

EXPERIMENTAL EVALUATION OF CIRCULATION CONTROL AERODYNAMICS
ON A CYLINDRICAL BODY

by

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ABSTRACT

Title of Thesis: Experimental Evaluation of Circulation
Control Aerodynamics on a Cylindrical
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In this study, an experimental investigation is conducted on a two-dimensional circulation control cylinder with blowing taking place from a single spanwise slot to determine its aerodynamic characteristics. The results include detailed pressure distributions (both chordwise and spanwise) for a range of momentum coefficients and slot locations. The measured results showed that the lift coefficients up to 4.8 were produced at momentum coefficients of 0.14 in a turbulent flow condition. The experimental results of lift coefficients were correlated satisfactorily with analytical results. The surface flow patterns were observed using the oil and smoke techniques. Also flow field surveys of the model were obtained using total pressure, yaw and pitch probes.

A color video display technique was used to present the results of the flow field surveys. Based on this evidence, a flow field model of the circulation control cylinder is presented.

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LIST OF SYMBOLS

A	Model slot area, ft^2
C	Chord length, ft
C_d	Sectional profile drag coefficient
C_ℓ	Sectional height coefficient
C_m	Pitching moment coefficient about the quarter-chord
C_p	Pressure coefficient
C_μ	Momentum coefficient, $mV_j/(q S)$
h	Slot height, ft
ℓ	Sectional lift, lb
$\dot{m}$	Mass efflux, C.F.M. (slugs/sec ²)
P_ℓ	Local static pressure on the model, lb/ft^2
P_{t_d}	Duct (plenum) total pressure, lb/ft^2
P_{t_∞}	Freestream total pressure, lb/ft^2
q_∞, q	Freestream dynamic pressure, lb/ft^2
R_e	Reynolds number base on diameter
S	Model planform area, ft
T_t	Jet total temperature, °R
V_j	Jet velocity, ft/sec
U_∞	Freestream velocity, ft/sec

CHAPTER I

INTRODUCTION

Part A: Interest in Circulation Control Aerodynamics

In recent years considerable attention has been given to the circulation control concept due to the renewal of interest in short take-off and landing aircrafts, new demands on helicopter performance and the possibility of elimination of the helicopter tail rotor.

Part B: Basic Aerodynamics of Circulation Control

The aerodynamics of the circulation control concept is based on the well known "Coanda effect" where a low pressure sheet of air is emitted from a spanwise slot near the trailing edge of an airfoil. The sheet of air remains attached to the curved surface due to the balance between the centrifugal force and the suction pressure. The air jet re-energizes the boundary layer as well as introduces circulation by shifting the stagnation point around the curved trailing edge (Ref. 1). This concept is illustrated in Figure 1.

Part C: Background

The Coanda effect was discovered by Henri Coanda in 1910 while developing the design of an early biplane. When he tried to deflect the exhaust of the motor (to avoid burning of the wooden wing) the hot gases ended up flowing over the curved wing surface. This phenomena is well known today as the Coanda effect (Ref. 2).

The early work on circulation control aerodynamics was carried out at the National Gas Turbine Establishment (U.K.) by Cheeseman (Ref. 3). These studies included the measurement of section characteristics of circulation control airfoils. Also, a circulation control rotor was built and tested to obtain hover performance data.

In the last two decades, considerable research on circulation control aerodynamics has taken place at the David W. Taylor Naval Ship Research and Development Center (Review Paper by Englar and Applegate)⁴. They performed extensive wind tunnel testing on circulation control wing models and evaluated their performance for several different design variables including airfoil section, thickness and camber, slot height and position, blowing rate, angle of attack, Mach number, and the shape of Coanda surface. They also explored circulation control rotors for helicopters, as well as, stoppable rotor vehicles through scaled model testing in the wind tunnel.

There have been several full scale studies of circulation control wings and circulation control rotors. For example, Kaman under the sponsorship of the Navy built a full scale rotor called XH-2/CCR and tested it in the NASA Ames 40 x 80 ft. wind tunnel. This rotor was also flight tested. At the same time, the Navy A6 aircraft with a circulation control wing was also flight tested (Ref. 5). Sikorsky under the sponsorship of NASA and DOD is building a full scale stoppable rotor called the X-Wing. Figure 2 shows the X-Wing rotor (constructed by Sikorsky aircraft) mounted on the Rotor System Research Aircraft built by NASA. This aircraft is currently undergoing flight testing. The X-Wing configuration shown in Figure 3 was also proposed to take advantage of the circulation control concept. It has the capability of taking off vertically by rotating the rotor-wing and then transitioning to a fixed "X-Wing" configuration (two forward swept wings and two aft swept wings).^{6,7}

Another application of circulation control aerodynamics is on a helicopter tail-boom to replace the conventional tail rotor. In this case, a thin tangential slot ejects a sheet of air which is blown along the circular cylinder tail boom. Combined with the down-wash of the main rotor blade, lift can be generated to counteract the main rotor torque. The no-tail-rotor

(NOTAR) system shown in Figure 4 is an outgrowth of this concept (Ref. 8).

Recently, a large amount of work on circulation control airfoils and rotor blades was accomplished at the University of Maryland. For example, dynamic stability of a bearingless circulation control rotor blade in hover was investigated (Ref. 9). Also, significant effort was carried out to develop a method to calculate the steady and unsteady forces on circulation control elliptic airfoils (Ref. 10 and 11). In addition, the work presented herein was part of an ongoing task to expand the experimental data base for circulation control airfoil.

Part D: Objective of This Study

The objective of this paper is to explore the basic aerodynamic characteristics of a circulation control cylinder with blowing taking place from a single spanwise slot. This paper includes a detailed study of pressure distribution (both chordwise and spanwise) for a range of momentum coefficients and slot locations. Lift coefficients were calculated by integration of the static pressures over the cylinder. The measured lift coefficient was compared to the available analytical results. Flow visualization tests were completed using oil, smoke, and tuft methods. In addition, the flow field

around the circulation control cylinder was surveyed by means of total pressure, yaw and pitch probes. These data will be presented by using the color video display technique. Based on these data, a flow field model for the circulation control cylinder will be presented.

CHAPTER II

TEST APPARATUS AND TECHNIQUE

Part A: Test Program

The wind tunnel testing on the model was carried out in a 22 by 22 inch free jet wind tunnel. Figure 5 shows the test set up and equipment used for force measurement tests. Figure 6 shows the test set up and equipment used for flow visualization on the model. The two-dimensional circulation control cylinder model was mounted horizontally in the wind tunnel. The model was supported by a plexiglass platform at each end. This support arrangement made it possible to rotate the model; and hence, the location of the slot with respect to the free stream velocity could be changed.

The air for blowing was supplied through ducts attached to either end of the model forming a "T" supply line connected to the compressor. Control of the duct airflow was accomplished by opening or closing a two valve system.

During the experiment, surface pressure, duct pressure and temperature, and mass flow rate were measured. The model surface pressures were recorded using two multi-gauged scanivalves which were referenced to the

wind tunnel free-stream static pressure.

A series of test runs were made at different free-stream dynamic pressures corresponding to a model Reynolds number range from 1.181×10^3 to 1.47×10^6 . No significant effect of Reynolds number on the data was noted and a dynamic pressure equal to 10.5 lb./ft.ft. was chosen to allow for a wider range of momentum coefficient. The maximum momentum coefficient C_μ was limited to 0.16 because of the maximum amount of air that two compressors could supply. The following is a list of tests conducted.

1. Lift versus Momentum Coefficient. Data was obtained using surface pressure taps.
2. Lift versus Slot Location. Data was obtained by rotating the slot to different locations.
3. Qualitative features of flow directions were observed using a tuft probe. The objective of this test was to look for evidence of vortex development in the flow.
4. Surface flow patterns were observed using the oil flow technique.
5. Flow field surveys using total pressure, pitch and yaw probes were made at $C_\mu = 0.0, 0.04, 0.093$ and 0.105.

Part B: Model

The circulation control cylinder model was composed of four main structural sections: a support section, a knife edge and two end covers. These four pieces were built out of the same material to minimize the possibility of model warping induced by temperature variation during the test. This model had an outer diameter of 3.96 inches and was 22 inches long. Details of the model cross-section are shown in Figure 7. The knife edge and main section were built as separate components so that these could be modified easily.

Air enters the cylinder through ducts at either end of the model and exits through the slot formed by the main structure and the knife edge. Air supply plenum and pressure tap connections are shown in Figure 8. A special design feature of this model is the variable slot height. Varying the slot height was done by adjusting the position of the knife edge. For this experiment, slot height was set at 0.001 inch, using a 0.001 shim to set the slot height. The expansion of the slot caused by the pressurization of the duct is shown in Figure 9. This data was obtained by pressurizing the duct and measuring the resulting slot height with a thickness gage.

In order to gather pressure distribution data, the cylinder model was pressure tapped. There were 58 primary

pressure taps, located around the model at the midspan (see Figure 10). In addition, 30 pressure taps were placed at other spanwise locations to verify the two dimensionality of the flow. Figure 11 shows spanwise and chordwise pressure taps on the model.

The total duct pressure and temperature probes were located approximately at midspan and led out of the model through the end cover shown in Figures 12 and 13 respectively.

Part C: Hardware

A line diagram showing the components used in the test apparatus is given in Figure 14. The mass flow rate for the trailing edge blowing was measured by a turbine Hoffer flow meter, shown in Figure 15. This volumetric flow transducer gives a digital output directly proportional to flow rate. As shown in Figure 16, a pitot-static probe was used upstream of the open test section of the free jet wind tunnel to measure the total and static free stream pressures. These pressure lines were connected to the scanivalve and also to the alcohol manometer, in this way, free stream total pressure could be visually monitored.

The pressure lines of the pressure taps on the model were connected to the two multi-gaged scanivalves, shown

in Figure 17. These scanivalves connected individual pressure lines to the pressure transducers (one for the upper surface taps and one for the lower surface taps). The pressure transducers convert the pressure data into analog voltage output.

The CAMAC/LeCroy A/D equipment was used to convert the data from analog to digital values. This system includes a 4012 Traq system controller, a 8212-32 channel 100 khz digitizer, five 8800-32 k memory modules, four 1008, 8 channel amplifiers, and a 2216-16 channel relay. This system is shown in Figure 18.

An HP 1000 computer was used to control the equipment and process the data. A HP 2627A terminal was used as the command terminal and as the color video output device. A HP 2934 printer and a HP 7550 plotter were also used to display the data.

Two rotary valve air compressors made by the GAST company, were used to supply the air for the trailing edge blowing. These compressors were connected to both ends of a motor shown in Figure 19. In this configuration, the two compressors produced a maximum output of 90 cubic feet per minute at 10 psi.

One problem with these compressors was that the air temperature increased during the operating time. A 170 degree F temperature was generated when the compressors

were operated for about 15 minutes. Therefore, a cooling system was designed to keep the air flowing into the model at a constant temperature. This system is shown in Figure 20, and the inside is shown in Figure 21. It included thirty five foot long copper pipe coiled inside of a cylindrical water tank (O.D. = 2 ft., height = 3 ft). This maintained the blowing jet temperature to room temperature.

Part D: Software

The packages of Fortran codes were developed for this test. One for flow visualization and the other for force measurement. Figure 22 shows the schematic of the program for force measurement test and Figure 23 shows the schematic of the programs for flow visualization test. The subroutines names, together with brief descriptions of their functions are presented. Sample output displays are provided in Appendix 1. The program listings appear in Appendix 2.

Part E: Data Reduction

Measured surface pressures were converted into local pressure coefficient values and then integrated to obtain the lift coefficient. Some of the lift coefficients calculated by computer program were checked, using

graphical measurement methods of the plots of $C_p \sin$ (surface angle).

The blowing level is defined in terms of momentum coefficient. The jet velocity is calculated under assumption of isentropic expansion to freestream static pressure. Therefore, it is a function of pressure ratio and temperature.

$$V_j^2 = 2gRT_d \left(\frac{\gamma}{\gamma-1} \right) \left[1 - \left(\frac{p_\infty}{p_d} \right)^{\frac{\gamma-1}{\gamma}} \right]$$

The momentum coefficient was then defined as

$$C_\mu \equiv \frac{\dot{m} V_j}{q_\infty S}$$

The equation below was used to calculate the pressure difference in terms of vertical inches of the manometer fluid.

$$\Delta P = \rho_f g \Delta h$$

The free jet wind tunnel velocity was then obtained as

$$u = \left[\frac{2\Delta P}{\rho_\infty} \right]^{1/2} = \left[\frac{2}{\rho_\infty} (p_t - p_s) \right]^{1/2}$$

CHAPTER III

RESULTS AND DISCUSSION

Part A: Force Measurement Tests

These force measurements were designed to obtain data to correlate with the analytical results of Ref. 11. The analytical study shows that the flow on a circular cylinder without blowing separates at surface angles equal to 110 degrees. However, the nature of the flow given by the free jet wind tunnel is laminar (Reynolds number = 10.5×10^5) and this causes the separation to occur approximately at 75 degrees. Two strips of sand paper (fine grade 150 no., 25 x 22 inches) were glued on the exterior of the cylinder at surface angle +60 degrees to move the separation points closer to the analytical results. Figure 24 shows the sand paper on the upper surface of the model. Figure 25 shows the pressure distributions on the model respectively with and without sand paper. With sand paper, the flow is artificially made turbulent and the separation points shift from +75 degrees to about +110 degrees. Also, the pressure distributions on the upper and lower surfaces are quite identical.

Case 1: Blowing at 90 Degrees

In this case, the angular position of the slot was kept at 90 degrees. Figure 26 shows the surface pressure distribution for the cylinder with no blowing. The top right of the graph shows a cross section of the cylinder with the surface pressure distribution symbolized by the solid straight lines. The length of the bars perpendicular to the surface denotes the magnitude of the pressure. Each straight line (pressure data) represents one particular chordwise pressure tap at midspan of the model. A positive pressure occurs on the front surface between 40 degrees and the negative pressure occurs at other stations. The pressure distribution is symmetric on the upper and lower surfaces is caused by the presence of the slot. The bottom right of the graph shows the test conditions during a particular test run. The steadiness of the test is indicated by the duct pressure (displayed in red), duct temperature (displayed in blue), and mass flow rate for the jet (displayed in green). The duct pressure is the same as free-stream pressure for zero blowing. Therefore, the red dashed line indicates zero pressure differential. The duct temperature remained constant at 70 degrees F during the test. It took 7 minutes

to completely sample data around the cylinder. Also, a part of the graph indicates the quality of the two-dimensional flow by displaying the spanwise pressure coefficient at leading and trailing edges of the model (black dashed lines). A constant pressure coefficient along the span of the model indicates that two-dimensional flow was obtained. At the left half of the graph, surface pressure distribution with surface angle is plotted. Blue and red color lines respectively represent surface pressure on upper and lower surfaces of the cylinder. The black line represents analytical results. One can observe that there is good agreement between the analytical and experimental results. Flow separation occurs at an angle of 105 degrees. The sectional lift coefficient is determined by integration of surface pressure at a cross section. For this test, the lift coefficient is 0.0482. This small value (instead of being zero) may be due to flow angularity in the wind tunnel and/or asymmetry of model profile.

Figure 27 shows a data display of pressure distribution for a cylinder with a moderate blowing ($C_{\mu} = 0.482$). The pressure bar plot shows that the leading edge stagnation point shifts toward the lower surface. There is increased suction pressure on the

upper surface. The pressure on the lower surface as well as at the trailing edge is only slightly effected from the no blowing condition. The test condition plot shows the flow steadiness and that two-dimensionality were maintained during the test. For instance, duct pressure was 4.78 inches of mercury, duct temperature was 66 degrees F and the mass flow rate of the jet was 19.8 cubic feet per minute. The surface pressure distribution plot with surface angle shows the separation point on the upper surface of the model has moved substantially toward the trailing edge with blowing. On the other hand, the separation point on the lower surface remains almost unchanged. These separation points can be located at 140 degrees and -105 degrees respectively for top and bottom surfaces. A pressure jump on the lower surface at about -60 degrees is caused by the presence of sand paper strip. For this moderate level of blowing, a large suction lift coefficient of $C_{\ell} = 2.07$ is obtained.

Figure 28 shows results for a larger blowing rate ($C_{\mu} = 0.109$). Now there is a larger increase in suction on the upper surface due to increased blowing and a small reduction in suction on the lower surface. Test condition plots show that the pressure

coefficient along the leading-edge remained constant where as the pressure coefficient along the trailing edge was not uniform spanwise. The spanwise pressure coefficients, which vary from 0.0 to -0.6 suggest that the flow was not two-dimensional. A detailed study of the spanwise pressure distribution with increasing C_{μ} was undertaken. It was found that the two-dimensional flow conditions could be achieved only for blowing momentum of less than 0.064. To confirm this, a flow field survey of the wake was made to study the change of flow conditions with increasing C_{μ} . In the later section on flow visualization, results are presented in Figures 44 through 59. One may note that even at higher levels of C_{μ} , the test condition remained steady during the test run (duct pressure of 7.85 in., duct temperature of 68 degrees F and jet flow of 38.0 cubic feet per minute). For this test, surface pressure data showed the separation point on the upper cylinder surface has further moved towards the trailing edge. On the other hand, the location of the separation point on the lower surface is seen to be only slightly effected even at a high level of blowing.

Figure 29 shows the surface pressure distributions with changing blowing level. It is

interesting to note that the suction pressure on the upper surface increases with increasing blowing momentum. The suction pressure on the lower surface is only slightly reduced with increasing blowing momentum.

Figure 30 shows section lift coefficient with changing blowing momentum for the circulation control cylinder. In this case a maximum lift coefficient of 3.63 occurs at blowing momentum of 0.109. It appears that the lift coefficient could have been increased farther with increased blowing.

Case 2: Blowing at 80 Degrees

In this case, the angular position of the slot is brought forward to 80 degrees. Figure 31 shows the data display of pressure distribution for the cylinder with zero blowing. The pressure bar plot shows that a pressure jump on the upper surface at about +60 degree is caused by the presence of the sand paper strip. The test condition plots show the flow remained steady and two-dimensional during the test. The surface pressure distribution plot with surface angle shows the separation points on the upper and lower surfaces occur at angles of +105 degrees. For this test, the section lift coefficient

is obtained as $C_l = -0.17$. This small negative value may be due to flow angularity in the wind tunnel and/or asymmetry of model profile.

Figure 32 shows results for a cylinder with a large blowing rate ($C_\mu = 0.106$). One can see a larger increase in suction on the upper surface due to increased blowing and a small reduction in suction on the lower surface. Test condition plots show that the pressure coefficient along the trailing-edge was not uniform spanwise, it varied from -0.4 to -1.0. These plots suggest that the flow state was not completely two-dimensional as in Case 1. It was however, found that the two-dimensional flow conditions were possible for blowing momentum of less than 0.054. The test conditions like duct pressure, duct temperature and mass flow rate of the jet remained steady during the test run. The surface pressure data plot with surface angle showed the separation point on the upper cylinder surface has further moved towards the trailing-edge. One may note that even at higher levels of C_μ , the location of the separation point on the lower surface is seen to be only slightly affected.

Figure 33 shows a comparative picture of surface pressure distributions for different levels of

blowing. The suction pressure on the upper surface increases with increasing blowing momentum, whereas the suction pressure on the lower surface is only slightly reduced with increasing blowing momentum.

Figure 34 shows the suction lift coefficient with changing blowing level. The results obtained for this case are quite similar to those obtained for Case 1.

Case 3: Blowing at 100 Degrees

In this case, the angular position of the slot is brought backward to 100 degrees. Figure 35 shows the data display of pressure distribution for the cylinder with zero blowing. The test condition plots show the flow steadiness and two-dimensionality were maintained during the test. The surface pressure distribution plot with surface angle shows the separation points on the upper and lower surface occur at angles of +105 degrees. For this test, the section lift coefficient is 0.298. This non zero lift coefficient may be due to the same reason which was described in the previous two cases.

Figure 36 shows a data display of pressure distribution for a cylinder with a large blowing rate ($C_\mu = 0.112$). A larger increase in suction on the

upper surface and a reduction in suction on the lower surfaces are noticeable at increased blowing rate. Test condition plots show that the pressure coefficient along the trailing-edge was no longer uniform spanwise. On further investigation it was found that the two-dimensional flow condition was possible only for blowing momentum of less than 0.052. Also, the test conditions plot shows that duct pressure, duct temperature, and mass flow rate remained steady during the test run. Again, the surface pressure data plot with surface angle showed the separation point on the upper cylinder surface has moved to the trailing-edge, whereas the location of separation on the lower surface only slightly changed.

Figure 37 shows a comparative picture of surface pressure distribution for different blowing levels. Again, like Case 1 and Case 2 the suction pressure on the upper surface increases with increasing blowing momentum. Figure 38 shows the lift coefficient plot with changing blowing momentum. A maximum lift coefficient of 5.6 occurs at blowing momentum coefficient 0.14. Similar to the earlier cases, the lift coefficient could have been increased further with increased blowing.

Case 4: Blowing at 105 Degrees

In this case, the angular position of the slot is brought further backward to 105 degrees. Figure 39 shows the data display of pressure distribution for the cylinder with zero blowing. The surface pressure distribution plot with surface angle shows some differences of pressure on the upper and lower surface resulting in a suction lift coefficient of $C_{\ell} = 0.369$. Figure 40 shows a data display of pressure distribution for a cylinder with large blowing rate ($C_{\mu} = 0.107$). The pressure bar shows the surface pressure characteristics similar to other cases (increase and reduction in suction on the upper and lower surface at increased C_{μ}). Test condition plots show flow which is not two-dimensional but is steady during the test run. Figure 41 shows the change of surface pressure distribution when momentum coefficient is changed from 0.0 to 0.0913. Figure 42 shows the suction lift coefficient plot with changing blowing momentum, on this plot the analytical results of Ref. 11 are presented. One can see good agreement between experimental and analytical results.

Furthermore, the experimental data revealed the possible existence of a discontinuity at a very low level of blowing ($C_{\mu} < 0.02$), the Coanda effect is

not effective and therefore suction lift coefficient does not. This type of discontinuity was also reported by Englar (Ref. 12) and Abrahamson (Ref. 13). Actual pressure distribution data and oil flow studies indicated that the slot location was behind the separation point on the upper surface with zero blowing. Therefore, the one possible reason for this discontinuity may be that a certain amount of blowing level is required for flow attachment to occur at this slot location.

Figure 43 shows the lift generated at different angular slot positions with the same range of momentum coefficient. Interestingly, aft angular slot positions exhibit higher lift coefficients for a given C_μ . The overall behavior appears quite identical for different slot locations.

Part B: Flow Visualization Tests

As previously discussed, the flow field appears to be three dimensional at larger values of the momentum coefficient, due to the nonlinearity of surface pressure along the trailing edge of the cylinder (with or without sand paper strips). The following discussion is directed towards an understanding or identification of the flow field phenomena involved with the larger value momentum

coefficient conditions. Based on the flow field visualization data, a suggested flow field model for a circulation control cylinder is provided for future study.

All flow visualization tests were carried out at a Reynolds number of 10.5×10^5 with the angular slot position at 90 degrees. For this study, the sand paper strips were not used on the surface of the model. The blowing jet was maintained steady by keeping the temperature, pressure and mass flow rate of jet constant throughout the test. Four types of flow visualization tests were performed: oil tests, smoke flow tests, tuft wand tests, and color video display tests.

1. Oil Tests

Oil flow tests were completed using an oil made up of baby oil and a white powder (titanium dioxide). Pictures were obtained with a high intensity light entering the wind tunnel test section through the plexiglass and wall. Figure 44 shows oil flow patterns formed on the surface of the circulation control cylinder with zero blowing. The uniform accumulation of oil along the span (on the upper surface) indicates that two-dimensional flow was obtained. Figure 45 shows oil flow patterns with a large blowing rate ($C_{\mu} = 0.135$). The oil

accumulation on the upper surface consists of four weakly developed recirculation patterns. Two rotate counterclockwise and the other two rotate clockwise. These oil flow patterns suggest that the flow is not uniform along the span.

Figure 46 shows the oil flow patterns formed on the end wall with zero blowing. The oil patterns collected into two asymmetrical counter-rotating swirl patterns located about the cylinder center line. Figure 47 shows the oil flow patterns formed on the end wall with blowing C_μ of 0.09. One can see two oil swirl patterns merge into one that rotates counter clockwise. It is interesting to note that, this oil flow pattern is similar to a surface oil flow of a wing-wall intersection at a high angle of attack shown in Figure 48 (Ref. 14). As C_μ is further increased to 0.135, the oil swirl pattern becomes a dead air region located next to the trailing-edge (Figure 49). The oil patterns also show that the horseshoe vortex which passes across the upper surface of the cylinder, leaves the end wall surface further down-stream. The lower portion of the horseshoe vortex which passes under the lower surface of the cylinder, flows downstream and gradually diverges on the end wall surface.

2. Smoke Flow Test

Figure 50 through 53 shows photographs of smoke flow studies conducted at different locations around the circulation control cylinder with blowing ($C_{\mu} = 0.135$). The smoke was illuminated with a high intensity light entering the tunnel from one side of the plexiglass end wall. Figure 50 shows the smoke line on a cylinder when smoke is injected at mid-section and 6 inches upstream from the leading-edge. It indicates the flow was curving increasingly downward when the smoke passes over the upper surface of the model. Figure 51 shows similar results when the smoke was injected from the center line and 1.5 inches above the upper surface of the cylinder. Figure 52 is a photograph of when smoke was injected at 0.25 inches upstream from the leading-edge. The smoke divided into two streamlines: one flows over the upper surface of the cylinder and the other flows below. These two streamlines seem to merge together downstream of the model in a circulatory motion. The smoke streamline merge together in the same location as the recirculating oil patterns observed by means of the oil tests. A circulatory motion outline by smoke was quite apparent in Figure 53 when smoke was injected from the same location but further

downstream. The smoke study shows the presence of shed vortices at the surface of the cylinder.

3. Tuft Wand Test

The flow field behind the circulation control cylinder was also visualized with a tuft wand probe. Figure 54 shows the probe location below and downstream of the cylinder. It indicates that a vortex appeared to be rotating counter-clockwise in the flow. The distance from the end wall to this vortex is about the same distance as between the end wall and one of the recirculating oil patterns on the cylinder surface.

4. Color Video Display Test

For the color video display tests, a traversing rig was used to survey the flow field around the circulation control cylinder. This traversing rig allowed surveys to be made in a two-dimensional plane. This survey plane can be oriented so that it is parallel to the spanwise direction or perpendicular to the spanwise direction of the cylinder. Figure 55 shows these two survey planes relative to the cylinder. The data output from the transducers is fed through an analog to a digital

converter and then read into the central processing unit where it is processed. The processed data is converted to color bands which are then displayed on the color monitor. The detailed description of this technique is presented in Ref. 15.

Figures 56 and 57 show the color video display data survey in the spanwise direction. Figures 58 and 59 show the color video display data survey perpendicular to the spanwise direction (chordwise) of the cylinder. Data was obtained using total pressure, yaw, and pitch probes. Each figure shows a composite of the color video display data of: a. the total pressure level, b. yaw direction, and c. pitch direction. A sketch of the survey station location relative to the cylinder model is also included. The color code for the color video data display obtained by total pressure probe uses black color to represent the free-stream pressure and white color to represent maximum suction pressure (reversed flow); other colors represent different levels of pressure in between. The color code for the data obtained by the yaw probe uses black color to represent flow direction from the (-30 degrees) right and white color to represent flow direction from (+30 degrees) right and white color represents flow direction from

(-30 degrees) left. The color code for the data obtained by the pitch probe uses black color to represent downward flow direction from (-30 degrees) and white color to represent upward flow direction from (+30 degrees).

Figure 56(a) shows the spanwise total pressure probe survey of the spanwise flow field behind the cylinder with zero blowing. The region of white color represents the reversed flow in the wake behind the cylinder. The regions of red and dark green colors in the upper and lower section of the survey are associated with total pressure very close to the free-stream conditions. Figure 56(b) shows yaw probe data behind the cylinder with zero blowing. One can see that random dark blue and yellow colors which cover the entire surface of the survey indicate that no significant spanwise flow exists. Figure 56(c) shows pitch probe data behind the cylinder with zero blowing - blue and yellow colors are the only two colors which appear in the survey. This may be due to the survey being made so close to the cylinder, (i.e. the change in pitch direction of the flow is very small). Figure 56(a, b and c) shows no change in color along the span, suggesting that spanwise uniform flow exists with zero blowing.

Figure 57 shows the color video display data of the cylinder with blowing at $C_\mu = 0.105$. The location of this survey is the same as the location survey of Figure 56. The total pressure data in Figure 57(a) indicates that the large white color region seen in the zero blowing condition (Figure 56(a)) is reduced to two small white color regions. This suggests that the reversed flow in the wake region behind the cylinder was reduced to two small regions. It is interesting to note that the locations of these small wake regions correspond to the locations of the weakly developed recirculating oil patterns. Figure 57(b) shows the data obtained by using the yaw probe. One can see, the regions of concentrated black color located on the top of the white color region. This suggests that at this location the direction change from left to right which may be associated with one of the existing trailing vortices. Figure 57(c) shows the data obtained by using the pitch probe. A large region of red color at the top of the survey indicates strongly downward flow.

Figure 58(a) shows the chordwise total pressure data of the cylinder with zero blowing. The reduction of the wake in the downstream direction

(left to right) is very apparent. Figure 58(b) shows the data obtained by using yaw probe. Again, random dark blue and yellow colors which cover the entire surface of the survey indicate that no significant spanwise flow exists. Figure 58(c) shows the data obtained by using the pitch probe. The green and dark color located at the top of the survey indicates that the flow passing above the cylinder surface has a downward direction. The light blue color located at the lower region indicate the flow passing below the cylinder surface has an upward direction. However, the flow was symmetric at the center line of the cylinder.

Figure 59(a) shows the chordwise total pressure probe of the cylinder blowing ($C = 0.105$). The lack of white color indicates a reduction in the wake region. Figure 59(b) shows the data obtained by using the yaw probe. Other evidence of the trailing vortices was seen as a white color (spanwise flow) departs from upper and lower left (upstream) then joins together and moves to the right (downstream). Figure 59(c) shows the data obtained by using the pitch probe. One can see that the color code shows the flow was downward direction and asymmetric at the center line of the cylinder.

Figure 60 suggests a flow field model for the cylinder incorporating the circulation control concept. It includes four trailing vortices formed on the surface of the model and shed downstream. Two horseshoe vortices are rolled up around the strong trailing vortices. One can see even in the simple, well-known flow field of a body such as a cylinder, the flow becomes asymmetric and three-dimensional.

CHAPTER IV

CONCLUSIONS

The main conclusions of the present paper are summarized below:

1. Using sand paper strips on the top and the bottom of a cylinder, turbulent flow can be simulated.
2. With increasing blowing momentum, the separation point on the upper cylinder surface has further moved towards the trailing edge. Whereas, the location of the separation point on the lower surface seemed to be only slightly affected.
3. The suction pressure on the upper surface increases with increased blowing momentum. On the other hand, the suction pressure on the lower surface is only slightly reduced with increased blowing momentum.
4. Two-dimensional flow conditions could be achieved only for small blowing momentum ($C_\mu < 0.064$).
5. At zero blowing, there is net lift on a cylinder due to the flow angularity in the wind tunnel and/or asymmetry of model profile.
6. The existence of a possible discontinuity in the lift curve slope due to the level of blowing required for flow attachment to occur at different slot positions.

7. There was some influence of slot locations on lift coefficient. Aft angular slot positions exhibit higher lift coefficients for a given blowing momentum.

8. Measured lift coefficient with the angular slot location at 105 degrees results in a good correlation with analytical results.

9. A lift capability was demonstrated at low subsonic speeds for a circulation control cylinder. Lift coefficients up to 5.41 were produced at momentum coefficient of 0.162, for turbulent flow and angular slot location at +105 degrees.

Observation of the flow visualization surveys led to the following conclusions.

10. At high $C_{\mu} = 0.09$, the oil flow patterns observed on the end wall are similar to those observed in the case of wing-wall interaction at high angles of attack.

11. Oil flow patterns indicate four weakly developed recirculating patterns corresponding to four wake regions observed with a total pressure probe survey.

12. At high C_{μ} values, tuft wand and smoke probes show the existence of vortices which appear to shed from the surface of the cylinder, and interact with the separation wake further downstream.

13. Color video displays of total, yaw, and pitch probe surveys show that the circulation control concept

provides a significant reduction in the wake separation region.

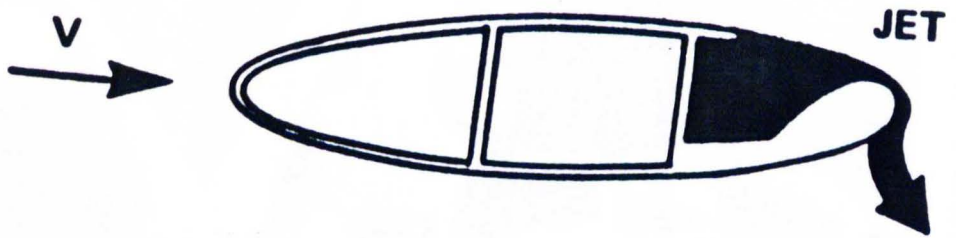
14. Color video displays of yaw probe surveys also show trailing vortices directly shed from the surface of the model, and

15. These vortices suggest a flow field model such as that in Figure 60.

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1

Basic Circulation Control Aerodynamics

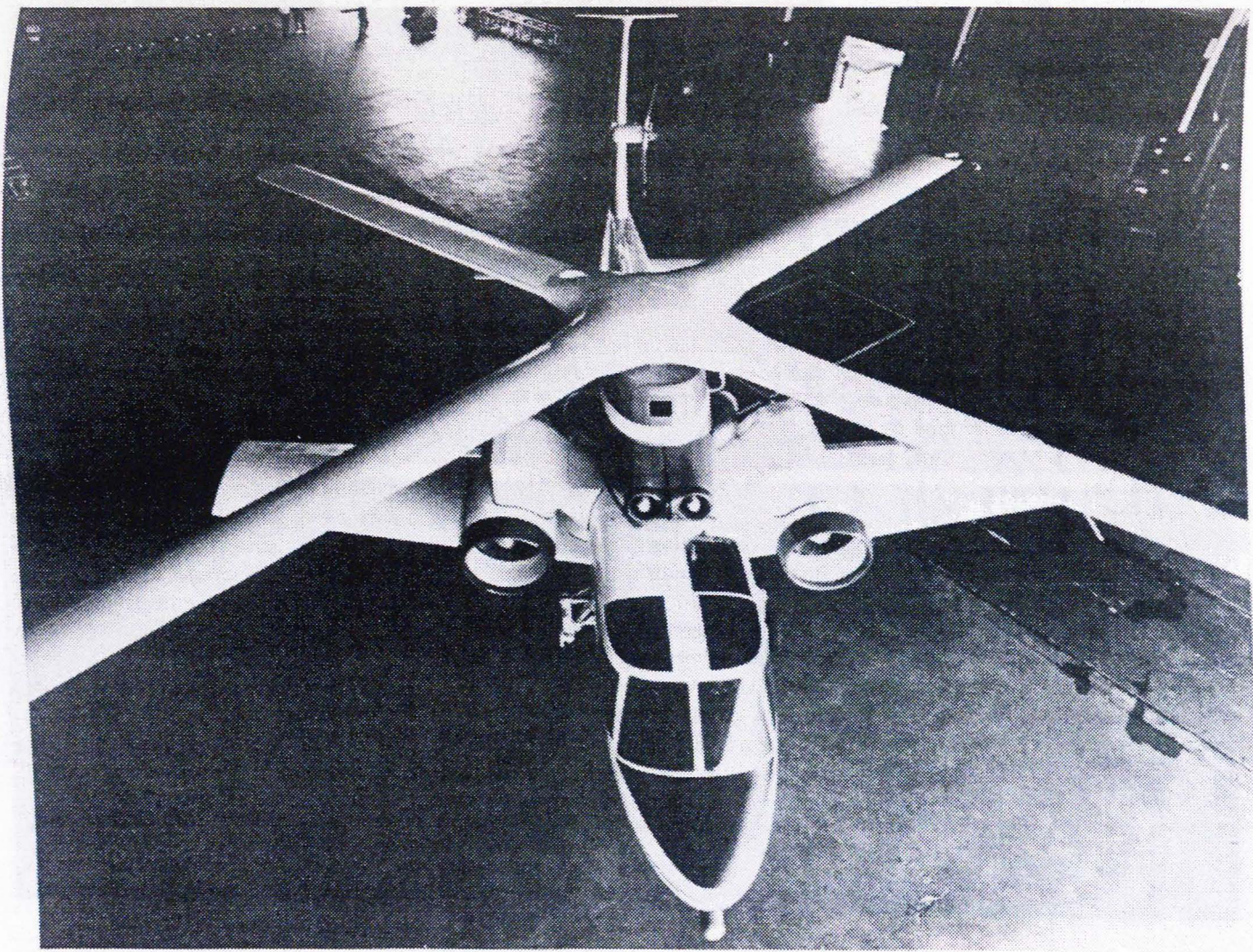


Figure 2 An RSRA/X-wing Verticle, Shown at Sikorsky Aircraft Stratford Facility
(Ref. 5)

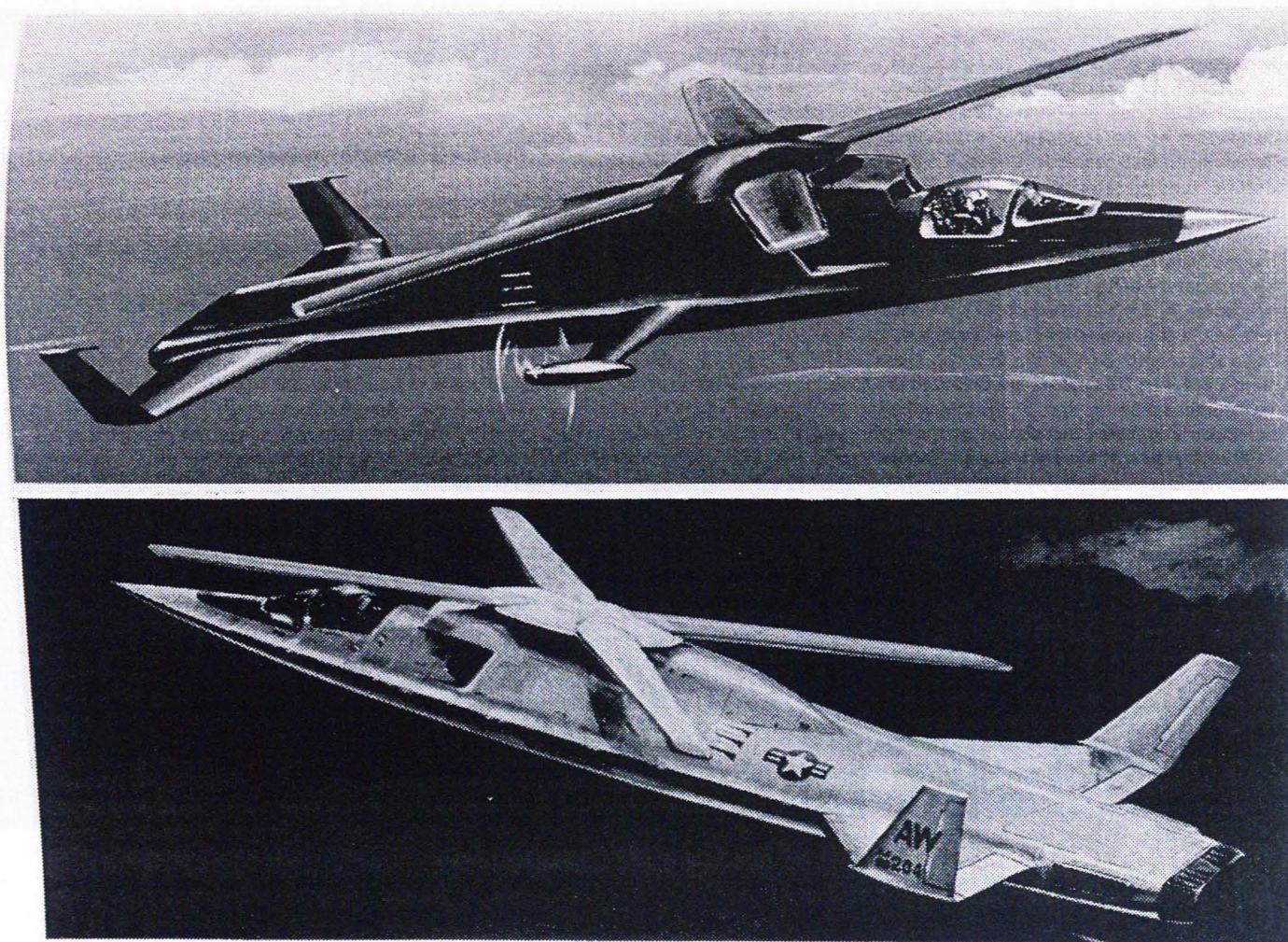
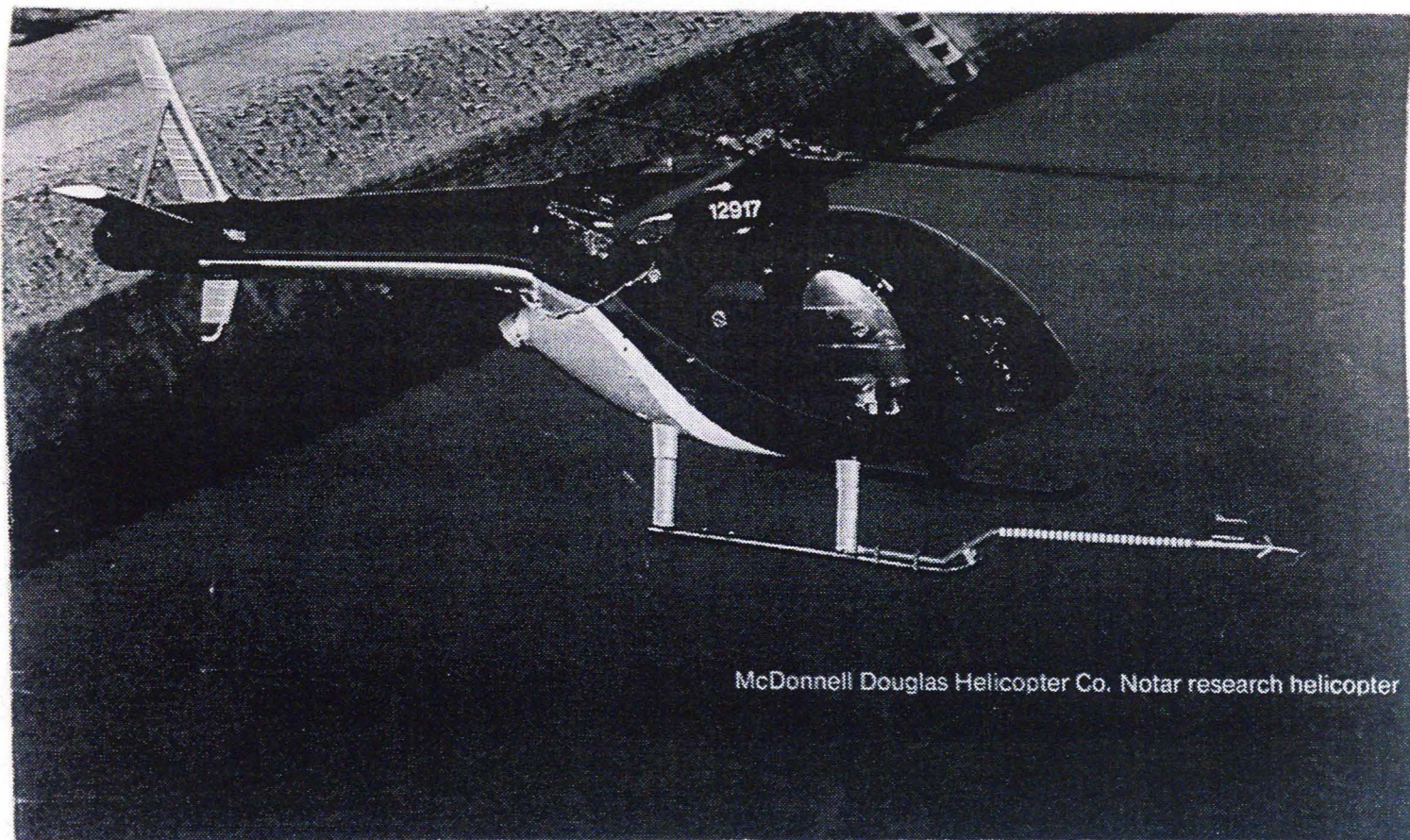


Figure 3 X-wing Vertical Takeoff and Landing Aircraft Concept
(Ref. 6)



McDonnell Douglas Helicopter Co. Notar research helicopter

Figure 4 McDonnell Douglas Helicopter Co. Notar Research Helicopter
(Ref. 7)

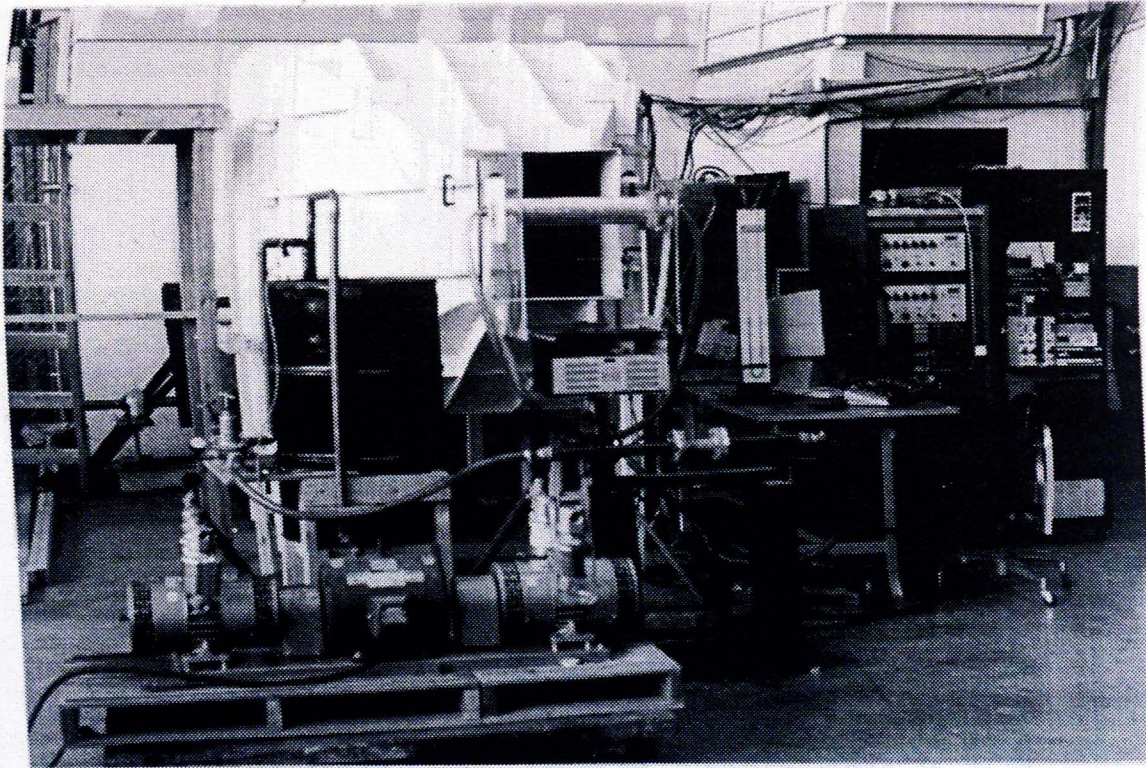


Figure 5 Test Set Up and Equipment for the Force Measurement Tests

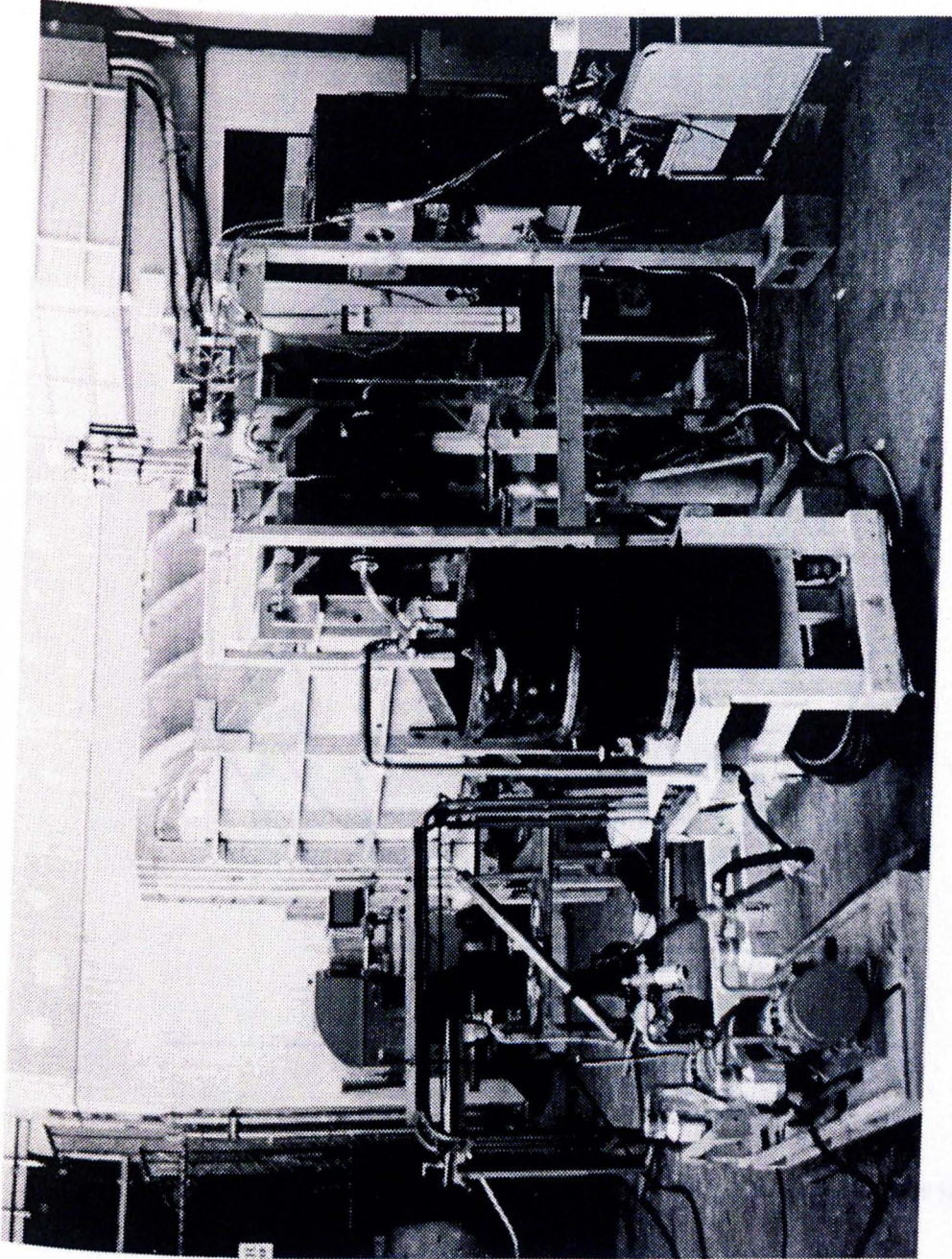


Figure 6 Test Set Up and Equipment for the Flow Visualization Tests

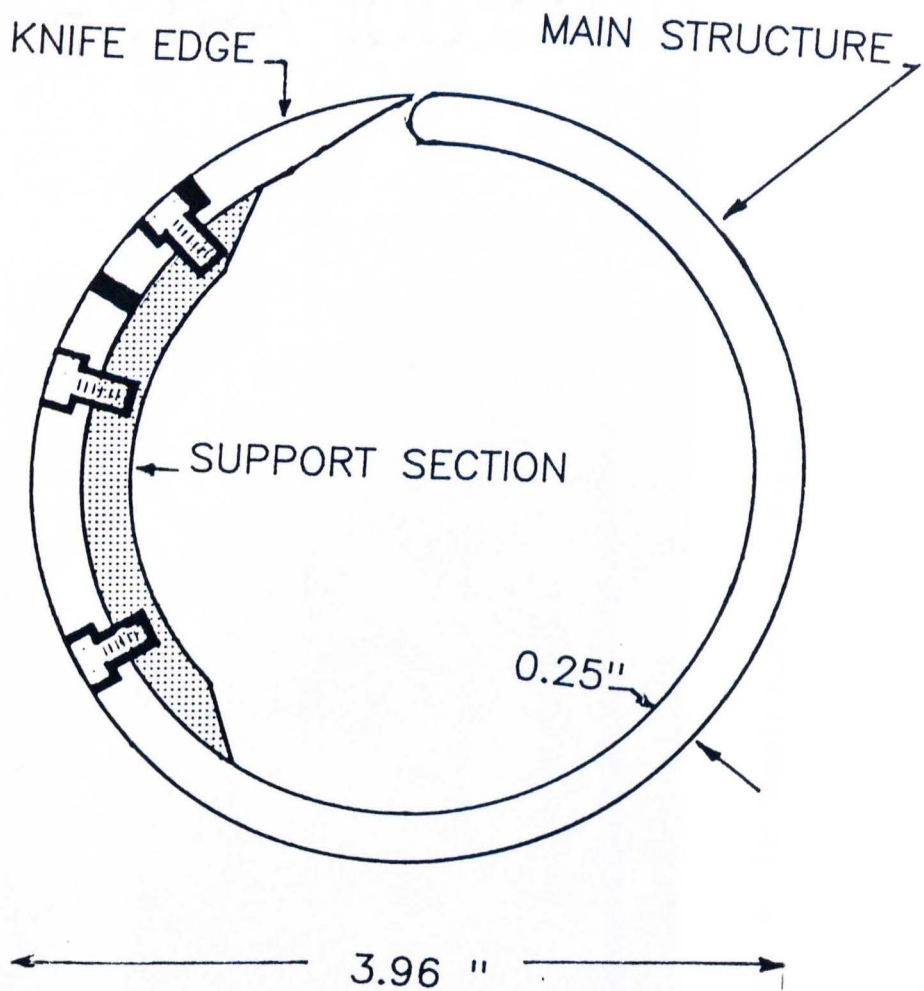


Figure 7 Details of the Models Cross-Section



Figure 8 Air Supply Plenum and Pressure Tap Connection of the Model

MODEL DETAILS

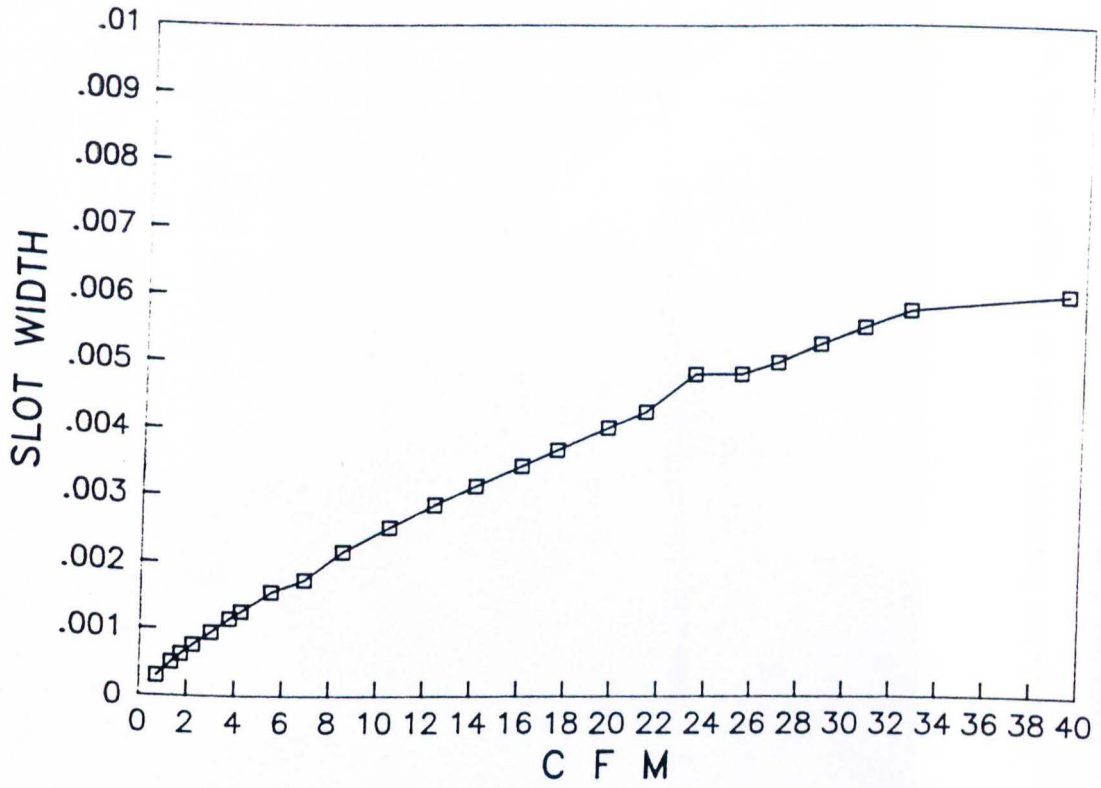


Figure 9 Variation of Slot Height with Mass Flow Rate

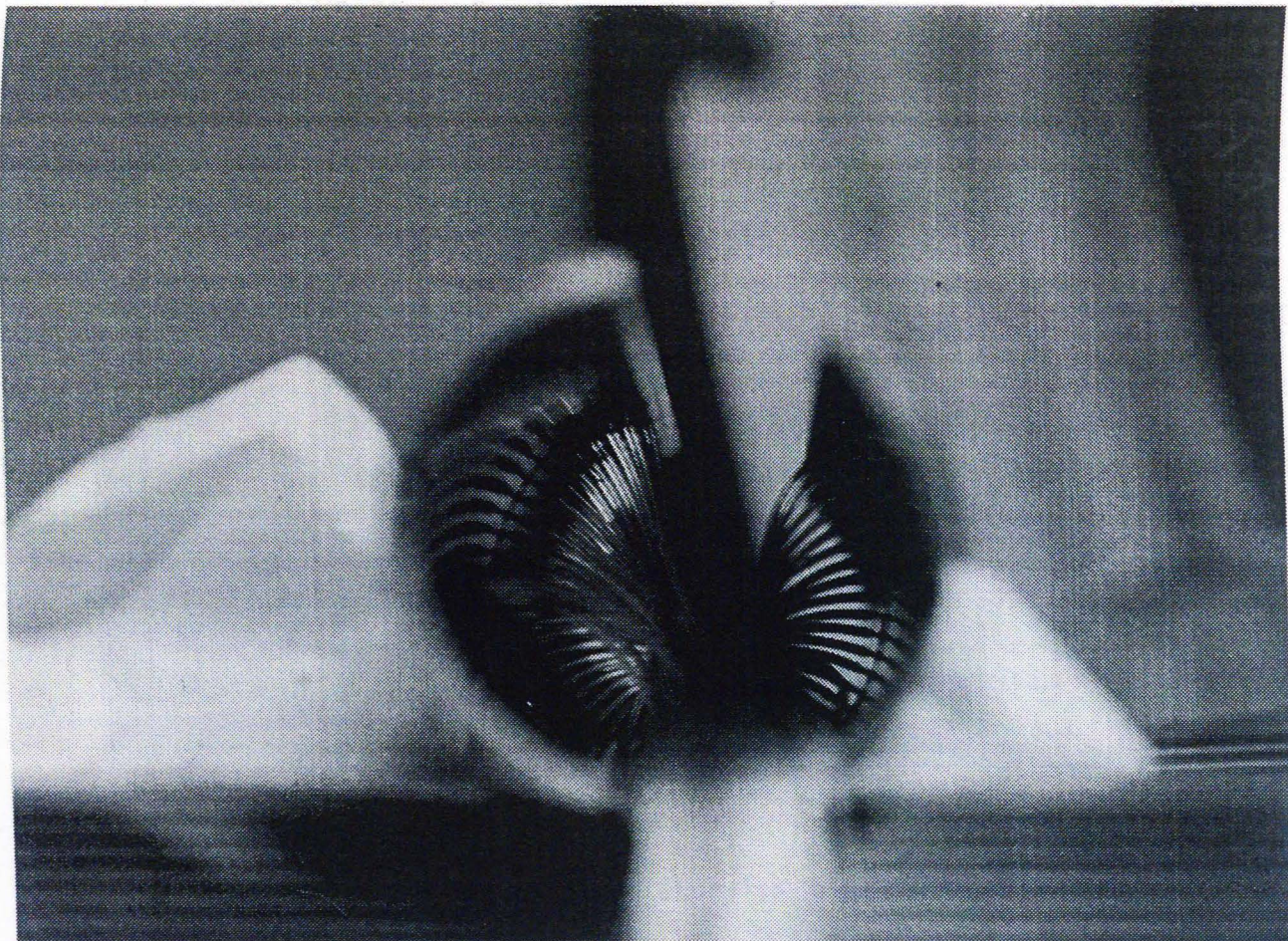


Figure 10 Chordwise Pressure Taps at Midspan of the Model
(looking from inside)

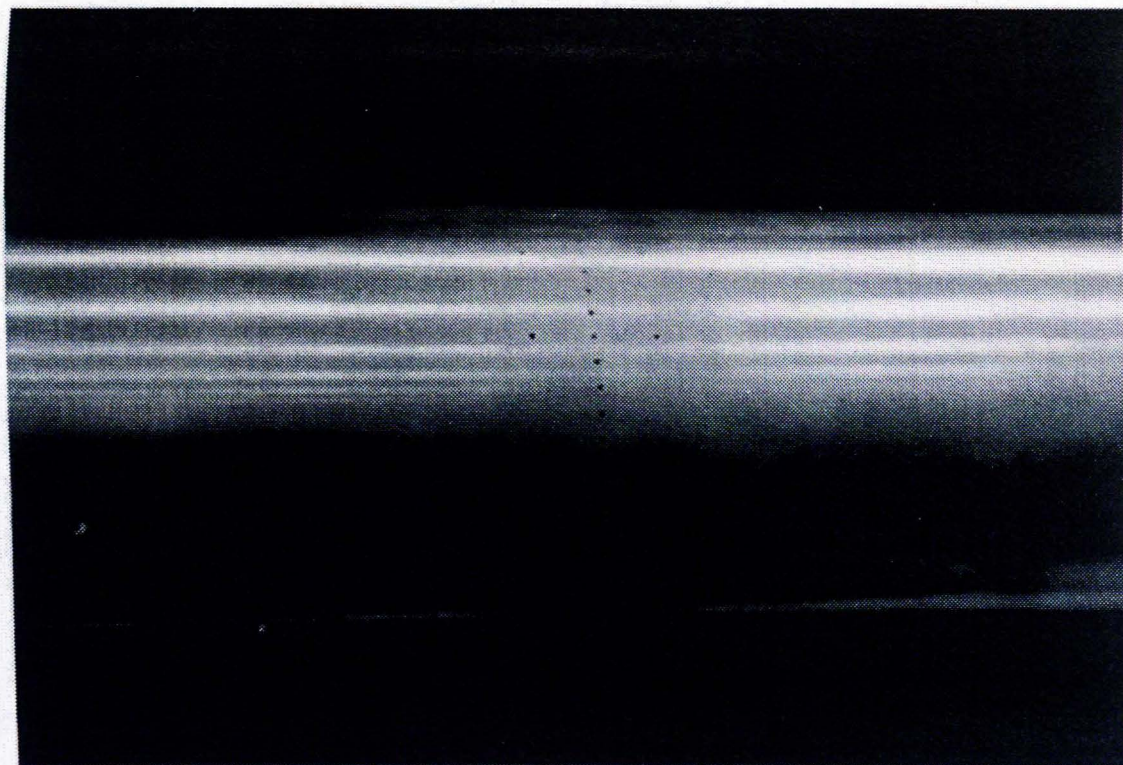


Figure 11 Spanwise and Chordwise Pressure Taps at Midspan
(looking from outside)

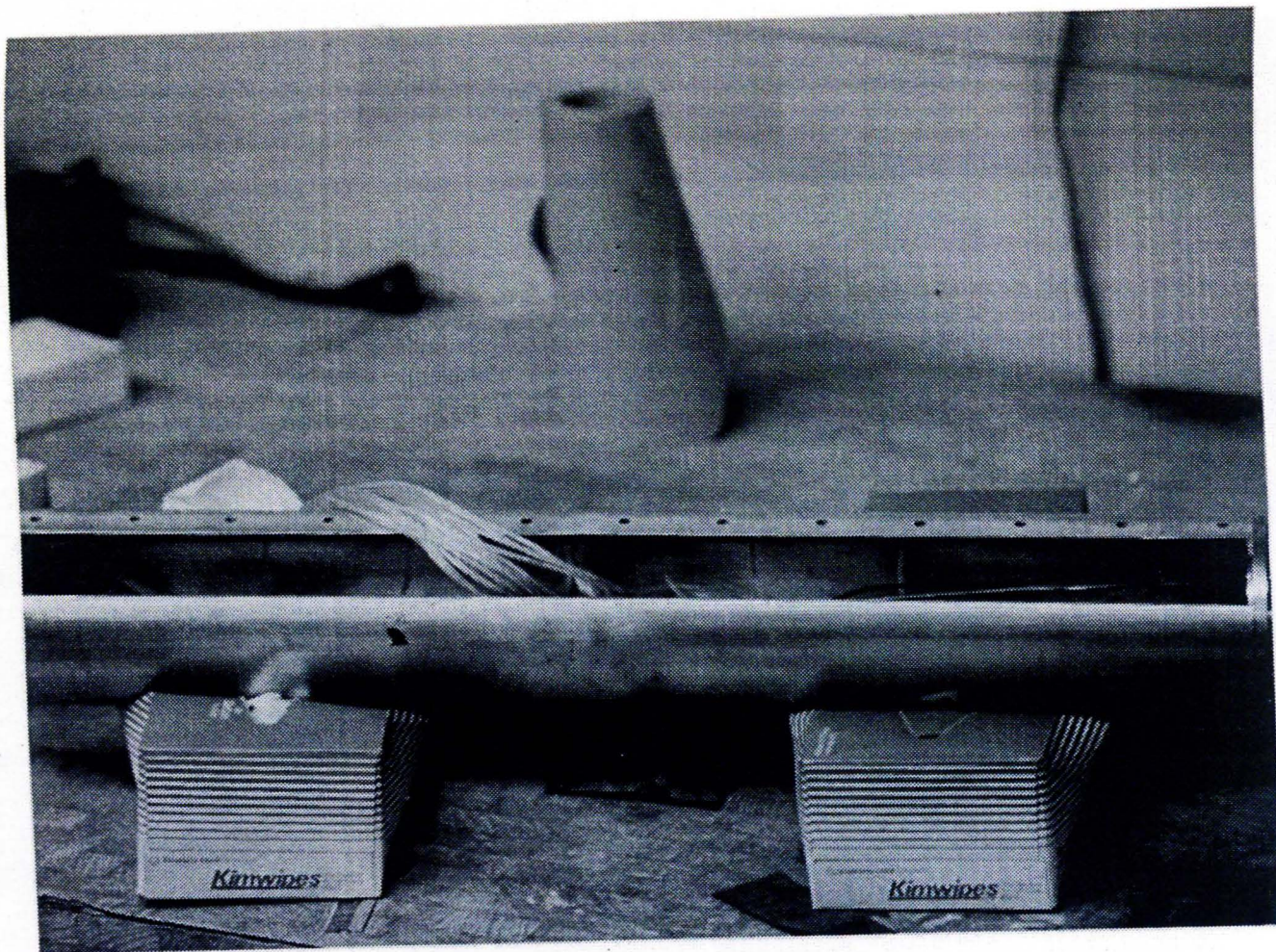


Figure 12 Total Duct Pressure and Temperature Probes Were Located Approximately at Mid Span of the Model

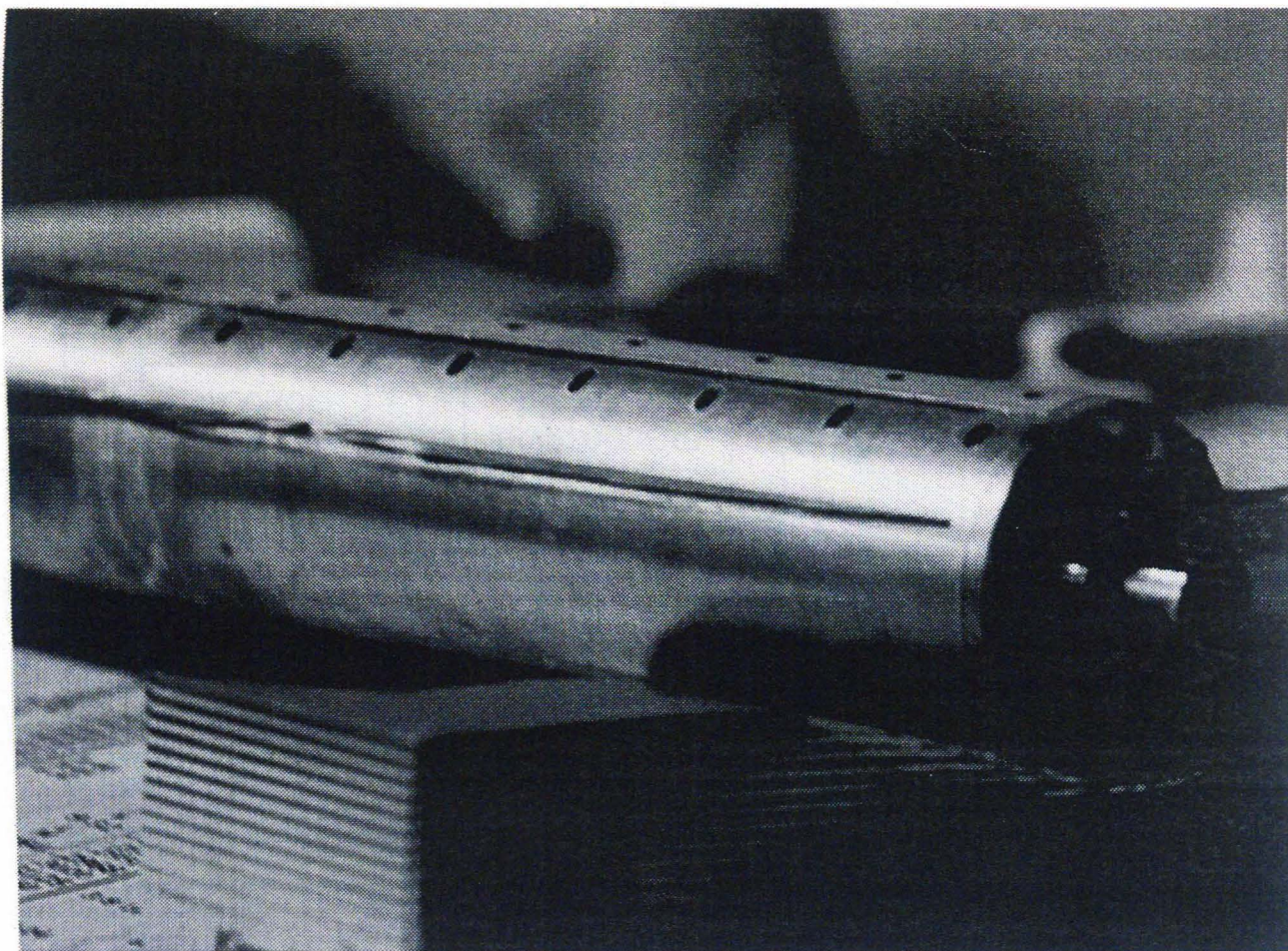


Figure 13 Total Duct Pressure and Temperature Probes Leading Out of the Model Through an End Cover

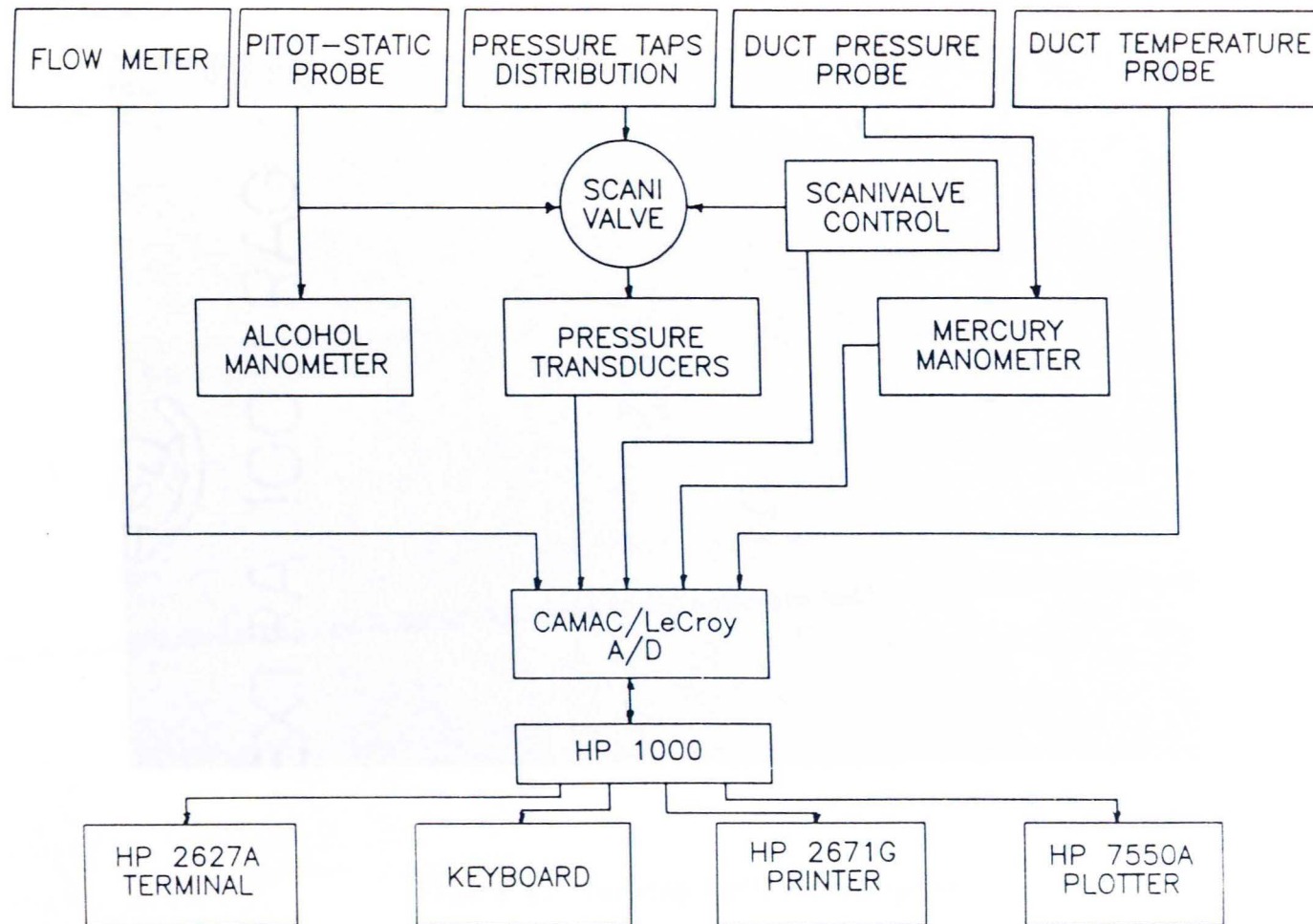


Figure 14

Hardware Connection for the Wind Tunnel Test

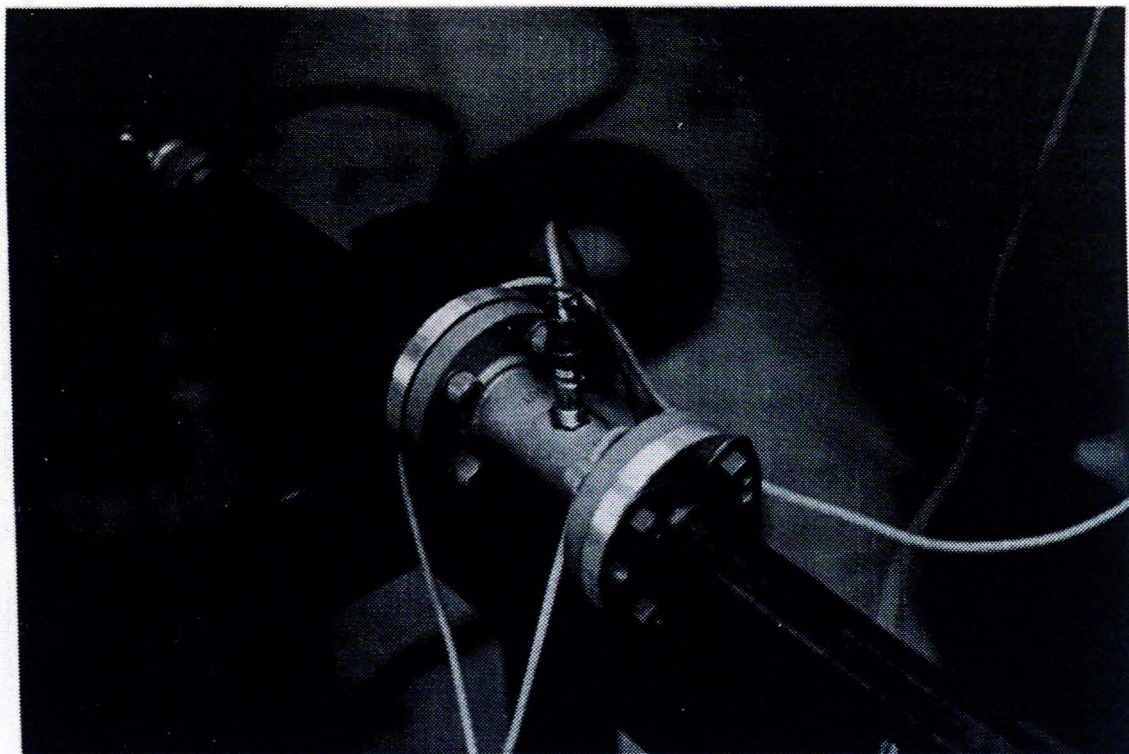


Figure 15 Turbine Hoffer Flow Meter

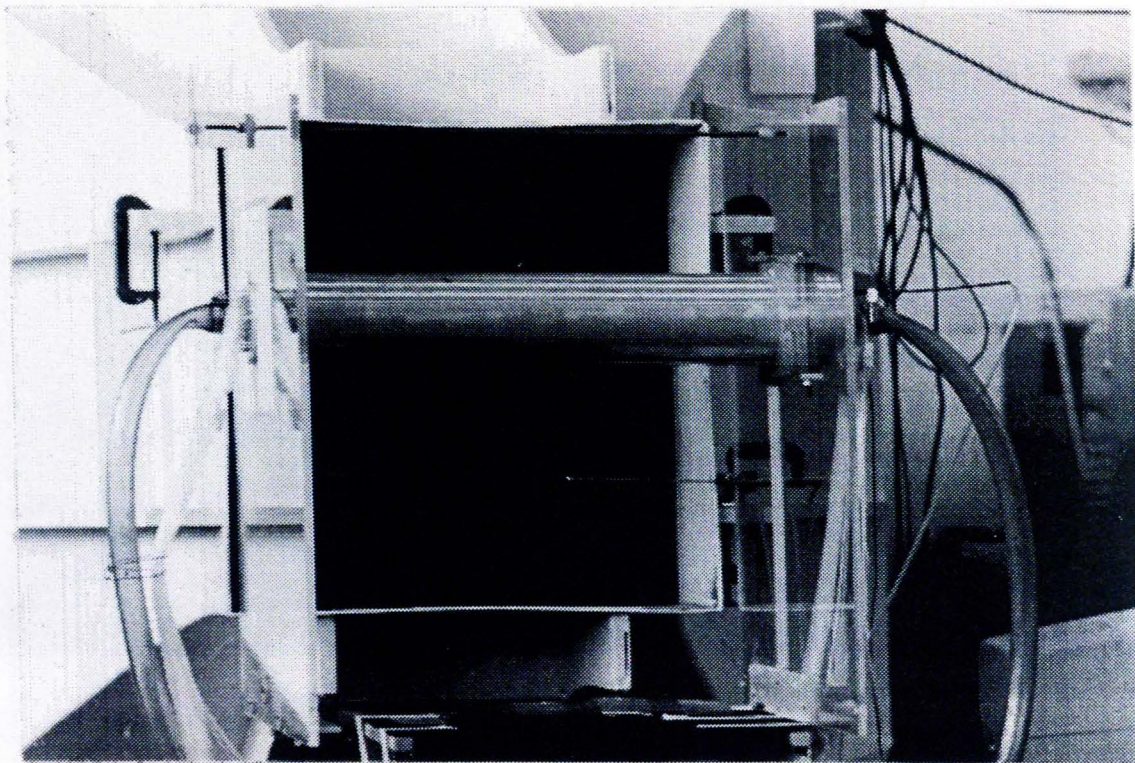


Figure 16 A Pitot-Static Probe Located Upstream of the Open Test Section

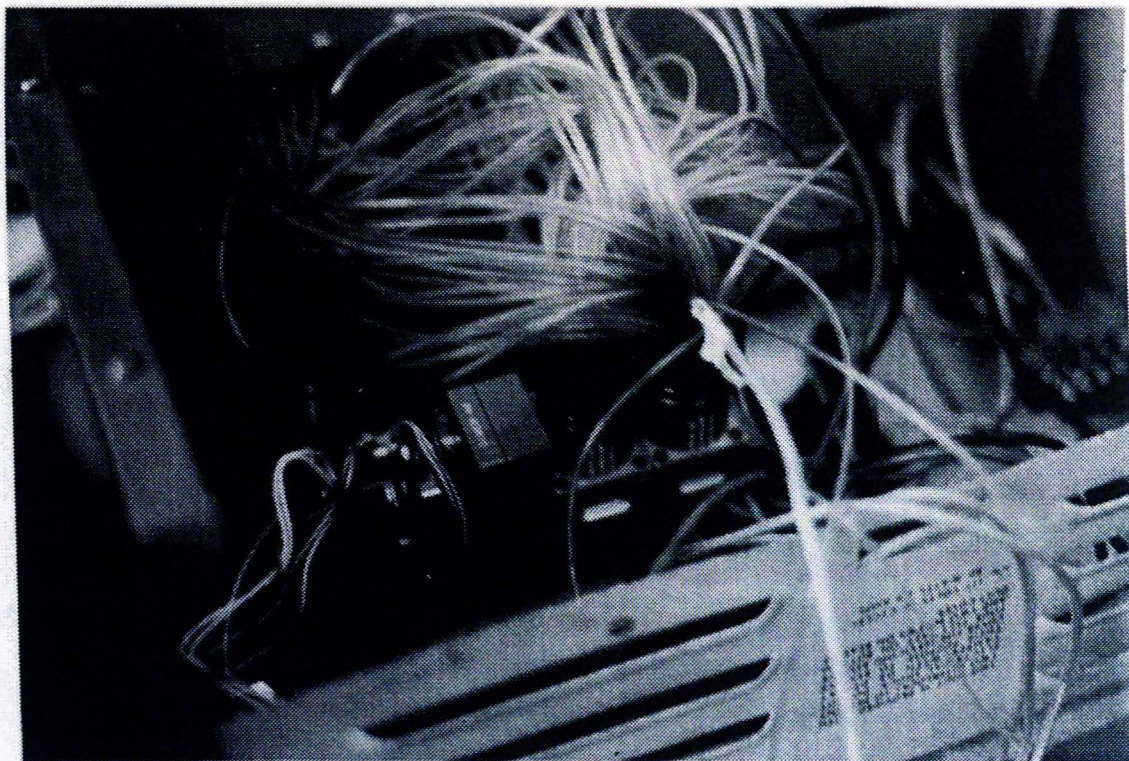


Figure 17 Pressure Lines of 78 Pressure Taps Connected into
Two Multi-Panel Scani-Values

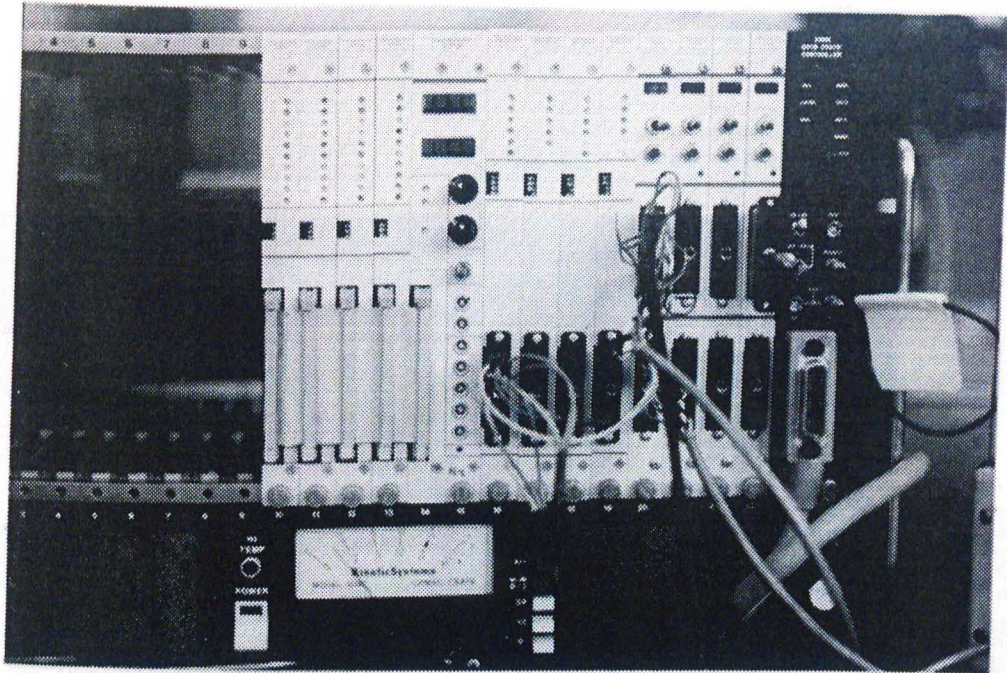


Figure 18 CAMAC/Larch A/D Equipment

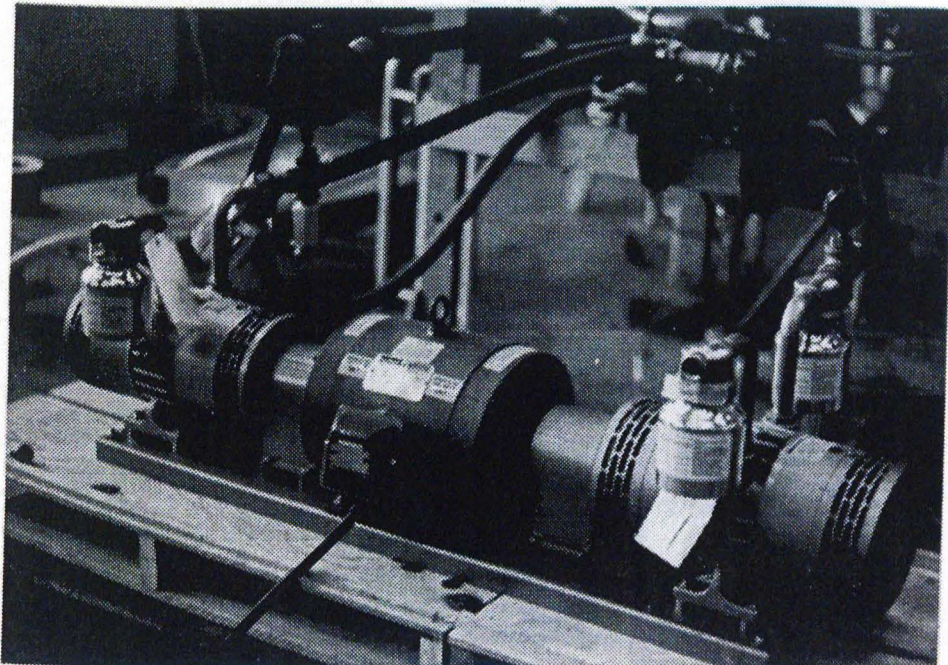


Figure 19 Compressors and Motor Used to Supply Air for the Trailing Edge Blowing

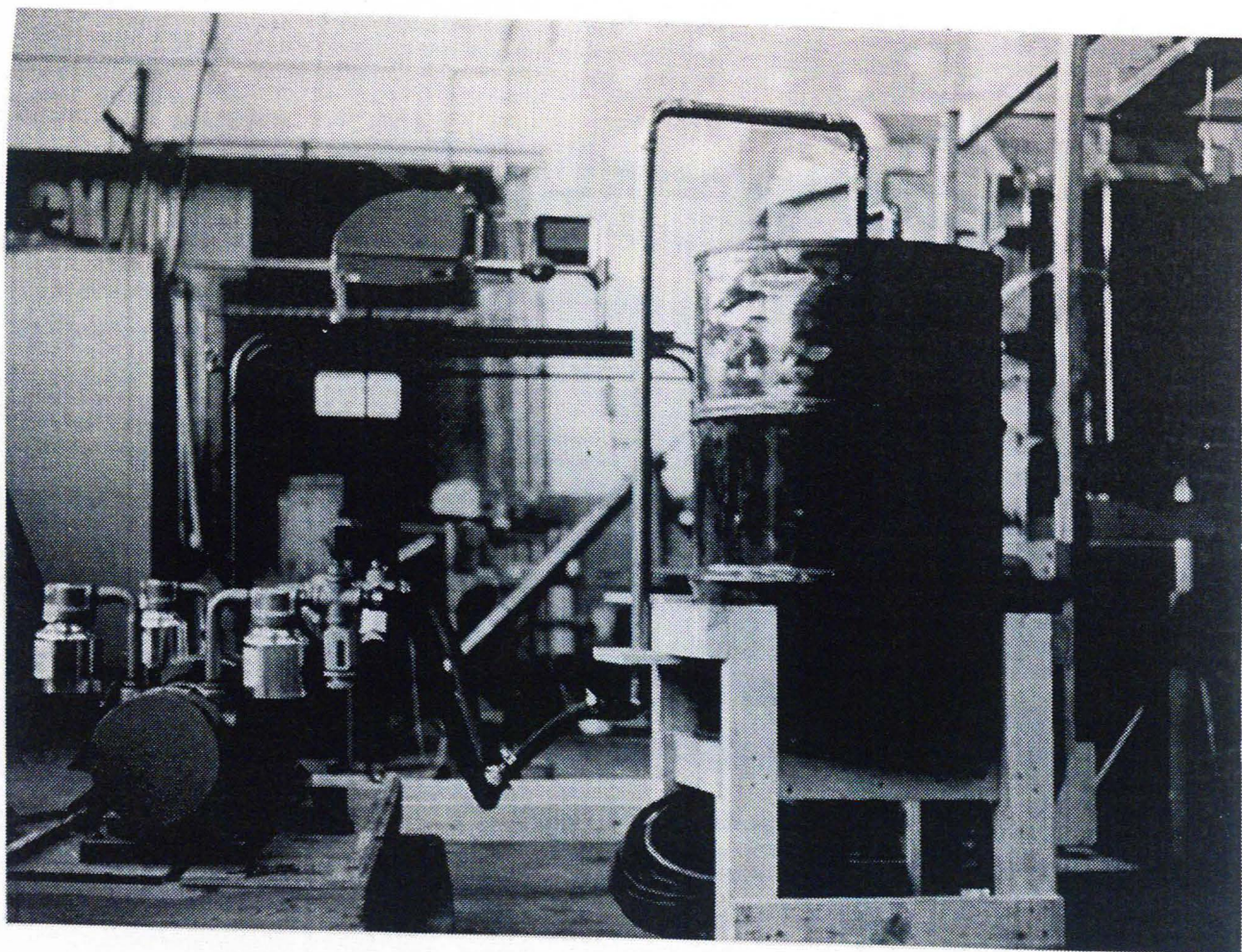
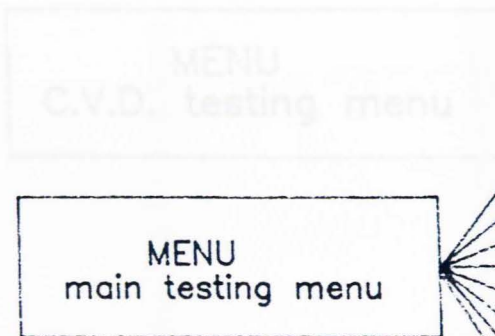


Figure 20 Outside and Inside of the Closed System



Figure 21 Inside Views of the Cooling System



CALIB.FTN :To calibrate pressure transducers.

GETIT.FTN :To read the pressure distribution of the model.

RENAM.FTN :To name the pressure data set and store in the disk.

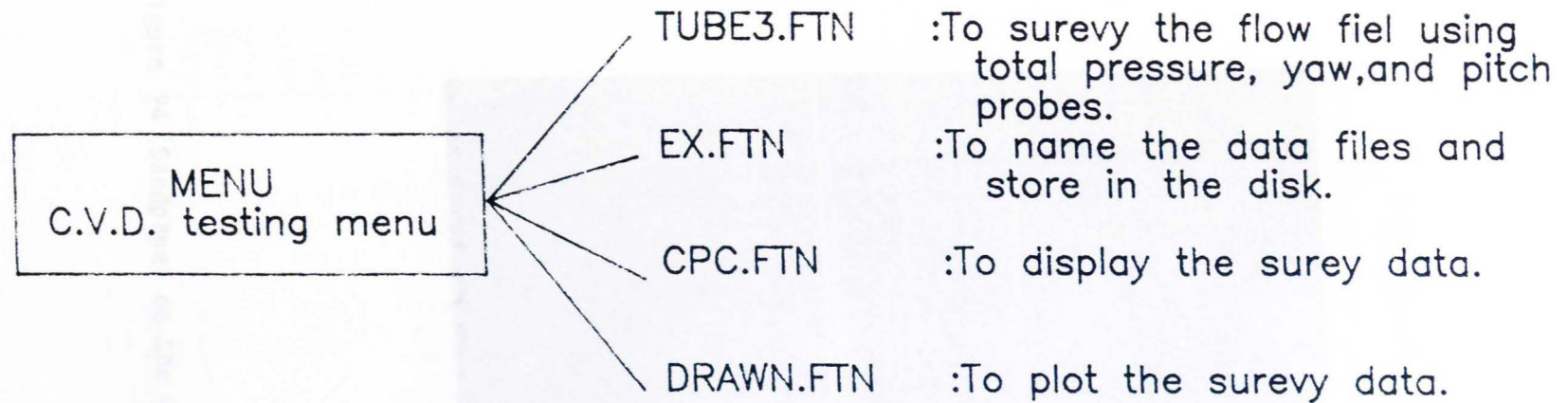
CPDGL3.FTN :To display pressure data.

CPDGL5.FTN :To plot pressure data.

PCP.FTN :To plot multiple data files

DELH.FTN :To compute delta H for a certain Re

VELCHK.FTN :To check velocity.



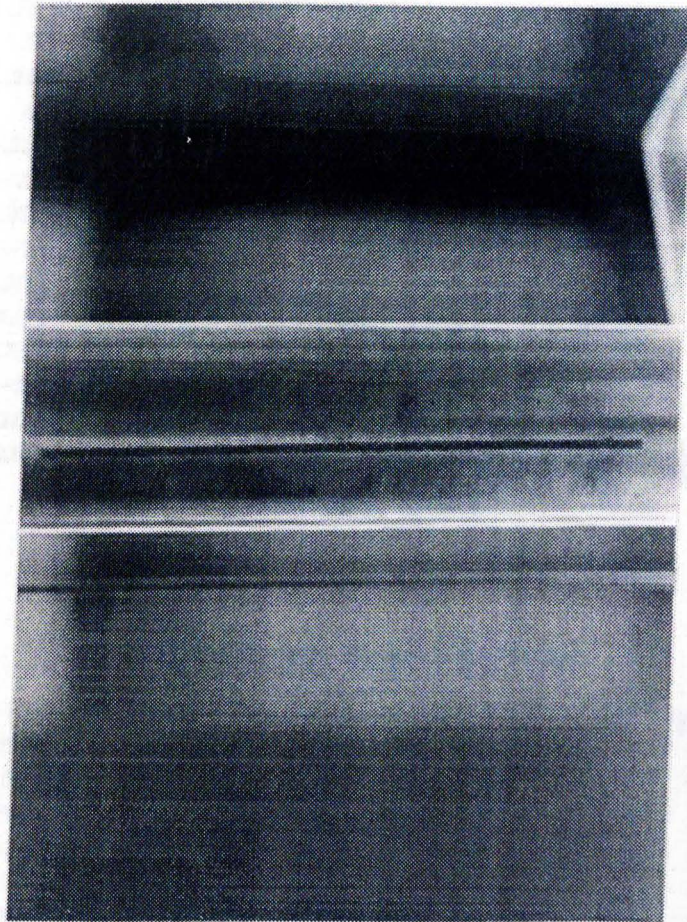
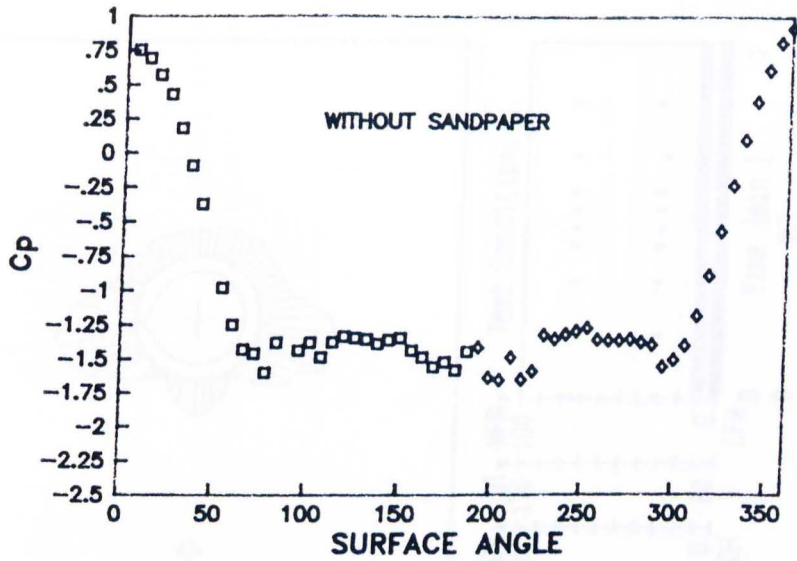


Figure 24 Sandpaper on the Upper Surface of the Model

PRESSURE DISTRIBUTION



PRESSURE DISTRIBUTION

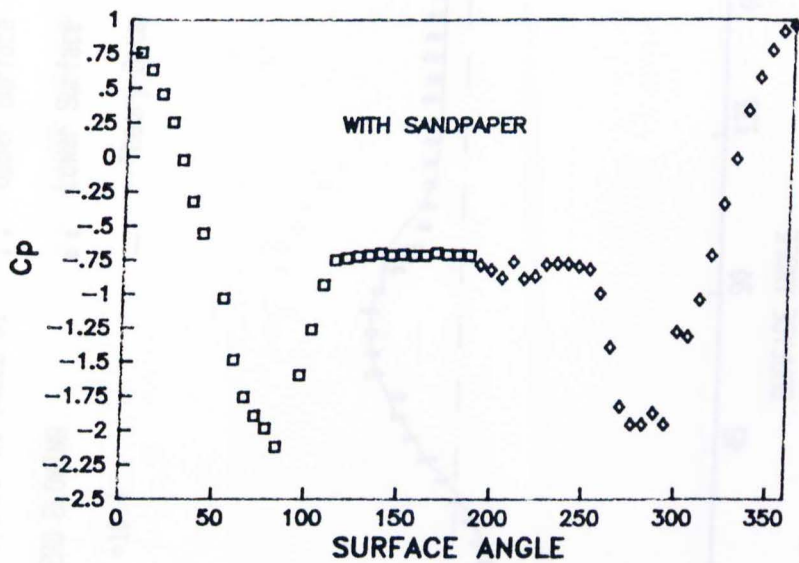


Figure 25 Pressure Distribution of the Model With and Without Sand Paper

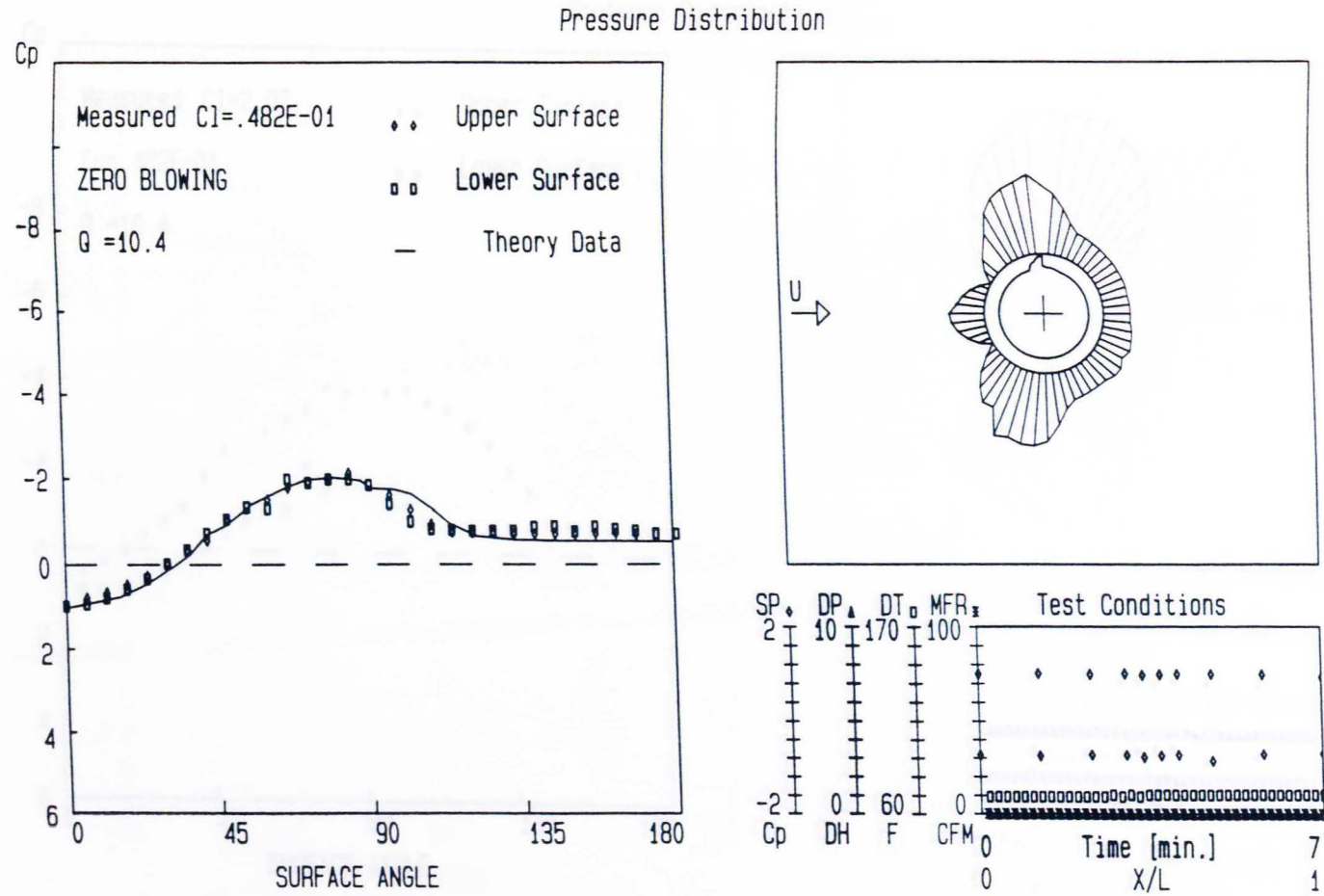


Figure 26 Data Display of Pressure Distribution for the Cylinder with Zero Blowing and $\phi = 90^\circ$

Pressure Distribution

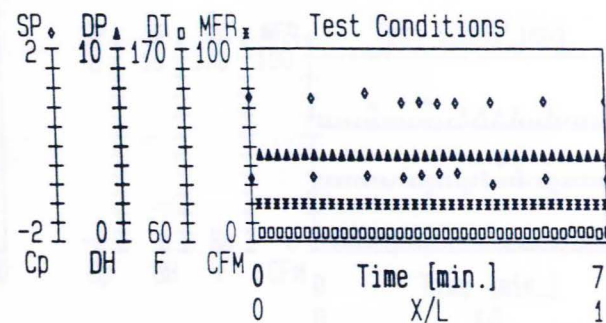
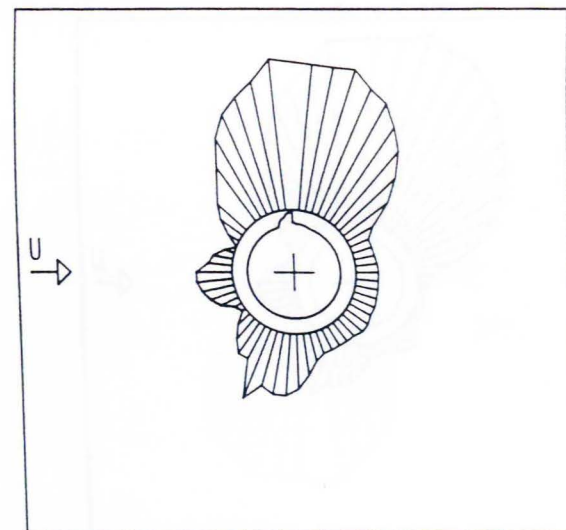
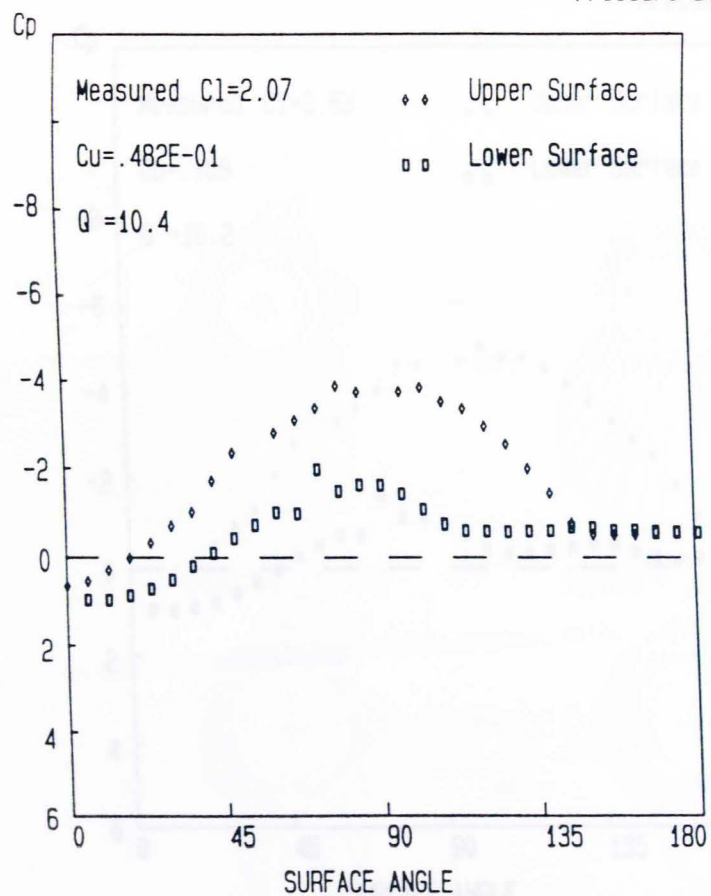
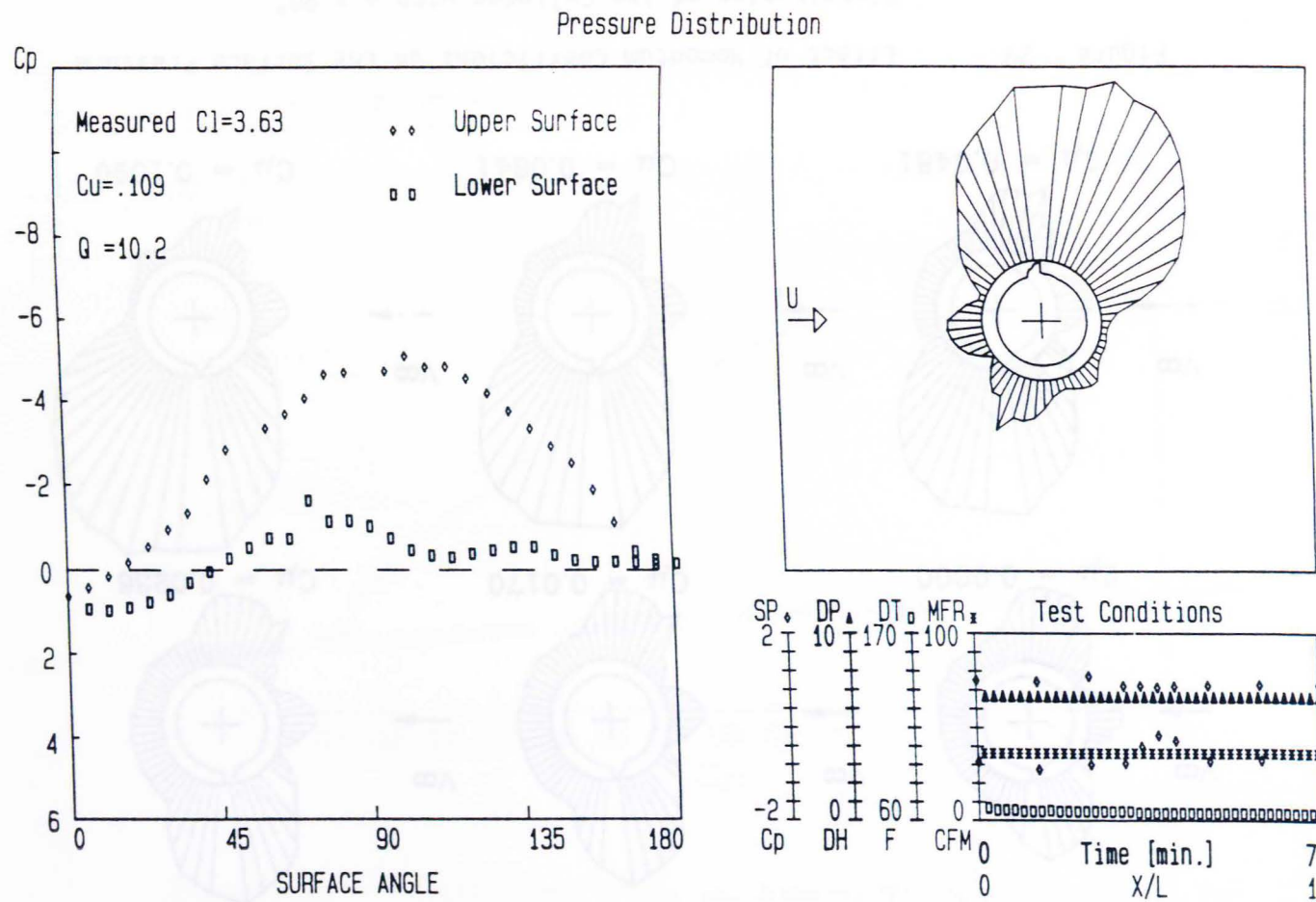


Figure 27 Data Display of Pressure Distribution for the Cylinder with $C_\mu = .0482$ and $\phi = 90^\circ$



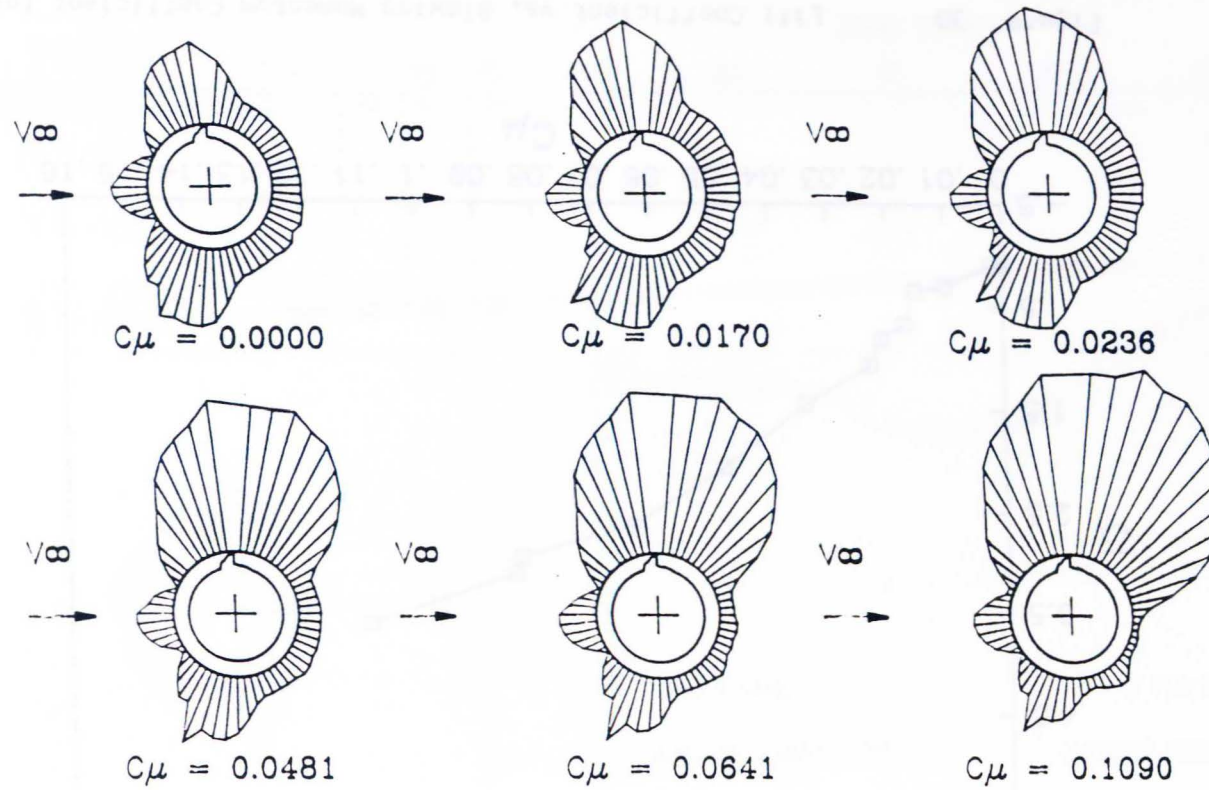


Figure 29 Effect of Momentum Coefficient on the Surface Pressure Distribution of the Cylinder with $\beta = 90^\circ$

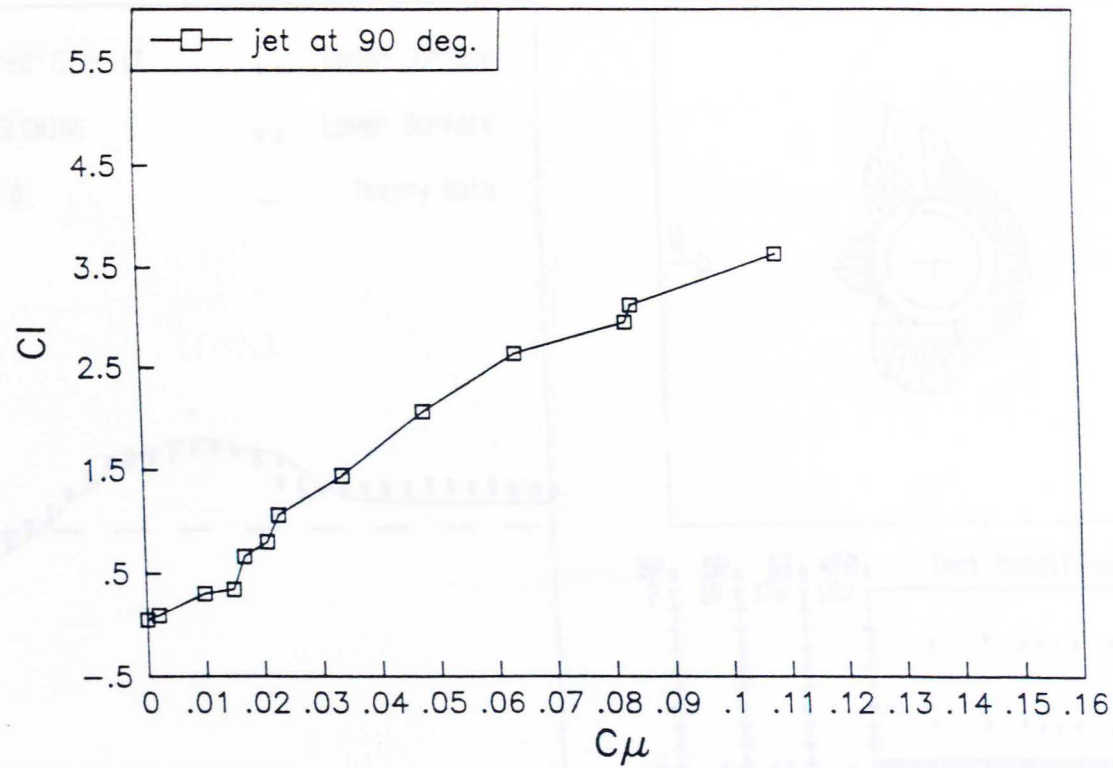


Figure 30 Lift Coefficient vs. Blowing Momentum Coefficient for

Cylinder with $\phi = 90^\circ$

Pressure Distribution

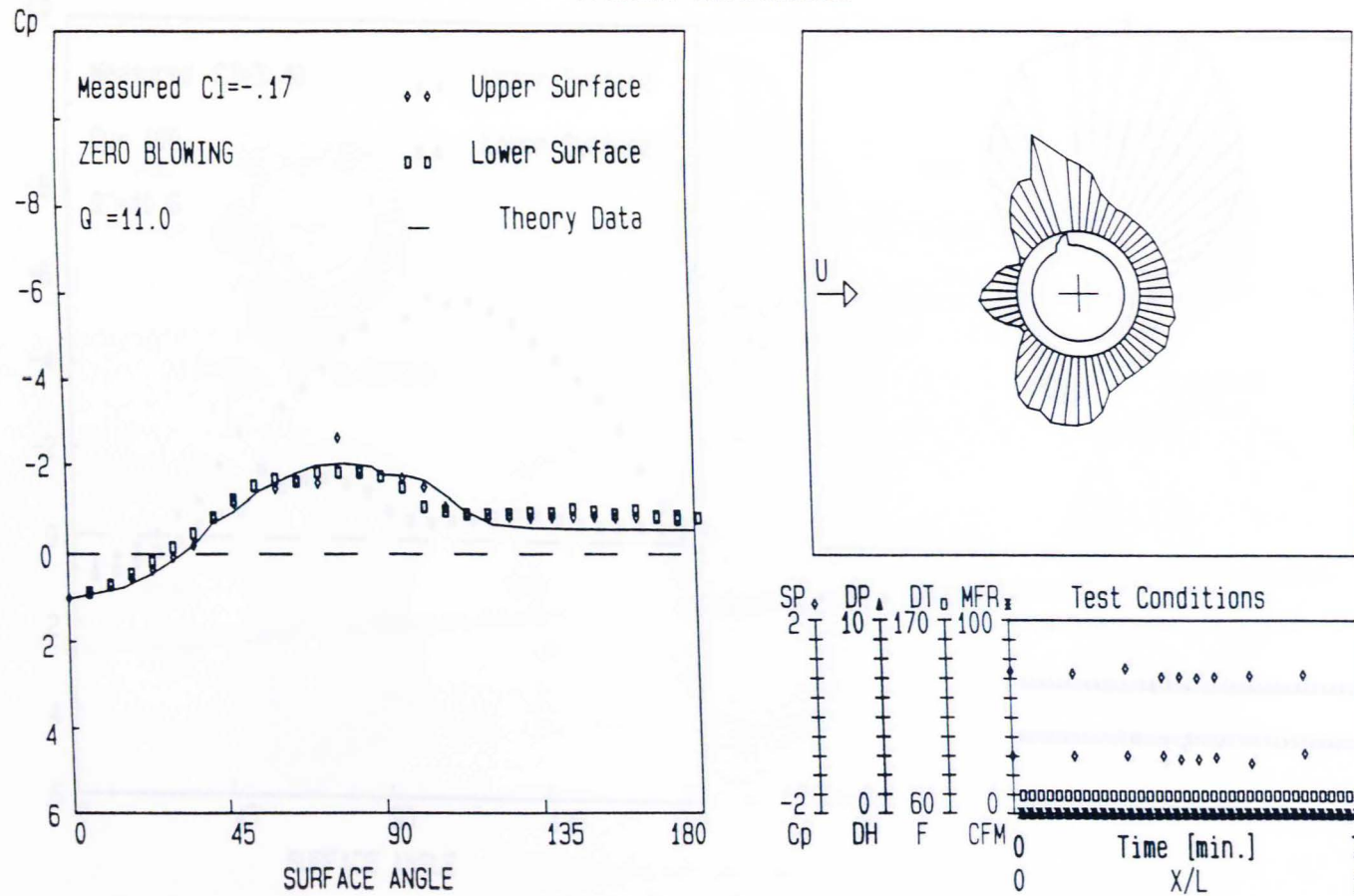


Figure 31 Data Display of Pressure Distribution for the Cylinder with Zero Blowing and $\phi = 80^\circ$

Pressure Distribution

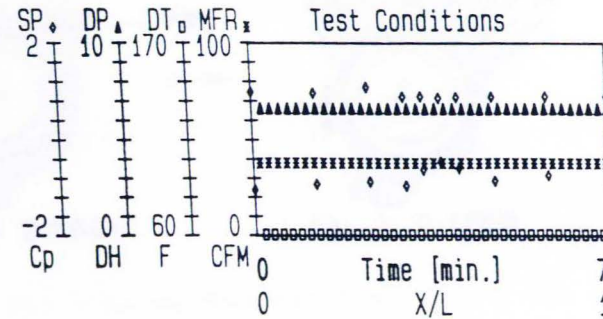
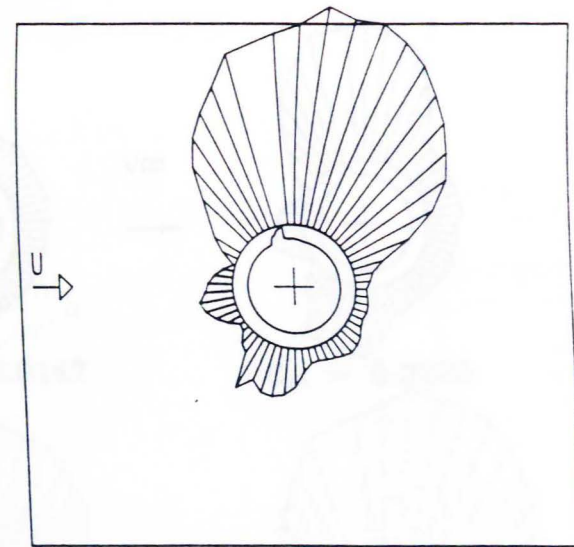
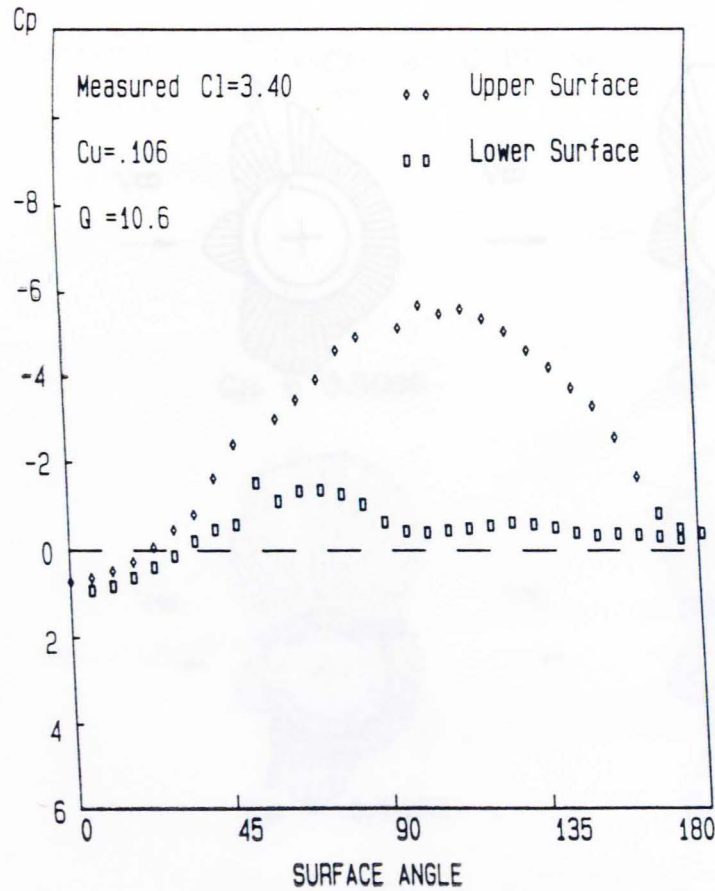


Figure 32 Data Display of Pressure Distribution for the Cylinder with $C_u = .106$ and $\phi = 80^\circ$

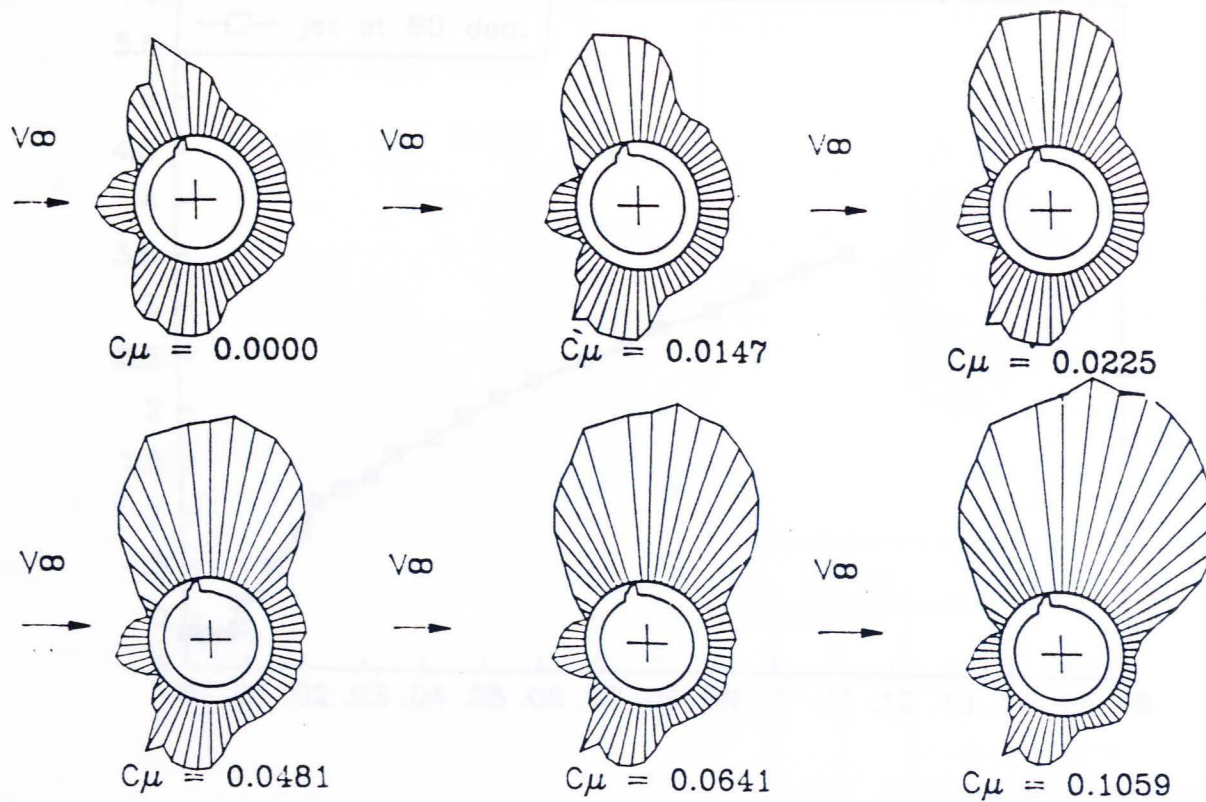


Figure 33

Effect of Momentum Coefficient on the Surface Pressure
Distribution of the Cylinder with $\phi = 80^\circ$

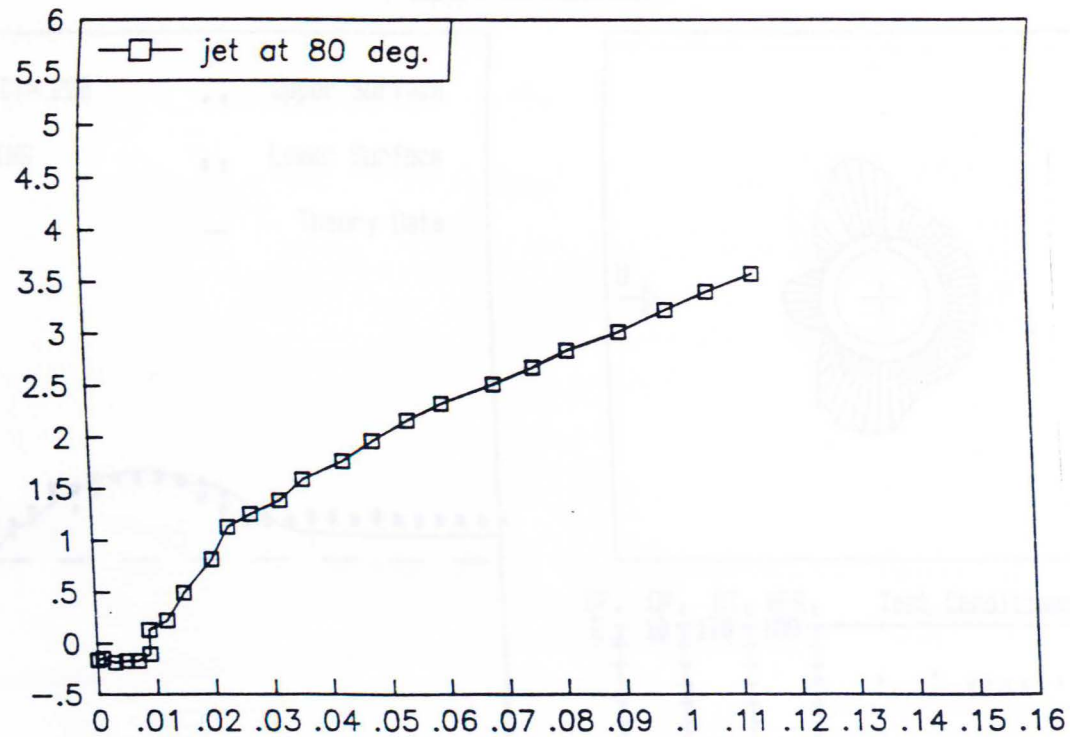


Figure 34 Lift Coefficient vs. Blowing Momentum Coefficient for
Cylinder with $\phi = 80^\circ$

Pressure Distribution

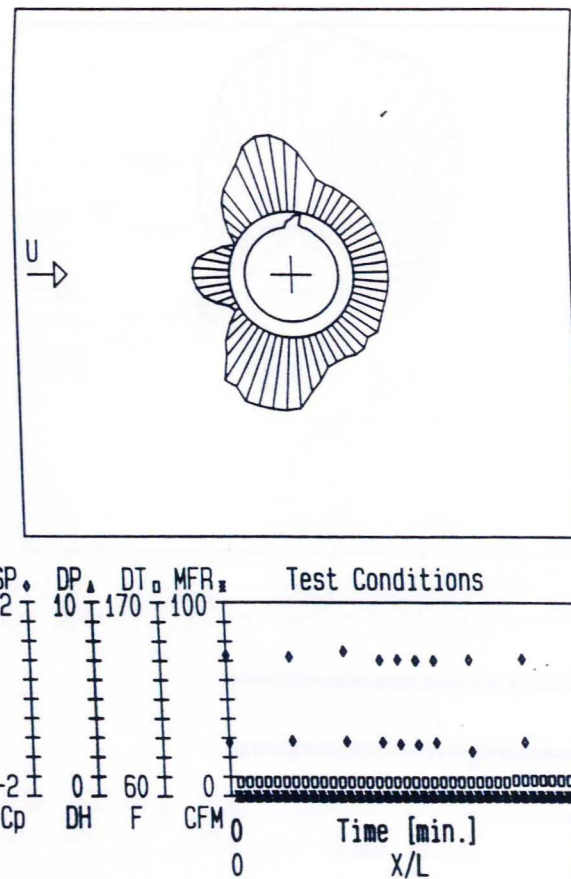
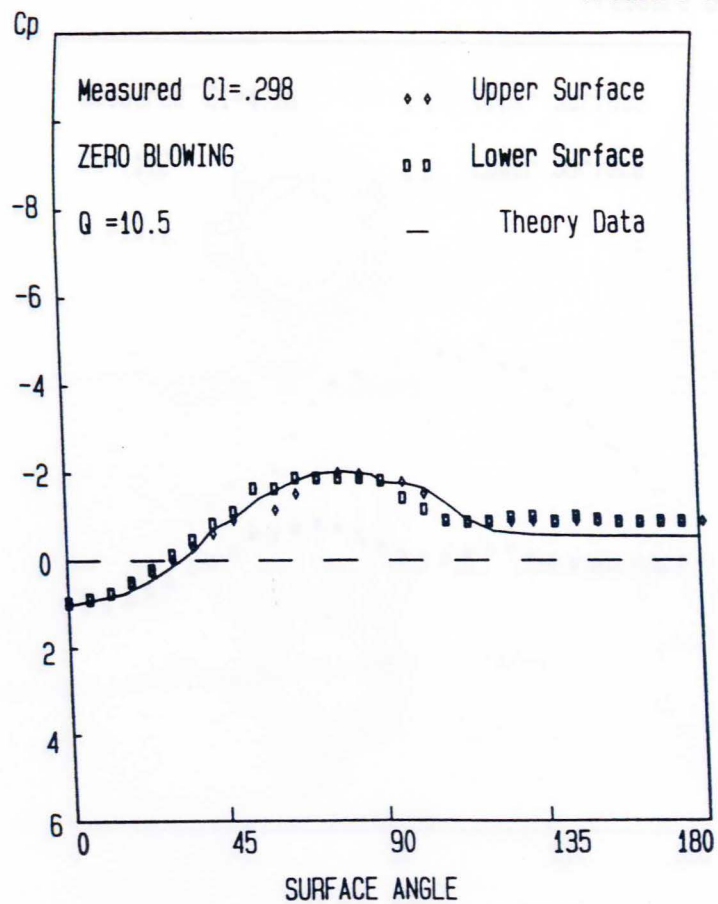


Figure 35

Data Display of Pressure Distribution for the Cylinder with
Zero Blowing and $\phi = 100^\circ$

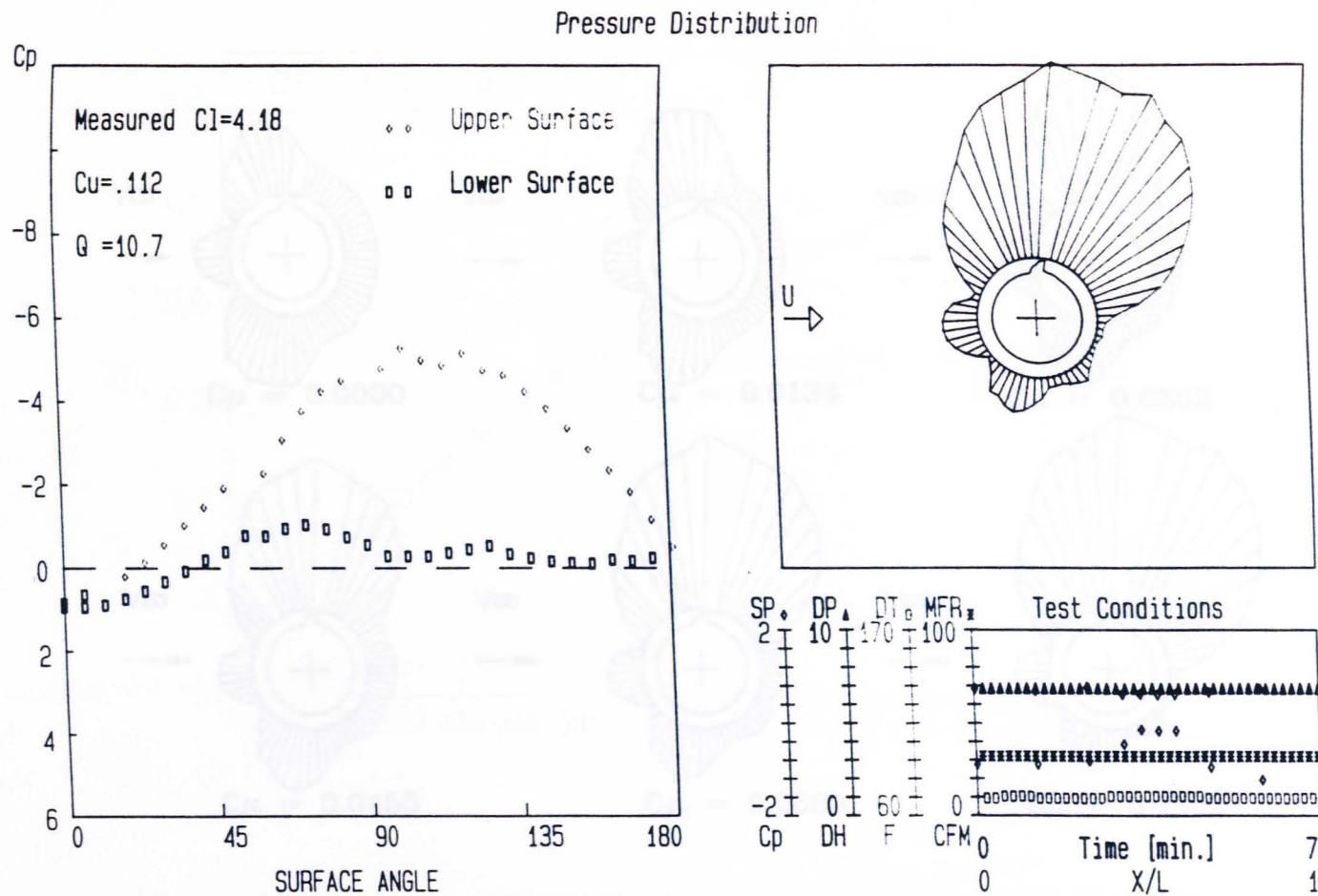


Figure 36 Data Display of Pressure Distribution for the Cylinder with $C_u = .112$ and $\phi = 100^\circ$

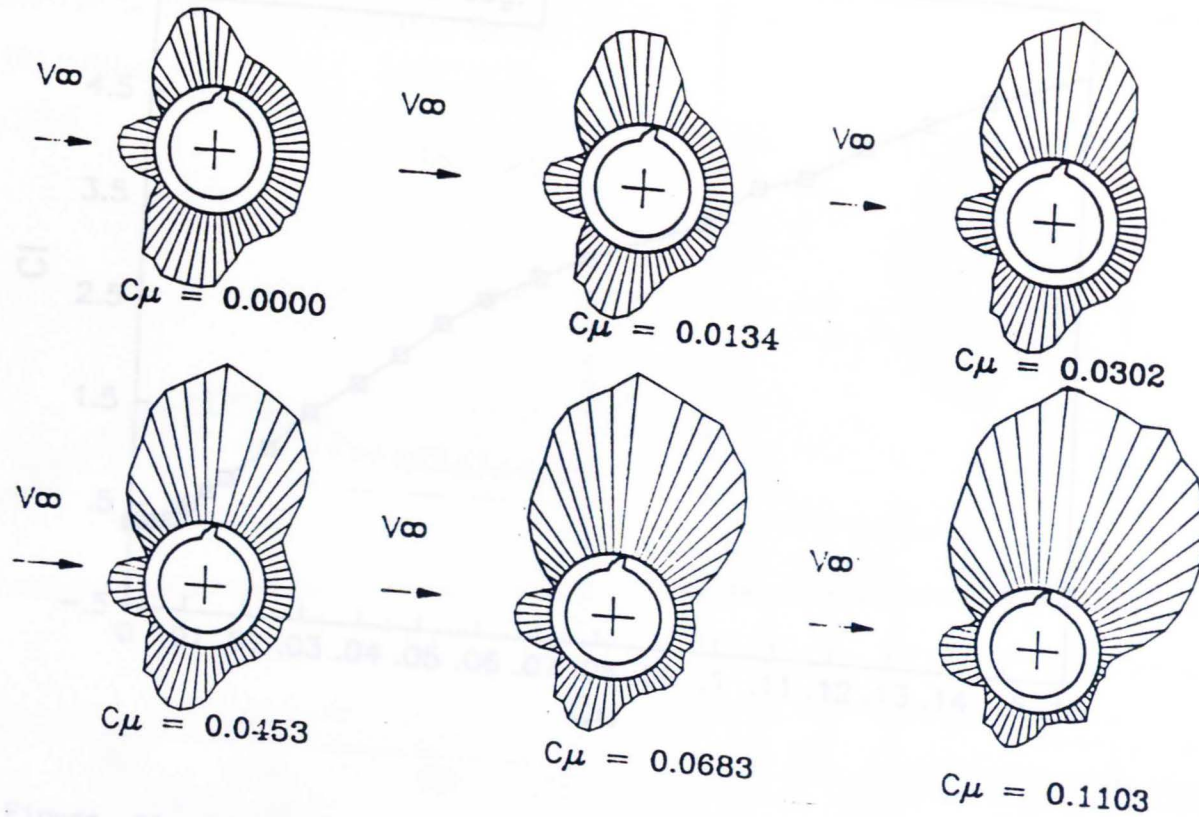


Figure 37

Effect of Momentum Coefficient on the Surface Pressure
Distribution of the Cylinder with $\phi = 100^\circ$

Cylinder with $\phi = 100^\circ$

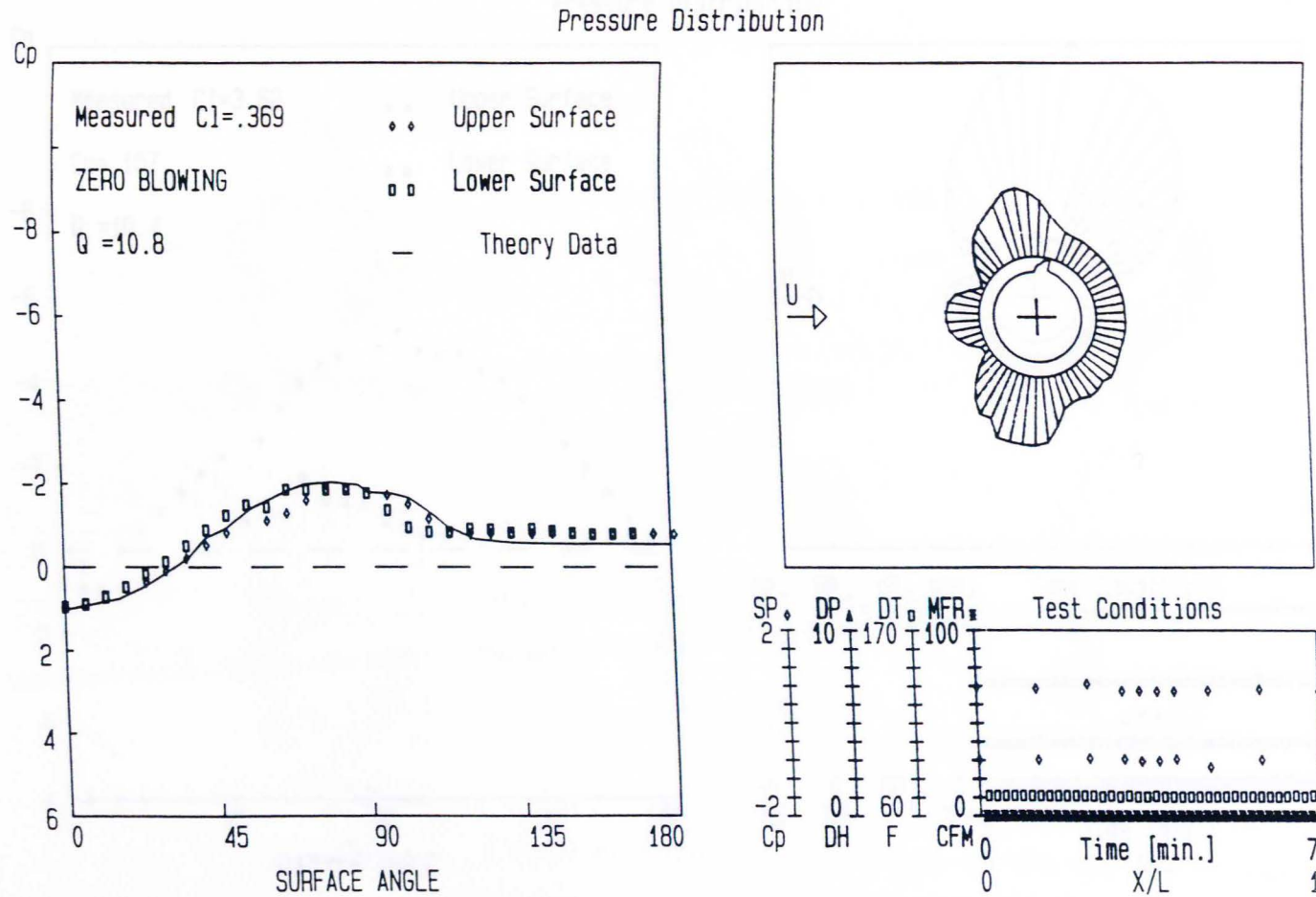


Figure 39 Data Display of Pressure Distribution for the Cylinder with Zero Blowing and $\phi = 105^\circ$

Pressure Distribution

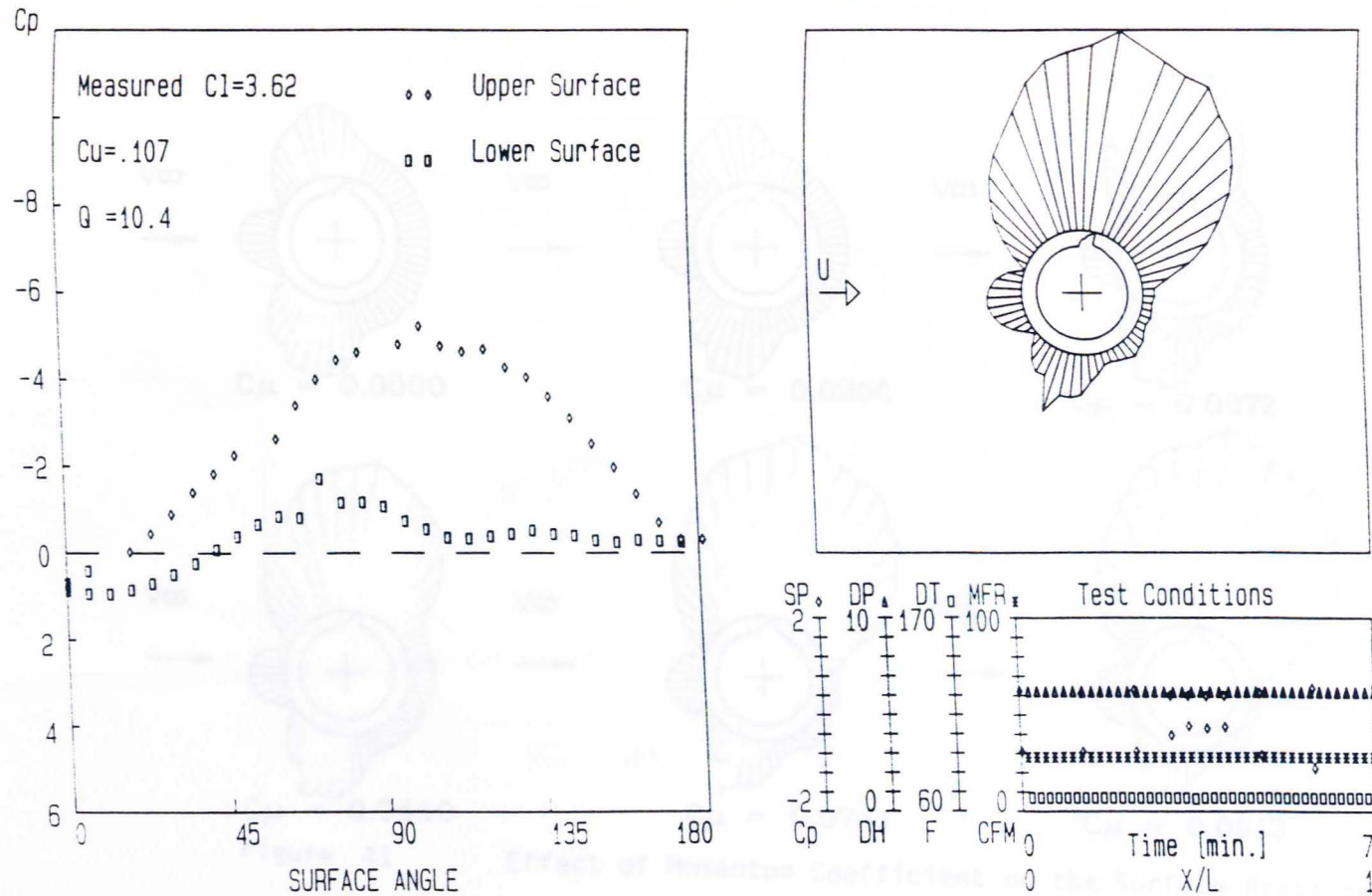


Figure 40

Data Display of Pressure Distribution for the Cylinder with $C_{\mu} = .107$ and $\phi = 105^\circ$

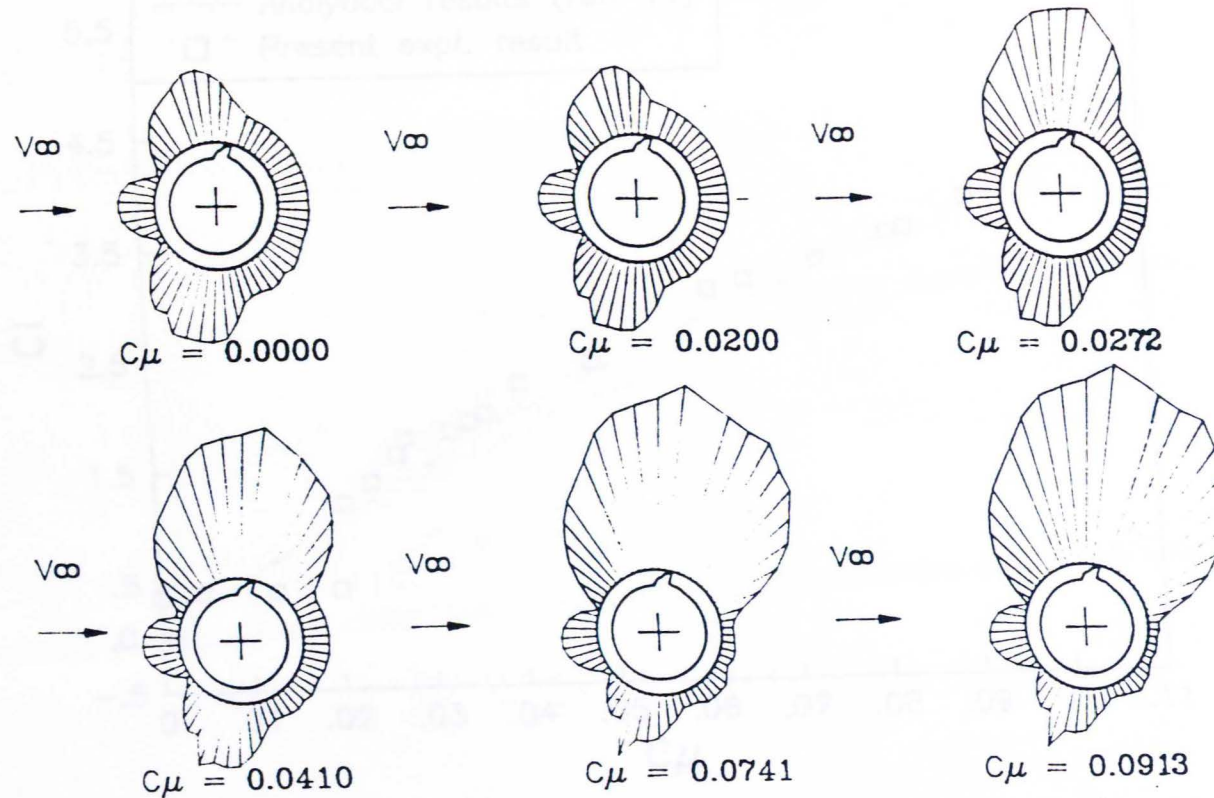


Figure 41

Effect of Momentum Coefficient on the Surface Pressure
Distribution of the Cylinder with $\phi = 105^\circ$

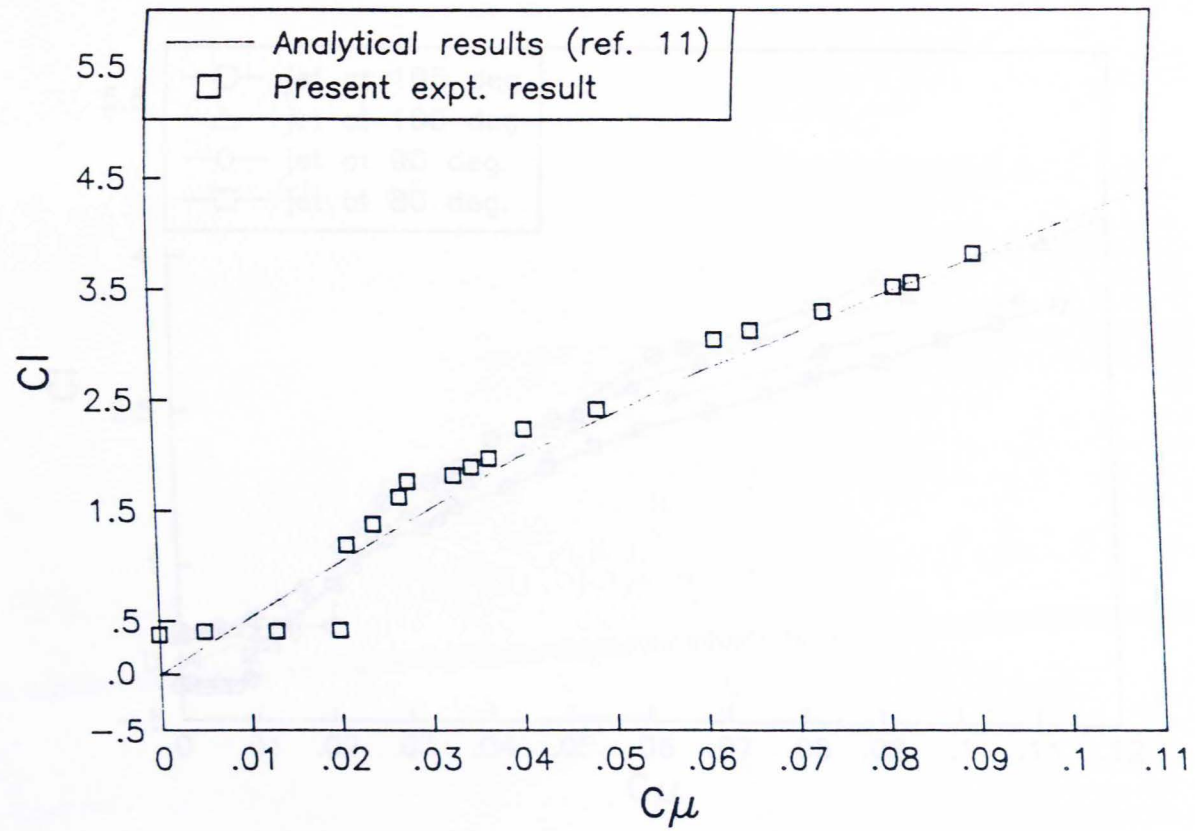


Figure 42 Lift Coefficient vs. Blowing Momentum Coefficient for
Cylinder with $\phi = 105^\circ$

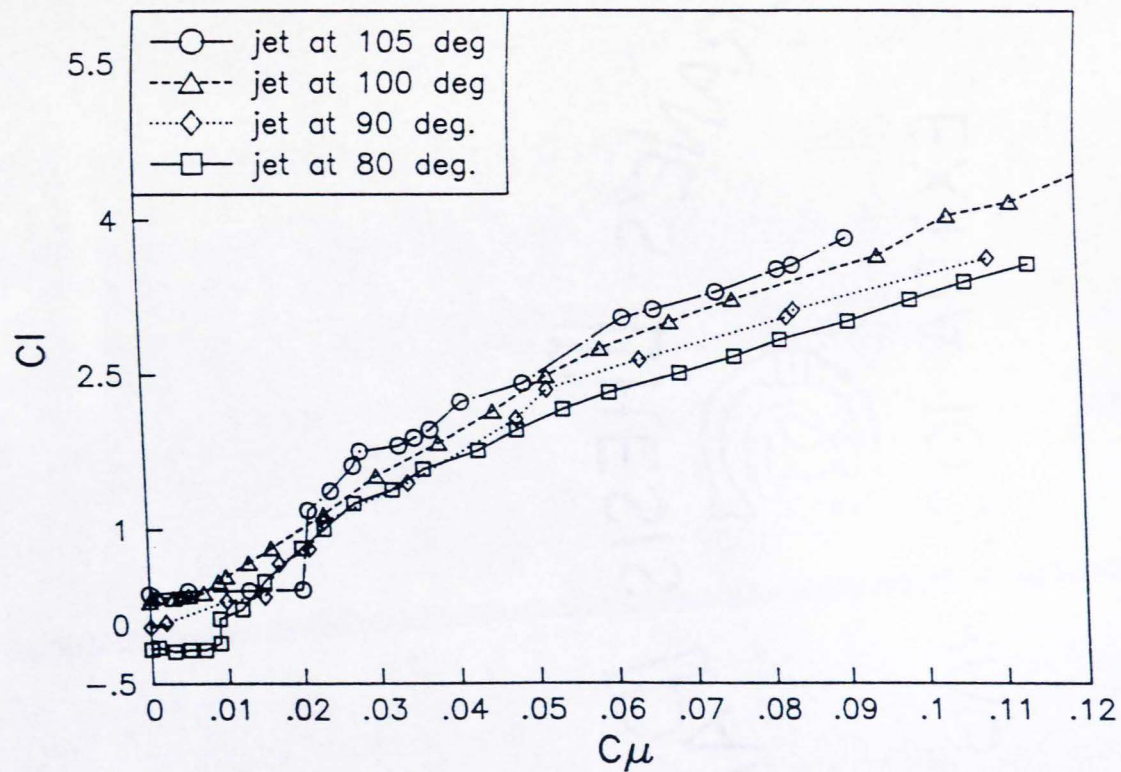


Figure 43 Lift Coefficient vs. Moment Coefficient and Change of Angular Slot Position

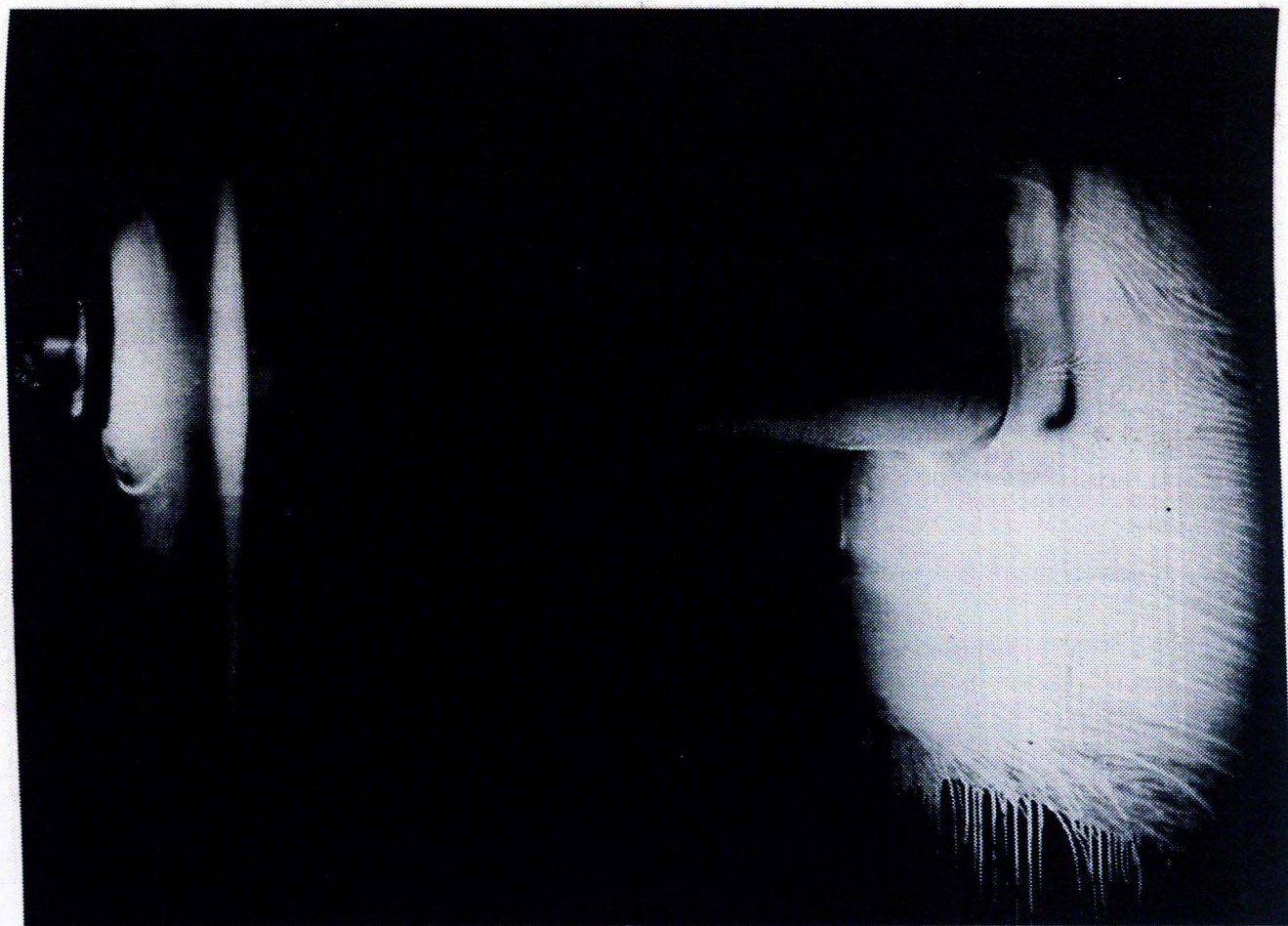


Figure 44 Oil Flow Patterns on the Surface of the Circulation
Control Cylinder for $C_\mu = 0.0$

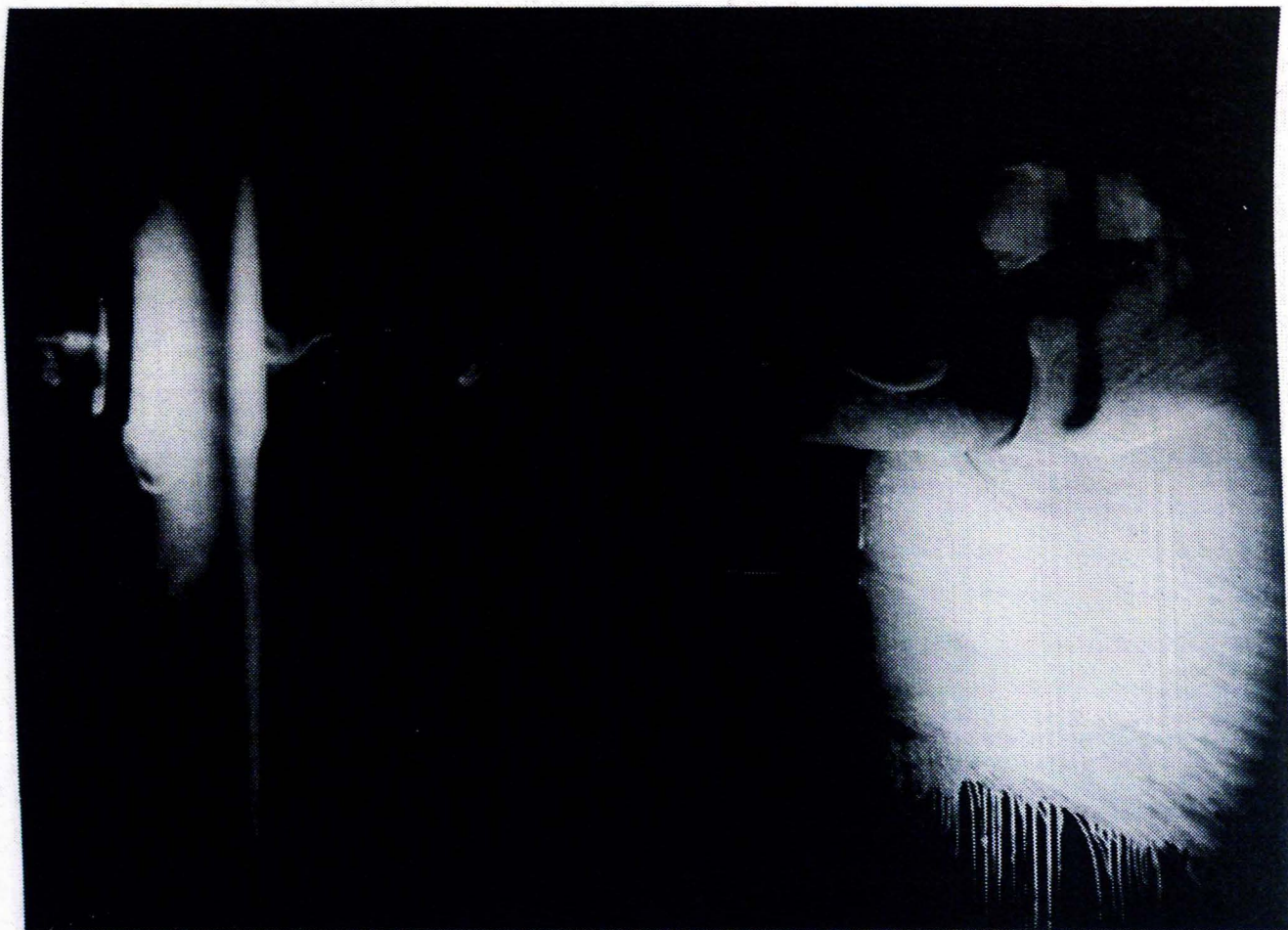


Figure 45 Oil Flow Patterns on the Surface of the Circulation
Control Cylinder for $C_\mu = 0.135$

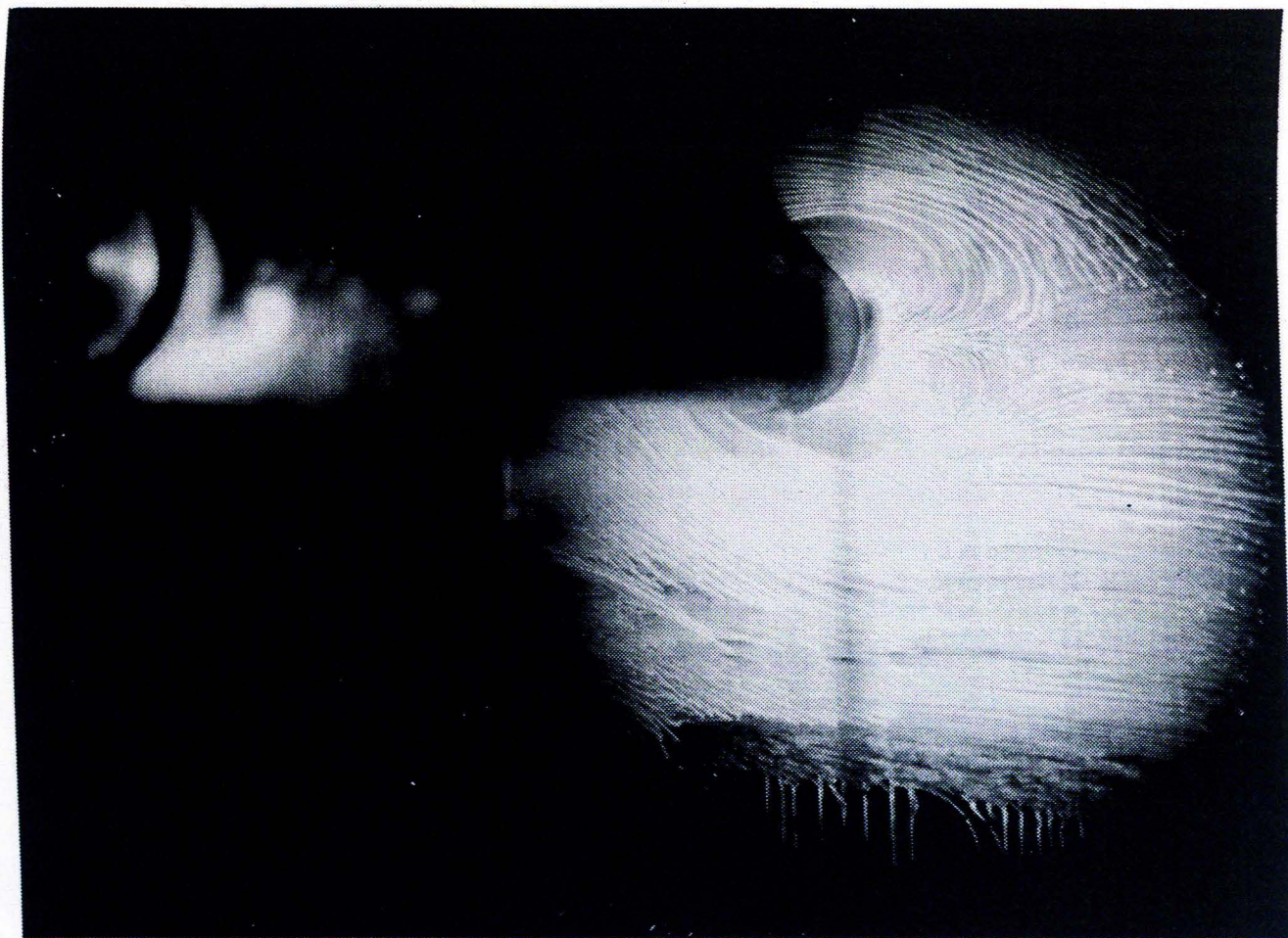


Figure 46 Oil Flow Patterns on the End Plate of the Circulation Control Cylinder with $C_u = 0.0$



Figure 47 Oil Flow Patterns on the End Plate of the Circulation
Control Cylinder with $C_{\mu} = .09$



Figure 48 The Surface Oil Flow of a Wing-Wall Interaction at a High Angle Attack

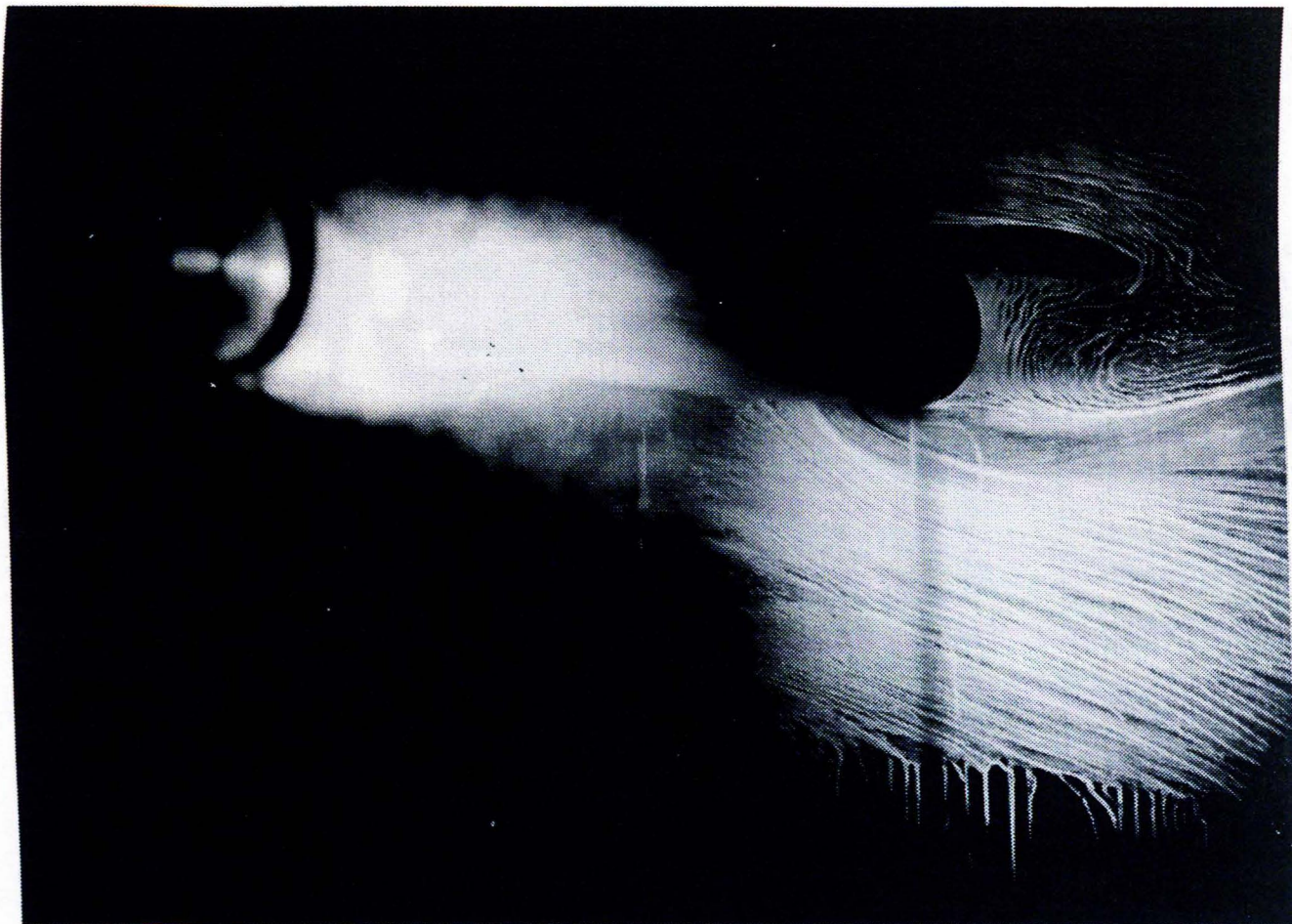


Figure 49 Oil Flow Pattern on the End Plate of the Circulation
Control Cylinder with $C_{\mu} = .135$

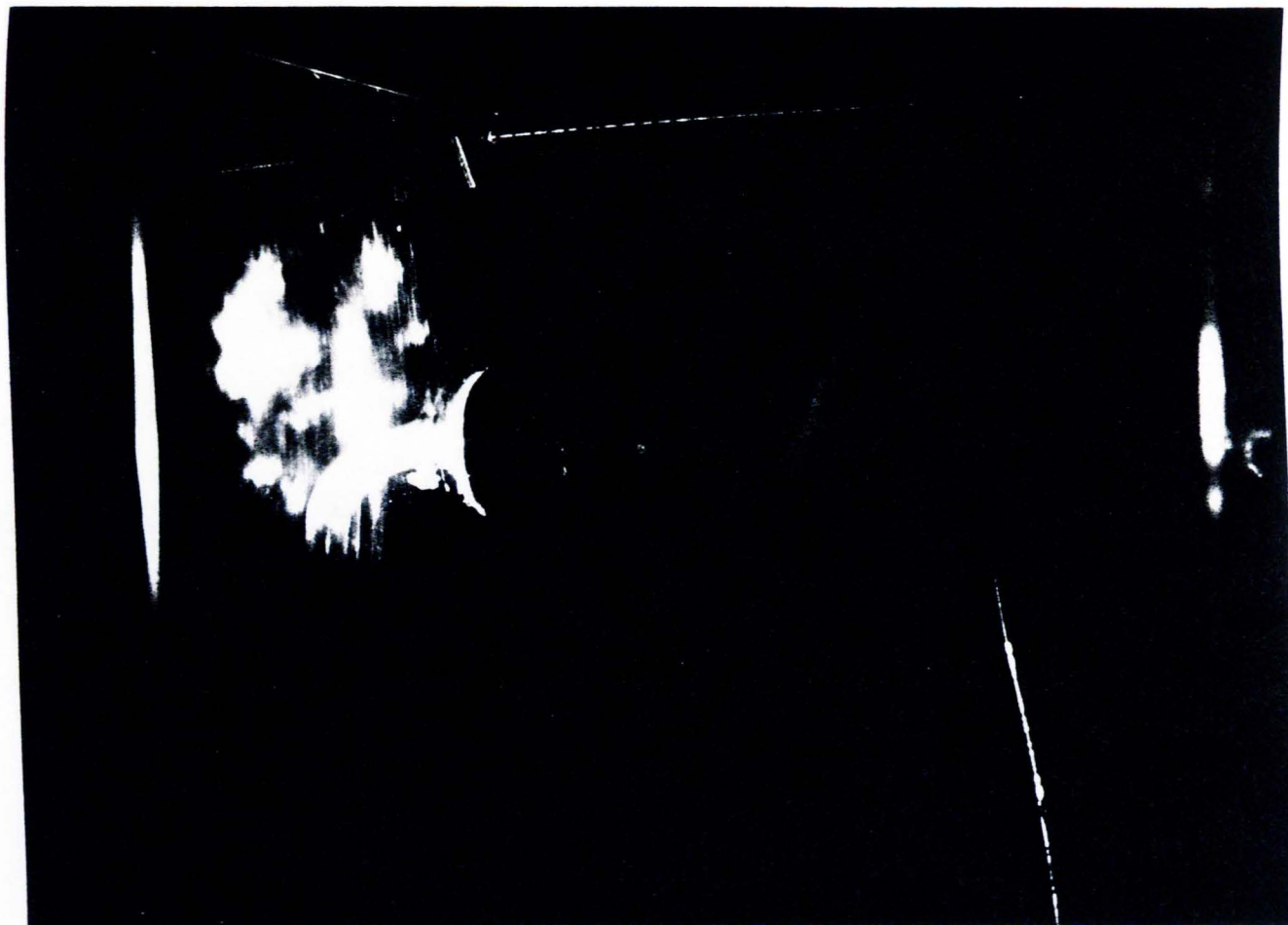


Figure 50A Smoke Flow Study on the Cylinder Model
(injected upstream)

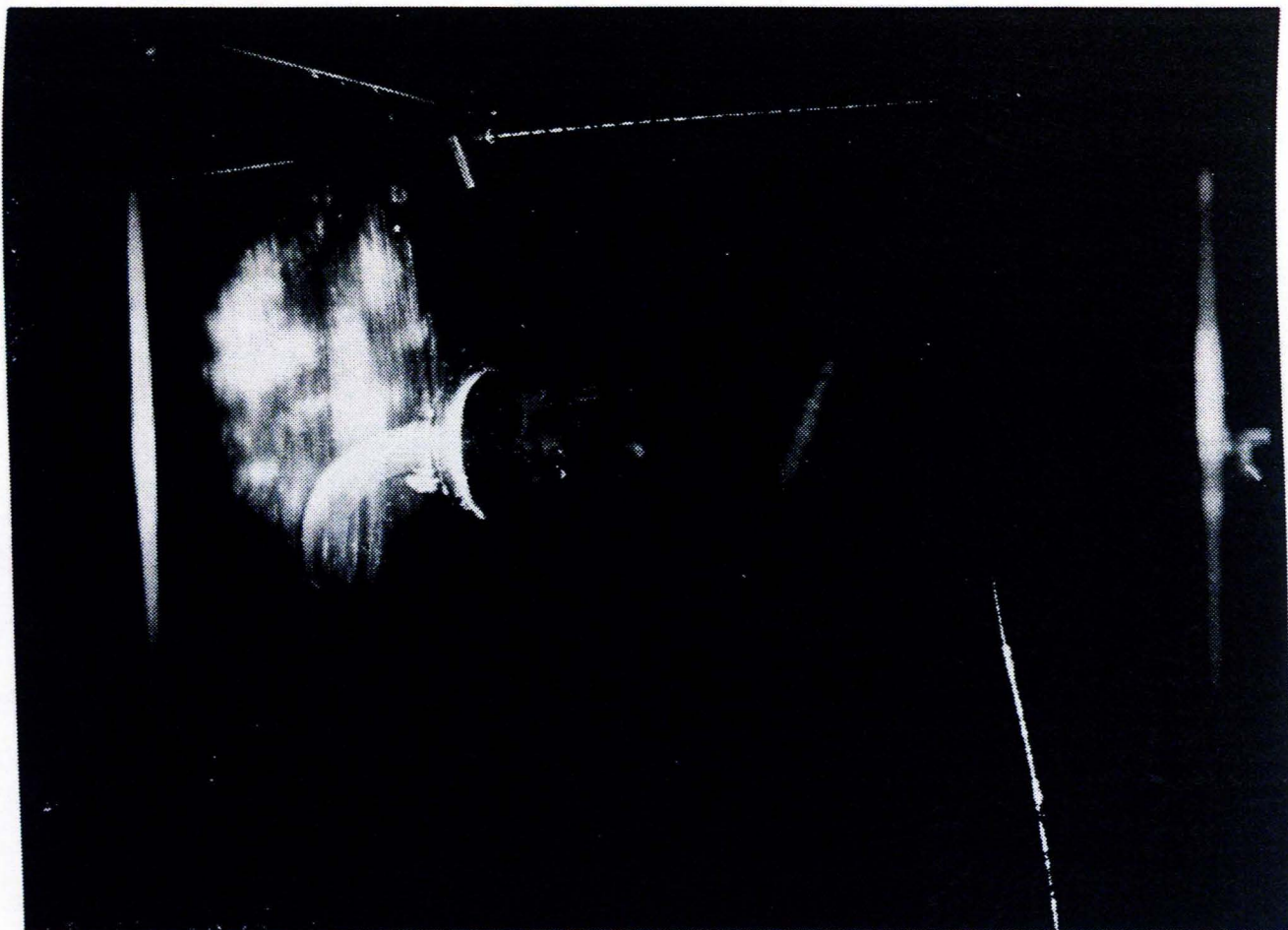


Figure 50 Smoke Flow Study on the Cylinder Model
(injected upstream)

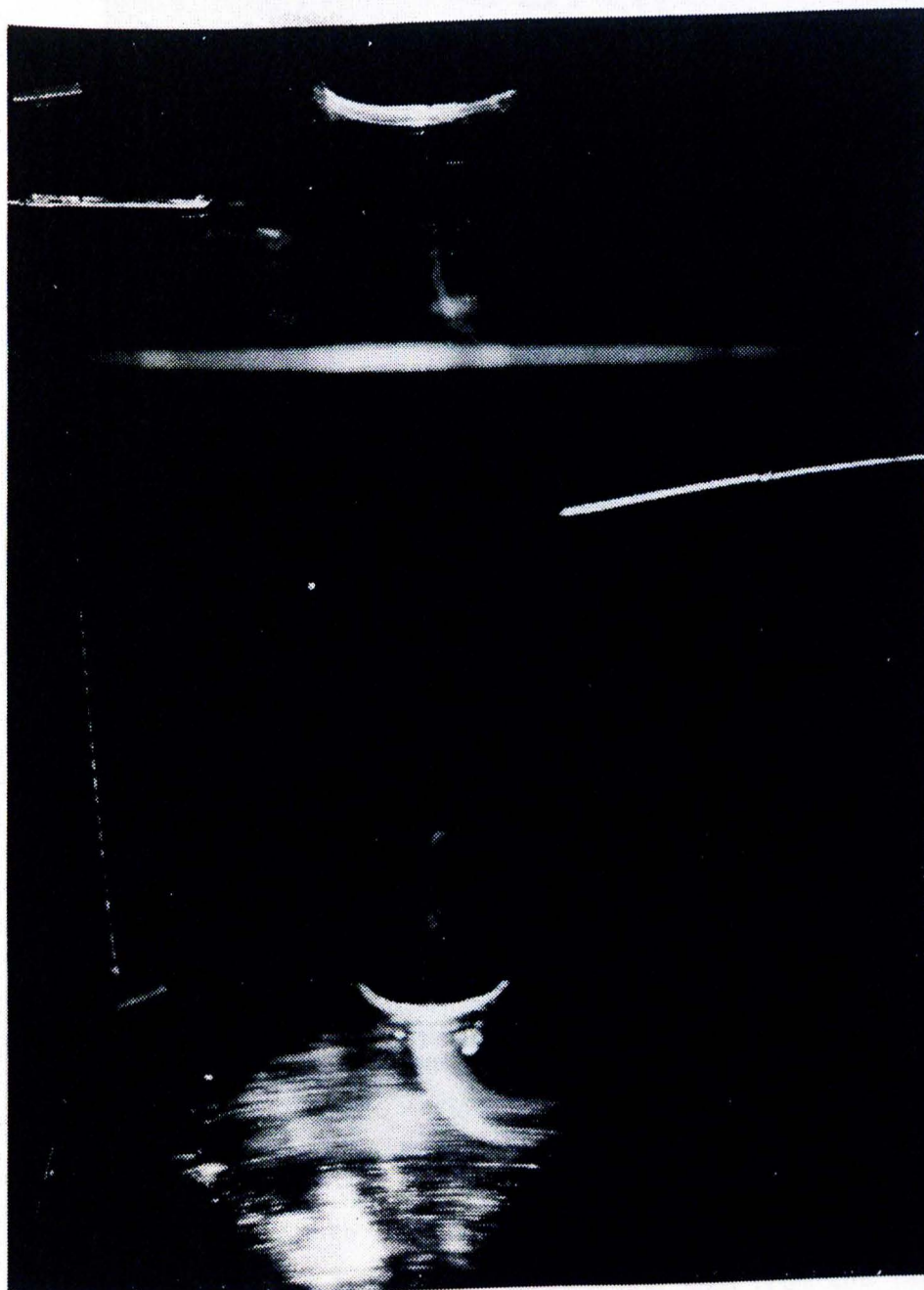


Figure 51 Smoke Flow Studies on the Cylinder Model at High C_u
(injected 1.5 inches above the upper surface)

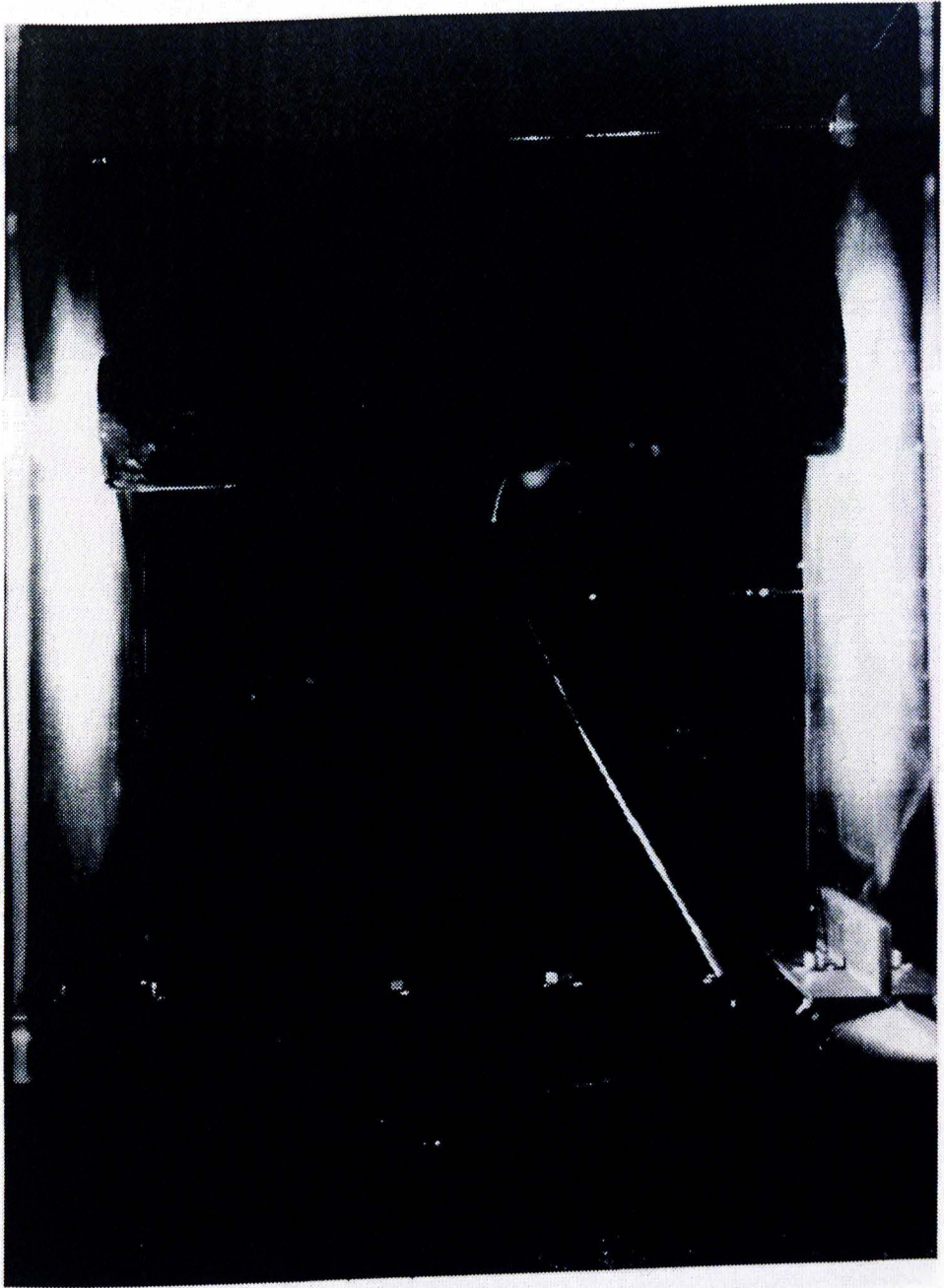


Figure 52 Smoke Flow Study on the Cylinder Model at high C_u
(injected .25 inches upstream from the leading-edge)

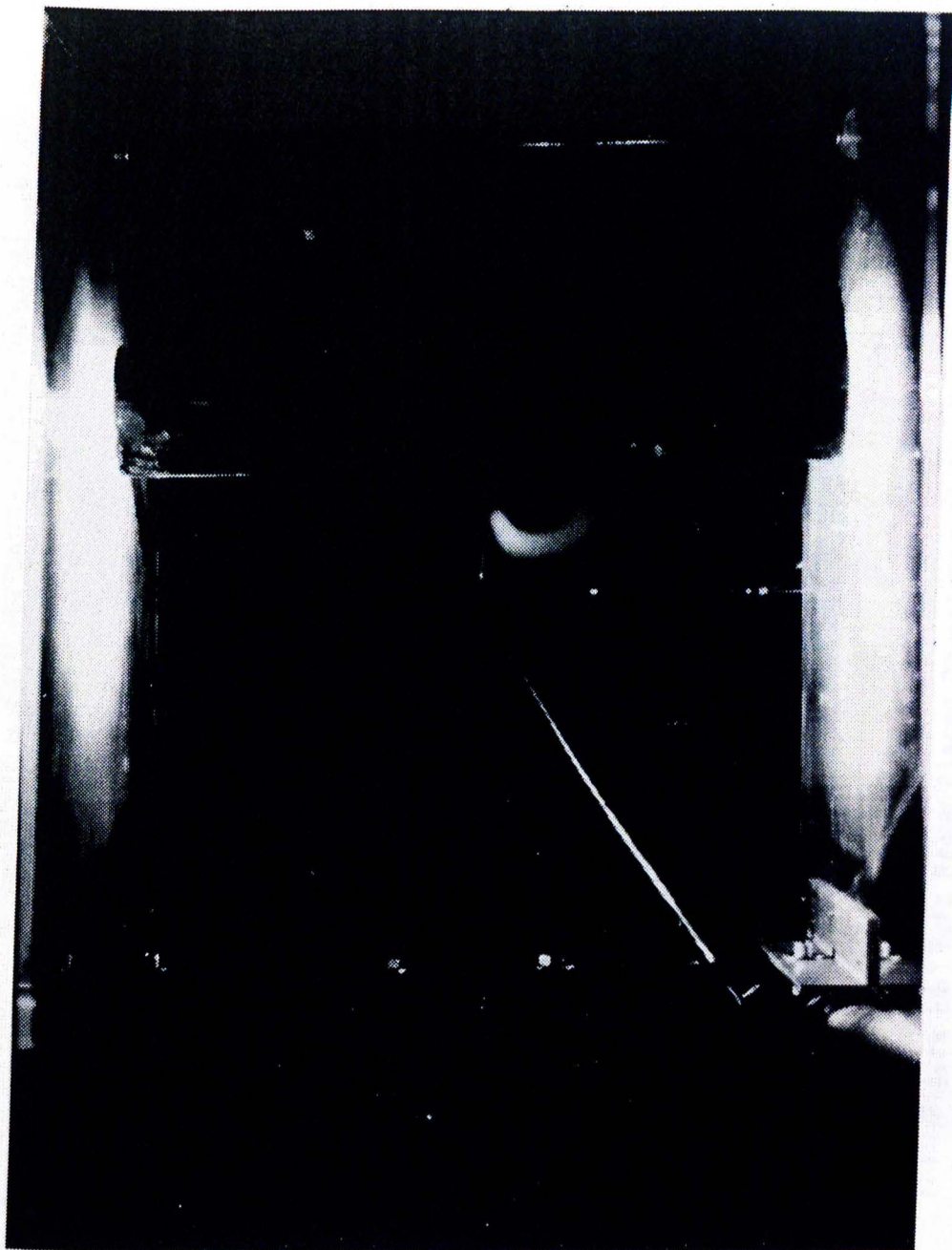


Figure 53 Smoke Flow Study on the Cylinder Model
(injected downstream)



Figure 54 Tuft Probe Placed Downstream of the Mode

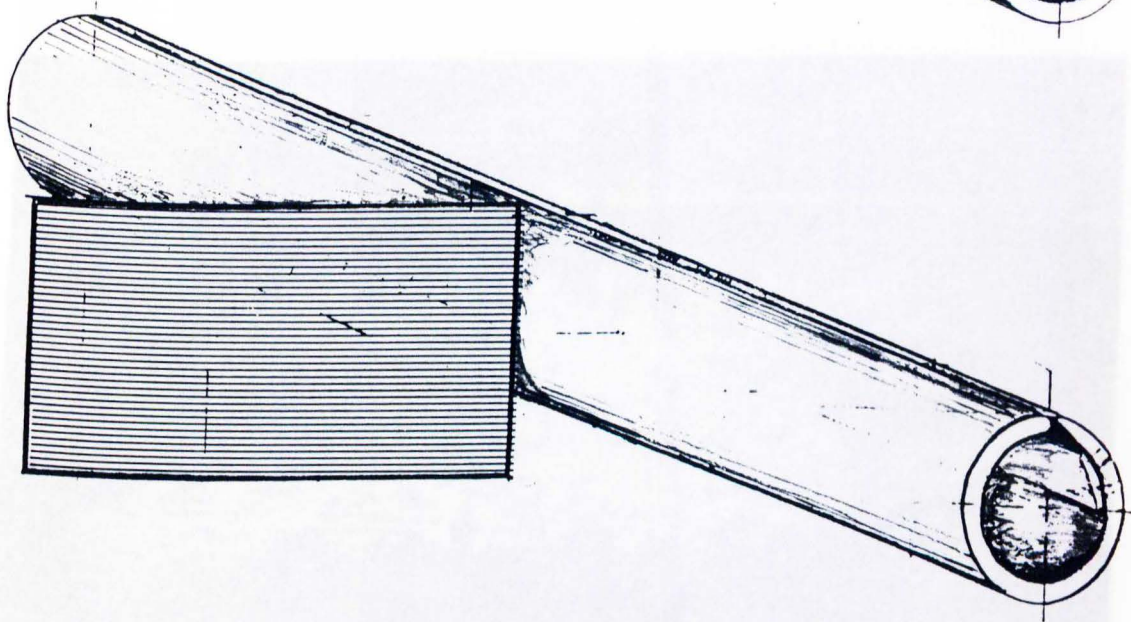
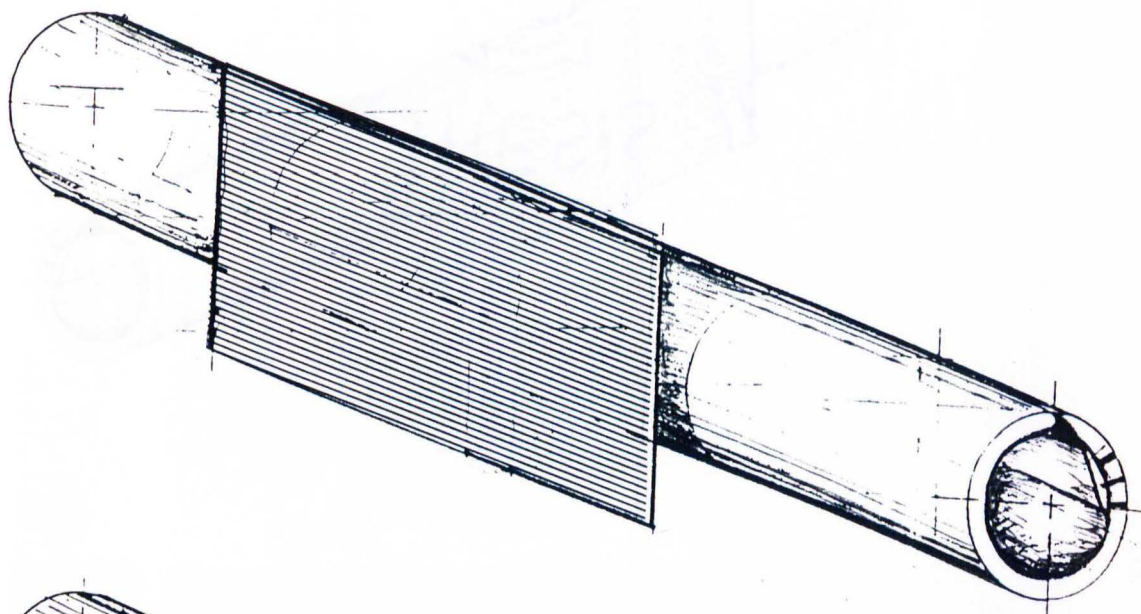


Figure 55 Two Color Video Surrey Planes

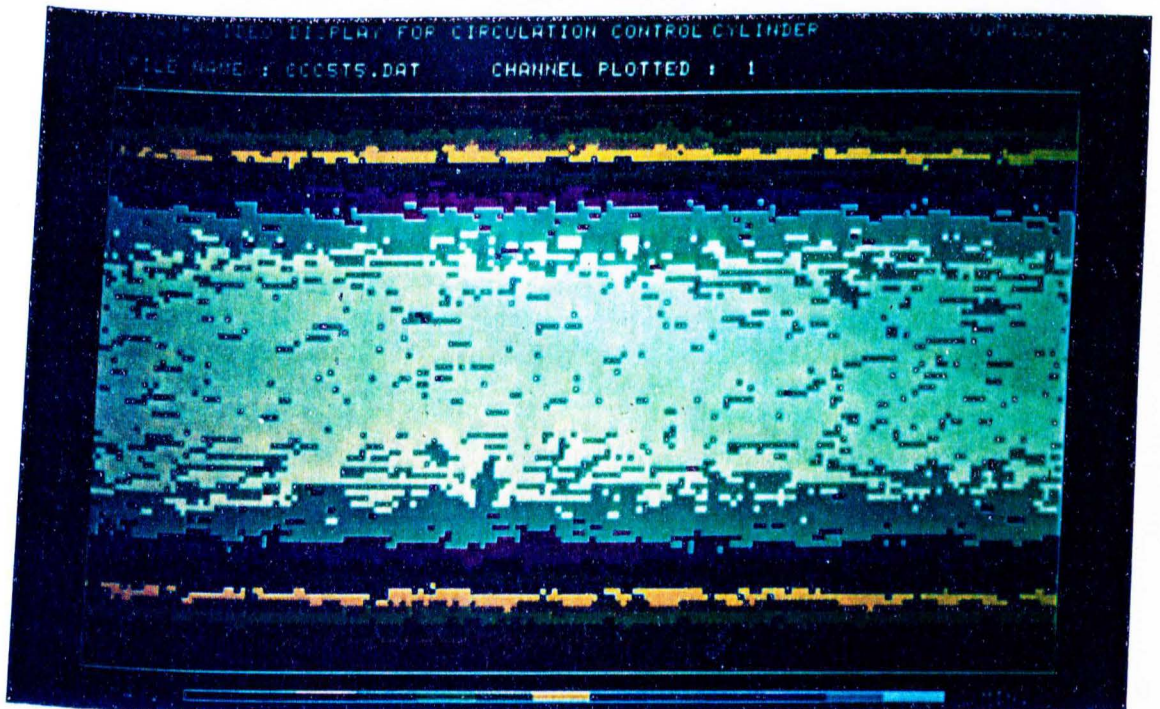
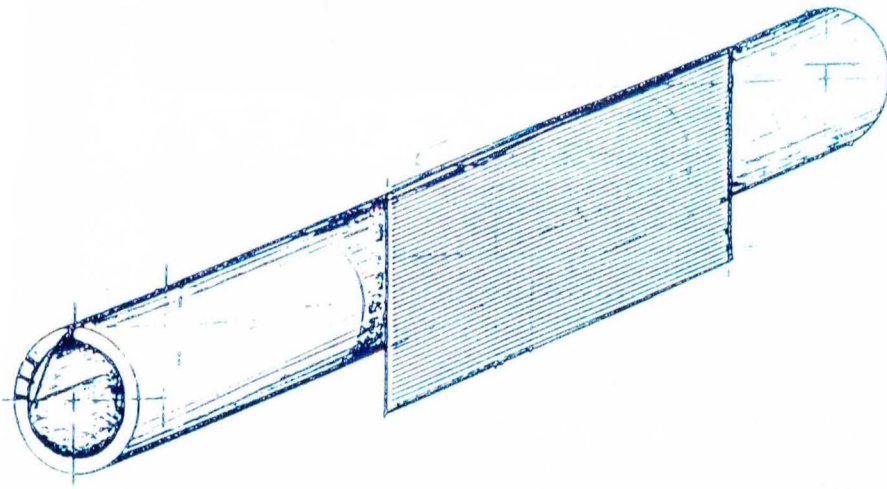


Figure 56(a) Spanwise Color Video Display Flow Field of the Cylinder with Zero Blowing (Total Pressure Probe)

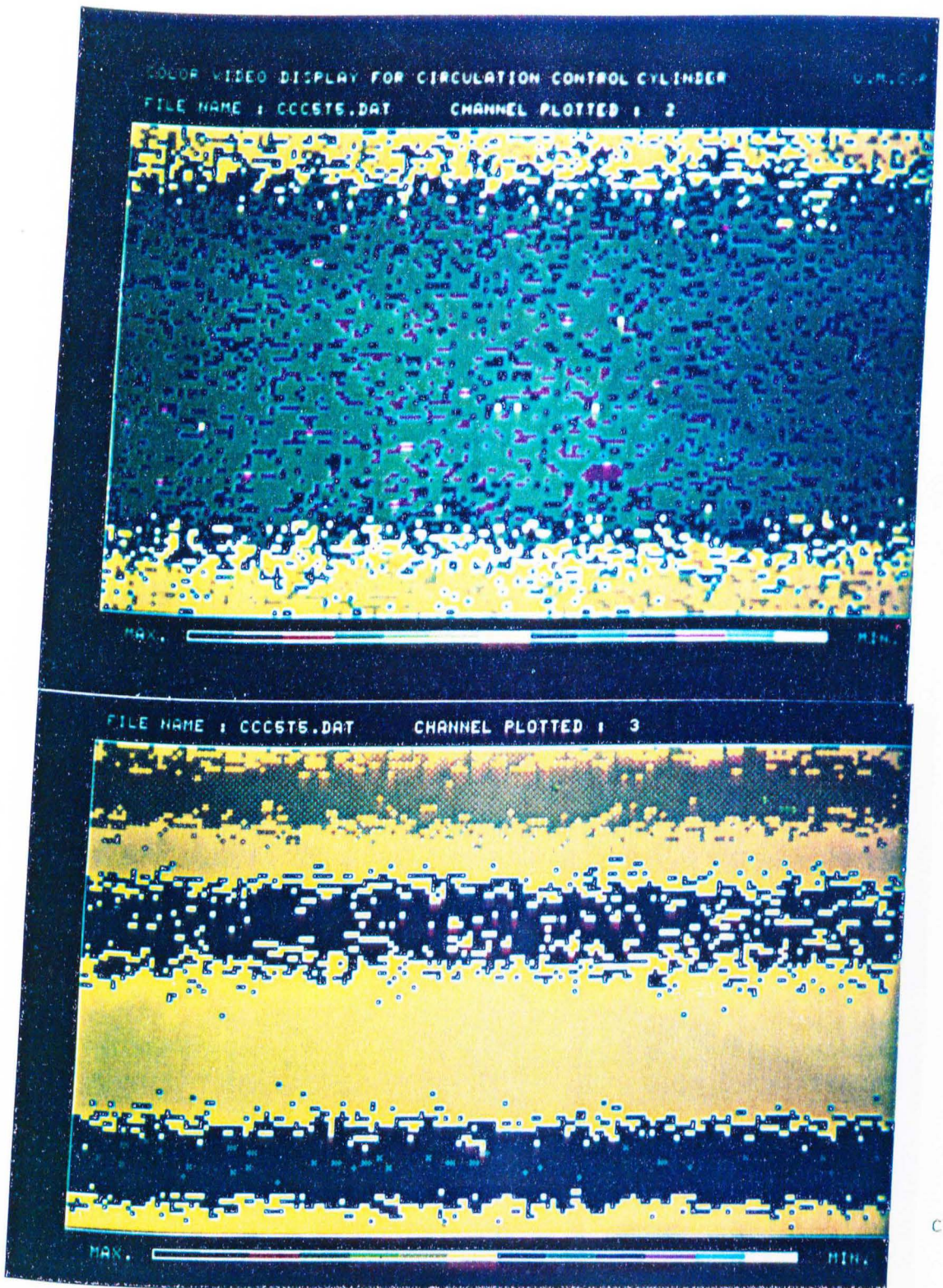


Figure 56(b,c) Spanwise Color Video Display Flow Field of the Cylinder with Zero Blowing (Yaw and Pitch Probes)

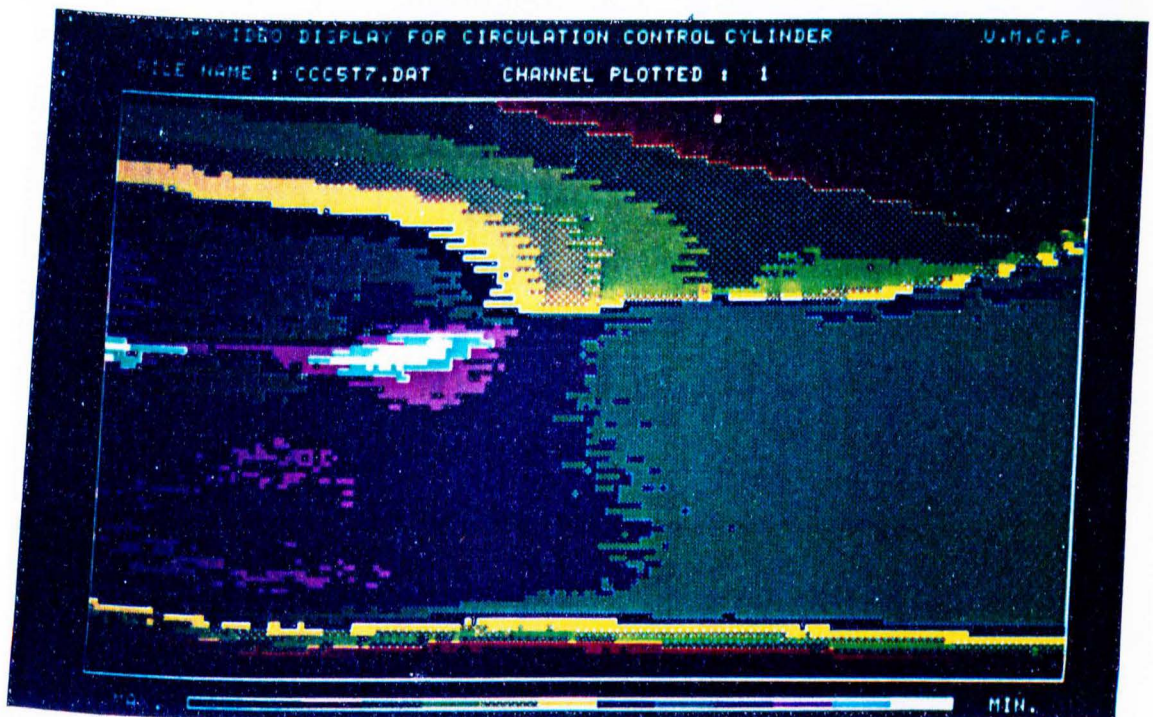
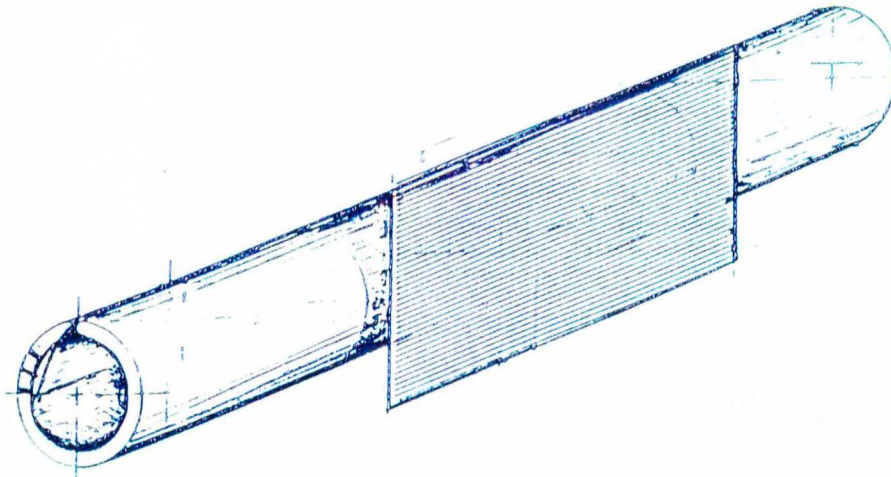


Figure 57(a) Spanwise Color Video Display of Flow Field of the Cylinder with $C_{\mu} = .105$ (Total Pressure Probe)

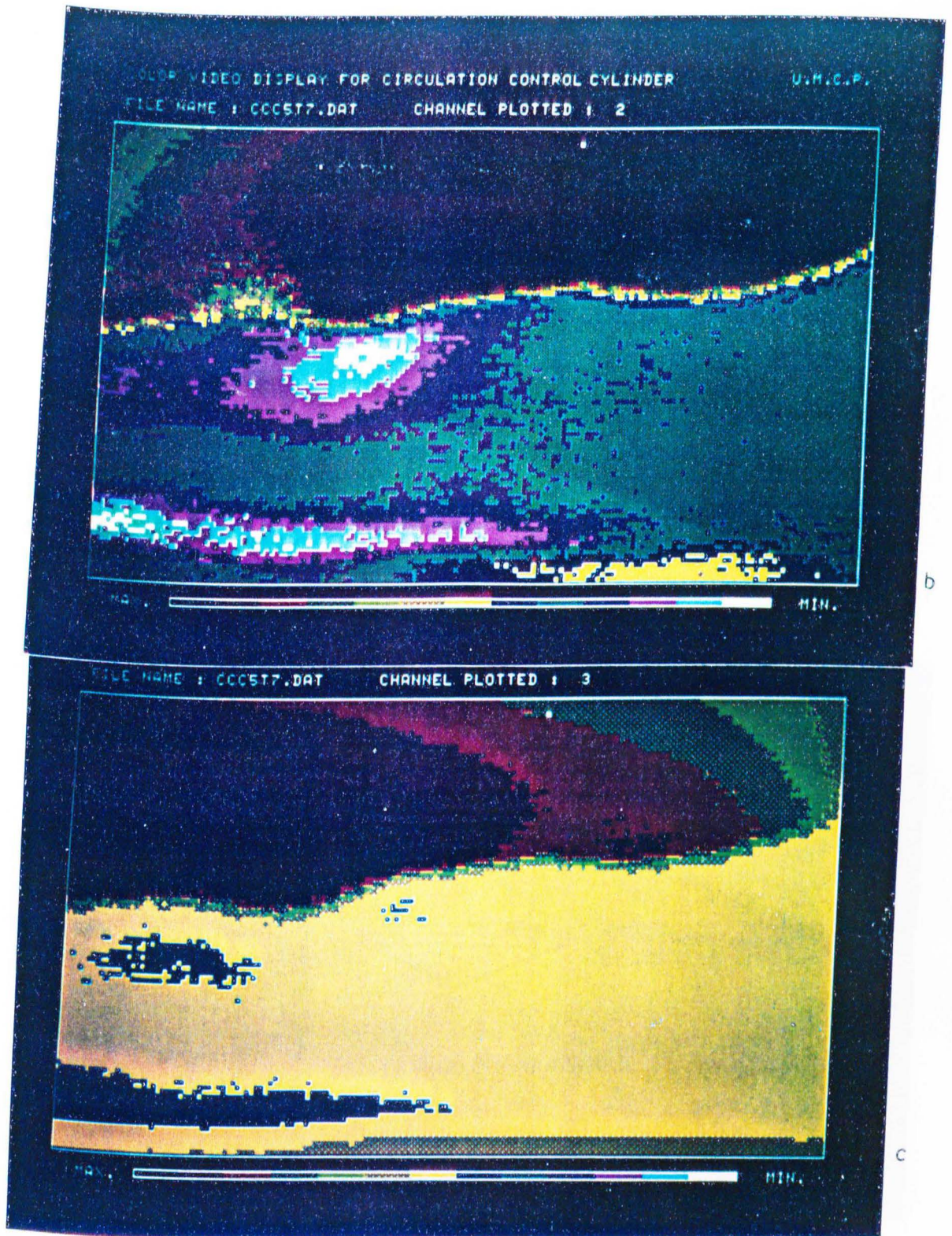


Figure 57(b,c) Spanwise Color Video Display of Flow Field of the Cylinder with $C_u = .105$ (Yaw and Pitch Probes)

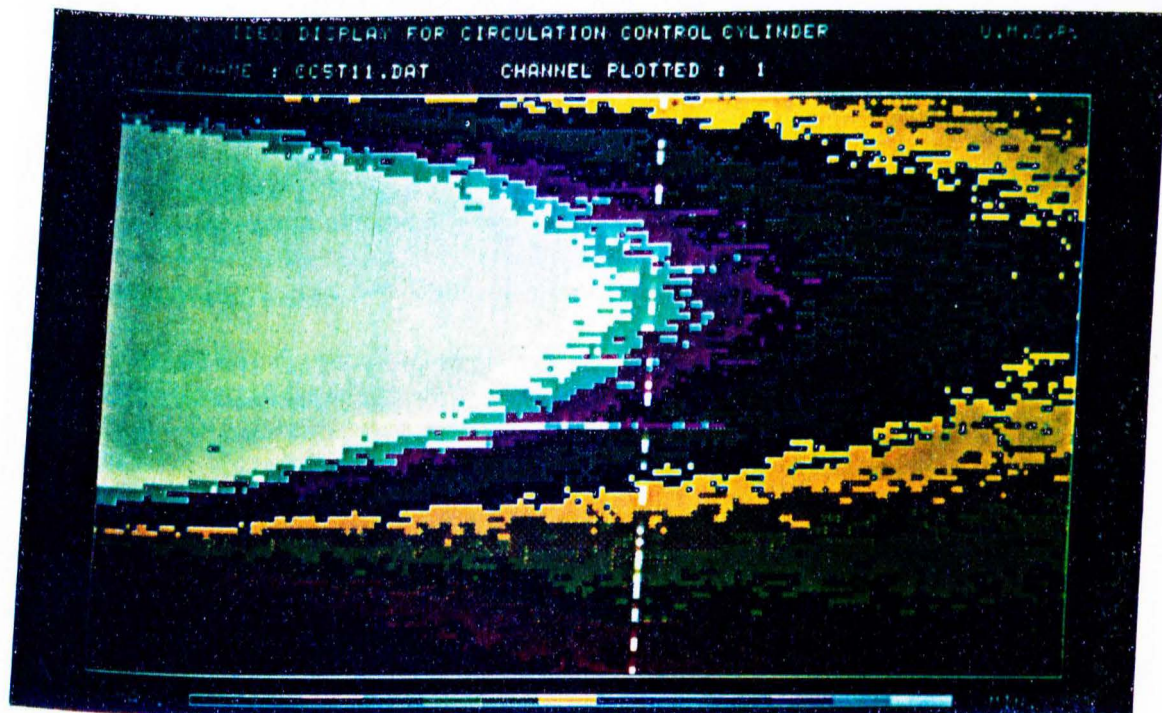
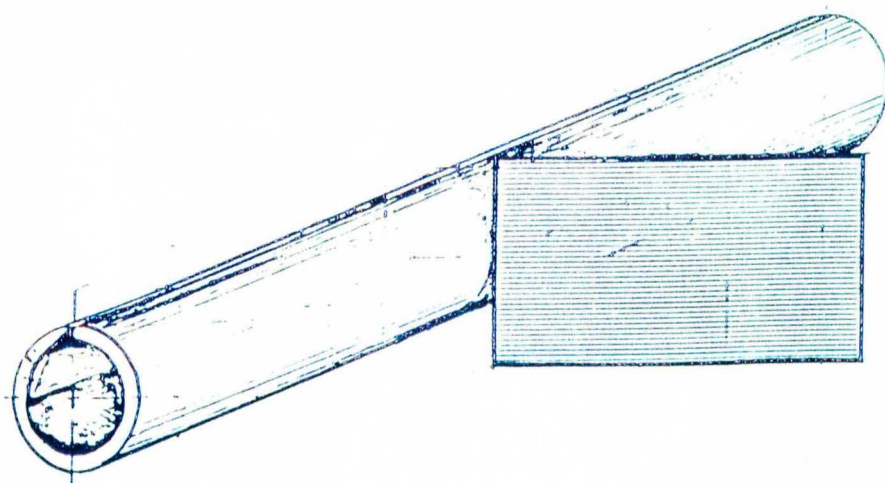
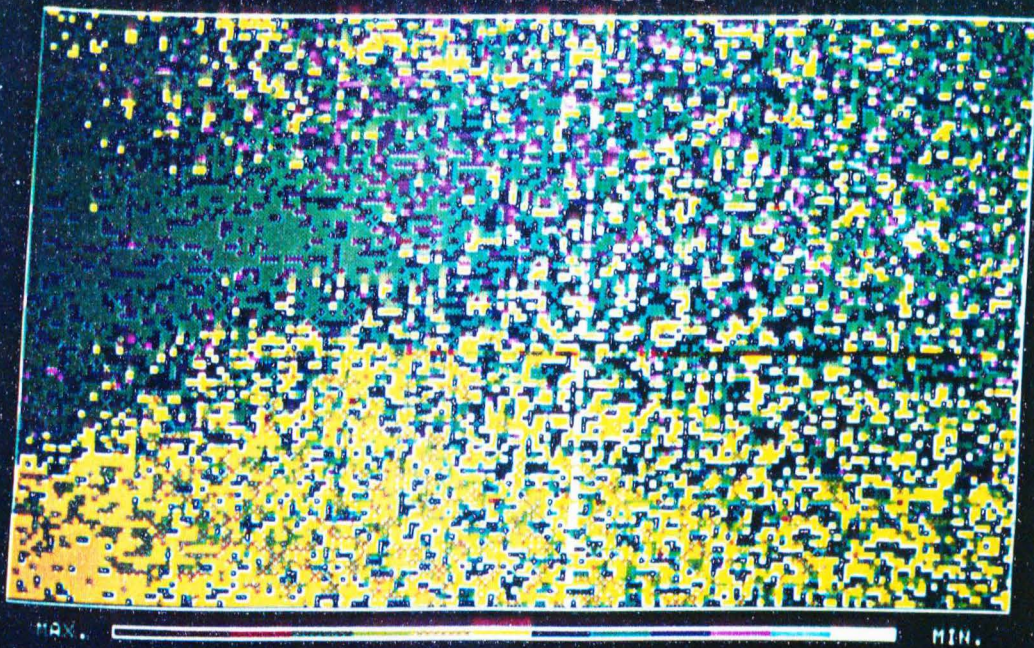


Figure 58(a) Chordwise Color Video Display of Flow Field of the Cylinder with Zero Blowing (Total Pressure Probe)

COLOR VIDEO DISPLAY FOR CIRCULATION CONTROL CYLINDER
FILE NAME : CCST11.DAT CHANNEL PLOTTED : 2

U.H.C.P.



FILE NAME : CCST11.DAT CHANNEL PLOTTED : 3

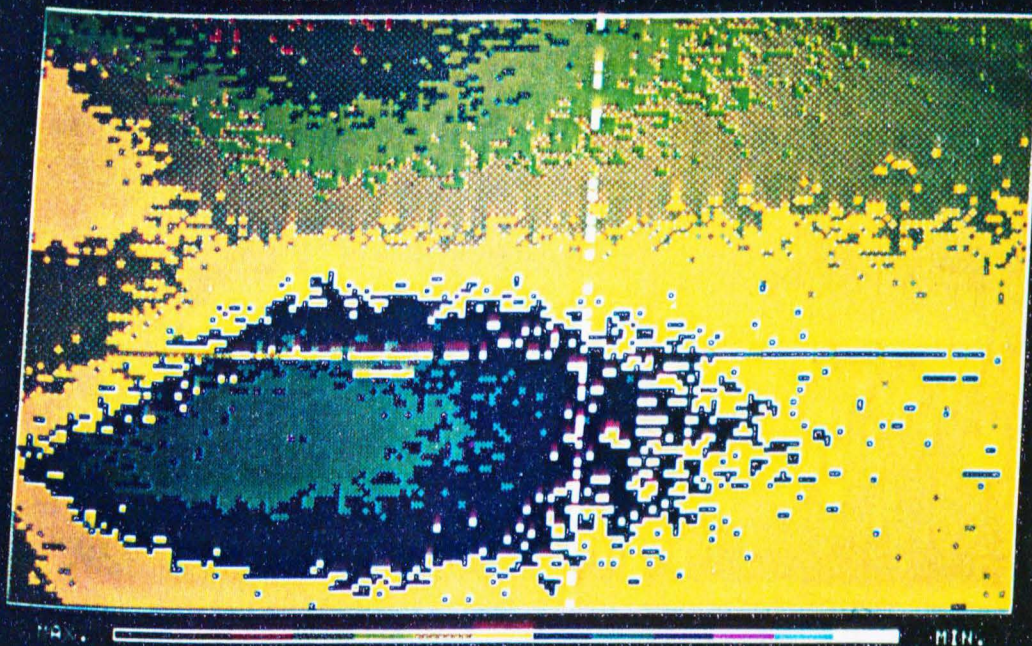


Figure 58(b,c) Chordwise Color Video Display of Flow Field of the Cylinder with Zero Blowing (Yaw and Pitch Probes)

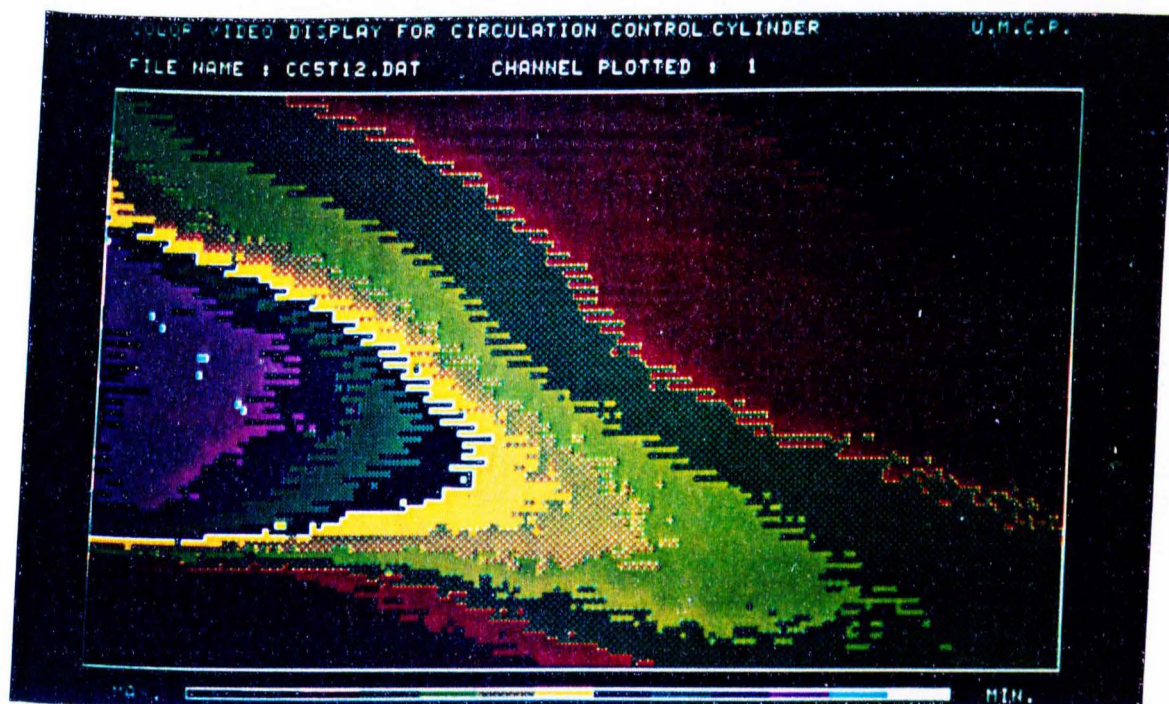
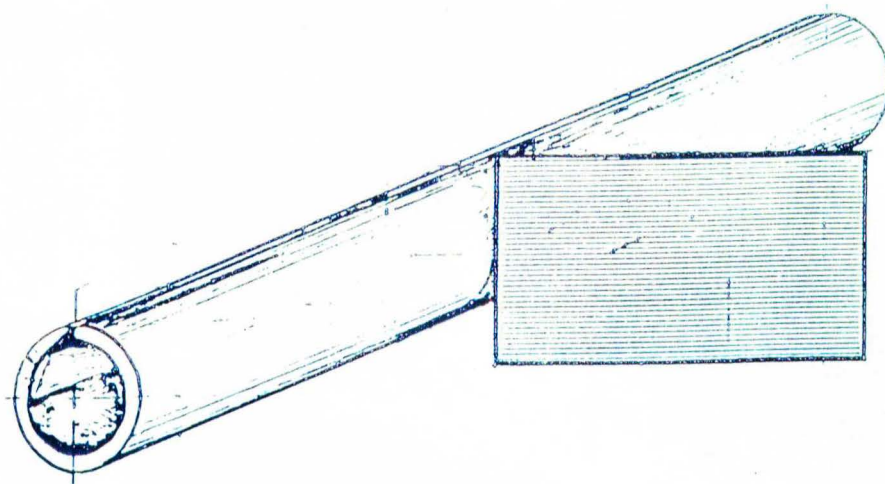


Figure 59(a) Chordwise Color Video Display of Flow Field of the Cylinder with $C_{\mu} = .105$ (Total Pressure Probe)

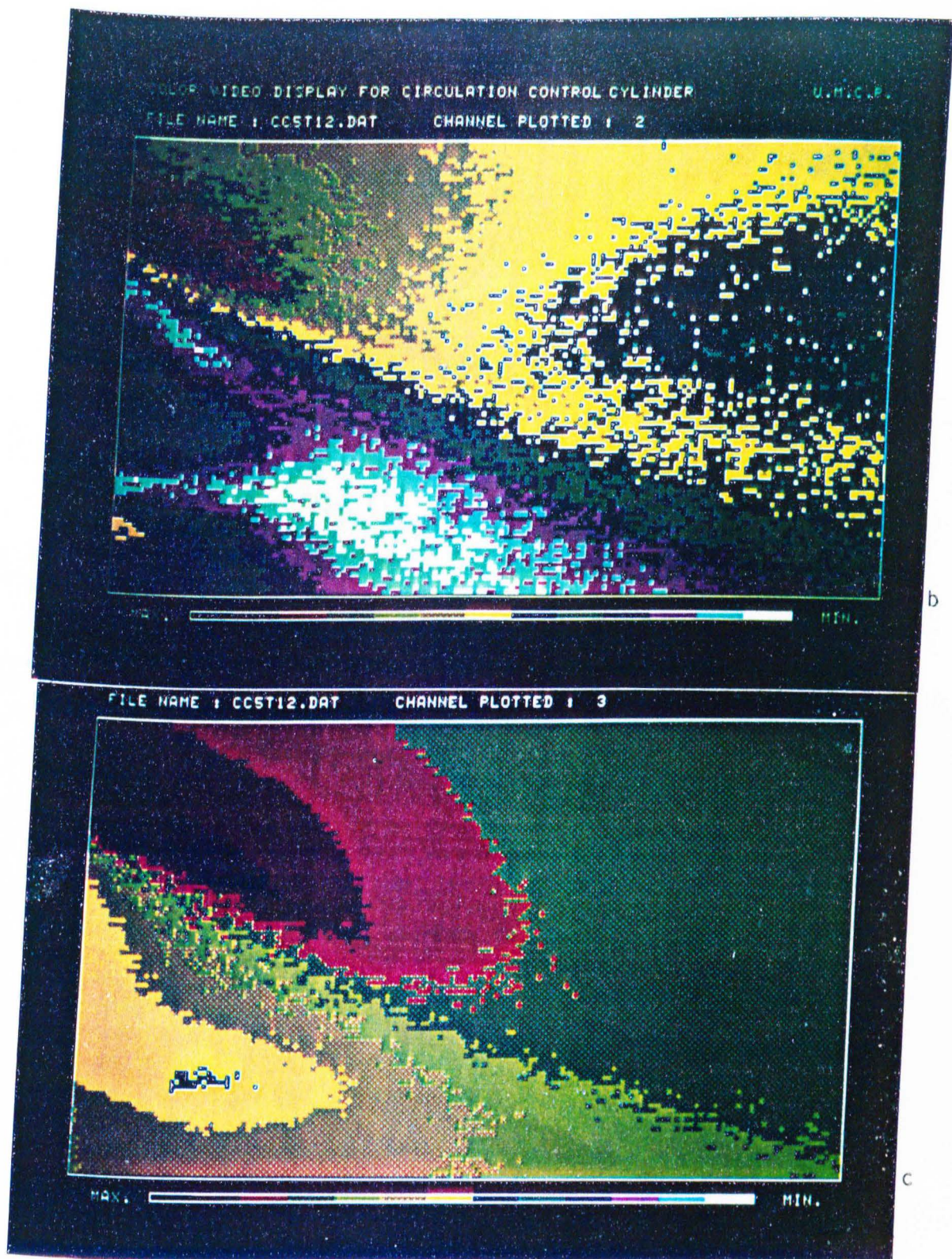


Figure 59(b,c) Chordwise Color Video Display of Flow Field of the
 Cylinder with $C_p = .105$ (Yaw and Pitch Probes)

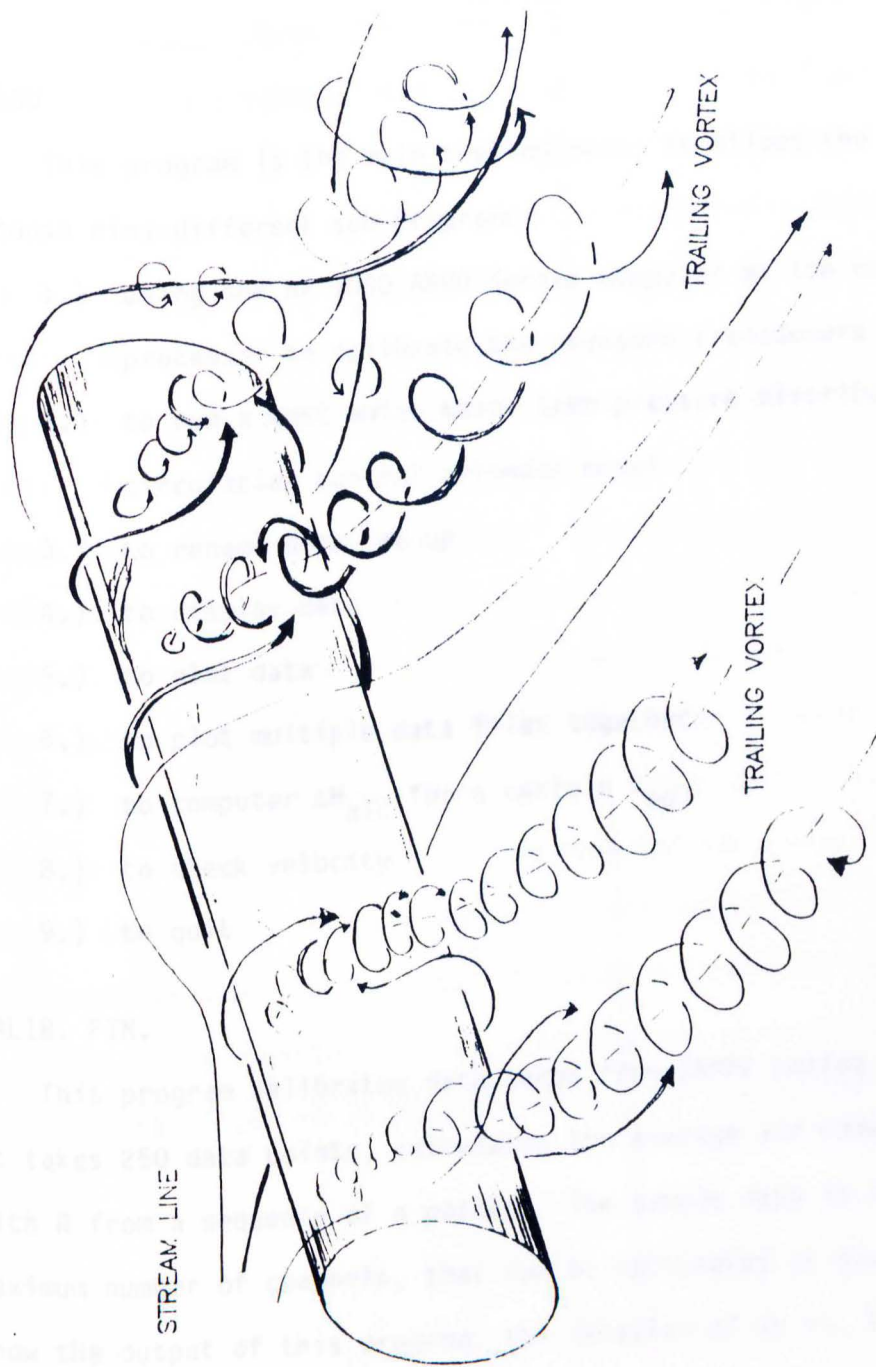


Figure 60 Suggest a Flow Field Model of Circulation Control
Cylinder

APPENDIX I

MENU

This program is the main testing menu; it allows the operator to choose nine different sub-programs.

- 1.) using the HP 1000 A900 Series computer as the controller and processor to calibrate the pressure transducers
- 2.) to run a test which means take pressure distribution data of circulation control cylinder model
- 3.) to rename data set up
- 4.) to display data
- 5.) to plot data
- 6.) to plot multiple data files together
- 7.) to computer ΔH_{alc} for a certain R_{ep}
- 8.) to check velocity
- 9.) to quit

CALIB. FTN.

This program calibrates data taken from CAMAC Lacroq A/D equipment. It takes 250 data points, calculates the average and computer $y = mx + c$ with R from a sequence of n points. The sample rate is 100 Khz and the maximum number of channels, that can be calibrated is given in Fig. 84. Show the output of this program, the relation of ΔH vs. Voltage of Channels five (Duct (plenum) total pressure) and ΔH vs. Voltage of Channels four (Local static pressure on the model)

GETIT

This real time program takes data from the circulation control cylinder model. First, the program asks for the free-stream temperature and barometric pressure, then the program reads the free-stream total pressure. Using this data it calculates the wind tunnel velocity and Reynolds number based on chord. This information is then displayed for the operator to check the testing conditions of the wind tunnel. The program then reads twenty spanwise local static pressures, 10 at leading edge and 10 at trailing edge, and graphically displays them on the terminal. The operator uses this data to determine the level of two dimensional flow. If the two dimensional flow parameters are satisfactory, (the pressure is uniform in the spanwise direction), the program then reads 58 chordwise local static pressures on the model and displays at actual pressure distribution. At the same time it reads mass flow, duct (plenum) total temperature, duct (plenum) total pressure, and graphically displays the data. In this way, the operator can study the flow steadiness on the surface of the model during the actual test. After reading the chordwise pressure tap data, the program calculates the average of T_j , $\dot{M}$ and using equation (1) to calculate the momentum coefficient. All of this data is stored in temporary data file for future use.

APPENDIX II

File: /HIED/CLASS/MENU.LST
 Created: Tue Mar 3, 1987 4:43:28 pm
 Updated: Tue Mar 3, 1987 4:43:32 pm
 Printed: Tue Mar 3, 1987 4:45:19 pm

M E N U

H E L P


```

2      program menu
3
4      *****
5      *
6      * main menu from which sub programs are scheduled
7      * with wait.
8      *
9      *****
10
11      integer bufr(1),prog(3,8)
12      character*1 esc,c
13      character   pname(8)*6
14      equivalence (prog,pname)
15
16      common // slopes,xcepts,coeffs
17      data prog /6hcalib ,6hgetit ,6hrenam ,6hdrwit ,6hpltit ,6hpcp ,
18      $6hdelh ,6hvelchk/
19
20      esc = char(27)
21      c = 'c'
22      5 write(1,*) esc,'H',esc,'J'
23      write(1,*) 'Main Testing Menu'
24      write(1,*) '*****'
25      write(1,*) ' '
26      write(1,*) '1 .... to calibrate.'
27      write(1,*) '2 .... to run a test.'
28      write(1,*) '3 .... to rename data set (getdata.dat).'
29      write(1,*) '4 .... to display data.'
30      write(1,*) '5 .... to plot data.'
31      write(1,*) '6 .... to plot multiple datafiles together.'
32      write(1,*) '7 .... to compute delta H for a certain Re.'
33      write(1,*) '8 .... to check velocity.'
34      write(1,*) '9 .... to quit.'
35      write(1,10)
36      10 format(////,4x,'Enter a number (1 - 9) : _')
37
38      read(1,*) bufr
39
40      if (bufr .lt. 1 .or. bufr .gt. 9) then
41          go to 5
42      else if (bufr .eq. 9) then
43          stop
44      else
45          ierror = FmpKpProgram(pname(bufr),pname(bufr),c,n)
46          call exec (9,prog(1,bufr))
47      endif
48
49      goto 5
50      end

```

Module MENU
FTN7X 2540/860213

No errors
No warnings

Prog: 480
Save: none

Blank common: 6
Local EMA: none


```

2      $cds on
3      $files 0,7
4
5      Program GETIT
6
7      C-----
8      C
9      C Program to take data from circulation control cylinder
10     C
11     C Hardware:
12     C ea type
13     C 1. 4012 - Traql system controller
14     C 1. 8212 - 32Ch 100Khz digitizer
15     C 5. 8800 - 32K memory modules
16     C 4. 1008 - 8Ch amplifier
17     C 1. 2216 - 16Ch relays
18     C
19     C Data taken is:
20     C
21     C 1 - Temperature in cylinder
22     C 2 - Pressure in cylinder
23     C 3 - Mass flow rate
24     C 4 - Pressure taps on cylinder surface
25     C 5 - Pressure taps on cylinder surface
26     C
27     C Relays used to trigger step and home scanivalve.
28     C 1 = home
29     C 2 = step
30     C
31     C Program run from menu and data displayed by drwit.
32     C
33     C Data written into getdata.dat
34     C Record is Ch1,Ch2,Ch3,Ch4,Ch5 (f10.4)
35     C
36     C 1/20/86
37     C
38     C-----
39
40     C WBUF is data written to 3988
41     C RBUF is data READ from 3988
42     C DATA is sampled data
43
44     INTEGER WBUF(3),RBUF(3),NEWDATA(4)
45     DIMENSION AVE(5)
46     CHARACTER*1 ESC,RESP
47
48     COMMON /CAMACDATA/ WBUF,RBUF !Define common blocks
49     COMMON /VULIS/ AVE
50     COMMON /WHICHSCANI/ ISTEP
51
52
53     00062 OPEN (97,FILE='DATA3.DAT') !Cylinder surface coordinates
54     00111 OPEN (87,FILE='XYDZD1.DAT') !2 D tap coordinates
55     00140 OPEN (96,FILE='XYTU1.DAT') !Upper surface tap coordinates
56     00167 OPEN (95,FILE='XYTL1.DAT') !Lower surface tap coordinates

```



```

57 00216      OPEN (91,FILE='GETDATA.DAT')      !Output file
58 00245      ESC = CHAR(27)                    !ESCAPE character definition
59
60 00255      WRITE (1,*) ESC,'H',ESC,'J'        !Home & clear display
61 00330      WRITE (1,*) 'Getit Program'        !Header label
62 00355      WRITE (1,*) '*****'
63 00402      WRITE (1,*) ' '
64 00427      WRITE (1,*) 'Do you want to change freestream variables? (y/n): _'
65 00454      READ(1,'(a1)') RESP
66 00504      IF (RESP.EQ. 'y'.OR. RESP.EQ. 'Y') THEN !reset conditions
67 00522          WRITE (1,*) 'Enter free stream temperature (F): _'
68 00547          READ(1,*) TFS
69 00571          WRITE (1,*) 'Enter barometric pressure (in Hg): _'
70 00616          READ(1,*) BPFS
71 00640      ELSE
72 00641          TFS = 90.0                      !Preset conditions
73 00645          BPFS = 29.98
74 00651      END IF
75 00651      WRITE (1,*) ' '
76 00676      610 WRITE (1,*) 'Enter angle of attack: _'      !Inquire AoA
77 00723      READ(1,*) ALPHA
78 00745      WRITE (1,*) ESC,'H',ESC,'J'        !Home & clear display
79 01020      WRITE (91,61) TFS                  !Write temperature
80 01046      WRITE (91,61) BPFS                 ! & barometric pressure
81 01074      WRITE (91,61) ALPHA                 ! & angle of attack
82 01122      61  FORMAT (F10.4)                 ! to output file
83
84 01122      WRITE (1,*) ESC,'*m/X'
85 01160      WRITE (1,*) ESC,'*pa,130,205,130,375,401,375,401,205,130,205,Z'
86 01216      WRITE (1,*) ESC,'*m5X'
87
88 01254      READ (97,500,END=520) XCUR,YCUR
89
90 01305      500  FORMAT (2F10.4)
91
92 01305      XCUR = XCUR*2.0
93 01313      YCUR = YCUR*2.0
94
95 01321      WRITE (1,*) ESC,'*pa,',XCUR*7+266,YCUR*7+290,'Z'
96
97 01413      DO 510 I=1,400
98 01417          READ(97,500,END=520)XCUR,YCUR
99 01450          XCUR = XCUR*2.0
100 01456          YCUR = YCUR*2.0
101 01464          WRITE (1,*) ESC,'*pb,',XCUR*7+266,YCUR*7+290,'Z'
102 01556      510  CONTINUE
103 01562      520  CONTINUE
104
105 01562      WRITE (1,*) ESC,'*pa,130,180,Z'
106 01620      WRITE (1,*) ESC,'*m/X'
107 01656      WRITE (1,*) ESC,'*1'      ACTUAL PRESSURE DISTRIBUTION'
108
109 01714      WRITE (1,*) ESC,'*m6X'
110 01752      WRITE (1,*) ESC,'*pa,30,50,30,158,195,158,195,50,30,50,Z'
111

```

```

112 02010      DO 530 I=50,158,6
113 02014          WRITE (1,*) ESC,'*m6X'
114 02052          WRITE (1,*) ESC,'*pa,27,' ,1,' ,33,' ,1,' ,2'
115 02130      530 CONTINUE
116
117 02135          WRITE (1,*) ESC,'*m3X'
118 02173          WRITE (1,*) ESC,'*pa,337,50,337,150,511,150,511,50,337,50,2'
119 02231          WRITE (1,*) ESC,'*pa,320,50,320,150,2'
120 02267          WRITE (1,*) ESC,'*pa,290,50,290,150,2'
121
122 02325      DO 540 I=50,150,10
123 02331          WRITE (1,*) ESC,'*m5X'
124 02367          WRITE (1,*) ESC,'*pa,315,' ,1,' ,325,' ,1,' ,2'
125 02445          WRITE (1,*) ESC,'*m1X'
126 02503          WRITE (1,*) ESC,'*pa,285,' ,1,' ,295,' ,1,' ,2'
127 02561          WRITE (1,*) ESC,'*m6X'
128 02617          WRITE (1,*) ESC,'*pa,341,' ,1,' ,347,' ,1,' ,2'
129 02675      540 CONTINUE
130
131 02702          WRITE (1,*) ESC,'*m7X'
132 02740          WRITE (1,*) ESC,'*pa,25,35,2'
133 02776          WRITE (1,*) ESC,'*12'
134 03034          WRITE (1,*) ESC,'*pa,25,20,2'
135 03072          WRITE (1,*) ESC,'*1Lp 1WU DIMENSIONAL CK.'
136 03130          WRITE (1,*) ESC,'*pa,25,163,2'
137 03166          WRITE (1,*) ESC,'*1-14'
138 03224          WRITE (1,*) ESC,'*pa,250,35,2'
139 03262          WRITE (1,*) ESC,'*1 0 70 0 TIME'
140 03320          WRITE (1,*) ESC,'*pa,255,20,z'
141 03356          WRITE (1,*) ESC,'*1 PJ 1J MFR TEST CONDITIONS'
142 03414          WRITE (1,*) ESC,'*pa,255,155,z'
143 03452          WRITE (1,*) ESC,'*1 10 170 100'
144
145 03510      1000 CONTINUE
146
147 03510          NUMTAPS = 40
148
149 03512          TPJ = 0.0
150 03516          TPJ = 0
151 03520          TIJ = 0.0
152 03524          TIJ = 0
153 03526          TVOL = 0.0
154 03532          TVOL = 0
155
156          C Set up controller and A/D modules
157
158 03534          WRITE (1,*) ESC,'H',ESC,'J'
159
160 03607          nslot = 21 !Slot 21
161 03611          NACTIVE = 6 !6 channels
162 03613          MEMC = 1 !1024
163 03615          IPTS = 8 !all PIS
164 03617          IRATE = 12 !1 KHz
165 03621          ICLOCK = 2 !internal clock
166

```

```

167 03623      CALL TADINIT(nslot,nactive,memo,ipts,irate,iclock)
168
169 03634      CALL HUME
170 03637      CALL CALIBDATA
171
172 03642      WRITE (1,*) 'READY ??????? :_'
173 03667      READ(1,'(a1)') RESP
174
175 03717      DO 20 I = 1,NUMIAPS
176
177 03726      WRITE (1,*) '-----STEP ',I,' -----'
178
179 03763          call exec(12,0,2,0,-1)
180 03773      CALL SAMPLE
181 03776      CALL STEP
182
183          C      CHANGE TO ENG. UNITS
184          C
185 04001      AVE(1) = 15.62500*AVE(1) - 0.0000000 !15.625=1000.0/64.0
186 04007      AVE(2) = -2.05163*AVE(2) + 0.0000000 !DH. M.
187 04015      AVE(3) = 17.57416*AVE(3) + 0.0000000 ! CFM
188 04023      AVE(4) = 04.16836*AVE(4) + 0.0000000 !inch alc
189 04031      AVE(5) = 00.92575*AVE(5) + 0.0000000 !inch alc
190
191
192 04037      WRITE (1,*) 'Value is ',(AVE(J),J=1,5)
193 04104      WRITE (9,40) (AVE(J),J=1,5)!Write raw a/d data to file
194
195 04146 40      FORMAT (5F10.4)
196
197          C ----- drawing Two - Dimentions Flow -----
198
199 04146      IF (1.EQ. 1) GO TO 60
200 04151      IF (1.EQ. 11) GO TO 15
201 04156      WRITE (1,*) ESC,'*m3X'
202 04214      CPU = AVE(5)/dpl
203 04222      WRITE (1,*) 'CP TWO DIMENTION = ',CPU
204 04253      READ(89,*) SCORP
205 04275      WRITE (1,*) 'SCORP = ',SCORP
206 04326      SCOR2D = 30 + SCORP ! 11 = (195-30)/15
207 04334      CP2DU = 62 + (CPU*6) ! 6 = (158-50)/18
208 04344      IF (1.EQ. 2)GO TO 12
209 04347 11      WRITE (1,*) ESC,'*pa,',XS2DU,YS2DU,SCOR2D,CP2DU,'Z'
210 04431      WRITE (1,*) XS2DU,YS2DU,SCOR2D,CP2DU
211 04472      XS2DU = SCOR2D
212 04476      YS2DU = CP2DU
213 04502      GO TO 20
214 04503 12      XS2DU = SCOR2D
215 04507      YS2DU = CP2DU
216 04513      GO TO 11
217
218          C ----- drawing PRESSURE DISTRIBUTION UPPER SURFACE -----
219
220 04514 15      CONTINUE
221 04514      CPDWU = AVE(4)/dpu

```



```

222 04522      WRITE (1,*) 'CP DISTRIBUTION = ',CPDWU
223 04553      IF (CPDWU.LT. 0.0) WRITE (1,*) ESC,'*m1X'
224 04614      IF (CPDWU.GT. 0.0) WRITE (1,*) ESC,'*m2X'
225 04656      READ(96,315)ANGU,XCURU,YCURU
226 04711      ANGLEU = (ANGU/180.0)*3.1415927
227 04721      CPDWU = ABS(CPDWU)
228 04727      SINANU=SIN(ANGLEU)*CPDWU*15.0
229 04747      COSANU=COS(ANGLEU)*CPDWU*15.0
230 04767      315      FORMAT (3F10.4)
231 04767      XCURU = 266.0 + (XCURU * 7.0)
232 04777      YCURU = 290.0 + (YCURU * 7.0)
233 05007      IF (1.EQ. 12) GO TO 310
234 05012      300      WRITE (1,*) ESC,'*pa','XPACPU,YPACPU,'Z'
235 05064      WRITE(1,*)ESC,'*pb','XCURU+COSANU,YCURU+SINANU,XCURU,YCURU,'Z'
236 05162      WRITE (1,*) ESC,'*pa','XPACPU,YPACPU,'Z'
237 05234      XPACPU = XCURU + COSANU
238 05242      YPACPU = YCURU + SINANU
239
240      C-----DRAWING PRESSURE DISTRIBUTION LOWER SURFACE-----
241 05250      CPDWL = AVE(5)/dpl
242 05256      IF (CPDWL.LT.0.0) WRITE (1,*) ESC,'*m1X'
243 05317      IF (CPDWL.GT.0.0) WRITE (1,*) ESC,'*m2X'
244 05361      READ(95,315)ANGL,XCURL,YCURL
245 05414      ANGLEL = (ANGL/180.0)*3.1415927
246 05424      CPDWL = ABS(CPDWL)
247 05432      SINANL = SIN(ANGLEL)*CPDWL*15.0
248 05452      COSANL = COS(ANGLEL)*CPDWL*15.0
249 05472      XCURL = 266.0 + (XCURL * 7.0)
250 05502      YCURL = 290.0 + (YCURL * 7.0)
251 05512      IF (1.EQ.12) GO TO 313
252 05515      312      WRITE (1,*) ESC,'*pa','XPACPL,YPACPL,'Z'
253 05567      WRITE(1,*)ESC,'*pb','XCURL+COSANL,YCURL+SINANL,XCURL,YCURL,'Z'
254 05665      WRITE (1,*) ESC,'*pa','XPACPL,YPACPL,'Z'
255 05737      XPACPL = XCURL + COSANL
256 05745      YPACPL = YCURL + SINANL
257 05753      GO TO 320
258 05754      313      XPACPL = XCURL + COSANL
259 05762      YPACPL = YCURL + SINANL
260 05770      GO TO 312
261
262 05771      310      XPACPU = XCURU+COSANU
263 05777      YPACPU = YCURU+SINANU
264 06005      GO TO 300
265
266      C----- drawing PRESSURE IN JET -----
267
268 06006      320      CONTINUE
269 06006      WRITE (1,*) ESC,'*m1X'
270 06044      PINJ = AVE(2)
271 06050      WRITE (1,*) 'PSI IN JET = ',PINJ
272 06101      PINJ = PINJ * 10.0
273 06107      IF (1.EQ. 12) GO TO 340
274 06112      WRITE (1,*) ESC,'*pa','XPAP,YPAP,'Z'
275 06164      330      WRITE (1,*) ESC,'*pa','XPAP,YPAP,XPAP+6.0,PINJ*50,'Z'
276 06262      XPAP = XPAP + 6.0

```

```

277 06270      YPAP = PINJ + 50.0
278 06276      TPJ = IPJ + AVE(2)      ! SUM PRESSURE IN JET
279 06304      IIPJ = ITPJ + 1
280 06307      GO TO 350
281 06310 340   XPAP = 337.0
282 06314      YPAP = PINJ + 50.0
283 06322      GO TO 330
284
285 C----- drawing TEMPREATURE IN JET -----
286
287 06323 350   CONTINUE
288 06323      WRITE (1,*) ESC, '*m5X'
289 06361      TINJ = AVE(1)      ! CHANGE TO F.D. affter * 1000.0
290 06365      WRITE (1,*) 'TEMPREATURE IN JET = ', TINJ
291 06416      IF (1.EQ. 12) GO TO 370
292 06421      WRITE (1,*) ESC, '*pa,', XPAT, YPAT, ',Z'
293 06473 360   WRITE (1,*) ESC, '*pa,', XPAT, YPAT, XPAT+6, TINJ-20.0, 'Z'
294 06571      XPAT = XPAT + 6.0
295 06577      YPAT = TINJ - 20.0
296 06605      IF(AVE(1) .GT. ITJMAX) GO TO 380
297 06613      IF(AVE(1) .LT. ITJMIN) GO TO 380
298 06621      ITJ = ITJ + AVE(1)
299 06627      IITJ = IITJ + 1
300 06632      GO TO 380
301 06633 370   XPAT = 337.0
302 06637      YPAT = TINJ - 20.0
303 06645      ITJMAX = AVE(1) + 0.010
304 06653      ITJMIN = AVE(1) - 0.010
305 06661      GO TO 360
306
307 C----- drawing MASS FLOW RATE -----
308 06662 380   CONTINUE
309 06662      WRITE (1,*) ESC, '*m6X'
310 06720      XMASS = (ave(3))      ! ave is ACFM
311 06724      WRITE (1,*) 'ACFM = ', XMASS
312 06755      IF (1.EQ. 12) GO TO 410
313 06760      WRITE (1,*) ESC, '*pa,', XPAM, YPAM, ',Z'
314 07032 390   WRITE (1,*) ESC, '*pa,', XPAM, YPAM, XPAM+6, XMASS+50, 'Z'
315 07130      XPAM = XPAM + 6.0
316 07136      YPAM = XMASS + 50.0
317 07144      IVUL = IVUL + AVE(3)
318 07152      IIVUL = IIVUL + 1
319 07155      GO TO 20
320 07156 410   XPAM = 337.0
321 07162      YPAM = XMASS + 50.0
322 07170      GO TO 390
323
324 07171 60   C-----
325 07175      IF (1.EQ. 1) THEN
326 07205      DP = (AVE(4)+AVE(5)) / 2.0
327 07211      DPU = ave(4)
328 07215      DPL=ave(5)
329 07252      WRITE (1,*) 'Dynamic pressure: ', dp, ' inches alcohol'
330 07277      WRITE (1,*) 'Is this OK? -'
331 07327      READ (1, '(a1)') RESP
332      IF (RESP.eq.'n'.or.RESP.eq.'N') READ (1,*) DP

```

```

332 02367      DP = DP / 12.
333 02375      TR = TFS + 460.0
334 02403      BPF51 = BPF5*70.73      !CHANGE TO LB/FIS
335 02411      DST = BPF51/(1/16.0*TR)
336 02425      VWI = ((2.*1.5/1*32.2*dp)/DST)**0.5      ! 2*roalcl*g*delh/roair)
337 02445      WRITE (1,*) ESC, 'm7X'
338 02503      WRITE (1,*) ESC, 'pa,30,320,Z'
339 02541      WRITE (1,*) ESC, 'IU = ,VWI'
340 02603      WRITE (1,*) ESC, 'pa,30,340,Z'
341 02641      WRITE (1,*) ESC, '11.F.S. = ,TFS
342 02703      WRITE (1,*) ESC, 'pa,30,310,Z'
343 02741      WRITE (1,*) ESC, '1B.P. = ,BPF5
344 10003      WRITE (1,*) ESC, 'pa,30,280,Z'
345 10041      WRITE (1,*) ESC, '1d.p. = ,dp*12.
346 10111      REN = (DST*VWI*(3.96/0/12.))/3.86368e-7
347 10123      END IF
348
349 10123      20 CONTINUE
350 10127      CLOSE(97)
351 10144      CLOSE(89)
352 10161      CLOSE(96)
353 10176      CLOSE(95)
354
355 10213      50 FORMAT (F10.4)
356 10213      AIPJ = (IPJ/11PJ)*70.73      !CHANGE TO IB/FIS
357 10227      IF (AIPJ .LT. 0.0) THEN
358 10232          AIPJ = 0.0
359 10236      ELSE
360 10237          END IF
361 10237      AITJ = (ITJ/11IJ)      !CHANGE TO F.D.
362 10251      ACFM = IVUL/11VUL
363 10263      IF (ACFM .LT. 0.0) THEN
364 10266          ACFM = 0.0
365 10272      ELSE
366 10273          END IF
367 10273      WRITE (1,*) 'AIPJ=', AIPJ, 'AITJ=', AITJ, 'ACFM=', ACFM
368
369 10344      ATTJ = AITJ + 460.0      ! F TO R
370 10352      DIP = AIPJ + BPF51      ! Total jet pressure
371 10360      AMJ2 = ((1.0-(BPF51/DIP)**.2857))! Mach= (1-(p/pd))**.5
372 10405      VJ = (12012.*AITJ*AMJ2)**.5      ! 12012.=2*R*(1.4/1.4-1)
373 10425      ATIJ = AITJ*(BPF51/DIP)**.2857
374 10451      DSTJ = BPF51/(1/16.0*ATTJ)      ! Jet density
375 10465      AMSSJ = (ACFM*DSTJ)/60.      ! Mass flow rate
376 10475      DP = 1.571 * 32.2 * DP      ! Convert delta H to delta P (q)
377 10503      CMOM = AMSSJ*VJ/(DP*((21.6875*3.967)/144)) !m0/q5 (Lu)
378
379 10525      WRITE (1,*) ESC, 'm7X'
380 10563      WRITE (1,*) ESC, 'pa,410,370,Z'
381 10621      WRITE (1,*) ESC, '1Cu = ,CMOM
382 10663      WRITE (1,*) ESC, 'pa,410,350,Z'
383 10721      WRITE (1,*) ESC, '1VJ = ,VJ
384 10763      WRITE (1,*) ESC, 'pa,410,330,Z'
385 11021      WRITE (1,*) ESC, '1DSTJ = ,DSTJ
386 11063      WRITE (1,*) ESC, 'pa,410,310,Z'

```



```

387 11121      WRITE (1,*) ESC, '*IRE = ',REN
388
389 11163      WRITE(91,*)CMUM
390 11210      WRITE(91,*)REN
391 11235      WRITE(91,*)DP
392 11262      WRITE(91,61)UJ
393 11310      SANG = 0.0
394 11314      WRITE(91,61)UW1
395 11342      WRITE(91,61)INT(SANG)
396
397 11374      CLOSE(91)
398 11411 999  CONTINUE
399
400 11411      STOP
401 11415      END

```

Module GETIT
FIN/X 2540/860213

No errors
No warnings

Data: 1939
Code: 4877

Blank common: none
Stack size: 155

Symbol Table

Name	Address	Usage	Type	Location
#1000	03510P	Stmt number		
#11	04342P	Stmt number		
#12	04503P	Stmt number		
#15	04514P	Stmt number		
#20	10123P	Stmt number		
#300	05012P	Stmt number		
#310	05771P	Stmt number		
#312	05515P	Stmt number		
#313	05754P	Stmt number		
#315	00033R	Stmt number		
#320	06006P	Stmt number		
#330	06164P	Stmt number		
#340	06310P	Stmt number		
#350	06323P	Stmt number		
#360	06473P	Stmt number		
#370	06633P	Stmt number		
#380	06662P	Stmt number		
#390	07032P	Stmt number		
#40	00026R	Stmt number		
#410	07156P	Stmt number		
#50	00043R	Stmt number		
#500	00016R	Stmt number		
#510	01556P	Stmt number		
#520	01562P	Stmt number		
#530	02130P	Stmt number		
#540	02675P	Stmt number		
#60	07171P	Stmt number		
#61	00011R	Stmt number		
#610	00676P	Stmt number		
#999	11411P	Stmt number		
ABS		Intrinsic	Generic	
ACFM	00042Q	Variable	Real	Stack
ALPHA	00226Q	Variable	Real	Stack
AMJ2	00052Q	Variable	Real	Stack
AMSSJ	00040Q	Variable	Real	Stack
ANGL	00166Q	Variable	Real	Stack
ANGLEL	00164Q	Variable	Real	Stack
ANGLEU	00172Q	Variable	Real	Stack
ANGU	00174Q	Variable	Real	Stack
ATPJ	00054Q	Variable	Real	Stack
ATTJ	00044Q	Variable	Real	Stack
AUE	00000+	Array, 1 dim	Real	L Common UOLIS
BPFS	00071Q	Variable	Real	Stack
BPFS1	00046Q	Variable	Real	Stack
CALIBDATA	00021X	Subroutine		External
CAMALDATA	00042X	Common label		External
CHAR		Intrinsic	Char*1	
CMUM	00034Q	Variable	Real	Stack
CUS		Intrinsic	Generic	
COSANL	00154Q	Variable	Real	Stack

Symbol Table

Name	Address	Usage	Type	Location
COSANU	00140Q	Variable	Real	Stack
CP2DU	00176Q	Variable	Real	Stack
CPDWL	00162Q	Variable	Real	Stack
CPDWU	00170Q	Variable	Real	Stack
CPU	00206Q	Variable	Real	Stack
DP	00030Q	Variable	Real	Stack
DPL	00072Q	Variable	Real	Stack
DPU	00101Q	Variable	Real	Stack
DST	00067Q	Variable	Real	Stack
DSTJ	00036Q	Variable	Real	Stack
DTP	00050Q	Variable	Real	Stack
ESC	00230Q	Variable	Char*1	Stack
EXEC		Intrinsic		
HOME	00020X	Subroutine		External
I	00103Q	Variable	Integer	Stack
ICLCLK	00214Q	Variable	Integer	Stack
INI		Intrinsic	Generic	
IPIS	00216Q	Variable	Integer	Stack
IRATE	00215Q	Variable	Integer	Stack
ISTEP	00000+	Variable	Integer	L Common WHILSLANI
ITPJ	00064Q	Variable	Integer	Stack
ITIJ	00061Q	Variable	Integer	Stack
ITVUL	00056Q	Variable	Integer	Stack
J	00212Q	Variable	Integer	Stack
MEMC	00217Q	Variable	Integer	Stack
NACTIVE	00220Q	Variable	Integer	Stack
NSLOT	00221Q	Variable	Integer	Stack
NUMTAPS	00213Q	Variable	Integer	Stack
PINJ	00124Q	Variable	Real	Stack
RBUF	00003+	Array, 1 dim	Integer	L Common CAMALDATA
REN	00032Q	Variable	Real	Stack
RESP	00230Q	*Variable	Char*1	Stack
SAMPLE	00023X	Subroutine		External
SANG	00022Q	Variable	Real	Stack
SCOR2D	00202Q	Variable	Real	Stack
SCORP	00210Q	Variable	Real	Stack
SIN		Intrinsic	Generic	
SINANL	00146Q	Variable	Real	Stack
SINANU	00132Q	Variable	Real	Stack
STEP	00024X	Subroutine		External
TADINIT	00017X	Subroutine		External
TFS	00073Q	Variable	Real	Stack
TINJ	00116Q	Variable	Real	Stack
TPJ	00065Q	Variable	Real	Stack
TR	00075Q	Variable	Real	Stack
TTJ	00062Q	Variable	Real	Stack
TTJMAX	00114Q	Variable	Real	Stack
TTJMIN	00112Q	Variable	Real	Stack
TVUL	00057Q	Variable	Real	Stack
UJ	00026Q	Variable	Real	Stack

Symbol Table

Name	Address	Usage	Type	Location
VOLIS	00025X	Common label		External
VWI	00024Q	Variable	Real	Stack
WBUF	00000+	Array, 1 dim	Integer	L Common
WHICHSCANI	00041X	Common label		External
XCOR	00224Q	Variable	Real	Stack
XCORL	00156Q	Variable	Real	Stack
XCURU	00142Q	Variable	Real	Stack
XMASS	00104Q	Variable	Real	Stack
XPACPL	00160Q	Variable	Real	Stack
XPACPU	00144Q	Variable	Real	Stack
XPAM	00110Q	Variable	Real	Stack
XPAP	00130Q	Variable	Real	Stack
XPAT	00122Q	Variable	Real	Stack
XS2DU	00204Q	Variable	Real	Stack
YCUR	00222Q	Variable	Real	Stack
YCURL	00150Q	Variable	Real	Stack
YCURU	00134Q	Variable	Real	Stack
YPACPL	00152Q	Variable	Real	Stack
YPACPU	00136Q	Variable	Real	Stack
YPAM	00106Q	Variable	Real	Stack
YPAP	00126Q	Variable	Real	Stack
YPAT	00120Q	Variable	Real	Stack
YS2DU	00200Q	Variable	Real	Stack

```

402      C-----
403      SUBROUTINE HUME
404
405      INTEGER WBUF(3),RBUF(3),NAME(3)
406      COMMON /CAMACDATA/ WBUF,RBUF
407      DATA NAME /0,0,0/
408
409      C Home relays      (relay 1)
410
411      412 00014      CALL CWRITE(14,0,16,0,0,1)      !relay 1
413 00025      CALL EXEC(12,name,1,0,-50)      !.5 sec delay
414 00035      CALL CWRITE(14,0,16,0,0,0)
415 00046      CALL EXEC(12,name,1,0,-300)      !3 sec delay
416 00056      RETURN
417 00060      END

```

Module HUME

FIN/X 2540/860213

No errors

No warnings

Data:

Code:

10

48

Blank common: none

Stack size: 8

Symbol table

Name	Address	Usage	Type	Location
CAMACDATA	00005X	Common label		External
CWRITE	00002X	Subroutine		External
EXEL		Intrinsic		
NAME	00000R	Array, 1 dim	Integer	Data
RBUF	00003+	Array, 1 dim	Integer	L Common CAMACDATA
WBUF	00000+	Array, 1 dim	Integer	L Common CAMACDATA


```
419 C-----  
420 SUBROUTINE STEP  
421  
422 INTEGER WBUF(3),RBUF(3),NAME(3)  
423 COMMON /CAMALDATA/ WBUF,RBUF  
424 DATA NAME /0,0,0/  
425  
426 00014 CALL LWRITE(14,0,16,0,0,2) !relay 2  
427 00025 CALL EXEC(12,name,1,0,-50)  
428 00035 CALL LWRITE(14,0,16,0,0,0)  
429 00046 RETURN  
430 00050 END
```

Module STEP	No errors	Data:	10	Blank common:	none
FIN/X 2540/860213	No warnings	Code:	40	Stack size:	8

Symbol Table

Name	Address	Usage	Type	Location
CAMACDATA	00005X	Common label		External
CWRITE	00002X	Subroutine		External
EXEC		Intrinsic		
NAME	00000R	Array, 1 dim	Integer	Data
RBUF	00003+	Array, 1 dim	integer	L Common CAMACDATA
WBUF	00000+	Array, 1 dim	integer	L Common CAMACDATA

```

432 C-----
433 SUBROUTINE SAMPLE
434
435 * Subroutine to take 100 samples from 5 channels and average
436
437     INTEGER WBUF(3),RBUF(3),DATA(1600)
438     REAL AVE(5),SLOPES(10),XCEPTS(10)
439
440     COMMON /CAMACDATA/ WBUF,RBUF
441     COMMON /COEFFS/ SLOPES,XCEPTS
442     COMMON /VOLTS/ AVE
443
444 00015 CALL COMND(21,0,10) !Clear LAMs
445
446 * Start digitizing and stop immediately with PIS
447 *
448
449 00023 CALL COMND(21,0,9) !f(9),start sweep
450 00031 call exec(12,0,1,0,-10) !Stop sweep
451 00041 CALL COMND(21,0,25)
452 *
453 * Test LAM for end of conversion
454 *
455
456 00047 RBUF(1) = 0
457 00051 DO WHILE (rbuf(1) .eq. 0) !READ LAM status register
458 00054 CALL CREAD(30,12,1)
459 00062 END DO
460
461 *
462 * LAM SET,READ DATA
463
464
465 *
466 * Clear LAM , SB disabled , 16 bit data (12 bit A/D) , Q repeat mode
467 * start memory READ
468 *
469
470 CALL COMND(21,0,10) !Clear the LAM
471 00063
472
473 00071 do i = 1,5
474 00075 CALL CWRITE(21,0,12,0,160,i) !READ 16 channels
475 00106 CALL CWRITE(21,0,12,0,126,0) !first sample
476
477 *
478 * wait 10mSec and start memory READ of 250 points
479 *
480
481 00117 call comnd(21,0,10) !clear LAM
482 00125 CALL CWRITE(30,0,12,0,1,0) !16 bit ucc mode
483
484 00136 CALL COMND(21,0,2) !f2
485
486 00144 CALL EXEC(1,33+1000,DATA,100)

```



```

487 00153 CALL CWRITE(30,0,17,0,0,0)
488 00164 CALL CCMD(21,0,10)
489 00172 total = 0.0
490 00176 DO J = 1,100
491 00202     total = total + data(J)
492 00213 END DO
493 00217 ave(1) = (total / 100.)
494 00231 WRITE (1,*) 'Avg = ',ave(1)
495 00266 ave(1) = (slopes(1) * ave(1)) - xcepts(1)
496 00321 WRITE (1,*) 'Total = ',total, ' M = ',slopes(1), ' B = ',xcepts(1)
497 00402 WRITE (1,*) '*****AVE*****',AVE(1)
498 00437 END DO
499          c CALL CWRITE(30,0,17,0,0,0) !Back to single,24bit transfers
500
501          RETURN
502 00443 END
503 00445

```

Module SAMPLE
FIN/X 2540/860213

No errors Data: 53 Blank common: none
No warnings Code: 293 Stack size: 1619

Symbol Table

Name	Address	Usage	Type	Location
AVE	00000+	Array, 1 dim	Real	L Common
CAMACDATA	00004X	Common label		External
CCMD	00002X	Subroutine		External
COEFFS	000021X	Common label		External
CREAD	00005X	Subroutine		External
CWRITE	00006X	Subroutine		External
DATA	00022Q	Array, 1 dim	Integer	Stack
EXEC		Intrinsic		
I	00016Q	Variable	Integer	Stack
J	00021Q	Variable	Integer	Stack
RBUF	00003+	Array, 1 dim	Integer	L Common
SLUPES	00000+	Array, 1 dim	Real	L Common
TOTAL	00017Q	Variable	Real	Stack
VOLTS	00012X	Common label		External
WBUF	00000+	Array, 1 dim	Integer	L Common
XCEPTS	00024+	Array, 1 dim	Real	L Common

```

505          SUBROUTINE calibdata
506          *
507          * SUBROUTINE to READ calibrateion data from sequential file
508          * calib.data. record is m,c,r,ichannel
509
510          dimension slopes(10),xcepts(10)
511          common /coeffs/ slopes,xcepts
512
513          open(90,file = 'calib.dat')
514 00026      DO 10 i = 1,5
515 00055          READ(90,*) slope,xcept,dummy,ichannel
516 00061          slopes(ichannel) = slope
517 00117          xcepts(ichannel) = xcept
518 00127          WRITE (1,*) ichannel,slope,xcept
519 00137      CONTINUE
520 00174      10 CONTINUE
521 00200      20 FORMAT (3F12.6,13)
522 00200      30 CLOSE(90)
523
524 00215      RETURN
525 00217      END

```

Module CALIBDATA
FTN/X 2540/860213

No errors
No warnings

Data: 24
Code: 143

Blank common: none
Stack size: 19