ROLLING HILLS RESEARCH
C O R P O R A T I O N

UNIVERSITY DESKTOP WATER TUNNEL
MODEL 0710

TUNNEL AND EXPERIMENT OVERVIEW

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Figure 1: View Through Up-Stream Window

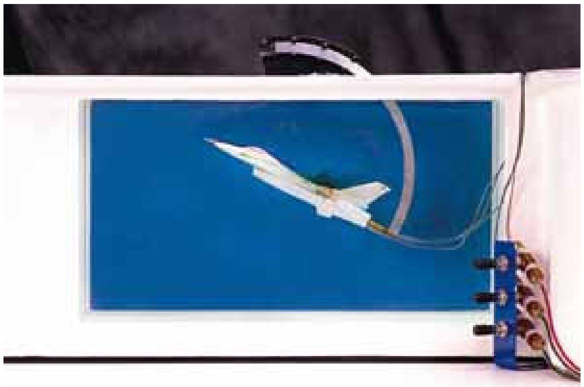

Figure 2: Side Window View

Basic Water Tunnel Circuit

Thank you for your interest in the Rolling Hills Research Corporation Model 0710 University Desktop Water Tunnel. The new University Desktop Water Tunnel is the latest addition to the RHRC line of water tunnel research products. While retaining many of the world-class features of RHRC's larger research water tunnels, the new Model 0710 is designed specifically to be an affordable teaching tool for High Schools and Universities. The Model 0710 offers views of the test section through one downstream window (Fig, 1) and two side windows (Fig. 2), all made of tempered glass. Flow visualization is provided by a three-color, pressurized dye system with individual needle valve controls. The Model 0710 features a variable speed motor, a turbulence reducing screen and honeycomb in the settling chamber, a 6:1 contraction ratio, and dual line return plumbing... just like RHRC's full size water tunnels, Models 1520 and 2436.

The University Desktop Water Tunnel is ideal for in-classroom demonstrations and student research projects. Inexpensive plastic models can easily be fabricated or assembled from off-the-shelf kits. Flat plates, cylinders, spheres, aircraft, and automotive models can all be used very effectively to demonstrate fluid dynamic phenomenon, from simple to very complex.

SPECIFICATIONS

Length	*112 inches*
Width	*46 inches*
Height	*47 inches*
Weight	*Approximately 900 lbs. w/water*
Capacity	*105 gallons*
Test Section	*7 inches x 10 inches x 18 inches*
Down Stream Window	*7 inches x 9½ inches*
Flow Velocity	*2 to 5 inches per second*
Centrifugal pump	*1½ horsepower, 115 volts, 16 amps*
Dye System	*Pressurized 3 color*
Table	*Steel with lockable swivel casters*

Optional Speed Control

The basic Model 0710 comes as a single speed unit. An electronic speed control (Fig. 3) can be added that greatly increases the flexibility of the system. Using the electronic speed control, the speed in the test section can be varied from 0 to 5 inches per second. The only buttons that are normally used are the four on the right-hand side: Start, Stop, Up Arrow and Down Arrow. The readout displays the approximate speed in the test section, in inches per second. The speed is increased by pressing the Up Arrow button and decreased by pressing the Down Arrow button. The tunnel can be stopped at any time by simply pressing the Stop button.

Figure 3: Electronic Speed Control Front Panel

<u>Calibration</u>

The Model 0710 water tunnel comes pre-calibrated so that the digital display shows the speed of the water in the test section, in inches per second. The calibration is tunnel specific, and a sample is shown in Fig. 4. The electronic controller has many additional programmable features that are described in the manufacturer's Installation and Operation Manual, which is included with the tunnel.

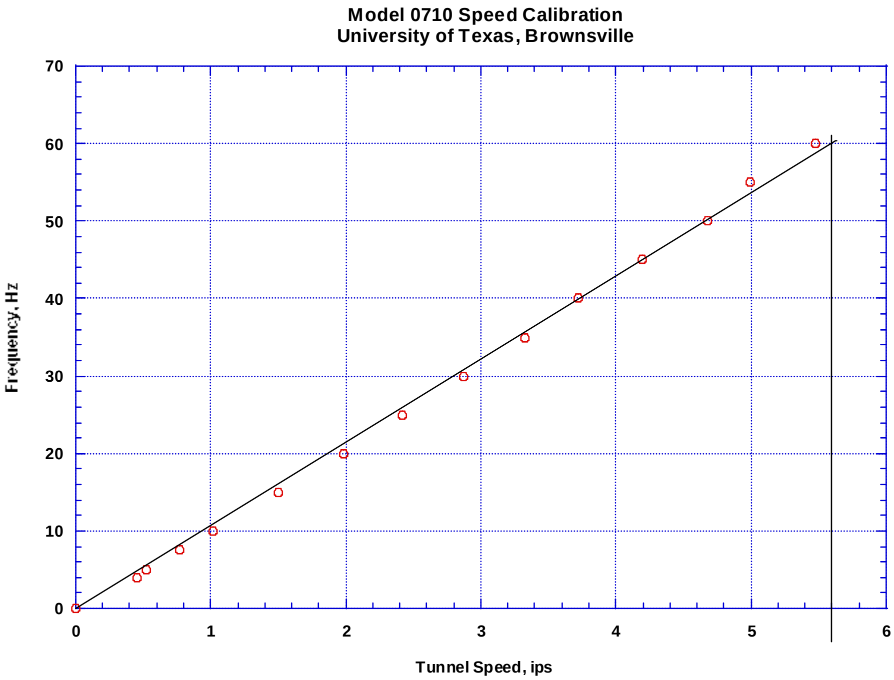

Figure 4: Sample Speed Calibration of Water Tunnel

EXPERIMENT OVERVIEW

This section provides a brief overview of the prepared experiments that RHRC currently provides. Additional experiments are currently being developed, including an inexpensive 1-axis force balance for indicating either lift or side force.

Optional Model Support Systems

Two different model support systems are available for the University Desktop Water Tunnel: a sting mount, and a wall mount.

Sting Mount

The sting mount (Fig. 5) is machined from aluminum and anodized to protect it from corrosion. The entire assembly bolts to the top of the water tunnel test section with two screws. There is only one position in the tunnel that the sting can attach, and it is located at the furthest downstream position. This locates the model near the center of the test section. Each experiment that uses this mount comes with its own sting. The sting slides into a mounting adapter on the C-strut, and is secured by two setscrews. If a homemade experiment is to be mounted on the C-strut, the sting should be made of ¼” stainless steel rod. The C-strut can be locked in position by two small thumbscrews, which must be loosened in order to adjust the position without damaging the assembly. The C-strut can be manually rotated with a small knob, which is attached to a gear that meshes with a rack on the C-section.

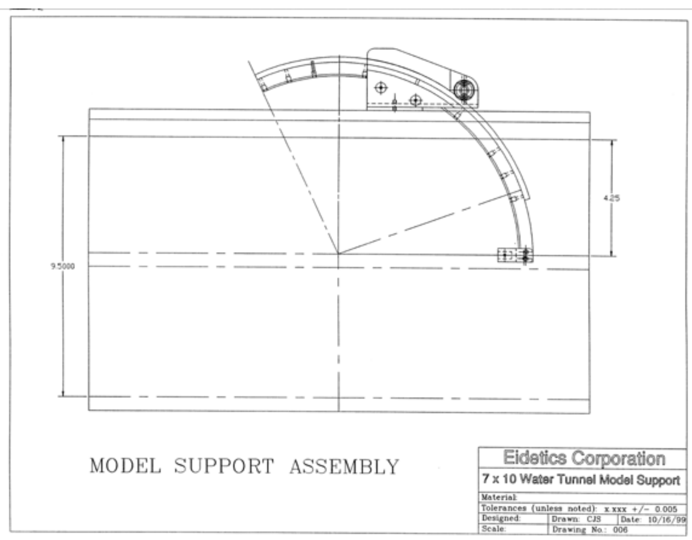

Figure 5: Sting Mount Model Support Design

The C-strut has engraved marks every 5º to indicate the model angle-of-attack. An additional line is etched on the clamping portion of the support and is used to indicate the zero position, as determined in RHRC’s lab. Both of the matching zero lines are tagged with a light blue paint dot (Fig. 6). This pointer is calibrated to indicate the position where the sting would be parallel to the tunnel flow. In addition, a stick-on pointer can be used to indicate any other reference desired. If a different reference point is desired, a new sticker may be applied. The C-strut provides an angle range of approximately -35º to +50º. In order to achieve even higher angles of attack, the adapter that attaches the sting to the C-strut can pivot upward an additional 15º. To change the adapter angle, simply loosen the two screws, pivot the adapter, and re-tighten the screws. In addition, the angle-of-sideslip can be adjusted by loosening the thumbscrew on the top of the mount (Fig. 7). An angle indicator shows the angle-of-sideslip.

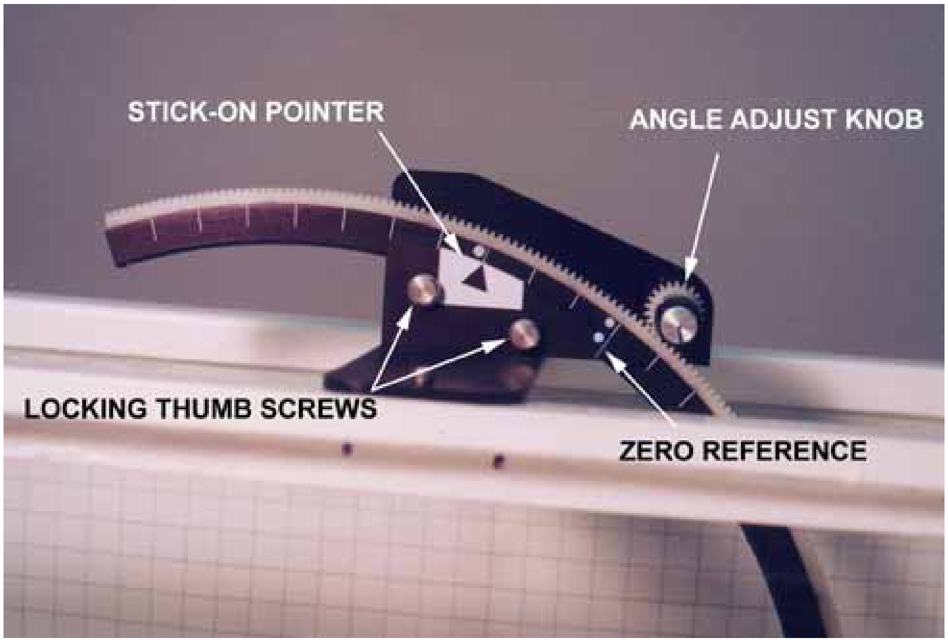

Figure 6: Features of Sting Mount and C-Strut

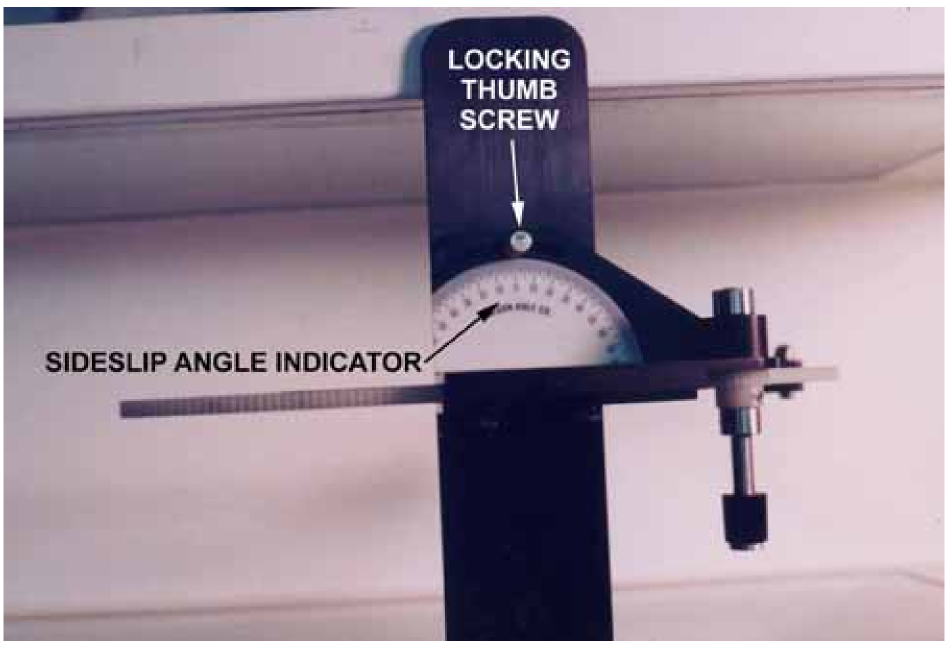

Figure 7: Sideslip Adjustment on Sting Mount Model Support

<u>Wall Mount</u>

The wall mount (Fig. 8) is made primarily of clear plastic so that it won't obscure the view of the test section. Because of this material choice, the wall mount should be handled with care to avoid damaging it. There are two configurations possible with the wall mount: push-rod adjustable angle-of-attack, and continuous rotation. Experiments such as RHRC's Rotating Cylinder use a pulley and hand crank to provide rotation. Experiments like RHRC's Airfoil use a push-rod control for adjusting discrete angles-of-attack.

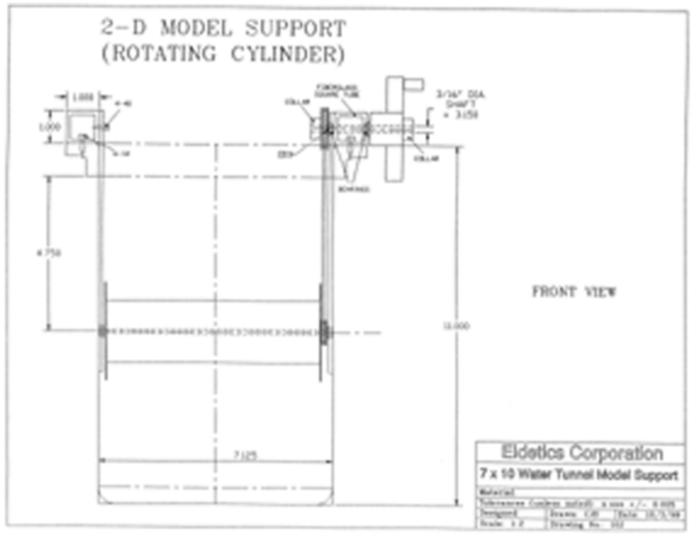

Figure 8: Wall Mount Design

The wall mount is composed of two major pieces, one for each side of the tunnel. The most complicated piece, the one containing both the hand crank and the pushrod, is mounted on the side of the tunnel opposite the speed control. Two screws attach each side to the tunnel, which are accessed through holes in the top of the rectangular, black, mounting frame. There are two mounting positions available for the wall mount, one in the front of the test section for observing wake behavior, and one near the center of the test section. Experiments are attached to the wall mount by sliding the stainless steel pivot pins into the ball bearings at the bottom of the wall plates. *The experiment must be mounted in the wall mount before the mount is attached to the tunnel*. In the case of the rotating cylinder, the rubber drive belt must be put in position before the pin is slid into the bearing. The push rod should be connected by sliding it over the appropriate control pin on the model, for non-rotating experiments, prior to installation in the tunnel as well.

I. Optional Prepared Experiments

The full experiment documentation is included separately with each experiment purchased. Below is a brief description of the four experiments that are currently offered. When purchased as a set, the four experiments, the dye wand and the model mounts come in a protective case (Fig. 9). A dye wand (Fig. 10) is available to help visualize streamlines and streaklines in the flow. The dye wand has a fairing that reduces the interference from vortices shed from the tube. The dye wand is normally mounted in a pair of holes located just upstream of the test section. The wand may also be attached at any of the wall mount screw locations. The position of the dye wand can be adjusted by loosening either of the two thumbscrews and sliding the wand up and down or side to side. Any of the three colors of dye can be connected to the wand.

Figure 9: Experiments in Protective Carrying Case

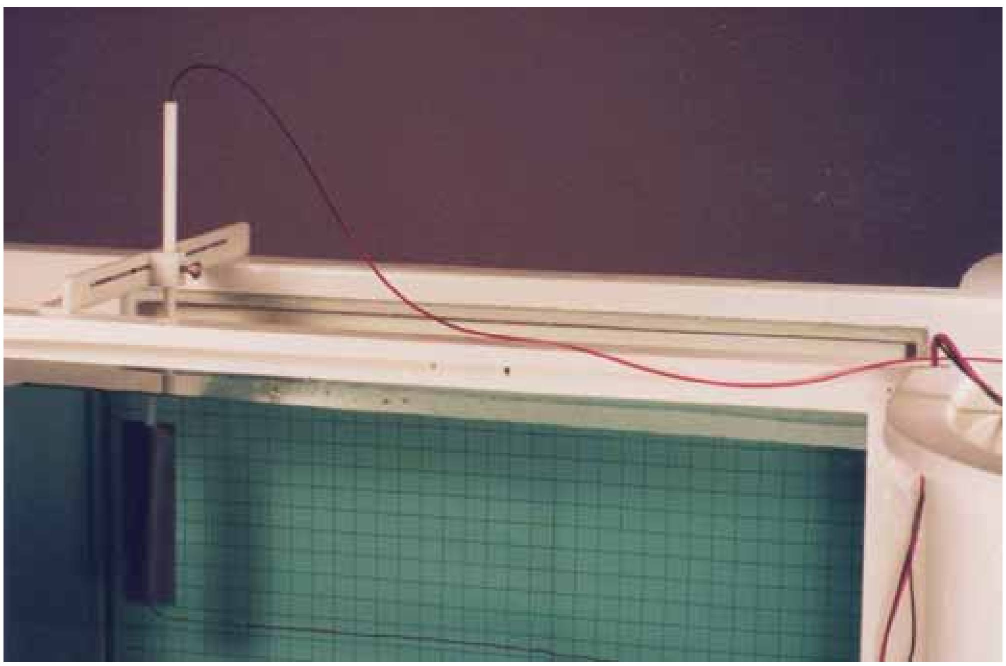

Figure 10: Dye Wand

<u>Cylinder</u>

The cylinder experiment consists of two long cylinders, one with dye ports that is stationary, and one without dye ports that rotates about its center axis. The stationary cylinder is used to show the regular pattern of shed vortex "streets" (Fig. 11). The dye wand is positioned upstream to show the difference in the streamlines with and without rotation, and provides an explanation of how lift is produced. Figure 12 shows the way the streamlines are lifted and curved due to the influence of the rotating cylinder. It is instructional to compare these streamlines to those observed with the airfoil model.

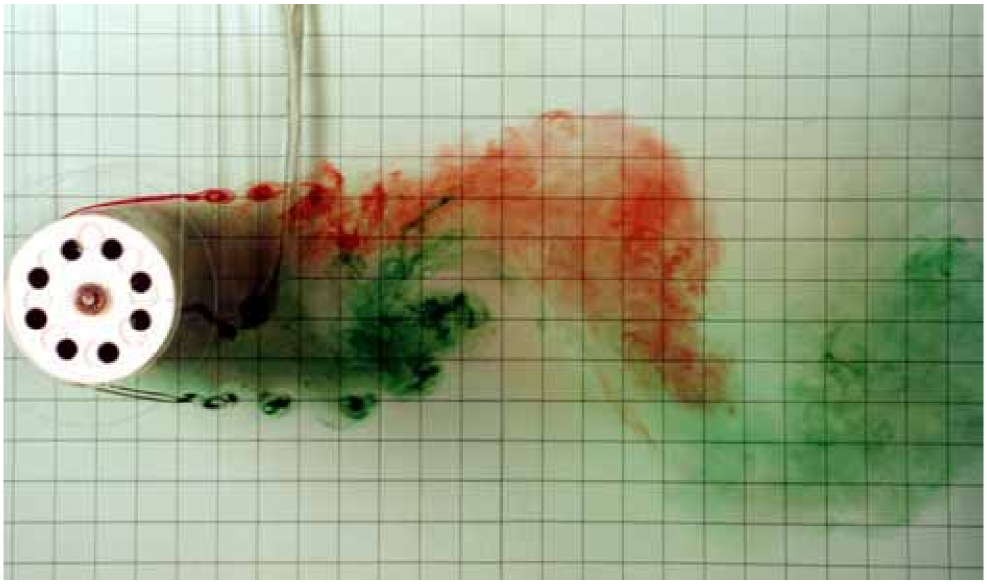

Figure 11: Shedding from Non-Rotating Cylinder

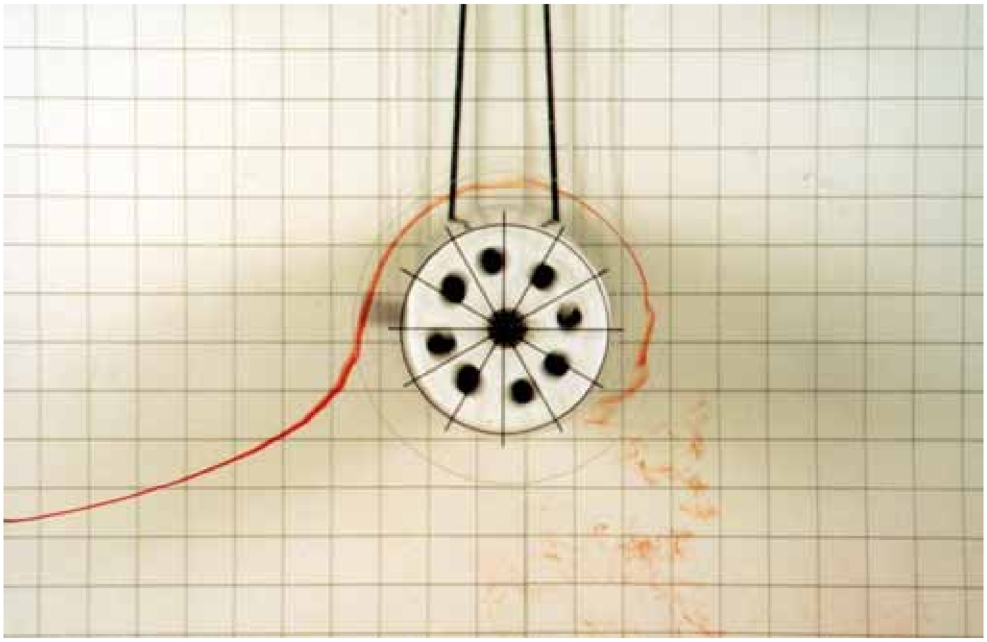

Figure 12: Curvature of Flow Induced by Rotating Cylinder

Airfoil

The airfoil experiment shows not only the streamlines associated with a lifting surface, but also the way it is affected by changes in angle-of-attack. Surface dye ports are used to show the boundary layer separation behavior that occurs as the angle-of-attack is increased (Fig. 13).

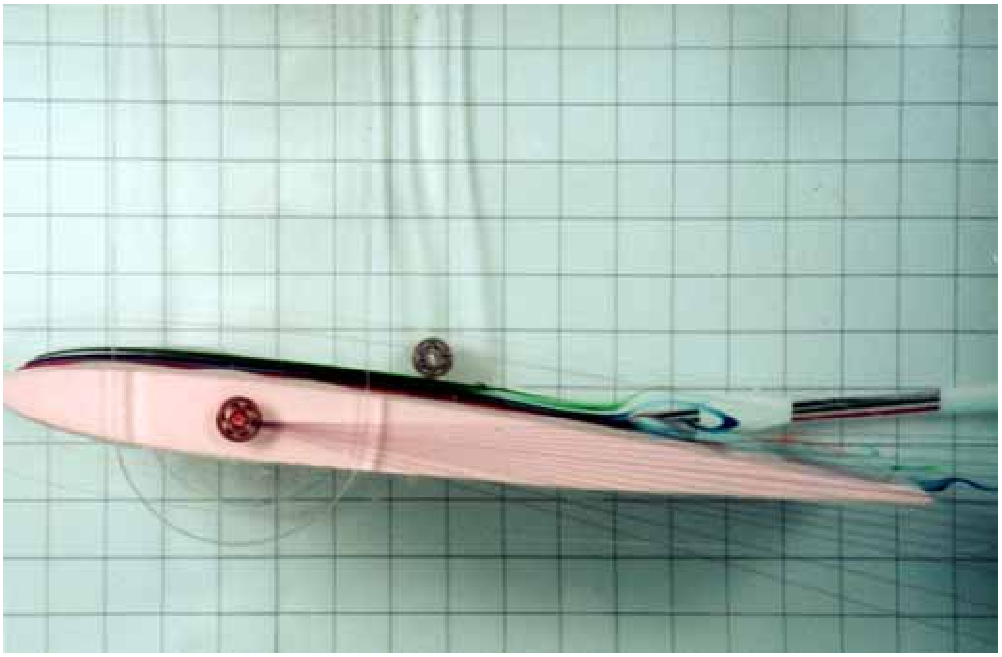

Figure 13: Flow Field Beginning to Separate on Airfoil

Forebody/Projectile

The forebody/projectile experiment demonstrates the extremely strong vortex pair that is created in the wake of a cylindrical body at high angles-of-attack (Fig. 14). This type of flow field plays a very important part in the directional stability and control of aircraft and missiles at high angles-of-attack. Small asymmetries or miniature control strakes can cause these vortices to become very powerful side force and yawing moment producers.

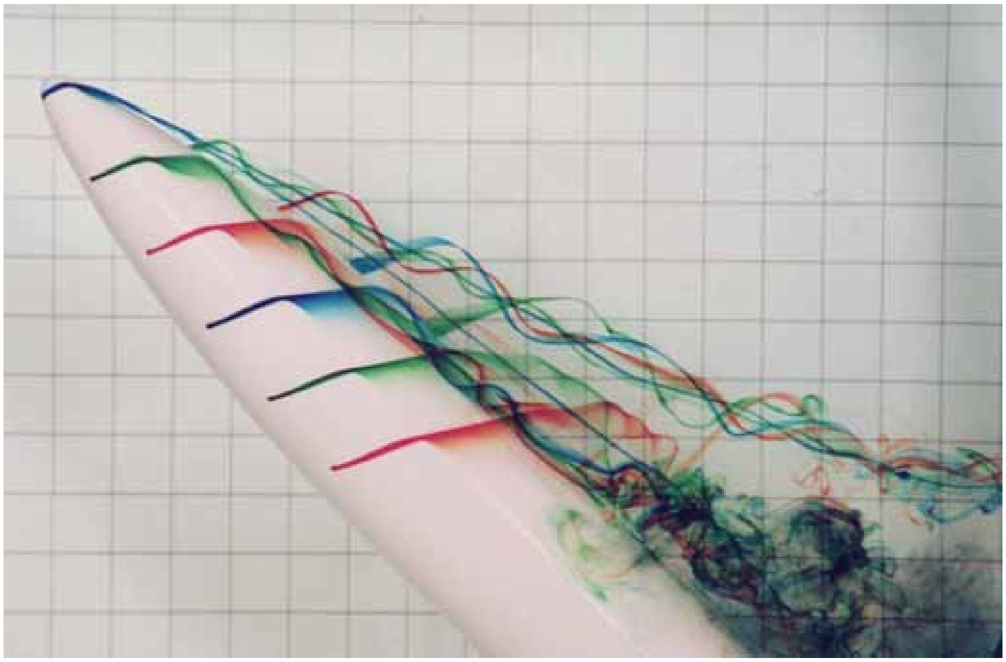

Figure 14: Strong Vortices Shed from Forebody/Projectile

Delta Wing Aircraft

The delta wing aircraft experiment is a fine example of a vortex dominated flow field. Very important parameters such as the vortex burst position are clearly visible, and can be studied as a function of angle-of-attack, sideslip and roll angle. The model has a removable vertical tail and moveable control surfaces. Figure 15 shows an example of vortex burst occurring near the vertical tail. The experiment write-up discusses not only the non-linear aerodynamics, but also the roll of vortices in limit cycle motions such as wing rock.

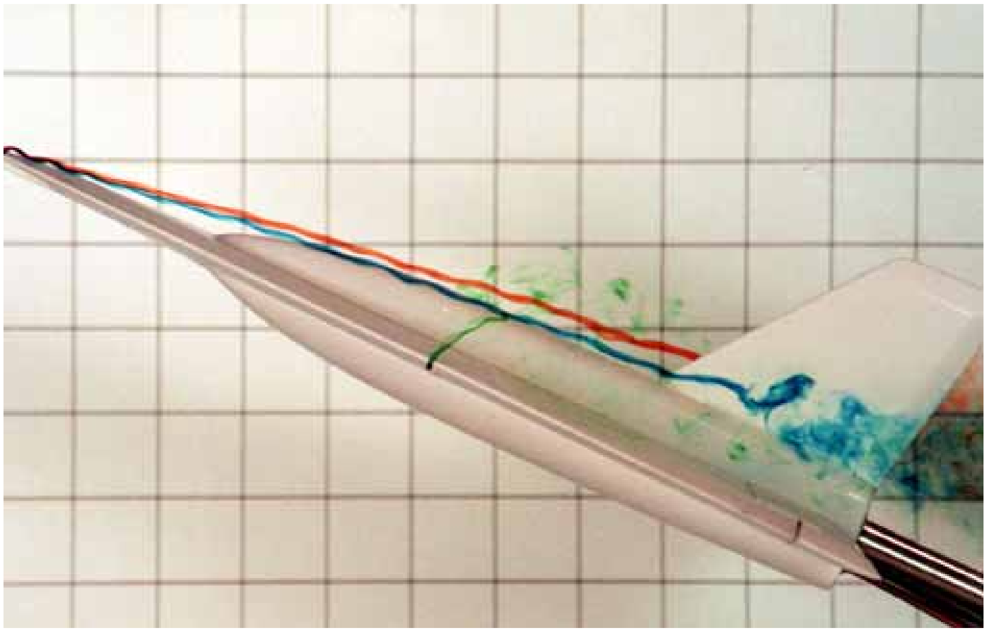

Figure 15: Vortex Dominated Flow on Delta Wing Aircraft

1-Component Strain Gage Balance

The 1-component balance allows students to measure either normal force or side force on a sting-mounted model. The balance easily fits onto the sting mounted model support at the base of the sting. The addition of quantitative measurements helps to form an understanding of the relationship between what is seen in the flow field, and what forces are "felt" by an aircraft. The balance comes complete with a data acquisition computer card (PCI bus for PC compatibles) and RHRC's graphical software that includes calibration routines, data plotting and data logging to a file.

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