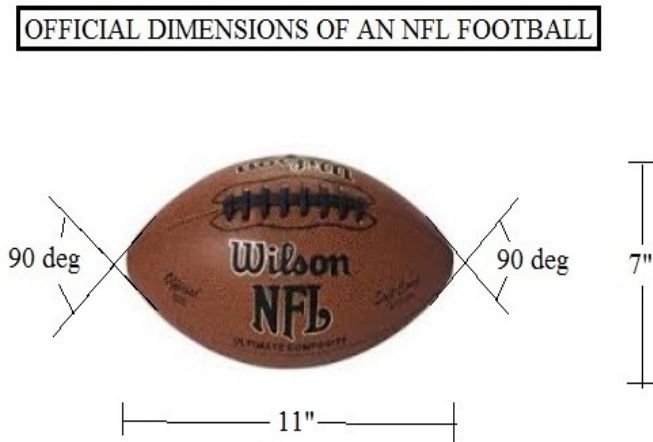


PRESSURE CHANGES EXPECTED IN AN INFLATED FOOTBALL SUBJECTED TO EXTERNAL TEMPERATURE VARIATIONS

It is well known that the pressure inside of automobile tires increases as they are driven at high speed. Likewise a football will experience a pressure change when moved between two places of different external temperature. The magnitude of such pressure changes in a football is at the center of the recent “Deflategate” controversy based on the lopsided win by the New England Patriots over the Indianapolis Colts where it was determined after the game that the Patriots were playing with footballs deflated by some 2lb/in² below the allowed pressure of 12.5 to 13.5lb/in². The Patriots’ head coach Bill Belichick and their star quarterback Tom Brady have both denied any wrong doing was involved but rather that the lower pressures were due to natural causes produced by temperature changes. The fact that underinflated footballs are easier to grasp and control under inclement weather such as the rainy conditions encountered during the Patriot-Colt game have caused many sports fans to question coach Belichick’s explanation. They find it difficult to account for the magnitude of the deflation without some deliberate deflation by a member of the Patriots’ staff. We want here to investigate the Patriots’ claim, from a scientific viewpoint, that pressure changes of the observed magnitude are possible.

Our starting point is to look at the dimensions of a standard NFL football. It has a cross-sectional shape reminiscent of the Visica Piscis formed by the intersection of two circles. Here is a figure giving the ball’s legal dimensions-



The ratio of maximum ball diameter to its length is around 0.6. The ball surface is made of a four-ply composite of cow hide and an inner impermeable membrane

containing air at a specified pressure. The weight of the ball lies between 14 and 15 oz. Each team brings their own balls to a game. These are vigorously inspected for any departures from the regulation numbers by the chief referee some two hours before the game. One assumes this inspection is done under supervised conditions and at normal indoor temperature conditions of about 20 deg C(=273+20=293 deg K). The balls are then returned to the team and brought out to the field during the next two hours by team staff. As I see it there are only two possible explanations of why the ball pressure could have dropped by some 2lb/in² during the time the official inspection was over and the balls reached the playing field. These are-

(1)-Someone on the Patriot staff lowered the pressure intentionally after the referee inspection or the balls were specifically designed to have a built-in controllable slow leak.

(2)-The drop in temperature between the inspection room and the playing field was large enough to account for the pressure drop via the standard universal gas law.

Eliminating one of these possibilities then clearly will show the other was the cause.

Lets begin by looking at the second possibility first. One knows that to a good approximation the air within the football follows the universal gas law which states that-

$$PV=nRT$$

where P is the gauge pressure within the football, V the air volume in the football, n the mole fraction, R the universal gas constant, and T the absolute temperature. On differentiating we arrive at the statement-

$$\frac{dP}{P} + \frac{dV}{V} = \frac{dT}{T}$$

This last expression contains the Boyles Law PV=Const, the Charles Law V=const. T, and the Gay Lussac Law P=const T as special cases. For the football problem we have that the volume of the ball remains essentially unchanged over a wide temperature range, so one is operating under a constant volume condition. This allows us to state the Gay-Lussac observation that-

$$dP=PdT/T$$

We thus expect that a temperature drop dT will produce a pressure drop of dP. If one makes the reasonable assumption that dT between the inspection room temperature and the playing field in the Patriot-Colt game was dT=21degC-5degC=16degC and P was set by the referee at 12.5 lb/in², we get a pressure drop of-

$$dP = -\left(\frac{16}{294}\right)(12.5) = -0.68 \frac{lb}{in^2}$$

This number is about one third of the pressure drop observed after the game and thus calls into question that temperature changes alone can account for the observations. Also not all of the Patriot's footballs had the same observed pressure drop, unlike what one would expect if the deflation was due to temperature changes alone. A more logical explanation is that the footballs were tampered with in some unknown manner. It is unlikely that the ball attendant was able to tamper with all twelve balls during the ninety seconds he was off camera. However, considering the high stakes involved in such professional games, footballs with controlled air leaks could have been involved. If these balls still exist, it might be worth checking their inflation valves.

In the future it may become necessary for the NFL to introduce a new rule were all footballs are supplied only by the referee staff and are never in the possession of either team prior to being played.