# Altitude Wind Tunnel/Space Power Chambers

NOTE: This text-only version of the AWT/SPC website has been created to facilitate printing of the text. The index below links to sections within this document. Please refer to the actual AWT website for more.

## MAIN PAGE

### Historic Facilities at NASA Glenn

When constructed in the early 1940s, the Altitude Wind Tunnel (AWT) was the nation's only wind tunnel capable of studying full-scale engines under realistic flight conditions. It played a significant role in the development of the first U.S. jet engines as well as technologies such as the afterburner and variable-area nozzle. In the late 1950s, the tunnel's internal components were removed so that hardware for Project Mercury could be tested in altitude conditions. In 1961, a portion of the tunnel was converted into one of the country's first large vacuum tanks and renamed the Space Power Chambers (SPC). SPC was used extensively throughout the 1960s for the Centaur rocket program.

### Interactive History

This multimedia piece allows one to interactively learn about the AWT facility and the research conducted there. The piece contains a chronological history ~~with~~ of the AWT from its construction and testing of early jet engines during World War II, through the space programs of the 1960s, and to its final use as the Microwave Systems Laboratory. In all, there are over 200 photographs and video clips, including a 1961 NASA documentary on the AWT. Also included are layouts with corresponding images of the facility in different configurations. Links to over 70 related reports and publications are provided, as well. **Launch history**

**View text-only version**

### Panoramic Views of the Altitude Wind Tunnel

Click photo areas below to view a Quicktime virtual reality view of that location as it appeared during final photographic surveys of the AWT in 2005 and 2007. The highlighted sections are scheduled for demolition in 2008. **View panoramas**

*Images: AWT control room, Aerial view of AWT in 2005*

## I. INTERACTIVE HISTORY

This multimedia piece allows one to interactively learn about the Altitude Wind Tunnel (AWT) facility and the research performed there.

**Launch Interactive History**
**Text only version of Interactive History**

The piece contains:

- A chronological history of the AWT from its construction during World War II and the testing of early jet engines, through the Mercury and Centaur programs of the 1960s, and up to the final use of the building for the Microwave Systems Laboratory.
- Photographic surveys of the facility in its wind tunnel, vacuum tank, and final configurations.
- Browsable gallery of over 200 captioned photographs and video clips
- A 9-minute documentary on the AWT produced by NASA in 1961.
- Links to over 70 reports and publications related to AWT research and the history of the NACA and NASA.

### Additional Altitude Wind Tunnel Resources

A detailed physical description of the AWT is located in the Facility section of this Web page. Timelines, documents, and a Historical American Building Survey—Historic American Engineering Record (HABS–HAER) report are contained in the Research section. The Mitigation section describes the efforts undertaken to document the AWT before its demolition. The Students area describes the history and operation of both wind tunnels and vacuum chambers.

## II. FACILITY

Altitude Wind Tunnel: NACA engineers devised a number of ingenious features for the Altitude Wind Tunnel (AWT) to overcome the difficulties associated with operating engines in simulated altitude conditions. These features included a unique steel shell, an air scoop, a make-up air system, and specially designed banks of cooling coils.

Space Power Chambers: Between 1959 and 1963 the facility was slowly converted from a wind tunnel into two test chambers: one a large area that created altitude conditions similar to those produced during the tunnel years and the other, a smaller chamber, which was significantly modified to create a space environment. The facility was renamed the Space Power Chambers (SPC) in September 1962.

Support Buildings: The AWT complex incorporated several external buildings, which were vital to the operation of the facility. These included the Office and Shop Building, Refrigeration Building, Exhauster Building, and others. The tunnel's cooling system was the largest of its kind in the world and considered one of Willis Carrier's most significant accomplishments.

*Images: Diagram of AWT complex, View from top of AWT's western leg*
*Refrigeration Building and compressors, Interior of SPC No. 1*

## A. Altitude Wind Tunnel

When it was built in the early 1940s, the Altitude Wind Tunnel (AWT) was among the most complex wind tunnels ever designed. Its large size allowed the testing of full-scale engines instead of trying to replicate engine behavior in small models. It was also the first to create altitude conditions in which to study engine performance under flight conditions. The ability to control altitude conditions while modifying engines was particularly important during the early development of the turbojet. In order to accomplish these tasks, NACA engineers at the Langley and newly completed Ames laboratories developed several components for the AWT that had not been previously used.

### Tunnel Components

Tunnel Shell: The AWT's shell had to be specially designed to withstand external pressure when the tunnel was evacuated and to endure the low temperatures of the high altitudes without becoming brittle.

Air Flow: The AWT drive fan could produce wind speeds up to 500 mph. Because engines were being run in the tunnel, the airflow had to be constantly purged and replenished with cool, clean air

Altitude Simulation: The most complex aspect of the AWT's operation was the simulation of altitude conditions. A massive exhauster system was built to thin the air and a refrigeration system that was unrivaled in the world was designed to produce the low temperatures.

Test Chamber: The 20-foot diameter test section was one of the largest in the country. It contained an intricate balance chamber to measure the engine's behavior and supply lines to run the engines. The control room used to run the aircraft engines and the tunnel was adjacent to the test section.

*Images: Schematic diagram of AWT complex, AWT tunnel shell, Drive Fan, Refrigeration System, Test Section*

## 1. Tunnel Shell

The overall shape of the Altitude Wind Tunnel (AWT) was similar to several other contemporary wind tunnels of the National Advisory Committee for Aeronautics, such as the 19-Foot Pressure Tunnel at Langley Memorial Laboratory and the 16-Foot High Speed Wind Tunnel at the Ames Aeronautical Laboratory. The AWT's internal pressure and temperature levels however, required new methods of designing the tunnel's steel shell.

The tunnel itself was a massive rectangular structure, which for years provided one of the highest vantage points on the laboratory. The tunnel was 263 feet long on the north and south legs and 121 feet long on the east and west sides. The larger west end of the tunnel was 51 feet in diameter throughout. The east side of the tunnel was 31 feet in diameter at the southeast corner and 27 feet in diameter at the northeast. The throat section, which connected the northwest corner to the test section in the middle of the long northern leg, narrowed sharply from 51 to 20 feet in diameter.

*Image: Aerial of wind tunnel*

**Foundations**: The tunnel was braced by a large elliptical support ring in each corner, the Shop and Office Building's test chamber in the middle, and a series of 120 support rings which lined the tunnel at 6 foot intervals. Eight of these support rings and the four larger corner rings were anchored to concrete and steel piers which elevated the tunnel. Unique steel rollers were used to bear the tunnel shell in a way that allowed the shell to contract and expand during the tunnel's dramatic temperature and pressure fluctuations. One row of five of the 22-inch long and 4-inch diameter rollers was stacked perpendicularly on a second row of five rollers. The rollers were placed between the concrete piers and the support ring buttresses.

*Images: AWT foundations , Construction of supports , H-shaped support , Northeast corner of AWT*

**Shell:** A team of engineers at the NACA's new Ames Aeronautical Laboratory were responsible for designing the AWT's distinctive shell in 1941 and 1942. The shell consisted of two steel layers with a blanket of insulation between. The inner steel layer was the primary tunnel structure. Its 1-inch thick steel could withstand external pressure when the tunnel was evacuated to high altitude pressure levels. A T-1 steel alloy with three times the strength of normal carbon steel was used to so that the shell could endure the low temperatures of the high altitudes without becoming brittle.

A 4-inch layer of glass wool was installed with steel mesh over the inner tunnel shell to retain the tunnel's low temperatures. The outer 1/8-inch steel shell was then constructed over this to protect the protection from the environment.

*Images: View of inner and outer shells, Exterior in 2005,*
*Wide end of AWT, Fiberglass insulation*

**Roof:** By the mid-1940s, a series of stairs, ladders, and platforms were built on the roof of the tunnel. Access was provided by doorways off the east and west sides of the second floor of the test chamber in the Shop and Office Building. Stairs led to the top of the west end of the tunnel. The walkway, interrupted only by the four corner rings, followed the top of the tunnel until ending at the west side of the test chamber.

Steel grated platforms replaced the original wooden platforms by mid-1945. An elaborate catwalk system would be added to the east end after the Space Power Chamber dome was added in 1963.

*Images: AWT roof with walkway, Aerial of office wing,*
*Men on top of tunnel, Aerial of AWT in 1980s*

## 2. Air Flow

The Altitude Wind Tunnel (AWT) could produce wind speeds up to 500 miles per hour through its large 20-foot-diameter test section at the standard operating altitude of 30,000 feet. The average speed at lower altitudes was 345 miles per hour. The airflow was created by a large fan near the southeast corner. Elliptical panels of turning vanes were installed in each corner to guide and even the airstream. The tunnel contracted from a diameter of 51 feet to just 20 feet as it approached the test section. This contraction accelerated the air velocity as it passed the engine studied. Contamination from the engine exhaust had to be removed to maintain the altitude conditions and replenished with clean air while the tunnel was running.

**Drive Fan:** A 12-bladed 31-foot-diameter spruce wood fan as used to create the airflow. The fan was driven at 410 revolutions per minute by an 18,000-horsepower General Electric induction motor that was located in the rear corner of the Exhauster Building. An extension shaft, sealed in the tunnel's shell with flexible couplings that allowed for the movement of the shell, connected the motor to the fan. A bronze screen secured to the turning vanes protected the fan against damage from failed engine parts sailing through the tunnel. Despite this screen the blades did become worn or cracked over time and had to be replaced. An entire new fan was installed in 1951.

*Images: Drive fan, New set of fan blades, Turning vanes, Deterioration of fan blade, Drive system diagram*

**Air Scoop:** A unique air scoop was installed immediately downstream from the test section to collect combustion byproducts as they were exhausted by the engines being tested. This scoop, which resembled an aircraft engine nacelle, was held at the center of the tunnel by a vertical support. Compressors in the nearby Exhauster Building drew the vented air out of the tunnel and discharged it into the atmosphere. It was estimated that this scoop would remove 40 percent of the engine exhaust and that a 6000-pound per minute exchange of air would produce a 95 percent clean airflow. In 1951, a large exhaust-gas cooler was installed underneath this section of the tunnel to improve the system.

*Images: Air scoop beyond test section, New compressors, Installation of exhaust gas cooler, J57 engine near air scoop*

**Make-Up Air:** A make-up air system was developed to replenish the air removed by the air scoop. Air from the atmosphere was drawn into a large air dryer located outside the tunnel's southwest corner. The dryer removed condensation from the air to prevent shocks to the tunnel's airflow. After the air was initially cooled in the building's primary coils, its moisture was absorbed by activated alumina beds in the dryer. The air temperature was reduced to the final desired level with a second set of cooling coils. This processed air was introduced into the tunnel through two portals in the western tunnel wall. One of the nozzles extended well into the tunnel and piped the new air directly through the test section. Later this pipe was extended and attached to the engine inlets to increase the tunnel's capacity.

*Images: Ramjet with air directed to inlet, Aerial of Dryer, AWT Damper Room, Make-up air line in 2005*

### 3. Altitude Simulation

The two primary aspects of altitude simulation are the reduction of the air pressure and the decrease of temperature. This was accomplished through the Altitude Wind Tunnel's (AWT) large exhauster and refrigeration systems. These were vital components to the AWT's operation and set it apart from other wind tunnels. The tunnel was originally designed for temperature altitude simulation of up to 30,000 feet and pressure altitude simulation of 45,000 feet. This capacity was increased over the years and reached 100,000 feet by the mid-1950s.

**Cooling System**: NACA engineers were having a difficult time developing a method of cooling the massive airflow in the AWT to levels necessary for the desired altitudes. Pressure was on to complete the tunnel for use during World War II, and Willis Carrier, who's Carrier Corporation had pioneered the refrigeration industry, took on the AWT project. After several months of studies, the Carrier engineers devised a cooling system that was the largest of its kind in the world. Carrier later referred to the AWT as his greatest achievement. The system could lower the tunnel's temperature to –47° F, and it was claimed that if used for other purposes it could generate 10,000 tons of ice per day.

The cooling system was powered by 14 Carrier compressors, which were housed in the Refrigeration Building to the west of the tunnel. The compressors converted the Freon 12 refrigerant into a liquid. The refrigerant was then pumped into the eight identical banks of cooling coils inside the tunnel's return leg. These coils were a collection of 260 copper-plated coils arranged in a zigzag design that covered a 51-foot width of the tunnel. The Freon absorbed heat as the air passed through the coils. The heat was transferred to the cooling water and sent to the cooling tower where it was dissipated into the atmosphere. At its original capacity, 20,000 gallons of cooling water were required for the system every minute.

*Images: Control room Cooling coils, Refrigeration equipment, Cooling Tower No. 1, Aerial of refrigeration lines*

**Exhaust System:** In addition to removing contaminated air through the air scoop, the exhaust system was used to reduce the air pressure to create the thin atmosphere found at high altitudes. The Exhauster Building directly to the east of the tunnel housed four 1750-horsepower exhausters. These pumped the air out of the tunnel and expelled it into the atmosphere.

The Exhauster Building pumps could originally only handle two–thirds of the 6000 pounds of air per minute required by the AWT, so the system was complemented by the Roots-Connersville centrifugal compressors in the Engine Research Building's basement. The original configuration could simulate altitudes up to 45,000 feet. Most tests were conducted over a range of altitudes beginning as low as 10,000 feet and increasing incrementally to 35,000 feet.

As part of a larger AWT modernization program in 1951, the exhaust system was overhauled. The Exhauster Building was expanded with more powerful compressors, an exhaust gas cooler installed under the air scoop, and circulating water pump house built. In 1957, the Propulsion System Laboratory's Central Air and Exhauster Building, which began operating in 1952 was linked to the exhaust system AWT and Engine Research Building systems. The result for the AWT was an improvement from 12 to 7 pounds per second at 50,000 feet and 66 to 51 at 28,000 feet.

*Images: Worthington exhausters, Exhaust pipe in 2005, Compressor in Exhauster Building annex, Central control room*

## A. Community Awareness Meeting

On April 27, 2006, NASA Glenn Research Center invited the public and NASA employees to a meeting in order to learn more about the NASA's plans to demolish the Altitude Wind Tunnel and the Propulsion Systems Laboratory 1 and 2. The attendees learned details about the proposed demolitions, the history of the facilities, efforts underway to document the facilities, and the results of the environmental impact studies conducted for the projects.

In accordance with the National Preservation Act, the meeting allowed attendees to ask questions and voice any opposition to the projects. The presentations were videotaped, and copies can be obtained by contacting the NASA Glenn History Office at history@grc.nasa.gov. The PowerPoint slides which combine the text of the talks with historic photographs and charts can be viewed below.

**Slides from the presentations:**
History of the Altitude Wind Tunnel
Demolition Plan and Environmental
Impact Historical Mitigation Project

**Documents:**
Event Brochure
Site Location Map
Press Release
Announcement

## B. Historical Mitigation Effort

Section 106 of the National Historic Preservation Act requires that Federal agencies document their historic facilities before any significant structural changes, demolitions, or relocations. NASA Glenn Research Center has a number of historic facilities, some of which are scheduled to be demolished. The NASA Glenn History Program, Preservation Officer, and facility managers have worked with the Ohio State Historic Preservation Officer to develop strategies, budgets, and work plans to record the history of these facilities.

The result will be a permanent documentary record for the facility, lessons learned insight for internal NASA use, increased public awareness of NASA Glenn contributions to society, educational resources, and a collected body of materials for future researchers. The Altitude Wind Tunnel project consists of two facets—the documentation and preservation of the facility's history and the interpretation and dissemination of that information to the public.