WESTERN MICHIGAN UNIVERSITY

Department of Mechanical and Aeronautical Engineering

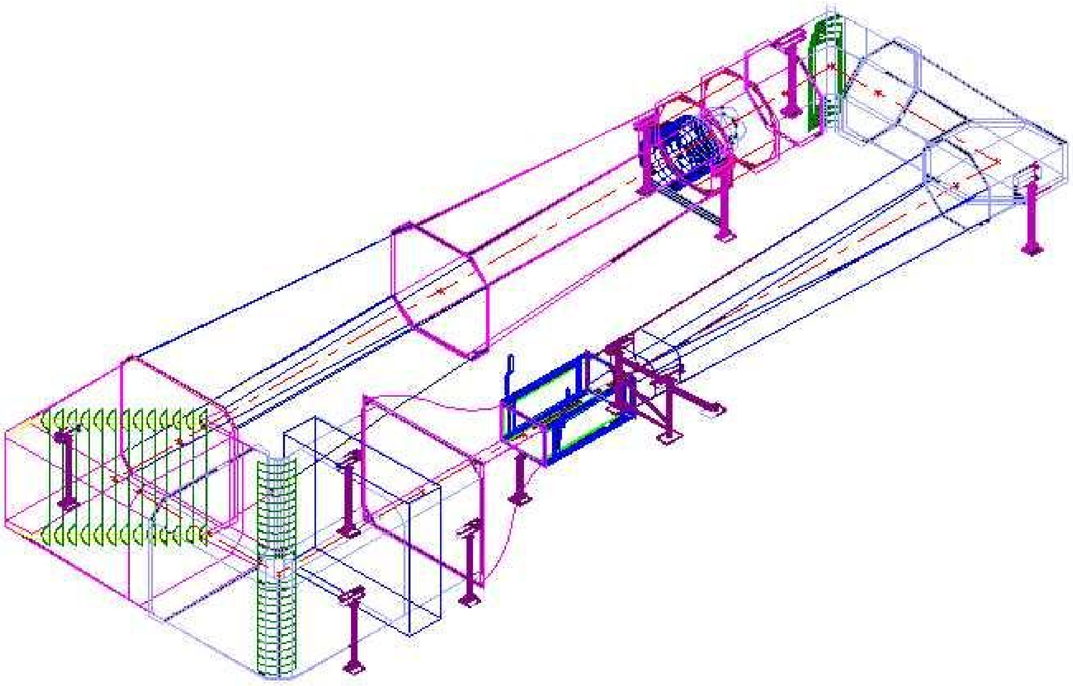
ADVANCED DESIGN WIND TUNNEL - FACILITY DESCRIPTION AND INSTRUMENTATION

INTRODUCTION

The Advanced Design Wind Tunnel (ADWT) is a part of Applied Aerodynamics Laboratory and located by Kalamazoo/Battle Creek International Airport. The ADWT was designed and built for McDonnell Douglas Corporation in 1972 and donated to Western Michigan University in 1994. The tunnel supports the university faculty and student research projects, and is available for commercial testing and development of a variety of aerodynamic configurations. Its operation requires minimal cost and personnel.

TUNNEL DESCRIPTION

The ADWT is a low speed, closed circuit, continuous flow, single return, and atmospheric pressure tunnel with a test section of 32-inches high, 45-inches wide, and 8-feet long. The circuit, as shown in the following Figure, is 161-feet long and consists of two 65.6-foot legs and two 14.9-foot legs. The contraction ratio of the stilling chamber to test section area is 10 to 1, and the total diffuser angle is 5.4°. A honeycomb and four removable screens in the stilling chamber are used to establish the flow direction and control the turbulence level. The main drive motor is a 125 hp D.C. motor equipped with a solid SABINA Digital speed controller. The 16-blade fan is 6-foot in diameter.

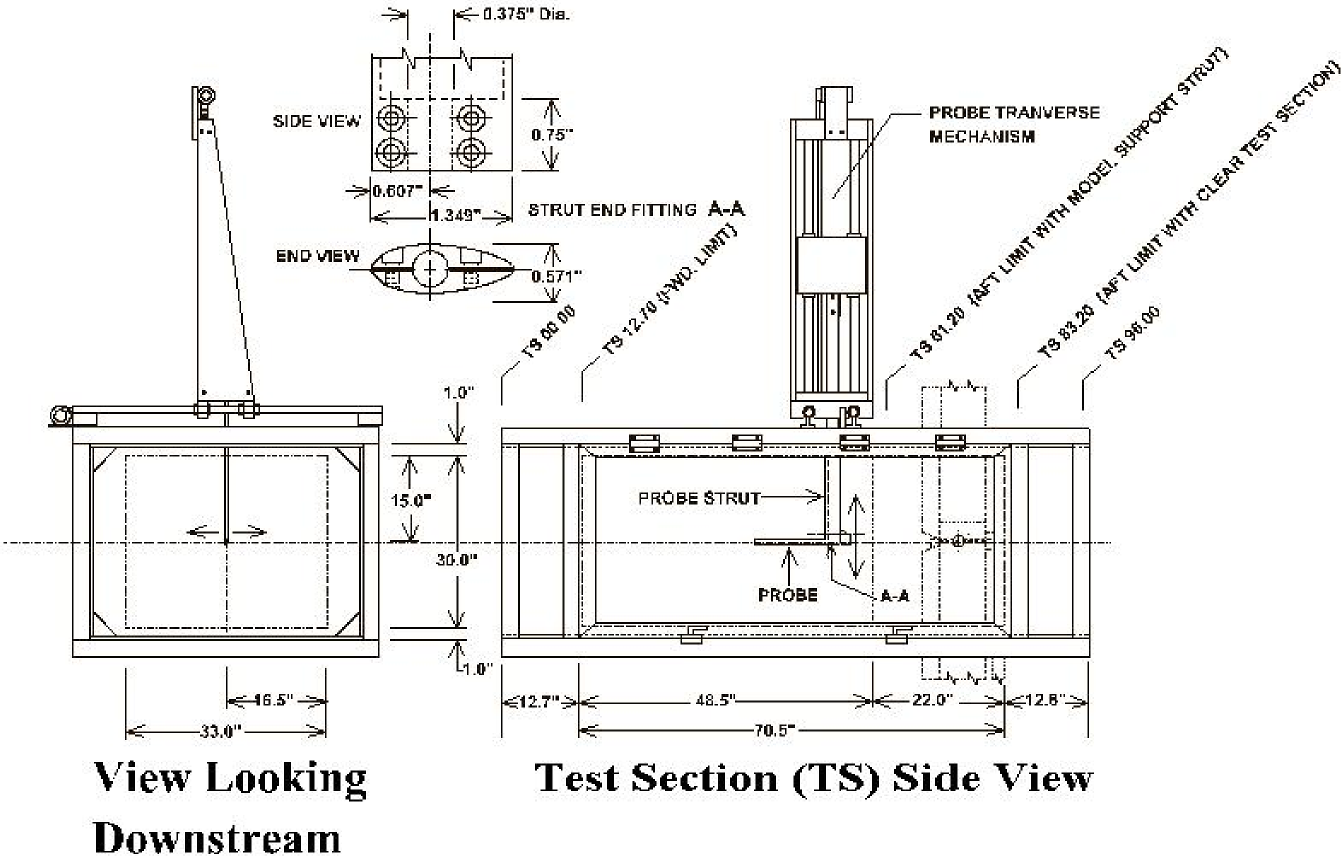


TEST CONDITIONS

The ADWT is normally operated at constant dynamic pressures up to 75 lb/ft^2, corresponding to a maximum airspeed of 250 ft/sec (170 miles/hour) and a Reynolds number of 1.3x10^3 per foot, with empty test section. The turbulence factor is 1.08, as found with a turbulence sphere.

MODEL SUPPORT SYSTEM

The basic model support system, for sting mounted models, is a computer controlled-parallelogram linkage mechanism capable of producing either pitching motion (angle of attack) or vertical translation. Sting pots are used to measure angle of attack within 0.1-degree increments. The general arrangement of the model support strut is shown in the following Figure. The center of rotation at 0.0-degree angle of attack is adjustable from 28 to 50-inch forward of the strut pivot, and from 6-inch above to 15-inch below the tunnel centerline. The maximum angle of attack range is 20-degree at the 28-inch center of rotation; and angle of attack range is reduced at the more forward positions. Vertical translation is continuously variable from the test section floor to within 2-inch from the ceiling. The strut can also be retracted through the floor to provide a clear test section, if desired. In addition to sting mounted models, ceiling or floor mounted models can be easily accommodated by means of removable panels, each 32-inch wide by 72-inch long.



View Looking Downstream

Test Section (TS) Side View

SURVEY STRUT

A ceiling mounted survey strut capable of holding a large variety of velocity, pressure, and other types of probes and rakes is available for boundary layer and flow field surveys. Very small models also can be supported by the system. The strut can be remotely driven to any point within a 30-inch high by 33-inch wide rectangular area, and can be installed at various tunnel stations.

FORCE AND MOMENT BALANCE SYSTEM

The tunnel is equipped with a strut mount-internal JR3 force-moment system and a sting mount-internal AEROLAB balance for the measurements of six-component force and moment. The tunnel is also equipped with a 3-component force and moment measurement balance. The operational limits of three balance systems are compared in Table 1. The strut mount balance has a diameter of 4.5 inches, a height of 1.2 inches and a weight of 1.0-pound. It is available for the measurements of force and moment of strut supported models. The sting mount balance on the other hand has a diameter of 5/8-inch with a cylindrical shape. The overhead balance has three mounting arms extending into the tunnel onto which a model may be mounted.

Table 1: Force and Moment Limits for the Strut and Sting Type Balance

SIX-COMPONENT	STRUT BALANCE	STING BALANCE	OVERHEAD BALANCE
Normal Force	100 lbf	150 lbf	1500 lbf
Side Force	50 lbf	100 lbf	N/A
Axial Force	50 lbf	25 lbf	500 lbf
Pitching Moment	225 in-lbf	250in-lbf	10000in-lbf
Yawing Moment	225 in-lbf	180in-lbf	N/A
Rolling Moment	225 in-lbf	200in-lbf	N/A

The sting balance uses a signal conditioner that consists of six separate printed circuit boards, one for each balance component. These boards supply excitation, amplification, and filtering for each respective strain gage bridge. A seventh circuit board combines and separates all six components to eliminate interactions. Balance results are displayed individually on panel meters with a resolution of 0.01 in engineering units. An on-line micro-computer is used for data acquisition and processing. The final force and moment data are tabulated and plotted in coefficient form for the range of angle of attack or yaw angle.

PRESSURE MEASUREMENTS

Both surface and field pressure measurements are available in the tunnel. The surface static pressures are measured through pressure tubes mounted on test model surface. The pressure tubes are made of stainless steel and have a diameter of usually 1/32- inch, and flushed with the model surface. They can be linked to a combination of 48 port and/or 32 port Scanivalve system, providing an amplified analog output to the data acquisition system. The scanivalve systems have a differential pressure range of 2.5 lb/ft^2.

Field pressures are measured around the test model or anywhere in the test section. Pitot-static probe is available for measuring both static and total pressure of the air stream simultaneously. The differential value of static and total pressures also provide tunnel local dynamic pressure, which, in turn, can be translated to give the local velocity of air stream. In fact, the differential pressure can be read by either using a manometer or a transducer. The transducer data is sent to A/D board and then to the computer for processing.

There are additional pressure probes to conduct measurements in the flow region of interest. A five-hole probe can be used to measure flow velocity and angularity. Several total and static pressure probes are available to make measurements anywhere in the test section. A survey rake can be used for studying the wakes of wings, tails and/or nacelles. A boundary layer probe can be used for examining boundary layer profiles by taking closely spaced pressures.

VELOCITY AND TURBULENCE MEASUREMENTS

Up to three-component velocity and turbulence quantities can be measured in the tunnel by using hot film/wire thermal anemometry in constant temperature mode. Hot film probe holder is mounted to the tunnel strut and positioned any location for the flow survey. The probe measures the air velocity by sensing the changes in heat transfer from its electrically heated sensors. Increase of velocity increases the rate of cooling of the sensor. The sensor heating current has to be increased to keep the temperature constant. A functional relationship is established between the feedback voltage and velocity on the thermal anemometry. The TSI Model 1051-B is used as the thermal anemometer, which is connected to the host computer via a direct analog interface for data processing.

The hot film anemometry can be implemented advantageously due to its sensitivity to small magnitude fluctuations and high frequency response. However, if a non-intrusive measurement is needed for a specific application, Laser Doppler Velocimetry (LDV) can be utilized. The tunnel has the space and transparent test section walls for the LDV set up. The seeding can be generated from the upstream location of the test section.

FLOW VISUALIZATION

Surface and field flow visualization can be made to understand the flow patterns over and around the test model. There are a variety of methods readily available for the flow visualization. The methods are compared in the Table 2 below:

Table 2: Comparison of Flow Visualization Methods

METHOD	SURFACE VIS.	FIELD VIS.	PHOTOS WIND-ON	PHOTOS WIND-OFF
Smoke	Yes	Yes	Yes	No
Oil	Yes	No	Yes	Yes
China Clay	Yes	No	Yes	Yes
Sublimation	Yes	No	Yes	Yes
Tufts	Yes	No	Yes	No

The smoke method is available for viewing the flow patterns anywhere in the model flow field. It uses a smoke generator to make the smoke and a probe to insert the smoke into the test section. It is also possible to generate the smoke by burning "oil" around an electrically heated wire. The wire can be located upstream locations of the test model. The tunnel must be ventilated to remove the smoke from its closed circuit, if extensive use is required.

The other flow visualization methods are applied on the model surface during wind-off conditions. The oil, China clay and sublimation methods are based on various kinds of mixtures. They are applied on the model surface, and slugged down in the direction of air, making the flow character visible when the air is turned-off. Tufts are easy to use and clean for wind-on flow visualization. They are made of thread and attached to the model surface in successive rows. As the air is turned on, the tufts flap in the flow direction.

PHOTOGRAPHY

The tunnel has photographic equipment to record testing. A 35-mm camera is available for photo-documentation of tests. A digital camera is used for taking the pictures and viewing them on computer in a sequence. A high-speed VHS video camera is available for recording active flow visualization or other phases of testing. The tunnel room has enough lighting for photography, but additional lighting can be provided upon request.

DATA ACQUISITION AND REDUCTION

The test data is acquired by using LabView 5.0 data acquisition software. The LabView software is installed on a Personnel Computer (Dell OptiPlex GX1p). The computer has a Pentium II Processor at 400 MHz, with 128 MB 100 MHz SDRAM. It uses Microsoft Windows NT and has word processing, Excel-spreadsheet and plotting packages for use. Visual BASIC and FORTRAN compilers are available for programming. Standard tunnel data corrections include blockage, wall effects and flow angularity. Other corrections can be applied to the data, if required. The test data is stored in either 3.5" floppy disks or Iomega Zip Disk or CD-ROM, depending on the data size. The data transfer is also possible via internet. The data plotting is made on-line with computer data acquisition system. The plots are usually made for six-component force and moment, and surface pressure distribution in coefficient form.

AREAS OF WIND TUNNEL TESTING

The wind tunnel is capable of simulating air motion over and around conventional as well as non-conventional aerodynamic objects. Aircraft related testing includes the models of aircraft and aircraft components such as engine, nacelle, propeller, wing, flap and controls. Non-aircraft testing is quite broad and includes automobiles, semi-trailer trucks, motor homes, motorcycles, snowmobiles, roofing materials, prefabricated chimneys, storm windows, window awnings, truck flares, street lights, street barricades, trash containers, golf balls and many others.

PERSONNEL

The ADWT is operated by the faculty and staff of Department of Mechanical and Aeronautical Engineering. The following is a listing for the personnel, including their phone extensions and e-mail addresses.

Erik Pederson	(269) 387-2238
Arthur Hoadley	(269) 276-3426
Abe Poot	(269) 276-3372
Peter Thannhauser	(269) 276-3415
Bill Liou	(269) 276-3430
Parviz Merati	(269) 276-3420

There are also a number of graduate and undergraduate students working part-time at the tunnel facility, towards their research projects.

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