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Publisher: Routledge

Informa Ltd Registered in England and Wales Registered Number:
1072954 Registered office: Mortimer House, 37-41 Mortimer Street,
London W1T 3JH, UK

Royal United Services Institution. Journal

Publication details, including instructions
for authors and subscription information:

<http://www.tandfonline.com/loi/rusi19>

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Published online: 12 Nov 2009.

To cite this article: Captain Frederick F. E. Beaumont R.E. (1864) Balloon Reconnaissance, Royal United Services Institution. Journal, 8:30, 52-66, DOI: [10.1080/03071846409428800](https://doi.org/10.1080/03071846409428800)

To link to this article: <http://dx.doi.org/10.1080/03071846409428800>

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LECTURE.

Friday, February 5th, 1864.

Colonel J. P. YORKE, F.R.S., in the Chair.

BALLOON RECONNAISSANCE.

By CAPTAIN FREDERICK F. E. BEAUMONT, R.E.

MR. CHAIRMAN, LADIES AND GENTLEMEN,—I have been asked to give a lecture on military reconnaissance by the aid of balloons, and I have agreed to do so, not, I can assure you, from a belief that I can do justice to the subject, but rather because I have taken a considerable interest in it, and I am unwilling that any effort on my part, however humble, should be wanting which might contribute to the advancement of practical science. Furthermore, if it serves no other purpose, this lecture may give a certain amount of publicity to the subject, and it is a fact becoming daily more apparent, that most new things are aided by publicity, and finally started under pressure from without.

The conservative element is so strong in this country, and we are so much averse to change, that generally it requires to be shown, not only that a thing is good, but that there is a positive evil, in some shape or other, in standing still, before we can make up our minds to change; and I have, too, heard it remarked, that under the pressure which resistance to innovation produces, we change, when we do begin, rather too quickly, gulping down reforms as we would take a dose of physic, instead of spreading them over such a time as would insure our getting the collective wisdom of many brains.

However that may be, making war by means of balloons certainly does not look like standing still; and even in this age of novelties it is somewhat startling to be told, that armies cannot be considered to be properly equipped unless they have with them the means of taking an occasional fly; and that the time has come when the only element of the four remaining unused is about to be made one of the slaves of war. Earth holds us while we fight our battles, fire drives our ships and propels our cannon-balls, water bears our navies, and now air is to give us the power, as it were, of omnipresence.

I shall not weary you by recapitulating what I have no doubt most of you already know—the early history of balloons; nor shall I follow the first inventors through their difficulties with hollow spheres, that were to rise through the abstraction of the air from their interiors, which idea was superseded by the *Montgolfière*, or heated air balloon, which again was improved upon by the substitution of gas for air. I may point out, however, that the theory of a balloon was correctly struck by the idea of an empty sphere, which would have a tendency to rise in the air with a force exactly equal to the weight of the air abstracted.

The pressure of the atmosphere on the outside of an exhausted receiver which is fatal to this plan, is got over by the substitution for the vacuum of a gas whose elasticity is equal to that of the air outside, but whose specific gravity is less—illuminating gas, or rather, which is generally used, a particular gas specially prepared so as to be light, and hydrogen, are the only gases used.

I should here do justice to our ancestors, and state that there is nothing new in the application of balloons to the purposes of a military reconnaissance; indeed it is one of the first uses that suggested itself (as it naturally would do) to the originators of balloons.

The following extracts from a paper written by Lieutenant Grover, R.E., show where they have been employed. Lieutenant Grover says:—

“The French, by whom the actual idea of balloons was originally conceived and carried into effect, were also the first to discover the adaptability of their invention to practical purposes. At the commencement of the Revolutionary War, about ten years after the production of the *Montgolfier* balloons, an *Aërostatic Institute* was formed by command of the French Directory (at the suggestion of Guyton de Morveau) in the *Ecole Polytechnique*, and under its superintendence reconnoitring war balloons were constructed by a M. Couté, and supplied to each republican army in the field. The army of the Rhine and Moselle was provided with two, viz., the ‘*Hercule*’ and ‘*Intrépide*’; another named the ‘*Céleste*’ was prepared for the use of the army of the Sambre and Meuse, the ‘*Entrepreneur*’ for the army of the North, and a fifth was destined for the army of Italy. That attached to the army of the Sambre and Meuse, under General Jourdan, was first used May, 1794, by Colonel Contelle, at Maubeuge, before Mayence, in reconnoitring the enemy’s works. This balloon, which was twenty-seven feet in diameter, and took at first fifty hours to inflate, was retained to the earth by two ropes, and the *aéronauts* communicated their observations by throwing out weighted letters to the General beneath. After this method of reconnoitring had been successfully practised four or five days, a 17-pounder gun was brought down to a neighbouring ravine, and (being thus masked) suddenly opened fire upon the balloon. Several shots were fired without effect, and the machine was then hauled down; but the next day the gun was forced to retire, and the reconnoissances were then carried on as before. After two or three weeks the balloon was moved to Charleroi, distant from Maubeuge

"about thirty-six miles. To save the expense and trouble of another inflation, it accompanied the troops at a sufficient height to allow the cavalry and baggage waggons to pass beneath, ten men marching on either side of the road, and each man holding a separate rope attached to the balloon, which was thus retained at its proper elevation. After making one observation on the way, the balloon arrived before Charleroi at sunset, and the captain had time before close of day to reconnoitre the place with a general officer. Next day they made a second observation in the plain of Tûnet; and at the battle of Fleurus, which took place on the following day, June 17th, 1794, the balloon was employed for about eight hours, hovering in rear of the army at an altitude of 1,300 feet.

"The Austrians after some time discovered it, and a battery was opened against the aéronauts, but they soon gained an elevation out of the range of the enemy's fire, and the information concerning the Austrians' movements (which they were enabled in this manner to supply to General Jourdan) contributed mainly, it is said, to the success of the day,* the result of which was the loss to the Prince of Coburg and the allied armies of all Flanders, Brabant, &c."

"The next battle that the French gained through the assistance of a balloon was near Liège, on the Ourte river. As the Austrian officers afterwards said, 'One would have supposed the French general's eyes were in our camp,' for they were attacked at the critical moment of sending off their guns and baggage by the rear, the French (though occupying much lower ground than the Austrians) having been intimately acquainted with all their movements by means of their balloon. The result of this battle was of very considerable importance to the French, as it gave them all the country between Liège and the Rhine.

"They afterwards used reconnoitring balloons at the sieges of Mentz and Ehrenbreitstein, 1799. A balloon was also attached to the army sent on the memorable expedition to Egypt. What service it rendered there we are not informed; but after the capitulation of Cairo it was brought back with the remains of the army to France, and was afterwards used by MM. Biot and Gay Lussac in their celebrated ascent for philosophical investigations."

The French again made use of balloons in their Italian campaign of 1859, a reconnaissance having been made by the brothers Goddard before the battle of Solferino on the 23d of June; and the latest employment of these engines of war is that by the Federals in the present American war. As I had an opportunity of inspecting their

* A Dr. Miers, of Hamburgh, in his journal that he published on his excursion to Paris tells us that:—"J'ai vu à Paris et à Meudon le Capitaine Coutelle, le même qui le 17 Juin, 1794, montoit le ballon qui dirigeoit la merveilleuse et importante reconnaissance de l'armée ennemie à la bataille de Fleurus, accompagné d'un Adjudant-Général. Je lui ai parlé de son voyage aérien, pendant cette bataille, si décisive par suites dont le succès est dû en partie à cette expedition acrostatique d'après le jugement unanime des personnes impartial. Coutelle correspondit avec le Général Jourdan, Commandant de l'armée Française, par les signaux de pavillon convenus."
—From *Major-General Money's Pamphlet*.

apparatus, and made one or two ascents before Richmond, I shall speak further of their arrangements.

I have now done with the past, and shall take the art as it stands at the present time. I shall commence by pointing out to you the nature of a balloon reconnaissance, and showing what is and is not expected to be gained thereby; and shall conclude by explaining the practical details of the apparatus necessary to a complete balloon equipment.

Everybody who has been with an army in the field must have noticed the anxiety with which reports from the front are looked for, and the care taken both by the quartermaster-general's and engineers' department to obtain information; and those who are strangers to active war must have remarked how often the word reconnaissance appears in newspaper reports of operations. Now a reconnaissance simply means an attempt to gain information of the whereabouts of an enemy, and as all dispositions should be made, if possible, with a certainty as to his position, it follows that the results of a reconnaissance are often of invaluable consequence to a general; and even when nothing has been discovered, a sense of safety in the knowledge of the absence of danger is produced, which can hardly be called only a negative advantage.

Those people, whose duty it is to survey or explore a country in the vicinity of an army, do so by penetrating in various directions so far as they dare go, by following out the rivers, streams, and roads, and, above everything, by taking all opportunities of extending their vision. An intelligent officer climbs the highest tree, ascends every rising ground, and gets to the top of any house that may offer him a chance of seeing more than he could do from the ground; in fact, he has never seen far enough; but with all his energy, it frequently happens, or to speak more correctly, it almost always happens, that his sight is bounded by woods, hills, or other obstructions, and this is chiefly the case in a closely wooded country, where he would most wish it otherwise. The highest tree is but a few feet above its neighbours; a house, if there, offers little better opportunity; while church steeples or monuments are seldom met with. The advantage of a hill overlooking a plain is lost with a change of position, and to see over a rising ground, however slight the rise may, is absolutely impossible. Considering the above, I think it will be concluded that if a reconnoitring officer could find a pillar like the Monument erected, say every mile of his route, it would much facilitate his operations. By one sight from such an elevation, he would be able to trace the course of the rivers, and roads, running beneath him; and he would be able, without traversing, to lay them down in some sort of way; he would, furthermore, be able to recognise the correctness of a map, should one be in his possession. Within his range of vision, the officer would be able to have certainly a much better idea than he could have from the ground, of the disposition of an enemy's forces; or if it so happened, to establish the fact of the ground being unoccupied.

Now, the balloon is proposed to supply this desideratum and nothing more. It is intended by its means to have a monument permanently

with an army, but with this difference, that in place of being established only every mile, it can be set up at will ; and in place of being only some 200 or 300 feet high it can be 1,000, and its range even further extended. It is true that as at present arranged it cannot be said to be always available, but of that I will speak again. I cannot myself see how it can be doubted that in some, if not in many instances, to obtain an extended point of observation must be a great advantage. The information brought from the balloon may often be negative, that is, the report will simply affirm that no enemy is in sight, or that no change has taken place since the last ascent ; still the time will come when the intelligence will be invaluable, as containing new or affirming doubtful facts, and at the worst the balloon can only be set down as a not very expensive incumbrance, when it should be remembered that its expense is, comparatively speaking, insignificant, the full cost of a suitable apparatus being roughly some £500 or £600 ; and as regards its being an incumbrance, it can be conveyed with as little inconvenience as three baggage waggons.

Many people have asked me rather sarcastically how I proposed to win battles by balloons. They had evidently borrowed their ideas of balloons from Tennyson's somewhat vague prophecy, where he says :

For I dipt into the future, far as human eye could see,
Saw the vision of the world, and all the wonder that would be ;
Saw the heavens fill with commerce, argosies of magic sails,
Pilots of the purple twilight, dropping down with costly bales ;
Heard the heavens fill with shouting, and there rain'd a ghastly dew,
From the nation's airy navies grappling in the central blue.

and fancied that iron-plated balloons and Greek fire poured upon the people below were not altogether beyond my notions.

Now, it will have been seen that the balloon is to take no active part in the fighting ; in fact, when within range of the enemy's guns it should be moved (though I may here remark that owing to its position and uncertain distance, a balloon is an extremely difficult thing to hit, and when struck, except by a shell or on the ear, little damage would be done that could not be easily repaired) ; and that, in fact, the balloon is supposed to be of no assistance to the general whatever, beyond placing him *au fait*, or as the Yankees call it, "posting him up to the latest date".

I will now give you the results of such reconnaissances as I have seen made, and make some remarks on the way in which they were carried out.

The theory of ballooning is so simple, and the practice of it so difficult, that opinions as to its success must be based upon the result of actual experiment rather than foregone conclusions.

The first time that I saw the American balloon used was in the spring of 1862. I joined McClellan's army at Cumberland, landing on the Pamunkey river, one march below the celebrated White House, and I accompanied their advance to Gains Mill, on the edge of the valley of the Chickahominy.

I may here mention that I came among the Americans a perfect

stranger, with no introduction of any sort or kind, but that after I had got clear of the Washington officials, by whom my journey had well nigh been frustrated, I was shown every possible attention, received at the head-quarters of the army with hospitality, and given every facility for going and seeing where and what I would.

It was at Gains Mill that I first saw the balloon. It was then with the advance guard of the army, under General Stoneman, the main body being some two days' march behind, and so far as I could learn no difficulty had been experienced in causing the balloon to accompany the advance, which, indeed, is its proper place. It can be allowed in still weather to rise some 20 or 30 feet, so as to clear obstacles, and the men holding the guy lines, march regularly along. If the wind be at all high, it is necessary to discharge the gas.

The staff and apparatus were as follows:—one chief *aéronaut*, professor, and a civilian, but who was given, I think, military rank; one captain's assistant, and 50 non-commissioned officers and men. There were then present with the army two balloons, and two generators. Whenever the weather was sufficiently calm, the balloon was up hovering over the camp at altitudes varying from 500 to 1,000 feet, and reports were sent in daily, or oftener if need be, of the observations taken, noticing any change that might have taken place in the disposition of the troops, or appearance of any works visible. Evening and morning were found to be the times generally best suited for observation, as the air was clearer and the shadows were larger.

The balloons were made of the best silk, very strongly sewn, and were inflated with hydrogen produced from two generators, which were simply large wooden boxes, lined with some material not acted on by sulphuric acid, and mounted on wheels, each being capable of being drawn by four horses. The gas was generated by the action of sulphuric acid and water on iron, and was passed through two lime purifiers before being delivered cool into the neck of the balloon. The balloons kept their gas for a fortnight, that is, having been filled up, they still retained, after that time, sufficient ascensional power to be of use.

The guy lines were three in number, one thicker than the other two, the intention being that one should take the main strain, the others acting simply as guys.

The method of manipulation was carried out as follows: the main rope was passed through a snatch block firmly attached to the ground, and each of the three having been manned by some ten men, the machine was allowed to rise. Communication was maintained when the altitude was small, by shouting, and at 1,000 feet, messages were written on a bit of paper, and dropped with a stone to the ground. Telegraphic communication was also established. Indeed, at the battles that resulted in McClellan's being driven back from Richmond, the instrument in the car of the balloon was in communication with the line wires leading to Washington, so that the President sitting in his closet might literally receive earlier intelligence than the general in the field, of the turn the battle was taking; this, however, was a vicious refinement, for it is needless for me to point out, that the only

information the government should receive, ought to come direct from the general in command.

It may be well here to explain the position of the army at the time I actually saw the balloon used.

M'Clellan, who was in command of the army of the Potomac, especially destined for the capture of Richmond, had landed with his forces at Fortress Monroe, an ordinary bastioned work on the extremity of the Peninsula, formed by the York and James rivers; he had advanced against the lines of Yorktown, which stretched from river to river some 30 miles above Fortress Monroe. The Confederates abandoned their position so soon as M'Clellan's arrangements for shelling it had been completed. I do not think, however, they had any further intention than that of delaying his advance as long as possible. Past Yorktown, he advanced, with his right resting on the York and Pamunkey rivers, until he reached the White House situated on the latter, at the point where it is crossed by the West Point and Richmond Railway. Here he left his water base of operations, and was obliged, for his supplies, to trust to land carriage. From the White House to Richmond is some 50 miles, and Gains Mill, which is on the bank of the,—so to speak,—Chickahominy valley, is about 10 miles from Richmond. The army, 100,000 strong, took up, in the first instance, a position entirely along the banks of the Chickahominy, some six miles on either side of Gains Mill. The left was then thrown forward across the stream, and this was the last onward movement made, as the Confederates succeeded in repulsing the advance, and at the same time attacking the White House position, cut off M'Clellan from his base of operations, and obliged him to beat a hasty and disorderly retreat to the cover of his gunboats on the James river.

Nature, in that part of Virginia, is prolific in vegetation. A great part of the land is still covered with trees, and as the ground is undulating, it was very unfavourable for making a reconnaissance. At Yorktown many ascents were made, but I did not hear that they had been attended with any advantage beyond the indirect one of looking into the enemy's works. No sorties of any importance were attempted, hence there was no particular gathering of men to be noticed, and the prolongations of the faces of the batteries, necessary to establishing correctly the position of the counter-batteries, were known by observation from the ground, so that on the whole there was little scope for the balloon; in such a position, however, plenty of circumstances *might* arise which would prove its value.

At Gains Mill I made one or two ascents, and had there an opportunity of judging practically of the advantages to be derived from a balloon reconnaissance. From the top of the hill whence the balloon was raised, my vision was bounded all round by trees, so that I could in no direction see further than half a mile. As we rose, it was curious and beautiful to watch the gradual extension of the horizon; first, the country appeared all wood, from the eyes enfolding, as it were, the tops of the trees; next open spaces began to shew themselves nearly beneath the car, and then, as the altitude increased, they could be seen further out.

Looking more closely, I could distinguish roads here and there crossing the open, and where the direction was favourable I could trace them through the woods.

The Chickahominy, like a silver thread, half hid in the line of trees that shaded its banks, lay beneath me, all signs of its forming the centre of a valley being lost, as from the car of a balloon one cannot trace the difference between hill and plain, owing to there being nothing to guide the eye.

After getting, as it were, my air legs, and becoming accustomed to the situation, my first anxiety was to see the Confederate soldiers, and my next to look at Richmond. So far as the enemies' army was concerned, I could only see their pickets thrown forward to the banks of the Chickahominy, with their supports on the heights behind them; no army was near them, unless it was concealed in the woods, whose tree tops only I could see. These woods were certainly big enough to have contained 50,000 men, provided they remained still, and did not light any fires, both somewhat unlikely provisions.

But Richmond, the looked-for goal, the capital of rebellion, lay clear enough away to the westward, with the sun glancing on the roofs, and the church steeples showing up above their neighbouring buildings; the city, could be distinctly made out. To get that place that then lay so temptingly beneath me, more blood was to be shed than possibly any other struggle in modern war had cost; and yet at that time the Federals were confident enough, and the expectation of soon being able to judge for themselves, gave a double interest to the inquiries as to what Richmond looked like. I could see the three camps of the Confederates round the place, one of them at Manchester, on the James River, but the distance (some 10 miles) was too great for me to distinguish more than the bare fact of there being three camps, and make the very roughest possible guess at their size. I could make out earthworks, thrown up apparently to bar the main approaches to Richmond, but of their character or strength I could judge little. Had the army got so near Richmond that the balloon could have ascended within three miles, a report of the nature of the defences could no doubt have been made, which would have cost a reconnaissance supported by a strong force to have obtained it in any other manner. I was present when the firing of a battery of artillery was directed from the balloon; the circumstances were as follows:—A picket of the enemy had established themselves among the trees on the banks of the Chickahominy, in a position near to the spot selected for a pontoon bridge; it became of importance to dislodge them, as it was fancied that they were strengthening their position, but owing to its being hid by some low banks, the battery that it was thought they were making, was invisible. The balloon being up and the signals preconcerted, the battery opened fire, the people from the car telling the artillerists which way their shot were dropping. The result of the operation was that the Confederates were driven from their cover; but I cannot say in that instance that I was impressed with the advantage of artillery fire directed from the air, though there are cases, no doubt, where a balloon might be similarly

and profitably employed. For instance it is not at all an uncommon artillery problem to breach an unseen revetment, when an occasional peep to see how the work was getting on, would be most welcome.

In this country some experiments on the subject of balloon reconnaissances have recently been carried out, and will, I believe, be continued next year. Up to the present time two ascents have been made, with a view of determining as a preliminary measure, first, the value of an elevated point of observation; and, secondly, whether the car of a balloon is capable of affording such a point. Simply with reference to the above, an ordinary balloon would do, provided a sufficiently still day were chosen; arrangements were therefore entered into with Mr. Coxwell for the use of his balloon, the Government finding the gas and necessary ropes.

The disposition of guy lines was the same as that which I have described as used by the Americans.

The first ascent was from Aldershot, on the day of the Royal review, which happened to be an exceptionably still one, with hardly a breath of air. Under these favourable circumstances an altitude of 1,200 feet was obtained, and the balloon was manipulated with ease; it took some quarter of an hour to haul the balloon down from its full height, and considerably less to raise it. Practice will, however, suggest both quicker and safer methods of managing this than that then used.

From 1,000 feet high the country lay mapped out beneath me for miles, though the haze prevented a very distant view. All notion of the relative height of ground was lost, indeed it was difficult to recognise as elevations the Hog's Back or Cæsar's Camp, on which latter place the troops were being reviewed. At that distance, then some three or four miles, the movement of the troops could be seen, and the tunes played by their bands distinctly heard, though from the ground neither the one or the other could be done.

During an ascent from the Arsenal, at Woolwich, the troops were sent out in different directions, so that if possible their positions might be made out from the balloon. This was not done, though I and my companion, Lieutenant Grover, examined the ground for an hour and a-half; it should be remembered, however, that the number of men in each division was small, and though we could not say where they were, we told where they were not, and the quantity of ground thus declared to be unoccupied was considerably more than could be seen from the top of any ordinary terrestrial point of observation. Afterwards when we were about a mile high, having gone away free, and somewhere over the new docks at Blackwall, we clearly made out the troops assembled on Woolwich Common, preparatory to being dismissed to their barracks. The result of these two experiments appeared to me to show that the manipulation of balloons in the absence of wind was simple; that an altitude of 1,000 feet or less gave a sufficiently extended range of vision, and that to those who were accustomed to it, there was nothing in the car of a balloon that made it unsuitable as a point of observation.

I must however confess that reconnoitring from a balloon is not a pleasant occupation, in fact it is as unpleasant as the free ascent is

delightful, the least wind causes the huge machine to oscillate, and the motion, both in ascending and descending, given to the car by the unequal action of the ropes is disagreeable; the danger, too, is much more in a partial than in a free ascent, and much caution is necessary; the ropes cannot be made over strong, or they would be too weighty, and in the event of their breaking, the balloon, relieved suddenly of so great a weight, would shoot up like a sky-rocket, though a judicious use of the valve would no doubt prevent serious consequences. I have now done with the practice of reconnoitring by means of balloons, and shall make a few remarks on the apparatus necessary to effect that practice successfully.

To be applicable to military purposes, a balloon must possess the following qualifications:—1st. It should be readily available after the order for an ascent had been given, and it should be capable of being used in any place.

2nd. It should be capable of being used in any wind less than 15 miles an hour.

3rd. The height capable of attainment must be 1000 feet.

4th. The apparatus must be able to take up two people at least, with ballast and the necessary observing apparatus.

5th. The balloon must be so made that it can retain its gas for a reasonable time, viz., a fortnight, that is, that at the end of that time, its ascensional power must be such, that it be still capable of being used with a reduced weight.

On considering the above requirements, it appears to me that the Montgolfier, or heated air balloon, is at once excluded on account of its necessarily large size, which would make it unmanageable in any but the quietest weather; furthermore, the practical details of the heating apparatus, and danger attending its use, would be great, though perhaps not insuperable.

Gas remains therefore, and the choice lies between coal-gas and hydrogen, the advantages of the latter are its less specific gravity, which for present purposes is of great importance, as with a given lifting power, it presents a proportionably less area to be acted on by the wind, and the materials necessary for its production are more easily available, coal being a bulky article to transport, and otherwise not found usually with an army, while iron always exists in every camp, and the proportion of acid necessary to produce hydrogen gas from it is not very large.

Now a sphere with a diameter of 30' has a cubical capacity of 14,000 feet.

1,000 cubic feet of air weighs 77 lbs., and, assuming the specific gravity of such hydrogen as would most likely be used at $\cdot 1$, 1,000 cubic feet of hydrogen would weigh 7.7 lbs., and 1,000 cubic feet of coal-gas at $\cdot 3 = 23.1$. We have thus

14,000 feet of air weighing 1,078 lbs.

14,000 feet of hydrogen weighing 108 lbs.

14,000 feet of coal-gas weighing 324 lbs.

which gives with hydrogen an ascertained power of 970 lbs., and with coal-gas 754 lbs.

This power has to lift as follows :—

Netting, car, and appurtenances.....	150
Silk bag	40
Two people	300
Three ropes, 1350' long each	298
Ballast instruments and spare ascensional power	182

Total..... 970 lbs.

With that weight the machine would, if filled with hydrogen, exactly float; a few pounds of ballast thrown out would cause it to rise.

Presuming that the best description of silk is used, the powers of a balloon to resist the dispersion of gas depend entirely on the varnish. I have mentioned that the American varnish answered the purpose; hence with an apparatus constructed as above, requirements No. 3, 4, and 5 are fulfilled; there remains Nos. 1 and 2. Now, as regards the first, that it should be capable of being used in any position and within a reasonable time after the receipt of an order, it is clear that this involves a portable gas apparatus. Hydrogen can be prepared in a variety of ways, nor does it require any apparatus unsuited to the rough work of a campaign; it can be made from zinc and sulphuric acid, iron and sulphuric acid, or iron and hydrochloric acid; it can, furthermore, be generated direct from water through the means of a voltaic battery, or by passing steam over red-hot iron.

The equations that show the first methods are:—

By the first, 32.6 lbs. of zinc and 49 lbs. oil of vitriol, produce 200 feet of hydrogen, weight 1 lb.

By the second, the same is done by 28 lbs. of iron and 49 lbs. of vitriol.

By the third, by 28 lbs. of iron, and 36.5 lbs. of hydrochloric acid.

The three as regards material to produce a given amount of gas, being as:—

81.6 : 77 : 64.5.

Now the balloon requires 108 lbs. of hydrogen which, to produce, will necessitate the consumption of (taking the second as the most desirable process) 3,024 lbs. of iron, and 5,292 lbs. of vitriol. These figures are theoretical, and supposing the chemical action to be complete; (which in practice it would not be) it might be thought at first sight that hydrogen would be obtained at a less cost of material by the battery and water process; this would not, however, be the case, as is apparent when it is considered that for a given amount of gas a given quantity of zinc must be consumed, and whether it takes place within the generator or separately in the battery, matters nothing.

I think that very possibly the last process mentioned, that of

passing steam over iron, heated red-hot, may be found an advantageous one, but I believe its action is uncertain. The question of the production of hydrogen upon a large scale has never yet, so far as I know, been thoroughly experimented upon, because the necessity for it has not existed; but in the event of a balloon apparatus for war purposes being got up, it would receive due attention. I am inclined, however, to doubt whether, all things considered, any process will be found better than that with sulphuric acid and iron. The amount of acid required to be carried is not very serious, and iron in the shape of old shot, tires of wheels, &c., is plentiful with any army on active service. Still, to provide against contingencies, provision should be made for distilling gas from coal or wood, if circumstances should render it necessary to do so, the arrangements for which, when the material is forthcoming, would be simple enough. Now as to the last and most difficult requirement of all, viz., that the balloon should be capable of being used in any wind not exceeding 15 miles an hour. I quite agree that this is a *sine quâ non*, as the value of the apparatus would be materially impaired if it could only be of exceptional use; and so far as I know, no actual ascents have been made under these circumstances; indeed it would be useless and dangerous to attempt them without a specially constructed apparatus. I am speaking, of course, only of partial ascents. On both the days when I ascended in England, there was no perceptible wind on the earth further than a mere breath.

The mechanical condition of a balloon acted on by the wind, and kept to the ground by ropes, will be readily seen, and provided the current of air be constant, the difficulty would easily be got over. The ropes having taken a proportionate angle, the balloon would remain steady, but the fickleness of the wind makes this impossible, and on the pressure being taken off, the balloon would rise rapidly, to be as quickly thrown down again when the next gust came; in addition to which, the unequal action of the air on the silk would cause the balloon to struggle in such wise, as to make the car a very unpleasant mode of conveyance. In these matters there is a wide difference between theory and practice; theory says the ropes won't break, and if they do not, it is no more difficult to sit in the rocking car of a balloon than in a boat bobbing about on the waves; but practice says, there is a considerable difference; if any one doubts it, I can only say, let them try. I believe, however, that with properly constructed apparatus, partial ascents may be made, notwithstanding a tolerable strength of wind; but practice alone can prove this, and it would necessitate very careful experiments, advanced by degrees, as confidence was gained in the machine.

The force impelling the balloon downwards is in direct proportion to the area exposed for the wind to act upon, hence the size of the balloon and ropes should be as small as possible. With this view I would make the ropes of silk, when they would have equal strength with considerably less size. I am not clear about it, but I think that the shape of the balloon, too, might be altered with advantage, if a balloon were given a cylindrical shape and anchored head to wind, it would ride

somewhat like a ship in a stream-way. The advantage would be gained, however, at the expense of weight, as the sphere is the form of greatest capacity for a given surface; and further, of convenience, as there are considerable practical difficulties in the way of employing any but a globular shape, owing to the unequal strain on the netting, to which an elongated form would be subject. A more likely scheme to answer, though, perhaps at first sight somewhat wild, is to combine the principle of the kite with that of the balloon, and so make the untoward force of the wind correct itself.

Ballooning is yet quite in its infancy, and the first apparatus got up for military purposes would, doubtless, receive many alterations, which practice alone could suggest. Still, in my opinion, it is even as the art at present stands, capable of useful application, and if it failed to answer all expectations, the failure would not be great, nor the experiment costly.

In conclusion, though I fear I have already overstepped my time, I beg to offer a few remarks on the subject of aerial locomotion, which has always some interest, but which lately has attracted especial attention; Nadar having brought over a big balloon, for the avowed purpose of collecting funds, with which to carry out his theories of air travelling, which, so far as I understand them from his writings, are remarkably visionary.

Supposing a hook to be put in the sky, and a balloon anchored to it, the wind would press on that balloon with a force depending on its velocity, and the area of the balloon.

Now, it is found that the pressure of the air on the surface of one square foot is equal to .005 lbs., and the pressure increases as the square of the velocity, because in a given time, with double the rate of motion, not only twice the number of particles strike, but they strike with twice the force, hence, at 15 miles per hour, the pressure would be 1.107 lbs.

Assuming the case of a balloon 30' in diameter, which is the size of the one I have spoken of previously, the area will be 675 feet; hence, neglecting the difference which would be caused on the one side by the spherical shape of the balloon, and on the other by the resistance of its cordage, car, &c., the total pressure exerted by a wind, moving at a velocity of 15 miles per hour, would be 742.5 lbs. Now the effect is the same so far as the balloon is concerned; whether it be stationary and the wind moving, or the air stationary and the balloon moving, which latter is the case in point.

To impart, therefore, to the balloon, a motion of 15 miles per hour, would require a continual pressure of 742.5 lbs.; now, with the very lightest possible description of machinery, and with that machinery made in the lightest manner, it might be possible to construct an engine, which would give a duty equivalent to 742.5 lbs. pressure, and yet be within the weight which the balloon could lift, viz., 970 lbs.

At first sight, one is apt to jump at conclusions, and fancy that the thing is done, but the greatest difficulty is yet to come; the engine may be ready to give the power, but it is useless unless it has some fulcrum against which to act, and the loss of power is so great in

obtaining a fulcrum from the air alone, as practically to render available only a very small proportion of the power at command, the remainder is consumed in giving the necessary velocity to the screw, or other machinery used.

This will be readily understood, if we think over the following considerations: a corkscrew, working into a cork, at each revolution advances the distance between two threads; the screw of a steam-vessel does not, but for every ten turns advances, say only nine times the difference between the two threads, or what is the same thing, nine times the pitch of the screw, this difference being called the slip. Now this is owing to the mobility of the particles of water, which themselves are driven back, and the slip would increase with the facility of these particles for motion, or, in other words with the mobility of the fluid, air being infinitely more subtle than water, the slip, in place of being $\frac{1}{10}$ th would be $\frac{9}{10}$ ths (I am not, of course, now using figures, other than as illustrations, they are not correct), hence, of the force which was at command, 742 lbs., only 76 lbs. would be available to drive the balloon, which would correspond to a velocity of $1\frac{1}{2}$ miles per hour. The remainder, 666 lbs., being wasted in keeping the necessary machinery in motion.

That this reasoning is correct, that little toy very clearly shows, which is usually brought forward by enthusiastic aeronauts in support of their theories, I mean the flying top, which consists of light vanes fixed on a shaft, to which is given a rapid rotatory motion by means of a string. While the rotatory motion is sufficiently rapid, the top continues to rise; the vanes may not be very mathematically set, but I doubt whether any theoretical setting would alter the effect, and it will be seen that it takes a very strong pull, amounting to some pounds, to enable the machine to rise, though itself perhaps weighing an ounce or two, thus showing the amount of power wasted, so to speak, in obtaining a fulcrum.

Now, I deduce from this, that all theorists who hope to attain aerial locomotion by any combinations of steam-engines, or by altering the known appliances of vanes, screws, &c., come under the class of people who do not understand their subject. The real points to be obtained, to enable aerial locomotion to become a *fait accompli* are two, either, and principally, a new motive power must be discovered which shall combine a greater power with a less weight, or some means must be found of obtaining from the air a fulcrum as available as that furnished by water.

It will be seen, however, that even with the assumption I have made, I have got a speed of $1\frac{1}{2}$ miles per hour, which may be said to be something, and, I think, that very possibly even 10 or perhaps 12 miles per hour, might be got; but were that speed gained, beyond its curiosity and the credit attaching to the first step in a new science, nothing practical would have been obtained; for in the stillest day there are currents of air moving from 10 to 15 miles per hour, against which the balloon could barely hold its own, and from 20 to 25 miles I suspect to be the more ordinary rate of the air, some half mile from the surface of the earth.

If, however, even in such a wind, a rate of motion of 10 miles per hour could be given, it would render balloon journeys less hazardous, as at the end of one hour's travelling the aeronaut would have the power of changing his position within 10 miles on either side of a given spot.

Under existing circumstances all plans of doing without a balloon, and imitating the top, may be put on one side at once as visionary; from what I have shown above, a weight of 970lbs., gives an effective pressure to counterbalance it of only 76lbs.; hence the machine must fall. Toys have been made with springs which support themselves until the springs are run down, which toys lead people at first sight to think the thing is practical. They forget, however, that the little spring when wound up represents the whole force, which has been put into it extraneously, and in reality has nothing whatever to do with the real question, unless the power which wound up the springs were supported by the machine itself. If, even it were possible, the fearful danger of making the safety of the apparatus, depend on the continuous action of a complicated piece of machinery, would be such that few but maniacs would make the experiment.