ENGINEERING REPORT

Subject: Initial Oil Absorption Results

Date: 12/28/16

Place: International Training & Research Center

Present: Dan Speranza

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Purpose:

This report summarizes the initial oil absorption testing for bowling ball coverstocks. Two different oil absorption methods were tested:

- Test pieces of coverstock placed in oil and measure weight gain (with and without a vacuum on sample)
- Place a drop of oil on ball and measure oil absorption time

The initial goal of the oil absorption project is to determine the best test method for conducting oil absorption. We want to initially try various options to determine which test method to pursue and which to drop from pursuing further.

Summary:

The pieces of coverstock placed in oil showed that weight gain happens mostly over the first 20 hours then the weight tends to level off. When pieces of coverstock were places in oil in a vacuum chamber, a large amount of air bubbles were pulled out of the samples, but the weight gain was not significantly different compared to testing without the vacuum.

The oil drop test, where the time was measured for a small oil drop to soak into a ball, showed that different colors in the same ball could have large differences in oil absorption rates.

Data:

Oil absorption is known to occur with reactive coverstocks. We are trying to determine the best test method and test procedure to measure this property. Therefore, we are taking two different approaches to evaluate oil absorption. For this test we used pure mineral oil which is the main ingredient in lane oils.

Weight Gain with Samples of Coverstock in Oil

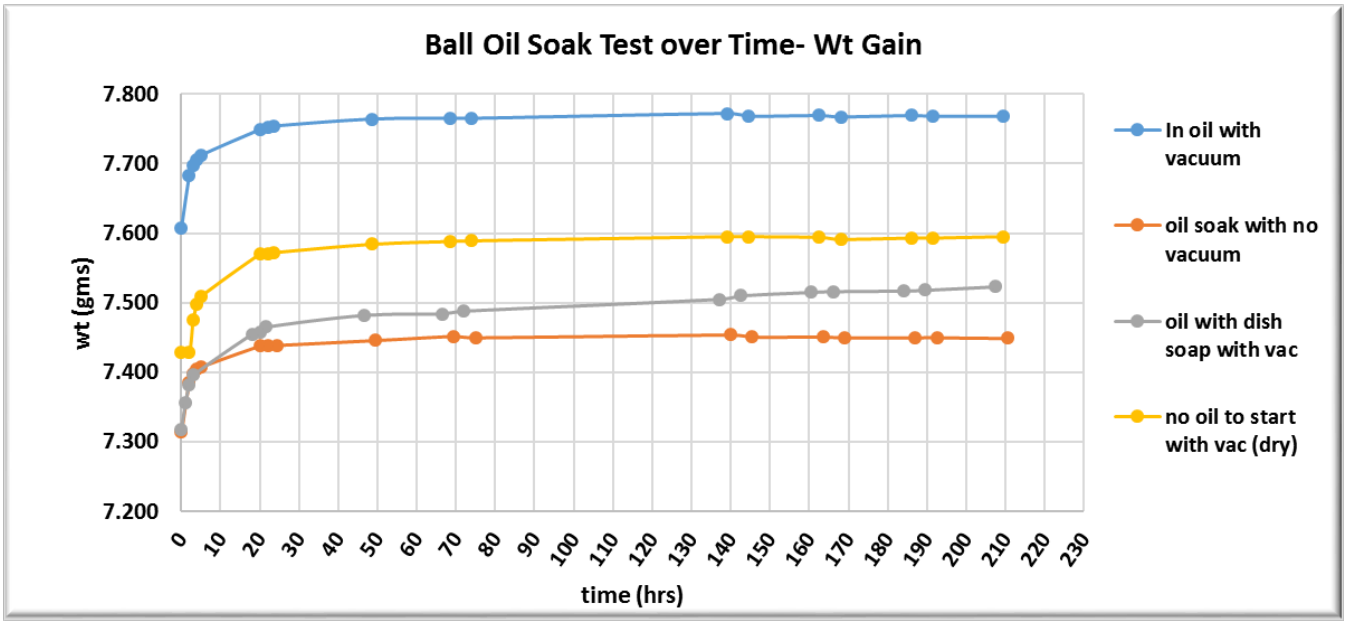
We wanted to determine how much mineral oil could absorb into a sample of reactive coverstock placed in a beaker of oil by measuring the weight gain. We thought we could increase the oil absorption rate by placing a coverstock sample into a vacuum and drawing the air out from the coverstock, which would make it easier for the oil to go into the pores. We tried:

1. Placing coverstock samples into a vacuum, pulling the vacuum to draw the air out and then placing the sample in a beaker of oil
2. Placing the coverstock sample into a beaker of oil and placing the beaker into the vacuum chamber before pulling the vacuum
3. We tried to reduce the surface tension by adding a little amount of detergent into the oil and placing the beaker of oil/detergent with test sample into the vacuum chamber to pull the air out

We observed that the coverstock samples placed in oil in the vacuum chamber drew a very large quantity of air out of the sample when we pulled the vacuum. The bubbling was intense for about 20 minutes. Over the next 20 minutes it slowed down. Air continued to be drawn at a slower rate but continuously for another 20 minutes. After 40 minutes, it slowed down again, and bubbles continued to come out of the coverstock sample at a not continuous rate for another hour.

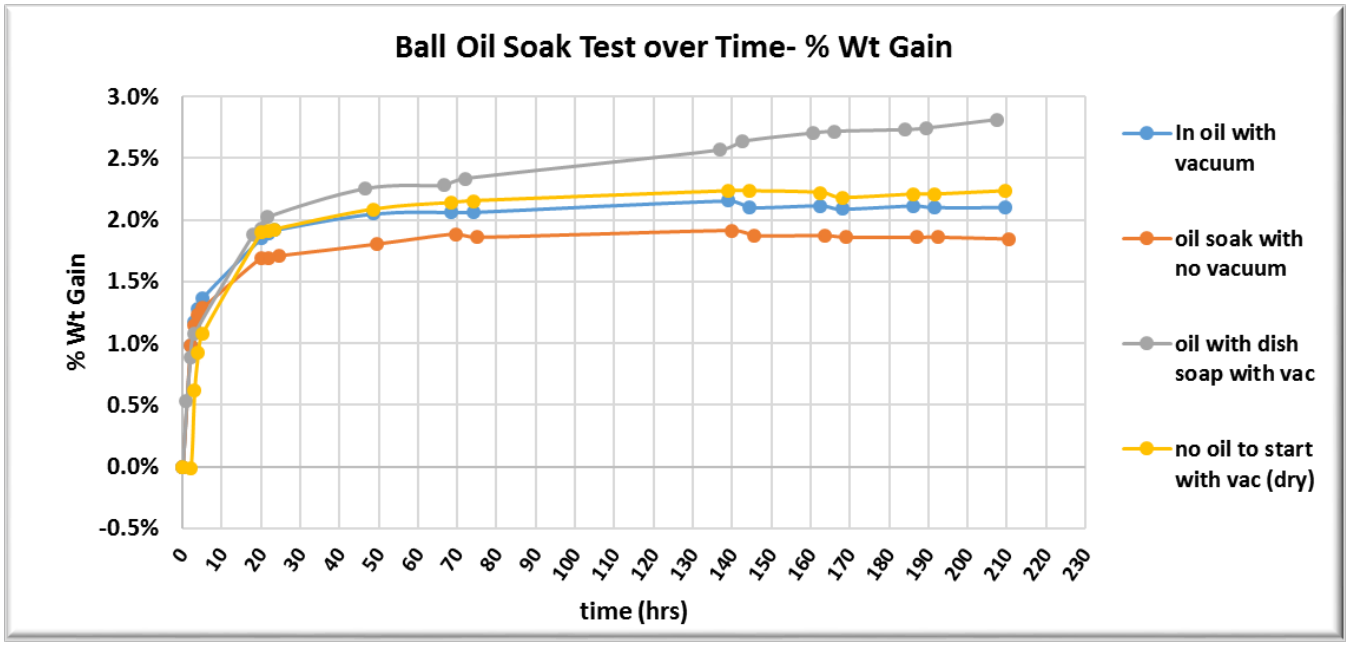
This proves that the coverstock has pores, which is the only way the bubbles could keep being drawn out of the sample for an extended amount of time. The bubbles filled the entire beaker and rose up about 1" above the oil initially. The oil, with a few drops of detergent, had air bubbles that wanted to overflow the beaker. We had to keep reducing the vacuum in the chamber to break the bubbles to prevent them from overflowing the beaker.

Below are the results from this test:



There is a rapid increase in the weight for the first 20 hours, and then the weight gain levels off. The one test with oil and dish soap (grey line in chart) did continue to increase in weight throughout the test period (210 hours).

Below is the weight gain as a percentage of the initial sample weight:

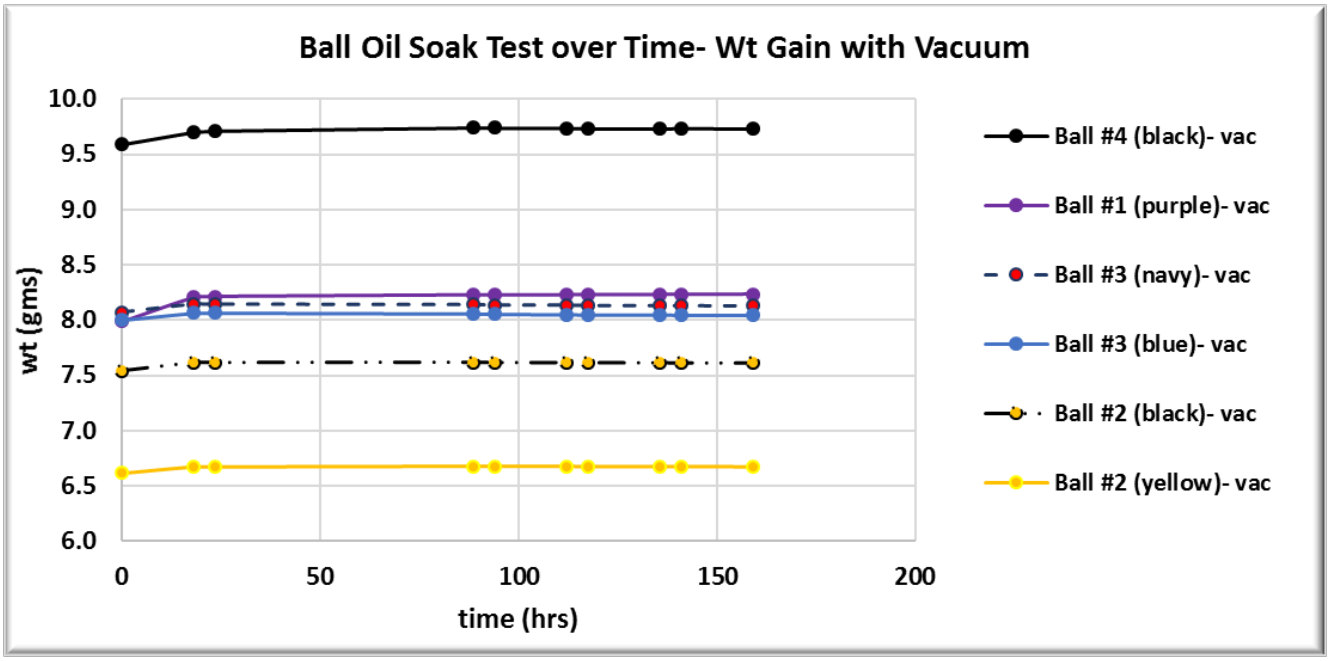


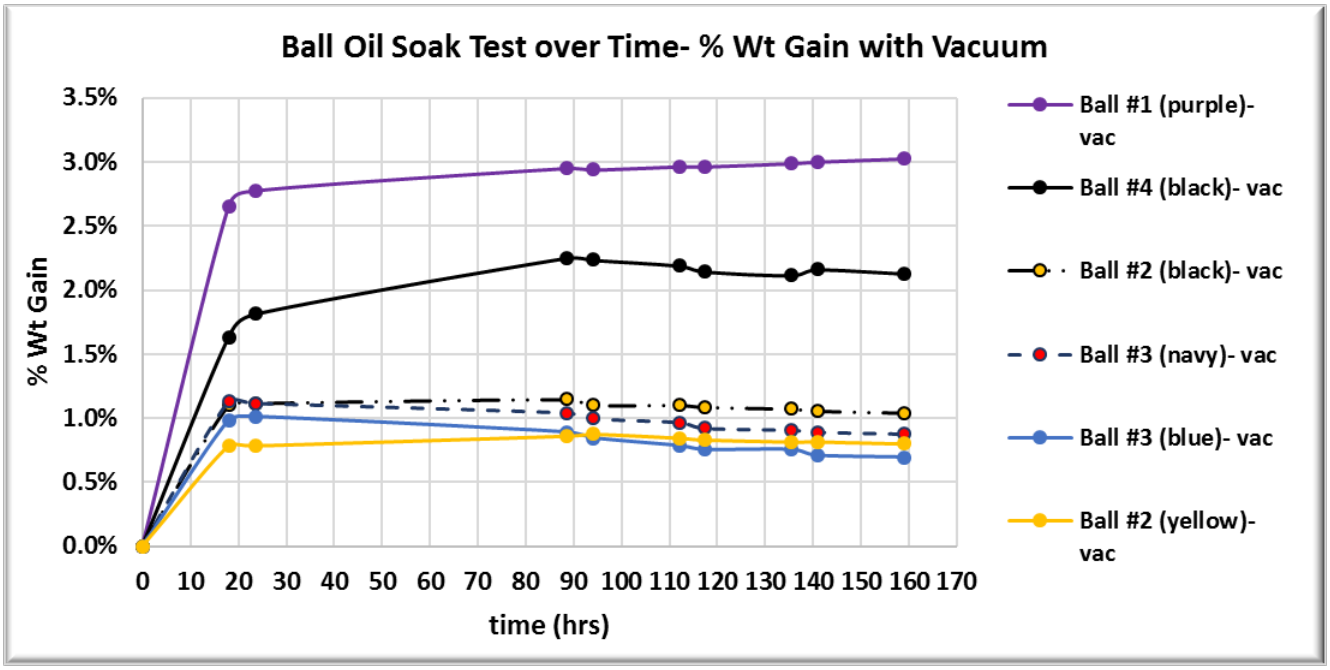
These initial tests used pieces of a production ball coverstock, the weight gain was about 1.7-2.0% after the first 20 hours in the mineral oil. After the initial 20 hours, there was little change in the weight, except for the one in the mineral oil with a few drops of dish detergent. Surfactants (dish detergent) might reduce the surface tension which makes it easier for the oil to seep into the pores in the coverstock.

We can continue studying ways to maximize the amount of oil absorption (we purchased other surfactants designed to reduce surface tension in mineral oil), but that is not the goal of the project. For now, we learned we can soak coverstock samples in mineral oil and get a good indication of total % weight gain during a 20-hour test.

Weight Gain with Different Ball Coverstocks

The second test is a continuation of the previous test. During this test, we soaked different pieces of ball coverstock in mineral oil and again measured the weight gain.

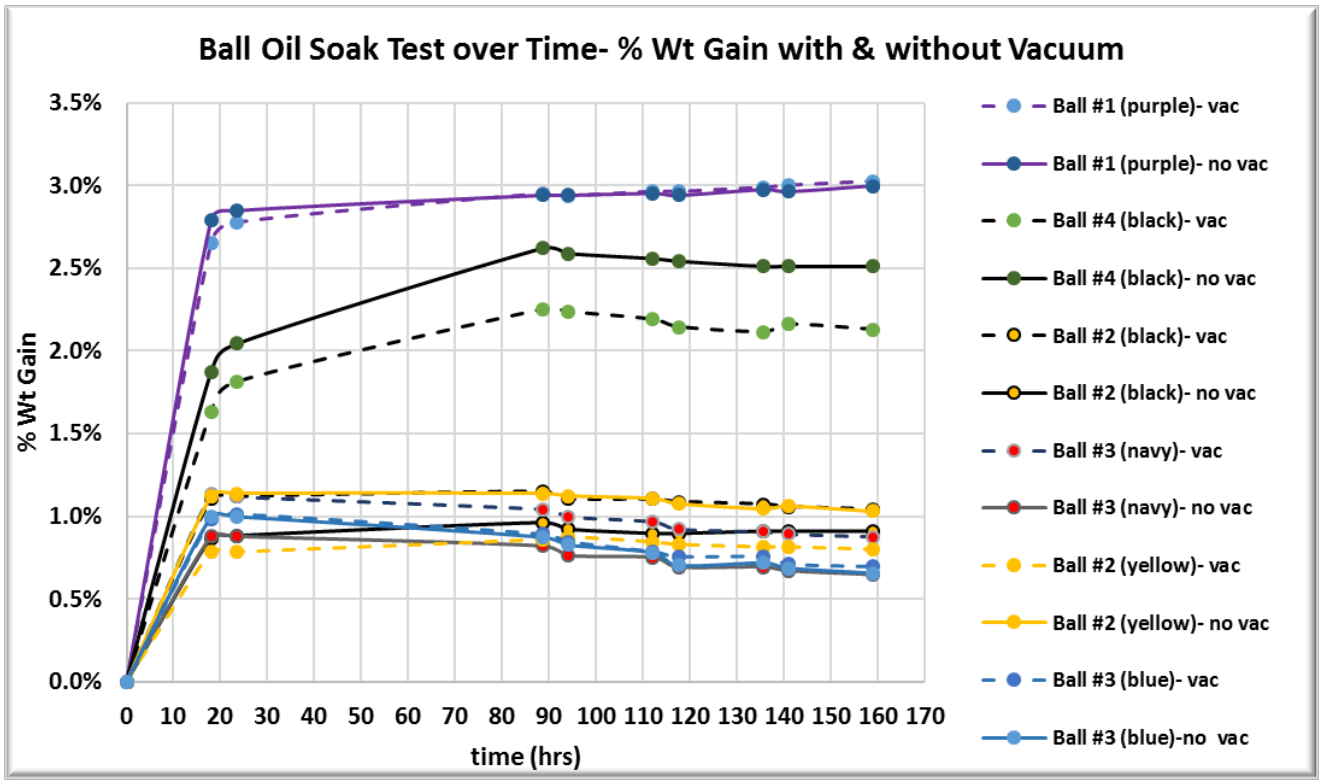




Four coverstocks increased their weight by approximately .75-1.0%. One coverstock gained about 3% in weight. Ball #4 coverstock increased its weight over a 90-hour time frame, where most other coverstocks had little, if any, weight gain after the initial 20-22 hours.

Interesting, that around the 90-hour oil soak timeframe, many pieces lost a small amount of weight. This is believed to be the point where the pores are filled with mineral oil. Now, the lighter density mineral oil is replacing some of the heavier density plasticizer inside the ball and reducing the sample weight.

Below is a chart comparing the above coverstock samples tested in both, a vacuum and not in a vacuum.



We can physically observe the vacuum draw air out of the coverstock sample by seeing air bubbles rising from the sample and floating to the top of the oil; but, in many cases, the oil absorption rate is the same with and without the vacuum assist. Therefore, we do not need the vacuum to conduct the oil absorption test.

Weight Gain with Multiple Samples from Different Ball Coverstocks

The next test was using the same coverstock samples, but with multiple samples taken from the same ball. In this test, we wanted to find repeatability for the weight gain test procedure. Therefore, we made 20 test samples from each coverstock we previously tested and did the same test.

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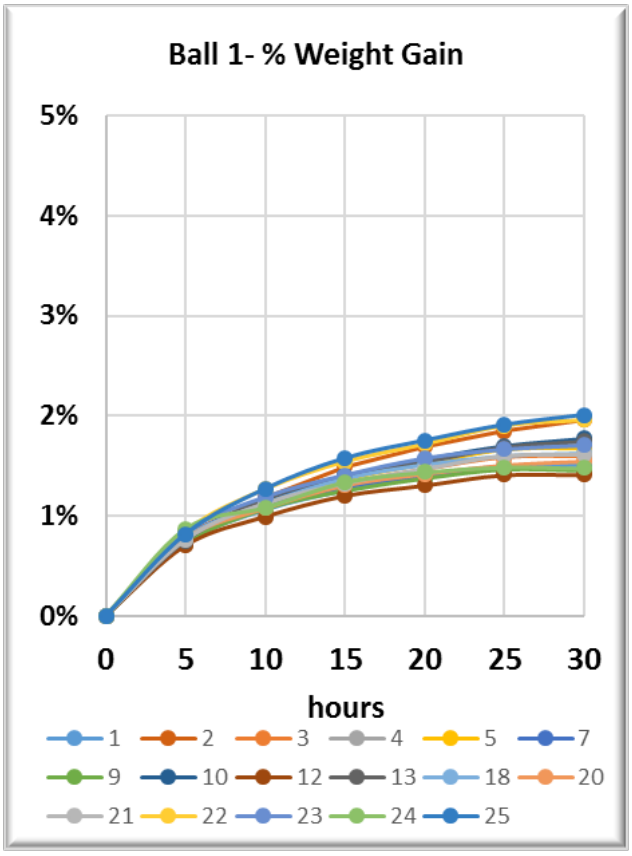
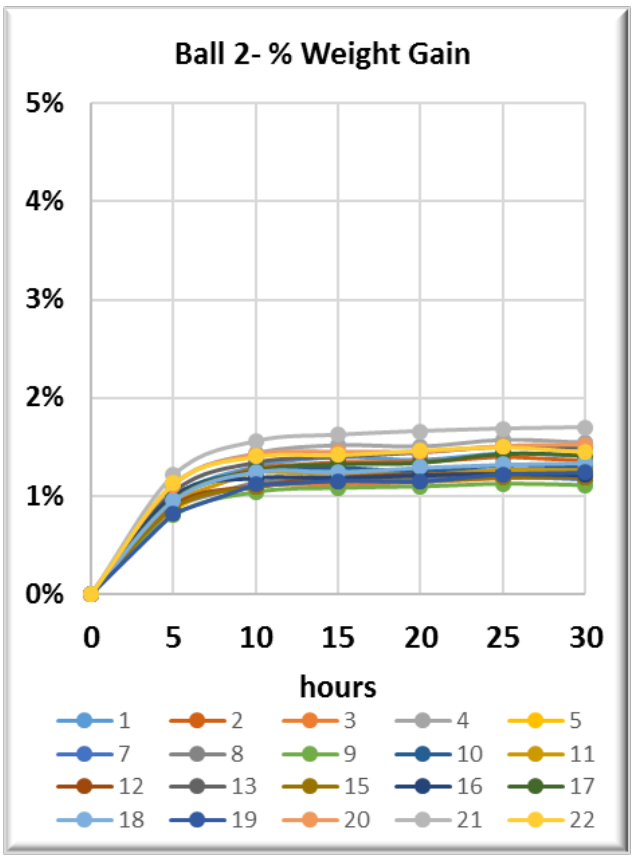
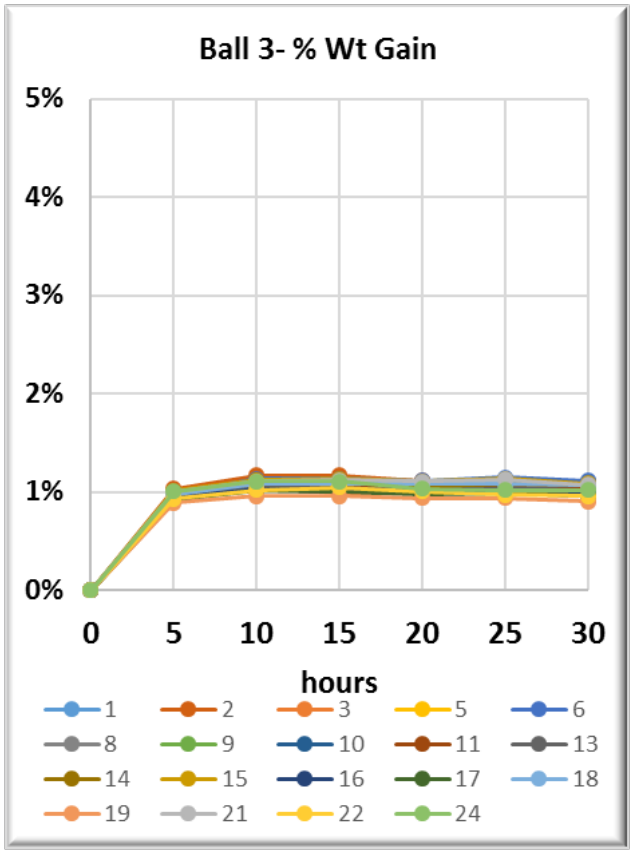
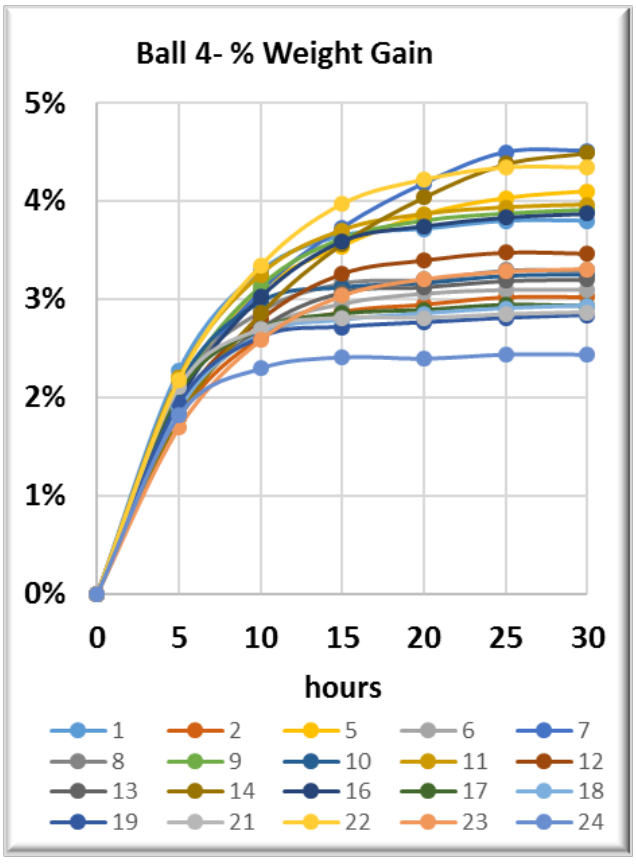




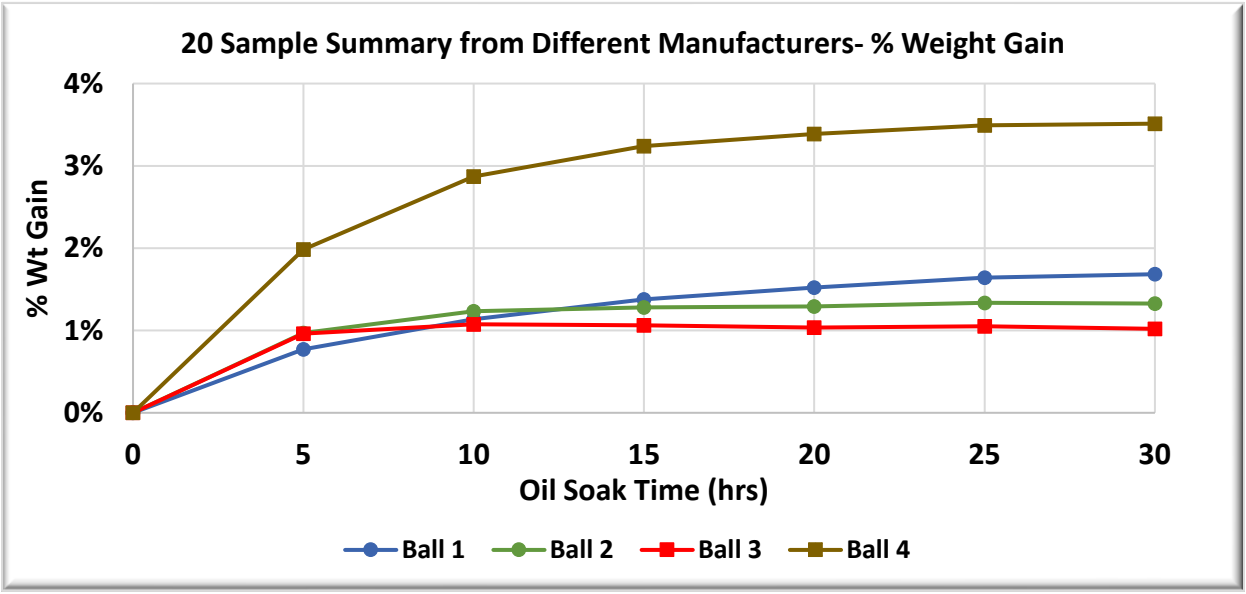




Ball #3 coverstock had the most consistent percent weight gain over all 20+ samples, with all samples gaining about 1% in weight. Ball #1 and #2 had more of a range in percent weight gain, covering about 0.6% weight gain range between the minimum and maximum oil absorption samples.

Ball #4 coverstock, which had the largest % weight gain, had a large range in weight gain covering approximately 2% range between the minimum and maximum weight gain samples.

Below is a summary chart for the average weight gain for each coverstock tested above:



This chart is taking the total weight from all 20 samples before the test and determining the % weight gain for all 20 samples over time.

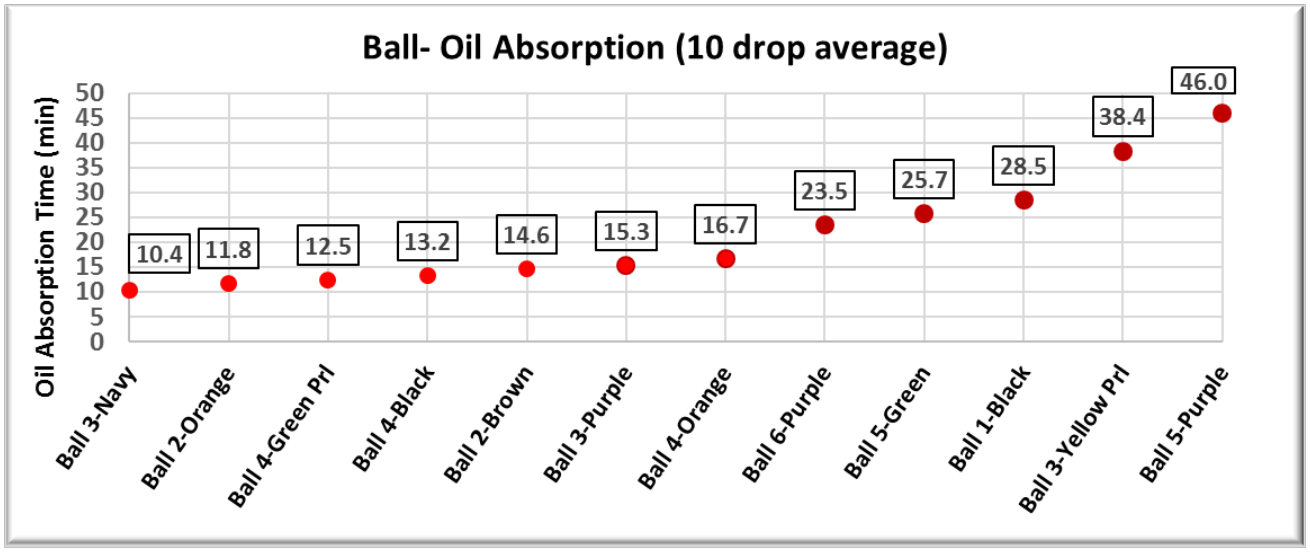
Ball #4 ball had the most oil absorption by far (3.5%) but also had the largest range (standard deviation) between individual pieces cut from the same ball. This chart confirms a few points:

- Ball #1 is still gaining weight after 20 hours of the oil soak with multiple samples
- Balls #2, #3, and #4 coverstocks all achieve close to their maximum weight gain before 20 hours of oil soaking

Oil Absorption Time with Oil Drop

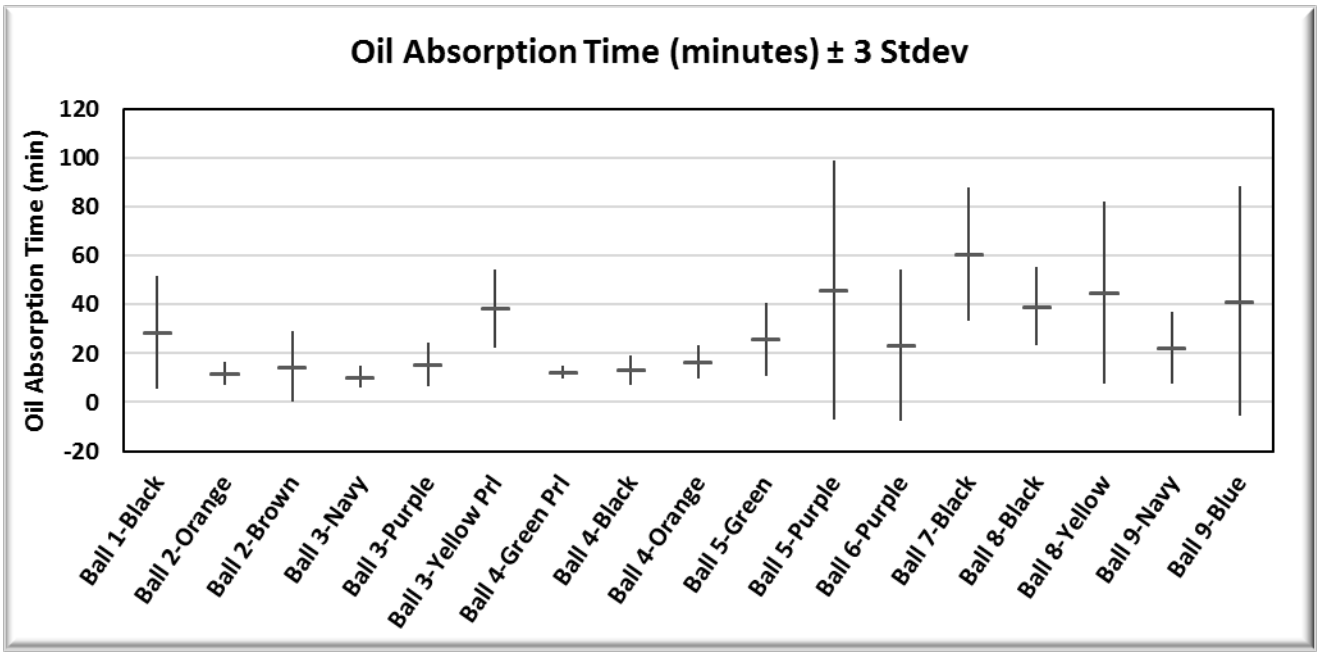
The second oil absorption test method involves applying a drop of oil from a metering syringe onto a bowling ball coverstock and measuring the time for the mineral oil to soak totally into the coverstock. A camera records the microscopic images every 15 seconds, so the tester can start the test and return any time after the oil is soaked in. Then, play back the images, to determine the total oil absorption time.

The test was repeated 10 times and the chart below shows the average oil absorption time.



There were some large variations in oil absorption times in different colors of the same ball. This might have to do with adjustments made during production to create the color pattern in a ball with multicolor coverstocks.

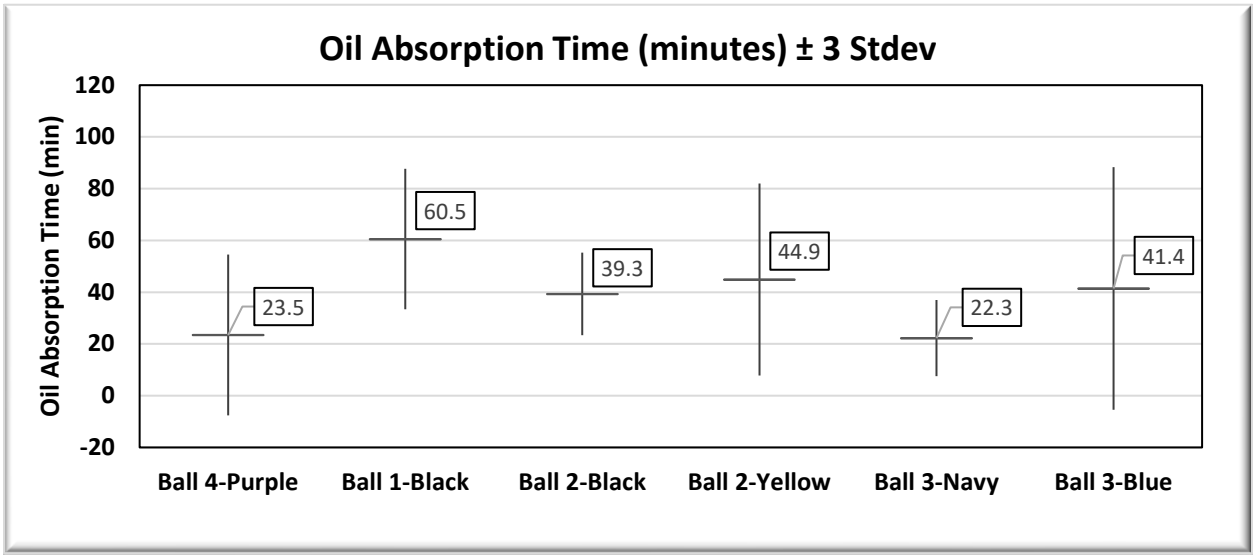
There were even some large variations in oil absorption times within a single color of some balls, which is shown in the chart below:



This chart (above) shows the average oil absorption time for the 10 separate tests on each color along with the range for ±3 standard deviations. Some ranges are very small (the overall height of the data point) and others are very wide (tall heights).

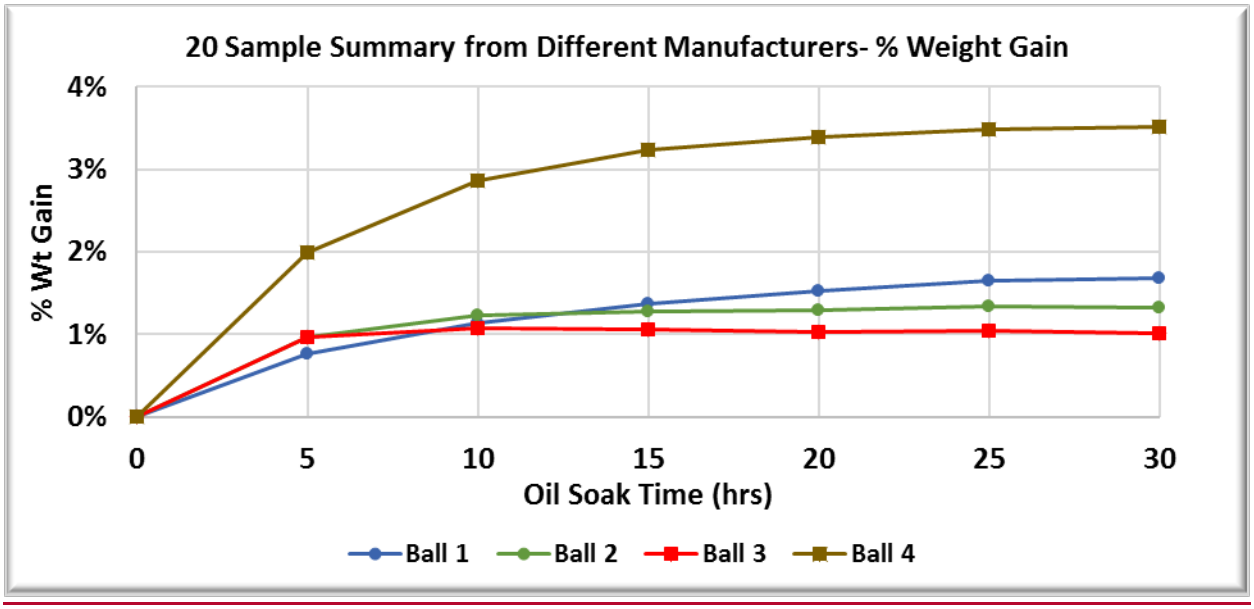
Comparison between the Two Oil Absorption Tests

Below are charts from testing the same balls in both the "oil soak/weight gain" test and the "oil drop soak in time" test. Ball #4 purple had the largest gain in weight in the oil soak test (3.5%) and a fast oil absorption time in the oil drop test (23.5 min).



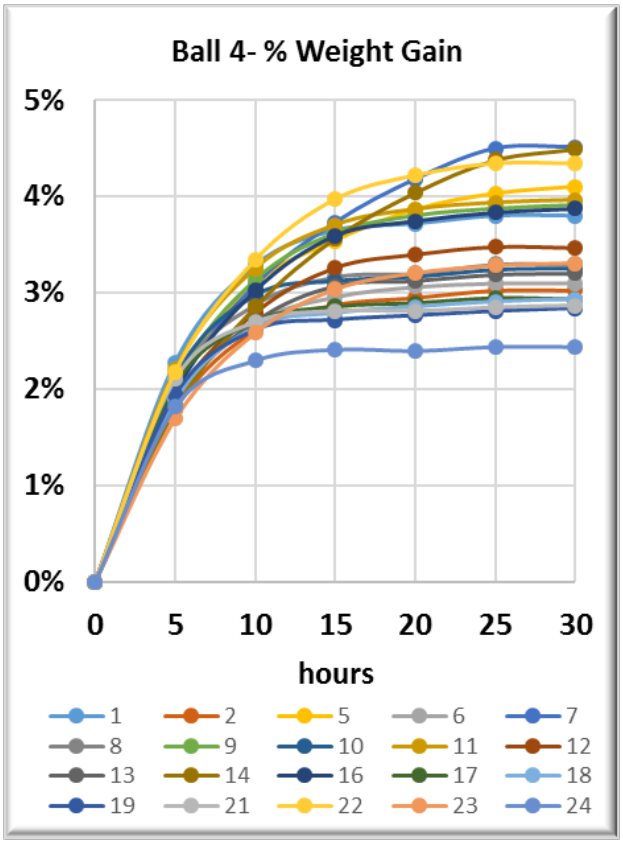
Ball #3 coverstock had a fast oil absorption time for the navy color (22.3 min) and a medium slow time for the blue color (41.4 min). In the oil soak test, this ball had the least weight gain (1.0%).

Ball #1 coverstock had the slowest oil absorption time (60.5 min) and took longer to gain weight in the oil soak test.

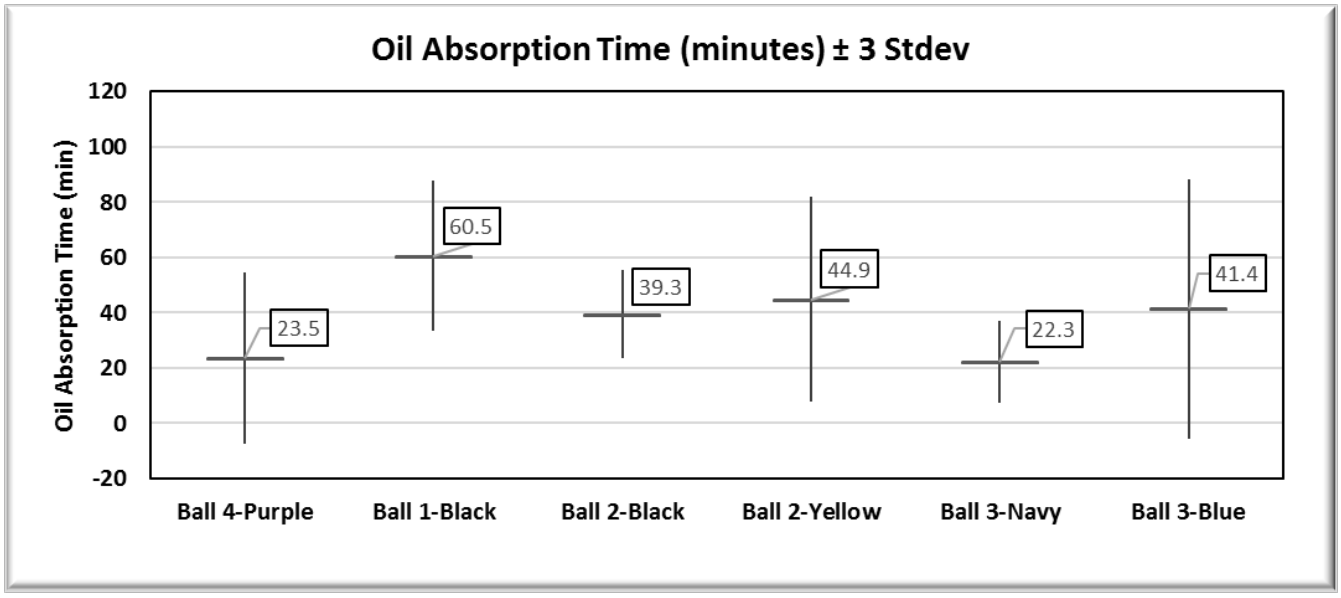


All the charts below show the repeatability between the “oil soak/weight gain” test and the “oil drop soak in time” test.

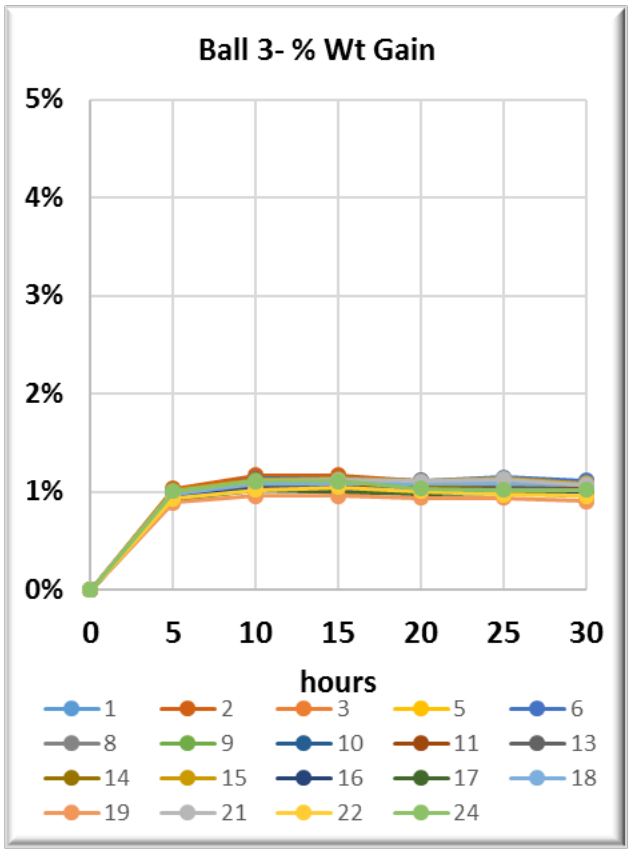
Ball #4 coverstock also had a large range of % weight gain from 20 different samples (see chart below).



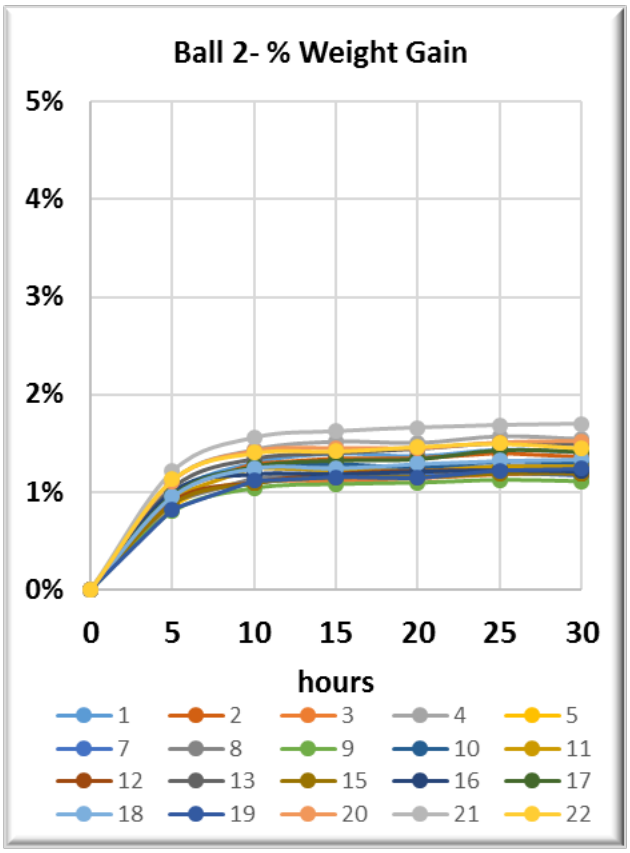
Ball #4 also had a fairly large range in the time for the oil to soak in (see chart below).



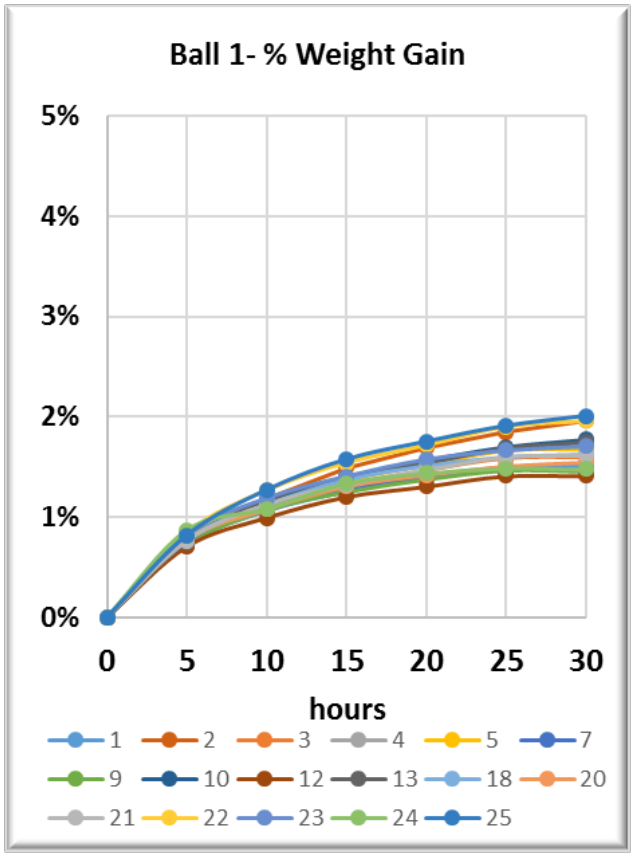
Ball #3 coverstock had a small range in the weight gain test (see chart below), but it has a consistent oil absorption time for the navy color and a wide range for the blue color (chart above).



Ball #2 was in the middle for the range of weight gain (chart below) and a fairly tight range in the oil absorption time for the black and larger range in the yellow (summary chart above).

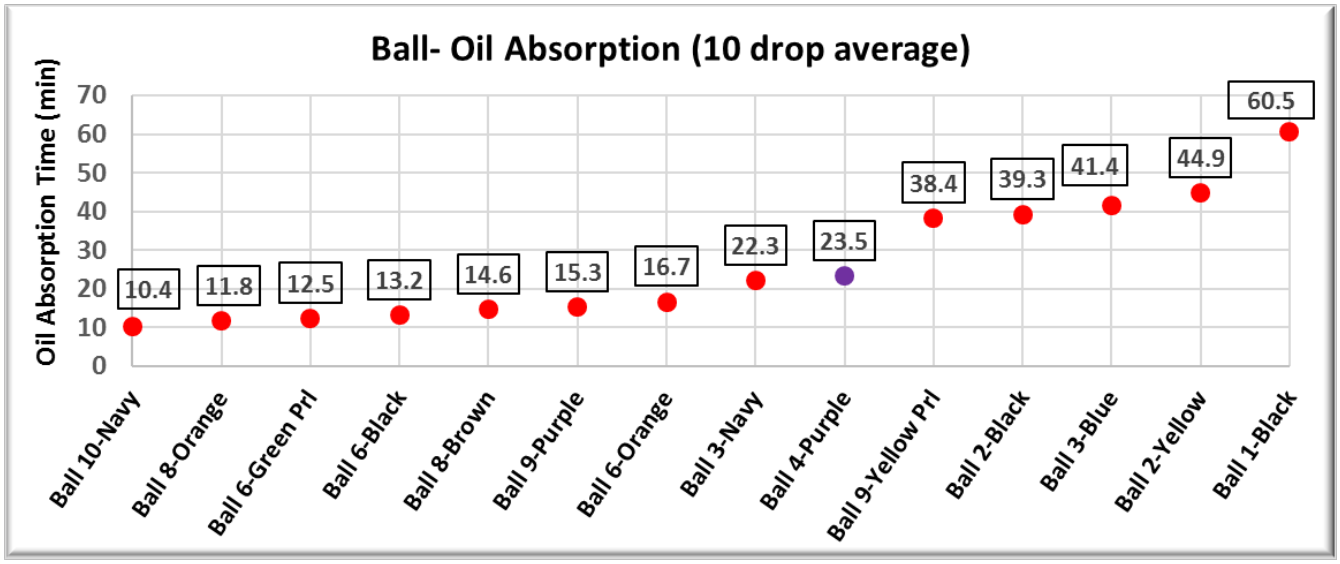


Ball #1 was the same as ball #2. It was in the middle of the range for consistency in the weight gain (chart below) and middle of the range for oil absorption consistency (summary chart above).



In conclusion, some coverstocks, or even colors within a coverstock, have a larger difference in the oil absorption rate in different areas of the ball which we must deal with.

While Ball#4 purple had a fast oil absorption time during the initial test, we have already found balls that absorb oil even faster. See chart below.



Next Steps

From the results during the initial set up test, we need to select a test and finalize the standard operation procedure to begin collecting data for all the balls sent in for approval. The goal is to select:

- The best test
- Most accurate and repeatable test
- Reasonable test time since it might become a specification in the future

Both tests seem to give similar results. Repeatability may be an inherent issue with some coverstocks that we must accept. Cutting coverstock samples from every approval ball takes about an 1-1/2 hour per ball to cut the samples, so it is time consuming with 340 ball approvals a year (plus any eight additional balls as the results approach the limit). Therefore, we will continue with the oil drop test, which requires no set up time for the test.

Next step is to set up the dropper test so we can test multiple balls at the same time, or we will never be able to test all the approval balls. We already found cameras that can magnify the image by 50 times, which is the magnification we are using now. And, we need to record images from multiple camera at the same time, which still needs to be investigated.