THE

Twenty-Second Report

OF THE

AËRONAUTICAL SOCIETY OF GREAT BRITAIN

Containing a selection from the Papers read at the General Meetings held at the Society of Arts, and the discussions arising therefrom.

Under the Chairmanship of Mr. JAMES GLAISHER, F.R.S., Mr. DOUGLAS ARCHIBALD read the following :—

KITE BALLOONS AND KITE TANDEMS.

The chief obstacle to the general use of captive balloons hitherto has been their extreme sensitiveness, and liability to damage by the action of wind. It is with a view to remedy these defects, and at the same time to gain extra lifting power by converting an enemy into a friend, that I have been led to construct the kite balloon.

The principal defects which captive balloons display under the action of wind are—

(1) Depression and vertical oscillation.

(2) Rotation on their axes.

(3) Jerking and uneven tension on their cables.

(4) Inability to withstand the wind on more than a limited number of days per annum.

(5) Danger of balloon fabric being destroyed by a sudden gust.

On the other hand, when the balloon is fastened on to the back of a kite in the manner I have proposed in my patented design, not only are all these defects to a large extent remedied, but several positive advantages are gained, which may be summarised as follows :—

(A) To raise the same weight a smaller balloon can be employed, since, if the balloon be properly sheltered and attached to the kite, the combination gives us nearly the sum total of the lifting powers of both the balloon and the kite; while by being placed in the rear of the kite the balloon fabric is *always* sheltered from the destructive action of the wind.

(B) When being hauled in, the combination instead of descending towards the earth, tends to rise by virtue of the increased lift of the kite.

(C) The aëronaut, by manipulation of the strings of the kite, can alter his elevation at will, without being hauled in or let up from below.

(D) The increased steadiness allows him to make observations with greater ease.

(E) Observations can be made at sea between ships or on exposed coasts, where at present captive balloons can hardly be employed at all.

(F) A greater altitude can be attained, since the velocity of the wind is always found to increase with the height above the surface, the general law (deduced from a number of observations, the results of which have been published in the British Association Reports for 1884-5) by the present writer being—

$$\frac{V}{v} = \sqrt[4]{\frac{H}{h}}$$

for heights above 400ft. above sea level.

I propose in the present Paper—

(α) To give an account of the kite balloon itself.

(β) To exhibit the defects of the ordinary captive balloon.

(γ) To show how they are remedied by the kite balloon, and finally to give some accounts of previous kite experiments, and a plan for raising instruments or men safely by means of kite tandems, either for scientific or military purposes.

(α) Kite balloon. The full description is given in specification No. 15,627, 1885.

(β) Then with regard to the defects of the captive balloon when used alone.

(1) The most serious of all are the depression and vertical oscillation. The former alone renders the balloon useless in a wind of any sensible strength, and is often very deceptive, since, while the captive balloon is being paid out, it rises like a free balloon, and all apparently goes well. As soon, however, as the line is checked and tightens up, the balloon rapidly descends until its ascensional force is equal to the component of the wind resolved normal to the direction of the earth-line in the position of temporary equilibrium. On the most favourable hypothesis, this pressure is equal to half that which would be encountered by a plane surface equal to that of a diametrical section placed normal to the wind, so that for a balloon 30ft. in diameter the wind pressure would be equal to a 176lbs. in a 14 mile wind, and 352lbs. in a 20 mile wind, and this pressure would be always acting so as to drive the balloon downwards, because the balloon would be fastened at its lowest extremity.

Now, if we take the capacity of such a balloon at 13,500c.ft., and its ascensional power at 540lb., roughly (with coal gas), we have about a third of its power lost at 14 miles an hour, and five-eighths at 20 miles an hour.

Besides permanent depression, the balloon alone is very sensitive to variations in the strength of the wind, dropping as it increases, and rising suddenly when it lulls, so that there ensues a continual battle between the wind and balloon.

often resulting in the complete defeat of the latter, and its final entanglement in trees and other terrestrial projections. The other day this behaviour of balloons was forcibly presented to my notice during an experiment at Lidsing, at which Major Templer let up two captive balloons, tandem, on a cable to support a photographic camera, which was to take a series of running instantographs of the country it passed over. The balloons went up majestically, and all seemed very satisfactory until a mile of cable had been run out and the winder locked. The balloons then rapidly sank, and the camera got so knocked about by the trees that the photographer told me he thought it most probable that the plates were all smashed, and thus the result of the experiment a failure. During all this time a large kite which I had made for Mr. Eric Bruce was flying steadily at one level, and would have done the whole business vastly better and without coming down when checked.

(2) The jerking or longitudinal oscillation of a balloon is another great drawback to captive ballooning, especially in the case of a man ascent. Whenever the wind blows in gusts, which is frequently the case in certain winds and near the earth, the balloon, by reason of the opposite forces acting on it, is continually rising and slackening its rope during a lull, until it meets a gust, which again drives it downwards, and horizontally to the end of its tether, which it reaches with a jerk, and a report which to the aëronaut sounds ominously like bursting. The effect of this jerking on the nerves is most destructive, and a plucky young officer of the Balloon Corps, who hardly knows what nerves are, told me that after an hour or two this banging became insupportable, not unlike the well known cumulative effect, mentioned by Tyndall, of walking along a dangerous arrête in the Alps.

(3) The rotation of a balloon on its axis has always been

a great source of discomfort, both in free and captive balloons; but in the latter it cannot fail to operate disadvantageously if they are to be used for reconnoitring purposes. It arises in this case from the fact that the wind causes the top of the balloon to assume a cup-shaped hollow, from which a moment of rotation results, first round one way and then round the other, the slightest departure from symmetry sufficing to produce instability and motion round the axis of the balloon.

(4) Owing to its fragility, and the simultaneous occurrence of the foregoing drawbacks, a captive balloon can only be flown on a very limited number of days per annum. Though I am not able to give accurate data on this point, I have been voluntarily informed by balloonists that captive balloons cannot be flown successfully on more than four or five days per month throughout the year. As soon, however, as I ventured to announce this fact in print (which I certainly did not invent, since it considerably surprised me), one captive balloonist hastened to rescue his balloon from disrepute by alleging that he had worked a balloon successfully on 15 days out of 28 in July, which he asserts to be "by no means the stillest of the summer months." Whether this be true or not, July is certainly below the mean of the year, and very far below that of the windiest month. The following figures show the average mean hourly velocity of the wind at Greenwich for 1883-4-5 for July, the year, and the windiest month. Mean hourly velocity (miles per hour) of wind: 1883-4-5, July 10, windiest month, $15\frac{1}{2}$, year, 12. Also if we take the year 1885 as an example, we find there were 156 days at Greenwich on which the average wind velocity during the 24 hours was 10 miles wind and under.

Considering the average of the whole year was exactly 12 miles an hour, it is scarcely likely that on more than half of these (taking the same proportion as my captive balloonist was able to fly in July when the wind was 10 miles an hour), could a captive balloon have been raised with safety—i.e., on 78 days out of the 365 days, and if we add on 22 more for luck, we get 100 days out of the 365, or $\frac{2}{7}$th of the year.

This is in a country where the average wind velocity throughout the year is about 10 to 12 miles per hour; but while in the interiors of large continents the wind is less than this, being on the average of a large number of observations, which include the interior: in Europe 10 miles per hour, America 9·5, S. Asia 6·5, W. Indies 6·2, at coast stations it is considerably more. For example, in Europe it varies at 12 coast stations from 11 miles in July to 19 in January; at Bombay and several other coast stations in India from $9\frac{3}{8}$ miles in November to 19 miles in July, and in the N. Atlantic its *mean* velocity throughout the year is estimated from numerous observations at about 29 miles per hour, varying from 25 in summer to 33 in winter. In such localities, therefore, the number of days on which captive balloons could be flown would be considerably less than in places situated inland. For military manœuvring near the coast, or for coast and naval purposes, then, it is obvious that captive balloons, as at present flown, would be almost useless, except on one or two picked days.

I shall hope to show subsequently that by the addition of the kite attachment in moderate weather, and the substitution of the kite by itself for the balloon in higher winds, observations could be made in such localities with success and safety.

(5) The possibility of the wind acting destructively on the fabric of a balloon, especially in a sudden gust, is, I imagine, an element of some importance. At all events, it has always been objected to the kite-balloon that the junction of the two would expose the latter to a strain which might

rend it. If this be so, then there must be some danger of rupture taking place in the balloon alone, either through jerking or a sudden gust. In my kite-balloon all danger of rupture is prevented by keeping the balloon as nearly as possible below the level of the top of the kite, and also by covering one-half of its upper surface with a hood fastened to the kite, which takes off the strain and also prevents the air from eddying into the wedge-shaped space between the plane of the kite and the sphere of the balloon.

In considering the advantages introduced by the combination of the kite and balloon, I shall first of all briefly allude to the way in which the foregoing drawbacks to the captive balloon alone are obviated.

(1) The addition of the kite almost entirely obviates depression and vertical oscillation in a wind, since the balloon and kite are oppositely affected, and while a lull tends to reduce the nearly permanent angle of the kite, it allows the vertical tendency of the balloon to assert itself, and thus correct any downward tendency due to the weight of the kite, which in any case is relatively small. On the other hand, a rise in the wind allows the kite's action to come into play, and prevents descent beyond a certain point. The addition of the tail of conical cups also greatly tends to insure steadiness, this kind of tail being self regulating, weighing next to nothing in a light wind, and increasing in pull as the wind rises.

(2) The rotation of the balloon on its axis is entirely prevented by the kite attachment, since the kite always flies with its face to the wind, and if properly adjusted, with its principal axis in the vertical plane through the direction of the wind and the point of attachment to the earth.

(3) Jerking or uneven tension on the cable is also prevented, since, even during a lull, the pressure on the kite

suffices to stretch the cable or wire fairly taut. The action of the kite in keeping the wire taut, is well exemplified in a preliminary experiment made at Tunbridge Wells Gas Works in the presence of Mr. Eric Bruce, on June 10, 1887, reported in *Nature* of July 21, 1887. The results of this experiment are exhibited in the following table:—

	Angle of Balloon.	Wire near Ground	Height attained in feet.
Balloon alone	38°	18°	693
Balloon and Kite	$41\frac{1}{2}$	35	789

Sag of Wire.
(1) With Balloon alone, 20°
(2) With Kite Balloon, $6\frac{1}{2}$°
Excess of height in latter case ....96ft.
Wind at Greenwich during trial, 12 miles an hour

Weight of
(1) Wire 4lb.
(2) Kite $2\frac{1}{4}$lb.
Raising power of balloon with hydrogen = 5lb.

The experiment took place in the bottom of a valley 260ft. above the sea, and surrounded by hills rising to 500ft. Even under these unfavourable circumstances, and with a very rough imitation of my patent, the addition of the kite—

(*a*) raised its own weight.

(*b*) increased the vertical height of the combination by 96ft.

(*c*) diminished the curve of the wire by $13\frac{1}{2}$°, thereby showing the existence of a greatly-increased lifting power.

(4) Again with respect to the number of days on which the combination can fly. We have already seen that the captive balloon alone cannot fly on more than 100 days per annum, the majority of which must be during the summer. Now, from a series of observations which I made with kites alone, on the velocity of the wind at different heights above the ground in 1883-4-5, I found myself able

to raise, by means of two kites spreading together, about 19sq.ft., four instruments, each weighing $1\frac{1}{2}$lb., to heights varying from 200 to 1,500ft., in winds raging from 7 to 30 miles per hour (at a mean of 700ft. above the ground—1,200 above sea level), which corresponded to 6 and 24 miles per hour respectively at Greenwich, 200ft. above the sea. Now, since at Greenwich there are 270 days per annum in which the wind is over 7 miles per hour and under 20 miles, it is plain that if the kites were able to lift several thousand feet of wire and four instruments at the former wind velocity, and to fly safely at a wind velocity ten miles over the latter, the kite ought to be a material assistance to the balloon on all these 270 days. Not only so, but if we take the 69 days on which the wind is *below* 7 miles an hour to be a portion of those on which the captive balloon can fly alone during the year, and subtract them from the theoretical 100 which represents its maximum performance, we find it would need the aid of the kite on no less than 239 of these 270 days.

Even if we extend the limit of the balloon alone to days on which the average wind velocity is under ten miles per hour, which is only two miles less than the average for the year, and we also limit the utility of the combination to days on which the wind is less than an average of 15 miles per hour, we still have 120 days on which the kite would be a necessary adjunct to the balloon. In any case, therefore, the addition of the kite would more than double the number of days on which the captive balloon could be flown.

(5) The risk of bursting the fabric of the balloon by its exposure to sudden gusts is a matter on which I do not possess any personal knowledge; but I have been led to infer that it is a fact of some importance owing to the avidity with which captive balloonists seize upon anything which affords what one of them terms a "wind shield."

About three years ago Mr. C. G. Spencer, the well-known balloon manufacturer, told me he had long been thinking of something to act as a wind shield, and my idea of uniting the kite to the balloon, which originated out of a desire to keep the former up in a light wind, appeared precisely to meet his desire to find a shield as well as support for the balloon in a high wind. Approaching the matter from entirely different standpoints, and with diverse aims, we found our common focus in the word "kite." It is also obvious that if it were not for fear of the destructive action of the wind on the fabric, captive balloonists would long ago have availed themselves of the vertical component of the wind by trying to make the attachment to the balloon on the side instead of below the car. The kite effectively allows this to be done by offering a steady plane instead of a rumpling curved surface, and, with the aid of the top hood, prevents all danger of tearing as long as the balloon is kept well within the area defended by the kite shield.

We may, therefore, consider that the protection afforded by the kite not only lowers the risk of bursting, but allows the balloon to be flown in a wind which would otherwise jerk a good deal of gas out of it and possibly destroy it.

Another point in connection with man-carrying ascents is the expense involved in the constructing and filling the large balloons which are necessary to lift a man. Now, I think I may say with some approximation to truth that the smallest balloon which is used to lift a single man is not less than 22ft. in diameter, with a capacity of 5,500 cubic feet of gas.

A 16ft. diameter balloon, whose capacity equals 2,100 c.ft., would lift 136lb. less, assuming the elevating power of 1000c.ft. of coal gas to equal 40lb.; but a kite attached to match it would, in a wind of a little over 20 miles an hour, lift this 136lb. and its own weight, which need not exceed 14lb. In such a wind, therefore, not only would the balloon be able to fly, protected by the kite, but one of half the capacity would, with a kite to match, easily lift the same weight.

Not only so; but there would be an economy in (1) Balloon fabric; (2) Gas; which in one ascent would more than equal the prime cost of the kite. The lifting powers exclusive of their own weights, for kites of the following dimensions in different winds are—

	Wind Velocity.		
	14 Miles an hour.	20 miles an hour.	30 Miles an hour.
18ft. by 14ft. = 126sq.ft.	... 48lb.	... 90lb.	... 220lb.
27ft. by 21ft. = 280sq.ft.	... 83lb.	... 208lb.	... 485lb.

These are calculated by the ordinary formula for pressure. $p = \cdot 005\ v^2$ (Smeaton and Rowe's empirical formula). This is believed to be incorrect, and in excess of the real pressure; but since the pressure on large surfaces increases with the periphery as well as the area, I have adopted it as giving a fair maximum on the assumption that the pressure is statical, which for large surfaces is nearer the truth than dynamical formula.

The angle of the kite to the horizon is taken to be either 30° or 60°. For any angle between these limits the pressure, and therefore lifting power, would be greater, and 45° would be $\frac{6}{5}$ of the above.

Then as to the positive advantages which I have already summarised.

(A) The experiment already referred to at the Tunbridge Wells Gas Works affords additional evidence in favour of this, since the wire at the lower end which made an angle of 35° with the kite balloon instead of 18° with the balloon alone, showed the existence of a great increase of lifting power. For signalling purposes, by means of the electric light, therefore, it is plain that a smaller balloon can be used with a kite to do the same work as a larger one without; and this applies *pari passu* to the case of man-lifting.

(B) The fact that when the kite or kite-balloon is being hauled in, it tends to rise in opposition to what happens in the case of a balloon alone, is very important, since this defect in the latter often endangers, not only its appendages but itself as well, by driving it into trees or to the ground.

(C) In the event of a kite-balloon being employed for man-lifting purposes with a car attached, it is readily seen that by attaching a pulley to one of the principal kite strings the occupant could vary the angle of the kite to the wind, and thus either adjust it to varying conditions, or else ascend or descend through some considerable space at will. This would be a great advantage for military purposes.

(D) The increased steadiness of the combination has been attested by all who have seen it, and I attribute this in a great measure to the addition of the cup cone tail. For any purposes of scientific observation, signalling, reconnaissance, or otherwise, this could not fail to be a distinct advantage.

(E) For observations on board ship or on coast stations the kite-balloon, as I have already shown, possesses distinct advantages, since the wind in such places is nearly always high. In fact, by its means I think a system of signalling between ships might be started by using Mr. Eric Bruce's ingenious electric translucent balloon, and thus ships might be able to communicate with each other when by the curvature of the earth or other obstacles they were ordinarily out of sight of each other.

To show the effect of height on the extension of the visible horizon, it may be noticed that while two observers, each elevated 60ft. above the sea, could only see each other's signals up to about 18 miles, a signal hoisted up to 600ft. above the sea could be seen on the *deck* of another vessel 30 miles off, and from a height up the mast for a still greater distance. It seems difficult to conceive any better way of raising signal lights to communicate between ships than either by means of kite-balloons or kite-tandems.

(F) The fact that the velocity of the wind increases with the height above the surface does not seem to be generally known as well as it ought, and within the range of my own experience, I find the vaguest notions afloat regarding its amount and constancy.

The general result of my own observations on this point may be gathered from the following figures, which represent 40 sets of observations, extending over the three years 1883-4-5.

Group.	No. of Observations.	Mean height of upper instruments above ground.	Mean height of lower instruments above ground.	Mean upper and lower velocities in feet per min.		Mean value of exponent x in the formula— $\frac{V}{v} = \left(\frac{H}{h}\right)^x$
				Upper.	Lower.	
1	7	250	102	1617	1174	0·372
2	3	322	128	2232	1679	·307
3	8	407	179	1705	1385	·275
4	5	549	252	2107	1773	·237
5	9	795	481	2192	1957	·250
6	10	1095	767	2236	2096	·194

The results of which show—(1) That the velocity always increases with the altitude; in fact, a reverse case has never occurred within my experience. (2) That the increase diminishes in a regular manner with the altitude, reaching a nearly constant terminal value which, by comparison with Dr. Vettin's cloud observations, I find can be best expressed by the formula—

$$\frac{V}{v} = \left(\frac{H}{h}\right)^{.25}$$

With the exception of the cloud stratum between 1,600ft. and 7,000ft., the formula with this value for the exponent holds for the average up to the cirrus. Thus a velocity of 12 miles an hour at 100ft. would correspond with one of 21 miles an hour at 1,100ft.; and to show that this is practically true from other observations taken at different levels, I will here quote the velocities recorded by Dr. W. Doberck for the wind at a base and top of Victoria Peak, Hong Kong, for 1884-5-6:—

Year.	Mean Velocity of Wind in Miles per hour.	
	Observatory 150ft. above sea level.	Victoria Peak, 1,816ft. above sea level.
1884	14·8	22·4
1885	14·0	25·0
1886	13·5	26·0
General means	14·1	24·4

The velocity at the upper station calculated from that at the lower by my formula would be 26·3 miles per hour, which is a little excess of the mean, and nearest what is probably the most correct in 1886, the observations only having been commenced in 1884.

These observations, which I could easy supplement by others showing the great increase everywhere in the velocity of the wind with the altitude, will suffice perhaps to show not only the futility of inferring the velocity of the wind and its effect on a balloon from observations near the ground, but the utility and power which the addition of the kite would insure at the higher levels.

Dr. Vettin, of Berlin, from observations of the clouds, gives the following figures for the velocity of the lowest cloud stratum and the wind at the earth's surface :—

	Altitude in feet.	Mean velocity in miles per hour.	No. of observations.
Under-cloud	1,600 ...	25 ...	1,292
Wind	Sea level ...	13·5 ...	4,168

If the lower velocity is taken to be that at 100ft., my formula would make the upper velocity equal 27 miles per hour, and the apparent motion of the clouds is probably lower than that of the wind. I am obliged to defer referring to the subject of kite tandems through lack of time.

The CHAIRMAN asked if any gentleman had any remark to make upon the communication they had just heard.

Mr. NORMAN said he would like to ask the author of the paper how he could carry a kite 16ft. square to different places. Would he have it made in sections?

Mr. ARCHIBALD replied that he would bring his 18ft. kite into that room without anyone noticing it. It would be like a lot of umbrellas, all folded up, and do not take up much room. The whole thing could be put together and taken to pieces, with screws and metal work quite easily.

The CHAIRMAN proposed a vote of thanks to Mr. Archibald for his paper. He was very glad he had taken up the subject of kites. They had been too much neglected, and there was a great field for experiment in them. With regard to the velocity of the wind, we could not yet calculate the velocity with pressure. He would caution them against taking the Greenwich results, where the anemometer was taken only one hour out of the twenty-four, because the day velocity of the wind was very different from that of the night. (Hear, hear).

Mr. ARCHIBALD: In this case I have taken the precaution to have hourly records.

The CHAIRMAN said that would be more to the purpose. He had thought it was merely taking the record once in twenty-four hours. He was very pleased with the account of the kite experiments. When the captive balloon was at Ashburnham Park, he had the privilege of going up at any time. The balloon had large ascending power, and although some days were rough, he ascended almost every day. Some people could bear bumps better than others.

The thanks of the meeting were given to Mr. Archibald for his Paper.

Mr. J. WETTER, of the firm of Fairfax & Wetter, Patent Agents and Consulting Engineers, having assisted in some late experiments, read a Paper on

A NEW METHOD OF ASCERTAINING THE POWER REQUIRED FOR PROPELLING BALLOONS AND OTHER BODIES THROUGH THE AIR.

The method which I propose to describe has been invented by Mr. Beugger for ascertaining experimentally, as far as possible, what power is required for propelling any given body through the air, and also for comparing with each other various shapes of balloons or "navigables" as regards the resistance they offer to propulsion.