12-FOOT PRESSURE WIND TUNNEL

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The 12-foot pressure wind tunnel, which has been dedicated today, is one of the most versatile wind tunnels ever constructed. Its outstanding features are low turbulence and control of the air density.

The pressure of the air within the tunnel can be varied from 1/6 atmospheric pressure to 6 times atmospheric pressure. This large density range introduced many structural and mechanical problems not usually encountered in wind-tunnel design. In the first place, the tunnel proper had to be a pressure vessel, capable of withstanding internal pressures of over 11,000 pounds for every square foot of area. For this reason, the tunnel shell was formed of electric arc-welded steel plate, varying in thickness from 3/4 inch to 2-1/4 inches.

The design of propellers capable of absorbing the full drive power over the exceedingly large range of densities posed another problem which had to be surmounted. Since the air density of 1/6 atmospheric pressure corresponds to that encountered at an altitude of nearly 50,000 feet while the air density at a pressure of 6 atmospheres is 36 times this value, it is obvious that conventional variable-pitch propellers do not afford a satisfactory solution. Instead, two coaxial fans have been employed, one containing 12 variable-pitch blades and a second containing 20 variable-pitch

blades. The fan containing 20 blades is connected to the drive shaft through a clutch and may be disengaged and allowed to windmill when it is not required to absorb the full 11,000 horsepower of the drive motor. As a further control of propeller performance, prerotation vanes with remotely adjustable flaps are placed upstream of each fan to direct the flow into the propeller blades. (See figures 4(a) and (b)).

The equipment for supplying dry, compressed air to the wind tunnel, or for evacuating the tunnel, is housed in an adjacent building which contains the electric drive motors. Here are located three multistage centrifugal compressors, absorbing a total of 4500 horsepower. The air leaving the compressors is cooled by water and Freon refrigeration coils, finally passing through a silica-gel dehumidifier where the moisture content is reduced to one ten-thousandth of a pound per pound of air.

The wind tunnel is cooled during operation by spray nozzles which direct water over the tunnel shell. The upper surface of the wind tunnel is protected from the sun by a canopy of corrugated asbestos.

From this brief description of the tunnel, it is obvious that a pressure tunnel involves some complexities not present in the atmospheric type of tunnel. It is therefore logical for you to ask, "Why is a pressure tunnel necessary and what are its advantages over the conventional atmospheric tunnel?"

Let us consider an atmospheric wind tunnel of size such that the Reynolds number of tests would equal those of the 12-foot tunnel at the same airspeed. This chart (fig. 4(e)) compares the two tunnels as to size, power required to drive the air, and cost of construction. We see that the atmospheric tunnel must be 6 times as large as the 12-foot tunnel and would require 6 times as much tunnel drive power. It would cost at least 3-1/2 times as much as the 12-foot tunnel. In all these respects, the 12-foot pressure tunnel retains a decided advantage. However, it must be recognized that much valuable information can be obtained by testing an actual flying article in a full-scale wind tunnel which cannot be obtained by testing a model at large scale in a pressure tunnel. The simulation of small protuberances, manufacturing imperfections, engine installations, and internal ducting in a small-size model is often impractical, and test results usually represent an idealized airplane which is impossible of exact duplication.

The 12-foot pressure tunnel is, however, a much more versatile wind tunnel than this hypothetical atmospheric tunnel and herein lies its greatest advantage. Remember that for a given size of model tested in an atmospheric tunnel, there is a definite Reynolds number for every Mach number at which a test is made. These performance curves for the 12-foot tunnel (fig. 4(d)) indicate the wide range of Reynolds number and Mach number combinations which are available. The curves represent maximum values which can be

obtained by testing a model of 1-foot chord at various tunnel pressures. Note that the highest Mach number is nearly 1, and compare this to the maximum Mach number of 0.3 for the hypothetical atmospheric tunnel. We must recognize the fact that at this velocity, the Reynolds number of such a test would be only about 1,500,000. However, at a pressure of 6 atmospheres, the Reynolds number would be 11,000,000 - the Reynolds number range for landing a full-scale aircraft. We thus see that the 12-foot pressure tunnel is not only capable of testing complete models at as large a Reynolds number as can any full-scale wind tunnel, but has the further distinction of being one of the only two wind tunnels in this country capable of testing large-size airplane models up to a Mach number of 0.95 or 0.96.

I have mentioned the low turbulence of the air stream in the 12-foot pressure tunnel. This feature, I believe, warrants further discussion.

In 1938, the NACA undertook construction, at the Langley Laboratory, of a wind tunnel specially designed to have low turbulence. During an exhaustive series of tests which led to the development of the NACA low-drag airfoil, considerable light was shed in the effect of tunnel turbulence on the measured aerodynamic coefficients, especially the drag.

When air flows over a body such as an airfoil or a fuselage, a thin layer of air adjacent to the surface is retarded due to friction between the air and the body. This thin layer is referred

to as the "boundary layer." Two types of boundary layers must be considered, namely, laminar and turbulent. Laminar boundary-layer flow is a smooth, orderly flow which usually prevails for some distance behind the leading edge of an airfoil. At some point along the chord, transition takes place, and the boundary-layer flow becomes turbulent. The skin-friction drag, resulting from a turbulent boundary layer, is many times that from a laminar one in the flight range of Reynolds number.

Suppose now that there exists an initial turbulence in the air stream. The adverse effect of air-stream turbulence is to cause transition from laminar to turbulent flow in the boundary layer to occur prematurely, thus increasing the area of the airfoil exposed to turbulent flow with a resulting increase in the drag. The three airfoils on this chart (fig. 4(e)) illustrate this effect in air streams of low, moderate, and high turbulence.

Wind-tunnel turbulence is a sideways, up-and-down or longitudinal motion of the air with respect to the general stream direction and velocity and is produced by the action of the propellers and the turning vanes. A few modern well-designed wind tunnels have air-stream turbulence which lies within the moderate range, but the turbulence level of most wind tunnels is in this high-turbulence range or even beyond the limit of this chart.

Since free air is considered to have zero turbulence, there is a factor of uncertainty in drag data obtained in a turbulent wind tunnel.

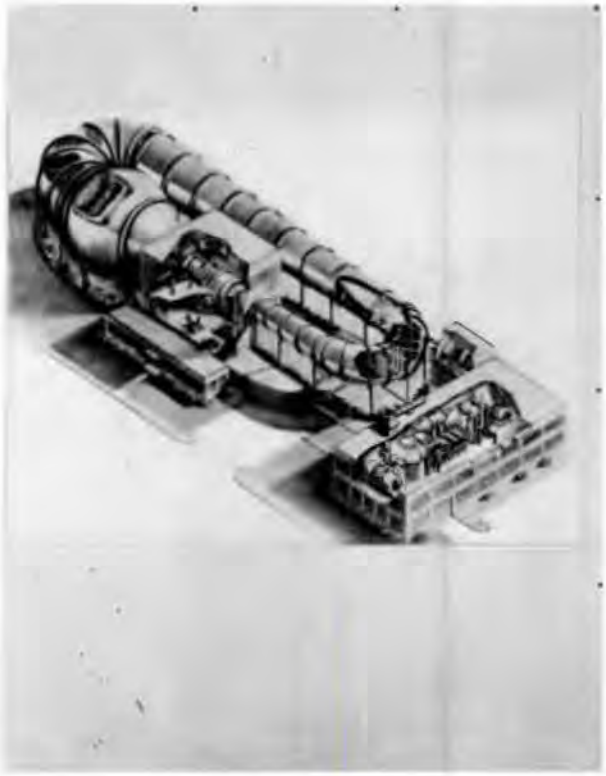
To verify this phenomenon experimentally under controlled conditions, a special NACA low-drag airfoil was tested in several

wind tunnels of different known turbulence levels. The airfoil was purposely designed to be rather critical to air-stream turbulence. Here we have plotted the measured minimum drag coefficient of this airfoil at a Reynolds number of 10,000,000 against the percent air-stream turbulence as measured with a hot-wire anemometer. Note the large increase in drag as air-stream turbulence is increased. As previously stated, this drag increase is due to the increasing area exposed to turbulent boundary-layer flow as a result of premature transition.

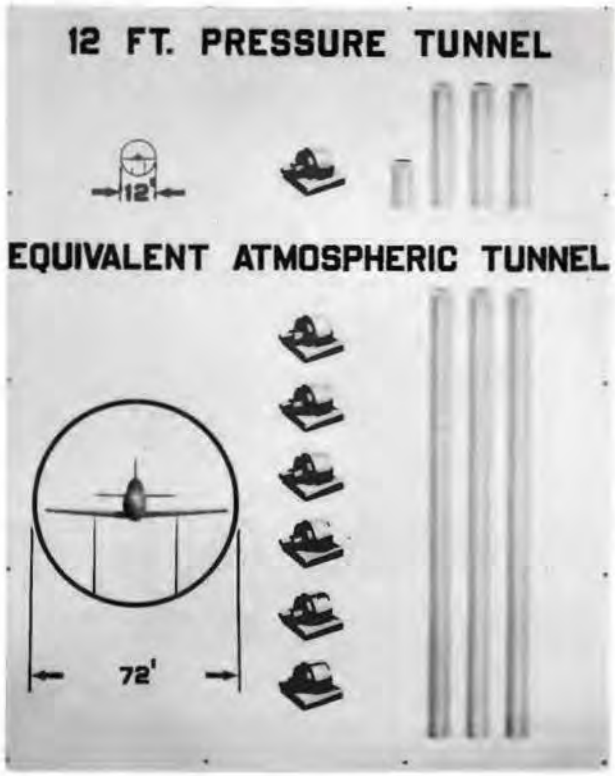
In applying wind-tunnel data to flight conditions, we cannot satisfactorily predict the effect wind-tunnel turbulence may have had on the drag data. It is therefore apparent that we should strive to maintain air-stream turbulence as near that of free air as possible. While we have not as yet measured the turbulence level in the 12-foot tunnel, the high contraction ratio of 35 to 1 and the eight antiturbulence screens should reduce the turbulence to a value equal to or below that of the two-dimensional tunnel at the Langley Laboratory. The turbulence level in that wind tunnel is at very nearly the lowest point on this curve - in a class by itself as far as wind-tunnel turbulence is concerned. The tunnel is, however, primarily suited to research on airfoils only. Thus it is clear that the 12-foot pressure tunnel is a logical extension to research facilities in order that complete airplane models may be tested in an air stream of truly low turbulence.

You will now be conducted through the 12-foot tunnel and will have an opportunity to inspect this equipment in detail.

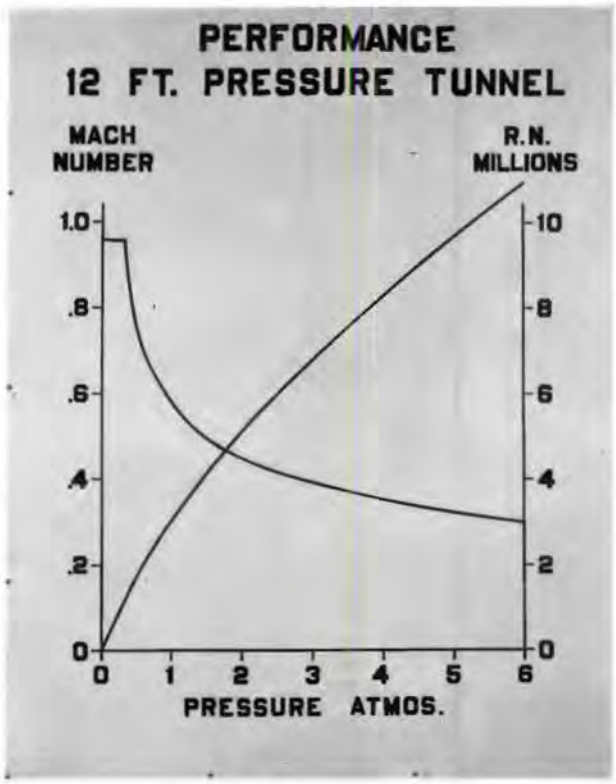
You will enter the tunnel at the test section through the main hatch and will proceed in the direction of the air flow, through the propeller section to the upstream side of the antiturbulence screens. You will then return, passing through the personnel hatch into the balance chamber, leaving the tunnel through the air lock. As a souvenir of this dedication and to enable you to recall at your leisure some of the details of the 12-foot pressure tunnel, an illustrated brochure describing the tunnel will be presented to each of you as you leave the building. (A copy of the brochure is included in this volume.)



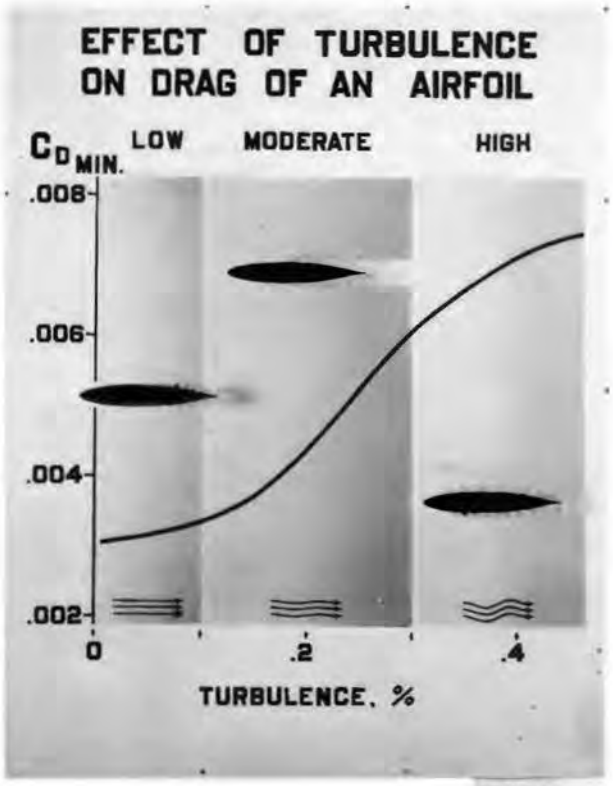
(b) First chart.



(c) Second chart.



(d) Third chart.



(e) Fourth chart.

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Figure 4.- Concluded.

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