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THE WIND TUNNELS OF THE NATIONAL FULL-SCALE AERODYNAMICS COMPLEX

John Moon

As aviation becomes increasingly advanced, wind tunnels are playing a more important role in the development of modern aircraft. The first studies of flight were focused on birds, and as a result, the first aircraft were built with bird-like structures. After years of failure, scientists realized that they knew little about lift and drag forces acting upon aircraft surfaces (aerodynamics). Thus, laboratories with controlled conditions were built to test wings, fuselages, and other surfaces on the aircraft. The principle behind the wind tunnel was very simple; one could either move the model through still air or let the air move past the stationary model. The latter choice, being more feasible, was used in building wind tunnels. Interestingly enough, the first wind tunnel was built 30 years before the flight at Kitty Hawk.

Today, there are many wind tunnels in use by government agencies, private industries, and major universities around the world. Two of the largest wind tunnels in the world are located at the NASA Ames Research Center in Mountain View, California. The 40- by 80-Foot Wind Tunnel in combination with the 80- by 120-Foot Tunnel is referred to as the National Full-Scale Aerodynamics Complex (NFAC).

The 40- by 80-Foot Wind Tunnel, named after the dimensions of its test section, was built during World War II by NACA engineers at Ames. NASA was originally called NACA (The National Advisory Committee for Aeronautics). Construction began in 1942 and was completed in 1944. The sole bid on the tunnel of $6,164,000 was made by the Pittsburgh-Des Moines Steel Company. The project ended up costing NACA about seven million dollars. Design and construction was supervised by Dr. Smith J. DeFrance, former director of Ames. The test section is 50 feet above ground and test models are lowered into the test area through the doors on the top of the tunnel.

The 40- by 80-Foot Wind Tunnel was the first full-scale wind tunnel to be built. Its six 40-foot-diameter fans, each powered by a 22,500-horsepower electric motor, produce test section airflow up to 330 mph. The extremely large size of the test section enables the testing of very large models, actual flight vehicles, and structures influenced by airflow, allowing closer simulation of actual flight. This tunnel became the primary facility for studying the flying characteristics of helicopters and vertical takeoff and landing (VTOL) aircraft. The tunnel tests examined the critical flight regime of the VTOL where the craft makes the transition from vertical takeoff to forward flight. The tunnel also helped study the structural failures of advanced helicopter rotors and new VTOL aircraft. With the use of well-instrumented tests, the causes of failure were easily found, leading to proper modifications.

The 80- by 120-Foot Wind Tunnel of the NFAC is one of the largest wind tunnels in the world. It is directly connected with the 40- by 80-Foot Wind Tunnel and shares the same fan drive system. This tunnel can produce top test section airflow speed of about 115 mph. Construction began in the late 1970s and owing to an unexpected incident the tunnel is still undergoing construction and modifications. The new tunnel will be an addition of a 600-foot-long leg extending northwest from the west side of the 40- by 80-Foot structure. Airflow through the new leg will enter through the intake at the end of the leg and flow through the test and drive sections. Then the exhaust will go through the vanes attached to the 40- by 80-Foot Tunnel. The total cost of this tunnel is expected to be over $85 million. The enormity of the test section will enable engineers to test real aircraft for their landing and takeoff characteristics. Because all aircraft must land and take off at low speeds, this large, low-speed wind tunnel should be useful far into the future.

The two tunnels of the NFAC are of two different types. The 40- by 80-Foot Wind Tunnel is a closed return wind tunnel (Gottingen type) with a half-mile-long circuit, whereas the 80- by 120-Foot Wind Tunnel is an open circuit tunnel (Eiffel type). A closed return tunnel is shaped in a circuit so that it has a continuous flow of air in a circular pattern. An open circuit tunnel, on the other hand, is a type of tunnel where the flow of air follows a straight path from the entrance through the test section, followed by the diffuser, a fan section, and an exhaust of the air. Although different, the two tunnels share the same drive system.

Both types of tunnels have their advantages and disadvantages. One major advantage of a closed return tunnel is that it requires less energy to operate than the open circuit wind tunnel. Moreover, there is less noise during operation. An open circuit tunnel, however, costs less to build because it doesn't need return ducts and corner vanes to recirculate the airflow.

The basic design of the NFAC wind tunnels is a subsonic tunnel built to test takeoff and landing qualities of aircraft. A major part of the wind tunnel is the fan drive system. The NFAC tunnels both share one fan system currently capable of 135,000 horsepower. This system is comprised of six 15-bladed fans that are 40 feet in diameter. Each wooden propeller is driven by a 22,500 horsepower electric motor. At full speed, the motors reach 180 rpm. As in most wind tunnels the fans on the NFAC tunnels are located downstream of the second corner because highest efficiency is developed at this position. Airflow is created by having a low pressure area in front of the test section and a high pressure area behind it. The motors for these fans are mounted in the nacelle, an aerodynamic casing for the motor attached to the fan. In order to cool the motor, cooling air is blown through the nacelle supports and into the nacelle itself. As the fans circulate the airflow, turning vanes guide the flow around corners with a 90 degree bend. In addition, the turning vanes were added to avoid significant losses of airflow. Usually these corners are separated by a short duct. The first two corners of a closed-circuit tunnel are the most critical because of the uniform velocity of airflow needed at the fan.

The test sections of the NFAC tunnels are 40 by 80 feet and 80 by 120 feet as suggested by their names. The smaller tunnel has an elliptical-shaped test section whereas the larger tunnel has a rectangular test section. The test section of a wind tunnel is obviously the most crucial section of the tunnel, because the aircraft is placed in this section and all activities go on in this place. Models are brought into the test sections through huge doors by using a crane system. The 40- by 80-Foot Tunnel has its doors on the top of the test section, and the models are lowered into the test area.

The larger 80- by 120-Foot Tunnel has two large doors located on the east side of the tunnel test section. For this tunnel a 75-ton-capacity gantry crane is used for transporting models to and from the test section.

Both tunnels have a similar model support system. In the centers of the test sections, there are three struts mounted on a turntable. These struts can be adjusted to accommodate different models. Different angles of pitch or yaw can be tested and analyzed. The turntable which holds the struts is mounted to the wind tunnel balance. This balance, located below the test section, records the different forces applied to the model by the use of levers. There are several scales to measure lift, rear lift, drag force, and side force; the scales are very accurate. For example, in the 40- by 80-Foot Tunnel the accuracy of its balance system ranges from 0.01% of full scale for lift to 0.09% of full scale for pitch moment.

One difference between the two tunnels is the acoustic equipment in the test sections. The 40- by 80-Foot is lined with six inches of sound-absorbing material because it is used to test jet-powered models and helicopters with rotors turning. The 80- by 120-Foot has no acoustic materials lining the test section walls which are made of sheet metal. Both tunnels are controlled by way of the control room located outside the tunnels. An array of monitors and other instrumentation can be found in the control room.

The National Full-Scale Aerodynamics Complex consists not only of the wind tunnels but also three branches comprised of many engineers, computer programmers, technicians, etc. Currently, there are three branches--Fixed Wing Aerodynamics (FFF), Rotary Wing Aeromechanics (FFR), and Research Operations Branch (FFN). These three branches are in charge of testing, maintaining, and operating the complex. The Fixed Wing Aerodynamics branch consists mainly of aeronautical engineers studying all aspects of fixed-wing atmospheric aircraft. This is done through testing fixed-wing aircraft in the wind tunnels. They are also involved in researching and testing experimental aircraft such as Forward Swept Wing planes. The Rotary Wing branch is involved more with rotorcraft than with fixed-wing planes. This branch studies different types of rotors and their aerodynamic characteristics. The third branch, Research Operations, is responsible for maintaining and operating the wind tunnels in the NFAC.

Testing models and actual aircraft is an integral part of the NFAC engineers' work. The 80- by 120-Foot Tunnel has never been in operation, so no testing has been done in that facility, but there have been over 500 tests done in the 40- by 80-Foot Tunnel ever since its completion in 1944. The first tests done in the tunnel were mainly defense related. Some aircraft tested in the tunnels are the F-84 Thunderjet, Douglas XSBD-2, and a couple of years ago a model of the Space Shuttle was tested in the tunnel to study its aerodynamic characteristics. Also, many fighter-bombers and helicopters have been tested there.

On December 9, 1982, a major accident occurred in the wind tunnel causing it to be shut down for almost four years. The accident occurred during a test of the new 80- by 120-foot test section when a set of diverter vanes failed, and pieces of the steel-covered wooden vanes were pulled into the fan drive system destroying most of the fan blades and scattering debris throughout the fan diffuser area. The system was running at 107 mph when the vanes failed causing a vacuum effect in the tunnel. Tests done earlier at similar speeds in the 40- by 80-Foot Tunnel showed no signs of any problems in the vanes, but the vanes did not divert the flow of air as they experienced a greater load when the larger test section was in use. The damage was about $35 million, most of which went into research, turning vanes and purchasing new fan blades. Luckily no one was injured in the accident.

The accident also caused problems with the testing schedule for Ames. Among the programs affected were the Grumman 698 tilt-nacelle vertical/short takeoff and landing (V/STOL) aircraft model, V/STOL fighter configurations, and a forward-swept wing aircraft model. The schedule had to be rearranged so work in the big tunnel could come later.

The incident, which took place in 1982, has greatly set back Ames' aerodynamics research, but the NFAC will be ready for operation early this fall after years of repair and modifications. New systems have been installed to monitor the wind tunnels better, so that no mishaps like that in 1982 will ever happen again. Many of the workers involved with the wind tunnels are eager to see them running again. The first aircraft to be tested in both wind tunnels will be the Grumman 698 V/STOL aircraft. Before any aircraft testing starts the two tunnels will undergo a thorough systems check. If all goes well the NFAC wind tunnels should play an important role in the future of aerodynamics.

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Figure 1.- The NFAC complex is a dominating structure at NASA Ames. The 80- by 120-Foot Wind Tunnel can be seen on the right extending from the 40- by 80-Foot Tunnel.

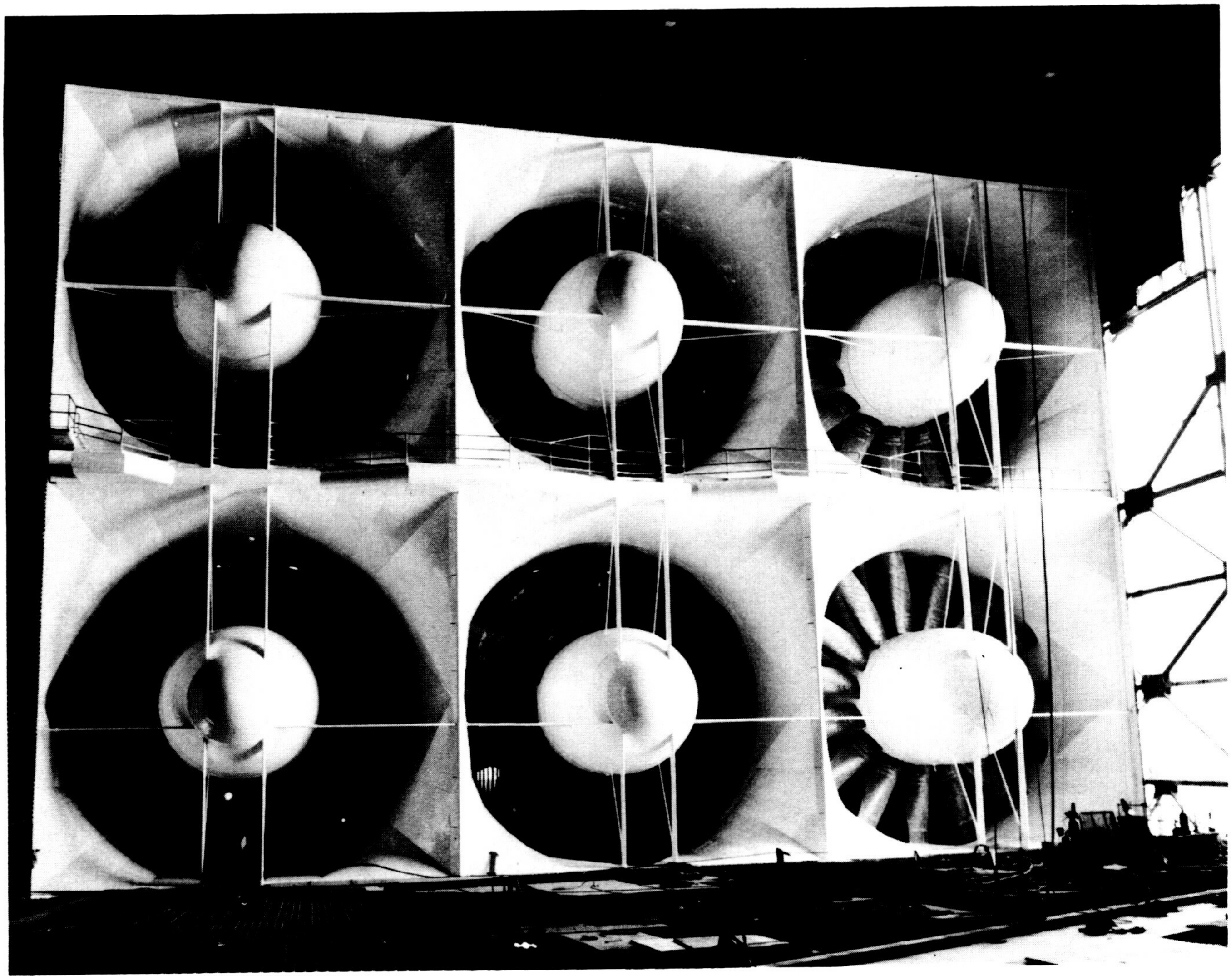

Figure 2.- The drive system consists of six 15-bladed fans each powered by a 22,500 horsepower electric motor.

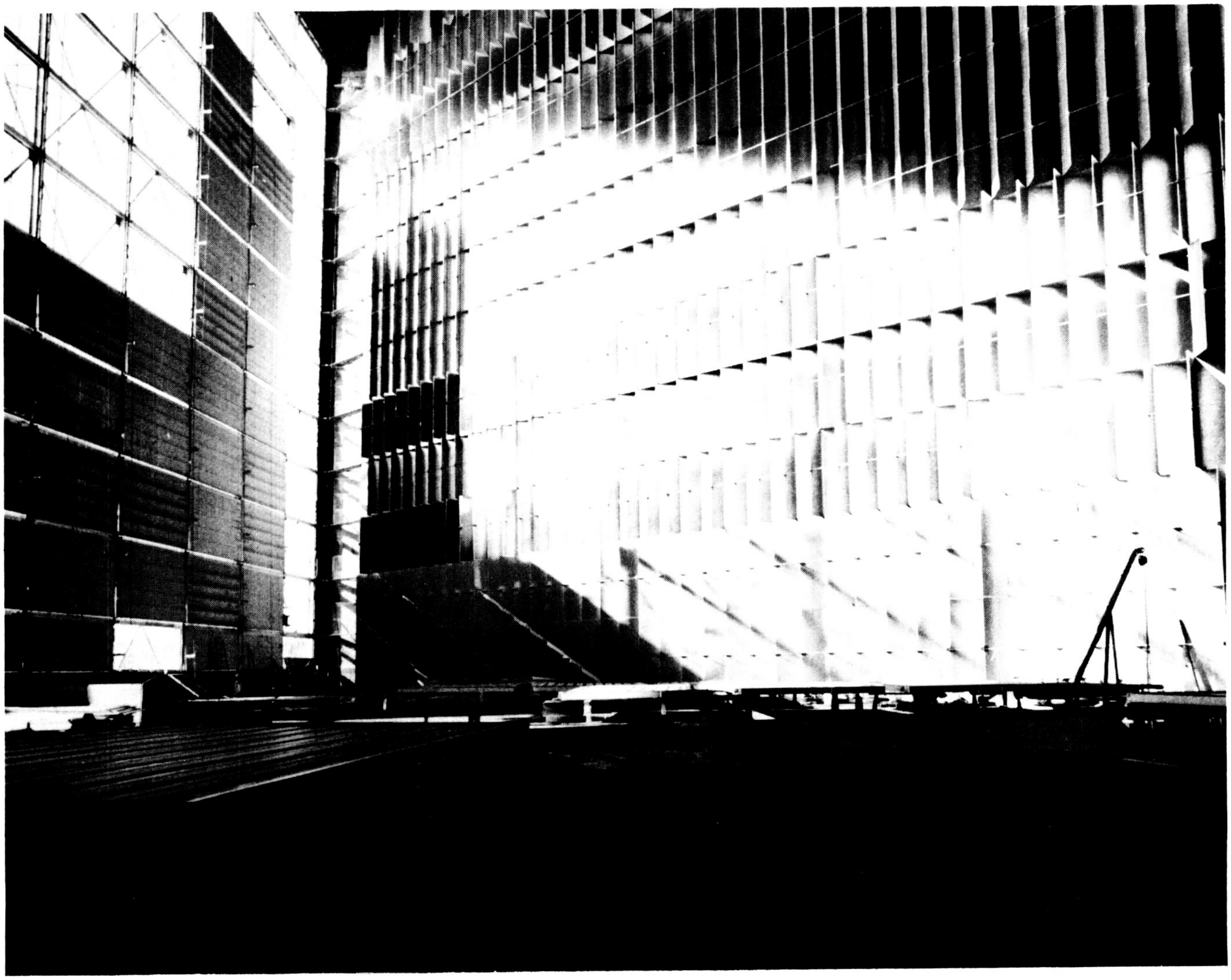

Figure 3.- Diverter vanes are used to direct the airflow around the corners of the 40- by 80-Foot Wind Tunnel.