NASA LANGLEY RESEARCH CENTER,       HAER No. VA-118-F
TWO-DIMENSIONAL LOW TURBULENCE PRESSURE TUNNEL
(Building 582A)
582A Thornell Avenue
NASA Langley Research Center
Hampton
Virginia

PHOTOGRAPHS
WRITTEN HISTORICAL AND DESCRIPTIVE DATA

HISTORIC AMERICAN ENGINEERING RECORD
National Park Service
U.S. Department of the Interior
1201 Eye Street, N.W. (2270)
Seventh Floor
Washington, D.C. 20005
Location: The Two-Dimensional Low Turbulence Pressure Tunnel (LTPT) (NASA Building 582A) is located in the NASA Langley Research Center (LaRC) East Area at 582A Thornell Avenue. NASA LaRC is located within the City of Hampton, Virginia.

The LTPT is located at latitude: 37.078886, longitude: 76.343683. This coordinate represents the approximate center of the facility. This coordinate was obtained on October 13, 2009, using Google Earth. The datum used for this point is North American Datum 1983. The LTPT’s location is restricted to the public.

Date of Construction: 1938-40

Present Owner: United States National Aeronautics and Space Administration (NASA)

Present Use: Vacant

Significance: The NASA LTPT is a significant historic resource at the national level for its association with advances in aerodynamics research and testing conducted by the National Advisory Committee for Aeronautics (NACA) and NASA LaRC. The LTPT was developed after researchers recognized the shortcomings of the data obtained in the earlier Variable Density Tunnel (VDT) due to its high stream turbulence level. To resolve this issue, the Two-Dimensional Low-Turbulence Pressure Tunnel, which had the lowest turbulence level of any wind tunnel in the world, was designed. This was an important development, because aircraft operate in an atmosphere with very low turbulence. The initial focus of research in the LTPT was to develop a design approach for airfoils with more laminar flow, and therefore lower drag, than attainable on the conventional turbulent-flow airfoils developed in the VDT. The systematic development of this family of so-called laminar-flow airfoils, along with the earlier contributions of NACA to the development of airfoils in the VDT, was a principal reason for NACA’s world-wide reputation in aerodynamics. The associated report on these airfoils is still considered to be the “Bible” of airfoil characteristics.
PART I. HISTORICAL INFORMATION

A. Physical History:

1. Date of Construction: 1938-40


4. Original Plans: The current plan and configuration of the facility matches the original plan for the building. The first portion of the facility constructed was the tunnel circuit begun in 1938. The completed tunnel was soon followed by the two-story L-shaped office building that wraps around the south and east sides of the tunnel constructed in 1940.

5. Alterations and Additions: The exterior of the LTPT has undergone few modifications since its time of construction and currently appears much as it did when first built. The only visible exterior modifications that have occurred include the replacement of all original doors and windows on the office building,
and the addition of solar resistant heat shields to the top of the tunnel shell. The replacement windows fit within the original openings and retain a similar light configuration.

The majority of modifications that have occurred to the facility consist of updates to the interior of the building, as well as to the mechanical equipment and computer systems within the tunnel to maintain up-to-date technology for the ongoing research carried out. These modifications include and are not limited to, the conversion of the tunnel for use with Freon in 1948, the addition of slotted walls in 1953; and the replacement of the original cooling coils and anti-turbulence screens, the addition of a tunnel-shell heating system, a two-dimensional model support and force-balance system, a sidewall boundary-layer control system, a remote-controlled survey apparatus, and a new data-acquisition system, all between 1979 and 1982. The electrical substation that provides power to the facility has also been replaced with a newer system at an unknown date.

B. Historical Context: The National Advisory Committee for Aeronautics (NACA) was established on March 3, 1915, with the mission of supervising and directing the scientific study of the problems of flight, with a view to their practical solution. European aviation advances and the potential for U.S. involvement in the First World War had largely been responsible for the creation of the NACA, which was officially approved as a rider on the naval appropriations bill for 1916.

The NACA was appropriated $53,580 for lab construction on August 29, 1916, but no funds were provided for purchasing or developing a laboratory site. Committee members were well aware of the Army's $300,000 appropriation for a flying field, and apparently saw it as their best opportunity for a laboratory location.1 The NACA initiated specific actions to establish a joint civil-military experimental field with the Army, and efforts to advance civil and military aviation coincided at a site eventually known as Langley Field, lying four miles north of Hampton, Virginia, on the flat lands facing the two branches of Back River, which opens out into the Chesapeake Bay.2

Work began slowly at Langley to plat streets, construct buildings, and grade two aircraft runways; however the U.S. entry into World War I in 1917 brought about accelerated construction and increases in money as well as personnel. NACA requested a small plot be assigned to them for the construction of their experimental laboratory at Langley,

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"near the water front and preferably near the western end of the field". The space was provided to them unofficially, but the army did not want to make an official sanction until further into the planning and development process of Langley Field.

When the war ended in 1918, Army airfield construction immediately came to a halt. Many bases across the country had been leased and were simply abandoned; however Langley had been created before the war with the intention of providing an experimental flying field and proving ground for aircraft, and therefore was retained after the war to carry out its original intent. The NACA once again repeated their request to officially have their plot at Langley sanctioned to them, stating that the laboratory building had already been completed and that construction of a wind tunnel for research was underway. It was therefore necessary to officially recognize their claim so as to avoid potential disputes with the Army.

By this time however, the Army Air Service had been reorganized and the NACA issue became entangled in the larger question of how post-war Army aviation would be structured. The Army believed there was no need at all for a separate organization to conduct experiments in aviation and aeronautics and claimed that such a division of control at Langley would become burdensome. The issue was resolved however when acting Secretary of War Benedict Crowell approved a memorandum stating that the "portion of Langley Field known as Plot No. 16 be definitely set aside for use by the National-Advisory Committee for Aeronautics for their purposes in constructing laboratories or other utilities necessary in scientific research and experiments in the problems of flight." The issue of dual control was resolved by authorizing NACA to conduct its work independent of the Air Service, with the exception that NACA personnel would come under the control of the Post Commander in matters pertaining to discipline, fire, guard, police and sanitation.

Despite the Army’s continued reservations, the NACA's laboratory was officially dedicated in conjunction with completion of its first wind tunnel on June 11, 1920. NACA's laboratory was officially named the Langley Memorial Aeronautical Laboratory (LMAL) in honor of Samuel Pierpont Langley, the "father of aviation." On January 15, 1921, legislation authorizing occupancy of quarters by LMAL personnel passed the Senate and was favorably reported to the House. Later that year, a new and more sympathetic Commanding Officer arrived at Langley Field, which greatly improved

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3 Hansen, James R. Excerpt about the Two-Dimensional Low Turbulence Tunnel from the Engineer in Charge. 1987. NASA LaRC Archives: 11
military-civilian relations. From this point on, the NACA’s researchers were finally able to conduct their work in earnest.5

When LMAL was officially dedicated in June 1920, the laboratory complex included three buildings. The “Research Laboratory” (Building 587), completed in 1918, which included administrative offices, drafting, machine/woodworking shops, and photography and instrument labs, as well as a lunchroom on the second floor. The wind tunnel building (Building 580), completed in 1920, which housed Tunnel No. 1, and the third building, which was a temporary structure for the engine dynamometer lab equipment.

The LMAL was in full operation by April 1921 and the NACA hired Dr. Max Munk to direct its growing aeronautical research program. A German theoretical aerodynamicist from the Zeppelin Company, Munk had abilities as a theoretician and generalist which the Committee expected would enable him to draw conclusions from LMAL’s research.6 Munk soon set about designing the LMAL’s second wind tunnel to address the problem of “scale effect.” This phenomenon had posed a serious problem for wind tunnel research, as it skewed research results and required correction to accurately simulate conditions encountered by an actual airplane in flight. In response, Munk designed and built the Variable Density Tunnel (VDT), which could vary air density “so that almost any model of reasonable size could be tested under conditions comparable to those encountered by a full-scale aircraft in flight”.7

NACA’s building program of the late 1920s was characterized by “daring and originality” in developing research equipment for the LMAL.8 With the VDT, NACA became renowned for “innovative research techniques and tools,” and they translated this fame into more funds from Congress for equally innovative facilities and equipment in the years to come.9

The LMAL continued Max Munk’s VDT program to develop improved airfoils throughout the 1920s and the results of this research were published in 1933 as Characteristics of 78 Related Airfoil Sections from Tests in the Variable-Density Tunnel. However, the great amount of airstream turbulence in the VDT gradually came to the attention of LMAL researchers. In 1930, a Full-Scale Tunnel (FST) was completed, and test results from that tunnel made it clear that full scale tests were more accurate reflections of actual flight conditions than VDT tests. Competition between LMAL’s

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5 Victory, John, “The Langley Laboratory,” TMs (Rough Draft) [photocopy] citing Memorandum Griffith to Victory, January 5, 1922 Langley Historical Archive, NASA Langley Research Center, Hampton, Virginia.
7 Ibid
8 Ibid: 106
9 Ibid: 93
VDT and FST sections produced a tunnel turbulence factor to compensate for VDT turbulence, but this was seen only as a short-term solution. Eastman Jacobs, head of the VDT section, began to push for a new, larger VDT with airstream quality approaching that of the smooth air of free flight. Jacobs thought that a low-turbulence pressure tunnel “would greatly enhance the two related lines of research that the VDT team had long been pursuing: development of new airfoils, and better understanding of the basic aerodynamic relationship between airstream turbulence, boundary-layer flow, and wing performance”.

Jacobs’ request for a new tunnel based on low turbulence levels was not accepted by Langley’s management based on technical doubts over the necessity of such a facility by other technical experts at Langley including Theodore Theodorsen. In addition, management believed that Congressional approval for the tunnel would be difficult to achieve based on the vague technical factors involved. However, aircraft icing problems were a high-priority issue in the NACA mission at the time, and Jacobs and Ira Abbott commenced to designing an “icing tunnel” which had the same dimensions and layout as a desirable low-turbulence tunnel. Using this ploy, prototype of the low-turbulence tunnel was built as the NACA Ice Tunnel with the stated purpose of investigating ice formation on aircraft components. The Ice Tunnel became operational in 1938 served its alleged purpose with a few rapid investigations of icing, and then its refrigeration equipment was quickly removed and the tunnel was converted with arrays of honeycomb and screens to reduce the turbulence levels to extremely low levels. The successful operation of this initial low-turbulence tunnel led to preparations to build a dedicated, pressurized low turbulence tunnel to be known as the Langley Two-Dimensional Low Turbulence Pressure Tunnel (LTPT).

Construction of the LTPT was authorized in 1938, and after two years of construction at a cost of $611,944.50, the facility became operational in 1941. The LTPT was larger, built of steel, and could test at pressures up to ten atmospheres. It was designed for testing airfoil sections at high Reynolds numbers approaching full-scale values and for extremely low airstream turbulence levels for laminar-flow airfoil research. The LTPT obtained high Reynolds numbers by increasing the tunnel air density up to ten atmospheres, and low turbulence was achieved by using a large contraction ratio of 17.6:1 with eleven fine-wire, small-mesh screen elements. At the time of its introduction, it had the lowest turbulence levels of any wind tunnel in the world. Its turbulence was less than one-hundredth that of the original VDT. With the completion of this tunnel,
the investigators now had “an incomparable tool” for developing airfoils. The new test capability focused on the development of low-drag airfoils that were incorporated into many military aircraft including new laminar-flow airfoils used on fighter aircraft. It was the site of airfoils cataloged by Ira Abbott and Edward Von Doenhoff in a report which became the “Bible” of airfoil information for future aeronautics studies.

In 1948, the LTPT was converted for use with Freon and was modified with slotted walls to permit transonic testing in 1953. Neither of these modifications were very successful however, and after 1955, testing in the LTPT was drastically reduced. During this time, the main function of the tunnel was on a standby basis as a pressure vessel for the nearby 26-Inch Transonic Blowdown Tunnel and other small high-speed tunnels. In the early 1970s, interest in the development of low-speed characteristics of new types of supercritical airfoils for commercial and privately-owned aircraft increased, and as part of NASA LaRC’s program on these topics, the LTPT was reactivated.

Between 1979 and 1982, the tunnel underwent a major rehabilitation to make repairs to aging and deteriorating elements, as well as to improve various components necessary for contemporary research. The two main objectives of this rehabilitation were to restore and improve the flow quality required for future laminar-flow research and to provide a two-dimensional model-support and force-balance system for high Reynolds-number testing of both single-element and multi-element airfoils.

Recent research applications in the LTPT have included extensive contributions of new airfoil designs, more efficient high-lift flap systems, and basic studies of flow phenomena at high Reynolds numbers. Aerodynamic studies of specific aerospace vehicles have contributed to the development of the X-1, F-100, F-111, F-14, F-15 and C-5A aircraft; and the Saturn, Apollo and Space Shuttle spacecraft. Additional research focused on problems of efficiently integrating engines into airframes for better performance of commercial and military aircraft.

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14 Ibid: 107
17 Hansen, James R. Excerpt about the Two-Dimensional Low Turbulence Tunnel from the Engineer in Charge. 1987. NASA LaRC Archives.
18 Ibid
20 NASA, “History of NASA’s Low Turbulence Pressure Tunnel.” No Date.
In 2006, the drive motor of the LTPT burned and the tunnel was deactivated from lack of funds to refurbish it. Plans for demolition of the LTPT have begun.\textsuperscript{21}

\textsuperscript{21} NASA, “History of NASA’s Low Turbulence Pressure Tunnel.” No Date.
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<td>1948</td>
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<td>1953</td>
<td>Tunnel Retrofitted to Slotted Throat Design</td>
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<td>1955</td>
<td>Tunnel Downgraded to Serve Strictly as a Pressure Vessel for the 26-inch Transonic Blowdown Tunnel</td>
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<td>1970s</td>
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<td>1983</td>
<td>Major Rehabilitation to Allow for Continued Use of the Tunnel Facility Completed</td>
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<td>2006</td>
<td>Drive Motor Burned Causing the Tunnel to Become Permanently Deactivated</td>
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PART II. STRUCTURAL/DESIGN INFORMATION

A. General Description:

Site

Building 582A was constructed between 1938 and 1940 and abuts the north side of the earlier Building 582 (Variable Density Tunnel). It is set back from Thornell Avenue with a narrow grassy lawn between the building and the street. A concrete sidewalk extends the length of the facade and is separated from the street by a narrow grass strip. There are widely space mature shrubs along the front of the building. A wide concrete sidewalk extends from the entry at the north end of the building and intersects the public sidewalk near the street. To the north side of the building is a narrow alley, and to the rear of the building is the former Transonic Blowdown Tunnel facility (Building 583).

Exterior

The laboratory and office portion of the LTPT is an L-shaped, two-story, Stripped Classicism-style building. It is constructed of red brick laid in a five-course American bond pattern set on a poured concrete slab foundation with footings and is topped by a flat roof covered with built-up materials. The facade is similar in composition to and inline with Building 582. (A photograph taken in 1940 shows that the front façade of Building 582 was appended to the earlier portion of that building at the same time that Building 582A was constructed.) The eleven-bay front façade of the office and laboratory building is organized into two blocks with a three-bay wide entrance block and an eight-bay secondary block. The three-bay block is delineated from the eight-bay block by projecting slightly forward and being topped by a slightly taller parapet which peaks above the central bay. This block features a centrally located main entrance consisting of double single-light doors with sidelights and transom. Above the transom is a cast concrete lintel that reads, “Two Dimensional Pressure Tunnel.” A wide window is set on the second-story above the entrance, and above this window is a cast concrete plaque with the NACA symbol.

Fenestration on the front façade of the building consists of aluminum windows with two fixed panes over two awning sashes set on cast concrete sills. The first floor windows are topped by a row of soldier-course brick lintels and the second floor windows are topped by four-course corbelled lintels. The windows are aligned vertically and are set in recessed panels that extend from the foundation up to the second story window lintels. In addition to the window sills and lintels, the building also features a cast concrete string course between the second floor and roof parapet which is capped by matching cast concrete coping. The only break in the string course is at the central bay of the entrance block where the cast concrete NACA symbol is located.
The south end of the building is only one-bay wide and has a similar composition to the front façade with narrow windows on both the first and second story. The majority of the rear of the building inside the L-shape is occupied and obscured by the large wind tunnel structure. The wind tunnel abuts the rear of the three-bay entrance block portion of the building, and the rear of the eight-bay block of the building is a blank brick wall. An enclosed walkway projects centrally from the rear façade of the building and leads under the wind tunnel to connect with Building 583 to the west. The side of the rear projecting portion of the L-shaped building features large industrial style-windows with a mixture of fixed and hopper panes and is where the large motor house of the tunnel structure connects to the building. The rear of this narrow wing of the building is only one-bay wide and has a set of metal double doors surrounded by louvered vents.

The exterior of the office and laboratory building remains mostly intact and has few modifications. The only significant alteration to the building is the replacement of all original doors and windows, although the replacements fit within the original openings.

Interior

The interior of the LTPT is divided into office space, workshop area, mechanical rooms, and testing areas. The main entrance to the building on the front façade, leads into a lobby area. This space has vinyl tile floors, and plaster covered walls and ceilings. From this lobby, a doorway to the right leads into a restroom, a doorway to the left leads into the main first floor hallway, a doorway on the rear wall leads to a second restroom, and a stairwell leads to the second floor. Both of the restrooms have been remodeled with typical materials such as ceramic tile floors and walls, and modern fixtures. The main hallway to the left provides access to the remainder of the first floor. This hallway has vinyl tile floors, wallpaper covered walls, and drop-tile ceilings. A doorway immediately to the right from this hallway leads out of the building through an enclosed corridor that connects to Building 583. On the left side of the main hallway are five doors that lead into three offices and a conference room. All of these spaces have been non-historically remodeled with carpeted floors, wallpaper covered walls, and drop-tile ceilings. At the end of the main hallway is a door that leads into the adjacent and connected Building 582, and just to the right is a door that leads into the facility motor room. The motor room is open through the second story and contains all of the mechanical, electrical, and motor equipment necessary for the operation of the facility. This room has poured concrete floors, exposed brick walls, and an exposed corrugated roofing system. The focal point of this space is the large motor and drive shaft that powers the fan blades in the wind tunnel. The motor rests on the ground near the rear of the room and is connected to the drive shaft that rests on a heavy raised concrete platform. This platform is accessed by a catwalk with a ladder to the ground floor. There are large industrial-styled metal casement windows on the side of this room and an exterior doorway to the rear. Overall,
the first floor of the LTPT building is simple, unadorned, and functional. All of the doorways have simple metal surrounds and the doors themselves are laminate wood. The windows have no embellishment and rest on simple wood sills.

The second floor of the LTPT facility is accessed by the stairwell in the main lobby. This stairwell appears original to the building, and consists of cast iron risers, treads, and railings. At the top of the stairs is a doorway that leads into the workshop area that occupies the majority of the second floor of the building. This room has hardwood floors, (although a large portion has been covered with vinyl tiles), exposed brick walls, and drop-tile ceilings. A large section of ceiling is left open for a suspended track system. This room contains many workbenches, tables and desks, along with various power tools and other equipment for the production of test models. At the far end of the workshop area is a doorway that leads into a short hallway with one office to the left. This office is similar to those on the first floor with carpeted floors, wallpapered walls, drop-tile ceilings, and simple door and window trim. A doorway at the end of this short hallway leads into the second floor of the adjacent and connected Building 582. To the backside of the enclosed stairwell in the workshop area is a storage area portion of the workshop and a control panel room for operating the wind tunnel. This control panel room is actually located within the tunnel structure, although it abuts the rear of the building and the two are connected at this point. Just to the left of the control panel room, is a tubular air lock corridor that leads into the test chamber section of the tunnel.

Throughout the LTPT building, all light fixtures, HVAC equipment, and other fixtures appear to be modern.

Tunnel

The closed-loop Low Turbulence Pressure tunnel is located to the north and west of the brick office and laboratory building within the area created by the L-shape. The ovalar-shaped, cylindrically-profiled tunnel circuit measures 145’ long by 58’ wide and covers a ground area of 8,400 square feet. It has a maximum diameter of 26’. The test section, and entrance and exit cones are surrounded by a twenty-two-foot diameter section of the shell to provide space to house much of the essential equipment. The tunnel is raised to the second floor of the office and laboratory building and rests on poured concrete piers. The tunnel varies in diameter, but is thickest at the test chamber section located immediately adjacent and connected to the rear of the three-bay entrance block of the lab building. It abruptly narrows to the south of this portion before slowly widening throughout the remainder of the circuit until it meets back up with the wide test chamber section again. The tunnel is constructed of welded steel plates that range from 3/8” to 2” thick. There are exterior transverse standing steel ribs to reinforce the steel skin of the tunnel circuit. The top half of the cylindrical tunnel is clad with heat-resistant solar panels.
The interior of the tunnel is accessed from the second floor of the office and laboratory building. A doorway in the workshop leads into an airlock chamber, which in turn, leads into the test chamber area. The test chamber is integral to the tunnel structure, although the wind tunnel itself is separate and flows through this area. A heavy, round pressure door separates the test chamber from the airlock. The room has a tubular cross-section composed of a poured concrete shell with metal flooring. The test-section portion of the tunnel flows through the room and has a rectangular cross-section that tapers out larger towards both ends. A complicated system of wires, tubing, computers, and other equipment connect from the main building to the tunnel test-section. There are several openings to the test section of the tunnel from within the plenum including the main access door, viewing windows on each side and the top, and a porthole-shaped two-dimensional model support mount window on each side. The two-dimensional model support structure straddles the tunnel and has arms that aim into the tunnel from each of the porthole openings. The opposite side of the test-section from the entrance to the plenum is accessed by a ladder and catwalk that straddles the tunnel.

Inside the tunnel test-section is a rectangular space composed of solid heavy metal. It is split by the full-height strut, shaped much like a fin, with a narrow arm (wake rake) that projects upwind (north). Upwind from the test-section, the tunnel abruptly widens before a series of tight-mesh screens. Beyond the screens the tunnel makes a 180-degree turn with several full-height wind channels. Downwind from the test-section, the tunnel slowly widens before making a 180-degree turn with a series of gridded turnvanes. At the rear corner of the tunnel, the large drive shaft enters the tunnel from the motor room, and is connected to a large twenty-blade propeller that spans the entire diameter of the tunnel.

1. Character: The LTPT has a unique character that is reflective of its specialized function. The LTPT office and laboratory building is similar to other facilities at NASA and incorporates a brick façade with minimal classical influences. Its protruding entrance block with a parapet, cast concrete string course, recessed window bays, and cast NACA plaque all indicate that it was designed to be aesthetically pleasing, and represent the architectural development of NASA LaRC. The attached wind tunnel structure to the rear of the building is especially interesting and worthy of attention. It is one of only several remaining exterior closed-loop wind tunnels that remain at NASA LaRC, as much of the current research being performed at the center is done on computers. The LTPT is therefore representative of the by-gone-days of research being performed in specialized wind tunnels and is an important aspect of the early development of research facilities at NASA LaRC. Because the large exterior wind tunnel is easily visible from the front and side of the office and laboratory building, as well as from much of the East Area, the LTPT is an important part of the visual character of NASA LaRC.
2. Condition of Fabric: Overall, the LTPT facility remains in a good condition, although it has begun to deteriorate from being abandoned. Moisture appears to be a threat to the resource as can be seen by sections of wallpaper that have begun to peel from the plaster, some sections of crumbling and missing plaster, and sagging or collapsing ceiling tiles in the office and laboratory building. The tunnel structure also remains in a good condition, although its numerous mechanical parts show some signs of wear and decay. Many of the components of the tunnel and its associated equipment are made of iron, steel, and other metal and exhibit some rusting from moisture. Despite the surface damage and deterioration to the facility, the overall structure appears to be solid.

B. Construction: The construction methods used at the LTPT are reflective of the specialized functions that were carried out at the facility. The office and laboratory building was built using a standard masonry structural system topped by a flat roof. The interior rooms of the building are furnished according to the uses of those spaces. The majority of the first floor serves as office space and therefore is finished with carpet, drywall, and drop-tile ceilings accordingly. The second floor serves as workshop space and is therefore left more unornamented for its utilitarian nature. The masonry walls are left exposed, the floors are hard wood, and the flat room support system is open allowing for a suspension track to be mounted.

The tunnel circuit has a much more complex design to accommodate its specialized function. The extreme conditions during testing such as high wind speeds, wide-ranging temperatures, and extreme pressures require that extraordinary construction materials and methods by employed. The tunnel structure is composed of a series of heavy steel rings fastened together into a continuous tube. The tube is reinforced by a series of transverse standing seam ribs on the exterior. It is anchored at one centrally located point and is supported at other points by flexible columns and sliding shoes in order to allow for movement due to temperature and pressure stresses. 22 A sun shade is provided over the top of the tunnel shell to reduce the differences in temperature between the upper and lower parts of the airstream due to solar heating to the upper part of the shell. 23

23 Ibid
C. Mechanicals/Operation:

Summary

The Two-Dimensional LTPT is a single-return, closed-throat type wind tunnel. The tunnel is powered by a massive drive system fan powered by a 2000 horsepower motor located at the southwest corner of the circuit. The twenty-blade fan propels air through the tunnel at speeds ranging from Mach 0.05 to 0.50, with air pressure ranging from 0.3 to 10 atmospheres absolute, giving a wide range of air densities.

A 350-psi offsite air supply system provides dry compressed air to the facility. Onsite storage tanks are utilized with an air capacity of 8000 cubic feet at 300-psi. A centrifugal five-stage compressor with a volume flow of approximately 15,000 cubic feet per minute powered by a 5500-horsepower drive motor supplies the air. The air is dried by an activated-alumina dryer system with a volume flow of 14,000 cubic feet per minute and an air-outlet dewpoint temperature of about -30°F is generally maintained. The heat exchanger upstream of the anti-turbulence screens can be used either for cooling or heating the airflow. An onsite compressor with a volume flow of 2,400 cubic feet per minute is used as an exhauster for tunnel vacuum operation.

After being propelled down the first length of the tunnel, the air is funneled through continuous splitter vanes as it makes a 180-degree turn towards the test section. Curved corners are used in this tunnel instead of the conventional right-angles used in other tunnels to minimize the stress concentrations associated with the high air pressures. There are nine fine-mesh screening elements to reduce turbulence levels located just before air approaches the high-contraction ratio entrance cone throat leading into the test section. The airstream enters the test section through a relatively short entrance cone from a large square section giving a contraction ratio of 17.6 to 1.24

The rectangular profiled test section can accommodate either two- or three-dimensional models. Two-dimensional test models usually completely span the 3’ wide by 7’ 6” tall test section, while three-dimensional test models typically have a smaller two foot span. For two-dimensional single or multi-element airfoil testing, the model is mounted by endplates to a unique model-support and force-balance system. For three-dimensional model testing, a wide variety of internal strain-gage balances can be used for force and moment measurements. The electronically scanned pressure (ESP) System provides highly accurate steady-state pressure measurements of the model and the facility. Airfoil surface boundary layers (BL) can be measured with a BL traverser mechanism mounted on the model endplate.

During the testing process, high-pressure air may be blown tangentially through slots located on the model end plates (sidewall boundary-layer control) to eliminate flow separation at the flap and sidewall juncture. The wake rake, which is mounted on the strut to the rear of the model mounts, can be positioned at various spanwise stations behind the model by means of the remote-controlled survey apparatus to enable the wake surveys to be made for various angles of attack.

Measurements of pressure on the model surfaces, wake rake pressures, and basic tunnel pressures are made with variable-capacitance precision transducers. The standard data acquisition system consists of an analog-to-digital converter, capable of acquiring 128 channels of analog data (up to 1000 Hz) and 40 channels of digital data, and a UNIX computer. Final data is reduced on a separate UNIX workstation. For data analysis, the facility provides UNIX and Macintosh computers. Customer supplied computers can be networked to the data reduction system if desired. Secure data links are available for classified projects. Photographic and video coverage of the test section is possible from the sidewall and ceiling windows. Video images of the model can be recorded on VHS recorders.25

After passing through the test section, the air escapes into the widened return leg before passing through turnvanes in the second 180-degree turn which guides it back to the propeller blades.

**Tunnel Specifications**

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**Tunnel Component Details**

The detailed mechanical components of the tunnel described below are compiled from information excerpted from the *NACA Technical Note No. 1283: The Langley Two-Dimensional Low Turbulence Pressure Tunnel*, as-built in 1947, as well as *NASA Technical Paper No. 2328: Recent Modifications and Calibration of the Langley Low-Turbulence Pressure Tunnel*, following rehabilitation in 1979-82.

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25 Wind Tunnel Enterprise. Low Turbulence Pressure Tunnel, NASA Langley Research Center. No Date
Drive and Control System - The air stream of the Langley two-dimensional low-turbulence pressure tunnel is driven by a twenty-blade aluminum-alloy propeller having a diameter of 13’. Counter vanes directly downstream of the propeller are provided to remove the twist from the airstream. The pitch of the propeller blades and the angle of the countervanes are adjustable. The propeller hub is enclosed by a 5’ diameter fairing. The propeller shaft extends through a packing gland in the tunnel shell and is connected to the motor located in the adjoining office and laboratory building.

The drive motor is a 2000-horsepower separately excited direct-current motor. Power is applied to the drive motor from a motor generator set. The field circuits of both the motor and the generator are equipped with vacuum-tube voltage regulators to minimize fluctuations in speed. Speed can be easily controlled throughout the entire range from idling speed to 600 rpm by varying the generator voltage and the motor field by manual movement of reostats in the regulator-control circuit.

Tunnel speed is measured on a manometer in terms of the uncorrected dynamic pressure of the airstream in the test section. An indication of the value is obtained from the difference between the pressures on an impact (total pressure) tube located in the large section of the tunnel ahead of the entrance cone and the static pressure on static orifices located a short distance upstream of the test section. Both the total pressure tube and the static-pressure orifices were calibrated against a standardized wind-tunnel calibrating pitot-static tube mounted in the tunnel test section. Factors with which to correct the measured total pressure and static pressures were thus obtained.

Screen Installation - The original screen installation was patterned after the screen installation in the earlier Langley Two-Dimensional Low-Turbulence Tunnel. Eleven screens were installed instead of seven and the suspension springs and fasteners were made considerably stronger to withstand the higher loads. The 0.0065-inch diameter wire size used allowed the tunnel to be operated below the critical Reynolds number of the wires up to a model Reynolds number of about $5.5 \times 10^6$ per foot of model chord. Upstream of the eleven 30-mesh screens, a 60-mesh screen was installed on a framework which supported the cooling coils.

During rehabilitation in 1979-82, the original screens were removed and replaced in order to increase the critical Reynolds number of the screen and thereby, increase the maximum Reynolds number for which low turbulence could be maintained. As part of the screen replacement, the wire diameter in the new screens was reduced to 0.0050”. The mesh was also increased from 30 to 39, and the screening material was changed from phosphor bronze to stainless steel. Because of advances in manufacturing techniques, the replacement screens were able to be produced in seamless 21’ x 21’ pieces as opposed to the three sewn together 7’ wide strips originally used.
Heat Exchanger – The original finned cooling coil was located in the large section of the tunnel immediately upstream of the 60-mesh screen to control the temperature of the airstream. This cooling coil was 5” thick and covered the whole area of the airstream. It contained a double row of copper tubes, through which water from a cooling tower was passed at the rate of 1000 gallons per minute.

This cooling coil was replaced in 1979-82 with a heat exchanger to provide both cooling and heating for improved usage during various weather conditions. The heat exchanger utilizes three steam injectors with modulated valves to control both temperature and volume flow of water through the coils. The energy expanded by the main-drive system is removed by the water flowing through the coils and transmitted to the atmosphere through a cooling tower located outside the facility.

In order to prevent extremely high humidity when the air in the tunnel is compressed, dehumidification of the air is necessary. This result is accomplished by a refrigeration unit in the test chamber containing coils for Freon-12 and water. Air from the tunnel is circulated through the refrigeration coils by a blower and the condensed moisture flows out of the tunnel through a drain trap. A relative humidity of approximately 50 percent is usually maintained.

The refrigeration unit also provides necessary cooling of the test chamber when the operating personnel are working inside. Additional coils for Freon-12, operating from the same refrigeration compressor as the coils in the test chamber, are installed in the air lock to provide cooling for personnel making entries into compressed air.

Blower Equipment - Auxiliary blower equipment consisting of three multistage centrifugal blowers, each driven by a 100-horsepower shunt-wound direct-current-motor, is installed inside the tunnel test chamber. Each blower has a maximum capacity of 3950 cubic feet per minute with a pressure rise of 3.5 pounds per square inch at atmospheric pressure and a maximum capacity of 1720 cubic feet per minute with an 8.0-pound-per-square-inch pressure rise at 10 atmospheres.

The blower duct system is interconnected so that flexibility in the use of the blowers in tunnel operation is obtained. Either one or two of the blowers is used for boundary-layer control of the test-section wall and for control of the test-section longitudinal static-pressure gradient. The remaining blower or blowers are used for tests requiring an external air supply.

Model Sizes - Models tested in the Langley Two-Dimensional Low Turbulence Pressure Tunnel usually completely span the 3-foot wide test section. Chords of these models have ranged from 6” to 100”. In general however, two ranges of chord size are used, namely a
24” chord for standard lift, drag, and pitching-moment characteristics, and a large-chord (70” to 90”) practical-construction models for drag measurements over a small angular range near design lift. Model chords for the determination of maximum lift coefficients have been limited to 36” because of the effect of the tunnel walls on the pressure distributions of large models at high lift coefficients.

Methods of mounting models for almost all tests except those in which pitching moments are to be obtained involve locking models to the angle-of-attack mechanism and completely span the tunnel test section with the ends of the model sealed to prevent air leakage. When pitching moments are to be obtained in the test, the model is mounted on a pitching-moment balance.

A major part of the 1979-82 tunnel rehabilitation was the installation of a new model and force-balance system capable of handling both single-element and multi-element airfoils. The airfoil model is mounted between two end plates, which are connected to the inner drums. The inner drums are held in place by an outer drum and yoke-arm support system. The yoke support system is mounted to the balance, which is, in turn, connected to the tunnel through a balance platform. The yoke arm is fabricated from aluminum in a monocoque structure to minimize weight loads on the balance system. The altitude of the model is controlled by a motor-driven, externally mounted pitch mechanism that rotates the bearing-mounted inner drums.

**Remote-Controlled Survey Apparatus** - Installed in 1979-82, the apparatus basically consists of an articulating arm mounted on an arc strut. Movement of the arm enables surveys using probes to be made over a range of positions in the tunnel test section. The arm is composed of three moveable components: a main boom, an offset boom, and forward-pivoting head. Each component has a position control device. The main boom is mounted on the strut with a pivot point allowing rotation in the vertical place. Its motion is controlled by the linear actuator. The offset boom can be rotated about the main boom by the roll actuator. This allows survey positions to be made at distance up to 12” from the tunnel centerline. The forward-pivoting head is mounted at the end of the offset boom and may be rotated in the vertical survey apparatus with a wake rake mounted on the forward-pivoting-head assembly. In addition, the entire apparatus can be positioned vertically in the wind tunnel by utilizing the movable strut, which moves within the confines of fixed leading- and trailing-edge fairings. The position and rate of movement of any survey device mounted on the apparatus are controlled by a microprocessor controller. Wake rake surveys using the remote-controlled apparatus provided acceptable drag results with a survey rate of about 0.10 inches per second.

**Data-Acquisition System** – The heart of the on-line data-acquisition system is a computer with a random access memory of 512K bytes coupled to a data-acquisition system with 192 analog and 16 digital recording channels, installed in 1979-82. This
system provides on-line data reduction and displays in real time, as well as instrumentation calibration capability for the tunnel. Force and moment data are measured with strain-gage balances which are temperature compensated and calibrated to account for first- and second-order interactions such that the system is generally accurate to within 0.5 percent of the design balance loads. Pressure data are taken with variable-capacitance precision transducers used with scanning valves. The data-acquisition system can accommodate up to ten 48-port scanning valves. The pressure transducers are automatically calibrated and are accurate within 0.5 percent of the reading plus 0.005 percent of the transducer rating. Each data point is generally computed on-line from ten scans of data taken over a one-second interval. Traversing probe data are taken in a continuous mode, and the number of samples changes with survey length and distance set between points instead of time intervals. Real-time data plots are displayed on cathode-ray tubes, and the system has hard-copy capability. Tunnel parameters are computed in engineering units and displayed in real time on a color cathode-ray tube.

**Types of Investigations to Which Tunnel is Suited** - The Langley Two-Dimensional LTPT, when originally built, was particularly well suited for investigation of the effects of the basic variables of shape, camber, and surface condition on airfoil, flap, and control-surface characteristics at Reynolds numbers in or near the flight range of modern airplanes. These basic variables can be studied and evaluated from two-dimensional flow data, which simplifies the problems to a great extent because many complicating factors entering the three dimensional tests are eliminated. Investigations are made with relatively inexpensive models of a size convenient for handling, and the results of the tests are quickly obtained with only a small amount of computation.

Investigations to find the aerodynamic characteristics of airfoils with air intakes and exits or with boundary-layer control slots can be easily made, and the wing-body interference effects of nacelles, fuselages, propellers, jets, and protuberances can be determined at relatively high Reynolds numbers with models of convenient size.
PART III. SOURCES OF INFORMATION

A. Primary Sources


Victory, John, “The Langley Laboratory,” TMs (Rough Draft) [photocopy] citing Memorandum Griffith to Victory, January 5, 1922 Langley Historical Archive, NASA Langley Research Center, Hampton, Virginia.


B. Secondary Sources


HISTORIC AMERICAN ENGINEERING RECORD

INDEX TO PHOTOGRAPHS

NASA LANGLEY RESEARCH CENTER, HAER No. VA-118-F
TWO-DIMENSIONAL LOW TURBULENCE PRESSURE TUNNEL
(Building 582A)
582A Thornell Avenue
NASA Langley Research Center
Hampton
Virginia

Chris Cunningham, Photographer November 2009

VA-118-F-1 VIEW OF OVERALL FACILITY, FACING SOUTHWEST
VA-118-F-2 VIEW OF FRONT FAÇADE, FACING NORTHWEST
VA-118-F-3 DETAIL OF MAIN ENTRANCE BLOCK, FACING NORTHWEST
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<td>Photocopy of Photograph (Original in Langley Research Center Archives, Hampton, VA [LaRC] (NACA L-19140) Photographer Unknown, Date 1940. VIEW OF TUNNEL UNDER CONSTRUCTION, TEST SECTION, FACING NORTHWEST</td>
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<td>Photocopy of Photograph (Original in Langley Research Center Archives, Hampton, VA [LaRC] (NACA L-22007) Photographer Unknown, Date September 18, 1940. VIEW OF FACILITY FOLLOWING THE COMPLETION OF CONSTRUCTION, FACING SOUTHWEST</td>
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<tr>
<td>Photocopy of Drawing (Original in Langley Research Center Archives, Hampton, VA [LaRC] Artist Unknown, Date Unknown. SCHEMATIC DRAWING OF LTPT FACILITY AND THE ADJACENT ICE TUNNEL FACILITY, FACING SOUTHWEST</td>
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HISTORIC AMERICAN ENGINEERING RECORD
SEE INDEX TO PHOTOGRAPHS FOR CAPTION
HAER NO. VA-118-F-3
Two-Dimensional Flow Tunnel

This tunnel is used for investigating airfoils under conditions approaching free flight at speeds up to 300 miles per hour and pressures from 1 to 10 atmospheres.