

# TRANSONIC WIND TUNNEL

## STATUS REPORT

### 31 MARCH 1999

#### 16 inch SSV

The O-ring length for the sleeve on the SSV is very critical. Too short and the O-rings do not seal good. Too long and it is difficult to install them in the grooves and get the sleeve into the outer cylinder of the SSV. The O-rings may shear off or the sleeve may be so tight it won't move. After a couple of years of experience it has been found that O-rings of N70 material and 0.210" diameter should be 46 inches long. Material from different batches may require slightly different lengths as the diameter will vary slightly and the stiffness of the material may vary as well.

No more than 14 ports on the SSV should be open at any one time. With 14 or few ports open the choke point of the main tunnel flow is in the SSV. Whatever happens upstream does not change that. With 15 or more ports open the choke point moves forward into the tunnel towards the test section. Controlling the Mach number becomes difficult if not impossible.

#### 13 Port Rake Leaks

The 13 port rake is installed with plastic tubing inside the tunnel with clamps on hose barbs using safety wire and out side the tunnel using tube fittings. The internal portion is normally left as a unit. The outside plumbing must be removed in order to remove the rake. These fittings are a potential source of leaks. Slight leaks in these fittings can cause the pressure traces not to level out to their true level during the run time. The pressure will continue to drop and the information obtained from them severely limited or non existent. Check the first run after installation for good data. If the pressure levels do not stabilize check the fittings. They should not rotate on the tube.

#### 5 hole conical probe

The 5 hole probe has provide acceptable results but a very extensive calibration should be done if much work is to be done using it. The probe has some asymmetries about it. A new commercially manufactured probe may be better in that it may be more symmetric.

#### Fill valve control

The main fill control valve is pneumatic operated. Near this valve behind the control valve is a regulator for reducing the 175 psi air to about 22 psi and an isolation valve. Currently the regulator must be taken apart and the seat placed correctly and then reassembled every time the control air (175 psi is started). The regulator should be replaced and a filter installed in this line upstream.

## Solenoid valve SSV close problem

The close solenoid on the 16 inch SSV does not close when necessary to close the SSV. The valve leaks severe enough to prevent SSV closure. Currently the vent port is connected to the valve above the sphere hatch. This valve must be closed in order to close the SSV and must be opened before the SSV will open.

## FFV problem & status

The Flex Flow Valve (FFV) is currently not used. A solid plate is installed downstream to block the flow. The available test window is shortened without the FFV but the tunnel still operates well. This plate was installed during 1990 ??? Correcting the FFV problems is probably a highly involved job of trouble shooting.

## Control System

The control system is fairly reliable although regular misfires do occur. Experience helps reduce the number of misfire runs. The system should be run through the fire sequence a few times before firing the tunnel.

A better system would be to have 3 or 4 timer circuits provide the timing using discrete resistor for some variation in timing. Use past tunnel runs to nail down nominal values and provide a small variation. The timer circuits would themselves control transistor which intern would control thyristor, which would control the power to the solenoids.

Proper design would eliminate several small timing variations.

## Diaphragm cutter pneumatic cylinder loose tie rods

This is a problem which has occurred twice and is difficult to find. The data appears as if the diaphragm cutter fired late. Try to increase pneumatic pressure may help for a short time but it is not the answer. The effect on the data is erratic and inconsistent. After a few runs of inconsistent diaphragm cutter operation it might be wise to check the pneumatic cylinder that fires the diaphragm cutter and ensure that the tie rods are tight, the hose connection is tight, and the hose is in good shape.

## Auxiliary flow pipe assembly warning

The boundary layer bleed off pipe from the diaphragm to the flex flow valve and ball valve must be assembled in a specific order to ensure there is now leakage. Any leakage will affect the Mach number control and the stability of the Mach number during the run period. The flex flow valve must first be attached to the pipe and securely tightened. The flange joint just outside the sphere near the ball valve must then be tightened securely. The joint downstream of the FFV can then be tightened up. A come-a-long may need to be used to pull the pipe downstream of the FFV back an inch or two to provide some working room for making up the first two flange joints. The come-a-long is attached to a post at the corner of the supersonic tunnel silencer.

## Test section Mach distribution deficit

The test section Mach number distribution has a slight dip in it at the location where the four upstream boundary layer bleed hoses attach. This could probably be eliminated by the addition of some hardware to disperse the suction over a longer length of the test section.

**TRANSONIC**

**OPERATOR'S**

**MANUAL**

31 MARCH 1999

*(Figures refer to those in the 31 August 1994 Manual update as that version was the starting point.  
That version was changed very little, just new information added and reorganized.)*

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## 1.0 TUNNEL DESCRIPTION

The UTA High Reynolds Number Transonic Wind Tunnel (Pilot HIRT) located in the UTA Aerodynamic Research Center, is a Ludweig tube wind tunnel designed to provide high Reynolds number transonic flow. A discussion of the principles of the operation of this type of wind tunnel will be presented in Section 2.0. Detailed Descriptions of the Pilot HIRT hardware are presented in this section. A schematic drawing of the pilot tunnel is given in Figure 1. This facility is a one-thirteenth scale model of a high Reynolds number transonic tunnel which was proposed for construction at Arnold Engineering Development Center (AEDC).

### 1.1 CHARGE TUBE

The Ludweig tube storage system (charge tube) is 13.94 inches in diameter and 111 feet in length. It can be charged to a pressure of 770 psia (hydrostatically tested to 1150 psig) This will produce a maximum stagnation pressure of about 500 psia. At the downstream end is a transition section 18.5 inches in length which channels the flow from the circular charge tube to the rectangular test section. The contraction ratio (area ratio) of the nozzle is 2.27, and the contours are designed to provide a smooth acceleration of the flow.

### 1.2 TEST SECTION AND PLENUM CAVITY

The test section, illustrated in Figure 3, has a rectangular cross-section 7.34 by 9.15 inches. The porous walls consist of two stacked plates with 60 degree inclined holes having a tapered porosity pattern in the upstream one third of the test section length. The combined plate thickness is 0.141 inches and the holes in the walls are 0.120 inches apart on centers in both directions in the uniform porosity region. The porosity can be varied manually on each wall in the range from 3.5 to 10 percent by moving one plate relative to the other.

The test section is surrounded by a plenum cavity which has a volume approximately 1.75 times that of the test section (neglecting the volume of the wall support structure). The wall support structure extends through this cavity to the outer shell, but it is designed so as to provide essentially no restriction to flow within the cavity.

### 1.3 EJECTOR FLAPS

The ejector flaps at the downstream end of the test section, shown in Figure 5, are 3.0 inches long and can be opened to provide a maximum gap height of 0.9 inches. The gap can be adjusted anywhere in this range with the flaps locked into position prior to a run. A provision is also included in the design of the flap actuating

mechanism to make a step change during a run from an initial setting to another opening.

The ejector flap opening height is determined by the flow Mach number desired. Flap openings of less than 0.3 in. are used to provide Mach numbers in the range of 0.65 \_ 0.95; openings in excess of 0.3 may be used for the higher Mach numbers. The exact Mach number is determined by the interaction of the ball valve opening and the flap opening height.

#### 1.4 MODEL SUPPORT SECTION AND DIFFUSER

Downstream of the ejector flaps is the diffuser assembly (see Figure 2). The first section contains another transition region from the rectangular test section to a circular diffuser section. Downstream of the transition is a conical diffuser with a 3 degree wall angle and an exit diameter of 16 inches. A sector model support is mounted in the upstream end of the transition section. Four instrumentation access ports are located downstream of the sector which are used to bring instrumentation leads and/or pressure tubing out of the tunnel.

#### 1.5 PLENUM EXHAUST SYSTEM

Flow in the plenum cavity may be exhausted to the atmosphere through the system shown in Figure 7. Ten 2-inch I.D. flexible hoses are attached around the downstream end of the plenum shell and run to a common manifold. Downstream of the manifold is a diaphragm holder, consisting of two plates, which sandwich a mylar diaphragm, and is held in place by a Grayloc clamp. The diaphragm is ruptured at the desired time by means of an pneumatically actuated arrowhead cutter. Downstream of the diaphragm assembly the air passes through a 6-inch variable orifice ball valve. The ball valve is set prior to a run according to the desired Mach number. The Flex Flow Valve is no longer used and is in the closed position. For more information on the Flex Flow Valve, see the original documentation from AEDC.

#### 1.6 STARTING DEVICE

The current starting device is a 12 inch diameter Sliding Sleeve Valve (SSV). This opens and closes by a system of pneumatic actuators. The SSV is closed to pressurize the tunnel. The Sleeve has 24 rectangular ports 2.5 by 2.75 inches each. Current operational parameters dictate that the SSV should be actuated approximately 46 ms before the plenum cutter is actuated. If the SSV has a consistent opening speed, the expansion wave from the SSV and the one from the plenum diaphragm will reach the test section at approximately the same time. The

current problems with this system involve the O-rings and consistent opening times.

As an alternative, a diaphragm (approximately 2 msec opening time) could be used as the main starting device. For this mode of operation the 16\_in valve is set in place and an additional mylar diaphragm is clamped between the diffuser and the valve. A cruciform with a pneumatic cylinder operated cutter is mounted inside the valve inlet approximately 2 inches downstream of the diaphragm to initiate diaphragm rupture. The valve sleeve is kept in the open position. Figure 10 is a view of interior of the 16 in. valve with cruciform installed. The drawback to this idea is the tear down of the tunnel after each run regardless. For more information on the 16 inch valve as well as the diaphragm start system see original AEDC manual.

### 1.7 EXHAUST SPHERE

All of the main tunnel flow, as well as that from the plenum exhaust system empty into a large exhaust sphere. From there it is carried out of the building through a four foot diameter duct into a 20 foot tall silencer system.

### 1.8 TOTAL AND STATIC PRESSURE PROBES

One static and two total pressure probes are located in front of the nozzle section. Two total pressure probes are used to help account for any irregularities that might exist in the flow. These pressures are mechanically averaged by joining the tubing together before splitting to two separate transducers. One transducer serves as the total pressure reading during the actual run. The other transducer (connected to a DVM) serves as the indicator for charge tube pressure as well as the main transducer against which all other transducers are calibrated during charging of the tunnel.

### 1.9 PLENUM CHAMBER STATIC PRESSURE PROBES

The test section free stream static pressure cannot be determined because the bleed air to the plenum chamber would cause any measurement to include part of the dynamic pressure. Instead the plenum chamber static pressure is determined by means of four equally spaced static pressure probes. The probes are mechanically averaged by joining to a single pressure tubing which is fed to the outside by means of an instrumentation access port. The four static pressure probes are used to account for any non-uniformity that might exist in the plenum chamber flow, and to cancel the dynamic pressure components as much as possible. Unfortunately, this excessive amount of tubing in addition to the size of the plenum cavity cause a large signal lag during data acquisition.

The pressure readings from the plenum were calibrated against the test section free stream static pressure by using a centerline probe. A correction factor was determined to obtain the test section Mach number from the plenum Mach number.

### 1.10 CENTERLINE PROBE

The Centerline Probe (CLP) is used to give accurate static pressures at various locations along the centerline of the nozzle and test sections. Combined with the temperature and total pressure readings from the charge tube just prior to the nozzle section, these static pressures yield the Mach number at each location.

The CLP contains 42 static ports that spiral around the CLP body from one end to the other. Port number 1 starts 2.5 inches in front of the nozzle section and ports 1 - 6 and 35 - 42 have a longitudinal spacing of 4 inches. Ports 6 - 19 have a longitudinal spacing of 1 inch and ports 19 - 35 a longitudinal spacing of 0.5 inches. Refer to Engineering Drawing 109910VW for more detailed information.

The front part of the CLP is secured in the charge tube with two mounting screws. The rear part is secured in the model support section, where the pressure tubing from the CLP is connected to the outside of the tunnel by means of an instrumentation access port.

## 2.0 THEORY OF OPERATION -- HIRT

The UTA Transonic Wind Tunnel is a tube type wind tunnel that was suggested by Ludweig in 1955. This type of facility is essentially a blow down wind tunnel with the air storage vessel or vessels replaced by a long supply tube.

### 2.1 CONCEPT

The basic concept of the tube wind tunnel is shown in Figure 8 where the starting valve is located downstream of the test section. During operation, the tunnel (charge tube, test section, etc.; see Figure 1) is pressurized to a charge tube pressure that is determined from the desired run stagnation pressure. Compressible flow theory dictates the charge pressure,  $P_4$ , and charge temperature,  $T_4$ , for a fixed nozzle contraction ratio. In this instance with a contraction ratio of 2.27 and a test section free stream Mach number of 1.0  $P_0 = 0.73 P_4$  and  $T_0 = 0.91 T_4$ . A change in the nozzle ratio or the desired test section mach number would, of course, alter the total pressure and temperature relationship in the second decimal place. The boundary layer characteristics in the charge tube and test section also will affect these relationships slightly, but are of secondary importance.

## 2.2 STARTING

After the main starting device (SSV or diaphragm) is opened, the unsteady wave, which moves through the tunnel and sets the high pressure air in motion, cannot establish a steady flow out of the charge tube until flow through the plenum chamber has reached an equilibrium value. This process is illustrated schematically in Figure 12. When the main starting device opens, the total flow rate consists of the combined flow rates entering the test section from the plenum and the charge tube. As the plenum pressure drops and the pressure ratio across the porous walls decreases, the flow rate out of the charge tube must increase to maintain the nearly fixed total flow rate. Eventually the flow rates become steady. This transient nature of the Ludweig tube is termed the starting process. From this description of the tunnel starting process, it can be seen that increasing the flow rate out of the plenum exhaust system during the tunnel start can have a marked effect on the starting time.

## 2.3 STEADY RUN TIME

The usable run time (about 180 msec) is limited by the charge tube length. This is a result of the time required for the expansion wave generated during the first instant of the starting process to pass through the test section, up the charge tube, reflect at the end and return to the test section. This defines the maximum possible time the test section flow can be at constant aerodynamic flow conditions. Since the starting process is included in this time, the starting time should be minimized as much as possible, thus affording the longest possible testing time.

## 2.4 AUXILIARY START DEVICES

In the pilot tunnel, three devices are provided to facilitate fast tunnel starts:

1. A plenum exhaust which can be opened independently from the main tunnel exhaust.
2. A controllable plenum exhaust system which can provide an excessive plenum exhaust flow during the starting process and be throttled to the lower exhaust flow required during the steady run. (Flex Flow Valve)
3. A flap system in the tunnel wall which can be opened to increase the flow area between the test section and plenum chamber during the tunnel start.

The plenum exhaust diaphragm is connected by a 6 inch ID line approximately 5 feet in length to the ball valve which controls the quantity of auxiliary mass flow from the plenum during the steady part of the run ( see Figure 7).

The design of the flap system allows for two setting during a tunnel run: one for the starting process and one for the steady run mode. The flaps may be actuated during a run by pneumatic cylinders. Their actual effect on the start time, however has not yet been examined experimentally.

## 2.5 VARIABLES TO TUNNEL CONDITIONS

