THE NEW WIND TUNNEL

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THE construction of the new Aerodynamic Laboratory was started several years ago in connection with the new Engineering Building. The main feature of the equipment of an aerodynamic laboratory is a wind tunnel. The new wind tunnel has been designed in such a way that a large part of it called for reinforced concrete as the structural material and therefore could be executed together with the construction of the building at a comparatively low cost.

After the construction of the building, the completion of the wind tunnel, requiring a considerable amount of rather expensive electrical equipment, wood work, etc., progressed slowly due to the limited funds which could, in justice to the other departments, be spent for this purpose. Due to the generosity of the Daniel Guggenheim Fund for Promotion of Aeronautics, the University obtained last year a subsidy for completion of the equipment of the new Aero-dynamic Laboratory and the work is now going on at full speed.

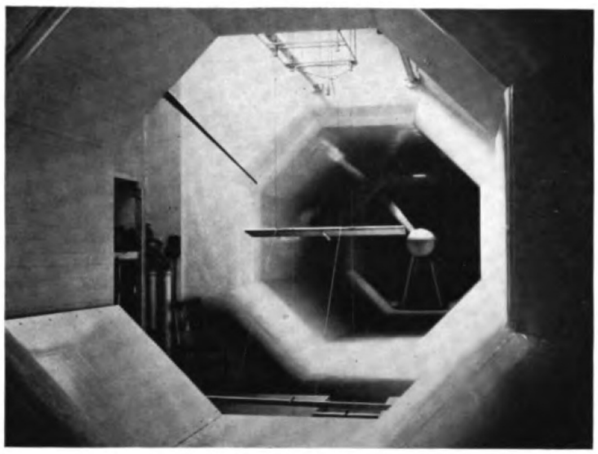

Photo by Swain.

FIG. 1. READY FOR A TEST. AN AEROFOIL IS IN PLACE ON THE DYNAMOMETER. THE PROPELLER CAN BE SEEN AT THE FARTHER END OF THE TUNNEL.

The new laboratory will certainly rank among the largest and more powerful equipments for aerodynamic research in this country and therefore may deserve some interest on the part of readers of this magazine, which is the reason for the following brief description of it.

The laboratory is located in the basement of the south wing of the East Engineering Building and occupies approximately 10,000 sq. ft. of floor area; it comprises two offices for the members of the teaching staff, a drawing room accommodating 24 large drawing tables, a shop for the laboratory mechanic, and the laboratory proper.

The chief apparatus of the laboratory is the wind tunnel and it occupies approximately 4,000 sq. ft. of floor area.

A wind tunnel, in general, is a device for production of an air current in which scale models of complete aircraft or of parts of air craft are immersed in the air current and the action of the air current upon these models can be measured by means of properly adopted scales or balances, usually called dynamometers. The character of the work and the methods used are, in general, very much like those used in naval tanks in connection with the models of ships.

There are a number of types of wind tunnels in existence. In broad lines, a wind tunnel can be described as a large tube through which the air flows under the action of a blower or fan, thus providing the necessary air current. The flow of air through the tube can be produced by application of pressure or suction on one end of the tube.

The pressure action of a centrifugal blower of the Sirroco type has been applied in the old small wind tunnel in the West Engineering Building. This old piece of apparatus is still used for some experiments and demonstration of certain aerodynamic principles in connection with the courses in Aeronautical Engineering, although it is quite inadequate for research work in some of the more intricate phenomena, requiring more accurate measurements, higher wind velocities, etc. For reason of comparison with the new equipment it will be mentioned here that the old wind tunnel of the above type produces an air current of only 3 ft. x 3 ft. in cross-section and 40 miles per hour maximum velocity at the expense of 12 K. W. motor energy to drive the blower.

The new wind tunnel is of the so-called "Venturi-tube double-return type with Eiffel chamber" and the arrangement of it is shown in Figure 2. The Venturi-tube is located centrally and is interrupted at the throat by the experimental chamber, so that a free jet of air passes through the chamber, thus giving a better visibility, free access to the model under test, and a more even distribution of wind velocity across the air current than is the case in the wind tunnels of the continuous type. This feature was introduced in the wind tunnels by Eiffel and therefore such an experimental chamber is referred to in aerodynamics as Eiffel's chamber. This central tube is of octagonal cross-section, 8 ft. diameter at the throat, i. e., at the chamber, and increasing in size in both directions toward the ends.

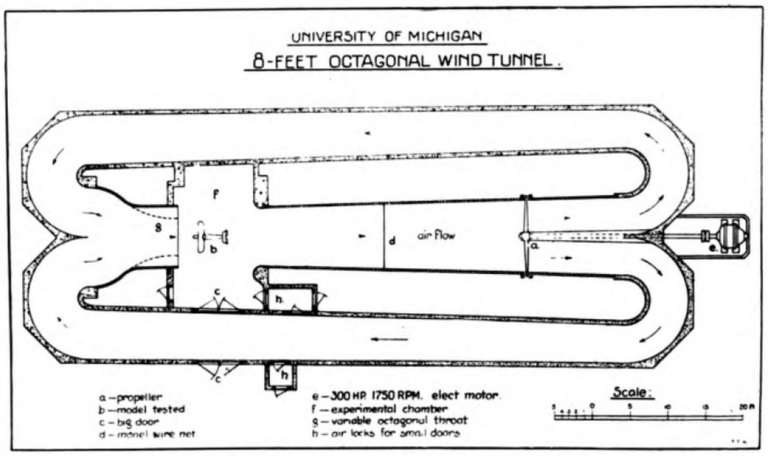

FIG. 2. DIAGRAM OF THE GENERAL LAYOUT OF THE WIND TUNNEL.

The diameter at the propeller effecting the air flow is 10.5 ft., thus the energy to be applied at the propeller in order to produce a given velocity of air at the throat is greatly reduced, in comparison with a tunnel of constant cross - sectional area. A further reduction of energy, necessary to produce an air current of given dimensions and velocity, is obtained by turning the air current behind the propeller back and making the air circulate inside of this return-type wind tunnel. The symmetrical arrangement of two return ducts insures a more regular flow at the throat, through the Eiffel's chamber.

The octagonal cross-sections of the Venturi-tube is changing gradually, behind the propeller, into a square section of 10.5 ft. x 10.5 ft., and at the entrance cone, on the opposite end, into a rectangular section of 10.5 ft. x 14 ft. These two ends are connected by means of the bends and return ducts of constant height of 10.5 ft. and gradually varying width.

The propeller, furnished by the Paragon Company, is driven by a Westinghouse variable speed A. C. motor of the slip-ring type of 300 HP. maximum capacity through the intermediary of a disengageable coupling and a long shaft supported by four S.K.F. ball bearings. The bearings inside the wind tunnel are encased in a cylindrical housing. The supports of the bearings are streamlined and the front of the hub is provided with an ellipsoidal spinner of the same diameter as the cylindrical bearing casing in order to provide, as much as possible, an unobstructed flow of the air. Figure 4 shows the view from the propeller toward the entrance cone. The elastically attached wire net in front of the propeller can also be seen in this view. It is installed there for protection of the rapidly revolving propeller against injury from objects which accidentally may be drawn in by the air current from the Eiffel chamber.

The speed of the motor is controlled by the observers from the Eiffel chamber. The anticipated wind velocity at the maximum rotational speed of the propeller, of 1750 R.P.M. is 110 miles per hour, however, this wind velocity can be raised still higher by choking the throat by means of eight wedge-like fairings fitted into the 8-ft. diameter throat. Three sets of these fairings enable the change of the diameter of the throat to either 7, 6 or 5 ft. diameter. The wind velocity at the smallest diameter is expected to be around or above 250 m.p.m. This is one of the several novel features of this wind tunnel.

Fig. 1 shows an aerofoil (model of a wing) suspended from the dynamometer in the middle of the air jet.

The Eiffel chamber, which is two stories high, has a moveable platform above the air jet carrying, for the present, one of the two future dynamometers. This dynamometer is of the so-called "three-component wire balance" type; it enables the meas-

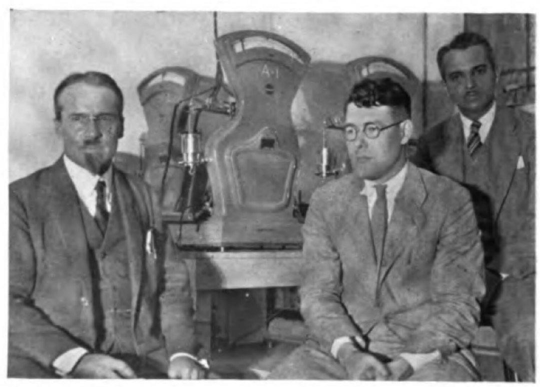

Photo by Korwin.

FIG. 3. LEFT TO RIGHT: PROFESSORS F. W. PAWLOWSKI, E. A. STALKER AND L. V. KERBER, THE DYNAMOMETER BALANCES ARE SHOWN AT THE BACK.

urement of the three components of the air reaction (lift, drag and lateral force) and their moments about the three axes of the model suspended on wires. Figure 5 shows the interior of the experimental chamber together with the motor control, dynamometer platform and an airplane model in test. Figure 3 shows the dynamometer and the three professors in conference, apparently worried about some puzzling results of a test.

The dynamometer consists of six sensitive scales furnished by the Dayton Scale Company: three for

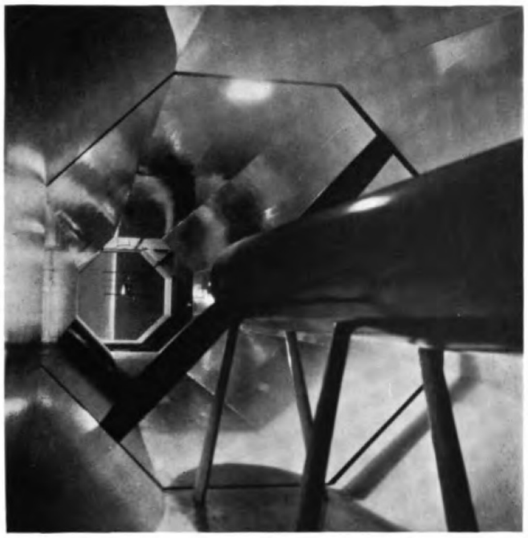

Photo by The Detroit News.

FIG. 4. A VIEW DOWN THE WIND TUNNEL, SHOWING THE PROPELLER AND A MODEL OF A QUADRAPLANE IN THE EIFFEL CHAMBER READY TO BE TESTED.

the lift, two for the drag and one for the lateral forces. The last one is installed on a shelf on the wall and visible in Figure 5. The maximum capacity of the dynamometer is 900 lbs. for the lift, 200 lbs. for the drag, and 60 lbs. for the lateral forces. It might be surprising to some of the readers of this article that forces of that order may be exerted by the air on the models, but this is nevertheless the case. In a wind tunnel of this caliber, comparatively large models can be used. For example, the multiplane, visible in Figure 5, has 54 inches wing span and over 5 sq. ft. wing area. It will lift about 270 lbs. at 100 m.p.h. and over 600 lbs. at 150 m.p.h. Large size of models enable to reproduce correctly to scale various small structural details which in the work with small models in small wind tunnels must be omitted.

The construction of models for aerodynamic tests is developing almost into an art of its own about which a few words may be said at this place.

The determination of the air forces acting upon the full size aircraft in flight is based on calculations made from the measurements of the forces acting on the model tested in the wind tunnels. These calculations are made by application of the so-called laws of dynamic similarity, which broadly may be stated as follows: The air reactions (or the reactions of any other medium, like water, for instance) on two bodies of different size, but geometrically similar, are proportional to the square of the ratio of any two corresponding linear dimensions of the two bodies and also proportional to the square of the ratio of velocities of the air in the two cases. For example, if the model of the aircraft to be investigated is made to the scale of 8:1, the wind velocity in the wind tunnel test was 60 miles per hour and the velocity of flight of the aircraft is to be 120 miles per hour and the forces acting upon the model were found to be 80 pounds of lift and 10 pounds of drag then the actual lift and drag on the full size aircraft will be

$$80 \times 8^2 \times \left(\frac{120}{60}\right)^2 = 20480 \text{ lbs. lift.}$$

$$10 \times 8^2 \times \left(\frac{120}{60}\right)^2 = 2560 \text{ lbs. drag.}$$

at the same density of the air. Of course actually the problem is more complicated due to the necessity of considering the variation of air density with the changes of temperature and barometric pressure and also of the effect of the viscosity of the medium on small and large bodies, but the requirements of geometrical similarity of the model to the full size aircraft is basic.

While small inaccuracies in reproduction of the shapes of certain parts of aircraft like fuselage and landing chassis are not very important, the accurate reproduction of the shapes of the wings is very important. The properties of the various types of wing shapes can be studied separately by means of the wing models (the so-called aerofoils) which must be made with great care and accuracy as even a very slight deviation from the assigned curvatures of the cross-section of the wings may result in very

Photo by Korwin.

FIG. 5. THE EIFFEL CHAMBER. ALL THE APPARATUS FOR MAKING THE TESTS IS LOCATED HERE. THE QUADRAPLANE VISIBLE IN FIG. 4 CAN ALSO BE SEEN HERE. THE DYNAMOMETER BALANCES ARE LOCATED ON THE PLATFORM ABOVE.

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maker, Manistee; Michigan Salt Co., Marine City; The Salt Products Co., Saginaw; The Diamond Crystal Salt Co., St. Clair; The Pennsylvania Salt Manufacturing Co., Wyandotte; Worcester Salt Co., Detroit, and Strable Lumber & Salt Co., Saginaw.

While small as compared with many of the other industries of the state, Michigan's salt-making must be reckoned as among its most important, not merely because it has given the state the leading position in this field, but because the qualities of the men engaged in the business have developed some of the most important improvements of the process within the borders of Michigan and have left an industry characterized by a very impressive pride in its own development.

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large variation of the aerodynamic properties of the wings.

These aerofoils are made of wood or of reinforced plaster of Paris. When the tests are to be made at comparatively high wing velocities and resultant air reactions are of an order of hundreds of pounds the question of strength comes in and the aerofoils must be made of metal (aluminum, bronze or even steel). Handwork is not always possible or adequate for making aerofoils and would be too expensive. Special machines are therefore, developed for cutting aerofoils from the different materials. In these machines the cutting tool is operated through an intermediary or guided by templates made with the utmost accuracy in metal from drawings of the desired profiles of the wings to be investigated.

A special room has been provided in the new aerodynamic laboratory for the installation of two different aerofoil machines. These machines are designed at the present time. One of these will be for cutting wooden aerofoils, the other for casting of plaster of Paris aerofoils.

As it is necessary to provide for the various investigations aerofoils of rather complicated shapes, the design of a suitable machine is a rather difficult problem. I will mention here only that the outlines of the wings used in modern aircraft are very seldom plane rectangular. Neglecting the different types of wing tips which are usually rounded in different ways, the width and the thickness of the wing varies often along the span of the wing, i. e., the wings are very often tapered both in width and thickness; besides, the profile (cross-section of the wing) may also vary along the span and the profiles do not necessarily remain geometrically similar, further the two symmetrical halves of the wing may be set together at a certain angle in the plane of the wing (the so-called sweep-back) or in a plane perpendicular to the plane of the wing (dihedral). All these requirements lead to an extreme variety of wing forms and require complicated machinery for production.

Other apparatus and dynamometers are now under construction, and, therefore, will be mentioned here only briefly.

A heavy drag dynamometer built around a 500-pound Toledo balance for experiments with objects in which the determination of drag will be the prime object, like: large size models of fuselages, models of dirigibles, engine radiators, airplane wheels in full size, etc.

A propeller dynamometer built around an electric motor of 200 h. p. capacity, enabling the use of 6-foot diameter propeller models, twice the size of any models used elsewhere, thus making it possible to eliminate certain errors in measurements. The dynamometer is of such a construction that it will permit the measurement of both the positive and the negative thrusts and torques at different positions of the axis of the propeller relatively to the direction of air flow, at fixed positions, and while the axis of the propeller oscillates about any given position. It is expected that this apparatus will open new vistas in propeller research.

A dynamic balance or an oscillograph, to record photographically the oscillations of an airplane about its axes and furnishing data for determination of the dynamic stability of airplanes.

Most of the above dynamometers are movable, on casters, to be put in or taken out of the Eiffel's chamber through the especially provided big doors visible in Fig. 2, for the following reason: It is a well known fact that it usually takes little time to run an aerodynamic test, very often one-half hour, while it takes several hours and even a few days to prepare the experiment on a dynamometer.

Consequently, since it will be possible to prepare experiments on the dynamometers outside of the wind tunnel without interfering with an experiment in process, the output of the wind tunnel will be greatly increased in comparison with other laboratories in which the dynamometer is a permanent feature of the wind tunnel. In this way the new laboratory will be able to better respond to the demands for tests of the rapidly developing aeronautical industries of the country.

It might be mentioned here also that another, small size high speed wind tunnel is being designed, to be operated intermittently by the same motor as the large one. In this wind tunnel it is attempted to obtain wind velocities approaching the velocity of sound; it will serve for calibration of speedometers for airplanes, test of elements, of propeller blades, and in general for the study of high speed phenomena.