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Free-Flight Tests on Kites in the 24-ft Wind Tunnel

By

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COMMUNICATED BY THE PRINCIPAL DIRECTOR OF SCIENTIFIC RESEARCH (AIR)
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Summary.—Reasons for Enquiry.—Tests were required to be made on six kites over a greater range of wind speed than for previous large-tunnel tests.

Range of Investigation.—The kites used during the investigation were (A) 3-ft Cody kite Mk. II, (B) 3-ft reversed Cody or Dyco kite, (C)3-ft Haldon kite, (D) 2 × 3-ft Cody storm kite with lateral cross-bracing, (E) 2-ft Cody kite Mk. III with bifurcated inner bridle and (F) 2-ft Cody kite Mk. III with longitudinal bracing.

Tests were made over the whole stable range of the kites and up to the highest safe wind speed. The kites were flown from a pylon and values of lift, drag and incidence of the forward and rear bridles were measured. Attempts were also made on two of the 3-ft kites (A and C) to improve their stability at higher wind speeds and low incidences.

Conclusions.—The maximum value of $(L-W)/D$ was below 2·5 and values of C_L, based on the fabric surface area, excluding the vertical panels, were not greater than 0·9.

The unmodified kites are unsuitable for high wind speeds. At low incidences, the kites tend to fall away from their flying position at speeds above 70 ft/sec, but this can be temporarily delayed by diagonal cross-bracing to lift the centre of the leading edges of the front lifting panels, and by tying the wing tips together. At high incidences, bending of the bamboos may disrupt the kite and it is recommended that a bifurcated bridle, which picks up at four points on each lower longitudinal, be used to prevent this bending. The parallel-rigged wing canes tend to take up a negative incidence as the lower longitudinals bend under load, and thus cause bending of the transverse bamboos. This can be avoided by using cross-rigging, the wing canes then taking up a slight positive incidence. The flapping of the vertical panels, which limits the usefulness of the kites at higher speeds, can be moderated by stiffening canes sewn in the fabric in a fore and aft direction.

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1. *Introduction.*—At the request of Research Department, Exeter, tests were made on a number of Cody-type kites to obtain data over a range of incidence and at higher speeds than those obtained in previous large wind-tunnel tests. The method of testing in the 24-ft wind-tunnel has also been improved so that the kites experience more nearly the actual flight conditions.

2 *Description of Kites.*—The following kites were used during the tests:—

(A) *3-ft Cody kite Mk. II* (*Figs.* 1, 2).—This is a double-cell box kite with protruding diagonal bamboos supporting wings. Those from the upper surface of the front box are longer than the others.

(B) *3-ft Dyco or reversed Cody kite.*—This differs from the Cody kite in that the lengthened wings are carried from the upper surface of the rear box instead of the front box.

(C) *3-ft Haldon kite.*—This differs from the Cody kite in having the lengthened wings cut back to the same size as the other wings.

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* R.A.E. Report Aero. 1737.

(D) 2 × *3-ft Cody storm kite with lateral cross-bracing as shown in Fig.* 3.—This kite is scaled down from the 3-ft Cody kite, horizontally but not vertically, and, in addition, has a horizontal spar lashed to the two lower longitudinals at the leading edge of the bottom panel of the rear box.

(E) *2-ft Cody kite Mk. III with bifurcated inner bridle* (*see Fig.* 4).—This kite is scaled down from the 3-ft Cody kite, although the distance between the front and rear boxes is larger than it would be for a true two-third scale model. The bifurcated inner bridle is designed to prevent distortion of the bamboos.

(F) *2-ft Cody kite Mk. III with longitudinal bracing* (*see Fig.* 3).—The longitudinal cross-bracing is also intended to prevent distortion of the bamboos and obviate shearing between the upper and lower longitudinals.

3. *Experimental Procedure.*—The normal kite has 4 attachment points from which two forward and two rear bridles depend. In flight, each forward and rear bridle on each side is attached to an intermediate bridle and the two intermediate bridles are in turn attached to the flying line. The inclination of the bridle introduces transverse stresses into the kite structure with consequent deformation. In previous wind-tunnel tests the suspension has been by parallel wires which did not introduce any transverse strain. The present tests were designed to reproduce as exactly as possible the flight conditions. For this purpose the junctions of the bridle with the intermediates were attached to a tube transverse to the wind direction and mounted on a pylon (*see* Figs. 1, 2). The two attachment points were spaced to agree with flight conditions. Thus, as long as the kite remained steady, the forces on the kite should be as in flight but if the kite yawed then the flight conditions were upset. With this arrangement the kite took up a flying incidence depending on the length of the forward and rear bridles. These lengths were varied during the test over the stable range of the kites*.

Measurements of incidences were taken with a 'Robot' camera using 35 mm. film, from which, on projection, bridle angles and the kite incidence could be obtained, the datum line for the latter being taken as the line joining the intersection of the bridles with the lower boom. Measurements of angles of incidence may not be more accurate than $\pm$ 1/2 deg. From the measurements of bridle angles, the mean tensions in the bridles have been calculated. In these calculations the fact that the bridles are not in vertical planes, but converge below the kite, has been neglected. The maximum error due to this cause is about 4 per cent. and the error arising from the measurement of the bridle angles is about $\pm$ 5 per cent.

4. *Results.*—Numerical results are given in Tables 1 to 7 whilst Figs. 6, 7 show curves of $(L - W)/D$ against C_L for various wind speeds and bridle lengths, W being the weight of the kite. The maximum value of $(L - W)/D$ obtained was below 2·5 and values of C_L, based on the fabric surface area excluding the vertical panels, were not greater than 0·9.

5. *Discussion of Results.*—5.1. *Distortion Due to Wind.*—General observations on the series of kites showed that on increasing the wind speed for constant bridle lengths, the kite incidence tends to decrease whilst the value of $(L - W)/D$† (tangent of the angle of the flying line) increases. The longer the rear bridles, the greater the decrease in C_L and the smaller the increase in $(L - W)/D$. If, however, the incidence is decreased to angles between 5 to 10 deg., there is a tendency for the shape of the front box to change radically, resulting in a decrease of lift on the front box so that the kite trims at a smaller incidence, further decreasing the front-box lift. At speeds above 70 ft/sec, with the longer rear bridles the kites may become unstable and swoop

* In order to safeguard the wind-tunnel fan on possible destruction of the kite at the higher wind speeds, a wire net 18 ft square, of 14 s.w.g., 1¾-in. mesh was prepared and suspended behind the pylon. Lengths of 5 cwt steel cable were lashed to the four longitudinals of each of the 3-ft kites, as an additional safety device in case of disruption of the bamboos.

† The ratio $(L-W)/D$ is an important factor in kite design and in this report it will be referred to as the lifting efficiency of the kite.

out of the jet. Using short rear bridles, the kites do not reach this low-incidence region (at moderate wind speeds) but distortion of the bamboos occurs at speeds about 100 ft/sec; at higher speeds the kites were considered unsafe. A cinematograph record was taken both of the unstable condition of the kites at low incidences and of the distortions of the bamboos at high ones.

5.2. *Effect of Bifurcated Bridle* (*Kite E, Fig.* 3, *Table* 5).—Much of the bending was eliminated by the use of a bifurcated inner bridle on one of the 2-ft kites (kite E). This kite, as well as the 2-ft kite with normal rigging (kite F) and the 2 × 3-ft storm kite (kite D), was considered to be quite safe, except at low incidences, at 120 ft/sec. Table 5 gives results obtained with the bifurcated bridle and shows that there was a smaller incidence change with wind speed than with normal bridles of similar lengths and that C_L remains almost constant. It would therefore appear that much of the change of incidence with wind speed obtained with normal rigging is due to distortion of the bamboos.

5.3. *Effect of Stiffening Canes for Fabric* (*Kite D, Fig.* 3, *Table* 4).—The 2 × 3-ft Cody kite (kite D) was also subject to less bending than the 3-ft kites and the 2-ft kite Mk. III with normal rigging, and its general behaviour was similar to the 2-ft. Mk. III with bifurcated bridle, but had a lower lifting efficiency (*see* Tables 4, 5, Fig. 7). The side canes in the fabric of the rear box prevented much of the flapping associated with the vertical panels. Additional tests with the 2 × 3-ft kite were carried out with the wire-bracing shown in Fig. 3, which prevented a tendency for the upper ends of the forward cross spars to bend and close the front box. This wire-bracing also slightly increased the lifting efficiency of the kite (directly proportional to the tangent of the flying line) at higher wind speeds (Fig. 7).

5.4. *Use of Longitudinal Cross-bracing* (*Kite F, Fig.* 4. *Table* 6).—The longitudinal cross-bracing on the 2-ft Cody kite Mark III (kite F) served little to reduce the bending of the longitudinals but prevented shear between the upper and lower booms. (It had previously been noted that kite D had considerable shearing of the upper longitudinals with respect to the lower ones.) At the same value of C_L, kite F also had a lower lifting efficiency than kite E with bifurcated inner bridle (*see* Fig. 7).

6. *Further Modifications to 3-ft Kites.*—Some further tests (Tables 7a, b, c, Fig. 8) were done with the 3-ft Haldon and Cody Mk. II (kites C and A respectively) with the object of improving the stability of the kites at low incidence without adversely affecting their lifting efficiency. The most promising results were obtained with a diagonal cord (AGA′ in Fig. 5) lashed to the centre cane of the lower panel of the front box, at its leading edge. This was done in order to prevent collapsing of this panel, it having previously been found that before the kites lose height, the shape of the lifting panels of the front box changes, the points F and G (Fig. 5) moving downwards. This alteration in the shape of the lifting surface is usually found in the rear box before any change occurs in the front one but appears not to cause any loss of stability, the kite remaining quite steady after the leading edges (L and M) of the centre canes have moved below KK′ and PP′ respectively. It was found advisable, however, to lash a thin vertical spar FG, in the front box, to prevent the top lifting panel collapsing, even when the lower panel is stayed by the cord AGA′.

In the case of the Haldon kite (kite C, Table 7a, Fig. 8) improvement made in the lifting efficiency of the kite was only very slight, but the kite could be made fairly steady at 80 ft/sec although above this, it had little margin of stability. Experiments to increase the back-box lift with respect to the front-box lift indicated that this instability is associated with a rapid backwards movement of the centre of pressure of the kite on increasing wind speed at low incidence.

Using a 3-ft Cody kite (Kite A) with 4-ft front and 8-ft rear bridles, the rear bridle was just slack (the kite flying only on the front rigging loops), and at speeds above 70 ft/sec the kite was unstable, swooping to the side of the jet. A fair improvement in stability was obtained by using a wire or cord AGA′ (Fig. 5) and a spar FG, with little change in the lifting efficiency of the kite (Fig. 8, Table 7). It was found here that the wings tend to take up a negative incidence at high wind speeds and thus close the front box. This will occur with parallel rigging of the wing canes ED and E′D′ and for high bending moments in the booms, but it is not likely to occur with cross-rigged wing canes. To prevent collapsing of the front box, the wing tips CC′ were joined by cord (ciné film records were taken of this at 100 ft/sec.).

7. *Effect of Tilting the Wing Canes.*—Some further tests were carried out with the 3-ft Cody kite Mk. II (Kite A) using front bridles of 4 ft with rear bridles of 7 ft 6 in. The kite is more stable than with 8-ft rear bridles, but still has a tendency to swoop out of the jet, provided the wind speed is raised sufficiently (approximately 90 ft/sec.). The wing canes were here given a slight, (approximately 5 deg.), and later a marked, (approximately 20 deg.), positive incidence with respect to the lower booms to prevent bending of the wings due to their having a negative incidence above 80 ft/sec and taking a down-load which caused both bending of the transverse bamboos and closing of the front box. A marked increase in lift above normal rigging was thus obtained (Table 7c, Fig. 8) at the cost of a correspondingly higher drag at 80 ft/sec and the kite shuddered violently in flight.

8. *Effect of cutting Away Part of the Lifting Surfaces.*—Wool tufts placed on the lifting panels of the front box of this kite indicated that the upper panel was stalled. It was later decided to remove this panel, but the kite flew at a much lower incidence and swooped out of the jet below 50 ft/sec. The upper lifting panel of the rear box was then removed and the kite had a greater incidence and was able to be flown at 60 ft/sec. The lifting efficiencies of the kite under these conditions were low (Table 7c, Fig. 8) but in flight, it was extremely steady owing to the high ratio of non-lifting to lifting surfaces.

Conclusions.—The unmodified 3-ft kites can be flown at wind speeds up to 100 ft/sec, but are unsuitable for higher speeds if set at high or low incidences. At low incidences, the fall of incidence with wind speed, which is due, partly to the increase of the aerodynamic forces compared with its weight, and partly to distortion of the kite, results in a reduction of lift on the panels of the front box, which consequently changes their shape, and the kite becomes unstable. At high incidences, the large forces involved at high speeds bend the longitudinal and transverse bamboos and may break them. Flapping of the vertical panels also limits the usefulness of some of the kites at high speeds.

The bending of the bamboos can be prevented by using bifurcated bridles, which pick up at four points on each of the lower longitudinals. To some extent, the distortion of the kites under high loads can also be prevented by longitudinal bracing between the upper and lower bamboos on each side, but this does not prevent the ordinary bending of the bamboos.

The sharp reduction of lift on the front box at low incidence can be delayed by diagonal cross-bracing to lift the centre of the leading edges of the lifting panels, and by tying the wing tips together (cords joining AGA′ and CC′ and strut from F to G in Fig. 5). Bending of the transverse bamboos can be reduced by using cross rigged wing canes (cords joining HD, H′D′, EB, E′B′ in Fig. 5). The present arrangement of parallel rigging (as shown in Fig. 5) tends to close the front box as the lower longitudinals bend under load. The flapping of the vertical panels can be moderated by stiffening canes sewn in the fabric in a fore and aft direction.

TABLE 1

3-ft Mk. II Cody Kite

Front bridle	Rear bridle	Wind speed (ft/sec)	Lift (lb)	Drag (lb)	$\frac{L-W}{D}$	Nominal incidence (deg.)	Total tensions (lb)		C_L	C_D
							Front bridle	Rear bridle		
3 ft 3½ in.	4 ft	30	88	56·3	1·16	30·4	67	78	0·78	0·50
		40	149	79·1	1·59	25·0	120	126	0·74	0·39
3 ft 3½ in.	4 ft 6 in.	50	219	96·1	2·04	21·6	169	152	0·70	0·31
		60	306	130·3	2·17	19·7	238	219	0·68	0·29
		80	507	213·1	2·27	19·0	406	345	0·63	0·26
3 ft 3½ in.	5 ft 6 in.	30	80	34·1	1·67	20·0	48	37	0·71	0·30
		40	123	45·7	2·19	17·6	83	57	0·61	0·23
		50	177	63·0	2·44	15·0	127	83	0·57	0·20
		60	239	88·6	2·44	14·0	172	124	0·53	0·20
		80	405	163·4	2·34	14·0	308	217	0·50	0·20
3 ft 3½ in.	7 ft	30	62	21·5	1·82	14·0	36	13	0·55	0·19
		40	88	29·4	2·21	10·3	60	18	0·44	0·15
		50	119	41·2	2·33	8·2	89	25	0·38	0·13
		60	156	59·3	2·24	8·0	121	39	0·35	0·13
		80	224	105·9	1·90	6·6	166	95	0·28	0·13
* 3 ft 9 in.	5 ft 3 in.	100	713	279·5	2·47	23·1	583	263	0·57	0·22
4 ft	5 ft	30	91	50·0	1·36	28·0	52	62	0·81	0·44
		40	152	75·0	1·72	25·7	98	102	0·76	0·37
		50	229	102·1	2·02	21·3	151	153	0·73	0·33
		60	322	141·5	2·11	21·0	227	201	0·71	0·31
		80	538	243·3	2·12	20·4	375	364	0·67	0·30
4 ft	6 ft 6 in	30	76	29·7	1·78	18·5	44	27	0·67	0·26
		40	113	39·7	2·27	15·0	75	37	0·56	0·20
		50	159	56·0	2·43	13·8	114	51	0·51	0·18
		60	216	79·6	2·43	15·8	159	79	0·48	0·18
		80	366	148·2	2·31	18·5	287	141	0·46	0·18
4 ft	8 ft	30	56	19·1	1·73	12·2	36	4	0·50	0·17
		40	75	24·9	2·09	8·0	54	5	0·37	0·12
		50	98	36·8	2·04	7·9	77	10	0·31	0·12
		60	118	51·9	1·83	7·5	90	24	0·26	0·12
*4 ft 3 in.	6 ft 3 in	100	677	307·2	2·13	19·1	549	280	0·54	0·24
5 ft	6 ft	30	93	55·1	1·27	29·7	47	59	0·82	0·49
		40	154	74·0	1·77	24·5	91	90	0·76	0·37
		50	233	106·4	1·97	22·0	151	124	0·74	0·34
		60	322	145·3	2·06	21·5	212	176	0·71	0·32
		80	531	248·1	2·05	23·0	380	276	0·66	0·31
5 ft	7 ft 6 in	30	76	29·4	1·80	17·0	39	26	0·67	0·26
		40	107	38·4	2·19	13·0	67	35	0·53	0·19
		50	152	56·8	2·27	13·5	109	45	0·48	0·18
		60	209	79·8	2·33	13·6	162	58	0·46	0·18
		80	356	150·5	2·21	14·6	278	129	0·44	0·19
5 ft	9 ft	30	54	18·6	1·67	11·2	34	3	0·48	0·16
		40	74	26·2	1·95	9·2	57	1	0·37	0·13
		50	97	38·3	1·93	8·5	79	7	0·31	0·12
		60	120	54·3	1·79	8·0	102	12	0·27	0·12
*5 ft 3 in	6 ft 9 in	100	733	351·1	2·02	22·0	568	319	0·58	0·28
*5 ft 3 in	7 ft 9 in	100	455	207·8	2·08	14·0	355	168	0·36	0·17

$C_L = L/\frac{1}{2}\,\rho\,V^2S$ $\qquad C_D = D/\frac{1}{2}\,\rho\,V^2S$

$S = 105{\cdot}5$ sq. ft $\qquad W = 23$ lb

* In view of the higher tension involved, 20-cwt bridles were used here, the lengths being chosen 3 in. too large in error.

TABLE 2

3-ft. reversed Cody or Dyco Kite

Front bridle	Rear bridle	Wind speed (ft/sec)	Lift (lb)	Drag (lb)	$\frac{L-W}{D}$	Nominal incidence (deg)	Total tensions (lb) Front bridles	Total tensions (lb) Rear bridles	C_L	C_D
3 ft 6 in.	5 ft	30	64	24·4	1·56	13·0	29	36	0·57	0·22
		40	95	33·4	2·07	10·0	53	59	0·47	0·17
		50	133	49·1	2·18	11·0	83	90	0·42	0·16
		60	187	73·2	2·20	11·0	104	133	0·41	0·16
		80	321	143·4	2·06	11·0	206	246	0·40	0·18
3 ft 6 in.	6 ft 6 in.	30	51	18·1	1·38	9·3	19	19	0·45	0·16
		40	67	24·7	1·66	7·5	32	27	0·33	0·12
		50	89	35·8	1·76	6·0	49	41	0·28	0·11
		60	117	51·6	1·76	7·0	69	61	0·26	0·11
		80	176	99·0	1·52	7·8	108	110	0·22	0·12
3 ft 6 in.	8 ft	30	41	14·4	1·04	8·6	16	6	0·36	0·13
		40	46	20·0	1·00	6·3	20	11	0·23	0·10
		50	56	29·7	1·01	4·8	29	17	0·18	0·10
		60	64	43·8	0·87	3·6	32	31	0·14	0·10
		80	72	81·5	0·56	3·8	31	69	0·09	0·10
3 ft 9 in.	4 ft 9 in.	40	110	45·6	1·84	15·7	63	76	0·55	0·23
		60	219	101·4	1·90	16·0	142	168	0·48	0·22
		80	378	192·2	1·83	15·8	256	308	0·47	0·24
		100	570	311·0	1·75	16·4	376	477	0·46	0·25
3 ft 9 in.	5 ft 3 in.	80	337	165·5	1·88	14·0	220	248	0·42	0·21
		100	522	217·4	2·28	14·1	370	344	0·42	0·17
4 ft.	6 ft.	30	59	22·0	1·50	14·9	22	25	0·52	0·20
		40	86	30·5	1·97	12·3	43	36	0·43	0·15
		50	120	45·5	2·07	11·0	70	52	0·38	0·14
		60	164	66·6	2·07	12·6	102	78	0·36	0·15
		80	292	134·8	1·97	12·5	187	156	0·36	0·17
4 ft	7 ft 6 in.	30	48	17·8	1·24	5·6	15	16	0·42	0·16
		40	59	23·8	1·39	6·0	26	20	0·29	0·12
		50	79	34·8	1·52	8·0	43	28	0·25	0·11
		60	101	50·1	1·50	8·8	59	42	0·22	0·11
		74	129	75·6	1·37	5·6	76	65	0·19	0·11
4 ft	9 ft	30	39	14·1	0·92	8·8	16	3	0·35	0·12
		40	44	20·7	0·87	5·3	21	8	0·22	0·10
		50	53	30·4	0·89	5·0	33	10	0·17	0·10
		60	61	43·8	0·80	3·7	40	19	0·14	0·10
		80	55	81·5	0·36	4·0	15	74	0·07	0·10
4 ft 9 in.	6 ft 3 in.	100	533	283·2	1·79	16·5	338	341	0·42	0·23
5 ft 6 in.	6 ft 6 in.	30	72	29·7	1·55	16·8	25	38	0·64	0·26
		40	110	42·1	2·00	13·7	48	60	0·55	0·21
		50	155	59·6	2·16	14·8	80	84	0·50	0·19
		60	217	92·9	2·06	16·4	121	124	0·48	0·21
		80	382	85·7	1·92	17·9	221	238	0·48	0·23
		100	595	325·5	1·75	20·0	366	372	0·48	0·26
5 ft 6 in.	7 ft 6 in.	30	60	22·4	1·52	13·6	21	24	0·53	0·20
		40	86	31·4	1·91	11·0	40	36	0·43	0·16
		50	120	45·1	2·08	10·9	64	51	0·38	0·14
		60	163	67·4	2·03	10·3	94	76	0·36	0·15
		80	295	38·6	1·94	10·5	179	156	0·37	0·17
5 ft 6 in.	9 ft	30	47	16·5	1·27	10·0	18	11	0·42	0·15
		40	58	23·2	1·38	8·0	27	15	0·29	0·12
		50	76	33·5	1·49	6·9	40	24	0·24	0·11
		60	99	49·9	1·46	6·2	57	37	0·22	0·11
		74	120	71·9	1·31	4·0	65	63	0·18	0·10

$S = 105{\cdot}5$ sq. ft, $W = 26$ lb.

* See end of Table 1

TABLE 3

3-ft Cody Kite, Haldon Modification

Front bridle	Rear bridle	Wind speed (ft/sec)	Lift (lb)	Drag (lb)	$\frac{L-W}{D}$	Nominal incidence (deg)	Total tensions (lb)		C_L	C_D
							Front bridles	Rear bridles		
3 ft	4 ft	30	67	37·0	1·24	28·0	56	63	0·70	0·39
		40	111	55·2	1·63	23·5	103	108	0·65	0·32
		50	158	73·0	1·88	22·0	153	158	0·60	0·28
		60	215	98·6	1·97	21·5	217	216	0·56	0·26
3 ft	5 ft	80	318	143·2	2·07	19·5	268	215	0·47	0·21
		100	418	197·6	2·01	20·8	360	294	0·39	0·19
3 ft	5 ft 6 in.	30	57	27·2	1·32	18·9	30	31	0·60	0·28
		40	89	37·7	1·80	15·5	55	48	0·52	0·22
		50	123	50·6	2·02	14·4	82	69	0·46	0·19
		60	165	70·4	2·04	14·4	116	96	0·43	0·18
3 ft	6 ft 6 in.	71·6	146	74·4	1·68	11·7	110	73	0·27	0·14
3 ft	7 ft	30	48	20·1	1·34	13·8	26	12	0·50	0·21
		40	66	27·4	1·64	10·0	42	16	0·39	0·16
		50	93	39·1	1·84	9·0	68	22	0·35	0·15
		60	112	52·7	1·76	8·0	84	33	0·29	0·14
4 ft	4 ft 6 in.	40	117	62·8	1·53	24·5	74	88	0·69	0·37
4 ft	5 ft	30	70	38·5	1·27	25·5	37	46	0·73	0·40
		40	109	54·0	1·63	21·5	64	73	0·64	0·32
		50	158	73·1	1·88	20·0	101	107	0·60	0·28
		60	217	99·0	1·98	19·5	146	148	0·57	0·26
4 ft	5 ft 6 in.	100	500	236·1	2·03	22·0	390	289	0·47	0·22
4 ft	6 ft	80	303	137·0	2·06	17·0	223	157	0·44	0·20
		100	381	173·4	2·08	16·5	283	205	0·36	0·16
4 ft	6 ft 6 in.	30	57	26·7	1·35	18·5	28	25	0·60	0·28
		40	85	34·0	1·88	14·5	51	34	0·50	0·20
		50	117	47·3	2·03	13·5	77	49	0·44	0·18
		60	157	66·6	2·04	14·3	110	68	0·41	0·18
4 ft	7 ft 6 in.	40	66	25·6	1·76	11·5	44	12	0·39	0·15
		60	114	50·5	1·84	9·6	87	27	0·30	0·13
		73·8	153	70·9	1·86	10·5	122	41	0·26	0·12
4 ft	8 ft	30	45	18·2	1·32	13·5	25	6	0·47	0·19
		40	60	23·5	1·66	9·5	40	7	0·35	0·14
		50	82	33·7	1·81	9·0	63	8	0·31	0·13
		60	104	48·5	1·71	9·0	85	14	0·27	0·13
5 ft	6 ft	30	70	40·5	1·21	26·5	32	43	0·73	0·42
		40	109	53·4	1·65	21·7	58	64	0·64	0·31
		50	157	71·6	1·90	20·0	90	92	0·59	0·27
		60	214	96·0	2·01	19·0	130	128	0·56	0·25
5 ft	7 ft	80	288	128·8	2·07	15·5	203	131	0·42	0·19
		100	386	164·8	2·22	14·0	277	178	0·36	0·16
5 ft	7 ft 6 in.	30	57	26·6	1·35	19·5	29	21	0·60	0·28
		40	81	32·9	1·82	14·0	48	28	0·48	0·19
		50	112	44·2	2·06	12·7	73	39	0·42	0·17
		60	149	63·4	2·02	12·7	102	57	0·39	0·17
5 ft	8 ft	80	187	87·6	1·90	7·5	134	71	0·28	0·13
5 ft	8 ft 6 in.	71·6	130	63·3	1·72	11·0	104	28	0·24	0·12
*5 ft 3 in.	6 ft 9 in.	80	322	147·3	2·04	16·5	218	161	0·47	0·22
		100	487	226·2	2·06	17·5	338	248	0·46	0·21
*5 ft 3 in.	7 ft 3 in.	80	280	123·1	2·10	15·0	199	118	0·41	0·18

$S = 89{\cdot}2$ sq. ft, $W = 21$ lb

* See end of Table 1

TABLE 4

2 × 3-ft Storm Kite with Lateral Cross Bracing

Front bridle	Rear bridle	Wind speed (ft/sec)	Lift (lb)	Drag (lb)	$\frac{L-W}{D}$	Nominal incidence (deg)	Total tensions (lb)		C_L	C_D
							Front bridles	Rear bridles		
2 ft 5½ in.	3 ft 10½ in.	40	58	32·1	1·31	22·0	33	31	0·67	0·37
		50	87	42·5	1·67	17·8	56	43	0·64	0·31
		60	115	56·5	1·75	16·5	75	66	0·59	0·29
		80	197	94·3	1·92	15·0	133	109	0·57	0·27
		100	307	146·3	1·99	14·6	214	168	0·57	0·27
2 ft 5½ in.	3 ft 11 in.	120	444	224·9	1·90	13·5	316	224	0·57	0·29
2 ft 5½ in.	4 ft 11 in.	30	31	17·1	0·88	20·7	14	11	0·64	0·35
		40	44	22·0	1·27	14·0	24	15	0·51	0·25
		50	59	29·1	1·48	10·6	37	20	0·44	0·22
		60	77	40·7	1·50	9·7	52	28	0·40	0·21
		80	124	65·3	1·65	8·0	90	47	9·36	0·19
		100	187	104·0	1·64	8·6	149	68	0·34	0·19
2 ft 5½ in.	5 ft	120	236	156·8	1·40	6·2	179	115	0·30	0·20
2 ft 5½ in.	5 ft 4¼ in.	30	30	14·9	0·94	19·0	17	5	0·62	0·32
		40	39	19·7	1·17	11·3	25	7	0·45	0·23
		50	50	26·0	1·31	8·6	36	8	0·37	0·19
		60	63	35·0	1·34	7·2	49	12	0·32	0·18
		80	98	59·7	1·37	6·0	80	27	0·28	0·17
		100	142	96·2	1·31	5·0	117	51	0·26	0·18
		120	170	153·1	1·00	4·9	124	107	0·22	0·20
*2 ft 5½ in.	*5 ft 4¼ in.	30	31	16·6	0·90	18·9	18	6	0·64	0·34
		40	42	21·0	1·24	10·0	28	7	0·48	0·24
		50	54	27·8	1·37	8·3	39	10	0·40	0·20
		60	70	36·8	1·47	7·6	57	11	0·36	0·19
		80	109	62·9	1·48	5·0	94	24	0·31	0·18
		100	159	104·0	1·38	5·0	148	35	0·29	0·19
		120	219	173·9	1·17	6·4	196	84	0·28	0·22
*2 ft 6¾ in.	3 ft 11 in.	100	337	172·9	1·86	14·9	214	195	0·62	0·32
		120	492	263·6	1·81	15·0	348	294	0·63	0·34

$S = 45{\cdot}6$ sq. ft, and $W = 16$ lb

* Wing bracing wires in front box joined, horizontal upper pair only.

TABLE 5

2-ft Mk. III Cody Kite with Bifurcated Bridles

Inner bridles: Forward 1	Inner bridles: Forward 2	Inner bridles: Rear 1	Inner bridles: Rear 2	Inter. Bridles: Forward	Inter. Bridles: Rear	Wind speed (ft/sec)	Lift (lb)	Drag (lb)	$\frac{L-W}{D}$	Nominal incidence (deg.)	Total tensions (lb) Inter. bridles: Forward	Total tensions (lb) Inter. bridles: Rear	C_L	C_D
1 ft 11 in.	2 ft 0 in.	1 ft 2 in.	2 ft 0 in.	2 ft 2½ in.	5 ft 10¾ in.	40	61	32·4	1·33	23·5	39	34	0·70	0·37
						50	93	39·9	1·88	17·6	66	48	0·69	0·30
						60	121	49·3	2·09	15·5	83	69	0·62	0·25
						80	140	58·3	2·09	6·3	98	94	0·40	0·17
1 ft 11 in.	1 ft 6½ in.	7½ in.	2 ft 0 in.	2 ft 2½ in.	5 ft 10¼ in.	40	62	34·9	1·26	23·3	43	23	0·71	0·40
						50	96	45·9	1·70	20·9	72	36	0·71	0·34
						60	134	61·9	1·88	18·0	104	58	0·69	0·32
						80	240	110·1	2·02	16·3	195	112	0·69	0·32
						100	384	179·2	2·04	16·9	324	182	0·71	0·33
						120	563	274·9	1·98	15·7	474	285	0·72	0·35

$S = 45{\cdot}6$ sq. ft, $W = 18$ ft

TABLE 6

2-ft Mk. III Longitudinally Braced Cody Kite

Front bridle	Rear bridle	Wind speed (ft/sec)	Lift (lb)	Drag (lb)	$\frac{L-W}{D}$	Nominal incidence (deg.)	Total tensions (lb) Front bridle	Total tensions (lb) Rear bridle	C_L	C_D
3 ft	5 ft	40	65	43·3	1·13	27·1	62	72	0·75	0·50
		50	100	59·7	1·41	24·5	100	106	0·74	0·44
		60	138	75·3	1·62	20·9	140	149	0·71	0·39
		80	217	103·8	1·94	14·5	217	235	0·62	0·30
3 ft	6 ft	30	37	25·5	0·82	29·2	23	28	0·76	0·52
		40	60	32·5	1·35	21·7	42	42	0·69	0·37
		50	91	43·1	1·74	16·8	69	63	0·67	0·32
		60	119	56·4	1·82	15·7	93	82	0·61	0·29
		80	186	85·6	1·99	12·2	149	120	0·54	0·25
3 ft	6 ft 6 in.	100*	272	113·1	2·26	14·0	227	123	0·50	0·21
		120*	359	156·0	2·20	12·7	290	190	0·46	0·20
3 ft	8 ft	30	31	16·9	0·89	18·0	16	10	0·64	0·35
		40	45	22·0	1·32	12·8	29	12	0·52	0·25
		50	60	28·3	1·56	10·0	42	16	0·44	0·21
		60	77	38·2	1·60	8·7	56	26	0·40	0·20
		80	112	66·3	1·45	9·7	90	43	0·32	0·19
4 ft	6 ft	40	65	44·1	1·11	27·9	43	48	0·75	0·51
		50	100	58·7	1·43	23·7	70	70	0·74	0·43
		60	139	75·5	1·63	20·3	100	98	0·71	0·39
		80	229	111·3	1·92	16·5	165	163	0·66	0·32
		80*	251	144·6	1·62	21·6	195	180	0·72	0·42
		100*	383	203·3	1·80	19·5	306	270	0·71	0·38
4 ft	7 ft	120*	403	172·3	2·25	12·1	321	193	0·52	0·22
4 ft	7 ft 6 in.	30	37	23·4	0·90	25·0	19	19	0·76	0·48
		40	55	28·4	1·37	17·8	33	25	0·63	0·33
		50	80	37·0	1·73	14·7	54	34	0·59	0·27
		60	103	48·3	1·80	13·4	70	48	0·53	0·25
		80	160	76·9	1·87	13·0	116	78	0·46	0·22
		100	240	120·2	1·86	13·0	183	113	0·44	0·22
4 ft	9 ft	30	27	16·4	0·67	17·0	11	10	0·55	0·34
		40	42	20·4	1·28	12·9	28	7	0·48	0·23
		50	56	27·7	1·44	11·0	44	6	0·41	0·20
		60	75	38·1	1·55	9·9	61	13	0·38	0·20
		80	118	65·3	1·56	10·0	110	16	0·34	0·19
		100	161	101·0	1·44	11·5	149	38	0·30	0·19
5 ft	8 ft 6 in.	30	36	23·2	0·86	24·3	18	17	0·74	0·48
		40	55	27·6	1·41	15·2	33	21	0·63	0·32
		50	78	36·2	1·71	12·5	51	29	0·58	0·27
		60	99	47·2	1·76	12·4	69	37	0·51	0·24
		80	156	75·8	1·85	12·0	117	59	0·45	0·22
5 ft	7 ft	40	68	45·6	1·14	27·6	40	45	0·78	0·52
		50	101	60·0	1·42	25·5	65	61	0·75	0·44
		60	139	76·8	1·60	20·5	88	89	0·71	0·39
		80	216	116·4	1·72	18·5	135	140	0·62	0·34
		100	320	150·2	2·02	14·5	203	203	0·59	0·28
5 ft	7 ft 6 in.	120*	434	185·9	2·25	14·8	324	199	0·56	0·24
5 ft	8 ft 6 in.	100	231	119·2	1·80	12·5	180	92	0·43	0·22
5 ft	10 ft	30	31	15·8	0·95	15·1	18	5	0·64	0·32
		40	42	19·9	1·31	11·3	29	5	0·48	0·23
		50	56	27·2	1·47	9·0	44	6	0·41	0·20
		60	74	37·8	1·54	9·5	64	7	0·38	0·19
		80	95	65·8	1·20	10·3	81	27	0·27	0·19
		100	153	100·2	1·37	10·0	146	30	0·28	0·18

$S = 45{\cdot}6$ sq. ft, $W = 16$ lb

* Owing to flabbiness of the vertical side panels of the 2-ft. Mk. III Cody kite oiiginally used, these tests were carried out with the remaining 2-ft kite (Table 5) with the bifurcated bridle removed and the lateral bracing replaced.

TABLE 7 (a)

3-ft Haldon Kite with 4-ft Front, 7 ft 6 in. Rear Bridles (Kite C)

Kite rigging (*see* Fig. 5)	Wind speed ft/sec	Lift lb	Drag lb	$\frac{L-W}{D}$	Nominal incidence (deg.)
Normal rigging	40 60 73·8	66 114 153	25·6 50·5 70·9	1·76 1·84 1·86	11·5 9·6 10·5
Spars at BB′ KK′ with points G and L lashed to these spars respectively, to prevent distortion of the two panels concerned.	30 40 50	46 53 59	19·7 22·7 30·5	1·17 1·32 1·18	14·7 10·0 8·1
Spars removed and cord lashed from A to G to A′ to give bottom panel a slight camber and prevent it from dipping.	30 40 50 60 80	49 68 94 121 145	21·5 27·7 38·7 54·0 81·7	1·30 1·70 1·89 1·85 1·52	14·7 10·0 8·9 8·0 5·4
As above but cord AGA′ tightened	30 40 50 60 80	49 72 100 130 201	24·0 31·7 42·0 57·1 97·2	1·17 1·61 1·88 1·91 1·86	14·8 11·8 11·3 9·2 9·4
Rear box stayed as for front box (cord KMK′) ..	30 40 50 60	48 71 93 115	22·4 30·1 37·9 50·6	1·21 1·66 1·90 1·86	14·5 9·5 8·2 7·3
Cords AGA′ and KMK′ with spars FG, LM lashed to centre canes at F, G, L and M.	30 40 50 60 80	49 66 87 102 87	22·9 27·7 36·0 47·3 75·6	1·14 1·55 1·78 1·67 0·85	14·1 9·7 7·9 6·9 Crashing
Spar LM and cord KMK′ removed	30 40 50 60 80 100	48 66 93 120 181 174	23·2 27·8 38·2 53·3 91·6 121·1	1·12 1·58 1·86 1·84 1·74 1·26	16·0 11·6 8·8 8·5 7·9 6·0

TABLE 7 (b)

3-ft Cody Kite Mk. II with 4-ft Front and 8-ft Rear Bridles (Kite A)

Kite rigging (*see* Fig. 5)	Wind speed ft/sec	Lift lb	Drag lb	$\frac{L-W}{D}$	Nominal incidence (deg.)
Normal rigging	30 40 50 60	56 75 98 118	19·1 24·9 36·8 51·9	1·73 2·09 2·04 1·83	12·2 8·0 7·9 7·5
Spar FG and 5-cwt cable AGA′; spar lashed to central canes at F and G.	30 40 50 60 80	57 80 109 142 203	20·4 27·4 40·7 58·3 100·7	1·62 2·04 2·09 2·02 1·78	12·8 10·4 9·9 7·7 7·8
As above but cable tightened	30 40 50 60 80	49 82 112 144 210	21·4 29·5 41·6 59·4 102·4	1·17 1·97 2·12 2·02 1·82	13·1 10·0 9·7 8·0 7·3
Wire further tightened and wing tips CC′ joined by cord.	30 40 50 60 80 100	50 86 117 154 231 243	23·4 31·5 44·9 63·2 109·8 169·3	1·11 1·97 2·07 2·06 1·89 1·29	12·6 10·2 9·8 8·9 8·5 8·0
As above but wire AGA′ replaced by cord.. ..	30 40 50 60 80	50 86 116 155 238	24·1 32·3 45·1 63·7 112·0	1·08 1·92 2·04 2·06 1·91	13·2 10·2 9·0 8·5 8·9

TABLE 7 (c)

3-ft Cody Kite Mk. II with 4-ft Front, 7 ft. 6 in. Rear Bridles (Kite A)

Kite rigging (*see* Fig. 5)	Wind speed ft/sec	Lift lb	Drag lb	$\frac{L - W}{D}$	Nominal incidence (deg.)
Normal rigging	30	64	20·2	2·03	15·0
	40	92	28·1	2·46	11·3
	50	125	41·6	2·45	10·3
	60	167	62·4	2·31	10·6
	80	273	116·2	2·15	9·5
Spar FG and cord AGA′, spar lashed to centre canes at F and G. Wing tips CC′ joined by cord.	30	66	27·2	1·54	11·5
	40	95	34·9	2·04	11·2
	50	133	50·3	2·17	10·0
	60	181	71·1	2·21	10·8
	80	297	129·4	2·11	10·6
	100	312	175·7	1·64	9·8
Wing cord CC′ and vertical spar FG removed ..	30	65	25·9	1·62	15·0
	40	94	32·7	2·17	10·7
	50	130	46·1	2·32	10·7
	60	177	67·0	2·30	10·9
	80	281	119·4	2·16	9·4
crashed	100	310			
Spars BB′, FG and cord AGA′	30	61	23·8	1·47	14·7
	40	85	30·7	1·92	10·8
	50	113	44·0	1·98	8·5
	60	148	61·1	2·00	9·5
	80	236	113·7	1·85	8·5
	98	278	165·4	1·52	9·0
Spar BB′ removed and wing canes DE, D′ E′ given slight camber by tightening cords EH, E′ H′ and slacking off DB, D′ B′.	30	68	27·9	1·58	15·0
	40	98	36·6	2·02	12·5
	50	137	52·4	2·16	9·9
	60	188	74·8	2·19	9·4
	80	302	132·5	2·10	9·5
	98	374	183·8	1·90	10·0
Spar FG removed but cord bracing retained ..	30	71	28·1	1·71	15·2
	40	101	37·3	2·09	12·0
	50	139	52·7	2·20	9·9
	60	190	73·9	2·26	9·8
	80	303	132·3	2·12	9·1
Spar HNH′ and trailing edge of centre cane GN lashed to it at N. Cord bracings removed.	30	72	30·3	1·58	14·0
	40	103	39·8	1·99	11·8
	50	143	57·0	2·09	11·3
	60	193	78·7	2·15	12·0
	80	306	137·5	2·05	13·3
As above with high camber on wings by tightening EH E′ H′.	30	79	48·1	1·14	15·6
	40	122	68·3	1·44	17·0
	50	190	99·1	1·68	15·2
	60	256	136·3	1·70	14·0
	80	430	230·3	1·76	12·0
Top lifting panel of front box cut out, centre cane and webbing retained.	30	50	19·5	1·38	8·2
	40	61	24·8	1·53	8·6
Top lifting panel of rear box also removed, in similar fashion to above.	30	55	22·7	1·41	15·8
	40	72	28·6	1·71	9·8
	50	96	46·0	1·59	10·5
	60	139	65·3	1·78	7·1

(96130) A*

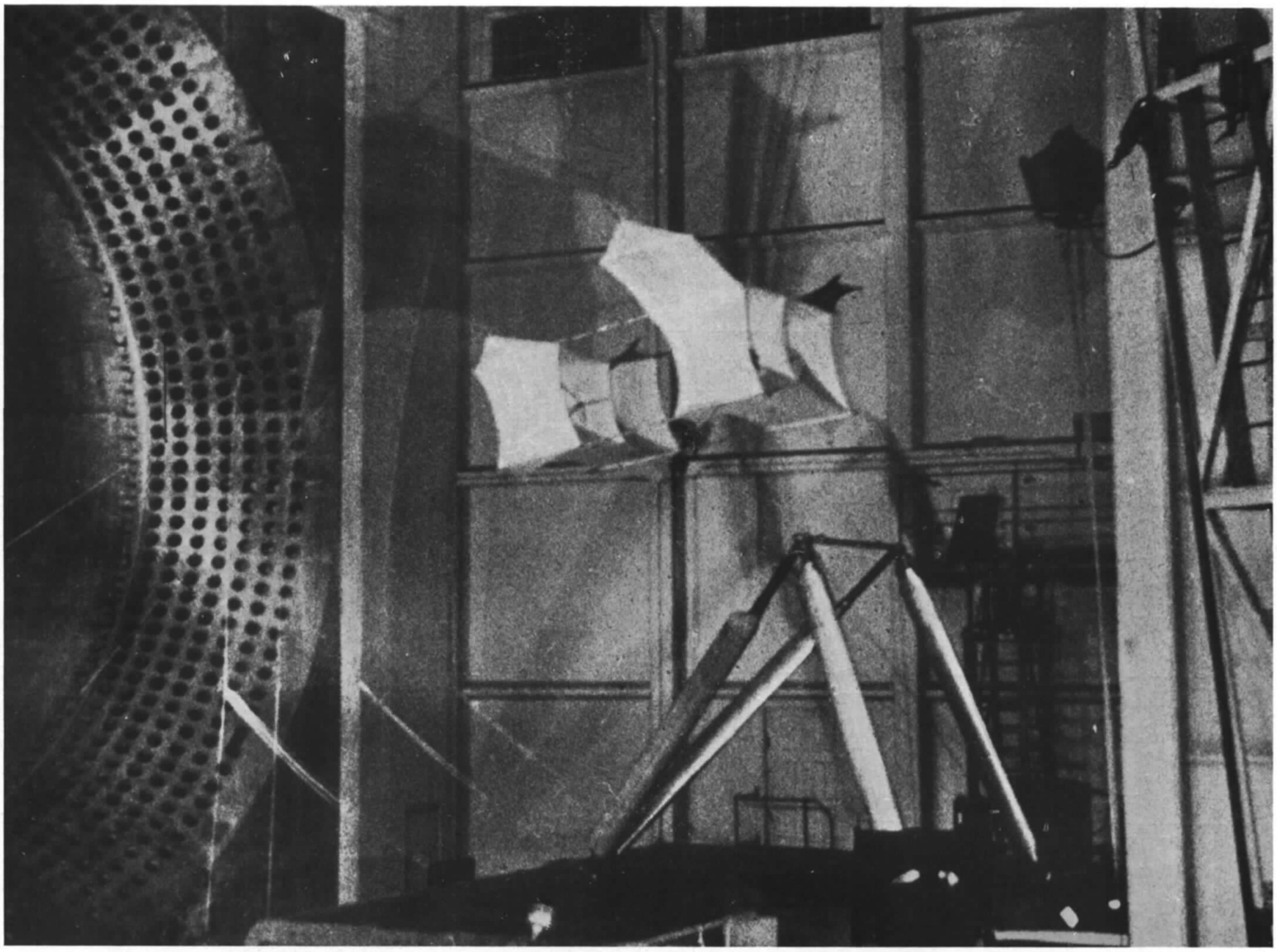

FIG. 1. 3-ft. Cody Kite Mk. II in Large Tunnel.

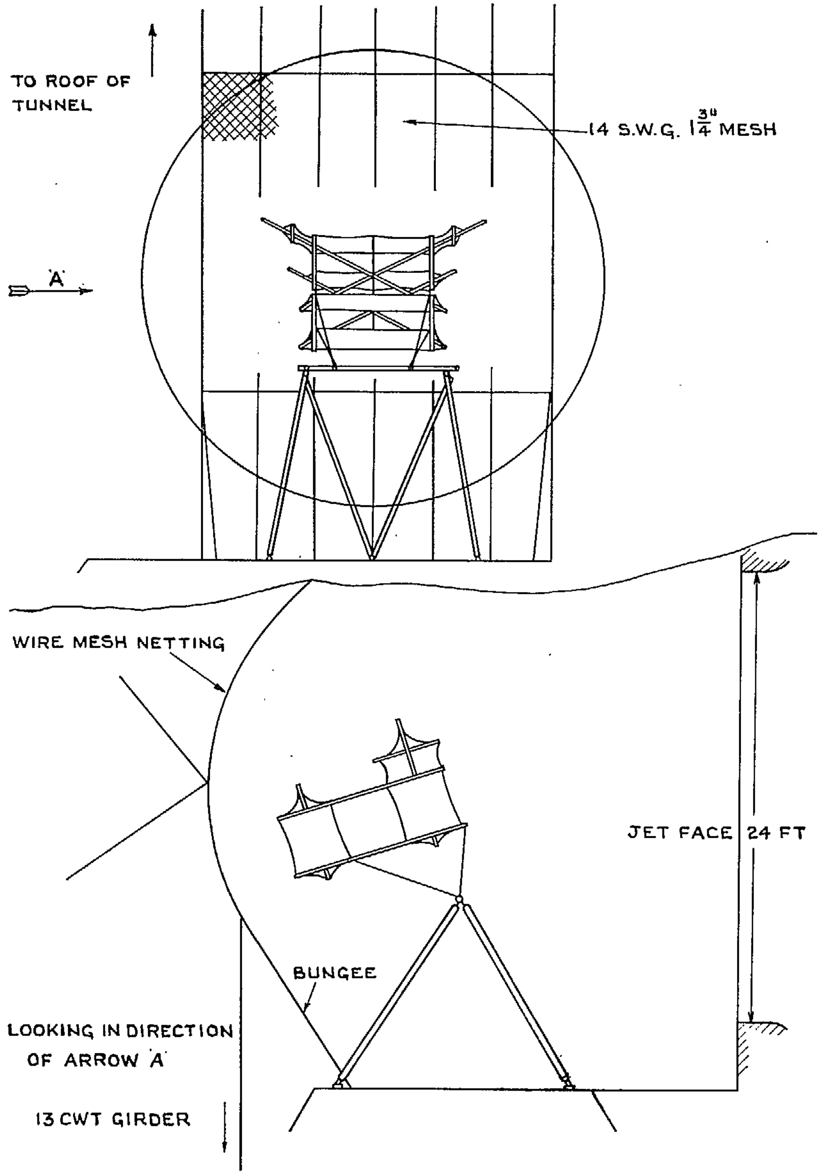

FIG. 2. General Arrangement of 3-ft Cody Kite in Large Tunnel.

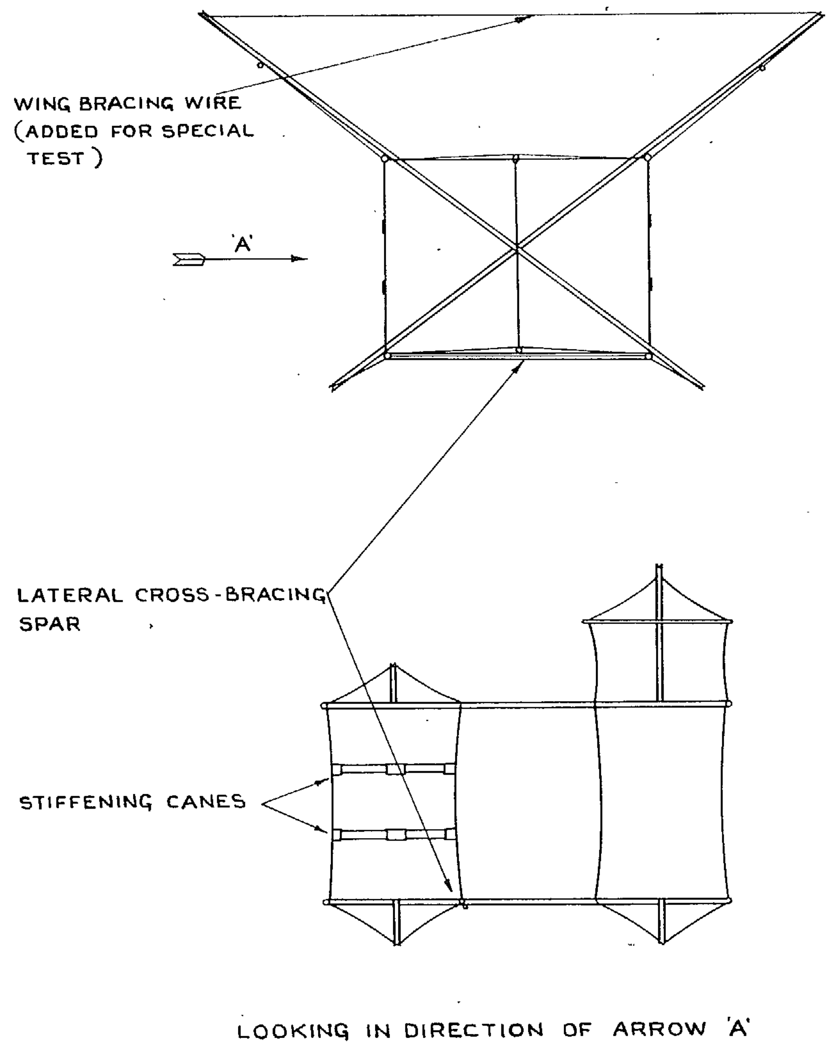

FIG. 3. Front and Side Elevation of 2 × 3-ft Storm Kite. (Kite D)

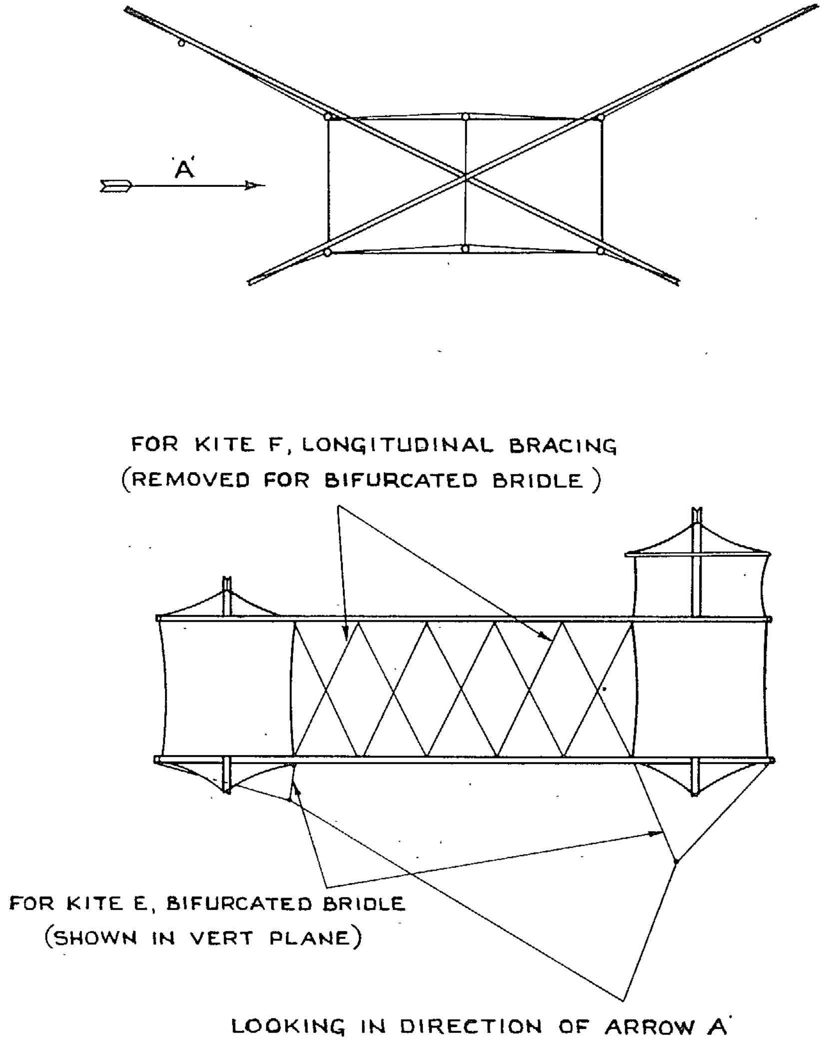

FIG. 4. Front and Side Elevation of a 2-ft Cody Kite Mk. III.
showing Alternate Arrangements of
E. Bifurcated Bridle.
F. Longitudinal Bracing.

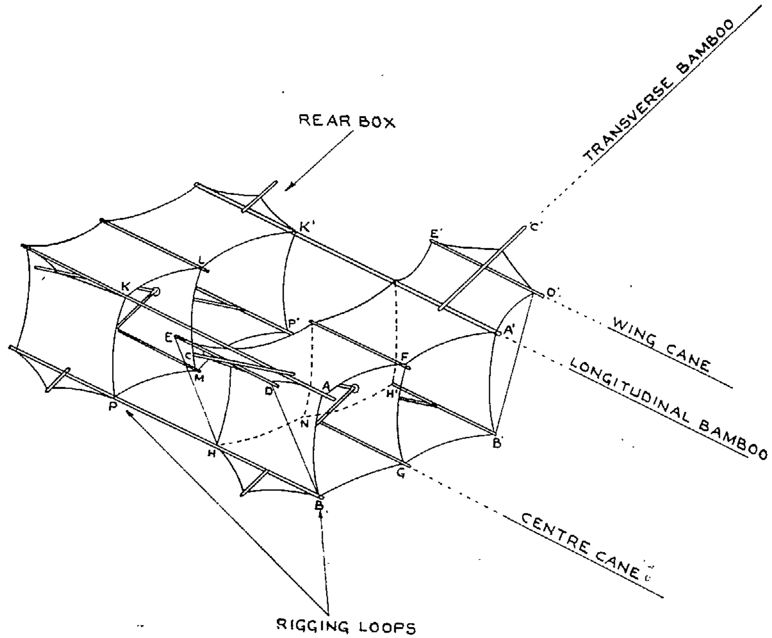

FIG. 5. Key Diagram for Table 7a, b, c. 3-ft Cody Kite Mk. II.

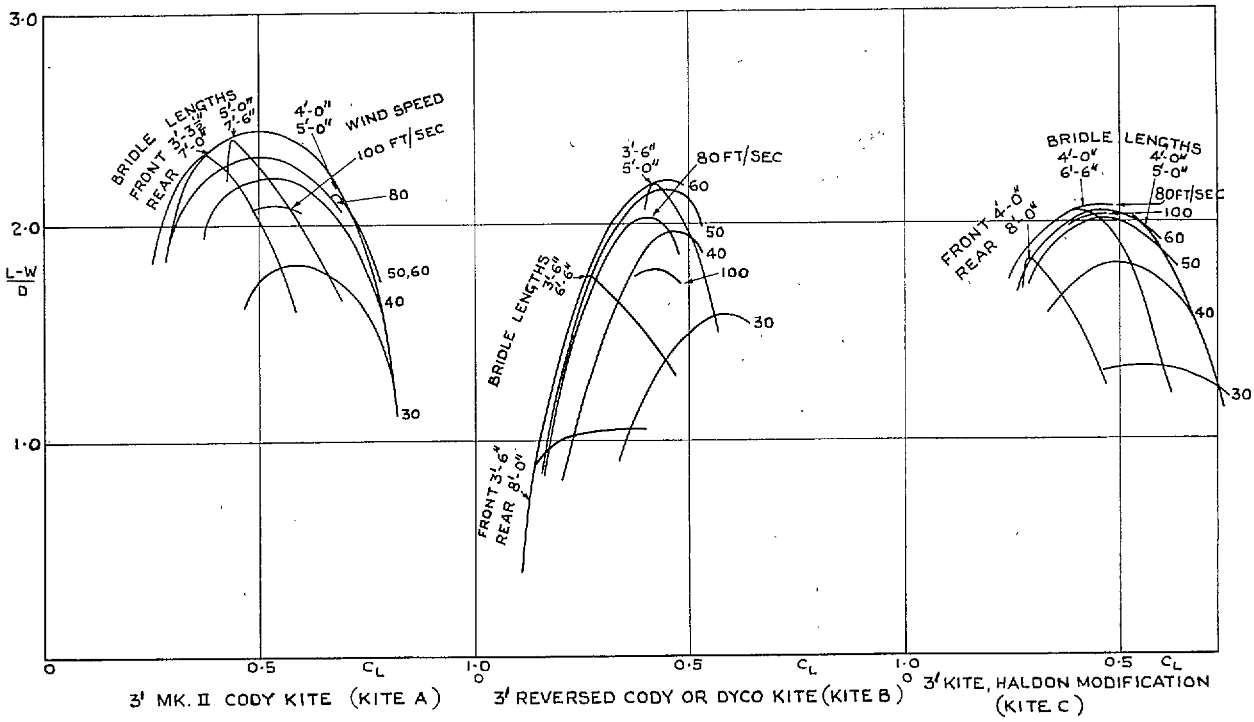

FIG. 6. Effect of Bridle Lengths and Wind Speed on Kite Efficiency—3-ft Kites.

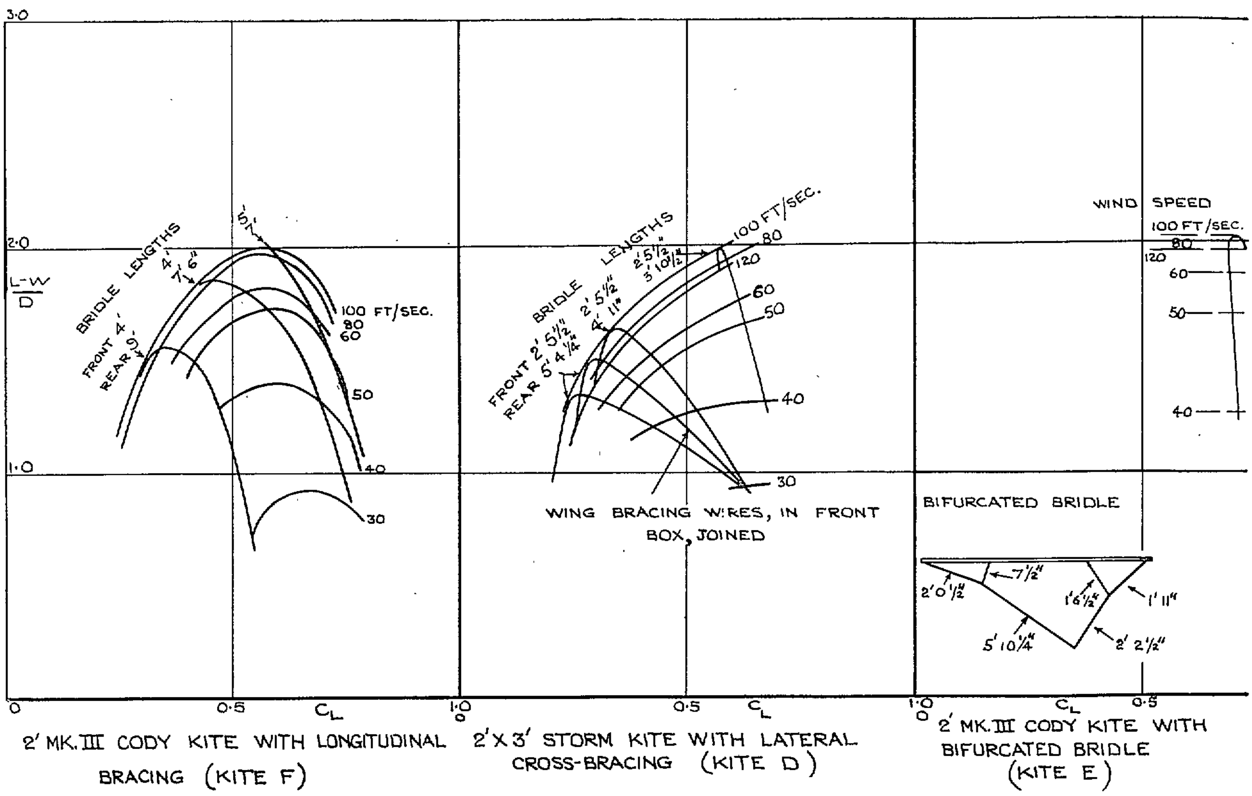

FIG. 7. Effect of Bridle Lengths and Wind Speed on Kite Efficiency—2-ft Kites.

(96130) Wt. 14/806 K.5 2/51 Hw.

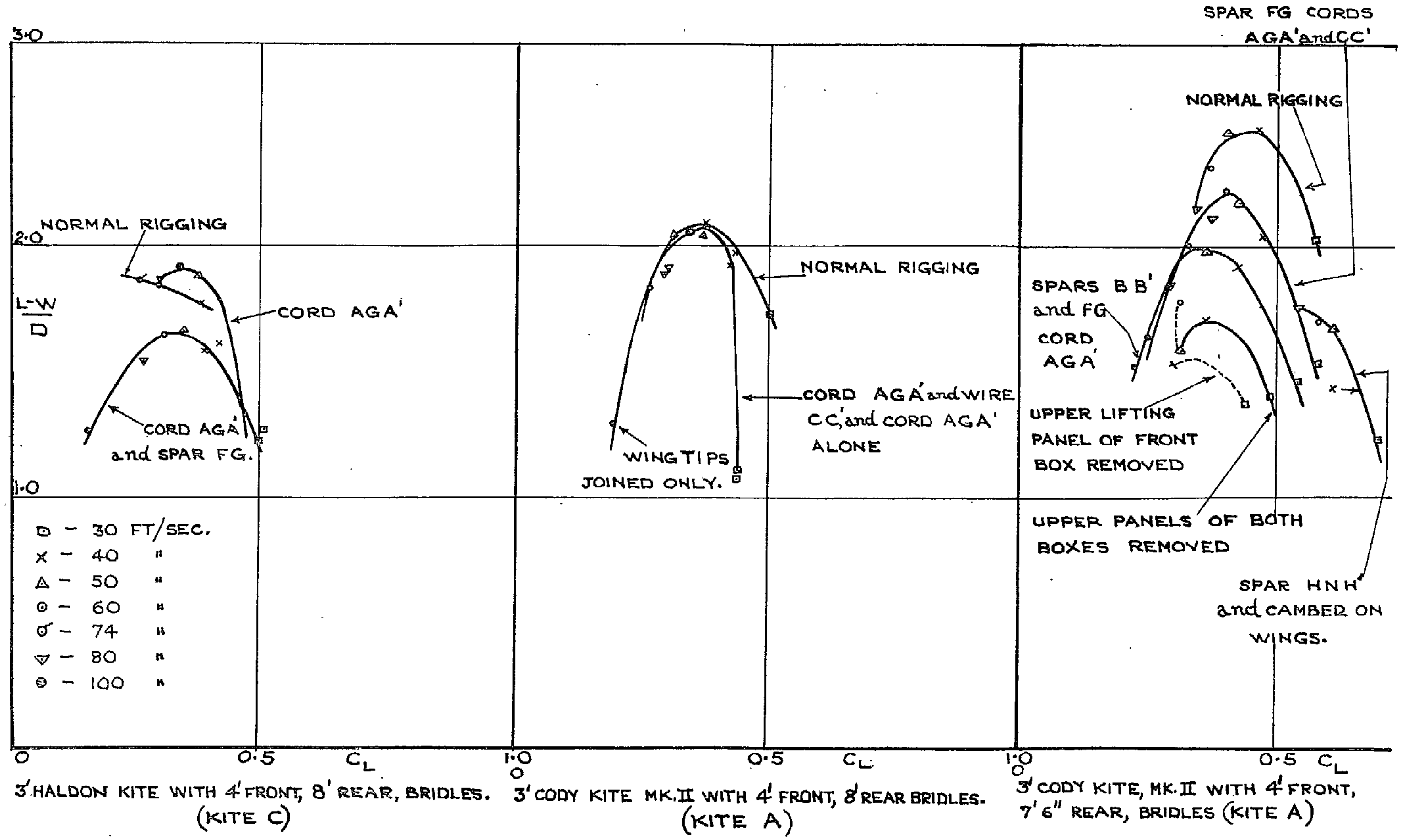

FIG. 8. Effect on Efficiency of Some Modifications to 3-ft Kites.
See (Key Diagram Fig. 5.)

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(A.R.C. Technical Report.)

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