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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS.

No. 205

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THE NEW FRENCH HIGH-SPEED WIND TUNNEL

By Lieut. Col. Robert.

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May, 1923.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS.

TECHNICAL MEMORANDUM NO. 205.

THE NEW FRENCH HIGH-SPEED WIND TUNNEL.*

By Lieut. Col. Robert.

The function of aerodynamical laboratories is to investigate the laws of air resistance and, more generally, the laws governing the flow of a fluid, such as air about a body immersed in it.

Since it is very difficult to experiment by moving a body swiftly through still air, we have had to adopt the principle of relative motion and to operate by creating an artificial airstream in which is placed the body to be studied, such body being stationary or, if a propeller, having a simple rotary motion imparted to it.

The plants set up for this purpose are called aerodynamic or wind tunnels. The first wind tunnels in France were built by Rateau in 1908, and by Eiffel in 1909. The two now in use are the Eiffel tunnel at Auteuil, and the tunnel of the "Institut Aérotechnique" at Saint-Cyr. Both of these have been placed at the disposal of the "Service Technique de L'Aéronautique," and are of the Eiffel type.

The main body consists of a truncated cylinder with an entrance cone at one end and an exit cone at the other. At the exit end there is a fan for producing and maintaining negative pressure. Air at the atmospheric pressure of the room is thus drawn

* From L'Aéronautique, January, 1923, pp. 32-35.

into the cylinder through the entrance cone, acquires velocity, passes through the throat of the cylinder at maximum speed and is then expelled by the fan. In the throat of the cylinder a certain length may be reserved for an experiment chamber and the speed of the air stream can be measured by the negative pressure in this chamber. The object on which the experiments are to be made is placed in the middle of the air stream and is connected with a special balance by means of which can be determined the magnitude and position of the horizontal and vertical components (drag and lift) of the resultant of the air pressures brought to bear upon it. All the research work, which has provided a firm foundation for aerodynamics, has been carried out by means of such tunnels.

In 1910, M. Eiffel brought together all available knowledge on air resistance before commencing his wind tunnel experiments: "The first tests on the resistance of fluids were made by Galileo and Newton, and since their time a good deal of work has been done in this field of research. Such work is of great practical importance and was bound to be made the subject of research by scientists. It must be admitted, however, that the multiplicity of researches has had the effect of introducing great confusion. That, of course, is due to the difficulty of the problem; but it is also due to the fact that each experimenter proceeded according to his own point of view and it is, therefore, difficult to compare the various results obtained. Hence, the specific resistance, far from being known as accurately as it should be, is still represented by figures which vary up to 100%. Methodical study is therefore necessary to throw light on this subject, since, although so much work has been done, the lack of uniformity in the results is very perplexing."

Since the above was written, much experimental work has been done, especially by Mr. Eiffel. The theory of the problem has also been carefully studied and invaluable results obtained. This belongs to the history of aerodynamics, on which we will not dwell.

Of these results, however, some directly concern the conditions of setting up an efficient wind tunnel and the precautions to be taken, in order to obtain data applicable to aircraft. One such result is the knowledge of the Law of Similitude by means of which data obtained on small test models can be applied to the conditions of flight of a full-size airplane. This law requires that the product Vl (V = relative speed, l = a dimension, usually the wing chord) be exactly the same for the model and for the full-size structure. In existing wind tunnels this equality cannot be obtained.*

Now, however, we know that it is sufficient to operate for values of Vl exceeding certain critical values and as large as possible. The theory of parallel flow and that of a wing of infinite span enable us to have the same value of Vl in the tunnel and to utilize the results obtained on a section of wing having the actual chord.

* It is really Reynolds number Vl/μ which should be constant. A wind tunnel of the Margoulis type has just been built in America in which the constancy of this number is assured by compressing the air stream to 25 atmospheres.

For propellers this Law of Similitude cannot be applied. Since the relative peripheral speed is almost that of sound, we can no longer consider the air as an incompressible fluid and we must get as near as possible to the actual working conditions.

Lastly, it is now known that the presence of even slight obstacles in the vicinity of the experimental body, especially in the zones of negative pressure, modifies the air flow and impairs the results.

The plans for the wind tunnel at Issy-les-Moulineaux were drawn up in view of these facts and of the experimental conditions rendered necessary by the various influences affecting air flow.

An effort was also made to improve the coefficient of utilization of the tunnel, that is, the ratio $P_s = \frac{P_u}{P_m}$, or the ratio of the useful power P_u of the air stream in the experiment chamber to the motive power P_m required for producing the stream. In particular, an investigation of the working of helical fans has been made in a wind tunnel one meter (3.28083 ft.) in diameter at the Eiffel Laboratory. Propellers of various pitches and with different spinners were mounted and tested with various forms of exit cones. The results led to the adoption of the characteristics given further along.

The tunnel at Issy-les-Moulineaux is of the Eiffel type described above. It comprises the entrance cone A, the experiment chamber C, and the exit cone D, with a total length of 36.2 m. (118.77 ft.). It is placed in a room measuring 62 by 24 m. (203 ×

78.7 ft.) and rests on two narrow walls parallel to its axis. This position and a passageway of 3 m. (9.8 ft.) permits of a regular return flow about the cylinder. The section thus arranged for the return flow will limit the velocity of the air in the room to 4 m/sec. (13.12 ft/sec.).

The cylinder is made of reinforced concrete and is streamlined in order to avoid, as far as possible, the formation of eddies. The structure was designed by the firm of Pelnard, Considère & Caquot, and built by the Société Anonyme de Constructions Industrielles et Travaux d'Art.

The entrance cone has a diameter of 9 m. (29.5 ft.). The air stream traversing the experiment chamber is 3 m. (9.8 ft.) in diameter and the mouth of the exit cone 6.6 m. (21.6 ft.). The interior of the exit cone forms an apex angle of 14°. Where the fan is placed, the section widens out in order to offset the space occupied by the spinner.

The fan is a propeller with six adjustable blades. It was made by the Levasseur Company, and is similar to the Levasseur variable-pitch propeller. The blades are of wood and each blade is held in a metal socket screwed to a steel hub so that the pitch can be adjusted. The diameter can also be varied.

The main characteristics of the propeller are:

Mean diameter,	6.50 m.	(21.32 ft.)
Width of blade,	0.55 m.	(1.80 ft.)
Original relative mean pitch,	0.60 m.	(1.97 ft.)

From tests made on a model 1.5 m. (4.9 ft.) in diameter, such a propeller, functioning as a fan in a cylinder, would have an efficiency of about 0.6.

The experiment chamber is 12 m. (39.4 ft.) wide, 9 m. (29.5 ft.) high, and 10 m. (32.8 ft.) long. In crossing the chamber, the cylinder is interrupted for a length of 5 m. (16.4 ft.). The passage of the air stream through it produces a negative pressure. which, at maximum velocity, will reach 400 kg/m² (81.9 lb/ft²).

The device for supporting the model and the dynamometric measuring apparatus rests on a metal frame placed on a truck running on rails at right angles to the axis of the air stream. The model is suspended by single steel wires or cables, according to its dimensions and weight. The other ends of the suspension wires are connected with manometric balances of variable sensitivity. The manometer readings, the indications of the instruments measuring the velocity of the air stream and the readings of the device giving the angles of attack are all transmitted by optical processes to a common recorder on sensitized paper, on which are thus inscribed continuous curves in function of the time as abscissa showing the components of lift and drag, the velocity of the air stream and the angle of attack of the model.

The fan is geared directly to a 1000 HP continuous current motor fed under variable voltage so that the R.P.M. of the fan can be varied from a very low number up to 600. For this purpose, the high voltage current of the sector (15,000 volts) is first lowered to 160 or 500 volts, then transformed into a continuous current by means of two groups of machines, one of which is a converter giving 320 kilowatts under a constant e.m.f. of 220 volts, the other being a synchronous motor driving a dynamo of 475 watts. This dynamo is mounted in series with the converter and increases the voltage. The 1000 HP motor may thus be fed under a e.m.f. varying from 0 to 540 volts. The whole of this special electric plant was installed by the Thomson Houston Company.

Thus constituted, the big wind tunnel of the Service Technique will give in the experiment chamber an air stream 3 m. (9.8 ft.) in diameter, with a speed of 80 m/sec. (262.5 ft/sec.), that is, about 300 km/hr. (186 mi/hr.).

The tunnel can be used for testing airplane models at the speed of actual flight, or models of fuselages or other airplane parts on a 1/2 or 1/3 scale, that is, on a scale comparable to the full-size parts, or propellers on a 1/3 scale.

The plant is almost completed. When it is in working order, the Service Technique will have three wind tunnels at its disposal and will be able to undertake all the research work rendered necessary by recent progress in aeronautics and will also be able to make the current practical tests required by constructors. No French airplane constructor has a wind tunnel of his own and the Service Technique makes all tests free of charge. In 1921, about a hundred models of airplanes or wings were tested in order to determine their polar curves and centers of lift.

Translated by Paris Office,
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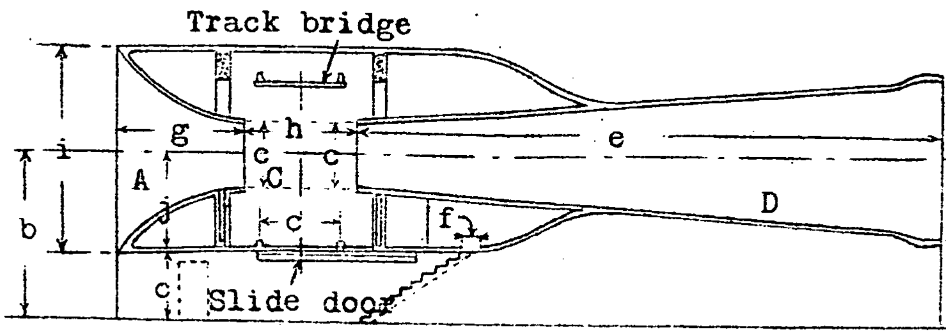
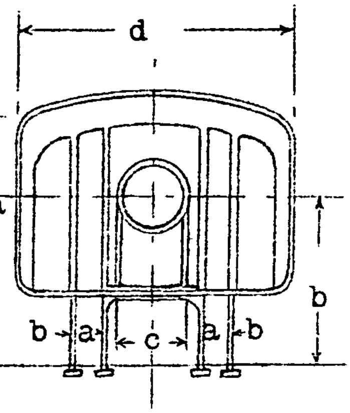
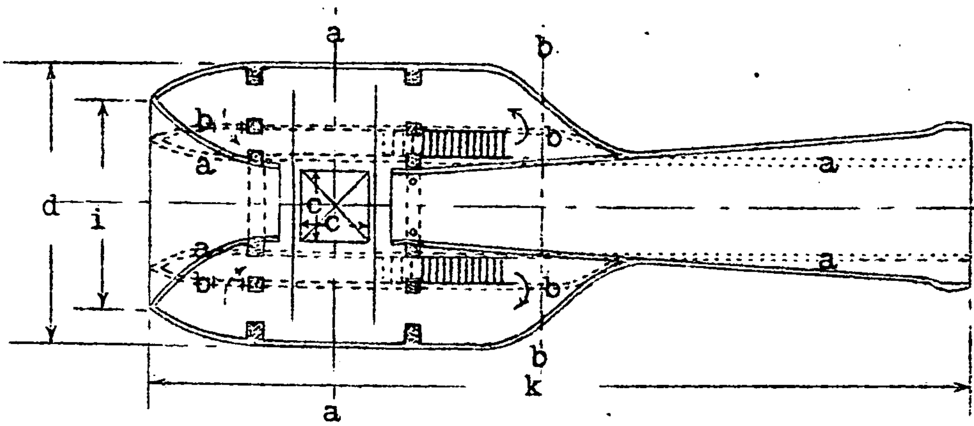
for Aeronautics.



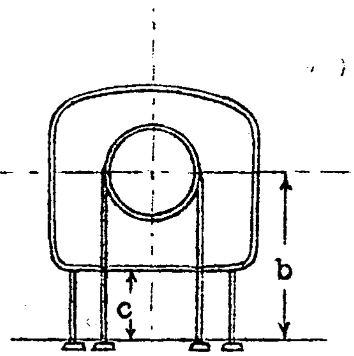
Sectional elevation



Section a - a



Sectional plan



Section b - b

a = 21.65 ft.

b = 23.62 ft.

c = 9.84 ft.

d = 39.37 ft.

e = 83.99 ft.

f = 3.28 ft.

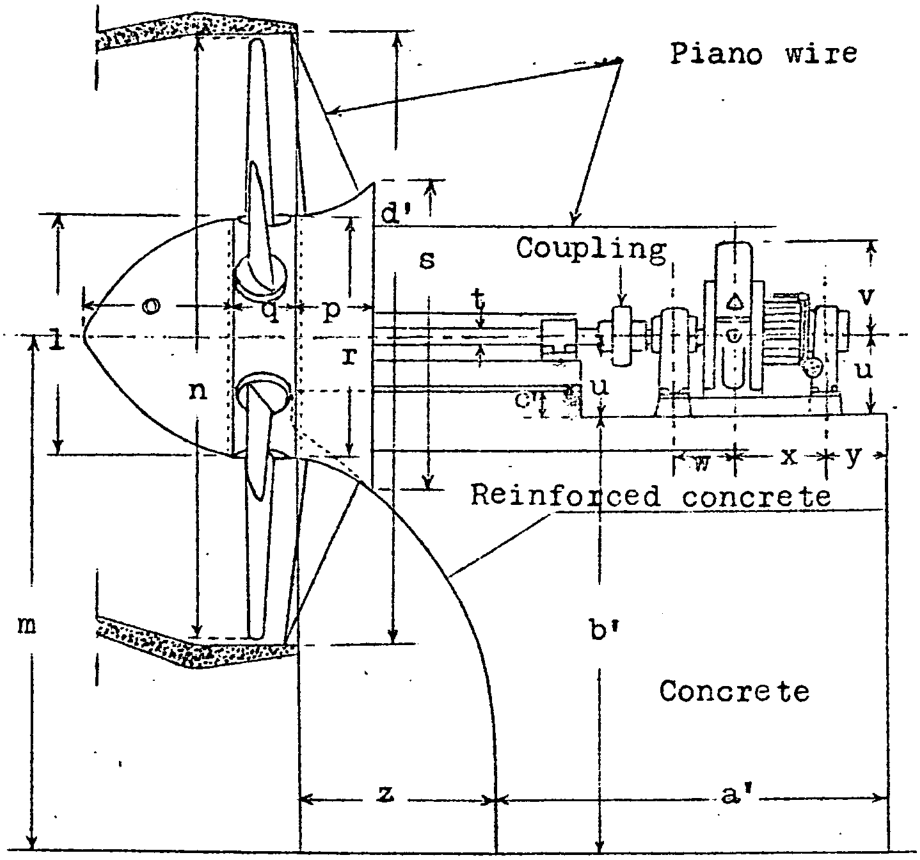
g = 18.37 ft.

h = 16.40 ft.

i = 29.53 ft.

j = 13.78 ft.

k = 118.77 ft.



l = 2.628 m (8.62 ft.)	v = 1.063 m (3.49 ft.)
m = 7.740 m (25.39 ft.)	w = .600 m (1.97 ft.)
n = 6.55 m (21.49 ft.)	x = 1.020 m (3.35 ft.)
o = 1.685 m (5.53 ft.)	y = .620 m (2.03 ft.)
p = .800 m (2.63 ft.)	z = 2.200 m (7.22 ft.)
q = .660 m (2.17 ft.)	a' = 4.200 m (13.78 ft.)
r = 2.630 m (8.63 ft.)	b' = 6.880 m (22.57 ft.)
s = 3.32 m (10.89 ft.)	c' = .300 m (.98 ft.)
t = .145 m (.48 ft.)	d' = 6.600 m (21.65 ft.)
u = .860 m (2.82 ft.)	