TECHNICAL MEMORANDUMS

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS.

No. 273

HISTORICAL NOTES ON AERODYNAMIC RESEARCH

By Charles Dollfus.

From "l'Aéronautique," April, 1924.

August, 1924.

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HISTORICAL NOTES ON AERODYNAMIC RESEARCH

By Charles Dollfus.

At the present time there exists no complete historical work on the scientific phase of aeronautics. This is a regrettable oversight which, it is to be hoped, will soon be remedied.

It is obviously interesting to know the names of those who were the first contributors to aeronautical science. Therefore, without claiming to give a complete history, I present in this article a summary list of names in chronological order relating to the history of experiments on the resistance of the air and its application to aeronautics.

A distinction should be made between researches of a general nature and those which were of special aeronautical interest.

The earliest tests on the resistance of air were made by such illustrious people as Galileo, Mariotte (1686), Newton, Daniel Bernoulli (1738), d'Alembert, Jorge Juan (1771), Thévenard, Robins, Euler (1777), Bouguer, Borda, Bossut, Coulomb.

Newton and Désagulliers dropped glass spheres in free fall in the air.

D'Alembert, Condorcet and Bossut made tests on behalf of the "Académie des Sciences" which were published in 1763 and which served as a foundation for the greater part of the succeeding work especially with whirling arms.

The experimenters of the 18th century all used the method of the body moving in the air at rest and almost always by means of a whirling arm, as did Robins and Ellicot about 1750. Borda in 1763 used a whirling arm and a pendulum utilizing square plates; the values he found were: $z = 0.69$ and $K = 0.092$. Coulomb between 1780 and 1790 used a whirling arm as did Vince (1778 - 1782). The latter with a circular plate found that $K = 0.082$ and $z = 0.67$. Vince also tested oblique resistances as did Hutton in 1788. Woltmann at Hamburg used the same method between 1780 and 1790 as did the Englishmen Rouse and Smeaton (the great lighthouse constructor) in 1759 and 1782, Edgeworth (1783) and Hutton (1786). The last with a thin square plate of 0.11 m^2 (.118 sq.ft.) found that $z = 0.62$ and with a plate of 0.021 m^2 (.226 sq.ft.) $z = 0.72$. Hutton also made experiments on resistance at speeds of ballistic bodies which his compatriot Robins had commenced about 1742. Borda, Hutton and Vince studied with the whirling arm the effect of the shape of solid bodies: prisms, cubes, cylinders and hemispheres.

Rouse appears to have been the first to apply to air the method of Mariotte for water: a fixed body in a moving fluid, by submitting the surfaces to the direct action of the wind.

It is the greatest genius of aviation, George Cayley, who appears to have been the first to devote aerodynamic researches to aeronautical applications. It was, in fact, for his airplanes that he tested surfaces by means of a whirling arm in the first years of the 19th century, which tests he described in his masterly

"Aerial Navigation" in 1809. After reading the text of this book with its sound and definite ideas on the aerodynamic efficiency of airplanes and on the streamlining of their parts it appears most probable that he carried aerodynamic tests still further but the documents are lacking which would reveal the complete work of this investigator.

From 1835 to 1839 a group of officers of considerable worth made at Metz a series of tests as well at speeds of ballistic bodies as at usual speeds. Piobert, Morin and Didion employed for these tests an apparatus in which the surfaces, guided by a silk thread, while falling turned the pulley which indicated the descent on a Morin recording instrument. The speed was from 8 to 9 m (26 to 30 ft.) per second. Another apparatus raised the body to be tested. A windmill with twenty blades was also used. In 1837 Didion gave to the Scientific Congress of Metz a communication entitled "Investigations on the Greatest Speed Obtainable in Air Navigation."

Other technical officers devoted themselves to this problem: Thibault at Brest in 1826, with a windmill, Duchemin, Poncelet and du Buat. The last established the paradox which bears his name and like Duchemin demonstrated the shortcomings of rotary tests. Thibault exposed thin planes mounted on springs to the direct action of the wind; he also studied curved surfaces and the phenomena of interaction.

From 1848 to 1850 Pierre Jullien of Villejuif, an investigator as modest as he was clever, made methodical tests on solids of good penetration by utilizing, as did Charles Renard much later, wood test pieces of various forms and of studying their movements in water. He likewise made interesting experiments with propellers.

The first aeronautical society of Dupuis-Delcourt, the "Société Aérostatique et Météorologique de France," which has stimulated so much good work, published in its Bulletin of 1853 a very clear note by M. Franchot describing a program of aerodynamical research on models of balloons and inclined planes to be made with an anemometric balance placed on a railway car or attached to a whirling arm.

Between 1864 and 1868 the famous British pioneer of aviation, Wenham, tested fixed surfaces in the current of air produced by a fan. It appears that to him is due the first application of this method now universally used in aerodynamics. He also made tests on superposed planes and planes with small chord.

In 1870 a scientific commission which included Hervé-Mangon and Durand-Claye, attempted to measure the air resistance of a spherical balloon of 650 m³ (22954 cu.ft.) volume inflated and towed by a car in the great hall of the Orleans railway station in Paris.

In 1872 the "Société Francaise de Navigation Aérienne" began the meetings where the methods of measuring the resistance of air for aviation and aerostation have so often been described. One name is of considerable importance, that of Alphonse Penaud, who took the greatest part in the discussions and made many experiments himself with a whirling arm constructed of steel in which every effort had been made to reduce the causes of vibration, with surfaces falling or rising in a straight line and with streamline bodies (a streamline balloon tested in free fall under the cupola of Val de Grâce in 1875; wood models displaced in water, etc.). It is to be hoped that the existing collection of these works and notes, unfortunately incomplete but most interesting, will be published in their entirety. They can be found in the valuable collection of "l'Aéronaute" from 1871 to 1878 and in an extremely rare booklet "Recherches sur la Résistance des Fluides" (1878).

Among others who worked on this question may be mentioned Joseph Croce-Spinelli, who described in 1874 a recording apparatus composed of a vertical surface moving horizontally on a cable with a drum inscribing the pressures, speeds, etc.; de Louvrie; Jules Armengaud, who proposed to test surfaces in front of the fan of MM. Geneste and Herscher 3 m (9.84 ft.) in diameter; David Napoli, engineer of the Eastern Railway Company, who was chairman of the "Commission d'Etudes de la Résistance de l'Air" at the Aeronautical Congress of 1889, and who was about to test on a truck an apparatus including a movable plane of 1 m² (10.76 sq.ft.) in area when death interrupted his work (1886-1890).

Marey before 1874 had measured on a whirling arm the resistance of birds' wings which were attached to chariots and moved in a horizontal line. Another whirling arm was used to record manometrically the resistance of the air, the body to be tested being composed of a Marey capsule.

In 1874, G. Hagen informed the Academy of Sciences of Berlin of the result of his tests with a windmill developed from that of Borda. The blades were 2.5 m (8.2 ft.) long. These tests, very carefully carried out, were made with square and round plates of small dimensions.

Charles Renard who experimented on much the same lines as Penaud, made many practical tests on the resistance of air beginning in 1875. In the unpublished papers which I have been so fortunate as to find recently and which will be deposited in the Aeronautical Museum, he mentions tests made below the cupola of Val-de-Grace with paper ballonets of various shapes (1878). Later he adopted the same method for tests on the resistance of air with ascensions of large balloons carrying passengers (1891 - 1895).

The great Alsatian engineer, G. A. Hirn, presented in 1881, to the Royal Academy of Belgium, an important note on the resistance of air as a function of temperature. In that note he described and illustrated three windmills, one with a horizontal axis, another with a vertical axis, and a third very specially designed to avoid errors due to the centrifugal force having blades parallel to each other which always remained in the vertical plane when the axis of rotation was horizontal.

In 1883 Goupil began aerodynamic tests with a whirling arm operated with a weight; later he exposed to the wind various bodies, notably thick lifting surfaces the thrust of which was balanced. The speed of this air current was known by an anemometer. Later, in the last years of the 19th century, Goupil built a true dynamometric balance for testing bodies in these conditions as well as a vane presenting a surface mormal to the wind, the resistance of which was recorded on a quadrant.

Otto Lilienthal published in 1889 the results of remarkable tests which he had made since 1871 with very simple equipment. He first measured the resistance of the air by means of an ordinary whirling arm and then he made many tests of fixed surfaces in an air current. These surfaces had many shapes, the wing tips being straight or curved, particularly the latter; also the surfaces were of various thicknesses, conditions which had not previously been much studied. The planes, of thin metal, of wood or of wicker covered with paper, were carried by a balanced vertical or horizontal strut. Lilienthal was thus able to make a large number of observations of the greatest interest; he derived from them the practical methods for the construction of his gliders to which contemporary aviation is so greatly indebted as I have already had occasion to bring out.

Lilienthal demonstrated the superiority from the aerodynamical point of view of testing fixed surfaces in a current of air rather than testing models with a whirling arm.

In 1885 Horatio Phillips, in England, made some extremely interesting tests on wooden models of wings intended for a multiplane airplane. For his tests he used the first aerodynamic tunnel the existence of which is certain and which was described at the time in "Engineering." This tunnel of square section, 1.83 m (6 ft.) in length, was prolonged by a diffuser of the same length with a diameter of 0.61 m (2 ft.) at the mouth of the exit cone and 0.20 m (8 in.) at its smallest section. At the exit of the tunnel and directed into the diffuser was a ring pierced with holes from which escaped a powerful jet of steam which produced a regular current of air having a speed of 18 m (59 ft.) per second.

The wings were placed in the tunnel, attached at the leading edge to two pivots and carried a weight on the rear third of the chord. The horizontal thrust was measured by weights placed on a scale pan attached by wire to the wing. Shutters permitted the air admitted into the tunnel to be reduced. Results of great importance were obtained with wings of curious curvature which it should be interesting to compare with modern wings.

Almost at the same time a series of investigators appeared all of whom studied the problem in connection with its aeronautical applications.

Ader, at this time, made many aerodynamical tests in his laboratory in the rue Pajou. Unfortunately no record remains of the work of this great investigator, not even the memory of the apparatus which he used in his tests.

Langley, who had commenced his work about 1880, brought them to bear on the subject with greater accuracy in 1887 when he founded the aerodynamic laboratory of Allegheny, Pennsylvania. His whirling arm with a vertical axis had arms 9.25 m (30.3 ft.) long. His works were devoted especially to the conditions of mechanical flight of bodies heavier than air but they were completed by a general series of tests on the resistance of air. Langley combined with his whirling arm a dropping apparatus to study the descent of a plane with a horizontal speed falling freely in space. The great scientist also mounted on the arm of the whirling arm a recorder of the resultant force in order to determine the total pressure produced by the air on a plane placed either normal or oblique to the wind. On the other hand, he made experiments with a truck running on rails and carrying a plate mounted on a strut with a spring, the movements of the plate being recorded on a chronograph. This apparatus was an improved version of that of Croce-Spinelli.

Despite their number and importance the tests of Langley do not appear to have been so accurate as others made at that time, notably those of Dines in England. This scientist who made a very important contribution to the study of the resistance of air also employed a whirling arm, but, thanks to a system of two levers placed at 90° attached to a pivot at the end of the arm of the whirling arm, he balanced the pressure on the plate by centrifugal force acting on a movable mass, the plate and this mass being placed at the ends of the two levers. Dines modified his apparatus to study the effect of obliquity of plates.

About 1888 Charles Renard at Chalais-Meudon created a double dynamometric balance for testing propellers. Colonel Renard devoted a large part of the years of his fruitful life to tests with various machines for dropping bodies, whirling arm (1896), etc. In 1904 he communicated to the "Académie des Sciences" the results obtained with the single dynamometric balance. Before 1899 he also used a tunnel of circular section. He made tests on the resistance and stability of streamline bodies, the resistance of metal plates of various shapes, honeycombs, heads of cylinders, portions of nets, etc. The original balances and the majority of the bodies tested still exist and are preserved at the Aeronautical Museum very close to the Chalais Laboratory where Charles Renard made his experiments.

About 1890 Wellner, in Austria, tested in the natural wind, surfaces having arched sections, using balances of an interesting and simple design which have been adopted by a number of subsequent investigators. Wellner also studied the deviation of air filaments on surfaces exposed to a wind current, these filaments being made visible by means of smoke. His works on propellers are well known.

In 1890 Faccioli in Italy used an anemometric balance for his aviation experiments. At the same period Parseval, Siegsfeld and Riedinger tested large surfaces falling vertically a distance of about 12 m (39.4 ft.).

The Eiffel tower was utilized by Messrs. Cailletet and Colardeau in 1892 for tests with a very curious dropping apparatus which recorded the instant when a body attained a uniform speed. The body was attached to a very light wire wound on six conical spools placed with their apices downward and turning practically without friction. At each section of 20 m (65.6 ft.) corresponding to one spool, an electric contact operated a stylus on a recording cylinder on which a tuning fork inscribed the 1/100 divisions of a second. One could measure exactly the length of time taken by the body to drop 20, 40 and 60 m (65.6, 131.2 and 196.8 ft.) and the instant when the speed became uniform.

The same year, in Germany, von Lössl published the results of tests made since 1882 with a small whirling arm and Zahm, in the United States, tested a recording anemometer and used later a large wind tunnel of square section 1.80 m (5.9 ft.) of width, having a propeller type fan. This tunnel, with those of Phillips and Maxim, was among the first used.

Hiram Maxim before building his large steam airplane made a series of important aerodynamic tests, using a large whirling arm from which hung a fairly large model of an airplane. This model turned under the action of its own propeller, operated through gearing. Maxim later used a square section tunnel of 0.90 m (2.95 ft.) per side. The bodies tested, of very varied nature, consisting of wood, metal or fabric planes, struts, steam condensers, etc., were placed just outside the exit of the tunnel. This tunnel had at the entrance two propeller fans driven by a steam engine, the fans being divided by a wood honeycomb to straighten the air current. A second honeycomb was placed in the forward third of the tunnel. This tunnel which marks an important date in aeronautical history and the origin of which is due to Phillips who collaborated with Maxim, was used for tests of the greatest variety, notably on the interference of planes and the effect on them of objects in their immediate vicinity.

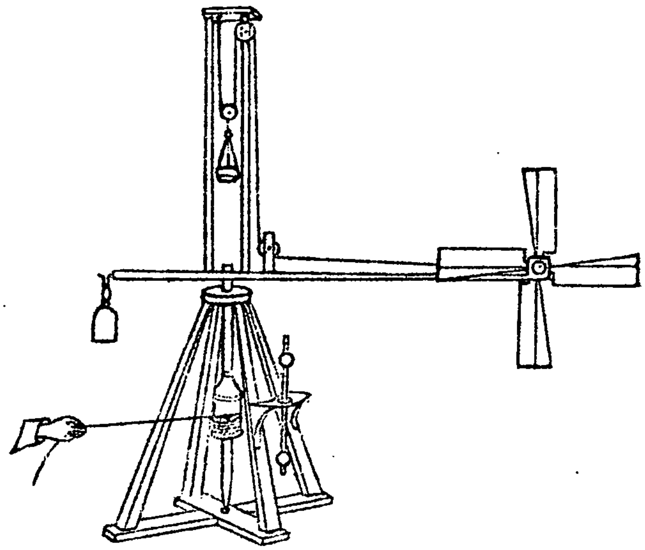
We should also note the tests of Mannessmann, at Tubinge (1899), with a very small whirling arm, of Franck and Hergessel with pendulum apparatus, of Abbe le Dantec (1899), of d'Aspinall with dropping machines, or Reichel (1901) with a whirling arm used in connection with the Siemens electric locomotives, of Finzi and Soldati in 1903 with a tunnel, of Soreau and of Canovetti (1899-1906) with trucks moving either on wires or on a narrow gage railway line. These trucks carried bodies, surfaces, cones, etc., of fairly large dimensions.

In 1903 Stanton in England made accurate and interesting tests in which he measured the total pressure on a plate and the local pressures on the front and rear faces, the first with a balance, and the second with a manometer. The instruments were placed in a vertical tunnel through which the air was drawn from bottom to top by means of a fan on a vertical axis.

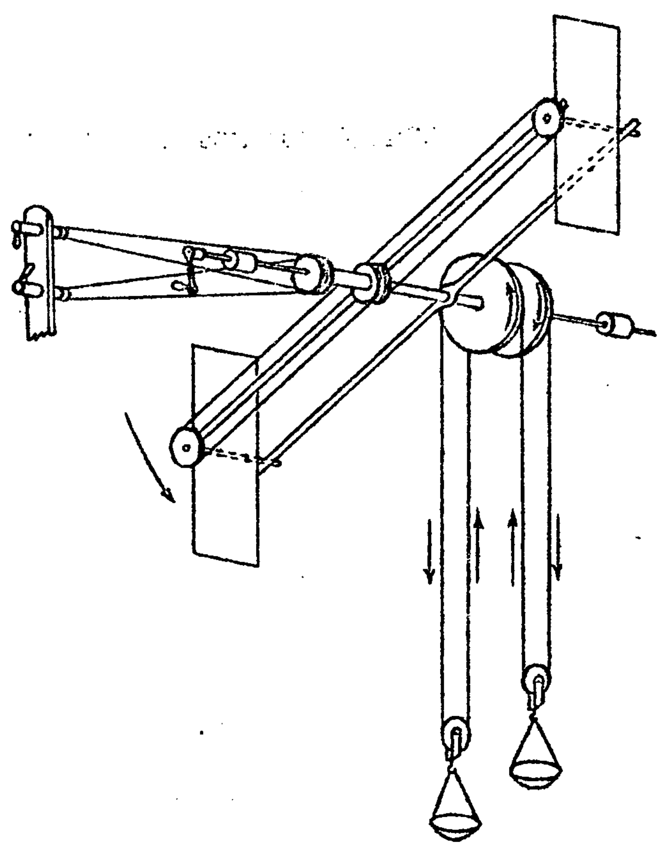
It is not widely known that the Wright brothers by means of aerodynamic tests determined the form of their first biplane which was, in 1903, the means for conquering the air. The famous American aviators combined scientific minds of the first order with an extraordinary practical ability. Before 1903 they had tested many very small metal surfaces in a tunnel likewise of small dimensions installed in their Dayton workshop. These surfaces were placed vertically in the tunnel and hung from a balance. After having obtained very useful data, the Wright brothers observed the movements of eddies using the smoke method of Wellner. These metal wing models still exist and I had the honor when visiting the laboratory of Orville Wright at Dayton to handle the original wing section of the first engine-driven airplane.

To study the aerodynamic laboratories which were created after this period and which aeronautical development has caused to be of use in general science for its greater profit would be beyond the scope of this article. It is sufficient to cite the fundamental and classic works of Gustave Eiffel from his 300 m (984.2 ft.) tower with dropping apparatus, those in his laboratory with the wind tunnel which he created and the work of Joukowski at the Koutchino laboratory near Moscow (1904), to recall the names of the great men now dead and entered into the domain of aeronautical history.

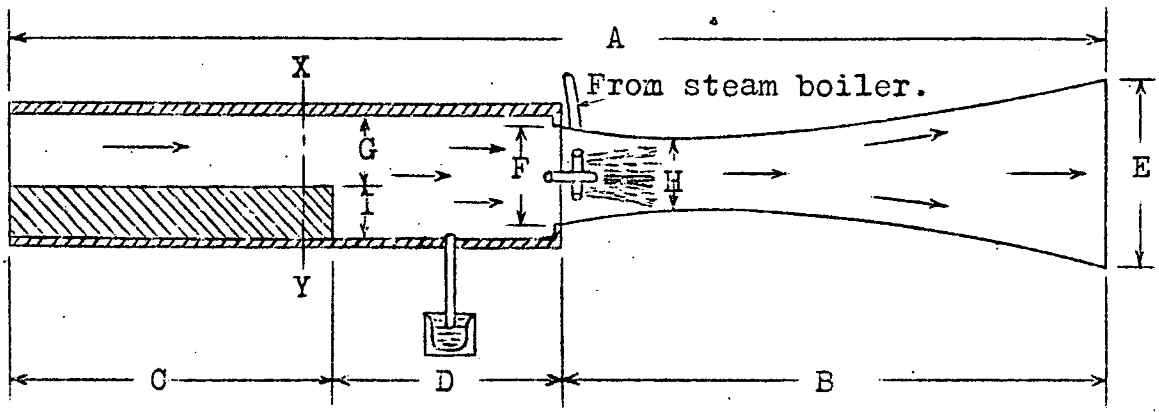
Translation by John Jay Ide,
National Advisory Committee
for Aeronautics.

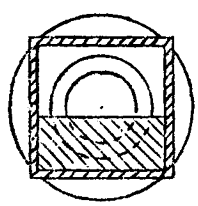


Whirling arm of Smeaton (1782).



Windmill with vertical blades of Hirn (1880).

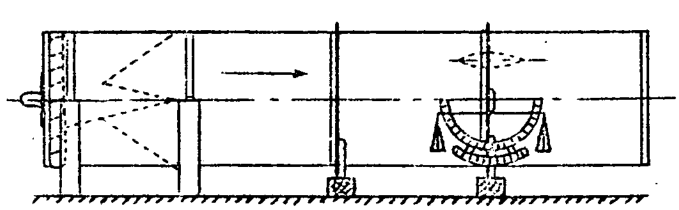




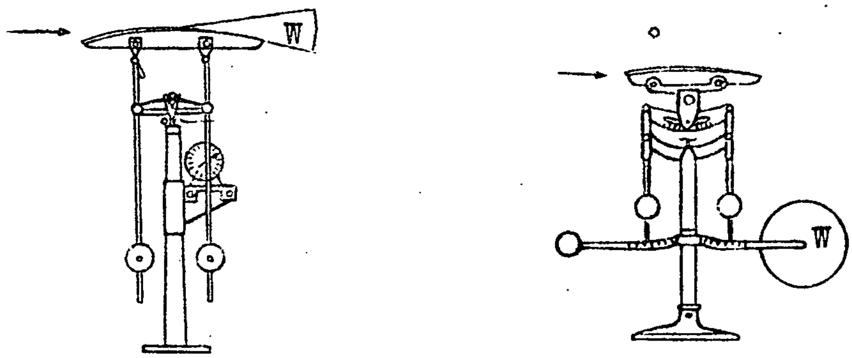
Section X-Y.

A = 12' 0" (3.66 m)
B = 6' 0" (1.83 m)
C = 3' 6" (1.07 m)
D = 2' 6" (.76 m)
E = 2' 0" (.61 m)
F = 1' 0" (.30 m)
G = 0'10" (.25 m)
H = 0' 8" (.20 m)
I = 0' 7" (.18 m)

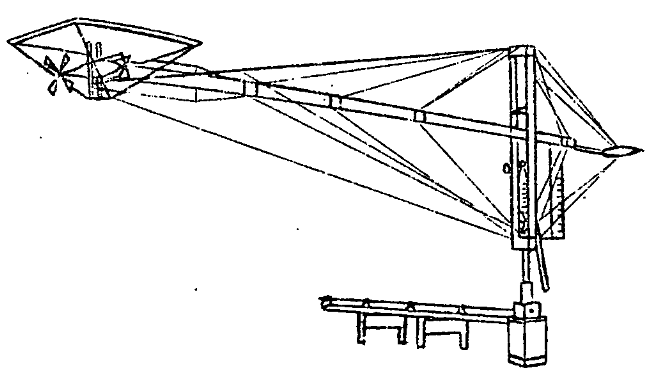
First aerodynamic tunnel of Phillips (1885).



Aerodynamic tunnel of Col. Renard.



Aerodynamic balances of Wellner for testing surfaces in the wind. (Note at W the fins for maintaining the surfaces in the axis of the wind).



Large whirling arm of Maxim (1892).