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COMPARISON OF UNITED STATES AND BRITISH STANDARD PITOT-STATIC TUBES

NATIONAL ADVISORY COMMITTEE
FOR AERONAUTICS

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BY A. F. ZAHM AND R. H. SMITH

Bureau of Construction and Repair, U. S. N.

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COMPARISON OF UNITED STATES AND BRITISH STANDARD PITOT-STATIC TUBES.

By A. F. Zahm and R. H. Smith.

PREFACE.

It has been stated by some experimenters that the standard pitot-static tube used by the United States Navy does not, at all airplane speeds, give the same differential pressure as the British standard pitot-static tube. Since the readings of these two tubes form the basis of comparison of a part of the British and American aerodynamic data, it was deemed advisable to calibrate them with reference to one another at all available wind tunnel speeds. This was accomplished in the 8 by 8 foot tunnel constricted to 4 by 4 feet and giving a fairly uniform air flow at all speeds up to 160 miles an hour. The table and illustrations were prepared by Mr. G. C. Hill.

DESCRIPTION OF TUBES.

Figs. 1, 2, 3, and 4 give the general exterior appearance of these instruments and the structural drawings of their nozzles. In shape both nozzles consist of round coaxial tubes terminating in a hollow conical nose with fine external taper as shown in the figures. The Navy tube has the steeper taper and the greater number of static holes in the external pipe. The holes in both are 0.040 inch in diameter. Both nozzles are attached to stream-line shanks which convey the static and impact pressures, respectively, to the opposite leads of their manometers or pressure gauges. The theory and general structure of such tubes are too well known to require detailed explanation.

MANNER OF TESTING.

During calibration the tubes were placed abreast in the 4 by 4 foot tunnel, equally distant from each other and from the walls, and supported from their shanks which ran vertically upward through the ceiling of the tunnel to liquid alcohol manometers having a 1 to 5 slope. Vibration was prevented by a fine wire attached to the lower ends of the shanks and to the side walls. During the test the British tube was made to read even miles per hour from 20 to 160, by increments of 10, and the corresponding pressure difference for the other tube was observed at the same instant, at the time when both readings were steady. After a complete and careful run, duly checked, the tubes were interchanged in position, and a complete new run was taken with the British tube still made the instrument of reference. The mean of the speed indications of the Navy tube, observed at any one speed in the two positions, was taken as the true reading, or what would be obtained in a uniform and homogeneous current.

By means of a hook gauge, the two manometer tubes were calibrated to 0.001 of an inch of water simultaneously and under the same pressure, allowance being made for the descent of the alcohol in their reservoirs. As seen from Table I and Fig. 5, the two straight glass tubes of the inclined manometer were of uncommonly uniform diameter, except where a weld in each tube was made during construction. Both were of German glass 3/16 of an inch in diameter. The meniscus could be located accurately to 0.01 of an inch along the tube, or 1/500 of an inch in vertical displacement, thus enabling the differential pressure in the nozzles to be read truly to less than 1 per cent at 20 miles per hour and still more accurately at higher speeds.

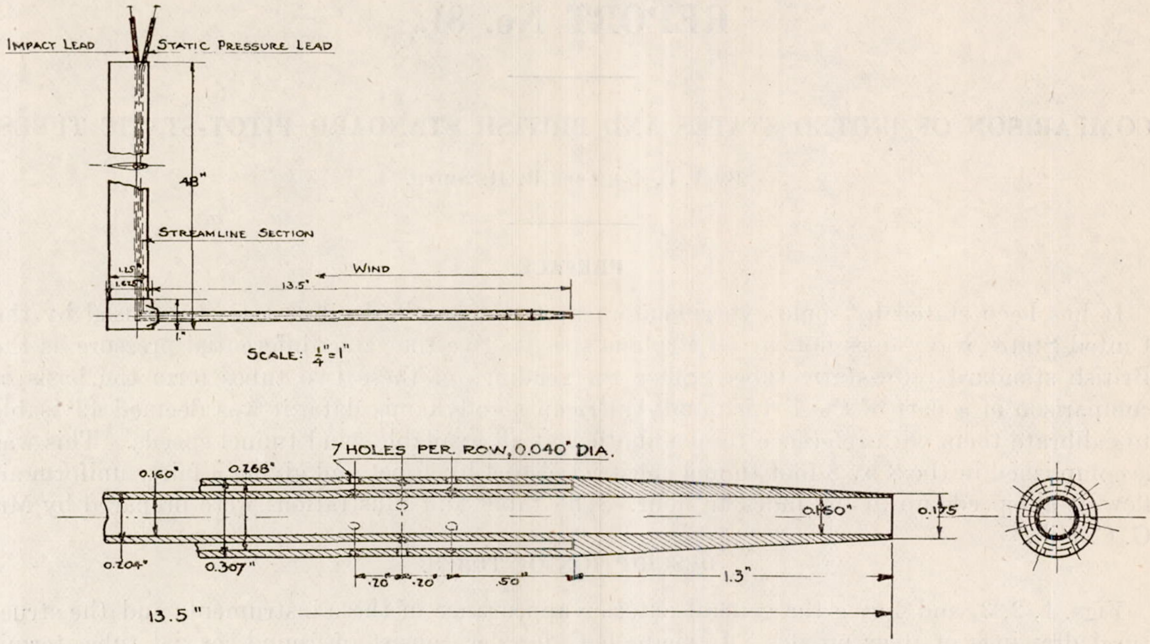

Fig. 3.—British pitot-static tube.

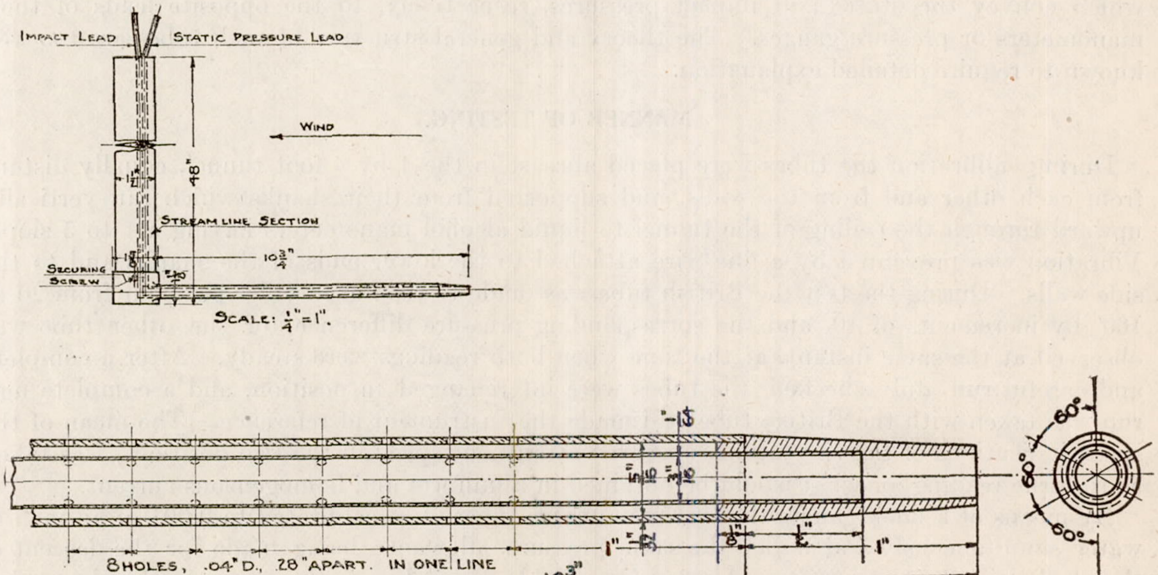

Fig 4.—U. S. Navy pitot-static tube.

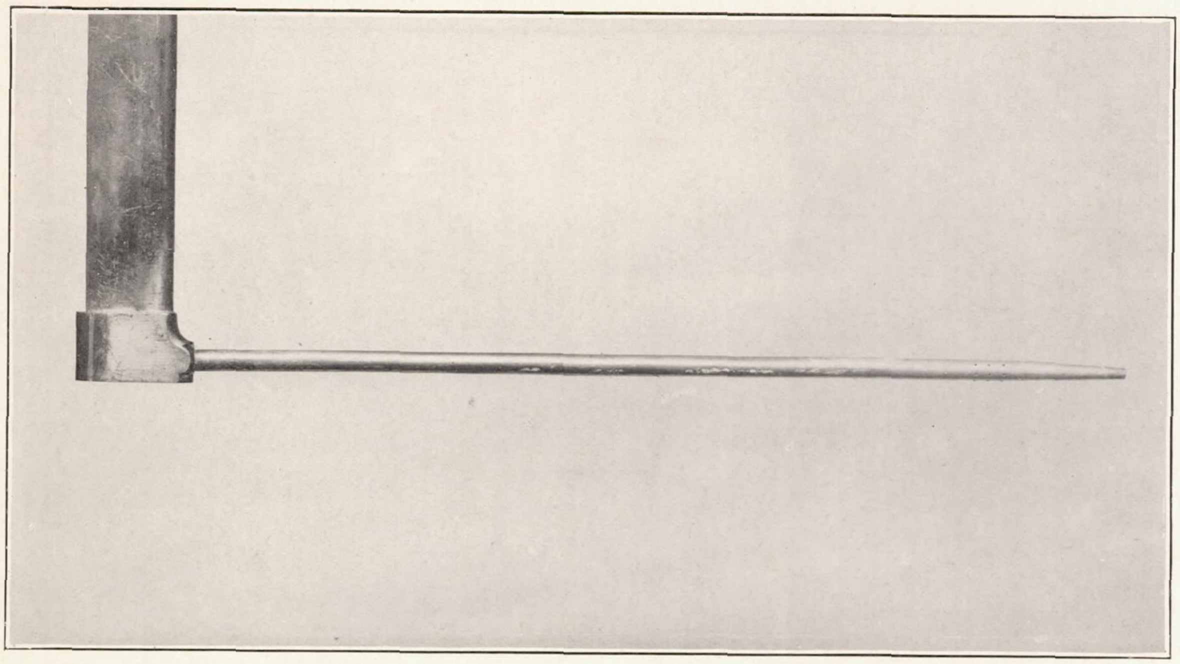

FIG. 1.—STANDARD BRITISH PITOT-STATIC TUBE.

6–1

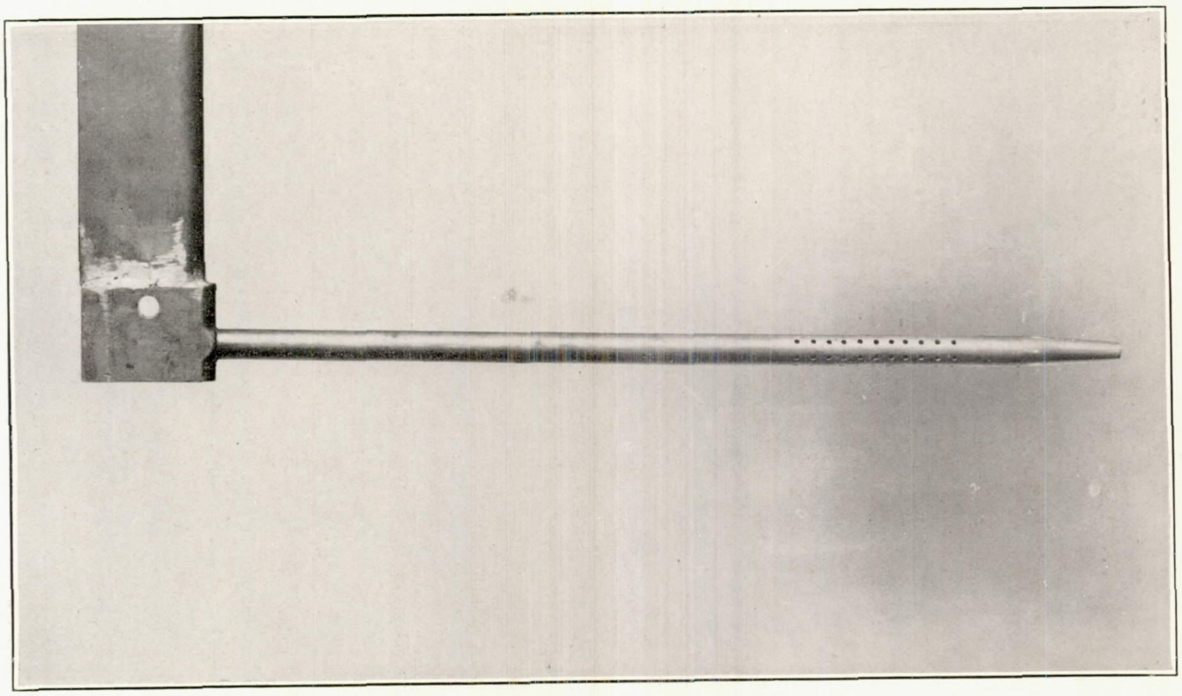

FIG. 2.—U. S. NAVY STANDARD PITOT-STATIC TUBE.

RESULTS.

Fig. 6 gives the final calibration data for the two tubes. When the corrected air speed indications of the United States Navy tube are plotted to the same linear scale, against those of the British tube, as a basis of reference, the data all lie on a straight line whose slope is unity. It had been alleged that the somewhat steeper cone of the Navy nozzle caused too low pressure in the static holes. From this diagram, however, it appears that the air speed readings of the two instruments are identical to the accuracy of indication of either instrument.

REMARK.

It seems most desirable that a standard pitot-static tube be accurately calibrated at all speeds used in aerodynamic research. The precise calibrations thus far made have stopped far short of the speeds available in modern wind tunnels and aircraft.

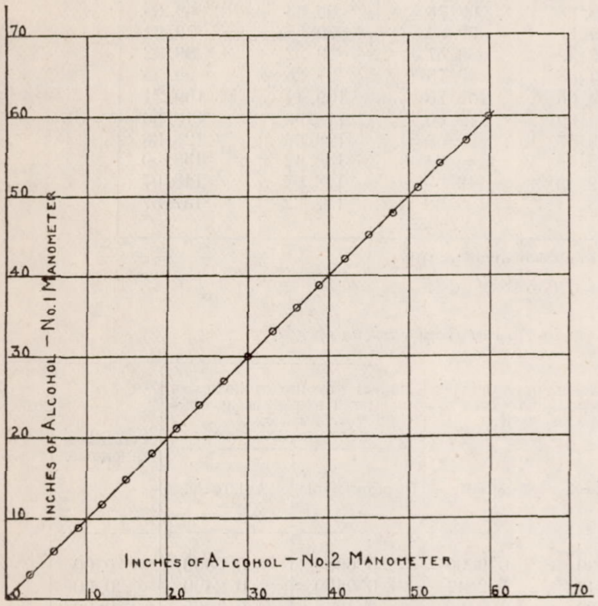

Fig. 5.—Readings of manometers 1 and 2 under same pressure.

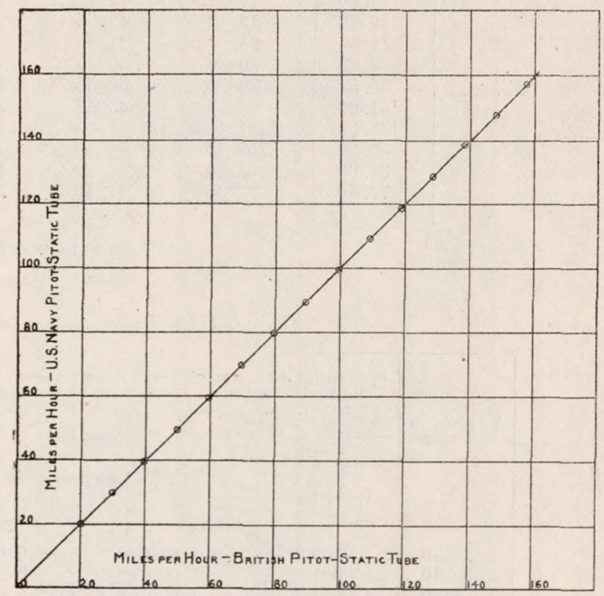

Fig. 6.—Simultaneous air speed indications of two pitot-static tubes.

Table I.—*Readings of two manometers under same pressure.*

[Inches of alcohol on 1/5 slope.]

Manometer No. 1.	Manometer No. 2.
3. 00	3. 01
5. 97	5. 98
8. 96	8. 96
11. 93	11. 93
14. 93	14. 94
17. 97	18. 00
20. 98	21. 00
23. 96	23. 99
27. 01	27. 02
30. 03	30. 03
33. 03	33. 03
36. 01	36. 00
38. 94	38. 93
42. 06	42. 00
45. 10	45. 00
48. 06	47. 90
51. 07	51. 03
54. 08	53. 96
57. 10	57. 03
59. 96	59. 99

TABLE II.—*Speed comparison of United States and British pitot-static tubes.*

Observed inches of alcohol on 1/5 slope.			Air speed.			
			$V=\sqrt{\frac{2}{\rho_o}p}$		$V=\left[\left(\frac{2\gamma}{\gamma-1}\frac{p_o}{\rho_o}\left(1-\left(\frac{p}{p_o}\right)^{\frac{\gamma-1}{\gamma}}\right)\right)\right]^{\frac{1}{2}}$	
British tube.	United States tube. (First position).	United States tube. (Second position).	British tube m. p. h.	(Mean) United States tube m. p. h.	British tube m. p. h.	(Mean) United States tube m. p. h.
1. 21	1. 23	1. 21	19. 95	20. 03	19. 95	20. 03
2. 71	2. 73	2. 71	29. 85	29. 92	29. 85	29. 92
4. 83	4. 85	4. 82	39. 85	39. 85	39. 85	39. 85
7. 55	7. 57	7. 53	49. 83	49. 83	49. 80	49. 80
10. 85	10. 88	10. 85	59. 76	59. 78	59. 71	59. 73
14. 80	14. 84	14. 77	69. 76	69. 76	69. 63	69. 63
19. 35	19. 40	19. 35	79. 77	79. 83	79. 58	79. 64
24. 40	24. 45	24. 33	89. 57	89. 57	89. 32	89. 32
30. 20	30. 30	30. 18	99. 68	99. 73	99. 28	99. 33
36. 55	36. 70	36. 55	109. 65	109. 75	109. 11	109. 21
[1]51. 05	43. 65	43. 52	119. 60	119. 60	118. 90	118. 90
[1]43. 50	51. 40	51. 05	129. 57	129. 57	128. 66	128. 66
59. 20	59. 40	59. 10	139. 56	139. 64	138. 42	138. 50
68. 00	68. 20	67. 80	149. 49	149. 49	148. 07	148. 07
77. 30	77. 35	77. 10	159. 41	159. 38	157. 62	157. 57

[1]Not corrected for weld in glass manometer tube.

Air density ρ_o=.07635 lbs./cu. ft.

TABLE III.—*Pressure of air on coming to rest from various speeds.*

Air speed in miles per hour.	Barometric plus impact pressure in standard atmospheres, i. e., in megadynes/sq. cm.		Impact pressure in pounds per square foot: 1 megadyne/sq. cm.=2,088 lbs. sq./ft.[1]		Impact pressure in inches of water: 1 megadyne/sq. cm.=401.8 in. of water.[1]		Percentage difference.
	Incompressible. $p=1+\frac{\rho_o V^2}{2}$	Adiabatic $p=(1+.000001747\ V^2)^{3.5}$	Incompressible.	Adiabatic.	Incompressible.	Adiabatic.	
0	1. 000000	1. 000000	0. 0000	0. 0000	0. 0000	0. 0000	0. 00
10	1. 000122	1. 000122	0. 2547	0. 2547	0. 0490	0. 0490	0. 00
20	1. 000488	1. 000488	1. 0189	1. 0189	0. 1965	0. 1965	0. 00
30	1. 001099	1. 001099	2. 2947	2. 2947	0. 4416	0. 4416	0. 00
40	1. 001954	1. 001954	4. 0800	4. 0800	0. 7851	0. 7851	0. 00
50	1. 003052	1. 003054	6. 3726	6. 3768	1. 2263	1. 2271	0. 07
60	1. 004396	1. 004400	9. 1788	9. 1872	1. 7662	1. 7683	0. 12
70	1. 005983	1. 005994	12. 4925	12. 5155	2. 4040	2. 4084	0. 18
80	1. 007814	1. 007833	16. 3156	16. 3553	3. 1397	3. 1473	0. 24
90	1. 009890	1. 009921	20. 6503	20. 7150	3. 9738	3. 9863	0. 31
100	1. 012210	1. 012259	25. 4945	25. 5968	4. 9060	4. 9257	0. 40
110	1. 014774	1. 014847	30. 8481	31. 0005	5. 9362	5. 9655	0. 49
120	1. 017582	1. 017687	36. 7112	36. 9305	7. 0645	7. 1066	0. 59
130	1. 020635	1. 020780	43. 0859	43. 3886	8. 2911	8. 3494	0. 70
140	1. 023932	1. 024130	49. 9700	50. 3834	9. 6159	9. 6954	0. 82
150	1. 027472	1. 027733	57. 3615	57. 9065	11. 0383	11. 1443	0. 95
160	1. 031259	1. 031594	65. 2669	65. 9683	12. 9126	13. 0589	1. 06
170	1. 035311	1. 035755	73. 7292	74. 6564	14. 1879	14. 3664	1. 26
180	1. 039587	1. 040147	82. 6585	83. 8269	15. 9062	16. 1311	1. 45
190	1. 044108	1. 044804	92. 0977	93. 5508	17. 7226	18. 0022	1. 58
200	1. 048873	1. 049728	102. 0475	103. 8321	19. 6373	19. 9807	1. 75

[1] See Report No. 20, United States National Advisory Committee for Aeronautics, Third Annual Report, p. 400.

$$p=p_o\left(1+\frac{(\gamma-1)\rho_o V^2}{2\gamma p_o}\right)^{\gamma/\gamma-1}$$

$$=(1+0.000001747\ V^2)^{3.5}$$

p_o=1 megadyne/sq. cm.

ρ_o=0.001223 gm./cu. cm.

γ=1. 40.

V=meters per sec.

NOTE.—Using γ=1.405 would lower values in columns 5 and 7 less than).02 per cent for speeds below 200 miles an hour.

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