# PROPOSED USE OF TIRE PRESSURE TO IMPROVE THE CALIBRATION OF THE BICYCLE WHEEL IN THE MEASUREMENT OF ROAD-RACING COURSES

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## ABSTRACT

I have shown that tire pressure bears a linear relationship to bicycle wheel size over 18 days and with temperature changes of up to 25 deg C. From a chart of the relationship, rate of change of wheel size with pressure is 0.01%/psi. In the method of course measurement with the bicycle wheel, this corresponds to a rate of change in the wheel calibration constant with pressure of 0.05 rev/km/psi or 1 ct/km/psi. Since I have shown that changes in pressure of as little as 0.1 psi can be detected, this means that changes in the constant of only 0.005 rev/km or 0.1 ct/km can be detected. Thus the calibration constant can be held constant within very acceptable limits throughout drastic temperature changes simply by monitoring tire pressure. Post-measurement calibration is not required nor the need for temporary calibration courses at the race course site.

I describe the necessary modifications of pressure gauges to achieve the desired sensitivity for course measurement with both Presta and Schrader inner-tube valves. The use of the unique Silca brass chuck allows even unskilled measurers to get accurate readings every time from the Schrader valve.

## INTRODUCTION

The RRTC method of determining the wheel calibration constant for course measurement involves pre-measurement and post-measurement calibrations. While this usually works quite well with calibration courses located alongside the actual course to be certified and where temperature changes steadily in one direction throughout measurement, it is clearly unsatisfactory for the great majority of cases where this is not so. Typically the measurer does the calibration early in the morning, but by the time he gets to the course to be certified, temperatures may have started rising sharply. The on-going loss of air from his tire will make for a shorter course, but temperature rise is usually predominant and the course ends up overly long. When he returns to the calibration course early in the evening, the temperature may have started to plummet below that of the morning calibration. The calibration constant is now higher than that of the morning, and he is now faced with the inconvenience of going back to the new course and lengthening a course already overly long.

In 2000 Mike Sandford gave some methods for correcting for the influence of temperature on the calibration constant, but these often involve the complex taking of temperature readings. Of course probably the greatest effect of temperature is that on the pressure within the tire itself, and I therefore undertook this study to see if monitoring this might be a simpler way of correcting for the change in the constant. Both a moderately high-tech wheel and an old low-tech wheel were included in the study.

## METHODS FOR HIGH-TECH WHEEL

*Wheel:* Mavic CXP-30 (alloy, deep rim).

*Tire:* Hutchinson Carbon Comp (700 x 23).

*Inner tube:* Butyl with an extended unthreaded Presta valve.

*Pressure gauge:* Accu-gauge (G H Meiser) with Presta adapter as shown below in readiness for a reading. This gauge is about 15 years old but a similar one is still available. I find it helps to put a little grease on the rubber tubing inside the adapter on the gauge, but I avoid getting too much on the Presta valve because this tends to make the connection hose to the floor pump slip.

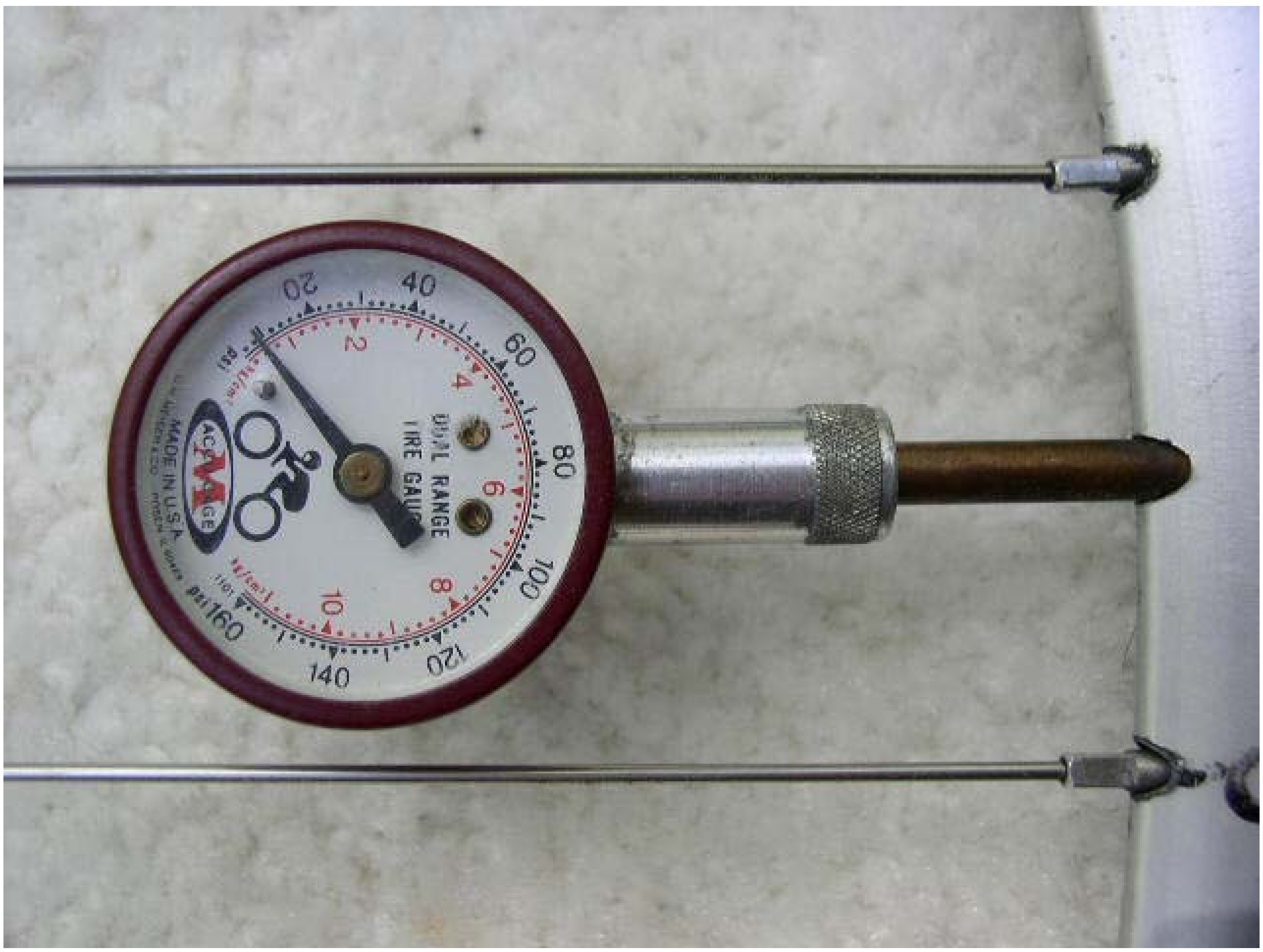
*Floor pump:* Silca with a built-in gauge. The connection to the Presta valve is of my own design and far more reliable than commercial ones. As shown below it consists of a hose connection that fits snugly around the valve, and is held in place with a wire clamp. It holds pressure indefinitely so that an accurate reading of tire pressure can be obtained from the built-in gauge. Sometimes pressure in the connecting tube has to built up above that of the tire for a few seconds before the valve opens initially. On releasing the clamp the hose pops off instantly.

*Test course:* Ray Road 400 meters (NC04009PH).Going south along the right-hand side of the road always gave about 0.02 rev more than going north.

*Revolution counter:* Protege 9 used as previously described (http://home.earthlink.net/~caverhall/newrevcounter/abstractcontents.htm).

*Thermometer:* The temperature gauge on the Protege was used. The bicycle was stored outside for the full 18 days of the tests so that the wheel was always in equilibrium with the outside temperature.

*Bicycle weight:* Myself (181 lb), frame (21lb) and pannier bags (10.6 lb) came to a total of 212.6 lb.



## METHODS FOR LOW-TECH WHEEL

*Wheel:* Steel rim with 36 spokes as shown below.

*Tire:* Silver Star (27 x 1.125; nylon and 20 years old).

*Inner tube:* Butyl with Schrader valve.

*Pressure gauge:* Accugauge (G H Meiser) with Presta adapter and modified for connection to a Schrader valve with the Silca Schrader brass chuck (SIL-PX-300) as shown below. The chuck is still available in slightly altered design from Colorado Cyclist ($8) and through the internet.

*Floor pump:* Silca with a built-in gauge and the Silca Schrader brass chuck

*Test course:* Ray Road 400 meters (NC04009PH).Going south along the right-hand side of the road always gave about 0.03 rev less than going north. This was contrary to what was found with the high-tech wheel and may have had something to do with the fact that there was a strong wind from the north in the case of the low-tech wheel tests.

*Revolution counter:* Protege 9 used as previously described (http://home.earthlink.net/~caverhall/newrevcounter/abstractcontents.htm).

*Thermometer:* RadioShack digital shaded. The bicycle was stored outside so that the wheel was always in equilibrium with the outside temperature.

*Bicycle weight:* Myself (183 lb), frame (24.5lb) and pannier bags (7 lb) came to a total of 214.5 lb.


**RESULTS**

Pressure Gauge Sensitivity

It is generally believed impossible to determine the pressure in a tire, because owing to the design of connectors, the very act of using a gauge spills a lot of air from the tire. Pressure is known accurately only at the moment the gauge is disconnected.

However, the Accu-gauge for Presta valves used in this work does not spill air to the atmosphere during the act of connection. The valve stem is inserted through an internal rubber tube in the gauge which effectively seals off the gauge from the outside before opening the valve. Air loss is only to the gauge dead volume.

No comparable gauge existed for Schrader valves, though Silca has made for many years a Schrader brass chuck for floor pumps which avoids air spill. One end of this ingenious chuck is screwed onto the stem and only opens the valve long after the pump is sealed from the outside. The other end is attached to the hose, and can rotate but remain sealed at the rotation interface through a small internal O-ring. By combining this chuck with the Presta Accu-gauge, I have designed an effective gauge for Schrader valves. The metal end of the Accu-gauge is very slightly reamed out to accept the hose attachment of the chuck as shown in the photograph immediately above. Note that this gauge does not require any skill to attach it to the Schrader valve and air spill never happen.

I next investigated the effect air loss due to the gauge dead volume on the pressure readings. To gain sensitivity I substituted the head of a gauge with a 5-cm dial for the original head with the 3-cm dial. This new head was graduated from 3-60 psi in divisions of 1 psi so that readings to a sensitivity of 0.1 psi could be achieved. Unlike the original head it did not have a plug in the head opening designed to press on the Presta valve end and open it while allowing air to enter the head through peripheral holes. Nevertheless, with the new head the Presta valve opened when the valve end reached the opening in the head and the valve end did not seal the head to air from the tire. With a tire pressure of 40 psi I took five successive readings removing the gauge from the valve after each reading. Astonishingly, neither with the Presta nor with the Schrader was I able to detect any overall pressure change, so that the dead volume of the gauges was having no detectable effect on readings. I intend to obtain a gauge head with a 5-cm dial that goes to 160 psi so that I can measure normal tire pressures to 0.1 psi.

## Relationship between Wheel Size and Pressure

Results from the high-tech wheel over 18 days are summarized in the first large table and chart below.

On the first day tire pressure was cycled down and up three times to demonstrate that the circumference could be precisely and repeatedly controlled by adjusting pressure. Five days later pressure was cycled down once more and closely similar circumferences found for the same pressures.

After ten days another test was conducted in which the pressure was not adjusted for 24 hr. This was designed to simulate what might happen to wheel circumference during the measurement process involved in certification. Note that from 9:45 to 17:18 temperature rose from 22 C to 27 C and there was a corresponding rise in pressure and circumference. However by 19:48 temperature had dropped rapidly to 21 C and circumference had gone below that of the morning. Pressure had gone from 117.8 psi at the start to 114.0 psi. No doubt much of this can be accounted for through air leakage, because other tests had shown that at 120 psi and constant temperature the loss rate is 0.25 psi/ hr. By the end of the 24-hr period further air loss and a fall to 10 C had reduced the pressure to 109.0 psi and further eroded the circumference. However, when the pressure was restored close to its original value of 117.8 psi, the original circumference was almost precisely reproduced. This despite the fact that the temperature was 12 C lower.

After 18.0 and 18.25 days, measurements were again made at 118 psi, and despite the fact that temperatures were much higher, circumferences found were practically identical within the limits of experimental determination. I have extracted these 118-mm measurements for the small table below with days measured from the first one.

| Days | Deg C | Circum, cm |
|---|---|---|
| 0 | 22 | 209.31 |
| 1 | 10 | 209.28 |
| 8.1 | 38 | 209.30 |
| 8.4 | 29 | 209.33 |
| | | |

All of the above data were summarized in the chart below. Note the excellent linear relationship between pressure and circumference despite the fact that the chart covers 18 days during which temperature varied greatly. Evidently, other than its effect on pressure, temperature does not appear to be a significant factor.

The slope of the line in the chart is 0.0211cm/psi or 0.010 %/psi. Assuming the wheel calibration constant is about 500 rev/km or 10,000 ct/km, the rate of change of the constant with pressure is 0.05 rev/km/psi or 1 ct/km/psi. Thus by using a gauge that can read to 0.1 psi, changes in the constant of as small as 0.005 rev/km or 0.1 ct/km can be detected.

The last table and chart below show the results from the tests with the old low-tech wheel. Results are very similar to those from the high-tech wheel with a line slope in the chart of 0.0259 cm /psi or 0.012 %/psi. A sensitive gauge should detect changes in the calibration constant of 0.006 rev/km or 0.1 ct/km.

## Conclusions for Race-Course Measurement

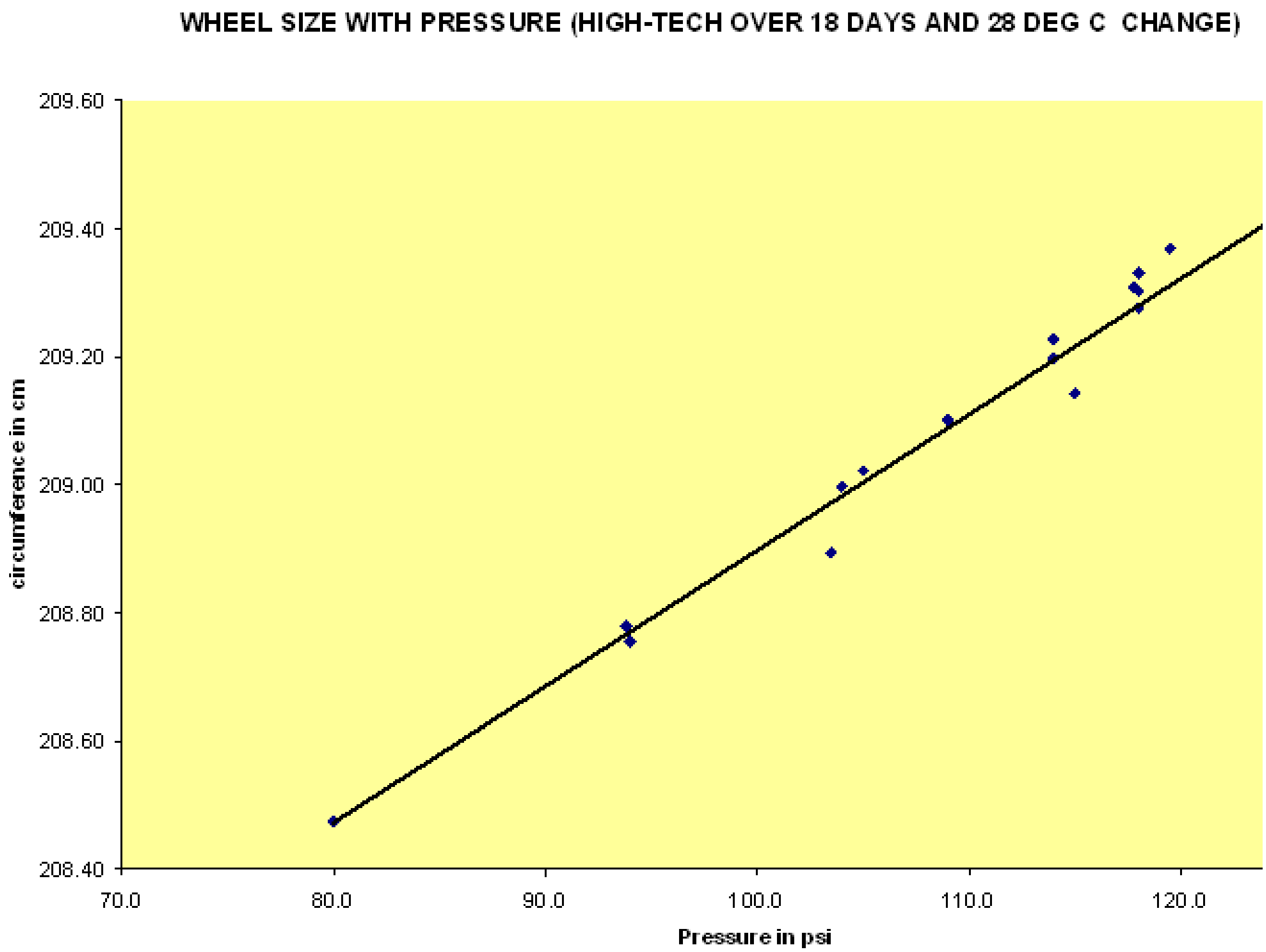
The ability of tire pressure monitoring to detect changes in the wheel calibration constant as small as 0.1 ct/km make it a very sensitive method of keeping the constant stable throughout the whole race-course measuring process. It simplifies the process by not requiring a postmeasurement calibration and the setting up of a temporary calibration course at the race site. The use of the unique Silca brass chuck allows even unskilled measurers to get accurate readings every time from the Schrader valve.

One possible procedure for a 5-km measurement would be to measure the pressure after calibration and adjust to this pressure at the start of each race-course ride. Pressure would be checked after each ride, and if it had not fallen more than 1 psi, distance at the rate of 0.5 m/psi would be added to that run. Otherwise the run would be repeated.

**WHEEL SIZE WITH PRESSURE (HIGH-TECH OVER 18 DAYS AND 28 DEG C CHANG**

| Date | Time | Deg C | Psi | Rev N | Rev S | Ave | Circum cr |
|---|---|---|---|---|---|---|---|
| 4/1/2005 | 11:00 | 24 | 125.0 | 190.960 | 191.010 | 190.985 | 209.44 |
| | 11:10 | 24 | 104.0 | 191.380 | 191.400 | 191.390 | 209.00 |
| | 13:30 | 21 | 125.0 | 190.965 | 190.985 | 190.975 | 209.45 |
| | 13:40 | 21 | 114.0 | 191.180 | 191.235 | 191.208 | 209.20 |
| | 13:50 | 21 | 105.0 | 191.360 | 191.375 | 191.368 | 209.02 |
| | 14:00 | 21 | 93.8 | 191.570 | 191.610 | 191.590 | 208.78 |
| | 14:10 | 20 | 80.0 | 191.830 | 191.910 | 191.870 | 208.47 |
| | 14:20 | 20 | 125.8 | 191.020 | 191.035 | 191.028 | 209.39 |
| | 14:30 | 19 | 94.0 | 191.600 | 191.625 | 191.613 | 208.75 |
| 4/5/2005 | 18:45 | 24 | 125.0 | 191.060 | 191.075 | 191.068 | 209.35 |
| | 18:55 | 23 | 115.0 | 191.250 | 191.265 | 191.258 | 209.14 |
| | 19:05 | 23 | 103.5 | 191.470 | 191.500 | 191.485 | 208.89 |
| 4/11/2005 | 9:45 | 22 | 117.8 | 191.100 | 191.110 | 191.105 | 209.31 |
| | 17:18 | 27 | 119.5 | 191.040 | 191.060 | 191.050 | 209.37 |
| | 19:48 | 21 | 114.0 | 191.160 | 191.200 | 191.180 | 209.23 |
| 4/12/2005 | 9:12 | 10 | 109.0 | 191.270 | 191.320 | 191.295 | 209.10 |
| | 9:27 | 10 | 118.0 | 191.110 | 191.160 | 191.135 | 209.28 |
| 4/19/2005 | 12:22 | 38 | 118.0 | 191.110 | 191.110 | 191.110 | 209.30 |
| | 18:15 | 29 | 118.0 | 191.080 | 191.090 | 191.085 | 209.33 |

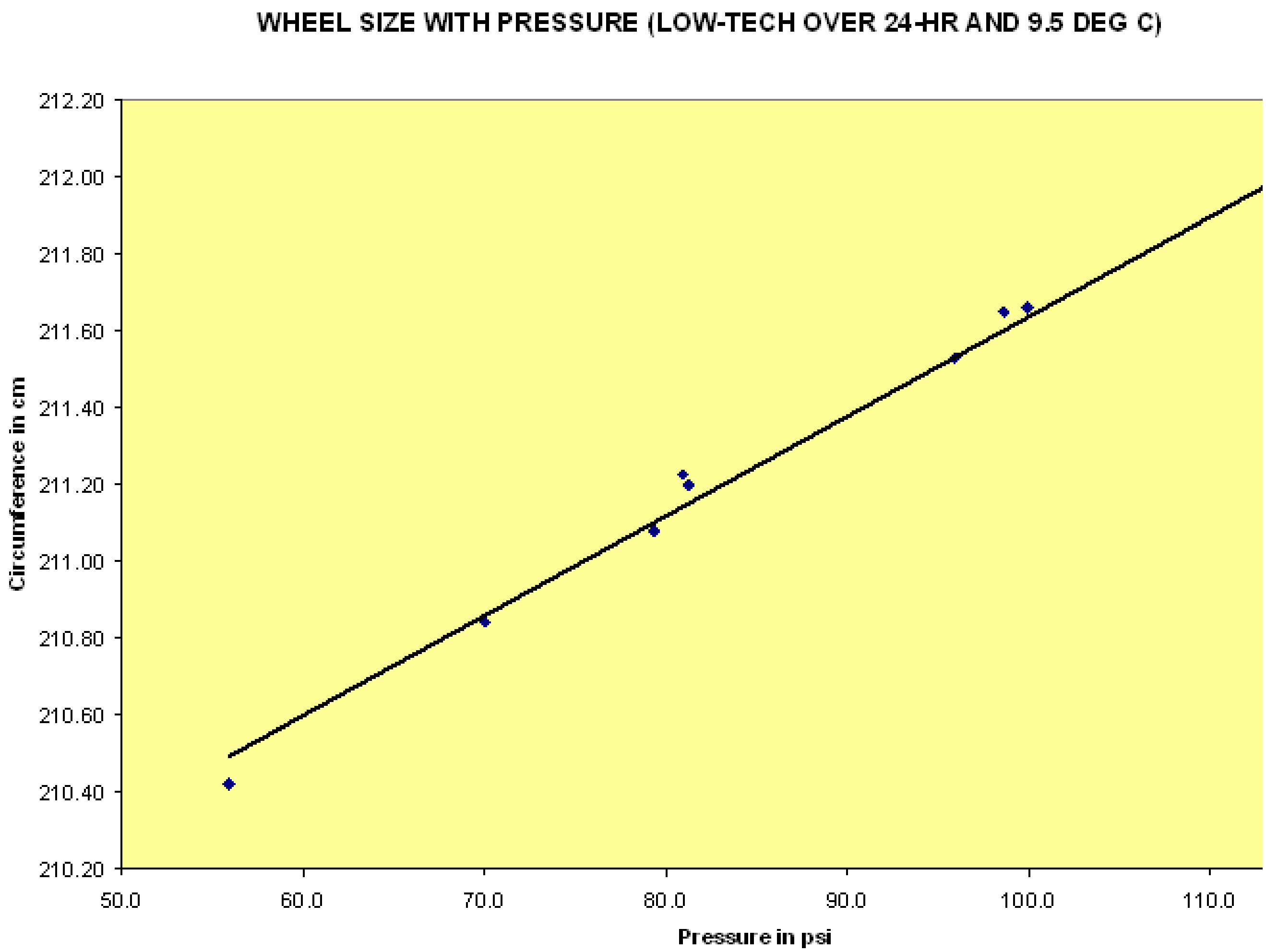
A: Pressure cycled down and up three times on this date.
B: Pressure cycled down once on this date.
C: Pressure not adjusted during this 24-hr period to simulate a course measurement.
D: Pressure adjusted back to that at the beginning of 24-hr period.
E: Precalibration and postcalibration in an actual course measurement.




**WHEEL SIZE WITH PRESSURE (LOW-TECH OVER 24 HR AND 9.5 DEG C )**

| Date | Time | Deg,C | Psi | Rev N | Rev S | Ave | Circum, cm | Not |
|---|---|---|---|---|---|---|---|---|
| 4/23/2005 | 18:30 | 16.9 | 98.6 | 188.990 | 188.990 | 188.990 | 211.65 | A |
| | 18:45 | 15.9 | 80.9 | 189.400 | 189.340 | 189.370 | 211.23 | A |
| | 19:00 | 15.7 | 70.0 | 189.750 | 189.680 | 189.715 | 210.84 | A |
| | 19:15 | 15.6 | 116.5 | 188.720 | 188.690 | 188.705 | 211.97 | A |
| | 19:45 | 14.5 | 99.9 | 189.010 | 188.950 | 188.980 | 211.66 | A |
| | 20:00 | 14.4 | 79.3 | 189.540 | 189.465 | 189.503 | 211.08 | A |
| 4/24/2005 | 17:15 | 11.7 | 81.2 | 189.410 | 189.380 | 189.395 | 211.20 | B |
| | 17:30 | 12.1 | 55.9 | 190.110 | 190.080 | 190.095 | 210.42 | B |
| | 17:45 | 9.4 | 95.9 | 189.110 | 189.085 | 189.098 | 211.53 | B |

A: Pressure cycled down, up, and down on this date.
B: Pressure cycled down and up on this date.


WHEEL SIZE WITH PRESSURE (LOW-TECH OVER 24-HR AND 9.5 DEG C)
Circumference in cm
212.20
212.00
211.80
211.60
211.40
211.20
211.00
210.80
210.60
210.40
210.20
50.0
60.0
70.0
80.0
90.0
100.0
110.0
Pressure in psi