Subject:	Differential RG Study- Repeat
Date:	8/10/15
Place:	International Training & Research Center

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Purpose:

After completing the first differential RG test, which was to vary the differential RG of the ball, we uncovered inconsistencies in the testing procedures and therefore changed the test protocol. Then, reran the test.

Summary:

The results from this retest produced similar results as the first run, but with some changes.

Performance was measured in four categories:

- Boards of hook
- Entry angle
- Total angle
- Break point location

During the second run:

- low differential RG (.000-.010) had the least performance
- .020 .040 were all about the same performance
- .050 .070 had the greatest performance

During the first run:

- .000 .020 had the least performance
- .030 .050 all performed about the same
- .060 .070 had the greatest performance results

So, the overall trend was the same but there was a shift in the differential RG that fell into the low, medium and high-performance categories.

Data:

After the original Differential RG testing was completed, it was discovered that the retest was generating less total hook. After going back and re-evaluating the original test results, the following was discovered:

- The initial ball velocities were inconsistent- speeds were consistent during a test run but varied from test to test. E.A.R.L. setting can be adjusted to achieve consistent speeds.
- The units of oil on the lane varied within a few units- a film of oil was being left on the lanes and not entirely stripped off. Double stripping fixed this issue.
- Abralon pads should have been changed after every test run. Will use new 2000-grit Abralon pads for every test in the future.





• If a test is stopped for a period of time and then re-started again, the results show more hook. Therefore, once started, a test must be run with no extended time delays.

After discovering these issues and developing solutions, the original Differential RG test was repeated.

Comparing results from run 1 to retest 3

Run 1 was the original test results. Run 2 were all the trials to identify why the total hook was less for all repeat tests. Retest 3 incorporated all the new changes and repeated the original test. Below are the results:







During the retest, all results showed less hook then the original test results- less total boards, less angle change and a later break point.

Below are the main effects plots for the retest which match the above summary graphs:













Interval plots:













Summary:

- Boards hooked increases as differential RG increases
- Entry angle and total angle increases as differential RG increases
- Break point decreases as differential RG increases





• There may be a section in the middle of each graph where the resulting values levels off before increasing or decreasing again at higher values of differential RG

Diff RG	# oil rings	Total track flare width (in)	Gap between oil rings	Observation
0.000	2	0.1875	0.188	(First test) continuous streak of carrydown
0.000	6	0.1875	0.038	looked like ball had two rings of oil touching each other
0.010	6	0.625	0.125	looked like ball had five oil rings, continuous streak of carrydown
0.020	6	1.125	0.225	amount of flare varied, sometimes no gap between rings up to .3" between rings
0.030	6	1.5	0.300	
0.040	7	2.25	0.375	
0.050	7	2.875	0.479	
0.060	7	3.5	0.583	
0.060	7	3.4375	0.573	
0.070	7	3.875	0.646	

Track flare:



Track flare width between each oil ring increases as differential RG increases.



Appendix

Oil Pattern:





The oil pattern did not change much between the original test and retest. With the double stripping for retest 3, it should have had a little less oil, which it did.

Below is a chart of the "boards of hook" for each shot with the various differential RG settings. The color zones in the chart are for the five-shot grouping before E.A.R.L. was repositioned. Charts from the first test and retest 3 are included to compare the differences.









During retest 3, all results hooked less compared to the first test. Below is a table of average boards of hook for each differential RG test during retest 3:

Diff RG	Average boards of hook	Difference from previous diff RG
.000	11.49	-
.010	12.70	1.21
.020	15.33	2.63
.030	14.95	38
.040	14.88	07
.050	17.34	2.46
.060	16.15	-1.19
.070	17.50	1.35

Total Hook Summary:

- There is a significant increase in the amount of hook (1 to 2.6 boards) when the differential RG was increased by .010 increments between .000, .010 and .020 differential RGs.
- There is little difference in the amount of hook between .020, .030 and .040 differential RGs (all three are within .45 boards of average hook).
- Then the amount of hook increases 1.27 to 2.62 boards for differential RG values of .050, .060 and .070.





Entry Angle:









The entry angle results mirror the boards of hook results:

- Less entry angle for all tests balls compared to the first test except for .000 differential RG, which only had 1.2 degrees during both tests
- Between .000, .010 and .020 the average entry angle increased close to 1 degree for each
- Between .020, .030, and .040 the average entry angle was about the same (3-3.2 degrees)
- For .050, .060, .070 the average entry angle increased again to 3.9-4.3 degrees

Once again, the entry angle steadily decreases from shot 1 to shot 30 for all balls tested. 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:













The Total Angle Change are more consistent from shot 1 to shot 30, but has the same trend as entry angle when going from .000 differential RG to .070 differential RG for retest3:

- Between .000, .010 and .020 the total angle increased
- Between .020, .030, and .040 the total angle was about the same (5 degrees)
- For .050, .060, .070 the total angle increased again (ranging between 5.8-6.2 degrees)



Break Point Location (ball path location closest to the gutter):









Break Point Location summary for retest 3 matched the other results:

- Break point moves closer to the foul line by approximately 2 feet for every .010 increase in differential between .000 and .020 -50.9 ft @ .000 diff RG vs 49.3 @ .010 differential RG vs 47.5 feet @ .020 differential RG
- Between .020 and .040 differential RG the break is about the same (47.5 feet)
- Between .050 and .070 the break point location is 45.5 to 46.7 feet

The break point 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 1 board at the arrows. As the launch angle increases the entry angle should decrease and the break point will move down the lane. Plus, any carrydown will add to this result.





Summary from retest 3: 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:

First test summary:

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

Retest 3 summary:

Diff RG	Ave Boards of Hook	Ave Entry Angle (deg.)	Total Angle Change	Ave. Break Pt (ft.)
.000	11.49	1.28	3.2	50.9
.010	12.72	1.95	3.8	49.3
.020	15.33	3.04	4.9	47.5
.030	14.95	3.15	5.0	47.7
.040	14.88	3.24	5.1	47.8
.050	17.34	3.90	5.8	46.2
.060	16.15	3.77	5.7	46.7
.070	17.5	4.31	6.2	45.5

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 .020 (first test showed .000 to .030). Then, between .020 and .040 differential RG, there is little change in these three properties (first test was .030 - .050). At .050 - .070 differential RG the values change once again (first test said .060 - .070).



