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CHAPTER V

WIND TUNNEL TECHNOLOGY, 1920-1939

Few research tools employed in the study and advancing technology of the phenomena of flight have proved as significant as the wind tunnel. Alterations in design often required free-flight testing, not always practical, because of possible danger to the test pilot, when major changes were contemplated. Moreover, tests are generally conducted more inexpensively by placing a model in a wind tunnel rather than building and equipping a full-size airplane for free-flight testing. This economy factor, especially in a governmental organization, inherently plays an important role.

In general two types of tunnels are used. The open-circuit, or Eiffel type, contains no passage for air to return for reuse through the tunnel. This type of tunnel draws air directly from the atmosphere. In a closed-circuit, or Prandtl tunnel, a return flow section is constructed to form a continuous path for the air, allowing its reuse. Because the closed-circuit wind tunnel makes more efficient use of its available energy, the open-circuit method, although cheaper to construct,

is seldom utilized. The type and construction of the wind tunnels erected at the Langley Memorial Aeronautical Laboratory were determined primarily by the method of testing they were to accomplish. A tunnel, once it was completed, was not a static tool; innovations were made as the state of the art evolved.

Nobody supposed that the wind tunnels could answer all aerodynamic questions raised. Edward P. Warner, former Langley Chief Physicist, attested to this, saying there was "no single standard by which all airplanes could be tested. Wind tunnel tests must be used with proper regard to the models used," Warner said, "and proper interpretations must be given to the results." Agreements with European governments permitted a comparison of wind tunnel results to determine how much discrepancy existed when testing the same model in various tunnels. Many models were tested not only at Langley, but also in wind tunnels at both the British and French aerodynamical research centers.


then the laboratory mechanics would build it. In this instance Weick, instead, drew sketches of portions of the balance on cross section sheets of paper and the instrument, after the approval of Dr. Munk, was constructed literally piece by piece. Only after the entire balance was finished was a complete drawing made by the Langley draftsmen—and then only for the laboratory's permanent records.

This first wind tunnel in the world in which the major parts of a full size airplane could be investigated cost $394,978.12 to build. Considering the value of discoveries resulting from investigations employing the propeller research tunnel, the price was extremely reasonable. The NACA cowling, nacelle placement innovations and value of the retractable landing gear were all directly related to research in the PRT. Prior to World War II the tunnel proved to be one of Langley's most valuable assets.

After completion of the propeller research tunnel, the next logical step was the development of a tunnel in

45. Interview with F. E. Weick. Weick recalls that the entire structure was built for a cost, in addition to salaries, of about $5,000. Approximately ten years later, when a more sophisticated balance was desired, the cost ran between $50,000-$100,000.

46. "Wind Tunnels at LMAL," November 15, 1943. 2.
which a complete airplane could be tested. For Langley it was a project of greater size and expense than any previously contemplated. The safety features of such a piece of equipment were obvious; no longer would there be any doubt when a new aircraft design was taken on its maiden flight. If a radical design change was incorporated in an aircraft, its aerodynamic soundness could be tested without having to make an actual flight. Ground-based full scale testing would reveal many of the dangers prior to free flight by eliminating any need for correction produced by scale effect.\textsuperscript{47}

For these reasons, J. S. Ames wrote the Director of the Budget in early 1928, outlining the need for a full-scale wind tunnel. At the laboratory, Smith J. DeFrance, who had previously worked with the variable density tunnel, was selected by Engineer-in-Charge H. J. E. Reid and Elton W. Miller, Chief of the Aeronautical Research Division, to lead the team which would formulate plans for the full-scale tunnel.\textsuperscript{48} Because this was the first tunnel with "an elliptic throat and with two


\textsuperscript{48} NACA Executive Committee Minutes, January 24, 1928; Interviews with S. J. DeFrance, June 16, 1967; H. J. E. Reid, January 10, 1967; and E. W. Miller, February 8, 1967.
propellers mounted side by side,"49 DeFrance and his
associates decided to build a 1/5 scale model to study
the air flow.50

During the planning stage, much effort was
expended in winning Congressional approval as the tunnel
would cost almost a million dollars. An appropriation
request was tendered in 1928 for $5,000 to be used in
design work for the full-scale tunnel. This having been
granted, the NACA asked for, and received on February 20,
1929, a two-year appropriation of $900,000 with which to
construct the tunnel.51 A contract was signed with the
J. A. Jones Construction Company in February, 1930, for
construction of the tunnel. DeFrance oversaw all phases
of the erection process, and later supervised its actual
operation.52


50. The tunnel in addition had a dual return
which had never been used before and which many
aerodynamicists, including Theodore Von Karman, thought
was not feasible. The 1/5 scale model proved it could
be done, and the model itself was later used for
testing. Ibid. DeFrance's assistants included Clint
Dearborn and Abe Silverstein. Interview with S. J.
DeFrance.

51. The War Department also granted the NACA
additional land on which to build the structure. NACA
Executive Committee Minutes, March 22, 1929; NACA 15th
Annual Report, 1929, 9; NACA 17th Annual Report, 1931,
11.

52. NACA 17th Annual Report, 1931, 11; Interview
with S. J. DeFrance.
The tunnel was completed and dedicated on May 27, 1931, at the sixth annual industry inspection of the laboratory. Not all the funds appropriated were spent and the leftover money was turned back to the Treasury, indeed an unusual action on the part of a government agency.\(^53\) Besides holding the cost to a minimum, the DeFrance-led team managed to have construction completed in less than two years, a major achievement for a project of this scope.\(^54\)

As shown to the 1931 visitors, the full-scale tunnel had a 30 by 60 foot open jet at the test section within an overall tunnel size of 434 feet in length, 222 feet in width and a maximum height of 97 feet.\(^55\)

Because the structural steel frame was outside the cement-asbestos sheets which formed the walls of the tunnel, one writer said it "looked as if it was built inside out."\(^56\) The test section was large enough to handle a full-size airplane with a wing span up to 45 feet through a range of 25 degrees of angle of attack. Air

\(^{53}\) Interviews with Manley J. Hood, June 15, 1967; and S. J. DeFrance.

\(^{54}\) "Wind Tunnels at LMAL," November 15, 1943, 3.


stream speed, powered by two propellers, each connected to a 4,000-horsepower motor, ranged from 30 to 115 miles per hour, with 24 intermediate speeds. An airplane, when being tested, was supported on the balance structure by struts "so that its thrust line... [was]...at the tunnel center line, 34 feet above the floor of the test chamber." Seven scales registered pressure on an airplane during a test, and with the push of a single button, each scale's reading was recorded. 57 Although only steady flight could be studied, the tunnel was the only one in the world where lift and drag characteristics of a full-size airplane could be investigated.

Not all those interested in aeronautical research, however, agreed that the new LMAL full-scale tunnel was as valuable as the NACA had promised. Dr. Max M. Munk, no longer a Langley employee, felt that "giant wind tunnels may prove a good investment for certain special research work, but not for investigating real airplanes." He contended that it was cheaper and more reliable to take measurements of a full-size airplane in free flight. 58 Also, one aviation journal, in the midst of a campaign denouncing the NACA, asserted that the money spent in


building the full-scale tunnel was wasted and, because of turbulence problems, the tunnel was unworkable.

Edward P. Warner, editor of Aviation and former LMAL employee, and George W. Lewis, NACA Director of Aeronautical Research, each in turn answered the criticism. In a radio address Warner asserted that the building of the Langley full-scale wind tunnel was one of the most important steps ever taken in improving airplane designs. In the full-scale tunnel, Warner claimed, "minor changes can be made and the results determined to a fraction of a per cent within a few minutes. That represents the last word in scientific equipment for study of the airplane." 60 Lewis, in testimony before the House Independent Offices Subcommittee, said that this tunnel would allow "all the forces acting on the plane...[to be]...accurately determined," as the tunnel could almost completely "simulate flying conditions." 61 After discovering a turbulence problem, Eugene Lundquist, an


LMAL civil engineer, strengthened the tunnel's beams and overcame the slight vibration.  

Over the years, the full-scale wind tunnel proved as important as any aeronautical tool at LMAL. Its greatest value, however, was realized during the period of World War II. As will be shown, investigations in the full-scale tunnel between 1938 and 1945 played a key role in the aerial defense of the United States.

Another problem which the NACA felt was adaptable to wind tunnel research was that of airplane spinning. Those engineers most concerned with measurements of stability and control desired to have some tool with which to determine the ability of various aircraft to recover from a spin. Furthermore, research on spin recovery was an absolute necessity to the armed forces as aerial military maneuvers often required a deliberate spin.

Earliest experimentation at LMAL on spinning problems was conducted in 1926 in a somewhat crude manner. Following preliminary tests in the atmospheric wind tunnel, a model made of balsa wood was dropped from the ceiling of an airship hangar. The reaction of the model

62. Interview with S. C. DeFrance.

camera and a small recording accelerometer were used to
gather data on the model's reaction to the gust. As
was many times the case at Langley, the success of this
tunnel led to larger tunnels of a similar nature.

In general, all technical developments in
aeronautics which originated at the Langley Memorial
Aeronautical Laboratory represent basically an advancement
in the art of wind tunnel research. The innovations for
which the NACA is most famous—the cowling, airfoils,
low drag wing, and others—all can be traced to the ideas
of Langley personnel for increased sophistication in
tunnel construction. Certainly without this technological
progress, scientific investigation into the phenomena
of flight would have been greatly retarded.

Fundamental research in aerodynamics must begin
with the accurate measurement of the action of the air
on an aircraft and its various parts. The wind tunnel,
by reproducing aerial conditions on the ground, made
research less dangerous and less expensive. Experimenta-
tion by use of the wind tunnel also allowed a much wider
range of innovative ideas to be attempted. Much
experimentation was carried out by "trial and error"

methods, made possible by the availability of rapid, ground-based wind tunnels.

Both military and commercial aviation benefited from investigations in the Langley tunnels. Walter S. Diehl, one of the foremost figures in Naval aeronautical research, for instance, wrote a great number of reports from raw data collected at LMAL. Industry designers also benefited from knowledge acquired from wind tunnel investigations at Langley. There can be little doubt that wind tunnel research at LMAL was one of the most important factors in the advancement of aeronautical science in the United States.

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100. Interview with Fred E. Weick.

101. Many of Diehl's writings were published as NACA Technical Reports throughout the years. Interview with Walter S. Diehl.