

## The Science behind Deflate-gate

It is easily deduced from basic thermodynamics that the weather during the 2014 Championship game between the Patriots and the Colts could have caused all of the deflation claimed at halftime. Poor measurement protocol by the referee notwithstanding, the observed deficits in pressure (psi) can be explained by the difference in temperature between the locker room (70 Fahrenheit) and the outdoor temperature (50 F), temperatures reported in the Ted Wells report.

The governing piece of physics is the ideal gas law:  $PV = nRT$ . In this equation  $P$  is the pressure,  $V$  is the football's inside volume,  $n$  is the number of moles of air inside the ball,  $R$  is the gas constant and  $T$  is the *absolute* temperature. For present purposes,  $V$ ,  $n$  and  $R$  are fixed and  $V$  shows very little variation within this range of temperature. Thus  $P$  is directly proportional to  $T$ . If  $T$  decreases, so does  $P$ .

The first important fact is that the  $T$  in the formula is absolute temperature, measure in Kelvin (K). To get the values of  $T$  for 70 F and for 50 F, we must convert units for  $T$ . The result is 294.25 K for 70 F, and 283.15 K for 50 F. Thus the change in absolute  $T$  going from inside the locker room to outside on the field is minus 11.1 K.

The second important fact is that the gauge-measured and quoted ball pressure is the pressure in excess of atmospheric pressure that is very close to 14.7 psi at either temperature. Thus the quoted acceptable range of psi for NFL footballs, 12.5 psi to 13.5 psi, is really actual pressures in the range 27.2 psi to 28.2 psi.

If the  $T$  decreases by 11.1 K out of 294.25 K initially, then the decrease is by  $11.1/294.25$  or 3.77 percent. Thus an initial pressure of 27.2 psi decreases by 1.025 psi, that is, to 26.175 psi, or after subtracting the atmospheric value of 14.7 psi, to a gauge value of 11.475 psi. This means balls initially at 12.5 psi, Brady's desired minimum value, end up at 11.5 psi by halftime. This accounts for all of the balls except for one that was low by another 1.0 psi (was this the ball handled by the Colts?).

Whatever motivation Brady may have had, or tacitly agreed to with his ball handlers, there is no evidence that anything other than Mother Nature fiddled with the balls. Think about balls in games at 35 F.

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