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The Accuracy of Air Tower Pressure Gages In Suburban Washington, D.C.

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The Accuracy of Air Tower Pressure Gages in Suburban Washington, D. C.*

B. G. Simson and R. W. Radlinski

A survey of 50 air tower pressure gages in service stations of suburban Washington, D. C., was performed. Results showed that a motorist using these towers has only a 20 percent chance of inflating his tires within ±1 psi of the pressure indicated by the tower's gage. It is shown that a calibration of the tower gages would reduce the standard deviation of the obtained pressure to 0.5 psi.

Key words: Air towers; tire pressure.

1. Introduction

A recent tire usage survey by the Davidson Laboratory of the Stevens Institute of Technology [1]† included an inspection of 72 air tower pressure gages at service stations in the Eastern United States. Results showed that "usually, the air tower delivers a pressure slightly less than the indicated setting." In another study of air towers [2], Consumers Union reports that "about 40 percent of the equipment was off between one and three pounds . . ."

The work described below deals with air towers at service stations in the suburbs of Washington, D. C. The close proximity of the test stations was chosen to keep environmental conditions, such as temperature and baromentric pressure, as constant as possible. All measurements were completed in about one week.

2. Test Procedure

A population of 200 service stations was chosen from the following suburbs of the Washington, D. C., metropolitan area: Chevy Chase, Silver Spring, Rockville, Wheaton, and Gaithersburg. From this population, a random sample of 50 service stations was selected for the survey.

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†Figures in brackets indicate the literature references at the end of this paper.

The apparatus used to measure the air tower pressure is shown in figure 1. It consists of a 0-60 psi test gage (specified by the manufacturer to have an accuracy of ±0.15 psi) connected to the spare tire of the survey team's vehicle. The air tower gage was set to the desired test pressure and the spare tire (previously deflated to low pressure) was "pumped up" until the tower bell stopped ringing. Then the test gage pressure was recorded. The test pressures* were 20, 24, 28, 32, and 36 psi and the sequence of pressure settings was randomized for each tower. The test gage was checked at the onset and conclusion of each test day against a master gage (specified by its manufacturer to have an accuracy of ±0.10 psi).

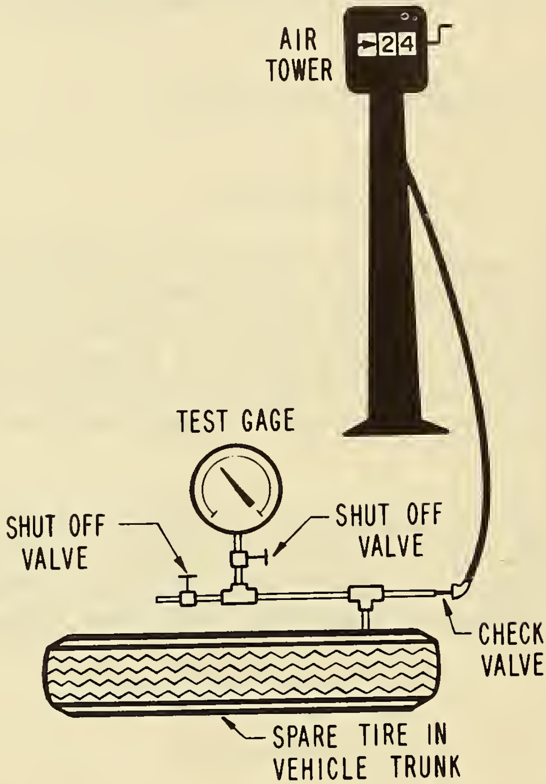

Figure 1. Apparatus for measuring air tower accuracy.

3. Data

The data collected from 50 service stations are shown in table 1. Reported are the test gage readings corresponding to air tower gage settings of 20, 24, 28, 32, and 36 psi, respectively.

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*All pressures are "gage" pressure, not absolute pressure.

Table 1. Test gage readings (psi) for various air tower settings

	Tower Setting				
Sample	20 psi	24 psi	28 psi	32 psi	36 psi
1	17.4	21.5	25.5	29.5	33.7
2	14.0	18.2	22.0	26.7	29.6
3	18.4	22.3	26.0	30.0	34.2
4	21.5	26.0	30.4	34.2	38.4
5	19.6	22.4	26.2	31.8	35.2
6	19.0	24.6	27.8	31.7	36.4
7	18.8	23.7	27.3	31.5	35.6
8	19.8	23.8	27.9	31.8	35.2
9	18.2	21.0	24.7	29.4	33.0
10	18.6	21.8	26.1	30.3	33.3
11	21.2	23.8	27.8	31.0	35.7
12	19.3	23.2	27.8	31.7	35.4
13	18.8	22.6	26.0	30.2	34.4
14	14.6	19.3	23.6	27.0	30.7
15	16.0	20.0	24.2	27.5	31.8
16	19.7	24.3	29.6	32.4	36.2
17	18.7	22.0	26.0	30.0	34.3
18	21.8	25.9	30.4	34.4	37.7
19	18.0	22.4	25.6	30.0	33.6
20	22.2	26.5	29.7	33.2	37.4
21	21.1	24.5	28.5	32.4	37.7
22	19.7	23.4	28.6	32.6	*
23	22.0	25.5	29.4	32.7	37.0
24	16.8	21.3	26.3	29.1	32.9
25	21.2	25.9	28.1	32.7	36.2
26	21.6	25.6	28.8	33.6	36.8
27	20.2	24.5	28.4	32.2	35.9
28	12.6	14.6	19.4	23.0	26.6
29	22.0	25.8	29.4	33.4	37.5
30	20.2	24.2	28.5	32.6	36.8
31	17.0	21.5	25.0	28.0	32.0
32	18.2	21.8	26.5	29.4	33.2
33	18.0	21.4	25.2	29.6	34.5
34	15.0	18.8	21.6	25.4	29.2
35	16.9	21.0	25.1	28.8	33.0
36	19.8	23.7	28.2	32.0	35.4
37	18.5	22.2	26.2	29.7	34.8
38	20.0	24.6	29.3	32.8	35.2
39	13.6	17.4	21.3	25.1	28.7
40	18.0	22.0	25.5	29.2	33.4
41	19.3	23.3	27.3	31.5	35.3
42	20.2	23.7	30.2	31.3	36.0
43	27.5	31.0	35.0	38.5	42.7
44	33.6	37.6	43.7	48.0	52.3
45	32.4	37.6	42.5	46.4	51.1
46	24.5	28.6	32.6	36.4	40.6
47	18.8	23.7	26.8	31.0	34.0
48	22.4	26.8	31.0	34.8	39.8
49	23.2	27.0	30.2	35.2	38.8
50	23.3	28.2	32.2	35.3	39.6

*Tower would not stop pumping at this setting.

4. Statistical Analysis

An analysis was first made to separate systematic and random type errors in the observed differences between the various towers. It is useful for this purpose to represent the data by an appropriate mathematical model.

The procedure is illustrated in figure 2. The abscissa represents the average values for all air towers at each of the five settings. The value denoted C is the average of these five averages. The ordinate represents the values obtained by air tower 17. The five points thus obtained fall close to a straight line, which is also shown on the graph. The height of this line at the point C is denoted by A and its slope by B.

If x_j is the abscissa for the *jth* point and y_j the corresponding ordinate, the situation is represented by the equation

$$y_j = A + B(x_j - C) + \text{random error} \qquad [1]$$

The "random error" term is added to express the fact that the points do not fall *exactly* on the straight line. This equation applied to air tower 17. More generally, the same process can be applied to any air tower. For the *ith* air tower, the equation will be

$$y_{ij} = A_i + B_i(x_j - C) + \text{random error} \qquad [2]$$

The parameters A_i and B_i may vary from one air tower to another. The following general facts can be derived from the above [2] equation.

(1) If A_i is constant for all towers, and B_i is unity for all towers, then

$$y_{ij} = \text{constant} + (x_j - C) + \text{random error}$$

In that case, there would only be random differences between the data obtained from different towers.

(2) If B_i is unity for all towers, but A_i varies from tower to tower, then

$$y_{ij} = A_i + (x_j - C) + \text{random error}$$

In that case, A_i represents a *systematic* shift for tower i, but this shift would be the same for all pressures.

(3) Finally, if B_i is not constant and not equal to unity for all towers, then the systematic shift from tower to tower would vary from one pressure to another. Actually, A_i and B_i will never be rigorously constant even if no systematic variations are present because of the effects of random fluctuations. It is then necessary to ascertain whether the fluctuations observed in A_i and B_i exceed what may be expected as a result of chance.

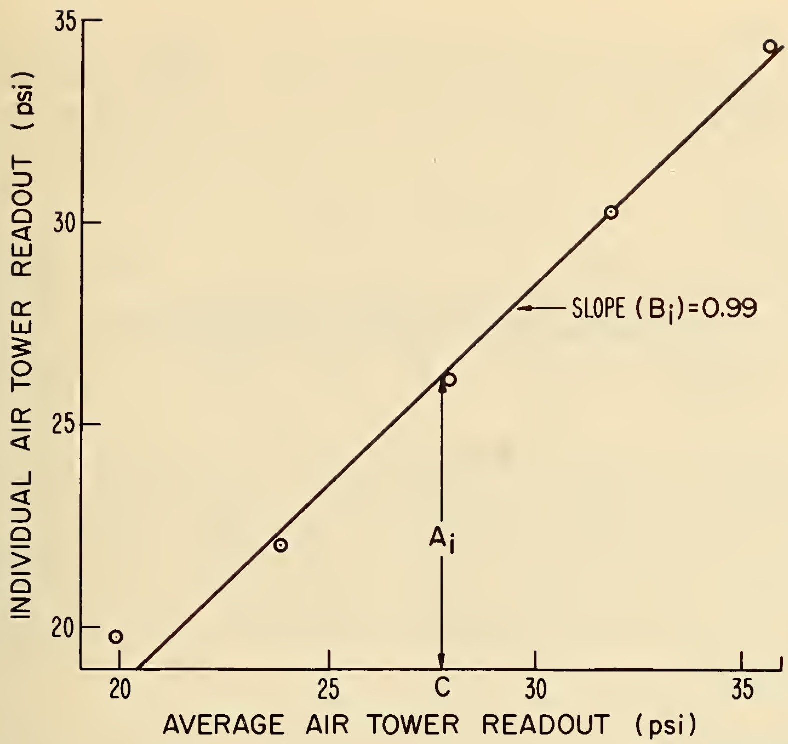

Figure 2. Pressure reading of air tower 17 vs the average reading of 49 air towers.

The values of A_i and B_i calculated for all 49 towers* are shown in control chart fashion in figure 3, and the value of C = 27.81. Also shown on the graphs are two sigma control limits. These limits indicate the variations in A_i and B_i that would result *from random fluctuations alone*, and they are such that, *in the absence of systematic effects*, approximately 95 percent of the plotted points should fall inside the bands determined by these limits.†

*Tower 22 was omitted because of incomplete data.

†A more detailed discussion of this statistical procedure may be found in reference [3].

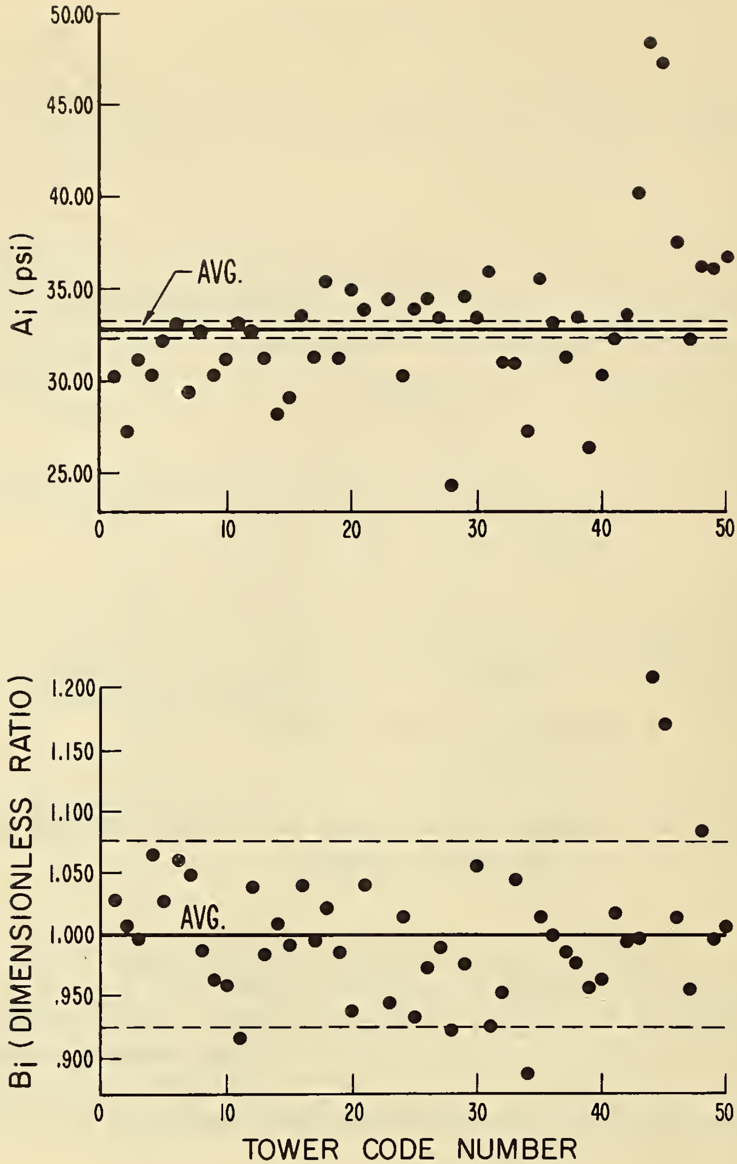

Figure 3. Parameters characterizing systematic differences between air towers.

It is obvious from these graphs that large systematic errors exist in terms of A_i between the towers since all but 5 points fell *outside* the two sigma control limits. All but six of the B_i points fall *inside* the two sigma band indicating that the differences in the B_i are mostly due to random error. Consequently, the systematic shifts observed between towers (fluctuations in A_i) are for all practical purposes constant for all pressures. It follows that calibration of any tower at a single pressure, say 28 psi, would result in a considerable improvement in obtaining uniform readings from different air towers.

The previous analysis is concerned only with *precision*, i.e., with agreement between towers. From the viewpoint of *accuracy*, a comparison must be made between the x_j, i.e., the average pressures obtained by all 49 towers, and the corresponding nominal values of pressure. The results are shown as follows:

Study of Accuracy

Nominal Pressure	20	24	28	32	36
x_j	19.87	23.86	27.89	31.72	35.69
Difference	0.13	0.14	0.11	0.28	0.31

It is seen that the average pressure for all towers is consistently smaller than the nominal pressure. The differences, however, are relatively small when compared to the random error. The latter is characterized by a standard deviation of 0.54 psi. Thus, if systematic errors are eliminated through calibration, a random error will remain which, with 95 percent probability, will fall within approximately ±1 psi. The additional inaccuracy measured by the differences shown above is then practically negligible.

In order to obtain a visual appraisal of the large systematic differences between the pressures for the various air towers, frequency diagrams are shown for the deviations from nominal pressure settings in figure 4 for the three settings, 24, 28, and 32 psi, which are the usual pressure limits for passenger car tires. The calculated mean and standard deviations for the three distributions were 0 and 4 psi, respectively. For the purpose of the following discussion, the gage reading differences were approximated to be normally distributed.

Analysis of the data in figure 4 showed the following results:*

(1) A motorist who uses an air tower, which has the characteristics of the sample discussed here, to inflate his tires has only a 20 percent chance of obtaining a pressure *within* ±1 psi of the setting he chooses on the air tower.

(2) The chance that a motorist will inflate his tires to a pressure which differs from the nominal air tower pressure by $\pm x$ psi is given as follows:

Pressure Deviation (psi)	Probability (percent)
±2 psi or more	62
±3 psi or more	45
±4 psi or more	32

*The calculations are based on a normal distribution with zero mean and a standard deviation of 4 psi.

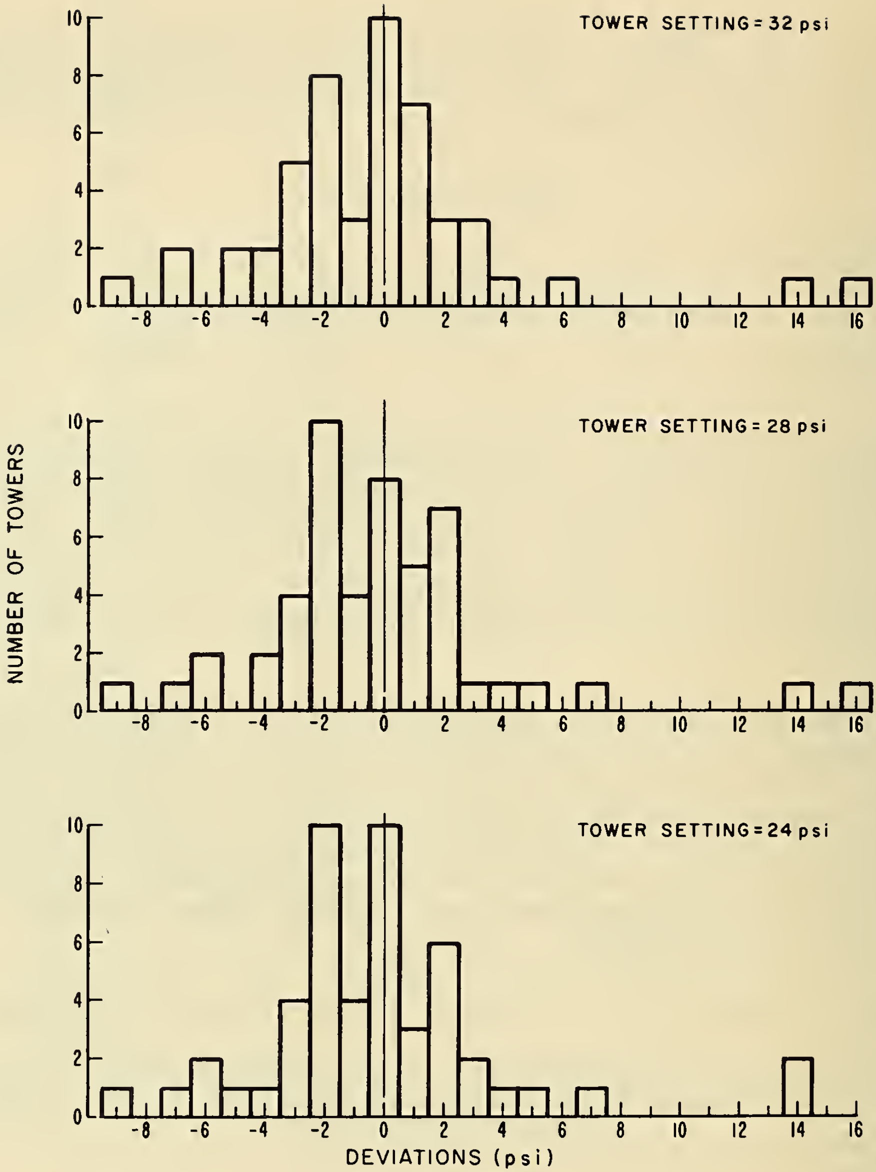

Figure 4. Inflation pressure deviations between air tower and test gage.

5. Recommendation

Results of the survey showed that a motorist, using an air tower in the areas described above, has only a 20 percent chance of inflating his tires within ±1 psi of the pressure he chooses on the tower's gage. The test team was informed by a number of service station managers that to the best of their knowledge the air towers were never calibrated. As indicated by the analysis, the air towers which were incorrect at one pressure setting were off on the four other settings by about the same amount. This indicates that a simple periodic calibration at a setting of, for example, 28 psi would be sufficient to reduce the standard deviation of the obtained pressure to 0.5 psi.

6. Acknowledgment

The statistical analysis was done by Dr. John Mandel, Statistical Consultant, Institute for Materials Research, whose assistance is gratefully acknowledged.

7. References

[1] Stevens Institute of Technology Report on Characteristics of Tire Usage in the Eastern United States, A Survey, I.R. Ehrlich and M.P. Jurkat, October 1968.

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