG. It also is listed below:

Diff RG	Ave. boards of hook	Difference from previous diff RG
.000	12.46	-
.010	14.20	1.74
.020	16.63	2.43
.030	17.80	1.17
.040	17.21	59
.050	17.90	0.69
.060	19.25	1.35
.070	21.03	1.78





Total Hook Summary:

- There is a significant increase in the amount of hook (1 to 2.4 boards) when the differential RG was increased by .010 increments between .000, .010, .020, and .030 differential RG.
- There is little difference in the amount of hook between .030, .040, and .050 differential RG (all three are within .7 boards of average hook).
- .060 differential RG hooks about 1.35 boards more than .050 differential RG and .070 Diff RG hooked 1.78 boards more than .060.

Entry Angle:



There is about a 1 degree increase in the average entry angle for every .010 increase in differential RG between .000 and .030. Between .030 and .050 there is little change in the entry angle (approximately 4.1 to 4.3 degrees). But, then at .060 and .070 differential RG, the entry angle increases again, another ½ degree. Both .060 and .070 had about the same entry angle. The entry angle slowly decreases from shot 1 to shot 30. This has to do with increasing the launch angle every five shots, which should reduce the final entry angle.





Therefore, a better indicator of angle change is "Total Angle Change," which is adding the Launch Angle and Entry Angle:



Here, the results are more consistent from shot 1 to shot 30, but it has the same trend as entry angle when going from .000 differential RG to .060 differential RG. There is about a 1-degree increase in the average total angle for every .010 increase in differential RG between .000 and .030. Between .030 and .050 differential RG, there is little change in the total angle (approximately 6.0 to 6.2 degrees). But, then at .060 differential RG, the total angle increases again, another ½ degree. The Total Angle Change for .060 and .070 differential RG is about the same (6.7-6.8 degrees).





Breakpoint Location (ball path location closest to the gutter):



The average location of the breakpoint moves closer to the foul line by approximately two feet for every .010 increase in differential between .000 and .020. Between .020 and .030 differential RG, the breakpoint moves forward about one foot. Then, the breakpoint location is at approximately the same location with a differential RG between .030 and .050. At .060 differential RG and .070 differential RG, the breakpoint moves further up the lane (towards the foul line) again approximately one foot.

The breakpoint location moved down the lane between the first shot and the last. But, remember that the launch angle was increased every five shots as we moved in 1.5 boards at the foul line and only one board at the arrows. As the launch angle increases, the entry angle should decrease, and the breakpoint will move down the lane. Plus, any carrydown will add to this result.





Table of track flare and location at pins:

Diff RG	# oil rings	Total track flare width (in)	Gap between oil rings	Observation	High hits	Solid hits	Light hits	Shots that missed head pin wide
0.000	6	0.1875	0.038	looked like ball had two rings of oil touching each other, ball never hit head pin	0	0	0	30
0.010	6	0.625	0.125	looked like ball had five oil rings, hit head pin once, continuous streak of carrydown	0	0	1	29
0.020	6	1.125	0.225	amount of flare varied, sometimes no gap between rings up to .3" between rings	0	2	13	15
0.030	6	1.5	0.300	mostly light pocket hits with many missing the head pin or just barely touching head pin	0	3	20	7
0.040	7	2.25	0.375	mostly light hits	0	3	17	10
0.050	7	2.875	0.479	earlier Bk Pt than .040, mostly light hits	0	7	17	6
0.060	7	3.4375	0.573	almost all shots hit pocket (light or solid)	1	18	11	0
0.070	7	3.875	0.646	only ball that ever hooked high (& many shots did), all shots were solid or high, appears to have a sooner break point	12	16	2	0

Track flare summary:

The width of the track flare on the ball ranges from .1875" wide for the .000 differential RG ball to 3.875" wide for the .070 differential RG ball. The gap between each oil rings increases approximately .075" to .100" for every .010 increase in differential RG. As the differential RG increased, the ball was more likely to hook more and strike more.

Location at pins:

All balls were thrown with the same E.A.R.L. laydown location and launch angle. Plus, the location was moved left after every five shots to simulate a 1-1/2 board move at the foul line and a one board move at the pins. The goal was not to hit the pocket with every test ball but to get a relative final ball position at the pins with the same E.A.R.L. settings.

The .000 and .010 differential RG balls seemed like they hooked about as much as a traditional polyester ball missing the head pin to the right on almost all shots.

Summary: The results for the average boards of hook, average entry angle, and average break point location for all 30 shots for each differential RG are tabulated and charted below:





Diff RG	Ave boards of hook	Ave entry angle (deg.)	Total angle change	Ave. break pt (ft.)
.000	12.46	1.22	3.11	50.42
.010	14.20	2.13	4.03	48.00
.020	16.63	3.33	5.22	46.30
.030	17.80	4.07	5.97	45.24
.040	17.21	4.07	5.97	45.80
.050	17.90	4.28	6.18	45.54
.060	19.25	4.76	6.66	44.38
.070	21.03	4.89	6.79	44.19



For the three ball path properties (hook, entry angle, and break point location), there is a significant change when the differential RG increases from .000 to .030. Then between .030 and .050 differential RG, there is little change in these three properties. At .060 and .070 differential RG the values change once again.



