The AMA History Project Presents:
Biography of SIR GEORGE CAYLEY

December 27, 1773-December 15, 1857

Written by JEH (8/1923); Transcribed and reformatted by JS (9/2010)

The following was published in the December 17, 1923 issue of Aviation Magazine, *written by J.E. Hodgson, previously published by The Journal of the Royal Aeronautical Society in August of 1923*

Sir George Cayley's Work in Aeronautics

Early Pioneer Originated Airplane Flight Theory and Anticipated Metal-Hull Airship

Among the world's great aeronautical pioneers, Sir George Cayley holds a place the importance of which is not generally realized, if it is not totally overlooked by the contemporary flying world. His principal claim to lasting fame lies in his remarkable ability to grasp and expound the basic principles underlying the theory of power flight with machines both lighter and heavier than air at a time when contemporary knowledge of the subject was, almost without an exception, a tangled web of fallacious speculations. As a pioneer of the airplane, Sir George ranks particularly high, for he was the first, as far as is known, to reduce the problem of mechanical flight to terms of engineering, and to test-in 1809- the results of his laboratory work by means of gliding experiments.

The twentieth anniversary of the definite solution of the problem of mechanical flight by the Wright brothers makes it therefore particularly timely to recall the main points of the work done by Cayley in furtherance of air navigation. The account which follows is taken from an excellent paper read by J.E. Hodgson before the Newcomen Society in London, England, which was published by The Journal of the Royal Aeronautical Society *of August 1923.* – Editor

Sir George Cayley was born at his ancestral home Brompton Hall, in the North Riding of Yorkshire, on Dec. 27, 1773. The bent of his mind toward scientific pursuits became apparent in early years, and it is said that his interest in aerial navigation was inspired when he was not more than 10 or 12 years old by the Montgolfiers' discovery of the balloon. As he himself relates, his first experiment in aeronautics was made with a Chinese "flying top" in the year 1796, and it is significant of his steadfast attachment to the subject, that as late as 1854, he sent a description of an improved type of this aerial toy to the distinguished French aeronaut and writer, Dupuis-Delcourt. In 1795, he married Sarah Walker (the only daughter of Rev. George Walker, F.R.S., and President of the Literary and Philosophical Society of Manchester), by whom he had a large family.

Early Contributions on Aeronautics

His first published contributions on “Aerial Navigation” (mechanical flight) appeared in *Nicholson’s Journal of Philosophy* in 1809-10; in 1816-17 he expounded in the pages of Tilloch’s *Philosophical Magazine* his ideas on navigable balloons, a subject to which he returned in letters published in the *Mechanics’ Magazine* in 1837. Further contributions (suggested by the discussion on Henson’s “Aerial Carriage”) to the latter periodical in 1843, with two articles in the Bulletin of the “Societe Aerostatique et Meteorologique de France” in 1853, complete the record of his extent writings. It can hardly be doubted that these cover but a small part of all the investigations, calculations, and experiments made on aeronautical matters over many years. Of his life and scientific labors apart from aeronautics, little is known. Politics and the affairs of the family estates doubtless occupied much of his time, but it is clear that his chief concerns were science and engineering in general, and aeronautics in particular. He built a shed or outhouse at Brompton in which he conducted a large number of experiments on the application of electricity as a motive power, and on the development of the gas engine. In the latter direction, he contributed to Nicholson’s Journal in 1807 a “Description of an engine for affording mechanical power from air expanded by heat,” but though constructed at Newcastle on what Cayley termed “a considerable scale,” it proved unsuccessful.

Later in life, he accepted the congenial office of chairman of the old Polytechnic Institution, while in 1852 he stood successfully as parliamentary candidate for the borough of Scarborough. He retired after two years and died at Brompton Hall on December 15, 1957.[1.]

Of Cayley’s character, it is difficult, from the meager knowledge available; to form a true conception, but the amplitude of his views on aerial navigation suggests a mind of great breadth of view, endowed with remarkable imaginative foresight. For as early as 1809 he expressed complete confidence in the practicability and security of mechanical flight as a method of transport, at a speed exceeding that of the railway train, and by 1816-17 he was advocating the navigable balloon with even stronger conviction, as offering “a direct, swift and easy floatage from any one point to every other on the face of the globe.” His large conception of air travel cannot be more forcibly expressed than in his own words. “An uninterrupted navigable ocean,” he said, “that comes to the threshold of every man’s door, ought not to be neglected as a source of human gratification and advantage.”

State of Contemporary Aerostatic Science

I pass to outline, as briefly as possible, the state of the science of aerostation, particularly with regard to the direction of control of balloons, at the time when Cayley first turned his attention to the subject. It is well known that the balloon was invented by the brothers Montgolfier in 1783 and that in October of that year Pilatre de Rozier first ascended into the air in a balloon of the Montgolfiere – that is a balloon inflated with hot-air rarefied by means of a fire burning a brazier.

1. It must have been a great source of satisfaction to him to live to hear of the first successful flight of a steam-driven airship, accomplished by Henri Giffard, in 1852, near Paris. - Editor

In the following December this method of inflation was improved upon by J.A. C. Charles, who introduced the use of hydrogen.

It was realized almost at the outset, that the use of the balloon as a method of aerial travel would be greatly limited, unless it were possible to devise a method of control. Oars or wings, consisting of a light framework covered with silk or other material, were the first forms of mechanism designed to afford manual propulsive power, J.P. Blanchard, in March 1784, being the first to experience – though not to admit – their inefficiency. Other projects tried or suggested were forms of jet propulsion (by means of hot-air, on the principle of aeolipyle of the ancients), or by the reaction of gunpowder exploded in the form of rockets. Yet another method – invented by David Bourgeois in 1784, which also engaged the attention of Montgolfier in France, and (at a slightly later date) of R.L. Edgeworth and Cayley himself in Great Britain – involved the use of an adjustable plane surface fitted beneath the balloon, whereby to obtain some measure of control from the pressure of air on such plane during the rise or fall of the balloon.

Of the great majority of these early schemes, it need only be said that they were faulty in theory or futile in application. An important exception must be made, however, in the case of the theoretical examination of the principles involved, undertaken by J.B. Meusnier, equally distinguished in military, scientific, and mechanical achievements. As early as December 1783, he prepared a memoir in which he suggested the need of making the form ellipsoidal, and introduced the use of the air ballonet. Meusnier's work and the drawings and plans which accompanied it, are very remarkable, as well in respect of form and the ballonet, as in his ideas of diagonal rope suspension of the car and in the application of airscrews – worked, of course, by manual power – for propulsion. The airship – it deserves to be so termed, if only for the fact that it was designed to be 260 ft. in length – was never constructed, and the only contemporary test of the ballonet principle was in its profitless application to the elongated free balloon of the brothers Robert, in which they made ascents during July and September 1784.

An air ballonet was, however, incorporated in the design of a "fish-formed" balloon invented in 1789 by Baron Scott, a French officer, who may possibly have taken his idea of shape from the so-called "Flying Fish" aerostatic machine exhibited in Cornhill in 1785, which there is reason to believe was the work of John Hoole, son of Samuel Hoole, watchmaker and mechanician, and (more notably) the friend of Dr. Johnson. Scott's ideas more probably inspired S.J. Pauly, a Genevan gunsmith, who actually constructed a "fish-formed" dirigible, which he tried with some measure of success at Sceaux in 1802, deriving an inadequate propelling power from the use of wings or revolving oars. In 1815, he came to London, and with the financial help of Durs Egg, a noted London gunsmith, the "Dolphin Balloon" was commenced at Kensington. The envelope – about 90 ft. long – was made of layers of gold-beaters' skin, and it was to contain an air ballonet of 21 ft. in diameter, horizontal stability being maintained by means of an adjustable weight suspended between the tail of the balloon and the car. A more important feature was the intention to obtain "the propelling impetus" from "a kind of atmospheric steam engine, invented by Mr. Collier." But financial and other difficulties proved insuperable, and "Egg's folly," as it was called by the cynics, was never completed. It represents however, in the main, the stage the navigable balloon had reached in Cayley's day, the chief features being the shape - tending toward streamline – the air ballonet to preserve that form, the suspension of a gondola or car beneath the envelope, and the suggested use of steam as a prime mover.

Cayley's Work on Dirigible Balloons

Coming to Cayley's own work on dirigible balloons, it has been already mentioned that his first published essays on the subject appeared in Tilloch's *Philosophical Magazine* during 1816-17. It is true that his earliest writings on aeronautics dealt with mechanical flight, but I take his contributions to "lighter-than-air" theory first, because his ultimate faith in the success of aerial navigation over the world's surface was based on the possibilities of the navigable balloon. He made this clear beyond dispute in one of his last letters on the subject. He pointed out that it had been proved that elongated balloons of a large size were capable of being driven through calm air at a speed approaching that of the railway train, and could carry a considerable cargo by reason of their buoyancy. From these premises, he argued that "on a great scale, balloon floatage offers the most ready, efficient, and safe means of aerial navigation." "Elongated balloons of large dimensions," he wrote in the same paper, "offer greater facilities for transporting men and goods through the air, than mechanical means alone, inasmuch as the whole weight is suspended in the air without effort…and when the invention is realized, it will abundantly supply the increasing locomotive wants of mankind." Moreover, he gave prophetic utterance, with remarkable foresight, to the view, which after much ebbing and flowing, has in quite recent years received the support of distinguished aeronautical experts – the view that the relation of airships to airplanes is complementary and not competitive. "Mechanical flight," Cayley wrote in 1843, "seems more adapted for use on a much smaller scale, and for less remote distances; serving, perhaps, the same purpose that a boat does to a ship, each being essential to the other." [2]

Broadly speaking, it was Cayley's ability to grasp the basic scientific or mechanical principles underlying the theory of navigable balloons, rather than his skill as an inventor or designer, wherein lies his true greatness as a pioneer of the airship. He was, for instance, one of the first to realize fully the practical significance of one of the main factors on which airship theory rests – namely, the physical law that "the surfaces (and hence the resistance) increase as the squares of the diameter of the balloon, whereas the capacity to contain gas (and hence the supporting power) increases as the cubes of the diameter." If it were not for that principle, he knew quite well that the difficulties would be far greater. As to the factors involved in the question of resistance, he pointed out (as indeed others had already done), that obviously the spherical form of the ordinary free balloon should be lengthened horizontally, thus diminishing the cross-section for the same volume, and he realized the desirability of dividing the gas into several compartments.

With more originality the even suggested that dirigibles, "when used as permanent vehicles and on the true scale of magnitude, will probably be made of thin metallic sheets kept firm by

2 – The importance Cayley attached to the advantages of the airship is revealed in the fact that while he first stated them in the *Mechanics Magazine*, March, 1837, he not only reprinted them (as an interpolation), but enforced them in the final paragraph of his essay on mechanical flight, contributed to the same magazine in April, 1843.

condensation [that is pressure] with separate light bags of gas within." For a first experiment on these lines, he suggested that Charles Green's large balloon – presumably the famous "Nassau Balloon" of 1836 – should be requisitioned, and that two other balloons of smaller size should be "packed at opposite sides of this larger one," a suggestion which, however, was not tried. Of greater interest in his early anticipation of some degree of rigidity, revealed in the proposal to guard against the then unknown laws of resistance offered by fluids to solid bodies, but means of "light poles and internal cross bracings of wire or cord," designed to preserve the shape of his elongated spheroidal balloon.

Moreover, Cayley carefully considered the problems affecting the transmission of power from an engine suspended in a car beneath the envelope to the balloon itself- a point of particular moment in his own design owing to the need of keeping the boiler and furnace of the steam engine which he proposed to fit as far as possible below the envelope. As to his "prime mover," he had perforce to adopt the steam engine, but it is, I think, quite clear that he realized it was by no means an ideal form of power for the purpose, and there is reason to believe that his experiments, both with gas engines and electricity, were largely inspired by the idea of running those sources of energy to account in aeronautics.

With regard to the fabric of the envelope, which necessitated, as Cayley laid down, a material 'perfectly air-tight, light and strong," he suggested that the great expense of silk (covered with India-rubber varnish) would be prohibitive, and proposed as an alternative "double-cotton Indian-rubber cloth," as invented in 1823 by Charles Macintosh for waterproof garments and air-tight cushions. In this connection, it is of interest to note that Cayley's work was not wholly theoretical, for in 1816 he refers to a cloth weighing ½ lb. per sq. ft. as used in "my experiments."

Cayley's Airship Designs

In his first design of an airship, as communicated (with accompanying plans) to Tilloch's *Philosophical Magazine* in 1816-17, he provided for a Montgolfiere or hot-air balloon 300 ft. long, 45 ft. in elevation, and 90 ft. wide, made of "woolen cloth." In form, it was an elongated spheroid, with a conical head and a slight tapering toward the stern – on the axiom common among sailors, that a ship to sail well should have a "cod's head and a mackerel's tail" - and it was to be kept to its shape by the light poles and cross bracing before mentioned. The impelling power was to be derived from the deviation obtained from the pressure of air on a passive plane surface, a wholly inadequate method, the idea of which, as Cayley admits, was derived from the plan described by John Evans a year earlier.

In his next essay, Cayley goes far beyond his original ideas, and offers calculations based on the possibility of propelling an elongated balloon by wing waftage – that is, wings fitted to the sides of the car and actuated by mechanical power. He expressed a preference for this (mistaken) form of propulsion as against "rotary wafts" or airscrews, mainly owing to the difficulty of "giving firm support and communicating motion to the latter," though admitting the advantage they afforded of uniform action. This improved design was to be 144 ft. long, with a lift of 163,000 lb., which reduced by the weight of the materials (1,700 lb.) and of the engine, boiler, fuel, etc. (15,210 lb.), would leave about 34 tons. Stated in terms of performance, Cayley estimated that this would allow of the transportation of 50 men for 48 hr., on a voyage of 960 mi. in calm air.

Further consideration of this "balloon of 50 tons" led him to comment on the difficulties involved in the "stupendous bulk" – difficulties arising from expenses of construction and inflation and difficulties in "disposing of them when not employed." He does not appear to have contemplated the construction of immense airship sheds, such as have been erected in recent years, for he made calculations on the "horizontal drag" of large balloons at anchor, from which he deduced that this drag diminishes with size and oblong structure. Indeed, at a later date he laid down that "permanently-filled balloons would ride out storms when properly secured, without the danger of being driven to the earth or damaged."

Problem of the Prime Mover

In 1837, he revised the foregoing speculations in a lengthy communication to the *Mechanics Magazine*, wherein he sought to present considerations, which would be "most conducive at present towards a final accomplishment of the aerial object in view." His elaboration of the "inclined plane" method of propulsion involved the combination of a large Montgolfiere below and a smaller hydrogen balloon above, separated by the plane. But apart from the danger of such a combination – a danger experienced with fatal results in 1785 but Pilatre de Rozier – the method was not worth even the brief consideration Cayley gave to it. Moreover, the twenty years or so, which separated his essays, had resulted in improvements in the steam engine, which by 1837 gave promise of greater power for weight. In this connection, Cayley referred to the steam carriage of his friend Sir Goldworthy Gurney, the engine of which he calculated would give one horsepower for 200 lb. weight. But though he recognized that "lighter first movers than steam engines may be discovered, and made applicable to propelling balloons," he proceeded to take the case as he found it. With a hydrogen balloon of a similar shape to his original design, 90 ft. in diameter and 315 ft. long, he estimated there would be available for engine power, crew and cargo, a lift of about 29 ¼ tons. He further estimated that a balloon of this size would require an engine of 60 hp.

As to the application of propelling power, he still adhered to the idea of wings arranged in two tiers, but he also reverted to the idea of airscrews – "oblique vanes," as he said, "reversing the action of the sails of a windmill." As to the latter, he instanced the results of experiments made by the French Academy, which went to show that "a proper fulcrum or resistance for the engine power to work upon can be had at a velocity of 25 ft. per second." Finally, reckoning the engine, with fuel and water for four hours, at 510 lb. per horsepower, and deducting also the weight of the "machinery for waftage," Cayley arrived at the conclusion that traveling at the designed speed of 14 mi./hr., his balloon would have a useful load of about 9 tons.

Cayley never attempted the construction of a large navigable balloon, but we may well believe he was only deterred by reason of the great expense. This difficulty led him in 1816 to suggest experiments by public subscription, an appeal he renewed in 1837 in the form of a proposal to organize a “Society for Promoting Aerial Navigation.” It was doubtless the indifference shown toward his proposals that led him to write in 1843-in words which, with some modification, are even today not wholly inapplicable to the prevailing attitude toward the airship – “I think it a national disgrace in these enlightened locomotive times not to realize by public subscription the proper scientific experiments, necessarily too expensive for any private purse, which would secure to this country the glory of being the first to establish the dry navigation of the universal ocean of the terrestrial atmosphere.”

Contemporary Ideas on Mechanical Flight

Turning to the general conceptions of mechanical flight in Cayley’s time, and the ideas which had led up to them, it may be said at once that there were only two points of view – the one from which flight was regarded as a matter of flapping wings, and the other as a matter of impossibility any way. The old, the very old idea of wings, was doubtless inspired by the natural, not to say obvious, analogy of the flight of birds, a sense in which the practicability of the thing was first expressed by Roger Bacon in the middle of the 13th century, while early in the 16th century the idea occupied the great mechanical genius of Leonardo da Vinci.

Indeed, broadly speaking, it is true to say that flight was invariably regarded in the light of the imaginary achievement credited by Francis Bacon to the inhabitants of his “New Atlantis,” in 1627. “We imitate also the flight of birds,” says the sage, in a marvelously prophetic recital of countless mechanical devices and scientific notions practised in that Utopian community. Those words held good for something like the next two hundred years, not only, indeed, as an expression of aims, but as a baneful conception, which blocked other fields of speculation. For that reason it is unnecessary to enter into any detail, or to recall the endeavors – more numerous, probably, than is commonly realized – made during the 18th and 19th centuries to achieve flight by means of wings. Even in the years immediately preceding the discovery of the balloon, J. B. Blanchard was engaged in futile and fruitless attempts to construct a “flying vessell.” Not that the study of the principles involved in bird flight was in itself profitless; on the contrary, Lilienthal himself regarded it as “the basis of aviation.” But up to Cayley’s day, and long after, those principles were not understood; they gave rise to the most varied and impossible speculations, and the blind attempts made to imitate their apparent characteristics diverted attention from the more strictly mechanical aspects of flight.

It is because Cayley was among the first to approach the problems of flight from the mechanical and not, so to speak, from the ornithological point of view, and because he first conducted “gliding” experiments on a considerable scale, that he deserves to stand among the great pioneers of aviation in the direct line between such names as Leonardo da Vinci in the 16th, and John Stringfellow in the 19th century.

Cayley’s Work on Mechanical Flight

It has been seen that Cayley’s first experiment in such matters was made as early as 1796 with a Chinese or aerial top (identical with the device exhibited before the French Academy of Sciences in 1784 by Launoy and Bienvenu), which served at once to illustrate the principle of the helicopter and the airscrew. Though but a toy of a few inches in length, its capacity to demonstrate certain elementary but important principles in aeronautics, made a lasting impression on Cayley's mind, and (as already mentioned) only three years before this death he sent to Dupuis-Delcourt a drawing of one which he had made – the best, he said, that he had ever seen, capable of rising 90 ft. in the air.

Having collected a body of "facts and practical observations in the course of much attention to the subject" – to use Cayley's own words – he published his first essays "On Aerial Navigation," dealing with the subject wholly from the point of view of mechanical flight, in the pages of *Nicholson's Journal* during 1809-10. The character of his observations and experiments is at once shown in his ability to grasp essential principles. His reflections on bird flight led him to the belief – confirmed by so great an observer as Charles Darwin nearly 25 years later – that flying required less exertion than was commonly supposed. But he categorically denounced the idea of flight by means of wings (worked by muscular effort) as ridiculous. In his clearly expressed conviction that mechanical flight was possible, and in his enunciation of the "whole problem" as contained in the simple but comprehensive formula, "To make a surface support a given weight by the application of power to the resistance of air," he is revealed as the earliest true pioneer of the airplane. He had perfect confidence in the practicability of transporting passengers and goods – the latter word is expressive of his large ideas - "more securely by air than by water, and with a velocity of from 20 to 100 miles per hour."

His earlier experiments in aerodynamics had revealed (the figures quoted are Cayley's calculations) that a surface of one square foot moving at a velocity of 11.538 ft./sec. generated a resistance equivalent to 4 oz., or at 17.16 it gave 8 oz. With some such data – obtained by an early form of "whirling table" – he proceeded to make gliding experiments, carried out over a number of years, on what he called "a considerable scale of magnitude" – apparently with a machine having a surface of 300 sq. ft. – and his enthusiastic description of one of the trial flights, made from the high ground behind Brompton Hall may be quoted as the first of its kind, and therefore historic and as in itself of great interest. "It was beautiful," he wrote in November 1809 "to see the noble white *bird* sail majestically from the top of a hill to any given point of the plain below it, according to the set of the rudder, merely by its own weight, descending in an angle of about 18 per cent with the horizon." Cayley states that the upward lift of this gliding machine was at times so strong that anyone running forward in it against a light breeze would be raised from the ground for "several yards together."

Considered Many Problems

But even at this date, Cayley's thoughts were also engaged on the question of propulsion, or the necessity of a "first mover" as he termed it. Realizing that a steam engine of the type invented by Boulton and Watt would be inadequate he looked more hopefully to the development of some such engine as was reported to have been designed by William Chapman of Newcastle – an early form of internal combustion engine, with oil of tar as fuel. Evidently, he intended to make some trial of a propelling apparatus with his glider, for he refers to the fact that an accident prevented his doing so.

He continued, however, to consider many other factors involved in mechanical flight – problems dealing with questions of initial velocity, the leverage on the wings, and the need for lightness in construction combined with strength. The latter he suggested for the first time might be achieved by designing superposed surfaces, as now usual in the biplane. The wings he conceived should be supported by diagonal bracing – which he termed “the great principle for producing strength without accumulating weight” – while he foreshadowed the necessity of streamline design in the maxim, that “in the art of aerial navigation every pound of direct resistance that is done away with will support 30 lb. of additional weight without any additional power.”

Henson’s Steam Airplane

On the publication in 1843 of particulars of Henson’s “steam carriage,” he returned to the subject of mechanical flight, and further explained his ideas on two letters to the *Mechanics’ Magazine* in April 1843. His criticism of Henson’s scheme, though accompanied at the outset with an expression of encouragement, clearly indicated his reasoned doubts as to its success. In the first place, “the magnitude of the proposed vehicle,” involving a terrific stress on the necessarily light structure of the main supporting surfaces or wings – 150 ft. span and 30 ft. chord, as designed – afforded ground for serious misgivings. The stress or “leverage” on the wings Cayley again suggested might be overcome by securing the required surface not “in one plane, but in parallel planes one above the other,” and he went so far as to propose a triplane, or “three-decker” as he termed it. Moreover, while expressing his conviction “that the inclined plane, with a horizontal propelling apparatus, is the true principle of aerial navigation by mechanical means,” Cayley doubted Henson’s ability to provide the “very great engine power – the *sine qua non* of the case” – which the design required.

As in the case of navigable balloons, Cayley’s design for an “aerial carriage” (which he described in the same paper) is hardly as interesting, and certainly not as sound, as his examination and discussion of theoretical principles. His plan shows that instead of obtaining the required supporting surface by means of rigid horizontal wings, he proposed two sets of superposed circular planes (designed when in motion to act as helicopters) set at an obtuse angle, and revolving in contrary directions. These circular planes he termed “elevating fliers” to distinguish them from two smaller horizontal airscrews for propelling the machine. The “framing” or fuselage was to be covered with canvas at once to increase the surface and afford protection to the engine, while a “broad horizontal rudder or tail” was designed for use in ascent or descent, and to act as a stabilizing “elevator” in flight, with a small vertical rudder for lateral guidance.[3]

[3] *Cayley’s aeronautical writings, as referred to in the foregoing, are: -*
1. On Aerial Navigation (Mechanical Flight), contributed to Nicholson’s “Journal of Philosophy,*” Vol. XXIV, 1809, pp. 164-174; Vol. XXV, 1810, pp. 81-87 and p. 161, etc.*
2. On Aerial Navigation (Dirigible Balloons), Tilloch’s “Philosophical Magazine,*” Vol. XLVII, 1816, pp. 81-86 and 321-329; also Vol. L, 117, pp. 27-35*
3. Practical Remarks on Aerial Navigation (Dirigible Balloons), “The Mechanics’ Magazine*”, Vol. XXVI, 1837, pp. 418-428; also (in the same publication) Retrospect of the Progress of Aerial Navigation, pp. 263-265, and On the*

Principles of Aerial Navigation, pp. 273-278, both in Vol. XXXVIII, 1843, and both dealing with Mechanical Flight.
4. Memoire sur le Vol Artificiel (Wing –Propelled Gliding), Bulletin de la Societe Aerostatique et Meteorologique de France,*" No. 4, 1853, pp.147-151.*
The three papers in Nicholson's Journal (No. 1) were reprinted in the Aeronautical Society's Annual Report for 1876, and again as Aeronautical Classics, No. 1, 1910; also in Means' Aeronautical Annual for 1895. The "Practical Remarks" (No. 3) were reprinted in Aeronautics*, Vol. II, 1909, p. 142, and Vol. III, 1910, p. 1.*

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