

Deflate Gate : Preliminary Tests and Possible Science Explanations

Introduction:

The following two **preliminary** tests were run to assess whether ball preparation and temperature would explain the deflate-gate scenarios, namely, that the Patriots balls could be so far out of specification while the Colts were not.

The tests were performed to assess whether the “transients” due to pumping the ball to 12.5 PSI(g) just before testing could account for a ~1.5-2.0 PSI(g) change in pressure once the balls were put in a cooler environment -- “the N.E. Patriots scenario”. It appears the Patriots also “rub” the balls prior to submission to the refs (could also alter temperature of the ball skin and air inside in a similar manner to the pumping from flat). A second test, the “Colts Scenario” has the ball settle at 70F and 13.5 PSI(g) for ~1 Hour prior to starting the test. Only topping up pressure was performed during this “equilibration” preparation for the experiment (not a complete inflation of the ball).

The possible science explanation in short is as follows:

1. The temperature drop from 70F (inside) to 50F outside on the day of the AFC championship game resulted in a pressure drop due to the ideal gas law ($PV = nRT$)
2. **Hypothesis 1:** The pumping process, immediately prior to the Patriots scenario being tested elevates the temperature of the air inside the ball to greater than the ambient 70F. This results in an accentuated pressure drop once the balls were brought to the cooler outdoor environment.
3. **Hypothesis 2:** The temperature drop from 70F (inside) to 50F outside on the day of the AFC championship game resulted in the rubber bladder of the ball getting weaker, and thus pushing less on the air inside (see this cool video: <https://www.youtube.com/watch?v=YojXjDP2hTY>).
4. **Hypothesis 3:** When wet, leather is more easily stretched and easier to form – though when dried out again, it will become stiff and hard to form (why forming leather is done with a wetting process).

Hypothesis 2, 3 and 4 are the “transients” that the Patriots are likely using to suggest that “science” is behind deflate-gate. The tests performed test Hypothesis 1 and 2 (Hypothesis 3 was not tested).

The two test specifics are:

- **TEST # 1: “Patriots Scenario”:** Ball was inflated in a 70 degree room using a hand-pump immediately prior to the testing. The pressure in the ball initially was <1 PSI(g) and the temperature was 70F. After pumping, the ball was measured three times in the 70F environment (once directly after pumping, once 6 minutes

after and once ~30 mins after) before being put in an approximately 50F environment to observe. Specifics are:

The ball was tested at 70F as follows:

- Immediately after pumping in ~70F
- After 6 minutes in ~70F: to mimic the time when a referee could have tested the ball.
- After 37 minutes in ~70F: to mimic the time when a referee would likely have finished testing.

Subsequently The ball was placed in a ~50F environment (attic)

- After being placed in the ~50F environment the ball was tested routinely (see appendix A images).
 - After ~6.5 hours, the ball was returned to the ~70F room and tested after 15 minutes of being allowed to acclimatize.
 - The ball was left overnight (~8 hours) at ~70F and tested.
- **TEST # 2: “Colts Scenario”:** The ball was topped off with air until it had settled at 13.5 PSI and 70F – this was considered an “equilibrium state”.
 - Once the pressure had stabilized to 13.5PSI and 70F, the first data-point was taken.
 - The ball was then placed in the attic ~50F and monitored routinely (see Appendix B images).
 - After 1.5 hours the ball was returned to the 70F room and allowed to sit for 30 minutes for a final reading.

Some notes

- **Pressure Gage Effect Test:** In initial tests, the pressure gage was repeatedly inserted and removed from the ball and no noticeable effect on the pressure measurement was observed (same measurements recorded for all).
- **Temperatures:** Temperatures appear to have remained relatively consistent for all testing based on digital house thermometers. Temperature was not logged. Future tests should log temperature carefully to ensure that it remains consistent.

Summary of Testing Results

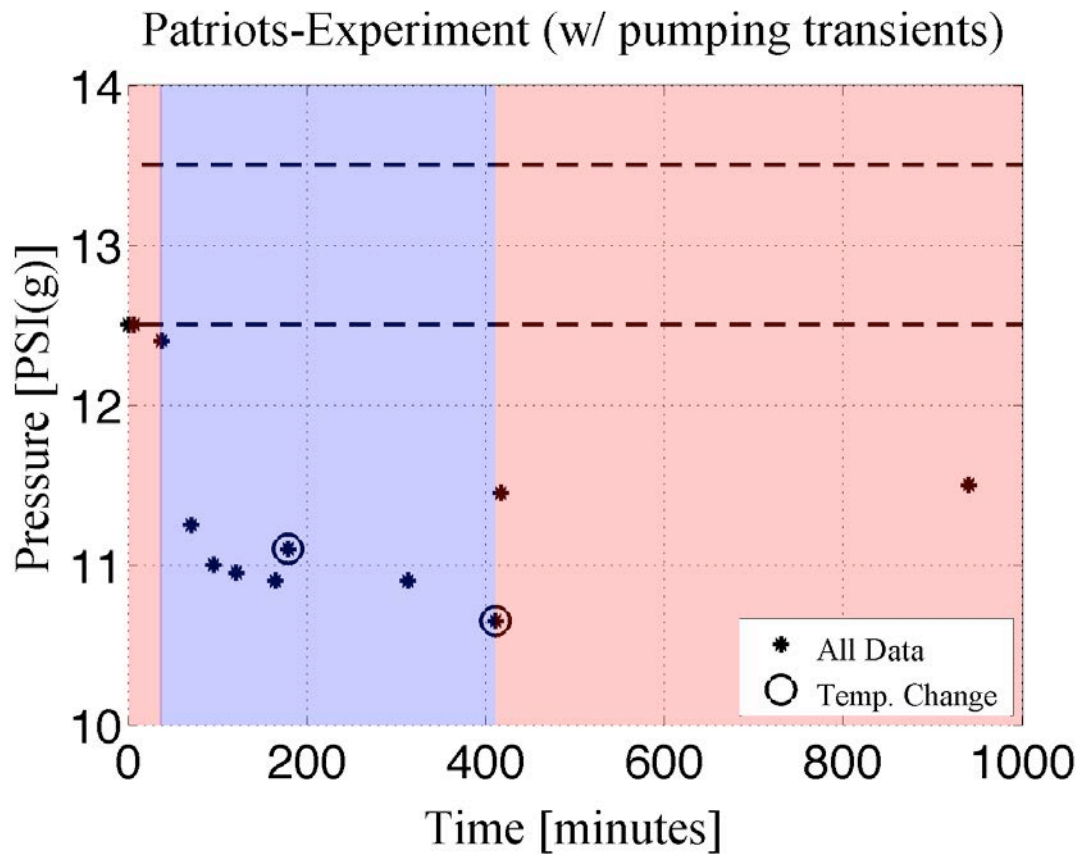


Figure 1: Plot of the pressure w.r.t time for the Patriots' model. Red indicates ball is in ~70F environment, Blue indicates ball in ~50F environment. Ball is pumped from <1 PSI(g) to 12.5 PSI(g) in a 70F room at the start of the experiment. There are 2 anomalous points (indicated) – temperature increased slightly in the first one and lower slightly in the second (later at night in the attic, it seems to have cooled off).

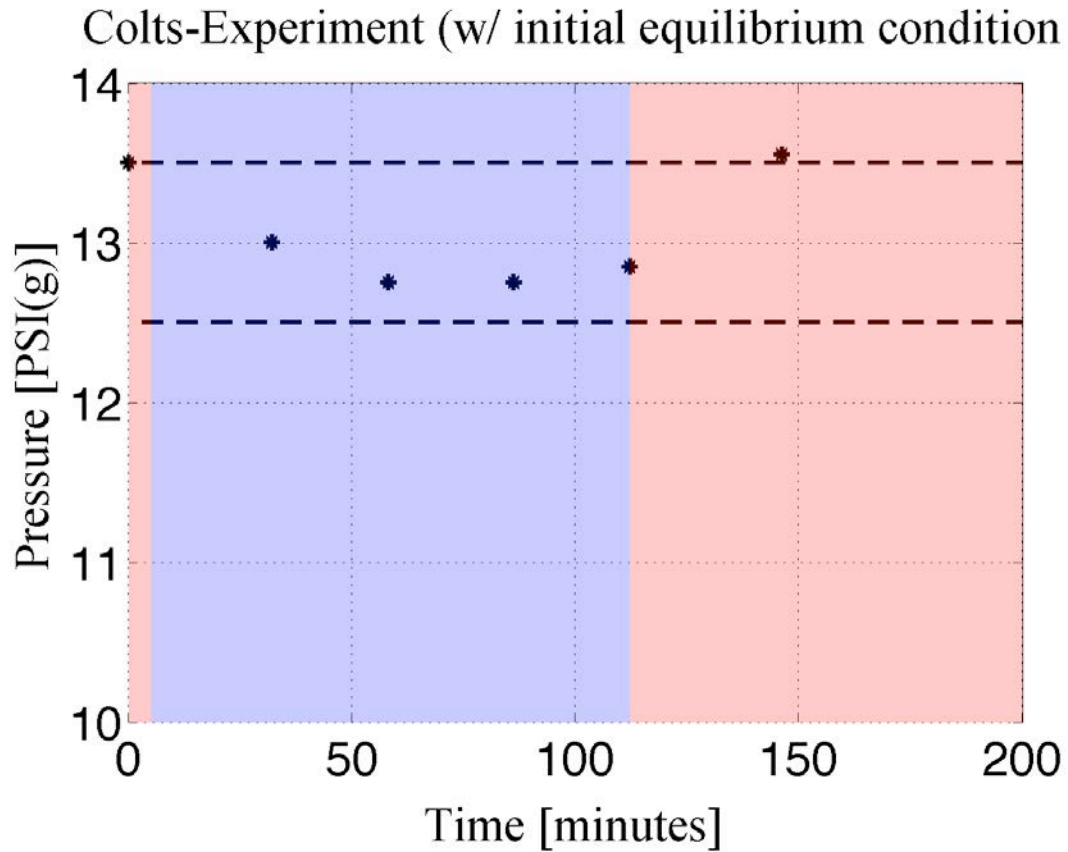


Figure 2: Plot of the pressure w.r.t time for the Colts’ model. Red indicates ball is in ~70F environment, Blue indicates ball in ~50F environment. Ball is allowed to equilibrate to 13.5 PSI(g) at 70F before testing begins to allow “transient” behavior to settle. Ball stays in spec throughout test!

Preliminary Conclusions

The experiments, while preliminary, show some interesting trends:

- **Patriots' scenario:** The action of pumping the ball or any other means of “artificially increasing the ball temperature” (via rubbing or similar) prior to testing can generate a sufficient temperature change to cause the pressure drops observed in the Patriots' balls.
 - This is likely due to a combination of:
 - Ideal gas law: as a gas cools, the pressure decreases
 - Altering the initial temperature of the ball above ambient conditions accentuates this pressure-temperature effect (rubbing the ball, pumping the ball, etc. can all cause the ball and air in it to rise in temperature above the ambient).
 - Rubber bladder properties: As a rubber bladder cools, it will become “weaker.” Though the leather takes the bulk of the pressure load, there may be some effect due to temperature change on the rubber bladder.
 - Leather tends to become more compliant when wet. Though the leather on the balls is likely treated to repel water, this may contribute to a slight volume increase of the ball, thus pressure decrease.
- **Colts scenario:** If a ball is equilibrated with its surrounding temperature (70F) and is at 13.5PSI(g) at the time, then moving it to a cooler temperature (50F) appears to result in a pressure change that falls within the NFL specifications.

Obviously, more testing must be performed for this to be conclusive (I think the Patriots have likely done quite a bit of testing by now), but these initial tests tend to suggest that both The Colts and The Patriots may have been affected by similar conditions and the preparation of the game balls immediately prior to testing could cause the equilibrium state necessary to result in different pressure drops for each team due overall to the temperature change!

Appendix A: Patriots Experiment Gage Photos



Figure A1: The Ball immediately after inflation reads 12.5 PSI (gage). This is 5:47pm, 1/24/2015, room is 70F. Ball has been inflated in 70F room from <1PSI(g) to 12.5 PSI(g).



Figure A2: The pressure in the ball 6 minutes after inflation (5:53 pm). Ball at rest in ~70.2°F room.



Figure A3: The pressure in the ball after 31 additional minutes at 71°F (6:24pm). The reading is slightly below 12.5 PSI(g), but barely noticeable.



Figure A4: The pressure in the ball is 11.25PSI(g) after an additional 30 minutes. The ball has been resting at 48.6°F air in attic for 31 minutes (6:57 pm).



Figure A5: At 7:22pm in 48.6°F air, the pressure has now decreased to 11.0 PSI(g).



Figure A6: At 7:47pm at rest in $\sim 50^{\circ}\text{F}$ air, the pressure has now decreased to slightly under 11.0 PSI(g).



Figure A7: At 8:31pm in ~50°F air, the pressure has now decreased to approximately 10.9 PSI(g).



Figure A8: At 8:45pm the pressure has risen to slightly above 11PSI (g). This was recorded as a temperature increase was also observed on the attic thermometer to slightly above 50F.



Figure A9: At 10:59pm with the temperature back to 49.0°F the pressure is slightly below 11PSI (g).



Figure A10: The pressure at 12:28AM (6hrs. 41 minutes after the start of experiment) was 10.6PSI(g). The temperature was ~46 F.



Figure A11: At 12:43am the ball is removed from attic to 70F room. Left to reacclimatize for ~15 minutes. Pressure increases to 11.45 PSI(g). Clearly well below the NFL 12.5PSI(g) requirement.



Figure A12: At 9:25am the next morning, the ball has been resting for ~8 hours in 70F room. Pressure recovers to 11.5 PSI(g). A whole PSI(g) of pressure has been “lost.”

Appendix B: Colts Experiment Gage Photos



Figure B1: 10:42AM, the ball is equalized at 13.5 PSI(g) – after being topped up from previous experiment at 9:30AM. Ball is brought up to attic for cooling to 50F.



Figure B2: 11:14am, the ball has been in ~50F attic for 32 minutes. The pressure has dropped to 13 PSI(g).



Figure B3: 11:40AM or approximately 1 hour after being placed in the cooler 50F attic, the ball now has a 12.75 PSI(g) pressure.

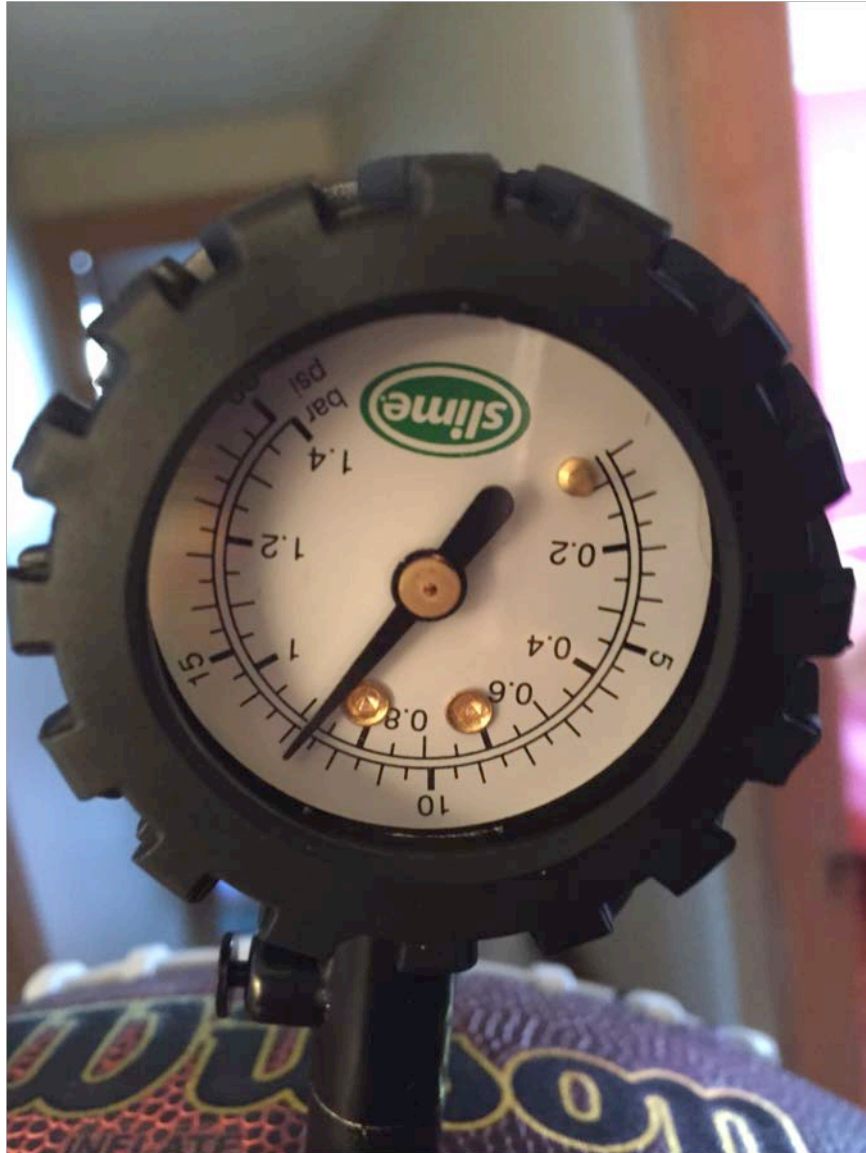


Figure B4: 12:08PM or approximately 1:26 after being placed in the cooler 50F attic, the ball still has a 12.75 PSI(g) pressure.



Figure B5: At 12:34pm the ball has been in the attic for 1 hr 52 min and now has a pressure of approximately 12.85-12.9 PSI(g).



Figure B6: At 12:34pm the ball was moved back to the 70F room and allowed to sit for 34 minutes. It was then tested and the ball at this point had a pressure of 13.55 PSI(g).

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