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TRASONIC CASCADE WIND TUNNEL MODIFICATION AND INITIAL TESTS.(U)

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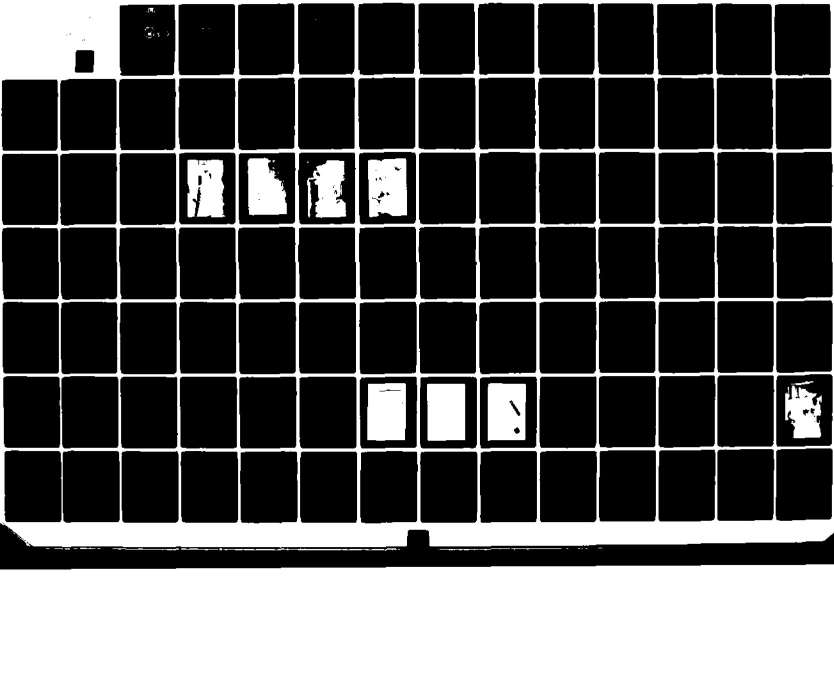

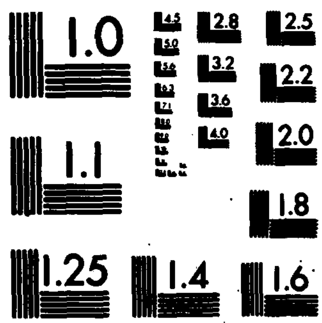
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# NAVAL POSTGRADUATE SCHOOL
## Monterey, California



# TRANSONIC CASCADE WIND TUNNEL MODIFICATION AND INITIAL TESTS

by

Karl Ferdinand Volland, Jr.

June 1980

Thesis Advisor: R. P. Shreeve

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The transonic cascade wind tunnel at the Turbomachinery Laboratory was modified by incorporting a perforated wall section in the upper nozzle block. The purpose of this modification was to cancel the oblique shock waves from the cascade blades and to aid in starting the supersonic flow in the tunnel. Test results indicated that the modification performed successfully. Supersonic flow was established through the cascade blading which models the relative flow at the tip of the laboratory's transonic compressor. A

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butterfly valve must yet be installed in the cascade exhaust to produce back pressures corresponding to the compressor's transonic operation.

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# TRANSONIC CASCADE WIND TUNNEL
# MODIFICATION AND INITIAL TESTS

by

Karl Ferdinand Volland, Jr.
Lieutenant Commander, United States Navy
B.S., U. S. Naval Academy

Submitted in partial fulfillment of
the requirements for the degree of

MASTER OF SCIENCE IN AERONAUTICAL ENGINEERING

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Author: Karl F. Volland, Jr.

Approved by: Raymond P. Shreeve, Thesis Advisor

Max F. Platzer, Chairman, Department of Aeronautics

William M. Tolles, Dean of Science and Engineering

# ABSTRACT

The transonic cascade wind tunnel at the Turbomachinery Laboratory was modified by incorporating a perforated wall section in the upper nozzle block. The purpose of this modification was to cancel the oblique shock waves from the cascade blades and to aid in starting the supersonic flow in the tunnel. Test results indicated that the modification performed successfully. Supersonic flow was established through the cascade blading which models the relative flow at the tip of the laboratory's transonic compressor. A butterfly valve must yet be installed in the cascade exhaust to produce back pressures corresponding to the compressor's transonic operation.

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## NOMENCLATURE

**English Letter Symbols**

a - Short Side of Rectangle, in.

E - Modulus of Elasticity

K - Wall Factor (a function of wall geometry and Mach No.)

M - Mach Number

P - Pressure, $lbf/in^2$

q - Dynamic Pressure, $lbf/in^2$

R - Open Area Ratio

S - Stress, $lbf/in^2$

s - Blade Spacing

t - Plate Thickness, in.

w - Deflection, in

z - Scale Factor

**Greek Letter Symbols**

$\alpha$ - Stress Coefficient

$\beta$ - Deflection Coefficient

$\Delta$ - Finite Difference

$\theta$ - Flow Inclination Angle Behind Oblique Shock

$\gamma$ - Stagger Angle

$\phi$ - Camber Angle

**Subscripts**

$\emptyset$ - Tunnel Air Supply Plenum

t - Total or Stagnation

m - Maximum

## ACKNOWLEDGEMENT

The work presented here was supported by significant contributions from many individuals. Their knowledge and dedication made the successful modification and testing of the Transonic Cascade Wind Tunnel possible.

Mr. Glen Middleton provided his expertise to the design and fabrication of the tunnel modification. Mr. Jim Hammer lent his competance as an experimentalist to the project, while Mr. John Morris and Mr. Steve Downey contributed to this work in the area of test set-up and configuration change. Mr. Alan McGuire dedicated his time and effort to insuring that a proper Engineering approach be adhered to in all phases of this work from modification design through the preparation of this report.

Associate Professor R. P. Shreeve offered the challenge and provided the overall guidance for this project, and created a dynamic and professional working environment. Without the efforts of each of these gentlemen this work could not have been completed.

# I. INTRODUCTION

The purpose of the work reported here was to modify and perform the initial testing of the small transonic cascade wind tunnel model as one task in the Transonic Compressor Research Program at the Naval Postgraduate School (NPS), Monterey, California. The cascade wind tunnel model was constructed in 1978 [Reference 1] in Building 230 at the NPS Turbopropulsion Laboratory. Preliminary blowdown tests were made through the empty nozzle [Reference 2]. Safe operation and good pressure control at a stagnation pressure of 50 psia for test times of up to 2 mins were verified. Impact pressure probe surveys on the vertical centerline at the nozzle exit showed the flow to be uniform to with $\pm$ 0.008 at a Mach number of 1.415.

The goals achieved in the present study were to design and install a porous wall section in the upper nozzle block, install the test blading and then to conduct the first experimental evaluation of the completed cascade model. Details of the porous-wall modification made to the nozzle are given in Appendix A. A modification made in the design of the cascade blade mounts to simplify the assembly of the cascade, is also given in Appendix A.

Following the modifications, a program of tests was run which was in three parts. First, Calibration Tests of the empty wind tunnel were conducted to verify tunnel operating conditions, and to establish a baseline for the pressure distribution through the test section. Following the Calibration Tests the cascade blades were installed and a series of initial Cascade Tests was conducted which verified that the blades and blade mounts and the perforated wall section had adequate strength, that the cascade model would "start" with the perforated wall vented to atmosphere, and that the scoops and by-pass ducts also worked properly. Detailed data was obtained and is discussed herein. Finally, the blades but not the scoops were removed and Wave Cancellation Tests were run to evaluate the effectiveness of the porous wall.

The instrumentation used in the tests consisted mainly of 89 static pressure taps distributed over the cascade side walls. Data was recorded and immediately analyzed using a Hewlett-Packard Model HP-3052/9845A data acquisition system interfaced with two 48 port Scanivalves. Software developed for the tests is detailed in Appendix B.

The body of the present document details the method and results of the three sets of tests. In Section II, the Cascade Wind Tunnel Model and instrumentation system are explained. In Section III, the test program and procedures are presented. An analysis of the results is presented in Section IV. Concluding remarks and recommendations are presented in Section V.

## II. CASCADE WIND TUNNEL MODEL AND INSTRUMENTATION

### A. INSTALLATION

Views of the Cascade Wind Tunnel installation are given in the four sections of Figure 1. The installation was modified from that presented in Figure 5 of Reference 1. First, the butterfly valve shown in Reference 1 was not installed. Second, during the Calibration Tests of the empty tunnel the scoop exhausts and perforated wall plenum exhaust were capped. Finally, the initial Cascade Tests, with blades installed, were conducted with scoop exhausts and perforated wall plenum vented locally to atmospheric conditions.

The design Mach number and total pressure for the cascade wind tunnel model were 1.4 and 50 psia, respectively [Reference 1].

### B. TEST SECTION

The test section configuration differed from that presented in Reference 1 because instrumented aluminum plates were used in place of the proposed plexiglass windows, and the upper nozzle block was modified to include a perforated wall section. The cascade configuration for each test is given in Section III.

### C. INSTRUMENTATION

To measure nozzle and test section static pressures, a series of 89 static ports were installed in the aluminum side (window) plates, 74 on the front plate and 15 on the rear plate as seen in Figures 1c and 1d. The static tap design is shown in Figure 2 which also shows the adopted system of axes. The coordinates of the ports are given in Table I.

The plenum total pressure was measured using a static tap in the plenum sidewall. (At design conditions of 50 psia and 520$^{o}$ R in the plenum, the static pressure and total pressure were negligibly different). All pressures were recorded by the data acquisition system (Appendix B) through two 48 port Scanivalves. One Scanivalve was equipped with a 0-15 psig the other with a 0-50 psig transducer. Both transducers were calibrated to read in psig to an accuracy of 0.01 psia.

The Scanivalve connections to the 89 test section ports are given in Table I. Ports 1 and 2 on each valve were connected to atmosphere and to the reference side of the transducer respectively. Port 3 on Scanivalve 1 was connected to plenum pressure. When the flow through the perforated wall was measured, the plenum exhaust static pressure and impact pressures were connected to ports 46 and 47 of Scanivalve 2 respectively.

# III. TEST PROGRAM AND PROCEDURES

## A. CALIBRATION TESTS

Test runs were made first with the tunnel test section configuration shown in Figure 3. Data from two runs are reported. The blades and scoops were removed, and the by-pass ducts and perforated wall plenum exhaust were capped. The tests were conducted to determine a baseline static pressure distribution in the test section. The first test also served to verify the nozzle operation at design conditions, and to verify that data could be obtained within the available tunnel run time.

## B. CASCADE TESTS

Runs were made next with the tunnel configured as shown in Figure 4. Data from two runs are reported. The blades and scoops were installed with the flat sides (bottoms) of the blades aligned with the tunnel axis. The by-pass ducts and perforated wall plenum were vented to atmospheric conditions. The tests were conducted to verify that the flow would fully start through the cascade model at design pressure and to obtain first measurements. The effectiveness of and flow through the perforated section of the upper nozzle block were also evaluated. An estimate of the flow rate from the porous section was obtained using measurements of the static pressure in the perforated wall plenum exhaust pipe and of the total pressure at the exit of the pipe.

One test run was made with the same test section configuration but with the perforated wall plenum exhaust capped.

## C. WAVE CANCELLATION TESTS

The final runs were made with the blades removed and the scoops installed as shown in Figure 5. Data from the two tests are reported. The by-pass ducts and perforated wall plenum were vented to atmospheric conditions for the first run and capped for the second. These runs were made to set up a condition where just one shock wave was present in the test section in order to more easily evaluate the performance of the perforated wall in reducing shock reflections.

## D. TEST PROCEDURE

The procedure followed in each test was the same. First the flow was started through the tunnel by opening the manual shut-off valve, followed by the pneumatically operated control valve (Figure 1b). The stagnation supply pressure was brought rapidly to, and controlled at 50 psia. (± 2 psi in all tests). A single entry at the data system keyboard initiated the sequential stepping (and recording) of the Scanivalves through 96 ports. When the scan was completed, the control and shut-off valves were closed. The recorded data were first stored on magnetic cartridge tape and then recovered by a data analysis program which generated plots of the measured pressure distributions.

# IV. RESULTS AND DISCUSSION

## A. DATA PRESENTATION

Fourteen tests were conducted in the present study. Six sets of experimental data, two from each of the three types of tests conducted, were analyzed and the results included herein. These data are presented in Appendix C.

## B. DATA ANALYSIS

The flow in the cascade wind tunnel was examined by comparing the expected shockwave patterns [References 3 and 4] in the cascade with the measured distributions of the pressure ratio ($P/P_{to}$) at the wall. In a flow at Mach number 1.4 an oblique shock can result in a maximum static pressure rise of approximately 23 percent. A normal shock causes the static pressure to more than double. Comparison of pressure ratio data for ports at the same position but on opposite faces of the tunnel test section indicated that there was no significant difference at the two walls. Plots of pressure ratio along the tunnel longitudinal centerline and along the four rows of pressure taps upstream of the blades at the cascade stagger angle (Figure 6) were made and used to examine the tunnel flow characteristics.

It should be noted that the following is a preliminary and limited analysis of recently obtained data. The data points on each plot have been joined by straight lines. In some cases only, the more probable distribution between points has been indicated by broken lines.

## C. CALIBRATION TESTS

The expected primary wave pattern for this test configuration is shown in Figure 7. Since the nozzle was under-expanded, an expansion fan was expected from the end of the lower nozzle block and an oblique shock might occur from the lower nozzle block and an oblique shock might occur from the lower bypass protrusion. A plot of pressure ratio vs. position along the tunnel centerline is given in Figure 8a. In this figure, the expected expansion fan appeared clearly and a small compressive disturbance might also have been present. Plots of pressure ratio along the four diagonal rows of pressure taps are given in Figures 8b to 8e. The region covered by these taps was seen to be free of strong waves, and the effect of the expansion fan from the lower nozzle could be traced. Of considerable importance is the degree of uniformity observed in all the taps which were upstream of the expansion fan. This upstream region should be unaffected by the installation of the cascade blades. The results of the two calibration runs were compared and the results were observed to be repeatable.

## D. CASCADE TESTS

### 1. Perforated Wall Plenum Exhaust Capped

The results of the test conducted with the tunnel in its design configuration with the perforated wall plenum capped resulted in the tunnel flow not starting at the design supply plenum total pressure of 50 psia. The pressure ratio along the tunnel longitudinal centerline is shown in Figure 9. Examination of the levels of pressure suggested that the flow was choked (pressure ratio - 0.5282 if losses are neglected) at the throat of the blade passage and that the nozzle itself was operating subsonically at the test section.

2. Perforated Wall Plenum Vented to the Atmosphere

Allowing flow through the perforated section of the upper nozzle block by uncapping the exhaust resulted in the flow being fully started at the design plenum pressure of 50 psia. The expected flow with the blades and scoops installed is shown in Figure 10. The side-wall pressure distribution is shown in Figure 11a to Figure 11e. The effect of the shock waves generated by the blades can be seen by comparing the data in Figure 11 with the corresponding sections of Figure 8. A comparison of Figure 11a with Figure 8a, and of Figure 11b with Figure 8b showed that the pressure rise from the first shock wave (labelled A in Figure 11) began measurably ahead of the position of the shock wave shown in Figure 10. Also, if the pressure drop upstream of point B on Figure 11a, which was repeated on several other runs made with this configuration, was correctly interpreted to be the expansion caused by the upper surface of the nearest blade, then the bow shock from that blade also appeared to be shifted forwards. These effects may have been the result of shock wave-boundary layer interaction on the side walls, but closer examination of the data is needed before definite conclusions are drawn. The probable distributions of pressure indicated in Figure 11a were inferred from the comparison with Figure 8a and with data obtained in the Wave Cancellation Tests.

For the data shown, the velocity at the exhaust port from the perforated wall plenum was calculated to be about 47 ft/sec and the mass flow rate was approximately 0.1 percent of the tunnel mass flow rate.

E. WAVE CANCELLATION TESTS

1. Perforated Wall Plenum Vented to the Atmosphere

The test section configuration and expected wave pattern are shown in Figure 12. The measured pressure distributions are shown plotted in Figure 13a to 13e. In Figure 13a, the (first) oblique shock wave was clearly indicated. The reflected shock wave did not appear, probably as a result of the strong expansion of the flow over the suction surface of the lower scoop.

The velocity at the plenum nozzle exit was approximately 12 ft/sec and the mass flow rate therefore significantly less than 0.1 percent of the tunnel mass flow rate.

2. Perforated Wall Plenum Exhaust Capped

The pressure distributions when the net flow rate through the perforated wall was reduced to zero are shown in Figure 14a to 14e.

An examination of the magnitudes of the pressure ratios in comparison to corresponding sections of Figure 13 showed that the effect of capping the exhaust was felt everywhere downstream of a Mach wave emanating from the beginning of the perforated wall. The pressures were lower downstream of the Mach wave when the wall exhaust was open compared to when it was capped. It appeared therefore, that the effect of the unrestricted mass bleed was to propagate an additional expansion fan from the top wall across the test section.

## F. STRUCTURAL INTEGRITY

The structural adequacy of the blades, blade mountings and upper nozzle block modification were verified at design operating conditions. No deterioration was evident after the reported program of tests was completed.

## G. CASCADE PERFORMANCE

The cascade was designed as a model of the relative flow at the tip of the transonic compressor being tested at the Turbopropulsion Laboratory. The present results indicate that there was a net pressure drop rather than a pressure rise across the blade row, as occurs in the compressor. This was because the back pressure on the blades at a supply pressure of 50 psia was too low. A control on the back pressure is necessary in order to adjust the shock waves from the bottoms of the blades to become normal shocks ahead of the blade passage throats. An examination of the present data suggested that the shock waves off the bottom of the blades were, in fact, weak and oblique.

## V. CONCLUSIONS AND RECOMMENDATIONS

This document reports the initial testing of the transonic cascade wind tunnel model. Detailed wall static pressure measurements were obtained both with and without test blades installed, and with and without flow from a perforated wall section newly installed in the upper nozzle wall.

All tests were at the design total pressure of 50 psia. Wave-free flow was verified at the exit of the empty nozzle, and repeatable reference data were established against which to evaluate the effect of installing the blades. With blades installed, expected bow shock waves and suction-side expansion fans were detected from the blading. However, lack of control on the back pressure allowed the flow to remain supersonic throughout the blade passages. The incorporation of the perforated wall in the upper nozzle block was found to be required in order for the flow in the tunnel to start when the blades were installed. The complete cascade wind tunnel model was structurally sound at design operating conditions.

Two modifications are recommended before testing is resumed. First, the butterfly-valve called for in the original design [Reference 1] should be installed in the cascade exhaust duct. The valve will allow the cascade back pressure to be varied over the range to be expected in the flow through the compressor rotor, of which the cascade is a two-dimensional model. Second, an optical window sould either replace or be incorporated into the present aluminum window plates. The flow visualization by Schlieren which the windows would allow, would greatly simplify the problem of evaluating effects of back pressure and perforated wall bleed rates on the wave structure in the cascade. This could greatly simplify the problem of optimizing the wave cancellation function of the perforated wall, and of selecting conditions at which detailed pressure, and possibly probe data, should be recorded.

************ STATIC PRESSURE PORT COORDINATES **************

SCANIVALVE NO. 1

FRONT FACE

| | | | |
|---|---|---|---|
| S V Port No. 3 | Pressure Tap No. 1 | X =-3.318 inches | Y= 0.000 inches |
| S V Port No. 4 | Pressure Tap No. 2 | X =-2.905 inches | Y= 0.000 inches |
| S V Port No. 5 | Pressure Tap No. 3 | X =-2.618 inches | Y= 0.000 inches |
| S V Port No. 6 | Pressure Tap No. 4 | X =-4.246 inches | Y=-1.344 inches |
| S V Port No. 7 | Pressure Tap No. 5 | X =-3.082 inches | Y= -.672 inches |
| S V Port No. 8 | Pressure Tap No. 6 | X =-2.306 inches | Y= -.224 inches |
| S V Port No. 9 | Pressure Tap No. 7 | X =-2.112 inches | Y= -.112 inches |
| S V Port No. 10 | Pressure Tap No. 8 | X =-1.918 inches | Y= 0.000 inches |
| S V Port No. 11 | Pressure Tap No. 9 | X =-1.724 inches | Y= .112 inches |
| S V Port No. 12 | Pressure Tap No. 10 | X =-1.530 inches | Y= .224 inches |
| S V Port No. 13 | Pressure Tap No. 11 | X = -.754 inches | Y= .672 inches |
| S V Port No. 14 | Pressure Tap No. 12 | X = .410 inches | Y= 1.344 inches |
| S V Port No. 15 | Pressure Tap No. 13 | X =-3.546 inches | Y=-1.344 inches |
| S V Port No. 16 | Pressure Tap No. 14 | X =-2.382 inches | Y= -.672 inches |
| S V Port No. 17 | Pressure Tap No. 15 | X =-1.606 inches | Y= -.224 inches |
| S V Port No. 18 | Pressure Tap No. 16 | X =-1.412 inches | Y= -.112 inches |
| S V Port No. 19 | Pressure Tap No. 17 | X =-1.218 inches | Y= 0.000 inches |
| S V Port No. 20 | Pressure Tap No. 18 | X =-1.024 inches | Y= .112 inches |
| S V Port No. 21 | Pressure Tap No. 19 | X = -.830 inches | Y= .224 inches |
| S V Port No. 22 | Pressure Tap No. 20 | X = -.054 inches | Y= .672 inches |
| S V Port No. 23 | Pressure Tap No. 21 | X = 1.110 inches | Y= 1.344 inches |
| S V Port No. 24 | Pressure Tap No. 22 | X =-2.846 inches | Y=-1.344 inches |
| S V Port No. 25 | Pressure Tap No. 23 | X =-1.682 inches | Y= -.672 inches |
| S V Port No. 26 | Pressure Tap No. 24 | X = -.905 inches | Y= -.224 inches |
| S V Port No. 27 | Pressure Tap No. 25 | X = -.712 inches | Y= -.112 inches |
| S V Port No. 28 | Pressure Tap No. 26 | X = -.518 inches | Y= 0.000 inches |
| S V Port No. 29 | Pressure Tap No. 27 | X = -.324 inches | Y= .112 inches |
| S V Port No. 30 | Pressure Tap No. 28 | X = -.130 inches | Y= .224 inches |
| S V Port No. 31 | Pressure Tap No. 29 | X = .646 inches | Y= [illegible] inches |
| S V Port No. 32 | Pressure Tap No. 30 | X = 1.810 inches | Y= 1.344 inches |
| S V Port No. 33 | Pressure Tap No. 31 | X =-2.594 inches | Y= 1.344 inches |
| S V Port No. 34 | Pressure Tap No. 32 | X =-1.430 inches | Y= [illegible] |
| S V Port No. 35 | Pressure Tap No. 33 | X = -.654 inches | Y= [illegible] |
| S V Port No. 36 | Pressure Tap No. 34 | X = -.460 inches | Y= .112 [illegible] |
| S V Port No. 37 | Pressure Tap No. 35 | X = -.266 inches | Y= 0.000 [illegible] |
| S V Port No. 38 | Pressure Tap No. 36 | X = -.052 inches | Y= .112 [illegible] |
| S V Port No. 39 | Pressure Tap No. 37 | X = .122 inches | Y= .224 [illegible] |
| S V Port No. 40 | Pressure Tap No. 38 | X = .898 inches | Y= [illegible] |
| S V Port No. 41 | Pressure Tap No. 39 | X = 2.062 inches | Y= 1.344 [illegible] |
| S V Port No. 42 | Pressure Tap No. 40 | X = -.388 inches | Y= -.224 [illegible] |
| S V Port No. 43 | Pressure Tap No. 41 | X = -.194 inches | Y= [illegible] |
| S V Port No. 44 | Pressure Tap No. 42 | X = 0.000 inches | Y= 0.000 [illegible] |
| S V Port No. 45 | Pressure Tap No. 43 | X = .194 inches | Y= .112 [illegible] |
| S V Port No. 46 | Pressure Tap No. 44 | X = .388 inches | Y= [illegible] |
| S V Port No. 47 | Pressure Tap No. 45 | X = .050 inches | Y= .112 [illegible] |
| S V Port No. 48 | Pressure Tap No. 46 | X = .224 inches | Y= 0.000 [illegible] |

**Table I. Cascade Wind Tunnel Static Pressure Tap Positions and Scanivale Port Connections**

SCANIVALVE NO. 2

| | | | |
|---|---|---|---|
| S/V Port No. 3 | Pressure Tap No. 47 | X = .050 inches | Y= -.112 inches |
| S/V Port No. 4 | Pressure Tap No. 48 | X = .224 inches | Y= 0.000 inches |
| S/V Port No. 5 | Pressure Tap No. 49 | X = .438 inches | Y= .112 inches |
| S/V Port No. 6 | Pressure Tap No. 50 | X = .632 inches | Y= .224 inches |
| S/V Port No. 7 | Pressure Tap No. 51 | X = .138 inches | Y= -.224 inches |
| S/V Port No. 8 | Pressure Tap No. 52 | X = .330 inches | Y= -.112 inches |
| S/V Port No. 9 | Pressure Tap No. 53 | X = .524 inches | Y= 0.000 inches |
| S/V Port No. 10 | Pressure Tap No. 54 | X = .718 inches | Y= .112 inches |
| S/V Port No. 11 | Pressure Tap No. 55 | X = .388 inches | Y= -.224 inches |
| S/V Port No. 12 | Pressure Tap No. 56 | X = .582 inches | Y= -.112 inches |
| S/V Port No. 13 | Pressure Tap No. 57 | X = .776 inches | Y= 0.000 inches |
| S/V Port No. 14 | Pressure Tap No. 58 | X = .970 inches | Y= .112 inches |
| S/V Port No. 15 | Pressure Tap No. 59 | X = .856 inches | Y= -.112 inches |
| S/V Port No. 16 | Pressure Tap No. 60 | X = 1.050 inches | Y= 0.000 inches |
| S/V Port No. 17 | Pressure Tap No. 61 | X = 1.244 inches | Y= .112 inches |
| S/V Port No. 18 | Pressure Tap No. 62 | X = 1.438 inches | Y= .224 inches |
| S/V Port No. 19 | Pressure Tap No. 63 | X = 1.194 inches | Y= -.224 inches |
| S/V Port No. 20 | Pressure Tap No. 64 | X = 1.388 inches | Y= -.112 inches |
| S/V Port No. 21 | Pressure Tap No. 65 | X = 1.582 inches | Y= 0.000 inches |
| S/V Port No. 22 | Pressure Tap No. 66 | X = 1.776 inches | Y= .112 inches |
| S/V Port No. 23 | Pressure Tap No. 67 | X = .022 inches | Y=-1.344 inches |
| S/V Port No. 24 | Pressure Tap No. 68 | X = 1.126 inches | Y= -.672 inches |
| S/V Port No. 25 | Pressure Tap No. 69 | X = 2.350 inches | Y= 0.000 inches |
| S/V Port No. 26 | Pressure Tap No. 70 | X = 3.574 inches | Y= .672 inches |
| S/V Port No. 27 | Pressure Tap No. 71 | X = 4.678 inches | Y= 1.344 inches |
| S/V Port No. 28 | Pressure Tap No. 72 | X =-2.905 inches | Y= 1.630 inches |
| S/V Port No. 29 | Pressure Tap No. 73 | X =-2.905 inches | Y=-1.850 inches |
| S/V Port No. 30 | Pressure Tap No. 74 | X = 2.905 inches | Y= 1.828 inches |

REAR FACE

| | | | |
|---|---|---|---|
| S/V Port No. 29 | Pressure Tap No. 75 | X =-5.360 inches | Y= 0.000 inches |
| S/V Port No. 30 | Pressure Tap No. 76 | X =-2.905 inches | Y= 0.000 inches |
| S/V Port No. 31 | Pressure Tap No. 77 | X =-2.594 inches | Y=-1.344 inches |
| S/V Port No. 32 | Pressure Tap No. 78 | X =-1.430 inches | Y= -.672 inches |
| S/V Port No. 33 | Pressure Tap No. 79 | X = -.266 inches | Y= 0.000 inches |
| S/V Port No. 34 | Pressure Tap No. 80 | X = .898 inches | Y= .672 inches |
| S/V Port No. 35 | Pressure Tap No. 81 | X = 2.062 inches | Y= 1.344 inches |
| S/V Port No. 36 | Pressure Tap No. 82 | X = .022 inches | Y=-1.344 inches |
| S/V Port No. 37 | Pressure Tap No. 83 | X = 1.126 inches | Y= -.672 inches |
| S/V Port No. 38 | Pressure Tap No. 84 | X = 2.350 inches | Y= 0.000 inches |
| S/V Port No. 39 | Pressure Tap No. 85 | X = 3.574 inches | Y= .672 inches |
| S/V Port No. 40 | Pressure Tap No. 86 | X = 4.678 inches | Y= 1.344 inches |
| S/V Port No. 41 | Pressure Tap No. 87 | X =-2.905 inches | Y= 1.630 inches |
| S/V Port No. 42 | Pressure Tap No. 88 | X =-2.905 inches | Y=-1.850 inches |
| S/V Port No. 43 | Pressure Tap No. 89 | X = 2.905 inches | Y= 1.828 inches |

**Table I. (Continued)**

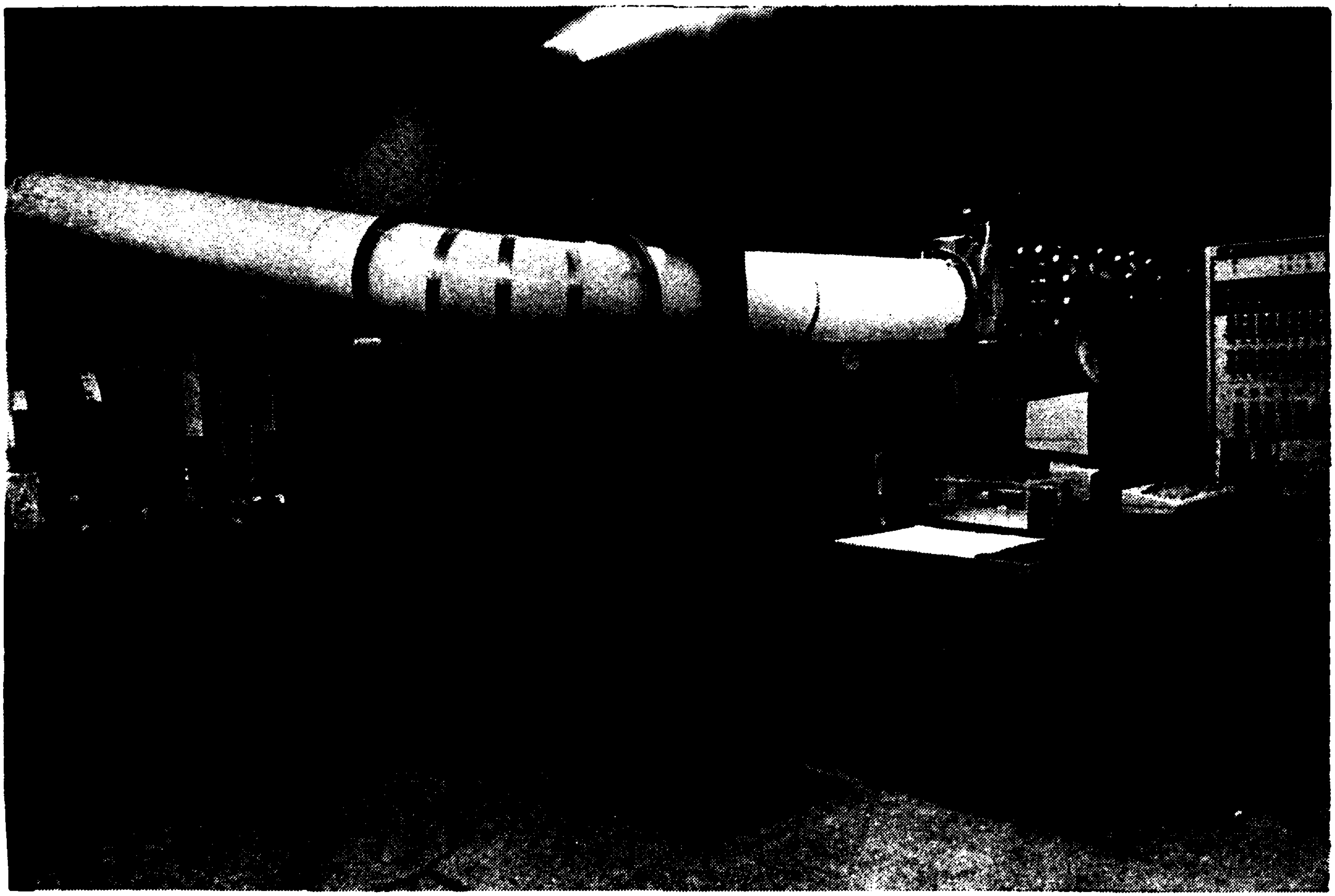


Figure 1a  Cascade Wind Tunnel Model Installation
Laboratory View

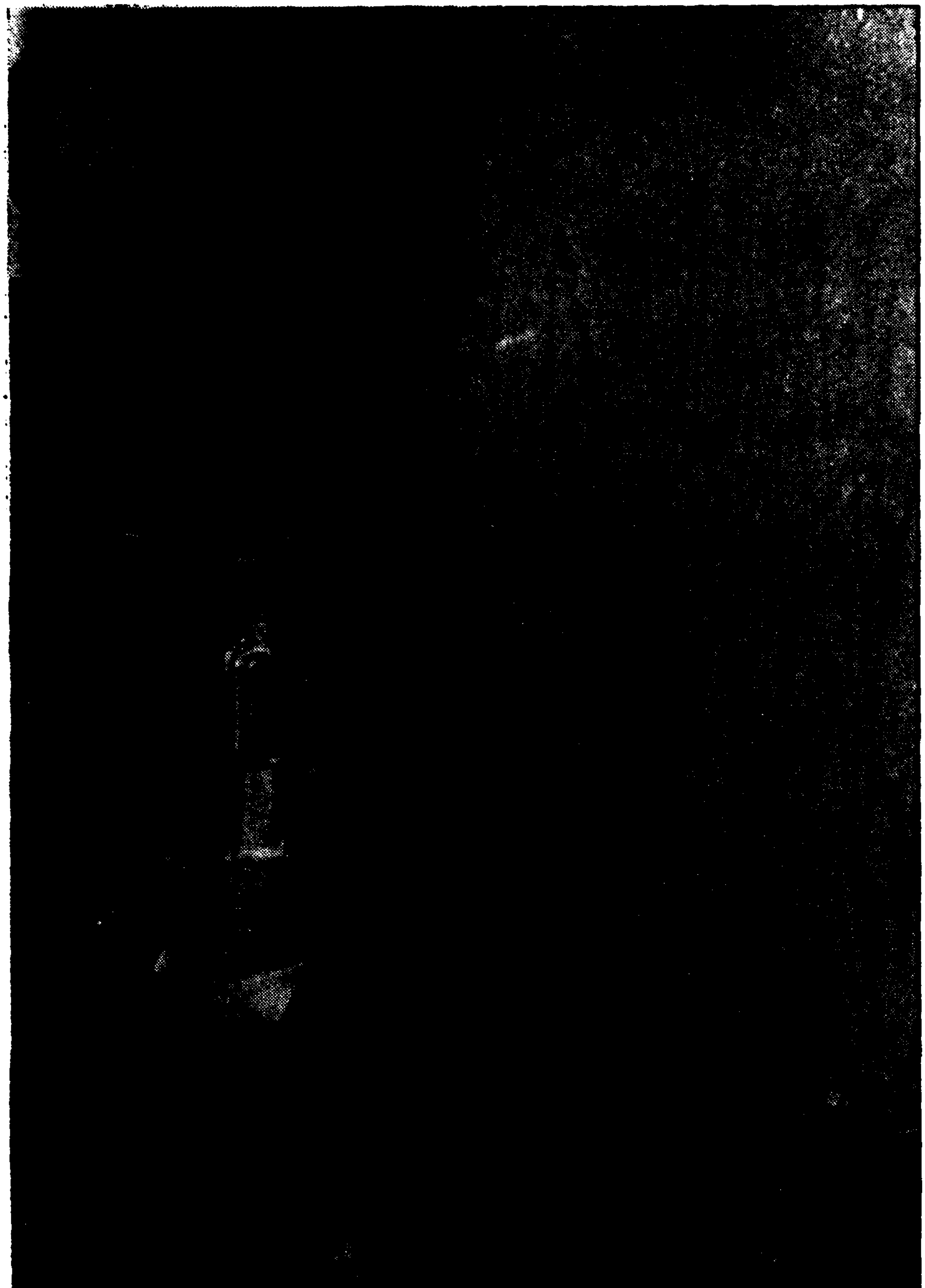


**Figure 1b  Cascade Wind Tunnel Model Installation Air Supply Valves**

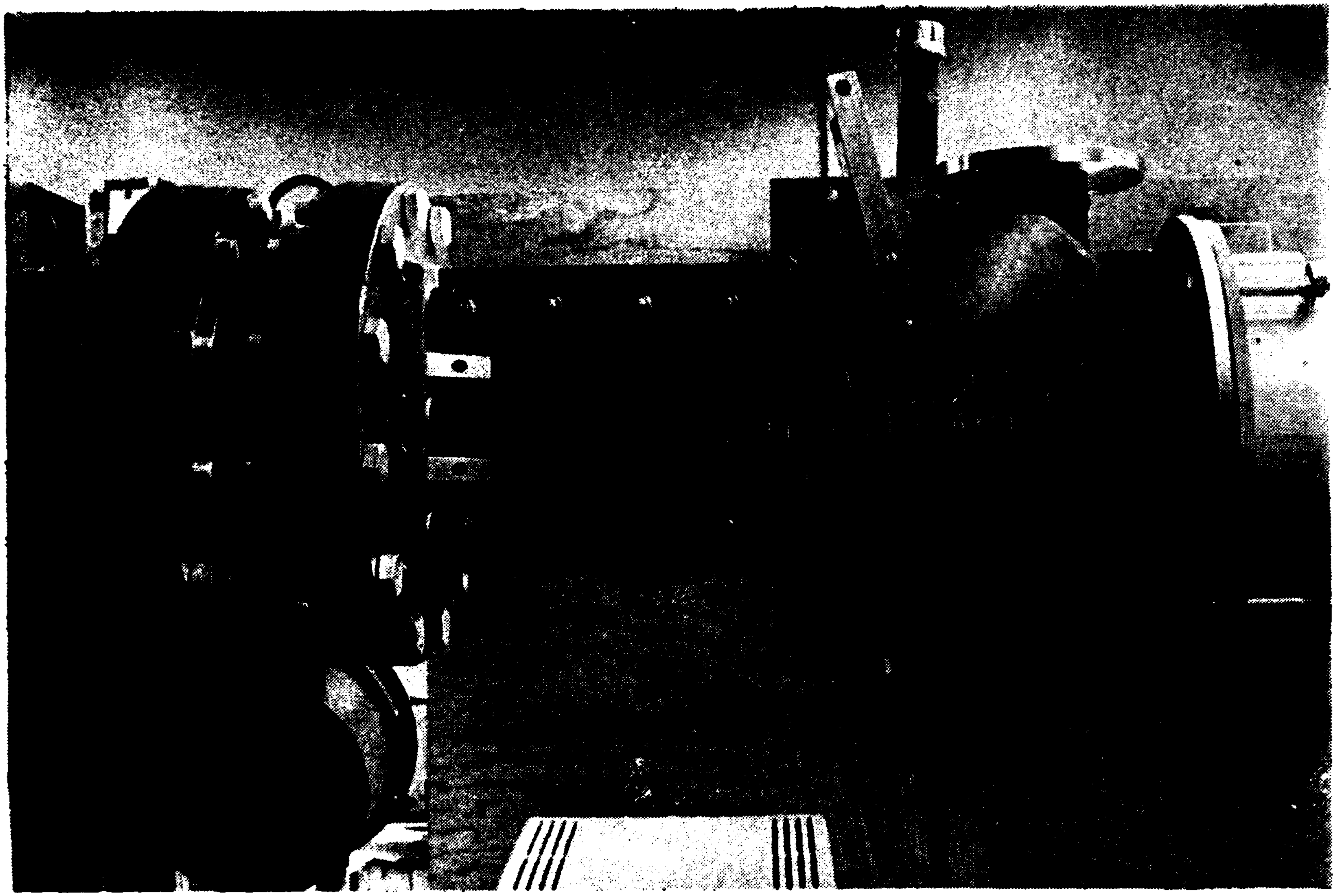


Figure 1c  Cascade Wind Tunnel Model Installation
South side of Test Section

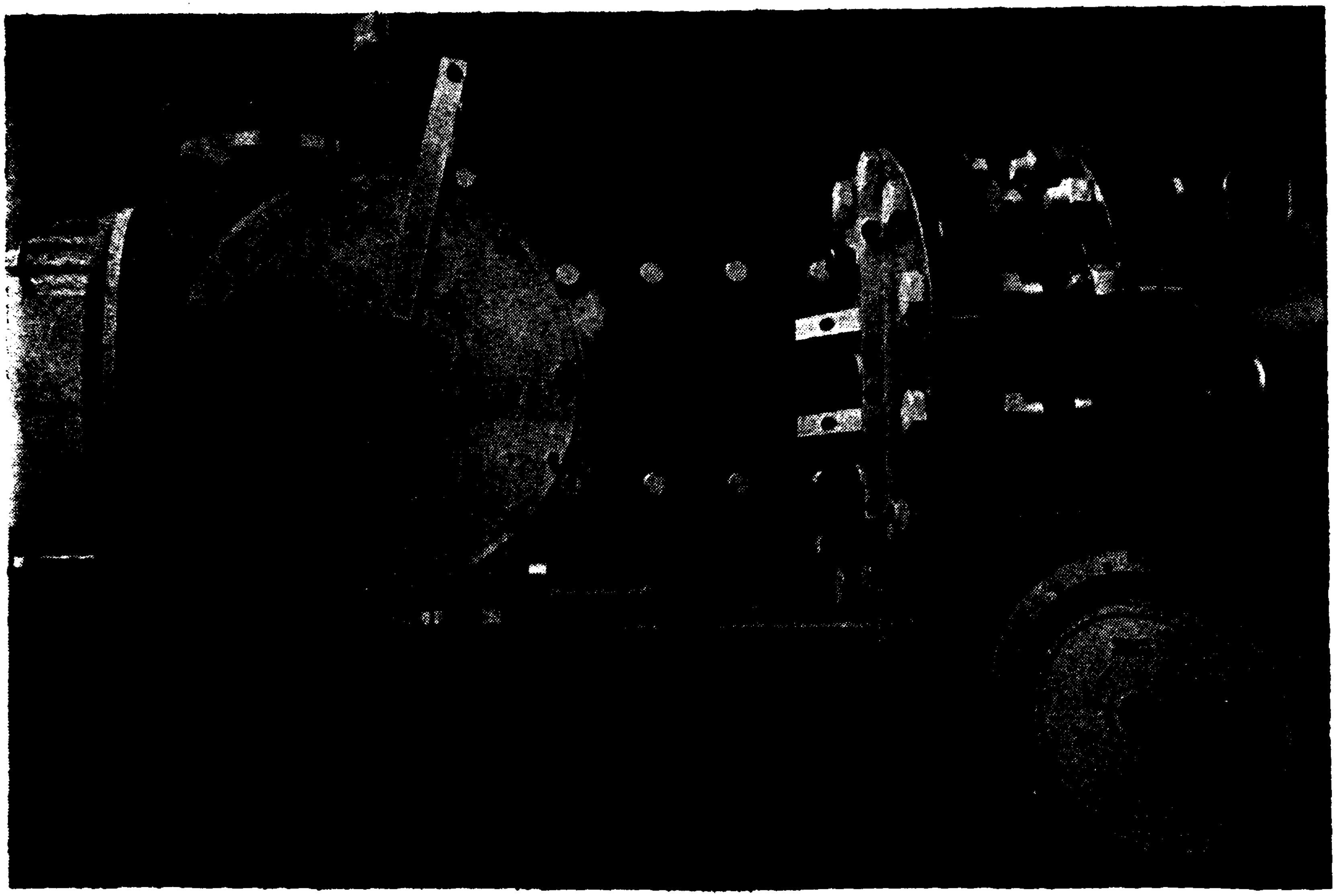


Figure 1d  Cascade Wind Tunnel Model Installation
North Side of Test Section

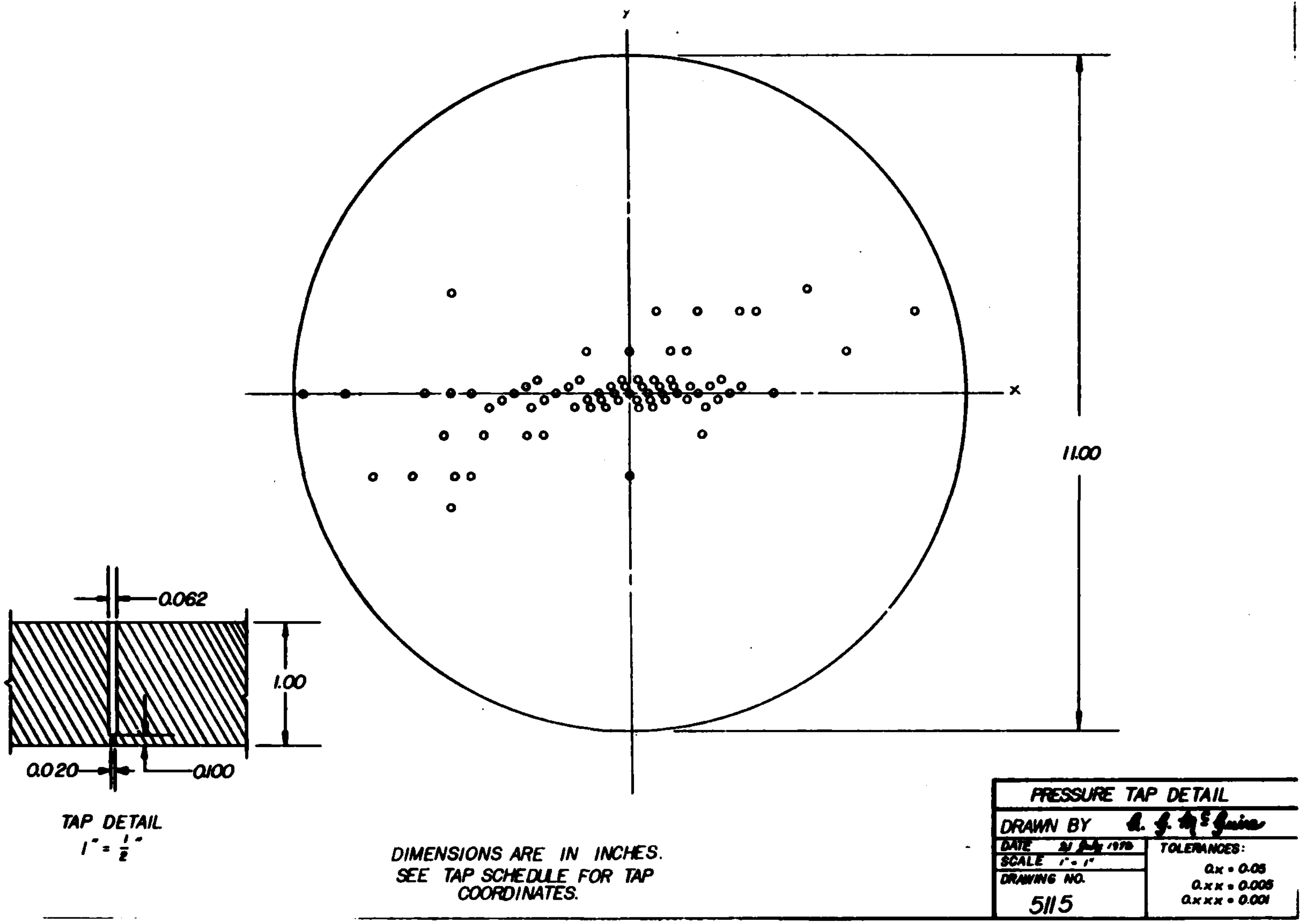



Figure 2 Cascade Wind Tunnel Test Section Static Pressure Tap Positions

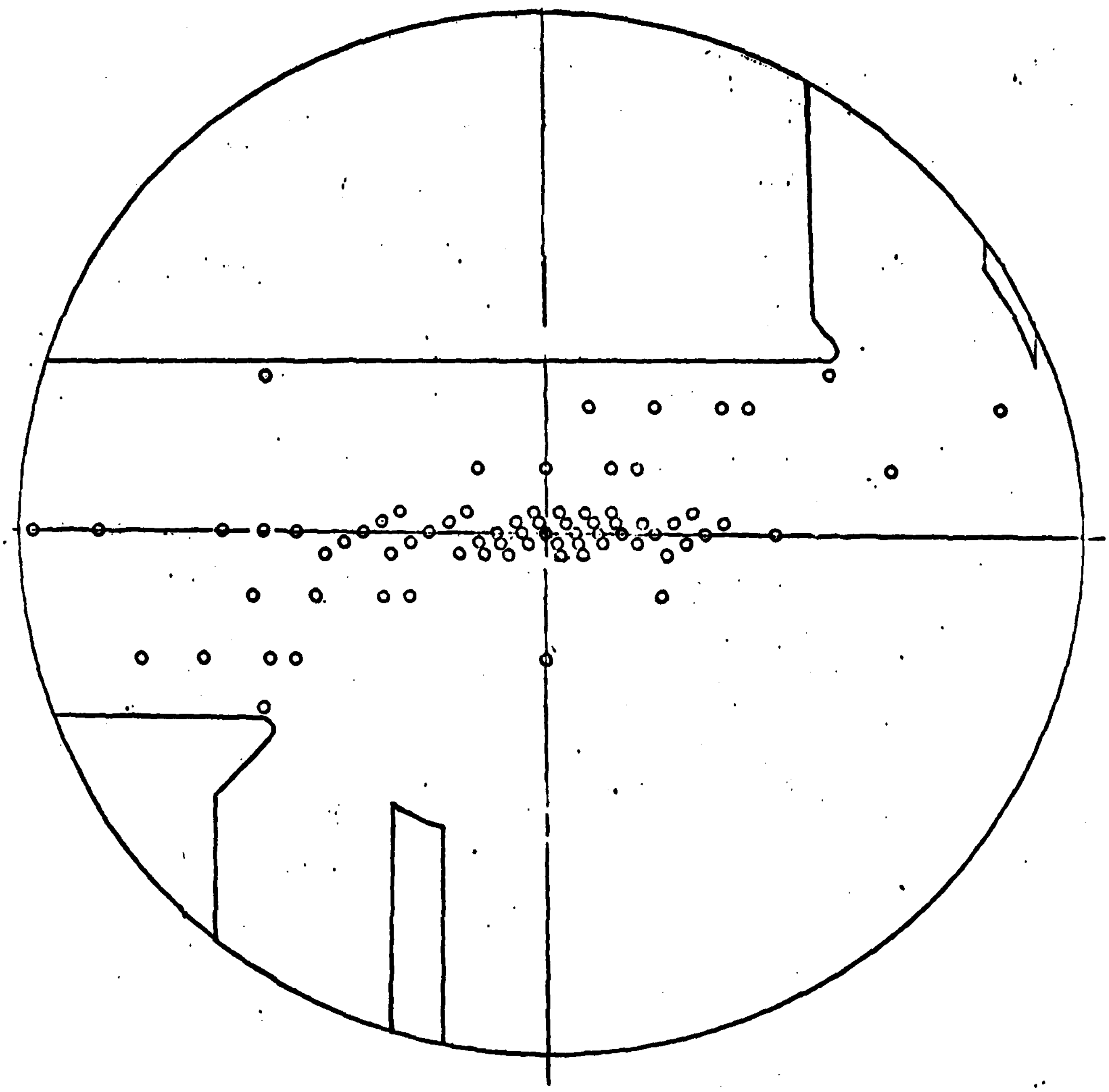


Figure 3. Test Section Configuration for Calibration Tests

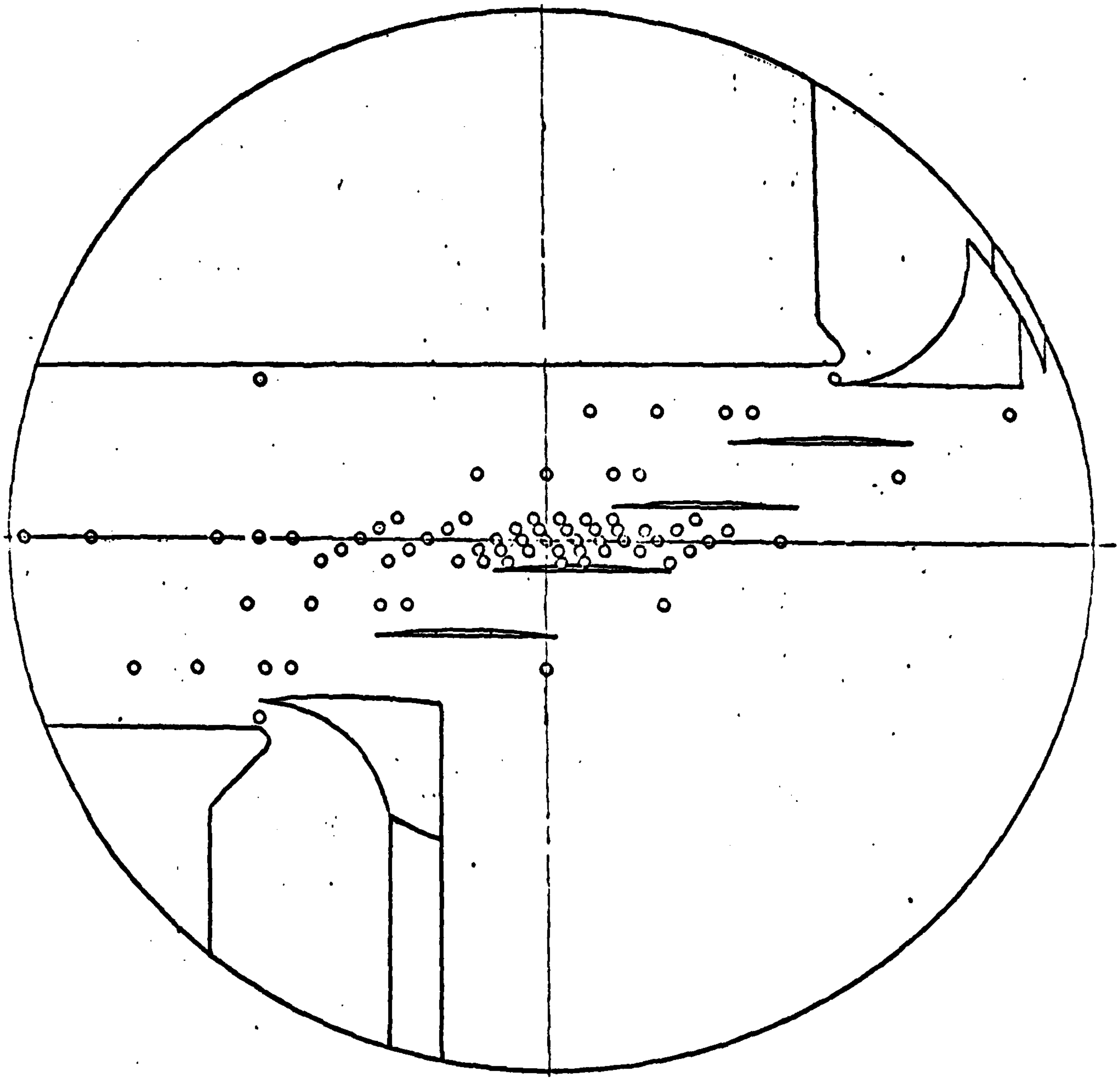


Figure 4. Test Section Configuration for Initial Cascade Tests

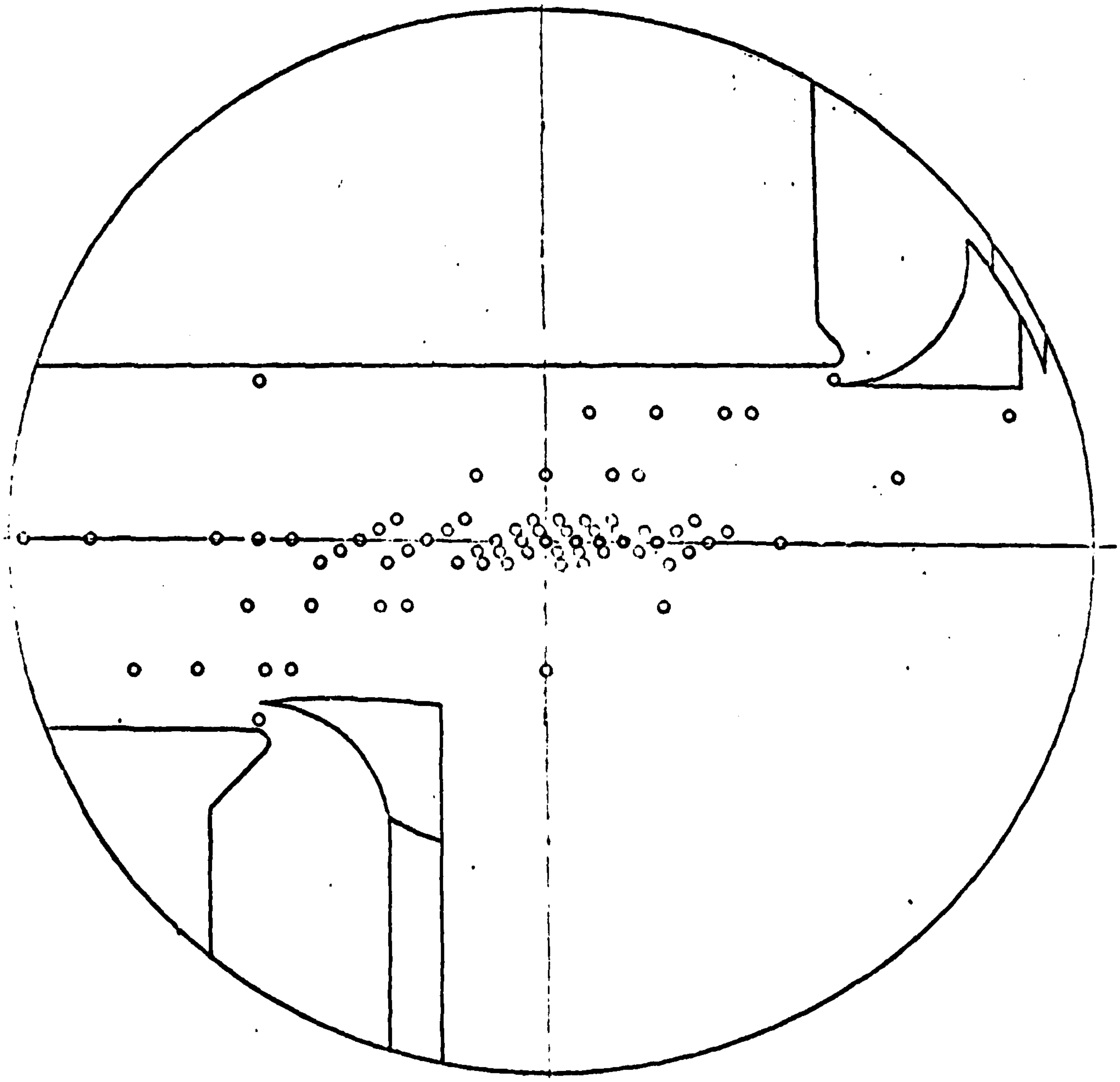


Figure 5. Test Section Configuration for Wave Cancellation Tests

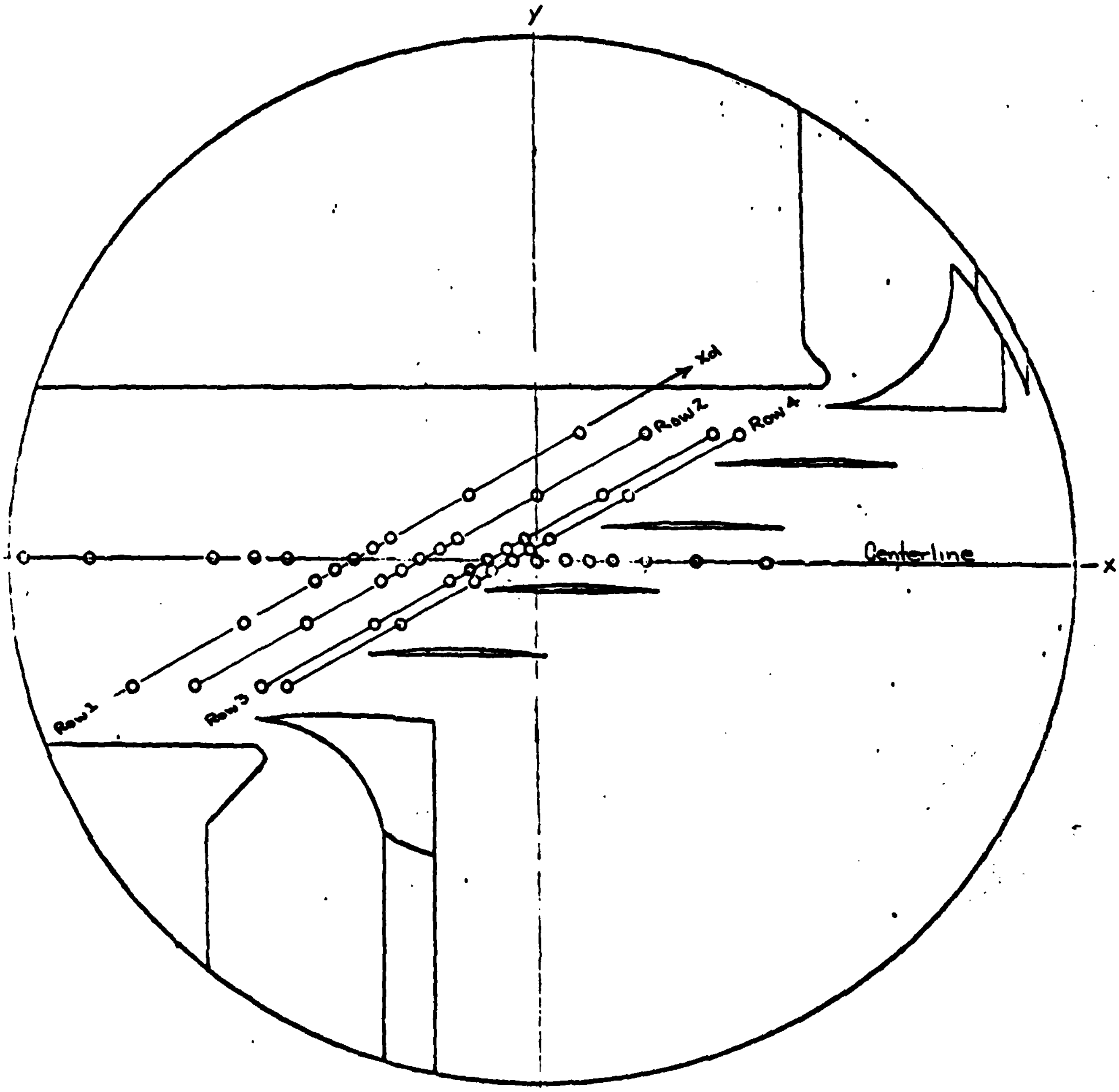



Figure 6. Centerline and Four Diagonal Rows of Static Pressure Taps for Which Data are Plotted

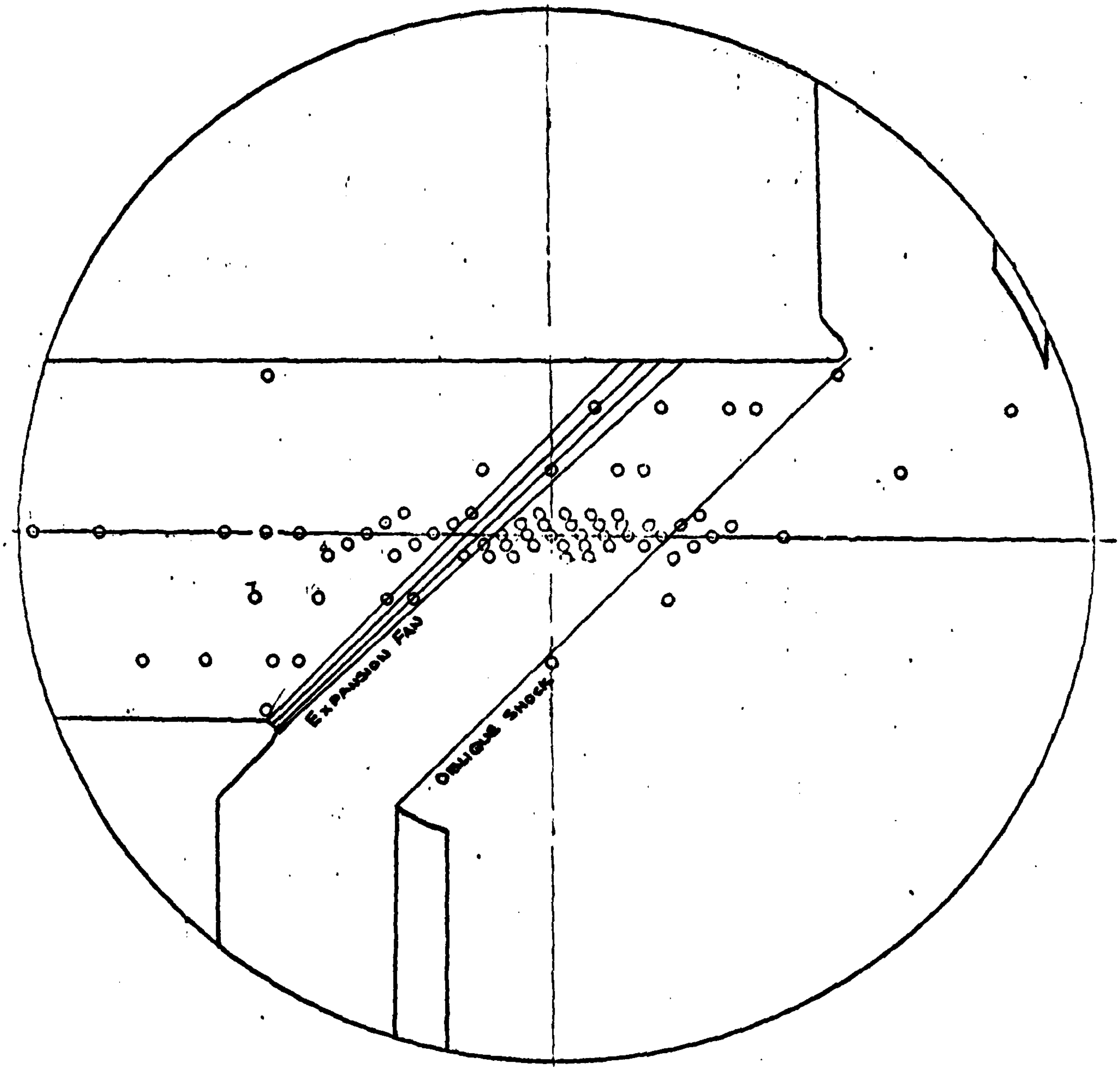



Figure 7. Expected Test Section Wave Pattern (Calibration Tests)

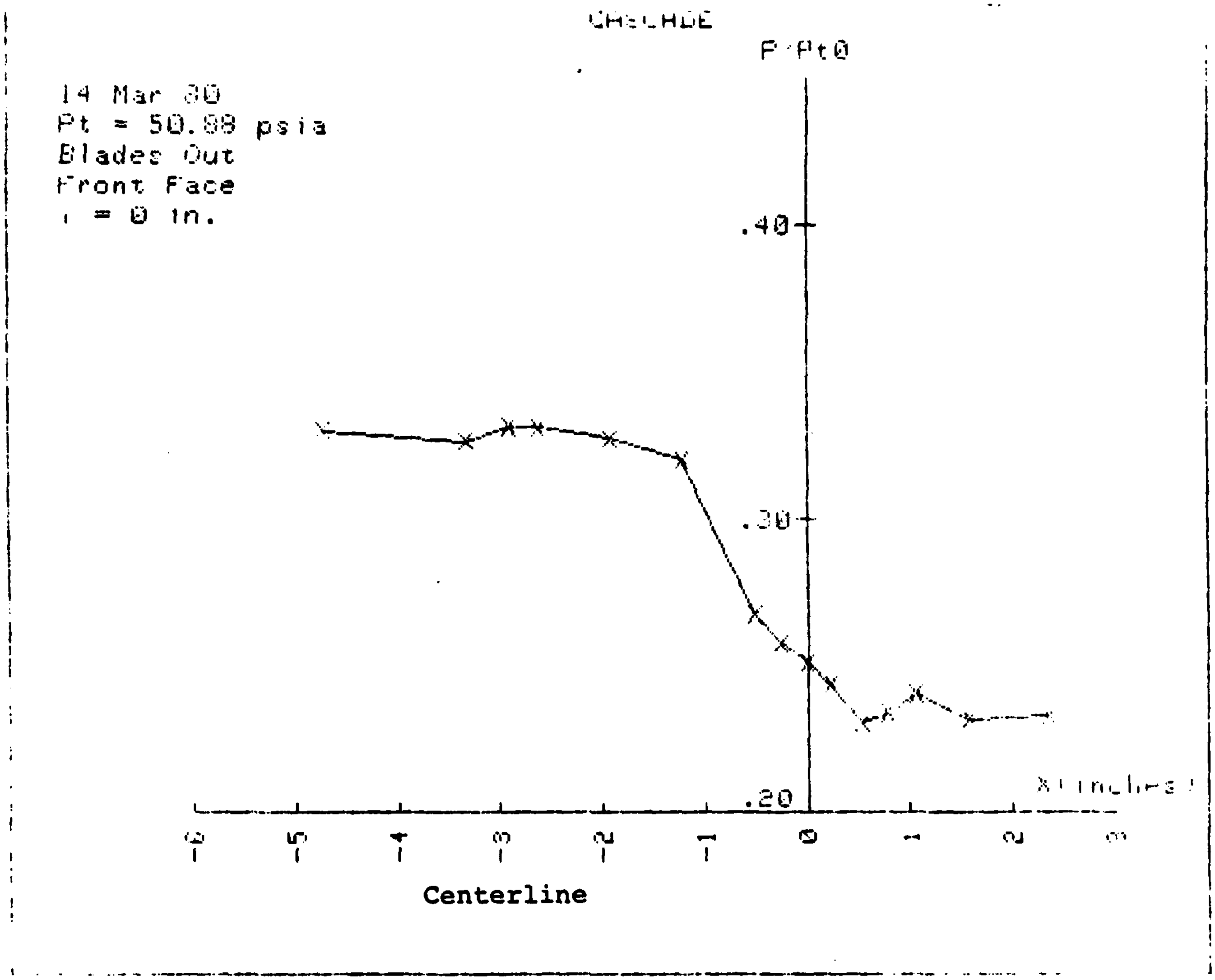



Figure 8a. Pressure Ratio vs. Position (Calibration Tests)

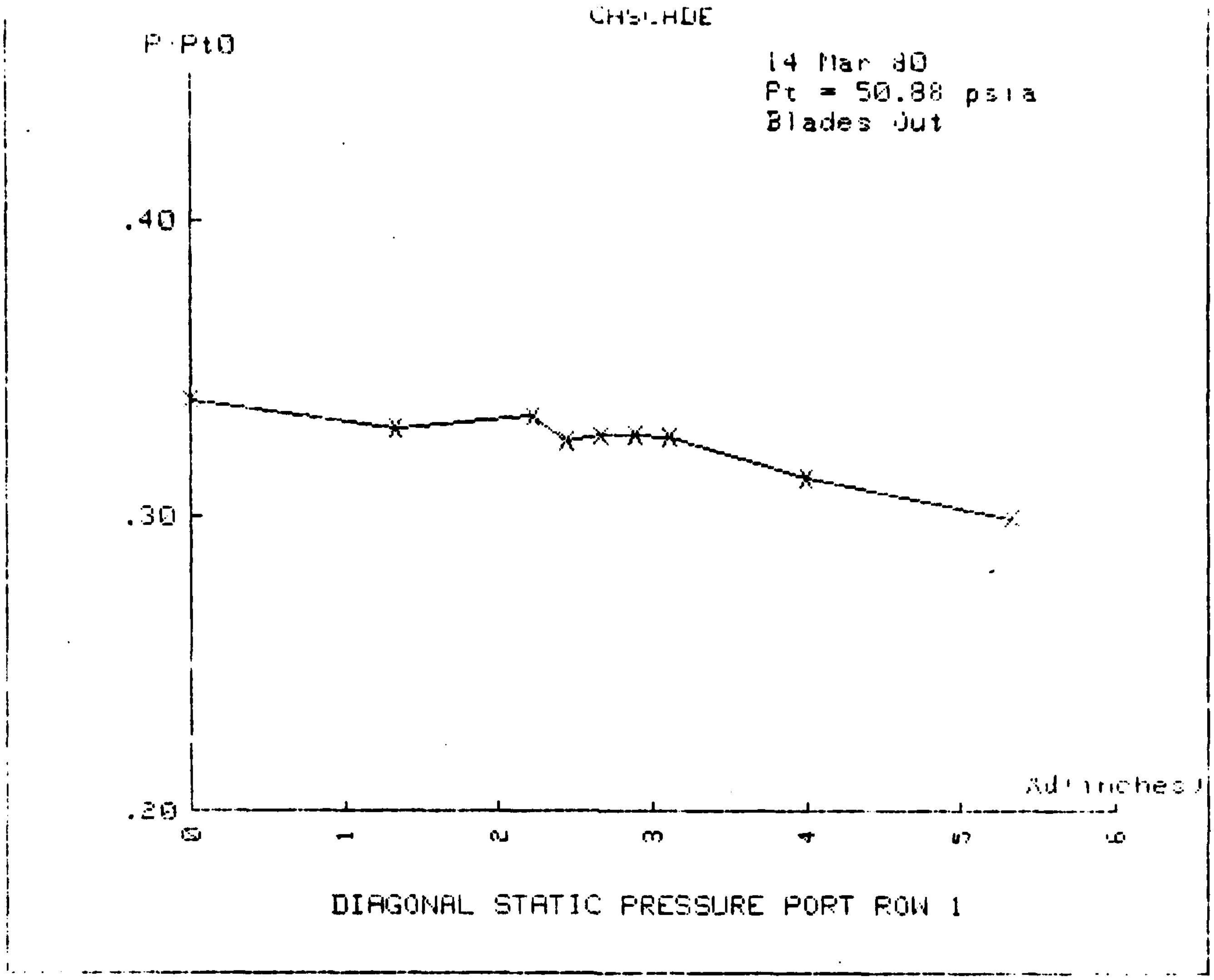



**Figure 8b. Pressure Ratio vs. Position (Calibration Test)**

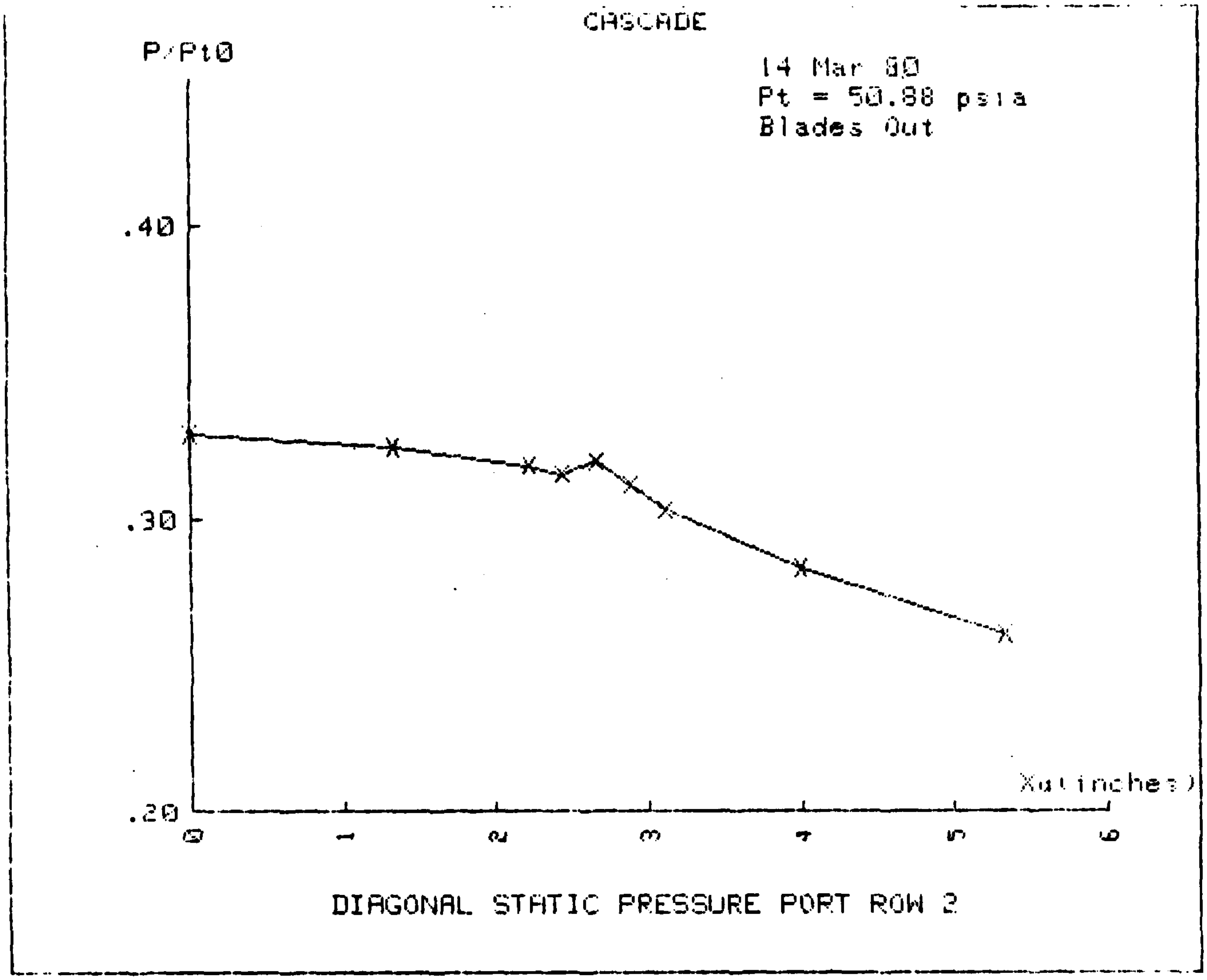



**Figure 8c. Pressure Ratio vs Position (Calibration Test)**

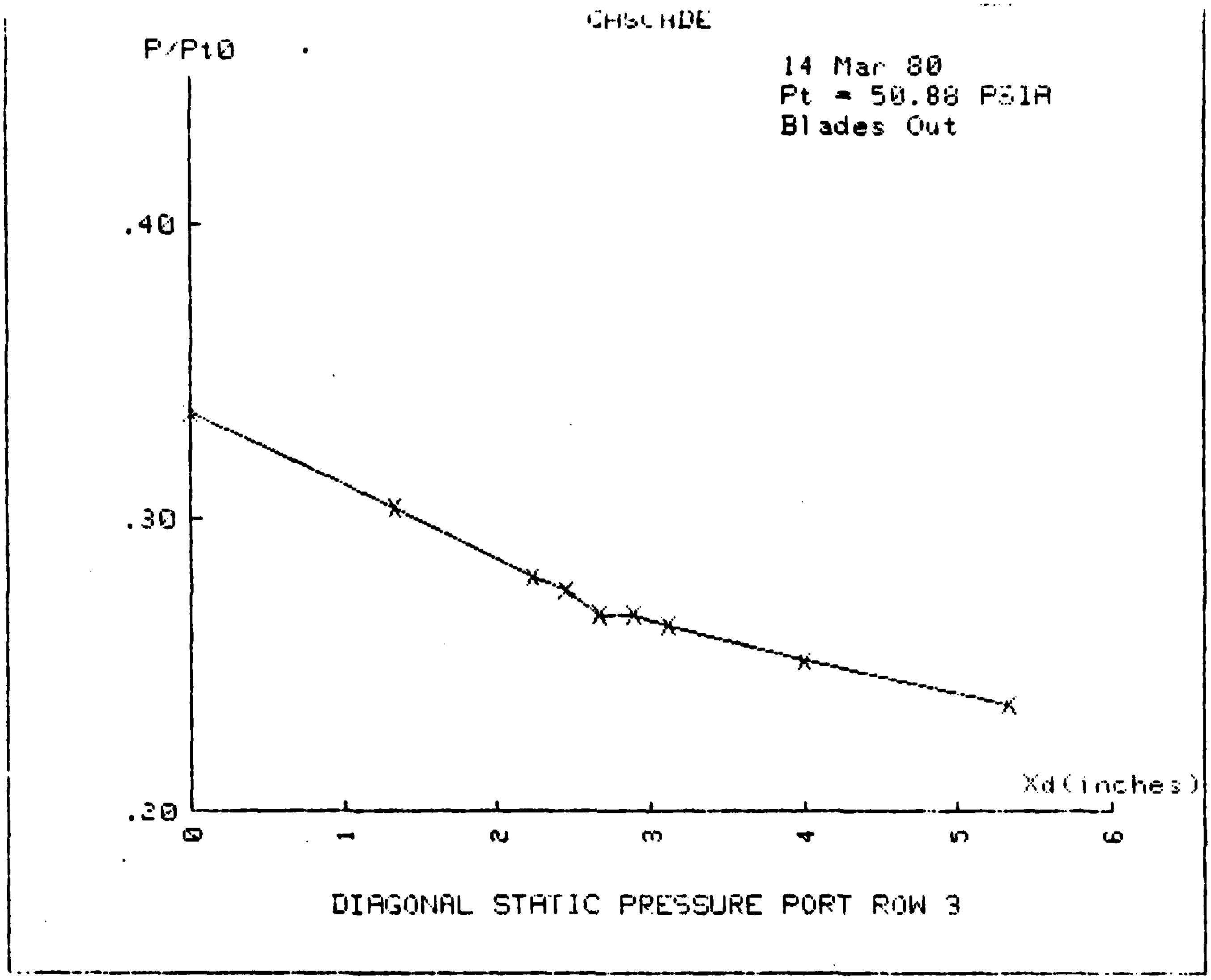



**Figure 8d. Pressure Ratio vs. Position (Calibration Tests)**

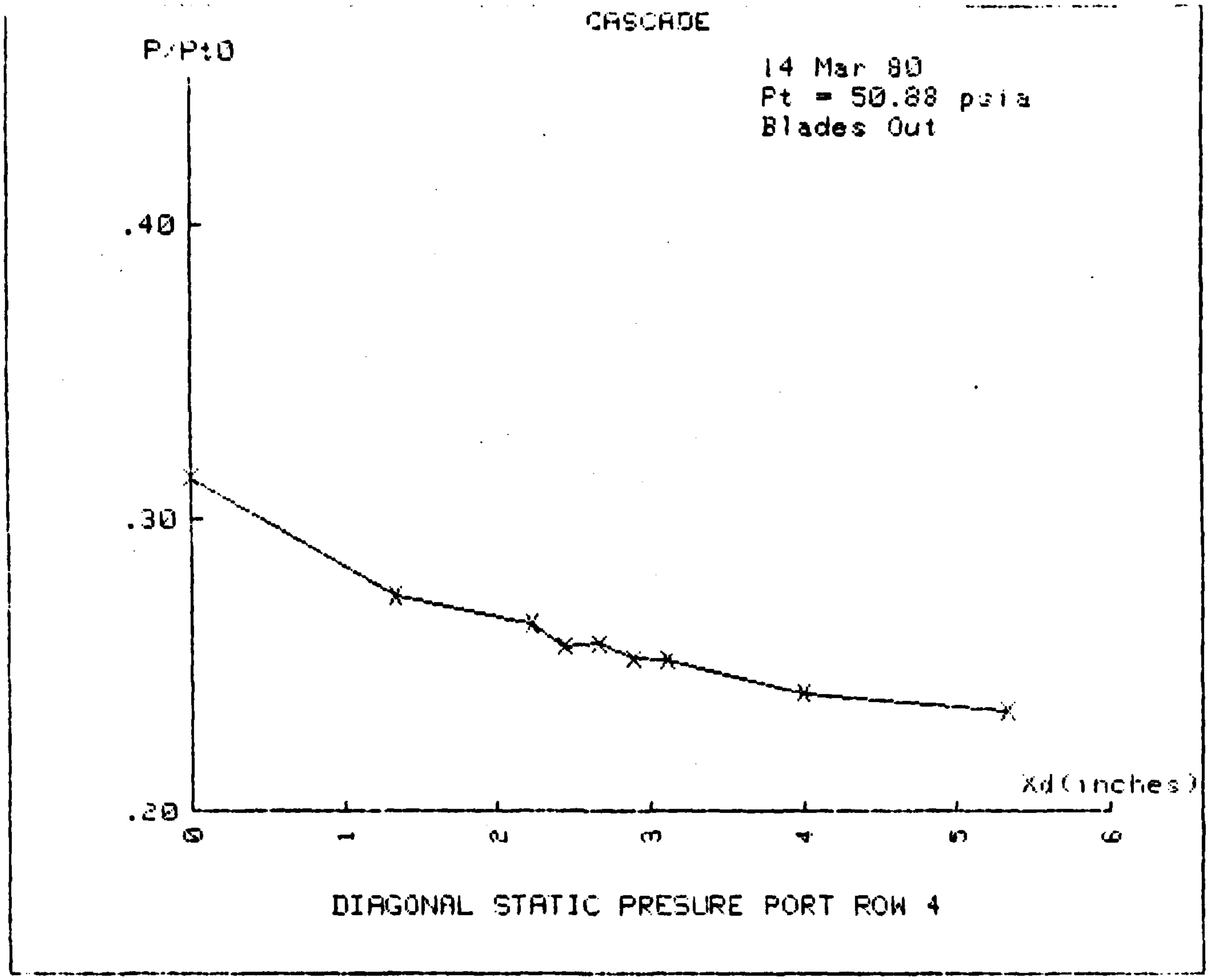



Figure 8e. Pressure Ratio vs. Position (Calibration Test)

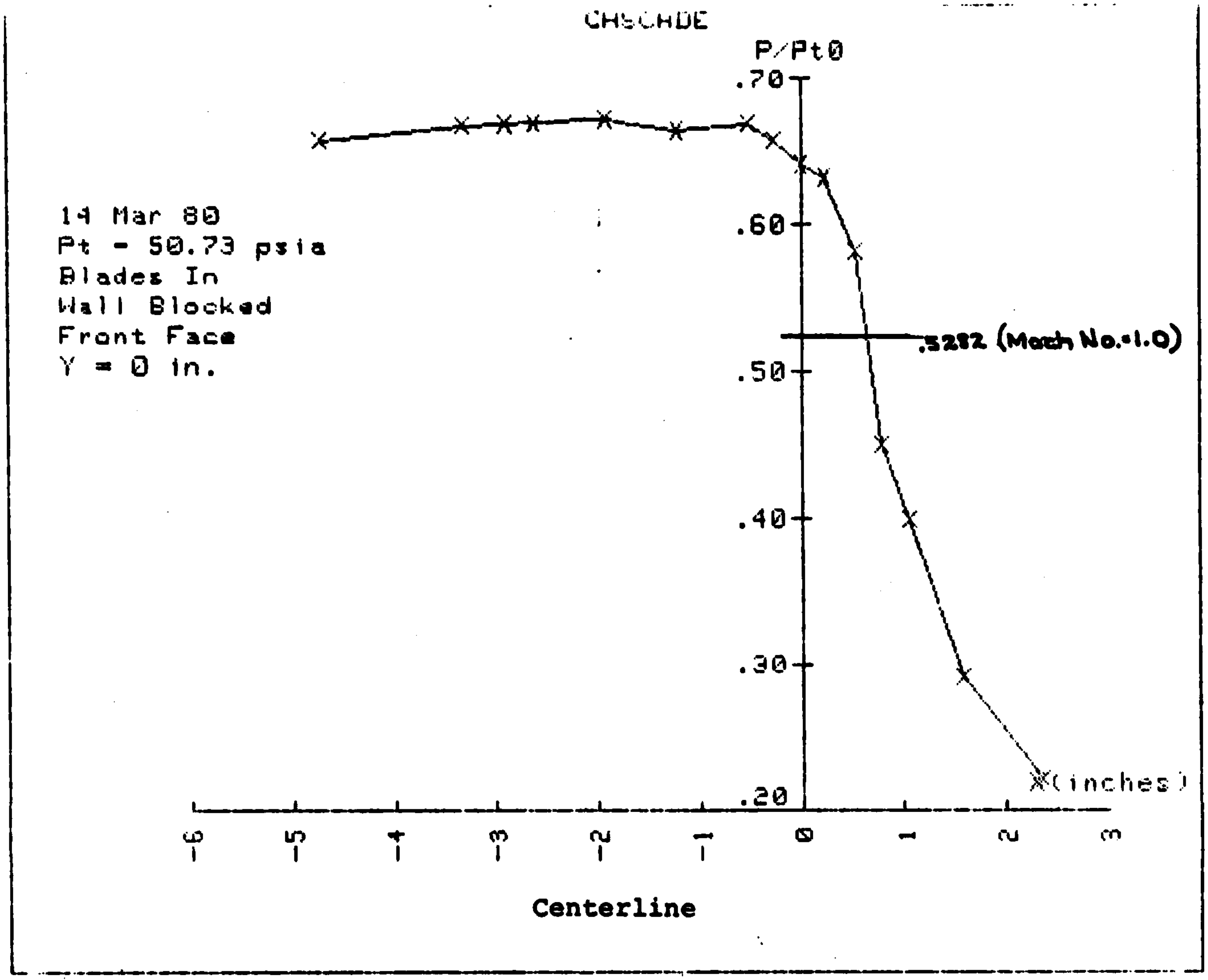



**Figure 9. Pressure Ratio vs. Position (Cascade Test I)**

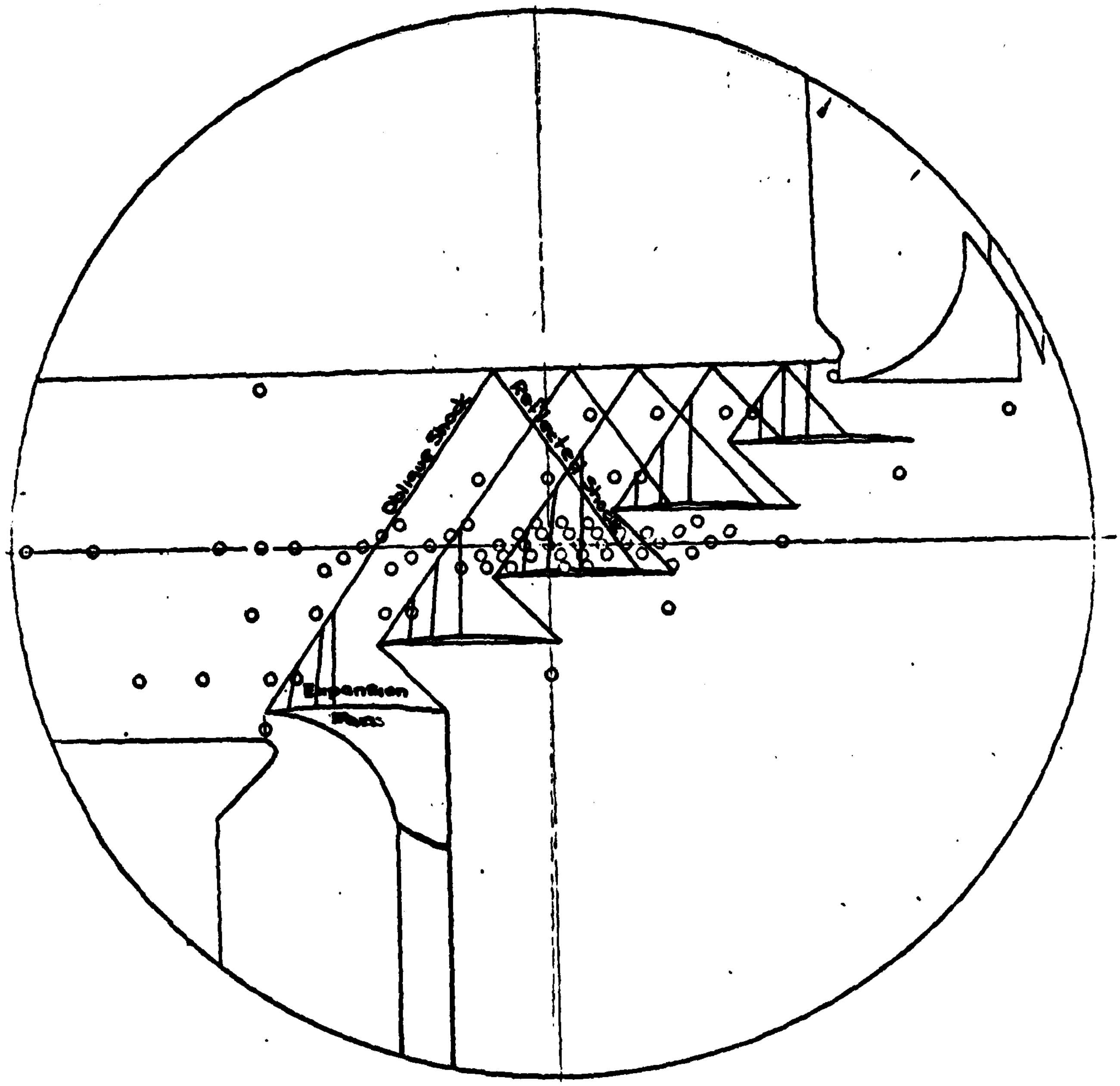



Figure 10. Expected Test Section Wave Pattern (Cascade Tests)

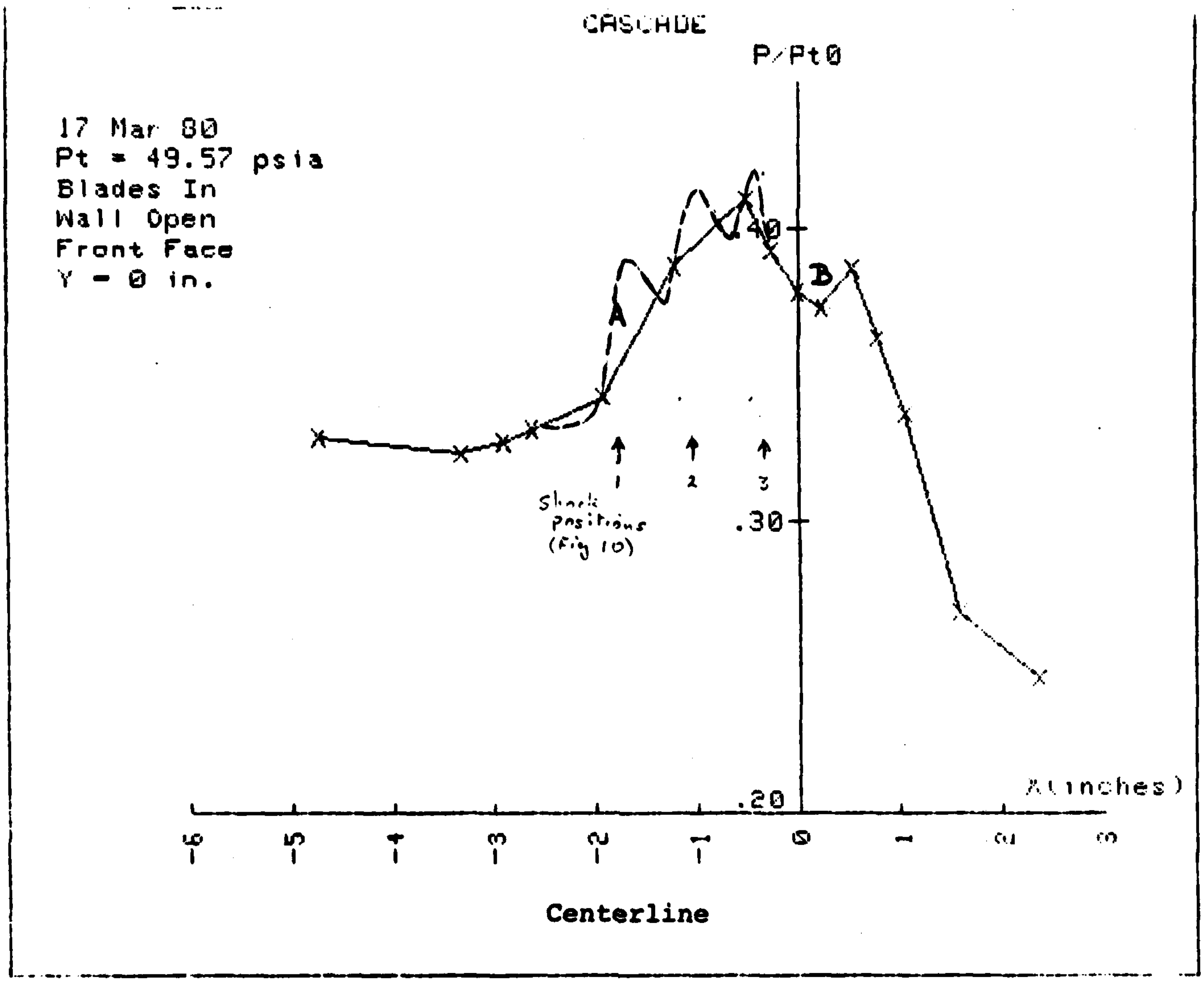



**Figure 11a. Pressure Ratio vs. Position (Cascade Test II)**

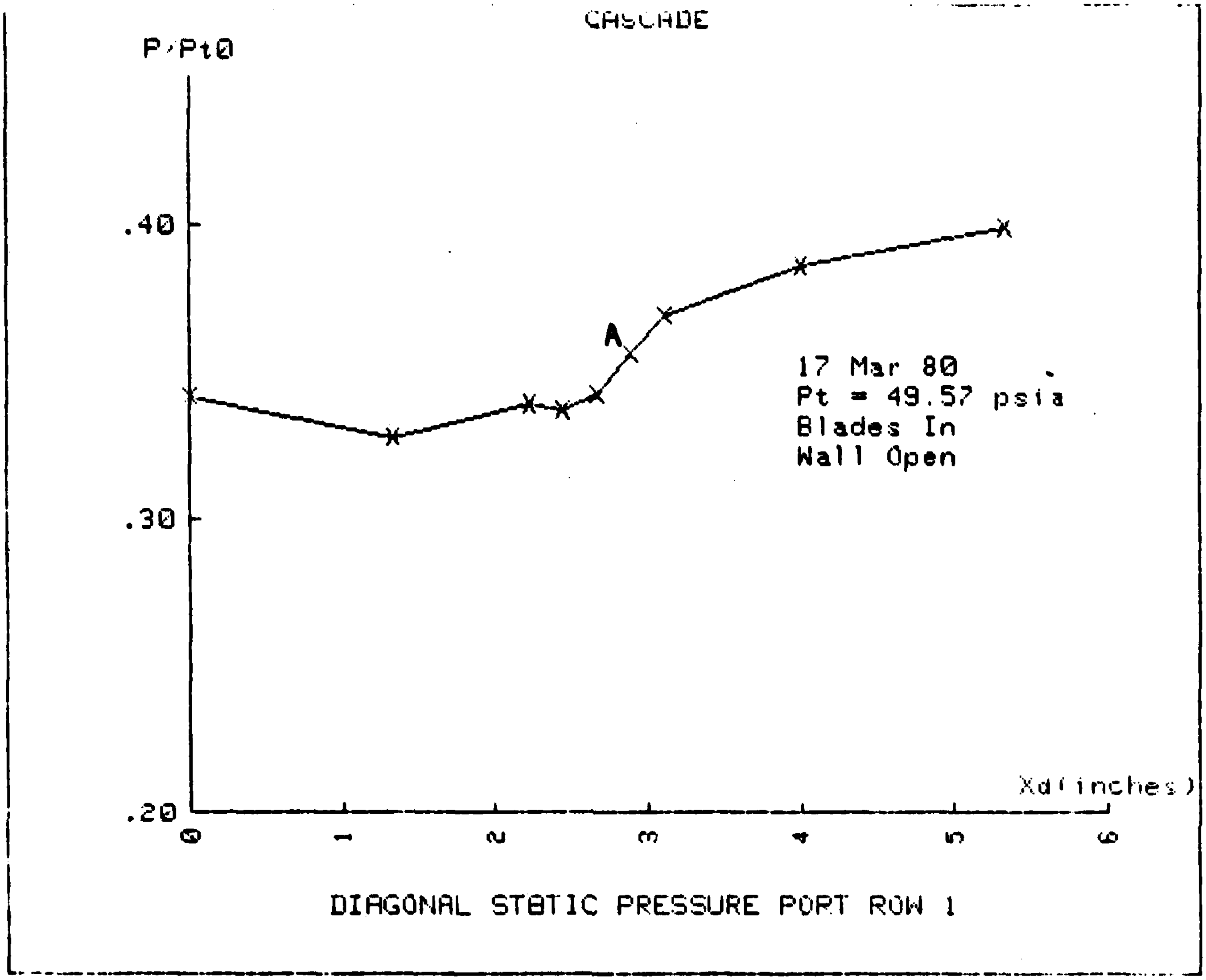



**Figure 11b. Pressure Ratio vs. Position (Cascade Test II)**

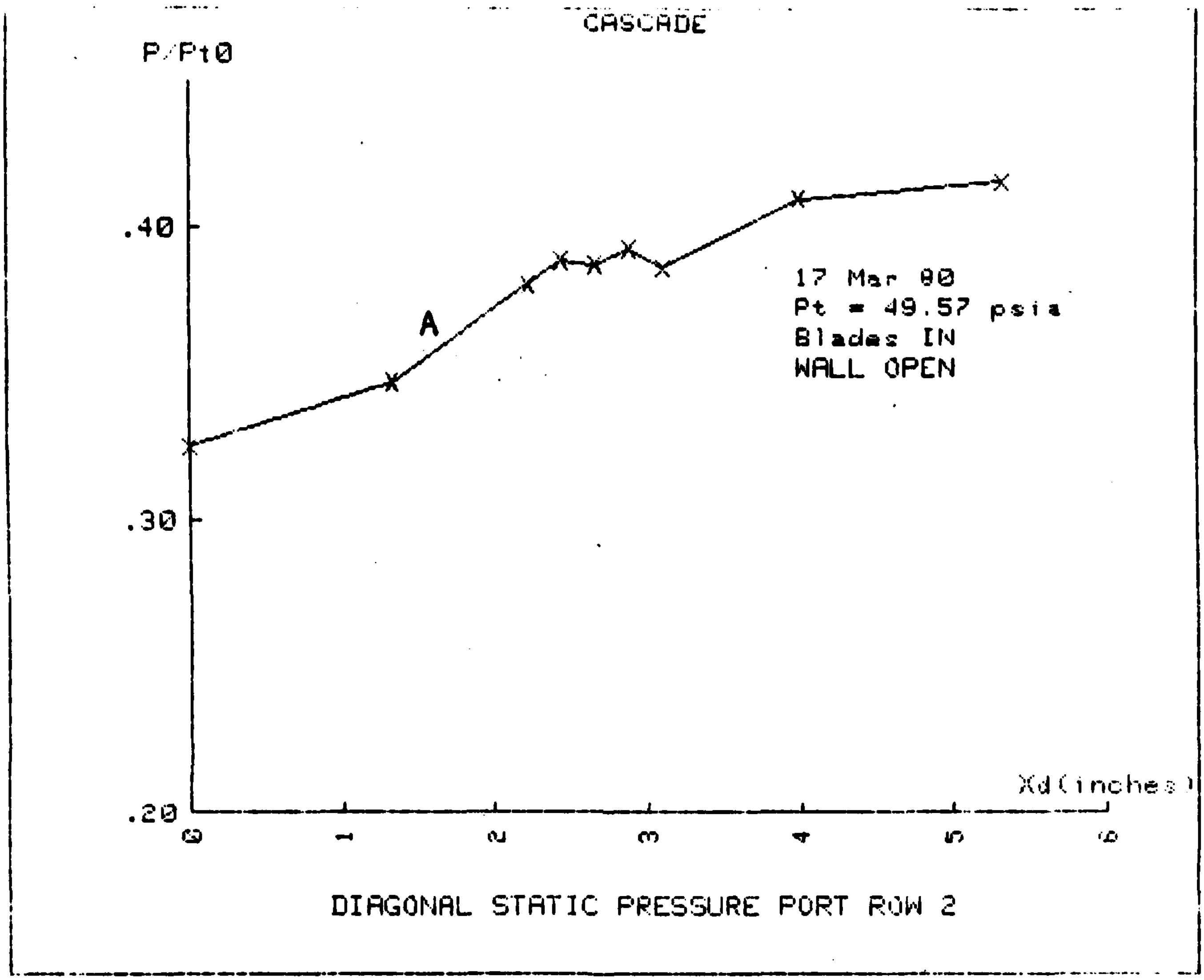



**Figure 11c. Pressure Ratio vs. Position (Cascade Test II)**

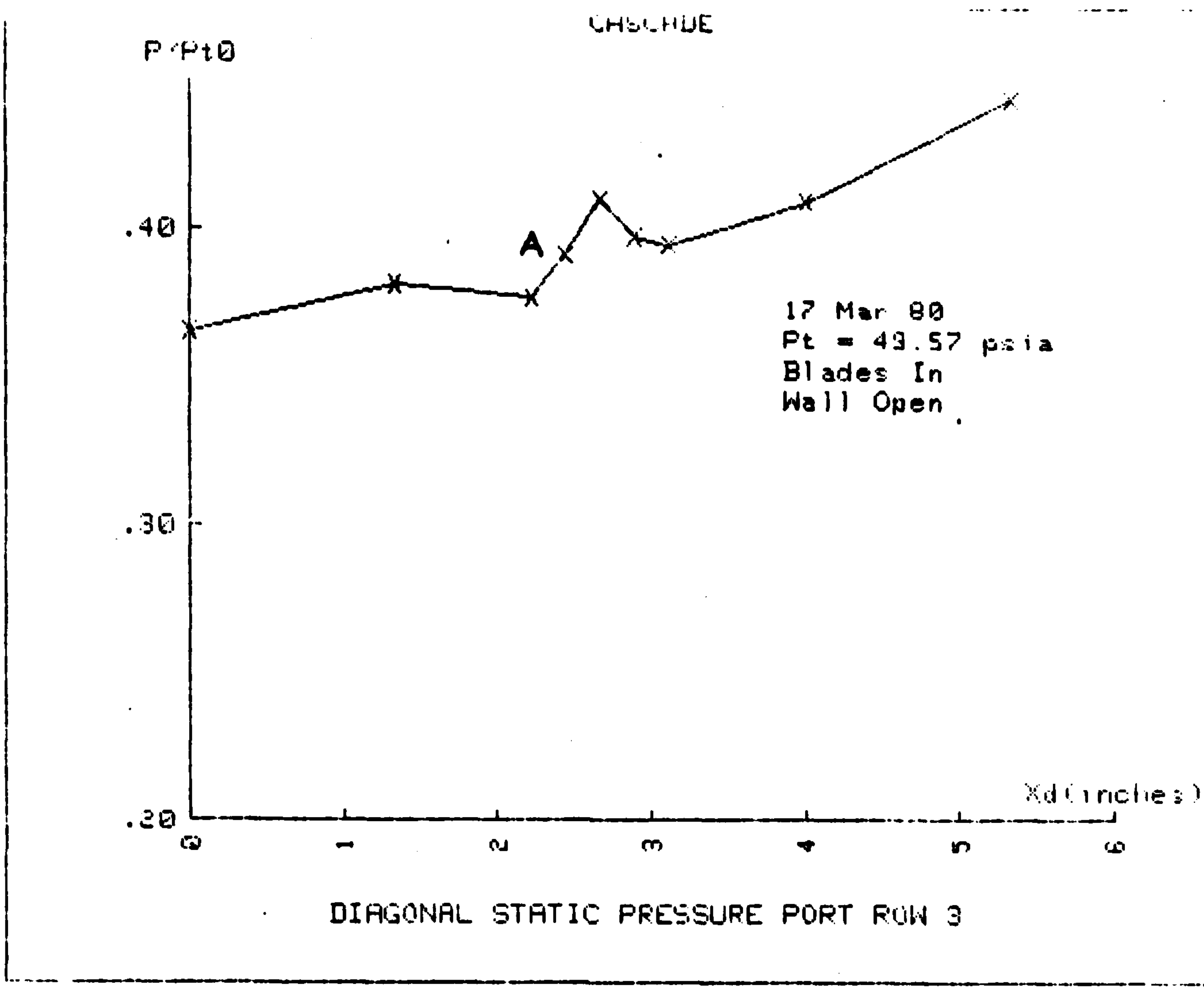



**Figure 11d. Pressure Ratio vs. Position (Cascade Test II)**

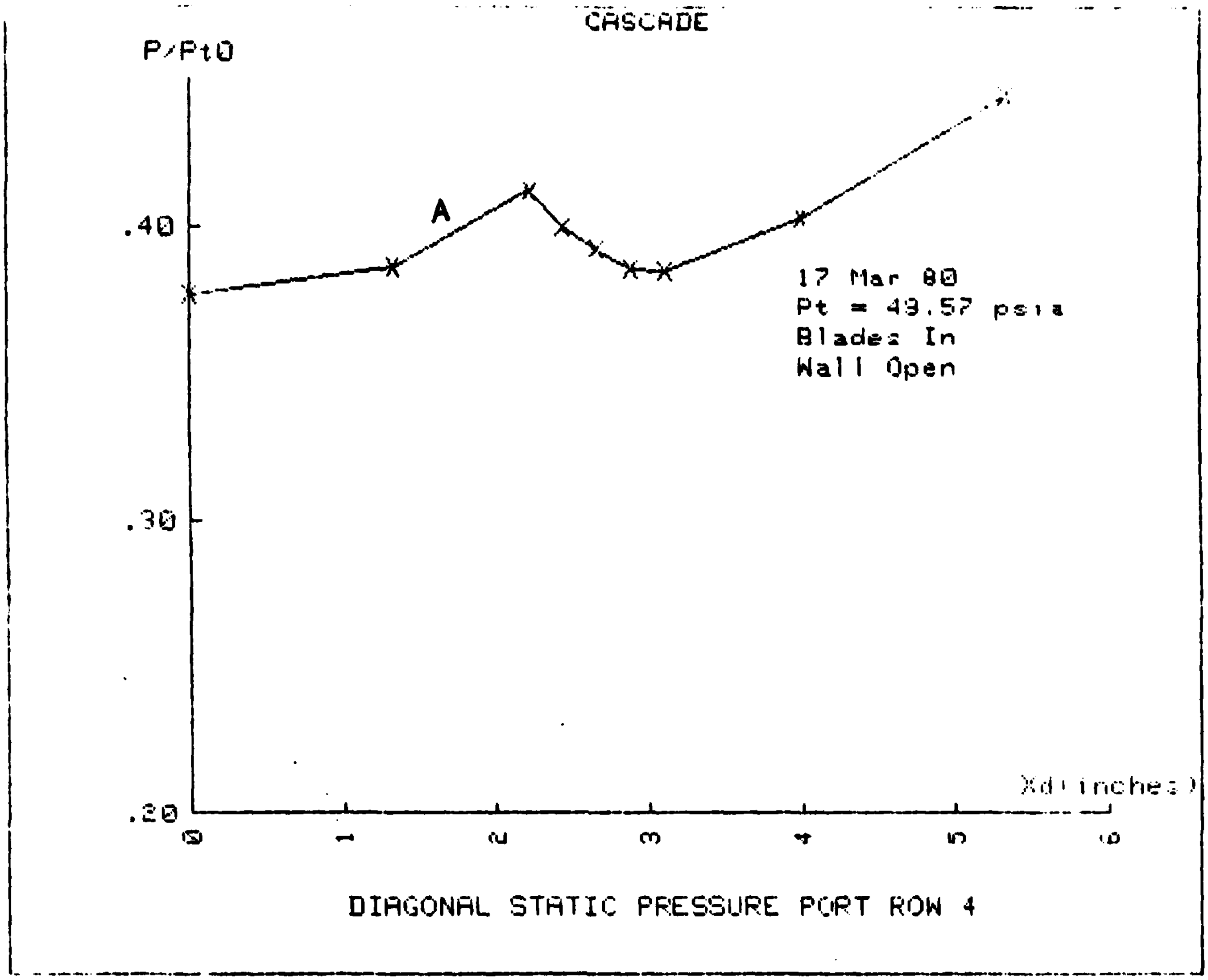



**Figure 11e. Pressure Ratio vs. Position (Cascade Test II)**

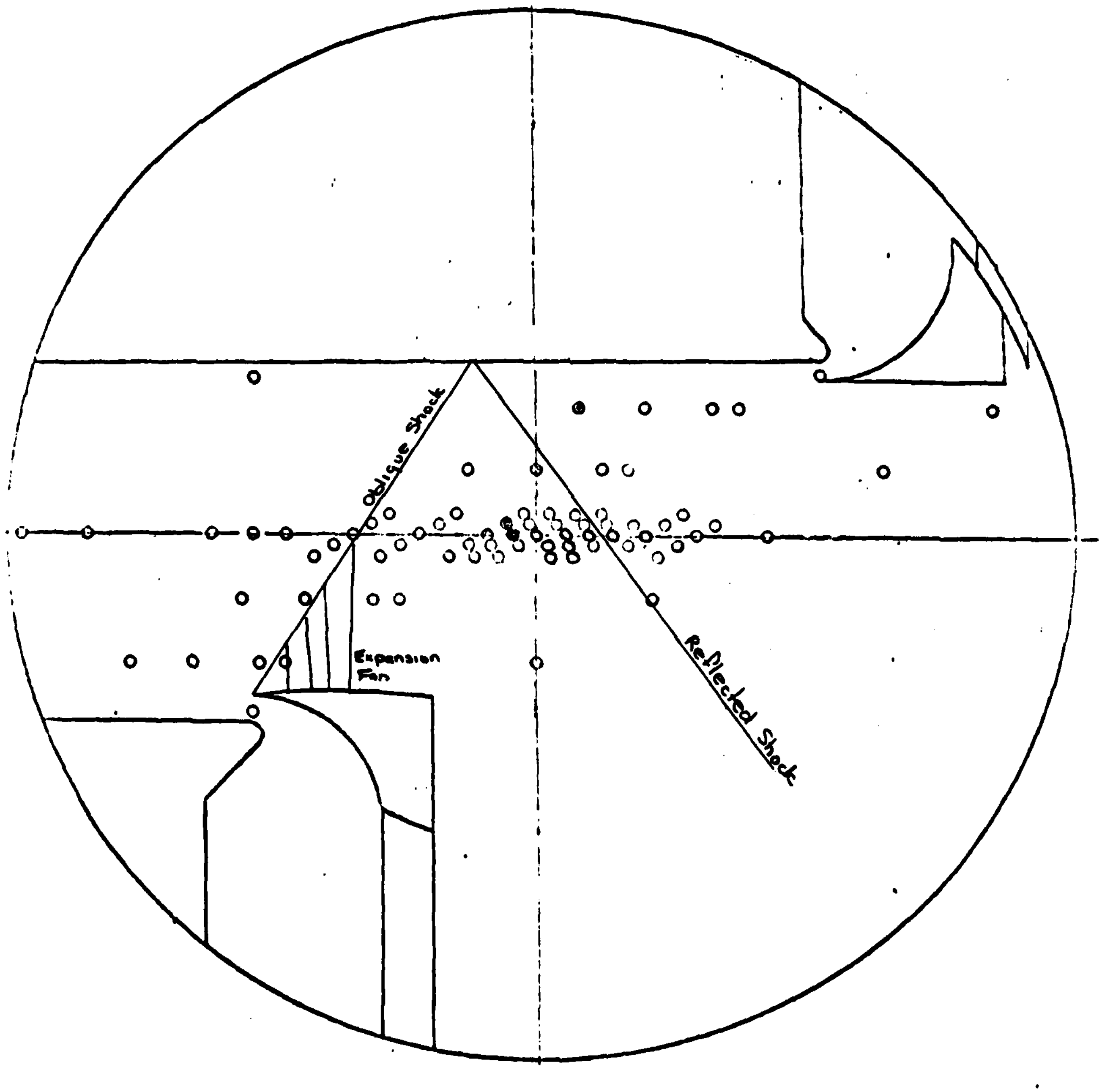



Figure 12. Expected Test Section Wave Pattern (Wave Cancellation Tests)

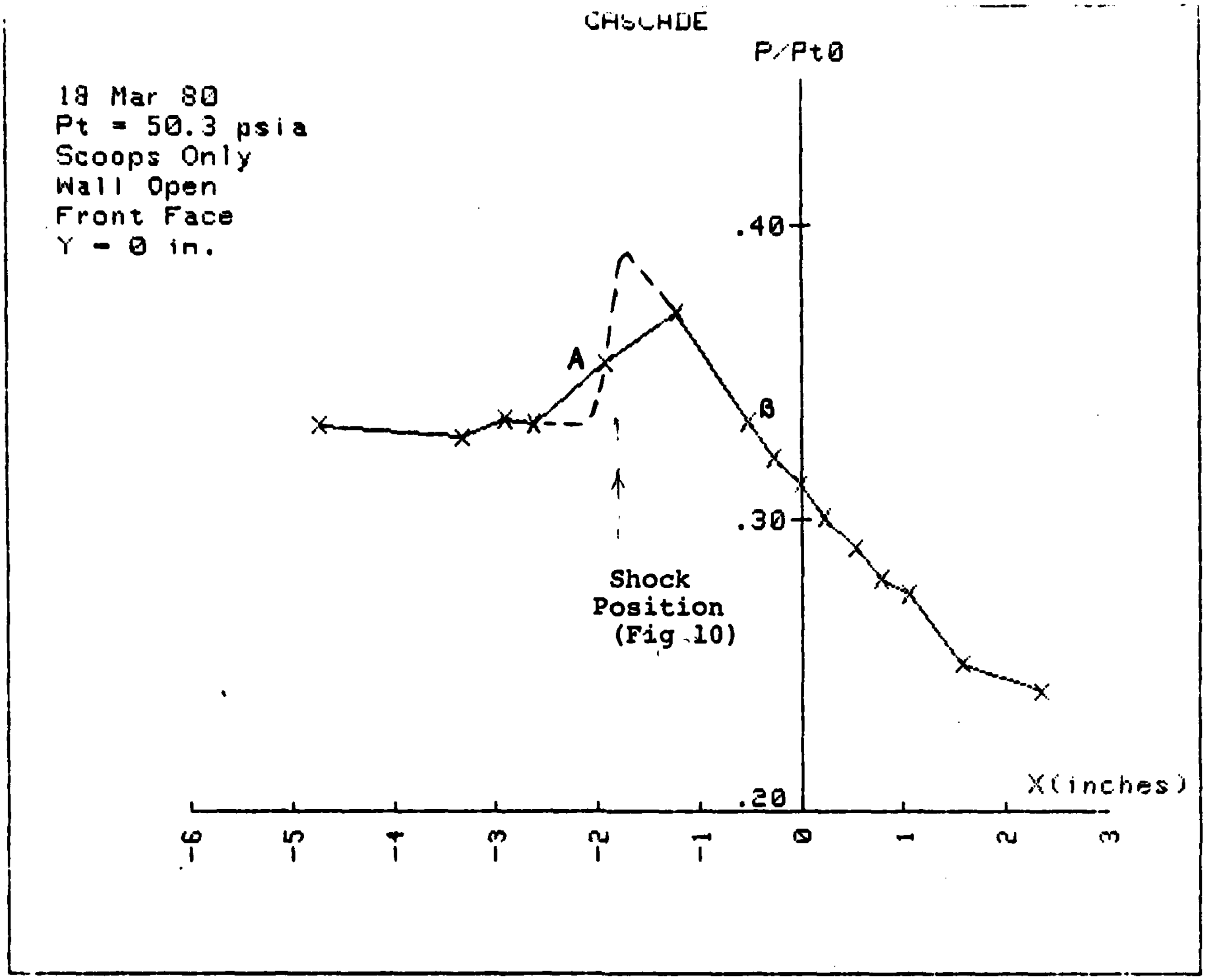



Figure 13a. Pressure Ratio vs. Position (Wave Cancellation Test I)

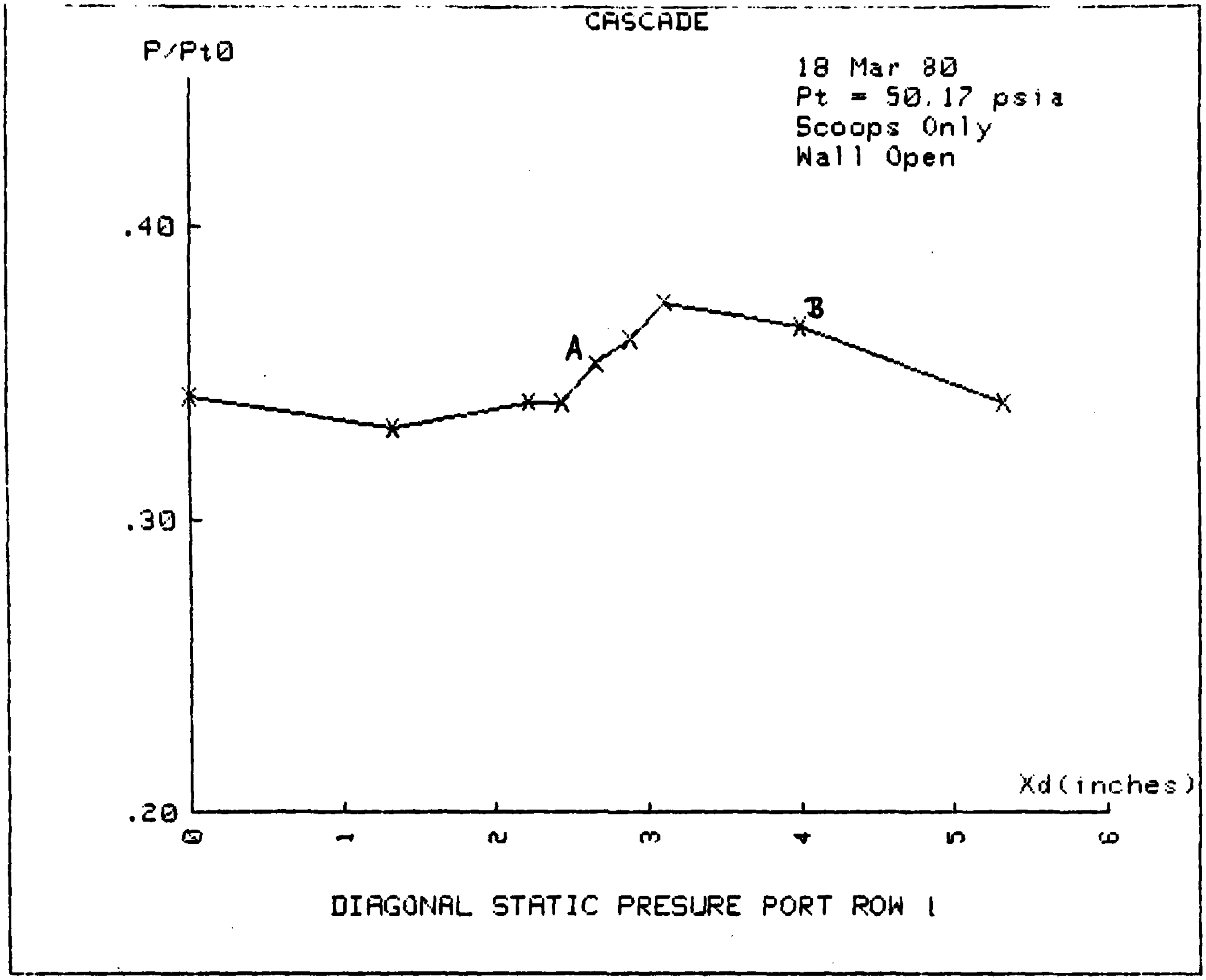



**Figure 13b. Pressure Ratio vs. Position (Wave Cancellation Test I)**

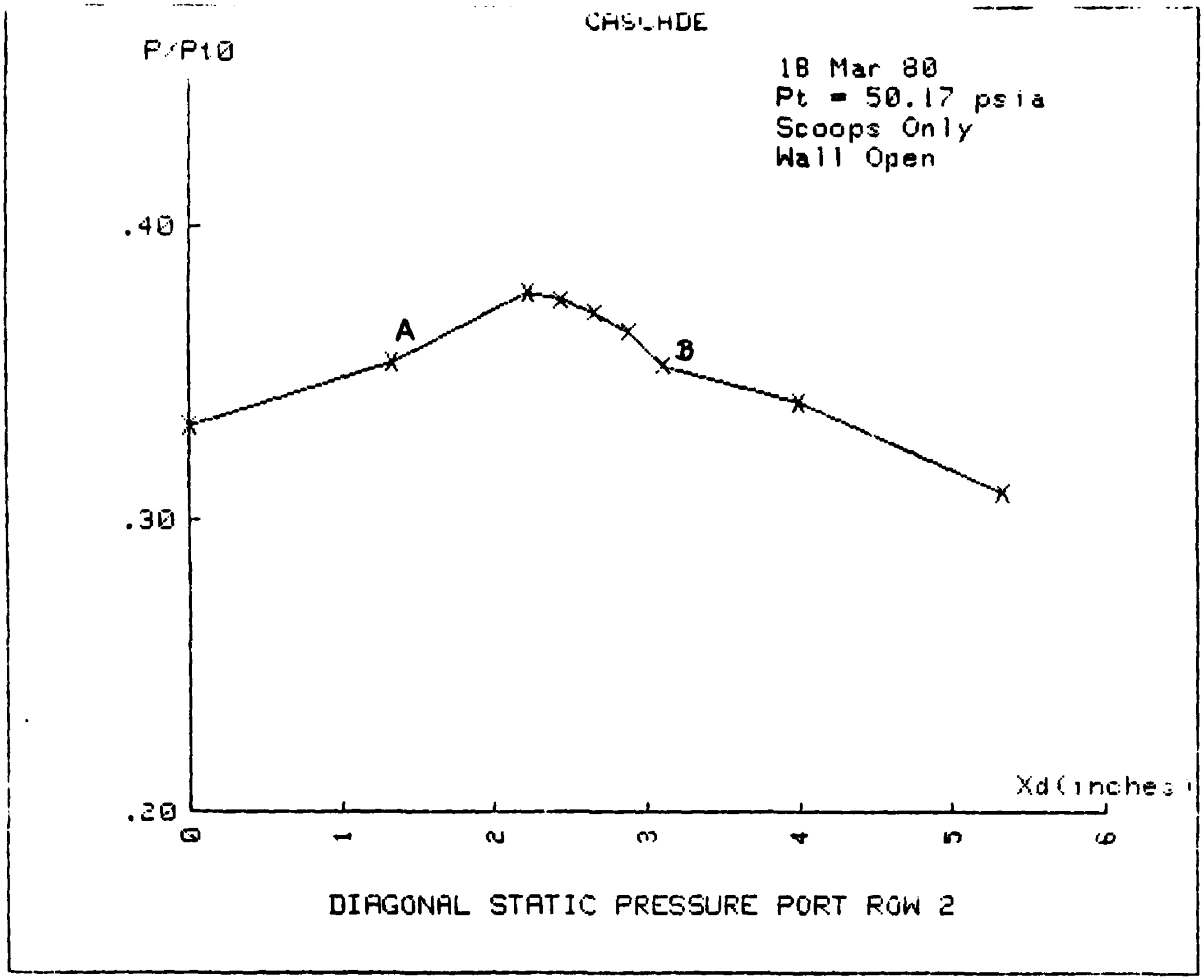



**Figure 13c. Pressure Ratio vs. Position (Wave Cancellation Test I)**

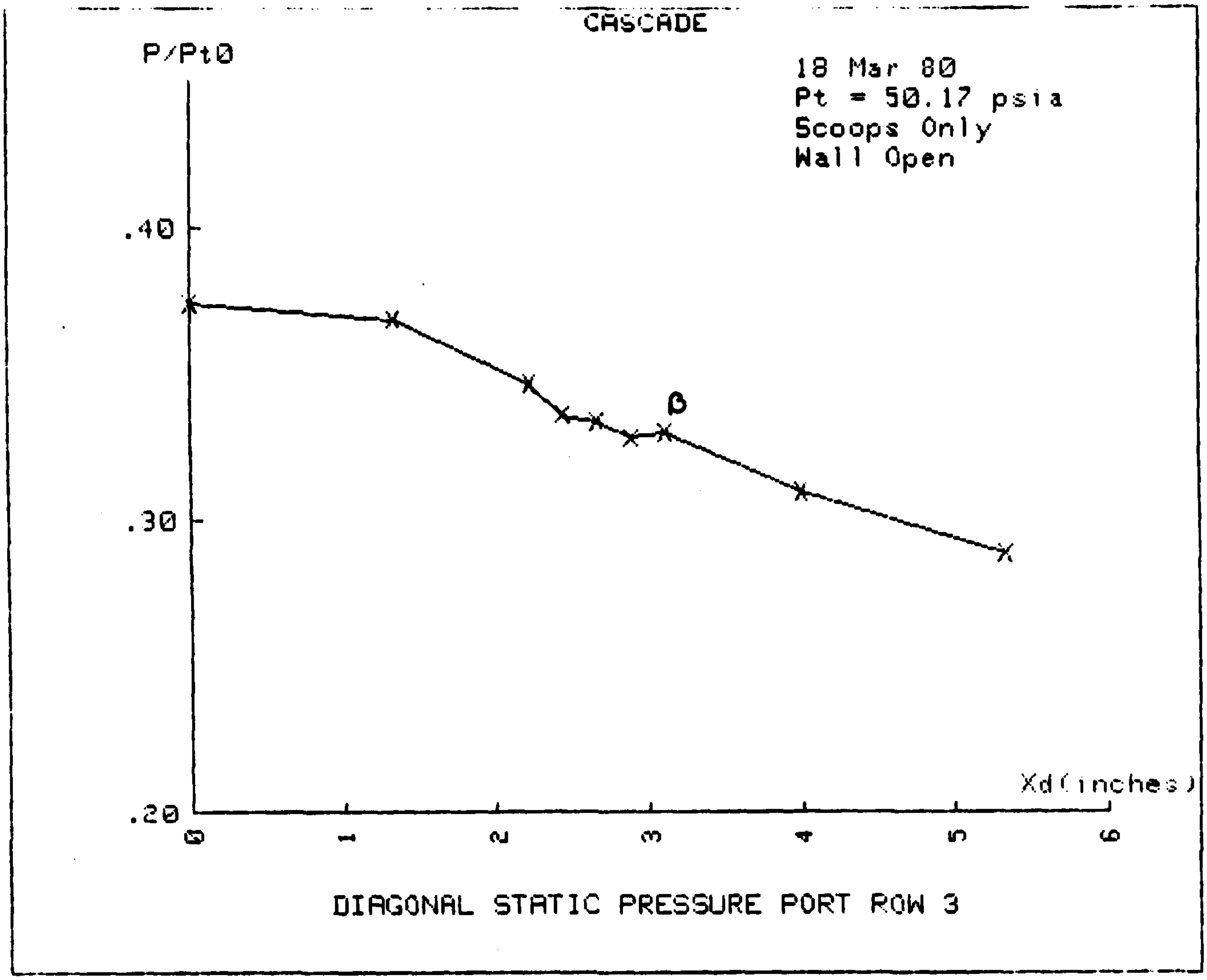



**Figure 13d. Pressure Ratio vs. Position (Wave Cancellation Test I)**

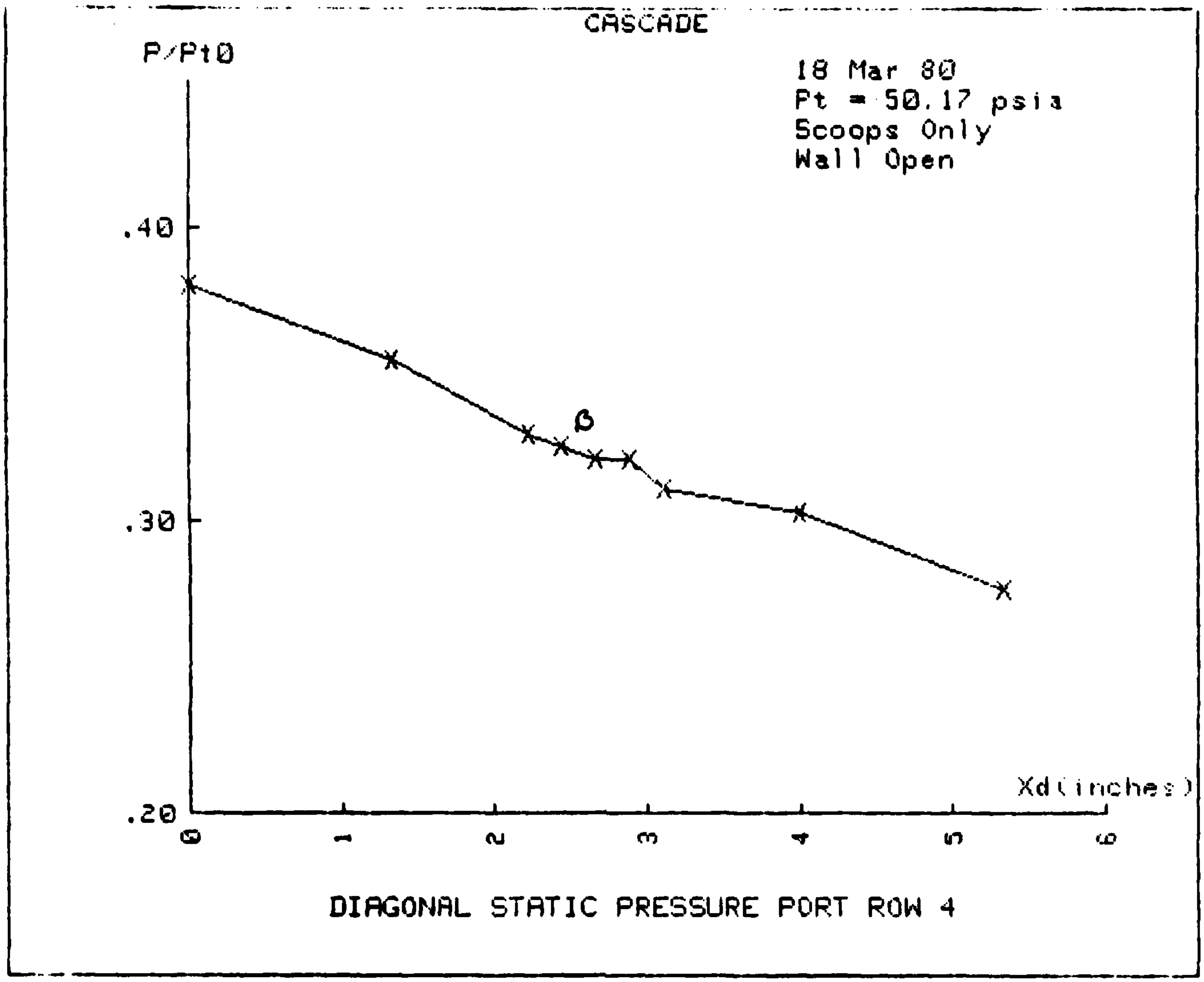



Figure 13e. Pressure Ratio vs. Position (Wave Cancellation Test I)

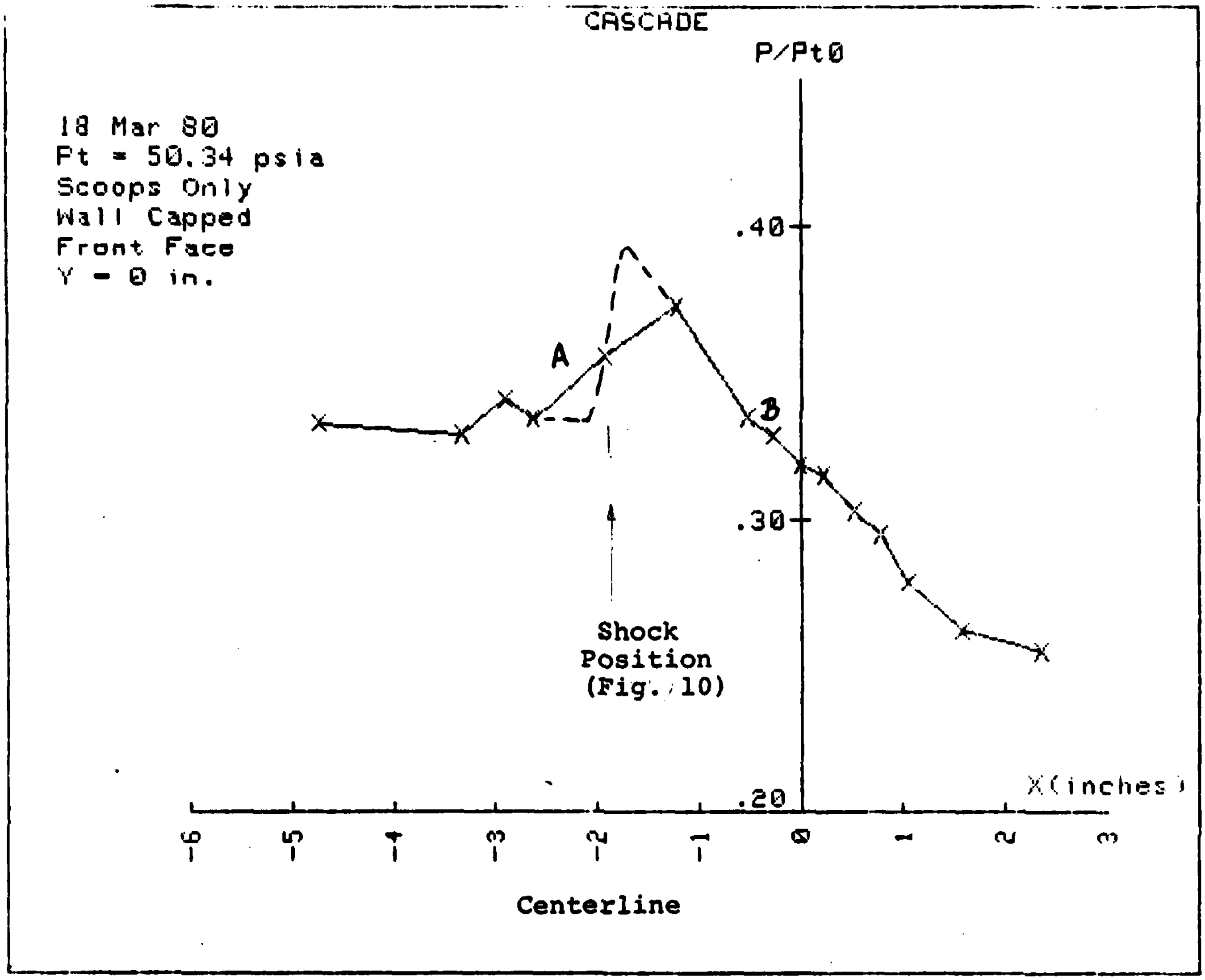



Figure 14a. Pressure Ratio vs. Position (Wave Cancellation Test II)

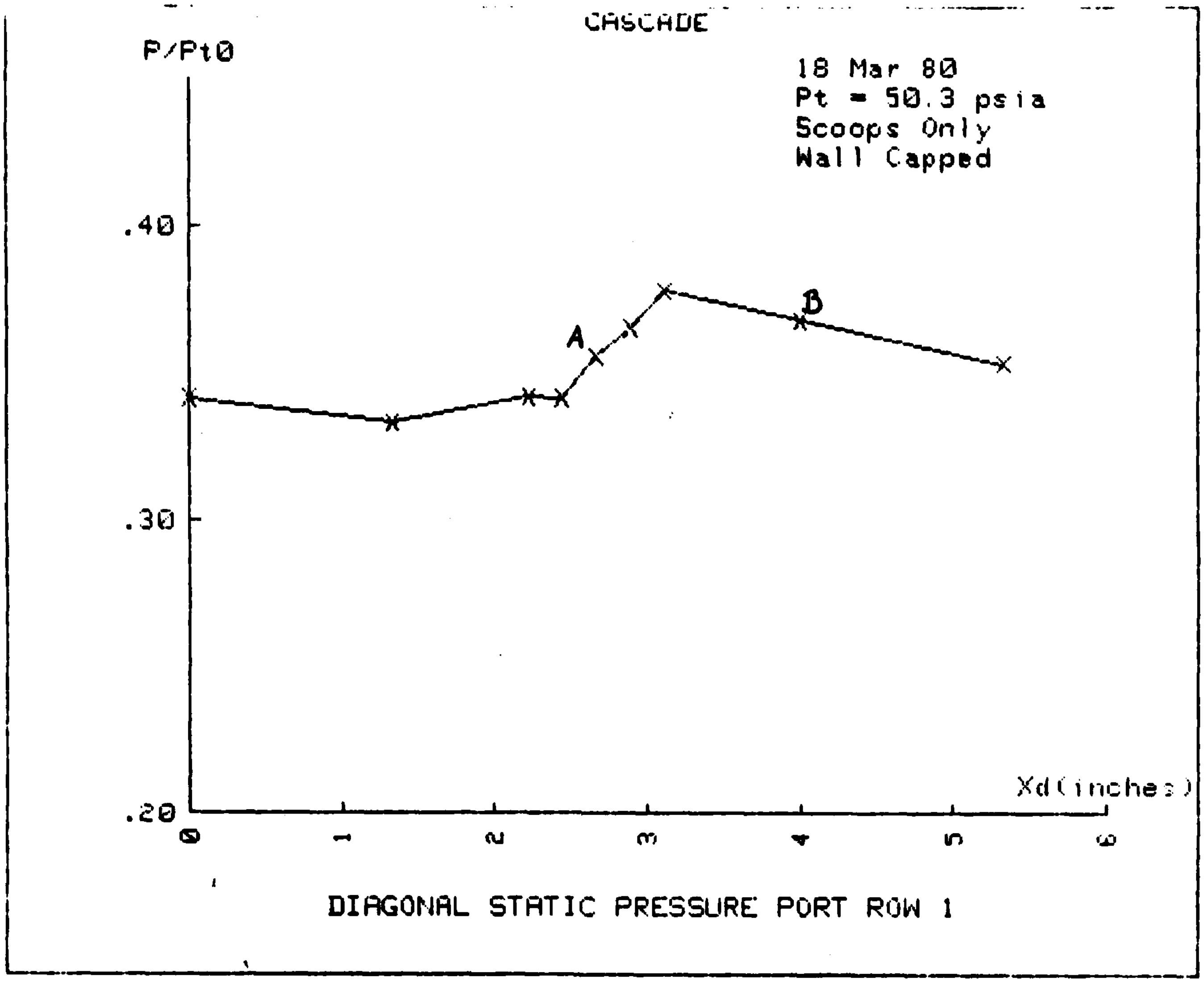



**Figure 14b. Pressure Ratio vs. Position (Wave Cancellation Test II)**

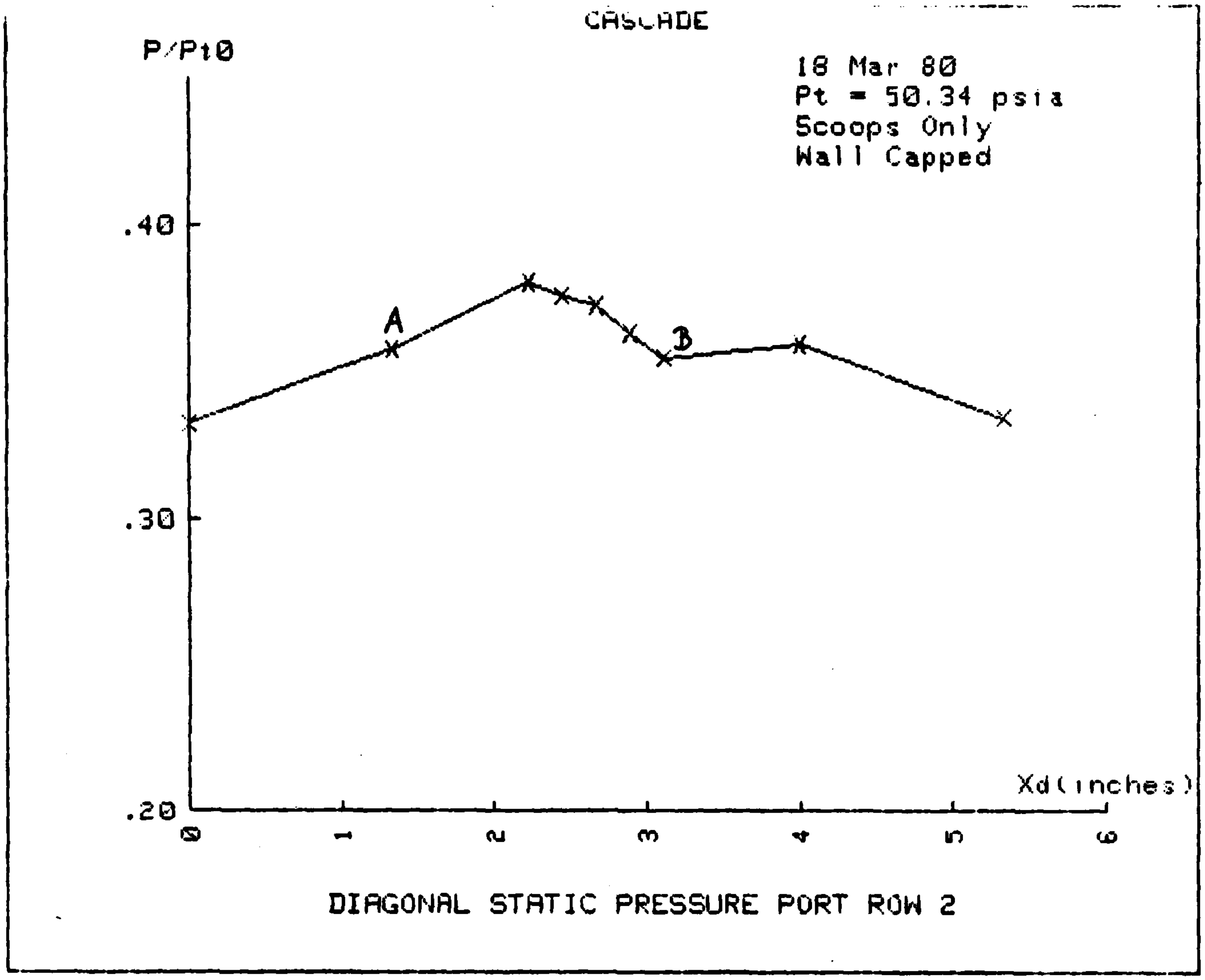



**Figure 14c. Pressure Ratio vs. Position (Wave Cancellation Test II)**

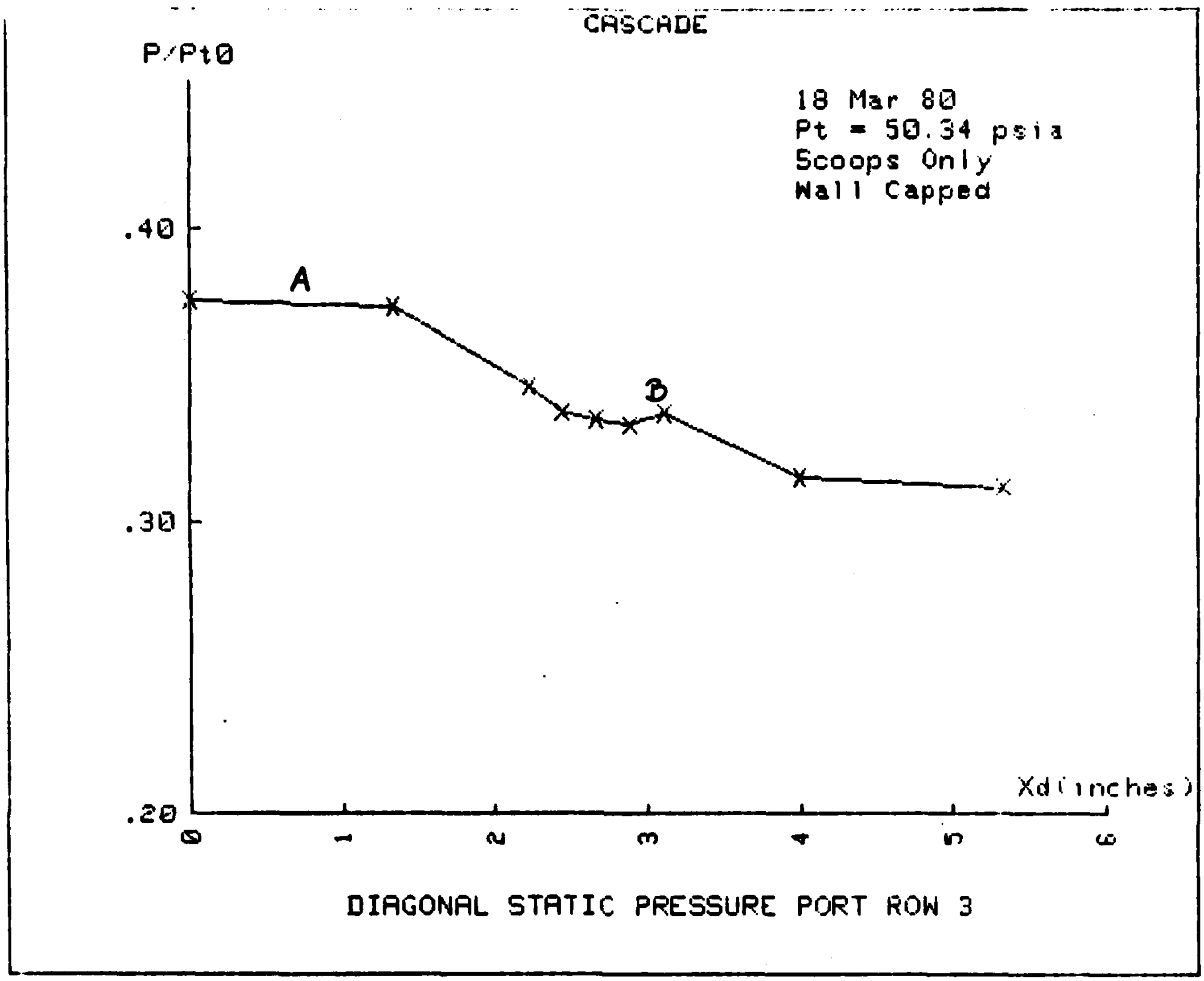



**Figure 14d. Pressure Ratio vs. Position (Wave Cancellation Test II)**

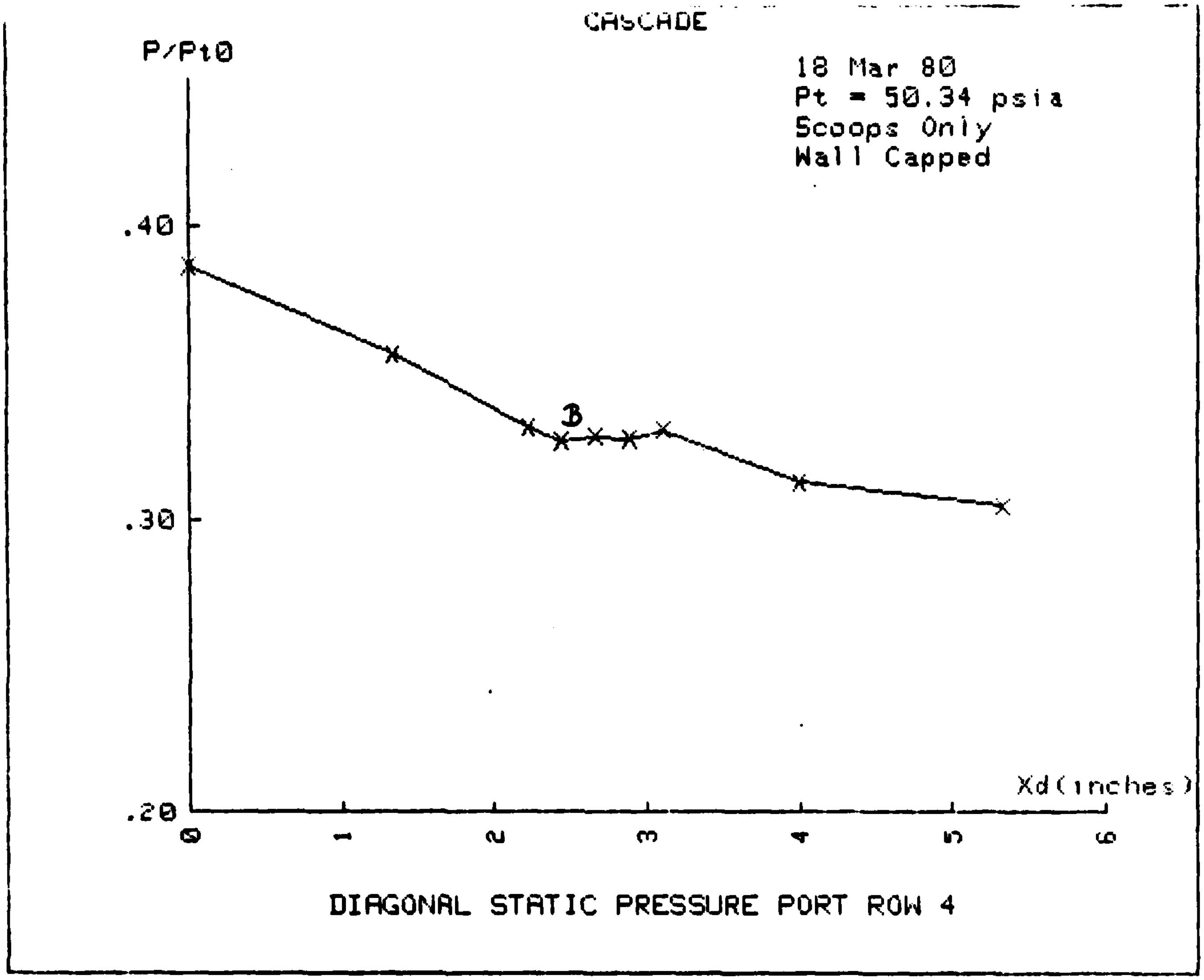



**Figure 14a. Pressure Ratio vs. Position (Wave Cancellation Test II)**

## APPENDIX A

## TRANSONIC CASCADE WIND TUNNEL MODIFICATIONS

### A1. UPPER NOZZLE BLOCK MODIFICATION

The performance of the cascade wind tunnel would be enhanced in two ways by incorporation of a perforated wall section in the upper nozzle block in the original tunnel test section [Reference 1]. First, a properly designed perforated wall would minimize the reflected disturbances caused by the shock waves generated by the blades and scoops. Second, the perforated wall, due to the air bleeding through it, would also assist in starting the transonic flow through the cascade.

a. Wave Cancellation Principles

In the transonic cascade wind tunnel operating at design conditions of Mach number equal to 1.4 at the nozzle exit, the blades will produce compression and expansion waves which will be reflected at the tunnel boundaries. Solid walls reflect shock waves as compression waves and expansion waves (generated as the flow follows the blade curvature) as expansion waves. An open boundary requires that a condition of constant static pressure be met along the boundary. A compression wave meeting an open boundary reflects as an expansion wave and an expansion wave reflects as a compression wave. The reflected waves in both the above conditions, in the case of the test cascade, would result in undesirable conditions that are not representative of the flow in an operating compressor. Since the open and solid boundaries produce wave reflections having opposite characteristics there is a possibility of eliminating the reflections by the proper mixture of open and solid boundaries. The ideal condition for shock wave cancellation would exist if the inclined flow behind the oblique shock produced a pressure drop as it flowed through the wall equal to the pressure rise through the incident oblique shock wave. This would result in equilibrium between the static pressure in the flow and in the plenum and no reflection would occur. Linearized theory of wave cancellation in perforated wind tunnels [Reference 5], resulted in the following equation for the open area ratio, R, , for no reflection.

$$\frac{\Delta p}{q} = \frac{2}{(M^2 - 1)^{\frac{1}{2}}}\left(\frac{1}{R} - 1\right)\theta = K\theta$$

This equation implied that the required open area ratio is independent of Mach number and shock intensity and for the present case would be have a value of $R = 0.5$.

In actuality the flow is not isentropic and does not follow linearized Prandtl-Glauert theory and in the transonic Mach number range the perforated wall open area ratio required for wave cancellation is significantly reduced from that predicted by linearized theory.

b. Perforated Plate Design

The design of the perforated plate required that the following parameters be considered; plate size, hole size, hole inclination, open area ratio, plate thickness and hole pattern.

(1) The size of the section of the upper nozzle block to be replaced by the perforated plate was determined by the expected shock wave pattern caused by the blades and scoops at design operating conditions. The shock wave pattern was determined over the full range of blade incidence angle available (± 3 deg) in the cascade. The plate was designed to insure that the forward-most shock would impinge on the plate downstream of the first row of perforations.

(2) The determination of the hole size, that is, the diameter measured perpendicular to the axis of the hole, was based on two criteria. Experimental results presented in Reference 6 indicated that the hole diameter was optimized when it was approximately 1/80 of the tunnel height. These

experiments also determined that the displacement thickness of the boundary layer should not exceed 15 per cent of the hole diameter in order to avoid irregularities in the flow over the perforated plate.

(3) The determination of the best inclination of the holes for the present cascade wind tunnel was based on linearized theory and experimental results as presented in References 5 and 6. Holes inclined in the direction of flow drastically reduced out-flow resistance and increased inflow resistance (Figure A.1). The inclined holes also resulted in characteristic curves of wall pressure differential vs. mass flow ratio having significantly steeper slopes at small and negative flow ratios. Using inclined holes avoided the irregular characteristic produced by straight holes.

(4) Experimental results reported in References 5 and 6 were used in selecting the proper open area ratio for the perforated wall section.

Experiments indicated that the open ratio required for wave cancellation with inclined holes was approximately 25 percent of that required for normal holes. The requirement for fewer holes greatly eased the problem of fabricating the perforated plate and reduced the risk of structural weakness.

(5) When the above plate design parameters were selected the plate thickness was considered. The effectiveness of the inclined hole configuration to guide inflow against test section flow requires that the lengths of the inclined holes are sufficient to produce this counter flow effect. Experimental data [Reference 5] indicated consistent, nearly linear characteristics when the hole diameter was between the plate thickness and twice the plate thickness. A plate thickness very nearly equal to the hole diameter was selected to insure the maximum plate bending strength without degrading the design with respect to wave cancellation.

(6) The perforation pattern was selected to give an even hole distribution over the

entire width of the upper nozzle block in the area covered by the perforated plate. The hole stagger angle, hole-to-hole and row-to-row separations were calculated to insure that the plenum plate support ribs would not be restrictive.

Data resulting from the design of the perforated plate are given in Table A-1 and the machine drawing of the plate is given in Figure A2.

Table A-1. Perforated Plate Characteristics

| | |
|---|---|
| Open Area Ratio (R) | 6% |
| Plate Thickness | 0.040 |
| Hole Diameter, in. (perpendicular to hole axis) | 0.047 |
| Hole Inclination | 60 deg |
| Plate length, in | 4.375 |
| Plate width, in | 1.880 |
| Hole Stagger Angle | 15.16 deg |
| Hole-to-Hole Separation (in rows), in | 0.167 |
| Row Separation, in | 0.167 |
| Material | 7075-T6 Aluminum |

c. Perforated Wall Plenum Design

The perforated wall plenum was designed to provide an evenly distributed pressure on the plenum side and to provide the required structural support for the perforated wall. The even pressure distribution on the plenum side of the wall was essential to create an even mass outflow over the entire perforated plate area.

The design required that when the plate was installed the dimensions of the upper nozzle block matched those of the original design [Reference 1] under all anticipated tunnel operating conditions. The plenum ribbed mounting structure was designed so that the stresses in the plate did not exceed the tensile strength or cause a bending deflection greater than 0.0005 inches with a pressure differential of 3 atmospheres across the plate. The stress (S) and deflection (W) were determined in accordance with Reference 7 using the equations:

$$S_m = \beta \frac{qa^2}{t^2}$$

$$W_m = a \frac{qa^2}{Et^3}$$

Since it was difficult to predict accurately the degree of weakening of the plate caused by the perforations, the worst case conditions were used. The stress coefficient (β) was taken for the case where all the edges of the plate sections analyzed were clamped, and the deflection coefficient, (a), was taken for the case where the section analyzed had all edges pinned.

The plenum exit was sized so that at the anticipated wall mass flow rate of less than 0.4 percent of the tunnel mass flow [Reference 5], by continuity, the exit velocity would be approximately 50 ft/sec.

The "O" ring on the upper nozzle block was rerouted around the perforated wall plenum. The machine drawing for the upper nozzle block modification is given in Figure A3.

d. Final Assembly

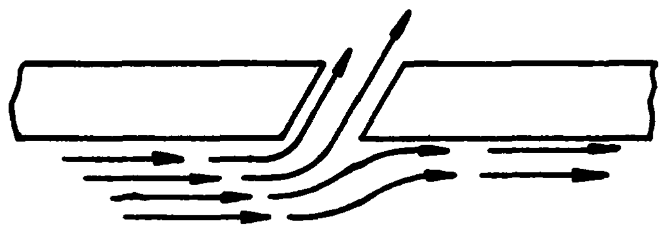
Views of the nozzle modification are given in Figure A4. The perforated plate was attached to the modified upper nozzle block with two screws on each end of the plate and Conley Weld Epoxy along the edges of the mounting ribs. The reassembled nozzle was reinstalled in the cascade wind tunnel.

A.2. BLADE AND MOUNTING PINS MODIFICATION

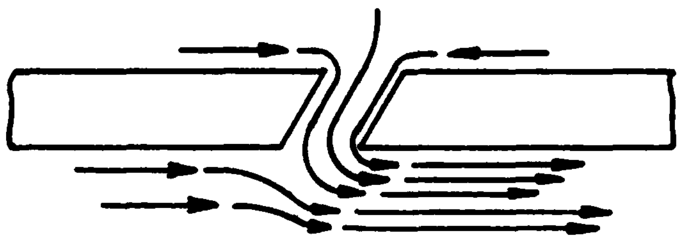
Revised [from Reference 1] machine drawings for the cascade blades and blade mounts are given in Figure A5. The revisions were required in order to show required blade dimension tolerances and surface smoothness, and to change the blade mounting pin design to make assembly easier. Cascade blade data are presented in Table A-2. The blades were manufactured by Experimental Engineering, Inc. of Irvine, California.

Table A-2 Cascade Blade Data

| | |
|---|---|
| Scale Factor (z) | 0.7 |
| Stagger Angle ($\gamma$) | 59 deg, 44 min, 35 sec |
| Camber Angle ($\phi$) | 4.7 deg |
| Blade Spacing (s), in | 1.344 |
| Blade Chord (c), in | 1.822 |
| Leading Edge and Trailing Edge Radii, in | .007 |
| Suction Side Radius, in | 11.431 |
| Maximum Thickness, in | .045 |



Flow Out of Test Section



Flow Into Test Section

Figure A.1 Streamline Pattern for Inflow and Outflow Through a Wall with Inclined Holes

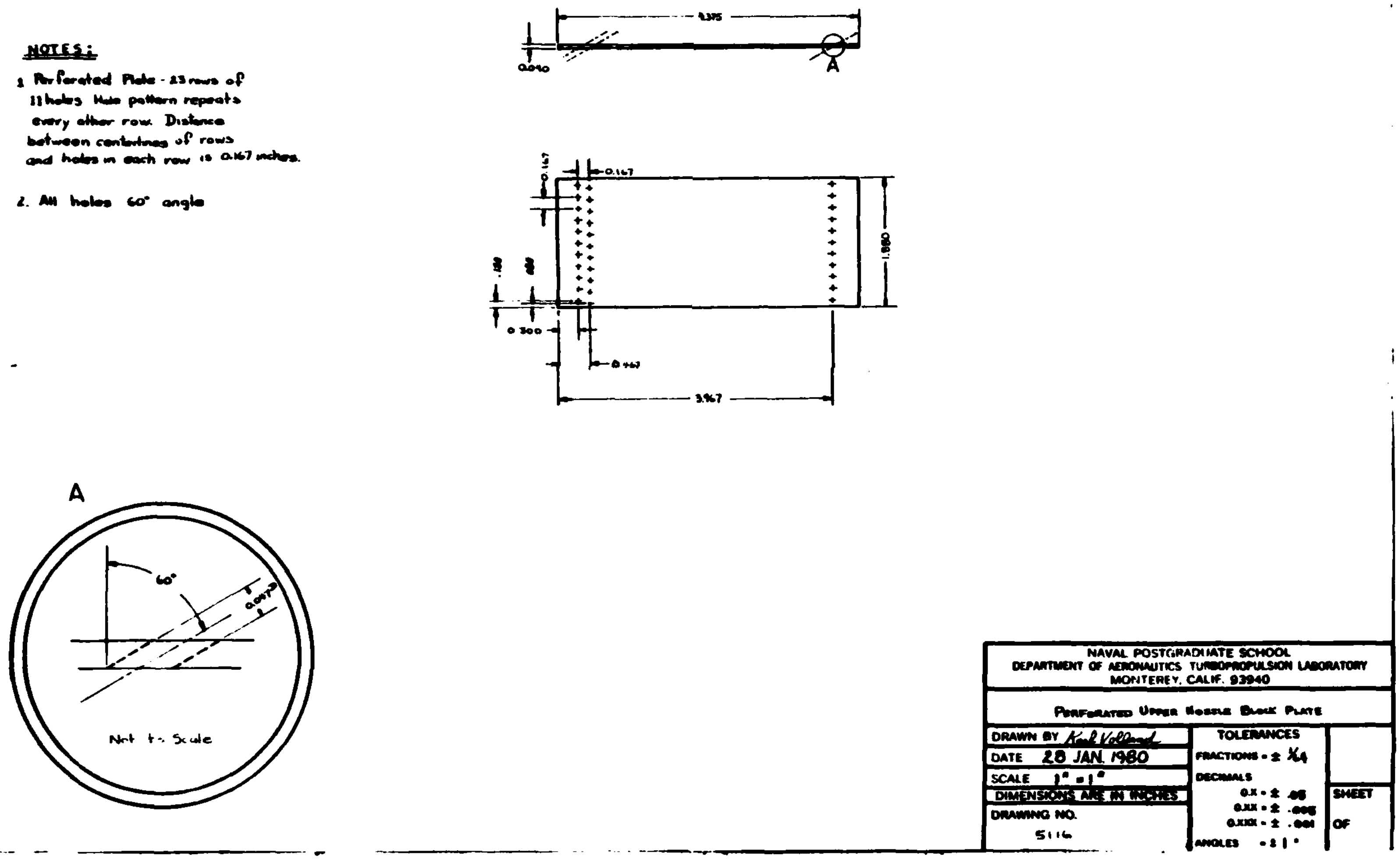



Figure A2 Perforated Plate Machine Drawing

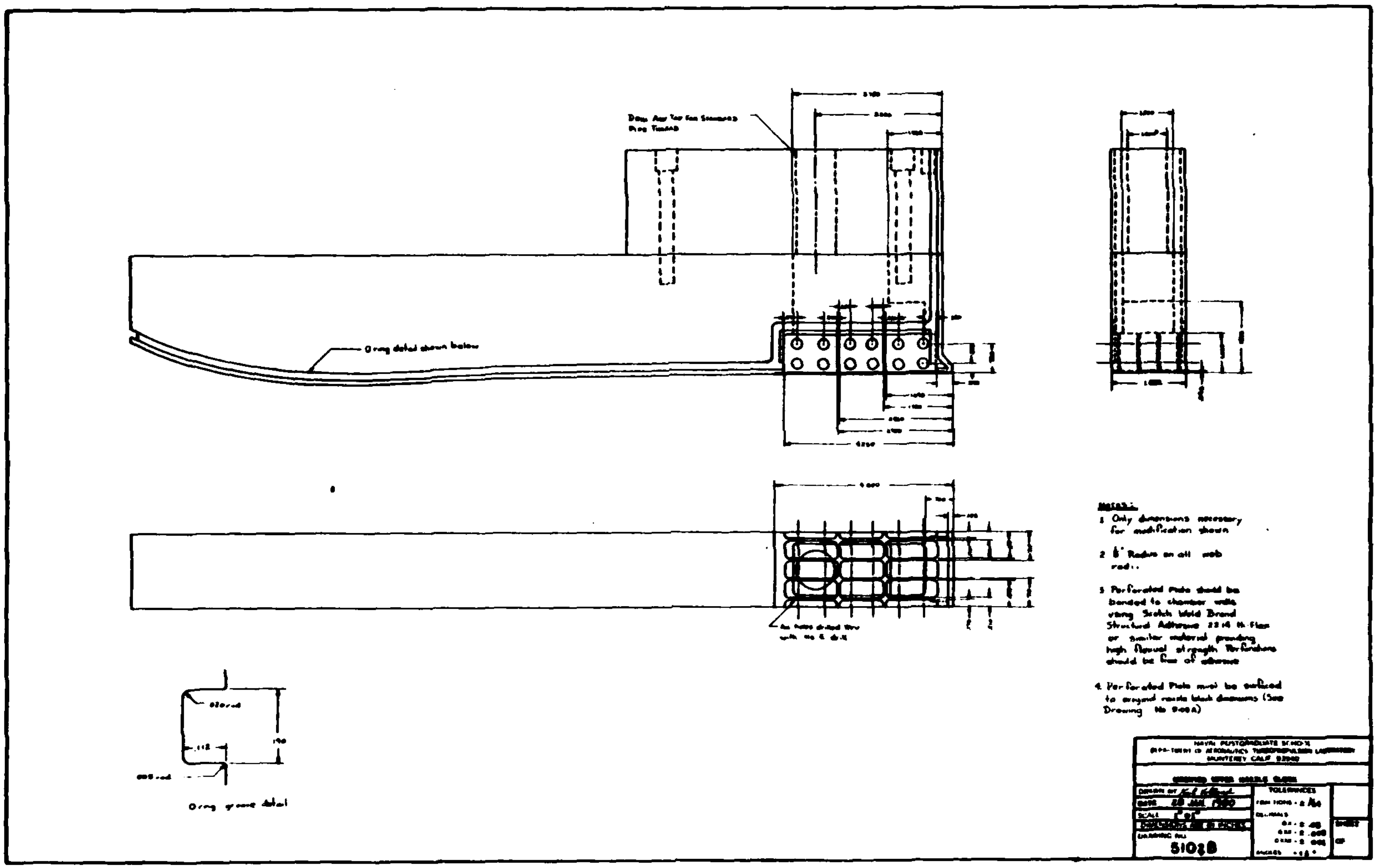



Figure A3 Modified Upper Nozzle Block Machine Drawing

Figure A.4a Assembled Upper Nozzle Block Modification
Top-rear Three Quarter View

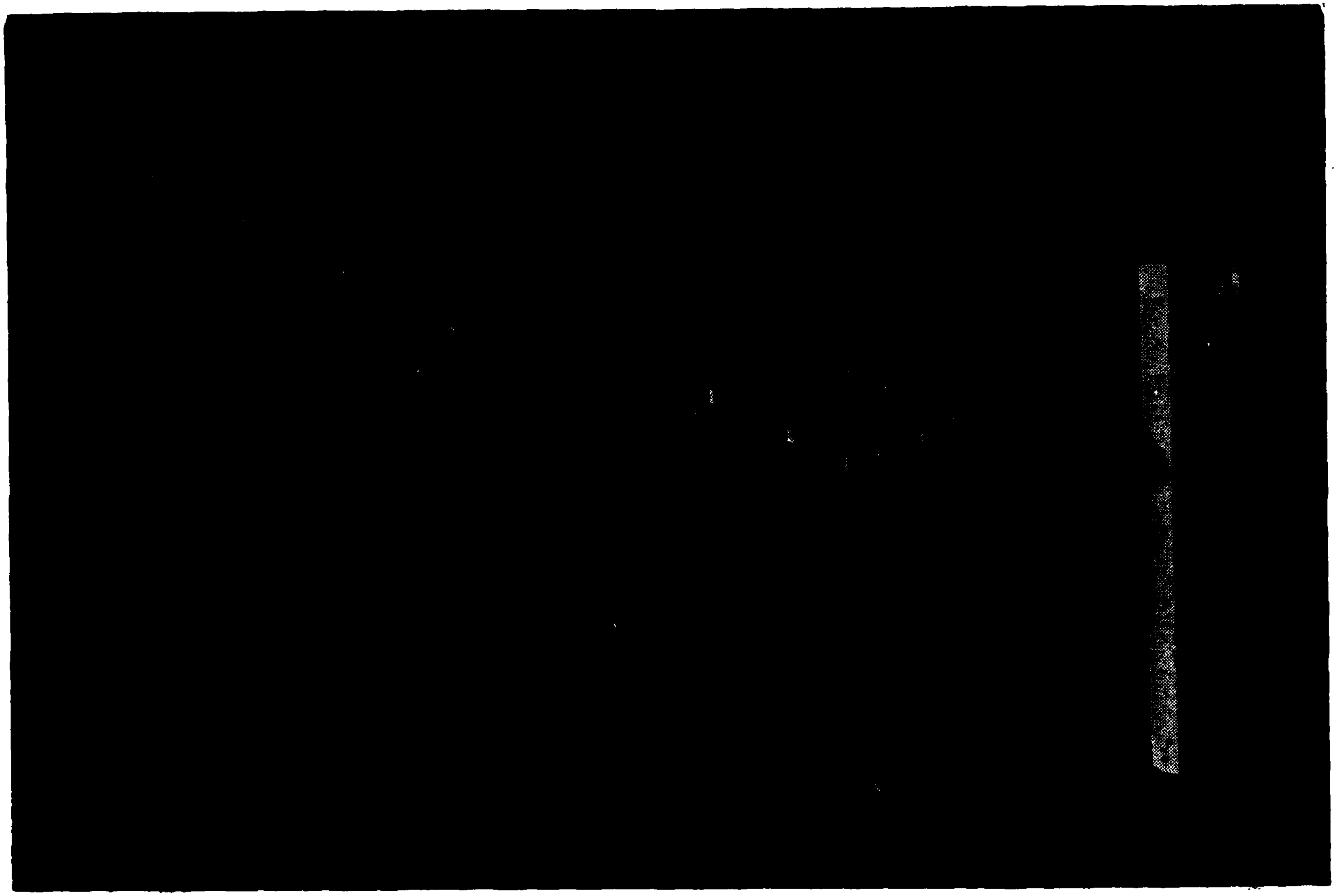


Figure A.4b Assembled Upper Nozzle Block Modification
Botton-rear Three-Quarter View

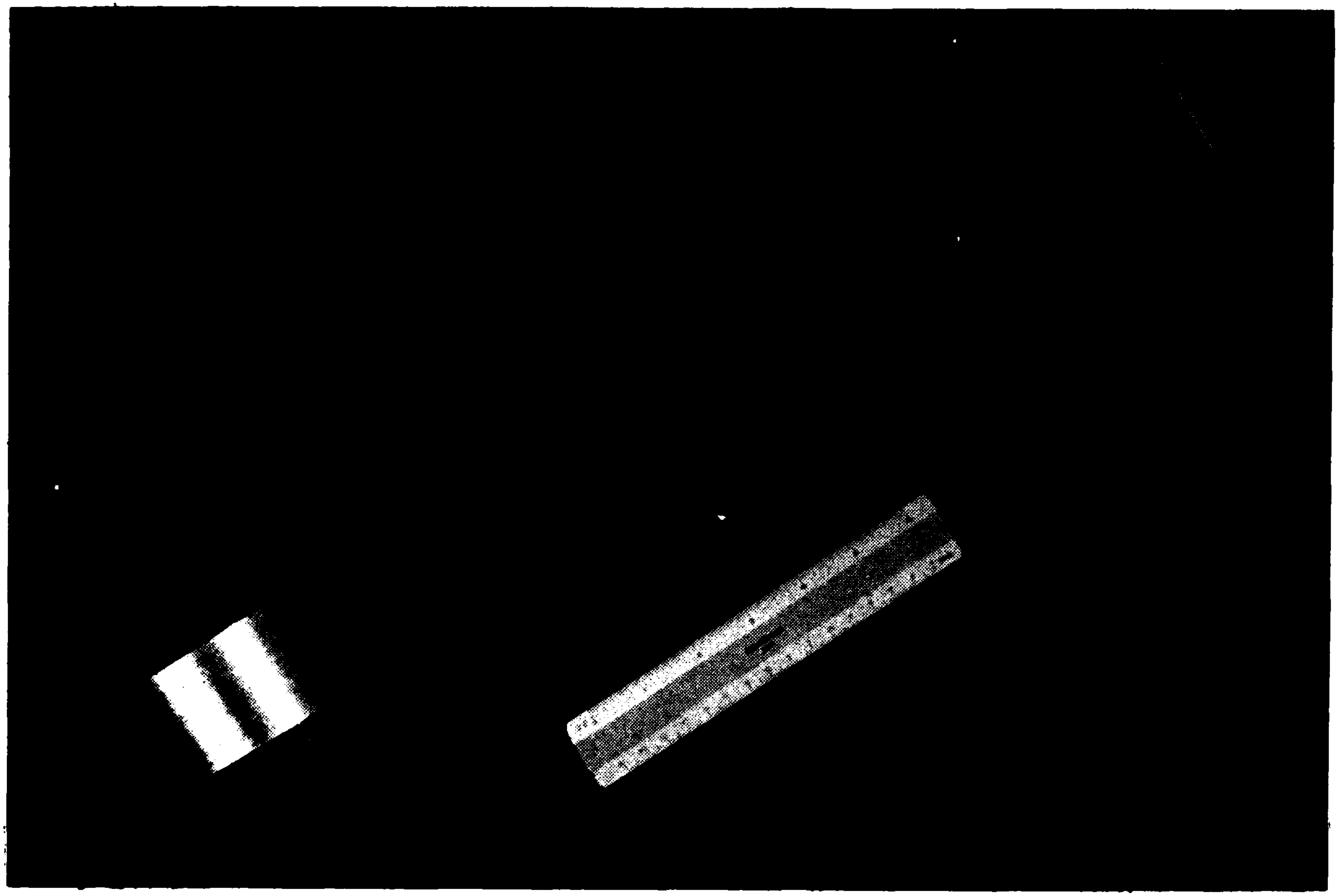


Figure A.4c  Assembled Upper Nozzle Block Modification
Bottom View

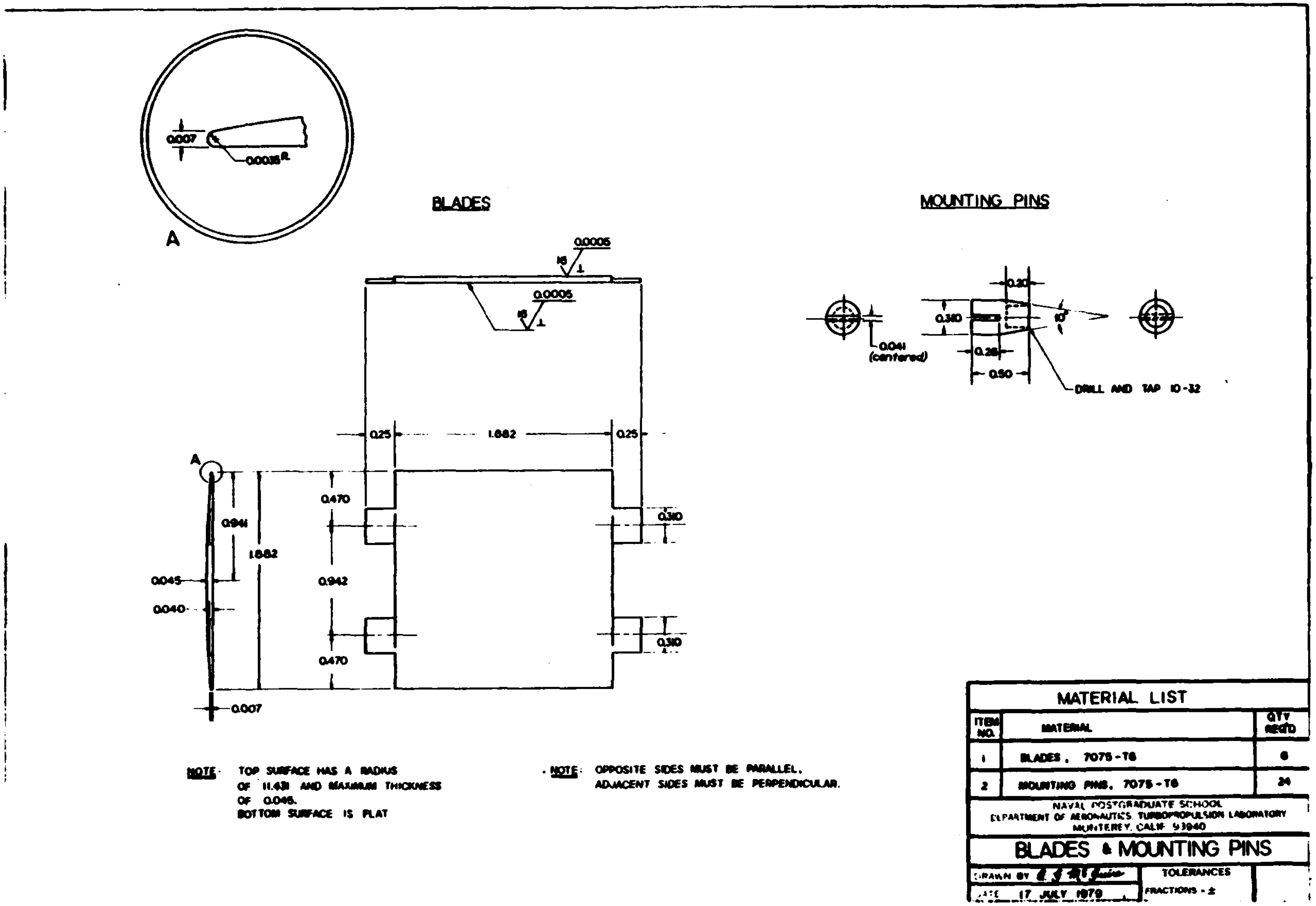
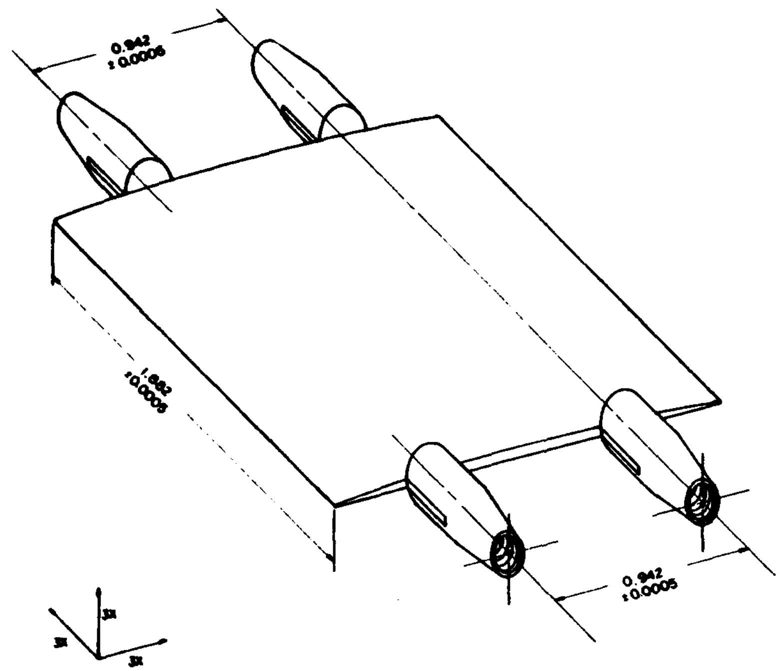



Figure A.5a Blades Mounting Pins




NOTES

1. MOUNTING PINS SHOULD BE BONDED TO THE BLADES USING SCOTCH-WELD BRAND STRUCTURAL ADHESIVE 2214 HI-FLEX OR SIMILAR MATERIAL PROVIDING HIGH FLEXURAL STRENGTH.
2. CONTOURED BLADE SURFACE, TOP AND BOTTOM, WITHIN 1.682 DIMENSIONS SHOULD BE FREE OF BONDING MATERIAL.
3. FINISHED PART SHOULD BE WITHIN TOLERANCES SHOWN.
4. CENTERLINES OF CORRESPONDING PLUGS SHOULD BE COINCIDENT TO ±0.0005 AT EITHER END.
5. CENTERLINES OF PLUGS SHOULD LIE WITHIN THE SAME PLANE, ±0.0005.

NAVAL POSTGRADUATE SCHOOL
DEPARTMENT OF AERONAUTICS TURBOPROPULSION LABORATORY
MONTEREY, CALIF 93940

BLADE ASSEMBLY

| | | |
|---|---|---|
| DRAWN BY [illegible] | TOLERANCES | |
| DATE 26 JULY 1979 | FRACTIONS ± | |
| SCALE AS SHOWN | DECIMALS | |
| DIMENSIONS ARE IN INCHES | .X ± | SHEET 1 |
| DRAWING NO. 5108D | .XX ± <br> .XXX ± <br> ANGLES | OF 1 |

Figure A.5b Blade Assembly

## APPENDIX B

## DATA ACQUISITION SYSTEM

### B1. SYSTEM HARDWARE

The Hewlett Packard model 3052A/9845A Automatic Data Acquisition System was used for both data acquisition and reduction. The system was augmented with the HG-78K Scanivalve Controller [Reference 8] and two 48 port Scanivalves[1]. The components of the HP 3052A data acquisition system are:

(1) HP-9845A Desk Top Computer/Controller,

(2) HP-3455A High Resolution/High Accuracy Digital Voltmeter,

(3) HP-3437A System Voltmeter,

(4) HP-3495A Scanner

(5) 98035A Real Time Clock

(6) HP-IB[2]

The integrated data acquisition system (Figure B.1) is shown schematically in Figure B.2

[1] "Scanivalve" is the registered trademark for a mechanical pneumatic selector switch manufactured by Scanivalve Corporation, P.O. Box 20005, San Diego, California 92120.

[2] The HP-IB is the Hewlett-Packard implementation of IEEE Standard 488-1975, "Digital Interface for Programmable Instrumentation".

## B2. DATA ACQUISITION AND REDUCTION PROGRAM

The modified BASIC Program "CASDAT" was written to acquire, store, and reduce data using the Hewlett-Packard HP 9845A computer and peripherials described above. The program is interactive with the operator and as such can be used for either data acquisition and storage or data reduction and storage, or both. The HP 3052A Data Acquisition System Software Package contains a large number of subprograms to simplify and expedite the data acquisition process, and several have been merged into Program "CASDAT".

The program listing provided in Table B-1 is self explanatory in that neumonic variable names are used. The program also contains remark (REM) statements to aid interpretation.

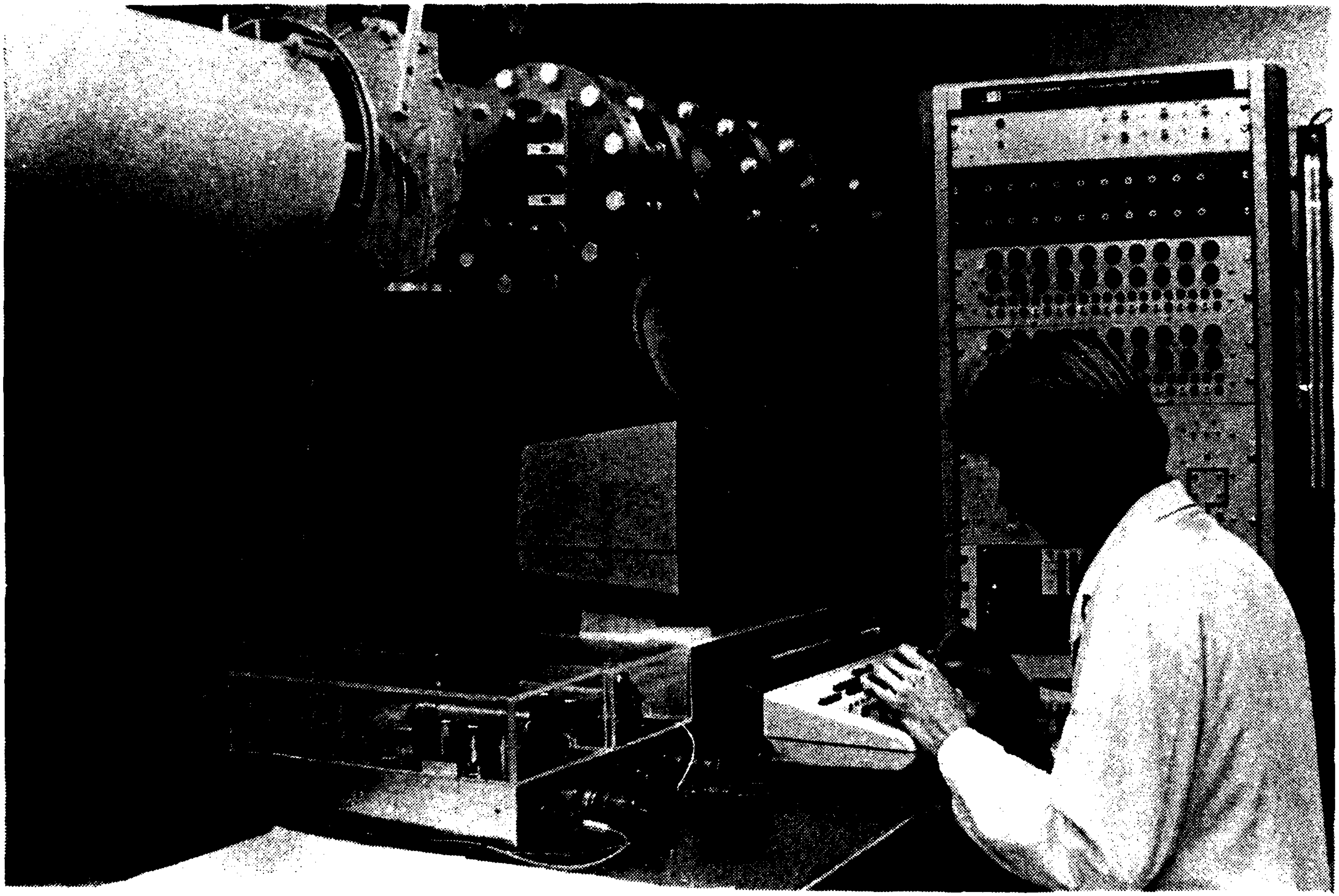


Figure B.1 Cascade Wind Tunnel Data Acquisition System

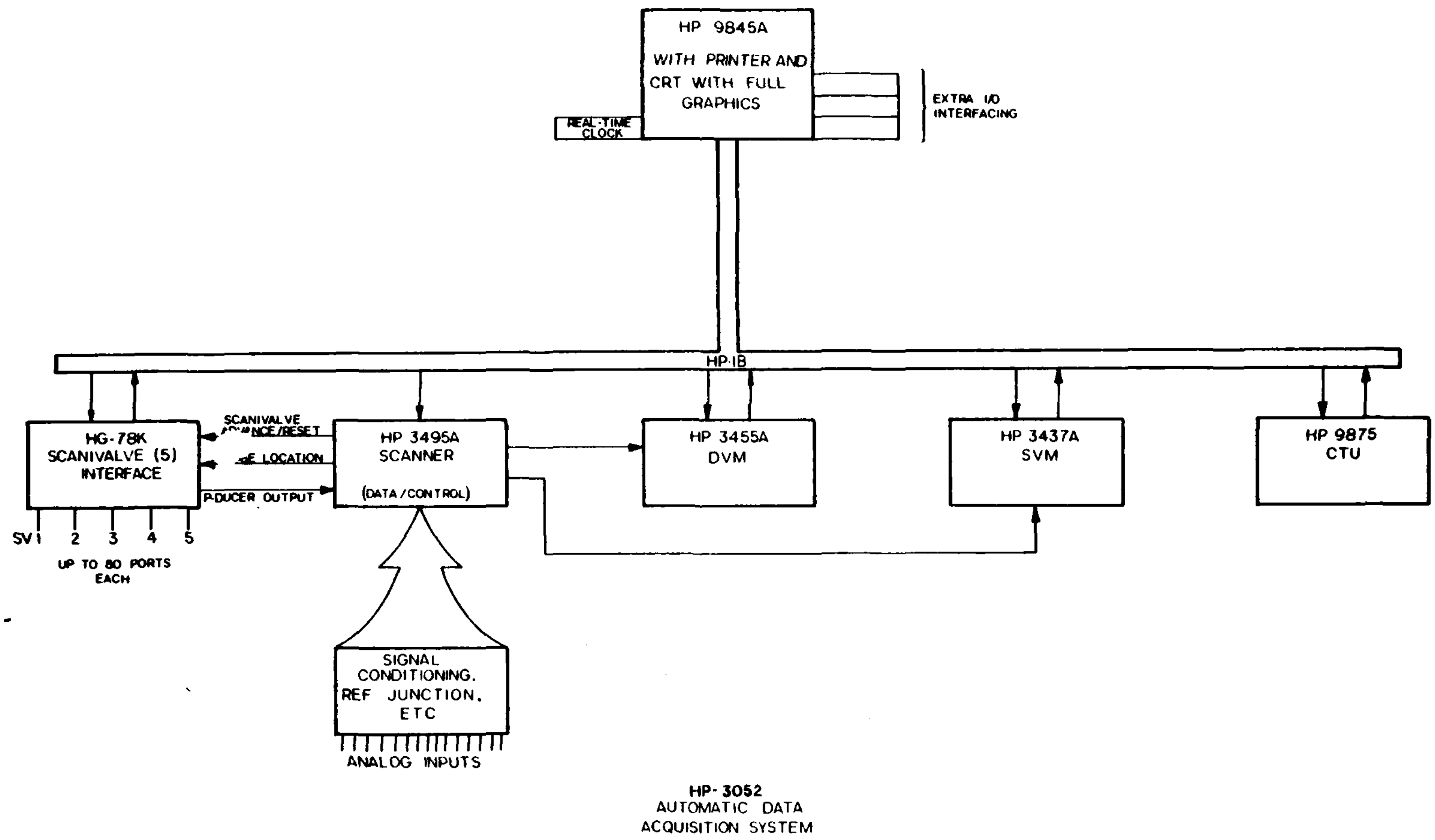



Figure B.2 Cascade Wind Tunnel Data Acquisition System Block Diagram

```
10 REM                  FILE NAME: "CASDAT"
20   REM
30   REM
40   REM DESCRIPTION: THIS PROGRAM PERFORMS SEQUENTIAL SCANNING OF SCANIVALVE
50   REM                "V" BETWEEN PORT ADDRESSES SPECIFIED.IT RECORDS, STORES
60   REM                AND REDUCES DATA.
70   REM
80   REM AUTHOR: K.F. VOLLAND
90   REM
100  REM  *****************PART 1 DATA ACQUISITION ********************
110  REM
120  REM
130  REM    VARIABLES:
140  REM    V= DESIRED SCANIVALVE
150  REM    A1= LOW PORT
160  REM    A2= HIGH PORT
170  REM    P= PRESENT SCANIVALVE PORT
180  REM    S= STEP SIZE ! As the program is now s=1 only can be used
190  REM
200  REM
210 OPTION BASE 1
220  DISP "IF YOU DESIRE TO REDUCE DATA ENTER 1";
230  INPUT C
240  IF C=1 THEN 260
250  GOTO 1100
260  COM Trm,Scn,Dum,Sum,Bus,Error
270  DIM Measurements(51),Filename$(6),Fileresults$(6),Pressure(46),Mach(46),Pre
ssureratio(46),Port(46)
280  PRINTER IS 16
290  CALL Init
300  CALL Dum(1,7,0,0)
310  DISP "Scanivalve# ";
```

Table B-1. BASIC PROGRAM "CASDAT"

```
320  INPUT V
330  REM
340  REM THIS PART OF THE PROGRAM ASSIGNS THE REQUIRED SCANNER CHANNELS TO THEIR
         FUNCTIONS FOR THE SCANIVALVE SELECTED.
350  IF V=1 THEN 400
360  IF V=2 THEN 440
370  IF V=3 THEN 480
380  IF V=4 THEN 520
390  IF V=5 THEN 560
400  Reset=45
410  Advance1=40
420  Dataread=0
430  GOTO 590
440  Reset=46
450  Advance1=41
460  Dataread=1
470  GOTO 590
490  Reset=47
490  Advance1=42
500  Dataread=2
510  GOTO 590
520  Reset=48
530  Advance1=43
540  Dataread=3
550  GOTO 590
560  Reset=49
570  Advance1=44
580  Dataread=4
590  CALL Chan(1,Reset) ! Resets selected scanivalve to port 1
600  WAIT 20
610  RESET Scn
620  DISP "Low,High";
630  INPUT A1,A2
640  DISP "STEP SIZE";
```

```
650  INPUT S
660  REM INPUT NON-SCANIVALVE REQUIRED DATA
670  DISP "Ambient Pressure";
680  INPUT Measurements(A2+1)
690  Measurements(A2+1)=Measurements(A2+1)*.49116
700  DISP "Total Temperature";
710  INPUT Measurements(A2+2)
720  DISP "Total Pressure";
730  INPUT Measurements(A2+3)
740  PRINTER IS 0
750  CALL Time ! This dates all data sheets
760  PRINT
770  PRINT "Scanivalve No.";V
780  PRINT
790  IF A1=1 THEN 850
800  FOR I=1 TO A1-1 ! This loop advances the scanivalve to the first port to be
 scanned in the run
810  CALL Chan(1,Advance1)
820  WAIT 40
830  RESET Scn
840  NEXT I
850  FOR K=A1 TO A2 ! This loop takes readings on the desired sequential scaniva
lve ports
860  CALL Chan(1,Dataread)
870  REM WAIT 10
880  Measurements(K)=FNRdvm
890 Measurements(K)=Measurements(K)*1000
900  PRINT USING Output;K,Measurements(K)
910 Output: IMAGE "Scanivalve Port Number ",DDD,15X,"Pressure = ",DDDDD.DDDDDD,
"  Psig "
920  CALL Chan(1,Advance1)
```

```
930  WAIT 20
940  RESET Scn
950  NEXT F
960  DISP "Insert Data File Name";
970  INPUT Filename$
980  CREATE Filename$,2 ! Creates a raw data file
990  ASSIGN #1 TO Filename$
1000 PRINT #1;Measurements(*)
1010 PRINT "Data Saved In File ",Filename$
1020 PRINT PAGE
1030 PRINTER IS 0
1040 DISP "ENTER 1 IF ANOTHER DATA RUN DESIRED"; ! Gives the choice of taking mo
re data or going on to the data reduction part of the program
1050 INPUT D
1060 IF D=1 THEN 260
1070 REM
1080 REM
1090 REM
1100 REM ******************PART 2 DATA REDUCTION *********************
1110 REM
1120 REM
1130 REM
1140  REM OPTION BASE 1
1150 DISP "INPUT DATA NAME OF DATA FILE O BE REDUCED";
1160 INPUT Filename$
1170 ASSIGN #3 TO Filename$
1180 READ #3;Measurements(*)
1190 CALL Time
1200 PRINT "Reduced data from data file ";Filename$
1210 DISP "NUMBER OF PRESSURE TAPS THIS RUN";
1220 INPUT A2
1230 PRINT
1240 PRINT
1250 REM PRINT "Total Pressure=",Measurements(A2+1)+Measurements(3),"Psia"
1260 PRINT "Total Pressure= 50.729 psia"
```

```
1270 PRINT
1280 PRINT "Total Temperature=",Measurements(A2+2),"Degrees F."
1290 PRINT
1300 PRINT "Ambient Pressure=",Measurements(A2+1),"Psia
1310 PRINT
1320 PRINT
1330 PRINT
1340 FOR J=1 TO 46
1350 Pressure(J)=Measurements(J+2)-Measurements(1)+Measurements(A2+1)
1360 REM Pressureratio(J)=(Measurements(A2+1)+Measurements(3))/Pressure(J)
1370 Pressureratio(J)=50.729/Pressure(J)
1380 Mach(J)=(5*(Pressureratio(J)^(1/3.5)-1))^.5
1390 Port(J)=J
1400 Pressureratio(J)=1/Pressureratio(J)
1410 PRINT USING Reduceddata;Port(J),Pressure(J),Pressureratio(J),Mach(J)
1420 Reduceddata: IMAGE "Static Pressure Port",DDD,"  Pressure=",DDDD.DDDD," Ps
ia",2X,"P/Pt0=",DD.DDDDD,"  Mach=",DDD.DDDD
1430 NEXT J
1440 DISP "Input Reduced Data File Name";
1450 INPUT Fileresults$
1460 CREATE Fileresults$,8
1470 ASSIGN #2 TO Fileresults$
1480 PRINT #2;Port(*),Pressure(*),Mach(*),Pressureratio(*)
1490 PRINT "Reduced Data Stored In File ",Fileresults$
1500 PRINT PAGE
1510 DISP "ENTER 1 IF YOU DESIRE TO REDUCE MORE DATA";
1520 INPUT Z
1530 IF Z=1 THEN 1150
1540 END
1550 SUB Init
1560 COM Tmr,Scn,Dvm,Sw,Bus,Error
1570 DATA 9,709,722,724,7
```

```
1580 REM! Tmr,Scn,Dvm,Svm,Bus
1590 ABORTIO Bus
1600 REMOTE Bus
1610 RESET Bus
1620 READ IO Tmr,5;Sig
1630 IF BINAND(Sig,48)=32 THEN OUTPUT Tmr USING "A";E
1640 SUBEND
1650 SUB Dvm(Function,Range,High_res,Data_rqs)
1660 COM Tmr,Scn,Dvm,Svm,Bus,Error
1670 Error=(Function<1) OR (Function>6)+2*((Range<1) OR (Range>[illegible]))
1680 RESET Dvm
1690 OUTPUT Dvm USING Fmt;Function,Range,High_res=1,Data_rqs=1
1700 Fmt: IMAGE "F",D,"R",D,"H",D,"D",D,"T3"
1710 SUBEND
1720 SUB Chan(Clear,Channel)
1730 COM Tmr,Scn,Dvm,Svm,Bus,Error
1740 Offset=ABS(Channel) DIV 80
1750 Error=(Scn MOD 100+Offset<30)
1760 IF NOT Error AND (Clear=1) THEN RESET Scn+Offset
1770 IF NOT Error AND (Channel<>0) THEN OUTPUT Scn+Offset [illegible]
-80*Offset
1780 SUBEND
1790 DEF FNRdvm
1800 COM Tmr,Scn,Dvm,Svm,Bus,Error
1810 TRIGGER Dvm
1820 IF F[illegible] A1 THEN 1840
1830 WAIT 100
1840 WAIT 50
1850 ENTER Dvm USING "F";Reading
1860 RETURN Reading
1870 FNEND
1880 SUB Time
1890 COM Tmr,Scn,Dvm,Svm,Bus,Error
1900 OUTPUT 9;"Request time"
```

```
1580 READ Function,Dvm,Svm,Bus
1590 ABORTIO Bus
1600 REMOTE Bus
1610 RESET Bus
1620 READ IO Tmr,5;Sig
1630 IF BINAND(Sig,48)=32 THEN OUTPUT Tmr USING "A";"E"
1640 SUBEND
1650 SUB Dvm(Function,Range,High_res,Data_rqs)
1660 COM Tmr,Scn,Dvm,Svm,Bus,Error
1670 Error=(Function<1) OR (Function>6)+2*((Range<1) OR (Range>7))
1680 RESET Dvm
1690 OUTPUT Dvm USING Fmt;Function,Range,High_res=1,Data_rqs=1
1700 Fmt: IMAGE "F",D,"R",D,"H",D,"D",D,"T3"
1710 SUBEND
1720 SUB Chan(Clear,Channel)
1730 COM Tmr,Scn,Dvm,Svm,Bus,Error
1740 Offset=ABS(Channel) DIV 80
1750 Error=(Scn MOD 100+Offset<30)
1760 IF NOT Error AND (Clear=1) THEN RESET Scn+Offset
1770 IF NOT Error AND (Channel<>0) THEN OUTPUT Scn+Offset USING "DD";INT(Channel)
-80*Offset
1780 SUBEND
1790 DEF FNRdvm
1800 COM Tmr,Scn,Dvm,Svm,Bus,Error
1810 TRIGGER Dvm
1820 IF I<>A1 THEN 1840
1830 WAIT 100
1840 WAIT 50
1850 ENTER Dvm USING "F";Reading
1860 RETURN Reading
1870 FNEND
1880 SUB Time
1890 COM Tmr,Scn,Dvm,Svm,Bus,Error
1900 OUTPUT 9;"Request time"
```

```
1910 ENTER 9;Month,Day,Hour,Time$
1920 DIM Month$(12)[5],Mer$[2]
1930 INTEGER Hour
1940 RESTORE
1950 FOR I=1 TO 12
1960 READ Month$(I)
1970 NEXT I
1980 DATA JAN,FEB,MAR,APR,MAY,JUNE,JULY,AUG,SEPT,OCT,NOV,DEC
1990 Mer$="AM"
2000 IF Hour>11 THEN Mer$="PM"
2010 IF Hour>12 THEN Hour=Hour-12
2020 IF Hour=0 THEN Hour=12
2030 PRINT Month$(Month);Day,Hour;":";Time$;"   ";Mer$
2040 SUBEND
```

# APPENDIX C

## TEST DATA

The results of the Calibration Tests, Initial Cascade Tests, and perforated wall Wave Cancellation Tests are given in Tables C-1, C-2 and C-3 respectively.

************************* CALIBRATION TEST 1 ******************************

Total Pressure = 52.274 psia
Plenum Total Temperature = 52 deg F
Ambient Pressure = 14.823 psia

| | | | |
|---|---|---|---|
| Tap No. 1 | Static Pressure= 52.274 | P/Pt0=1.0000 | Mach= 0.000 |
| Tap No. 2 | Static Pressure= 17.320 | P/Pt0= .3313 | Mach= 1.362 |
| Tap No. 3 | Static Pressure= 17.192 | P/Pt0= .3289 | Mach= 1.367 |
| Tap No. 4 | Static Pressure= 17.560 | P/Pt0= .3359 | Mach= 1.352 |
| Tap No. 5 | Static Pressure= 17.359 | P/Pt0= .3321 | Mach= 1.361 |
| Tap No. 6 | Static Pressure= 17.763 | P/Pt0= .3398 | Mach= 1.344 |
| Tap No. 7 | Static Pressure= 17.337 | P/Pt0= .3317 | Mach= 1.361 |
| Tap No. 8 | Static Pressure= 17.493 | P/Pt0= .3346 | Mach= 1.355 |
| Tap No. 9 | Static Pressure= 17.061 | P/Pt0= .3264 | Mach= 1.373 |
| Tap No. 10 | Static Pressure= 17.336 | P/Pt0= .3316 | Mach= 1.361 |
| Tap No. 11 | Static Pressure= 17.229 | P/Pt0= .3296 | Mach= 1.366 |
| Tap No. 12 | Static Pressure= 17.190 | P/Pt0= .3288 | Mach= 1.368 |
| Tap No. 13 | Static Pressure= 16.602 | P/Pt0= .3176 | Mach= 1.392 |
| Tap No. 14 | Static Pressure= 15.763 | P/Pt0= .3015 | Mach= 1.429 |
| Tap No. 15 | Static Pressure= 17.248 | P/Pt0= .3300 | Mach= 1.365 |
| Tap No. 16 | Static Pressure= 16.992 | P/Pt0= .3251 | Mach= 1.376 |
| Tap No. 17 | Static Pressure= 16.701 | P/Pt0= .3195 | Mach= 1.388 |
| Tap No. 18 | Static Pressure= 16.572 | P/Pt0= .3170 | Mach= 1.394 |
| Tap No. 19 | Static Pressure= 16.732 | P/Pt0= .3201 | Mach= 1.387 |
| Tap No. 20 | Static Pressure= 16.308 | P/Pt0= .3120 | Mach= 1.405 |
| Tap No. 21 | Static Pressure= 17.435 | P/Pt0= .3335 | Mach= 1.357 |
| Tap No. 22 | Static Pressure= 14.794 | P/Pt0= .2830 | Mach= 1.474 |
| Tap No. 23 | Static Pressure= 13.603 | P/Pt0= .2602 | Mach= 1.531 |
| Tap No. 24 | Static Pressure= 17.909 | P/Pt0= .3426 | Mach= 1.338 |
| Tap No. 25 | Static Pressure= 15.853 | P/Pt0= .3033 | Mach= 1.425 |
| Tap No. 26 | Static Pressure= 14.736 | P/Pt0= .2819 | Mach= 1.476 |
| Tap No. 27 | Static Pressure= 14.410 | P/Pt0= .2757 | Mach= 1.492 |
| Tap No. 28 | Static Pressure= 14.040 | P/Pt0= .2686 | Mach= 1.510 |
| Tap No. 29 | Static Pressure= 13.966 | P/Pt0= .2672 | Mach= 1.513 |
| Tap No. 30 | Static Pressure= 13.806 | P/Pt0= .2641 | Mach= 1.521 |
| Tap No. 31 | Static Pressure= 12.990 | P/Pt0= .2485 | Mach= 1.563 |
| Tap No. 32 | Static Pressure= 12.285 | P/Pt0= .2350 | Mach= 1.601 |
| Tap No. 33 | Static Pressure= 16.476 | P/Pt0= .3152 | Mach= 1.398 |
| Tap No. 34 | Static Pressure= 14.358 | P/Pt0= .2747 | Mach= 1.494 |
| Tap No. 35 | Static Pressure= 13.759 | P/Pt0= .2632 | Mach= 1.524 |
| Tap No. 36 | Static Pressure= 13.445 | P/Pt0= .2572 | Mach= 1.539 |
| Tap No. 37 | Static Pressure= 13.413 | P/Pt0= .2566 | Mach= 1.541 |
| Tap No. 38 | Static Pressure= 13.187 | P/Pt0= .2523 | Mach= 1.553 |
| Tap No. 39 | Static Pressure= 13.072 | P/Pt0= .2501 | Mach= 1.559 |
| Tap No. 40 | Static Pressure= 12.482 | P/Pt0= .2388 | Mach= 1.590 |
| Tap No. 41 | Static Pressure= 12.144 | P/Pt0= .2323 | Mach= 1.609 |
| Tap No. 42 | Static Pressure= 13.304 | P/Pt0= .2545 | Mach= 1.547 |
| Tap No. 43 | Static Pressure= 12.831 | P/Pt0= .2455 | Mach= 1.571 |
| Tap No. 44 | Static Pressure= 14.761 | P/Pt0= .2824 | Mach= 1.475 |
| Tap No. 45 | Static Pressure= 12.811 | P/Pt0= .2451 | Mach= 1.572 |
| Tap No. 46 | Static Pressure= 12.563 | P/Pt0= .2403 | Mach= 1.586 |

**Table C-1. Calibration Test Data**

CALIBRATION TEST 1 CONTINUED

| | | | |
|---|---|---|---|
| Tap No. 47 | Static Pressure= 12.919 | P/Pt0= .2471 | Mach= 1.567 |
| Tap No. 48 | Static Pressure= 12.468 | P/Pt0= .2385 | Mach= 1.591 |
| Tap No. 49 | Static Pressure= 12.235 | P/Pt0= .2341 | Mach= 1.603 |
| Tap No. 50 | Static Pressure= 12.413 | P/Pt0= .2375 | Mach= 1.594 |
| Tap No. 51 | Static Pressure= 11.907 | P/Pt0= .2278 | Mach= 1.622 |
| Tap No. 52 | Static Pressure= 11.905 | P/Pt0= .2277 | Mach= 1.622 |
| Tap No. 53 | Static Pressure= 11.888 | P/Pt0= .2274 | Mach= 1.623 |
| Tap No. 54 | Static Pressure= 11.954 | P/Pt0= .2287 | Mach= 1.619 |
| Tap No. 55 | Static Pressure= 11.690 | P/Pt0= .2236 | Mach= 1.634 |
| Tap No. 56 | Static Pressure= 11.683 | P/Pt0= .2235 | Mach= 1.635 |
| Tap No. 57 | Static Pressure= 11.773 | P/Pt0= .2252 | Mach= 1.629 |
| Tap No. 58 | Static Pressure= 11.700 | P/Pt0= .2238 | Mach= 1.634 |
| Tap No. 59 | Static Pressure= 14.735 | P/Pt0= .2819 | Mach= 1.476 |
| Tap No. 60 | Static Pressure= 12.099 | P/Pt0= .2315 | Mach= 1.611 |
| Tap No. 61 | Static Pressure= 12.087 | P/Pt0= .2312 | Mach= 1.612 |
| Tap No. 62 | Static Pressure= 11.720 | P/Pt0= .2242 | Mach= 1.632 |
| Tap No. 63 | Static Pressure= 11.817 | P/Pt0= .2261 | Mach= 1.627 |
| Tap No. 64 | Static Pressure= 11.981 | P/Pt0= .2292 | Mach= 1.618 |
| Tap No. 65 | Static Pressure= 11.726 | P/Pt0= .2243 | Mach= 1.632 |
| Tap No. 66 | Static Pressure= 11.806 | P/Pt0= .2259 | Mach= 1.628 |
| Tap No. 67 | Static Pressure= 11.909 | P/Pt0= .2278 | Mach= 1.622 |
| Tap No. 68 | Static Pressure= 12.756 | P/Pt0= .2440 | Mach= 1.575 |
| Tap No. 69 | Static Pressure= 11.847 | P/Pt0= .2266 | Mach= 1.625 |
| Tap No. 70 | Static Pressure= 11.287 | P/Pt0= .2159 | Mach= 1.658 |
| Tap No. 71 | Static Pressure= 12.016 | P/Pt0= .2299 | Mach= 1.616 |
| Tap No. 72 | Static Pressure= 17.005 | P/Pt0= .3253 | Mach= 1.375 |
| Tap No. 73 | Static Pressure= 15.207 | P/Pt0= .2909 | Mach= 1.454 |
| Tap No. 74 | Static Pressure= 10.930 | P/Pt0= .2091 | Mach= 1.679 |
| Tap No. 75 | Static Pressure= 17.142 | P/Pt0= .3279 | Mach= 1.370 |
| Tap No. 76 | Static Pressure= 17.132 | P/Pt0= .3277 | Mach= 1.370 |
| Tap No. 77 | Static Pressure= 14.832 | P/Pt0= .2837 | Mach= 1.472 |
| Tap No. 78 | Static Pressure= 14.802 | P/Pt0= .2832 | Mach= 1.473 |
| Tap No. 79 | Static Pressure= 13.398 | P/Pt0= .2563 | Mach= 1.542 |
| Tap No. 80 | Static Pressure= 14.754 | P/Pt0= .2822 | Mach= 1.475 |
| Tap No. 81 | Static Pressure= 14.790 | P/Pt0= .2829 | Mach= 1.474 |
| Tap No. 82 | Static Pressure= 14.789 | P/Pt0= .2829 | Mach= 1.474 |
| Tap No. 83 | Static Pressure= 14.781 | P/Pt0= .2828 | Mach= 1.474 |
| Tap No. 84 | Static Pressure= 11.969 | P/Pt0= .2290 | Mach= 1.618 |
| Tap No. 85 | Static Pressure= 14.709 | P/Pt0= .2814 | Mach= 1.478 |
| Tap No. 86 | Static Pressure= 14.822 | P/Pt0= .2835 | Mach= 1.472 |
| Tap No. 87 | Static Pressure= 17.189 | P/Pt0= .3288 | Mach= 1.368 |
| Tap No. 88 | Static Pressure= 15.294 | P/Pt0= .2926 | Mach= 1.450 |
| Tap No. 89 | Static Pressure= 10.921 | P/Pt0= .2089 | Mach= 1.680 |

Table C-1. (Continued)

************************ CALIBRATION TEST 2 **************************

Total Pressure = 49.500 psia
Plenum Total Temperature = 61 deg F
Ambient Pressure = 14.774 psia

| | | | |
|---|---|---|---|
| Tap No. 1 | Static Pressure= 49.482 | P/Pt0= .9996 | Mach= .023 |
| Tap No. 2 | Static Pressure= 16.299 | P/Pt0= .3293 | Mach= 1.367 |
| Tap No. 3 | Static Pressure= 16.193 | P/Pt0= .3271 | Mach= 1.371 |
| Tap No. 4 | Static Pressure= 16.423 | P/Pt0= .3318 | Mach= 1.361 |
| Tap No. 5 | Static Pressure= 16.394 | P/Pt0= .3312 | Mach= 1.362 |
| Tap No. 6 | Static Pressure= 16.791 | P/Pt0= .3392 | Mach= 1.345 |
| Tap No. 7 | Static Pressure= 16.414 | P/Pt0= .3316 | Mach= 1.362 |
| Tap No. 8 | Static Pressure= 16.562 | P/Pt0= .3346 | Mach= 1.355 |
| Tap No. 9 | Static Pressure= 16.158 | P/Pt0= .3264 | Mach= 1.373 |
| Tap No. 10 | Static Pressure= 16.209 | P/Pt0= .3275 | Mach= 1.371 |
| Tap No. 11 | Static Pressure= 16.284 | P/Pt0= .3290 | Mach= 1.367 |
| Tap No. 12 | Static Pressure= 16.250 | P/Pt0= .3283 | Mach= 1.369 |
| Tap No. 13 | Static Pressure= 15.592 | P/Pt0= .3150 | Mach= 1.398 |
| Tap No. 14 | Static Pressure= 14.847 | P/Pt0= .2999 | Mach= 1.433 |
| Tap No. 15 | Static Pressure= 16.360 | P/Pt0= .3305 | Mach= 1.364 |
| Tap No. 16 | Static Pressure= 16.160 | P/Pt0= .3265 | Mach= 1.373 |
| Tap No. 17 | Static Pressure= 15.837 | P/Pt0= .3199 | Mach= 1.387 |
| Tap No. 18 | Static Pressure= 15.693 | P/Pt0= .3170 | Mach= 1.394 |
| Tap No. 19 | Static Pressure= 15.922 | P/Pt0= .3217 | Mach= 1.383 |
| Tap No. 20 | Static Pressure= 15.510 | P/Pt0= .3133 | Mach= 1.402 |
| Tap No. 21 | Static Pressure= 15.138 | P/Pt0= .3058 | Mach= 1.419 |
| Tap No. 22 | Static Pressure= 14.090 | P/Pt0= .2846 | Mach= 1.470 |
| Tap No. 23 | Static Pressure= 12.976 | P/Pt0= .2621 | Mach= 1.526 |
| Tap No. 24 | Static Pressure= 16.657 | P/Pt0= .3365 | Mach= 1.351 |
| Tap No. 25 | Static Pressure= 15.141 | P/Pt0= .3059 | Mach= 1.419 |
| Tap No. 26 | Static Pressure= 13.979 | P/Pt0= .2824 | Mach= 1.475 |
| Tap No. 27 | Static Pressure= 13.780 | P/Pt0= .2784 | Mach= 1.485 |
| Tap No. 28 | Static Pressure= 13.352 | P/Pt0= .2697 | Mach= 1.507 |
| Tap No. 29 | Static Pressure= 13.336 | P/Pt0= .2694 | Mach= 1.508 |
| Tap No. 30 | Static Pressure= 13.171 | P/Pt0= .2661 | Mach= 1.516 |
| Tap No. 31 | Static Pressure= 12.589 | P/Pt0= .2543 | Mach= 1.547 |
| Tap No. 32 | Static Pressure= 11.947 | P/Pt0= .2414 | Mach= 1.583 |
| Tap No. 33 | Static Pressure= 15.603 | P/Pt0= .3152 | Mach= 1.398 |
| Tap No. 34 | Static Pressure= 13.662 | P/Pt0= .2760 | Mach= 1.491 |
| Tap No. 35 | Static Pressure= 13.247 | P/Pt0= .2676 | Mach= 1.512 |
| Tap No. 36 | Static Pressure= 12.884 | P/Pt0= .2603 | Mach= 1.531 |
| Tap No. 37 | Static Pressure= 12.908 | P/Pt0= .2608 | Mach= 1.530 |
| Tap No. 38 | Static Pressure= 12.681 | P/Pt0= .2562 | Mach= 1.542 |
| Tap No. 39 | Static Pressure= 12.639 | P/Pt0= .2553 | Mach= 1.544 |
| Tap No. 40 | Static Pressure= 12.151 | P/Pt0= .2455 | Mach= 1.571 |
| Tap No. 41 | Static Pressure= 11.875 | P/Pt0= .2399 | Mach= 1.587 |
| Tap No. 42 | Static Pressure= 12.990 | P/Pt0= .2624 | Mach= 1.526 |
| Tap No. 43 | Static Pressure= 12.535 | P/Pt0= .2532 | Mach= 1.550 |
| Tap No. 44 | Static Pressure= 12.699 | P/Pt0= .2565 | Mach= 1.541 |
| Tap No. 45 | Static Pressure= 12.451 | P/Pt0= .2515 | Mach= 1.555 |
| Tap No. 46 | Static Pressure= 12.349 | P/Pt0= .2495 | Mach= 1.560 |

**Table C-1. (Continued)**

CALIBRATION TEST 2 CONTINUED

| | | | |
|---|---|---|---|
| Tap No. 47 | Static Pressure= 12.621 | P/Pt0= .2550 | Mach= 1.545 |
| Tap No. 48 | Static Pressure= 12.249 | P/Pt0= .2475 | Mach= 1.566 |
| Tap No. 49 | Static Pressure= 12.124 | P/Pt0= .2449 | Mach= 1.573 |
| Tap No. 50 | Static Pressure= 12.131 | P/Pt0= .2451 | Mach= 1.572 |
| Tap No. 51 | Static Pressure= 11.699 | P/Pt0= .2363 | Mach= 1.597 |
| Tap No. 52 | Static Pressure= 11.906 | P/Pt0= .2405 | Mach= 1.585 |
| Tap No. 53 | Static Pressure= 11.807 | P/Pt0= .2385 | Mach= 1.591 |
| Tap No. 54 | Static Pressure= 11.928 | P/Pt0= .2410 | Mach= 1.584 |
| Tap No. 55 | Static Pressure= 11.758 | P/Pt0= .2375 | Mach= 1.594 |
| Tap No. 56 | Static Pressure= 11.792 | P/Pt0= .2382 | Mach= 1.592 |
| Tap No. 57 | Static Pressure= 12.105 | P/Pt0= .2445 | Mach= 1.574 |
| Tap No. 58 | Static Pressure= 12.093 | P/Pt0= .2443 | Mach= 1.575 |
| Tap No. 59 | Static Pressure= 12.618 | P/Pt0= .2549 | Mach= 1.546 |
| Tap No. 60 | Static Pressure= 12.556 | P/Pt0= .2537 | Mach= 1.549 |
| Tap No. 61 | Static Pressure= 12.141 | P/Pt0= .2453 | Mach= 1.572 |
| Tap No. 62 | Static Pressure= 11.940 | P/Pt0= .2412 | Mach= 1.583 |
| Tap No. 63 | Static Pressure= 12.226 | P/Pt0= .2470 | Mach= 1.567 |
| Tap No. 64 | Static Pressure= 12.033 | P/Pt0= .2431 | Mach= 1.578 |
| Tap No. 65 | Static Pressure= 11.823 | P/Pt0= .2389 | Mach= 1.590 |
| Tap No. 66 | Static Pressure= 11.781 | P/Pt0= .2380 | Mach= 1.592 |
| Tap No. 67 | Static Pressure= 12.281 | P/Pt0= .2481 | Mach= 1.564 |
| Tap No. 68 | Static Pressure= 12.741 | P/Pt0= .2574 | Mach= 1.539 |
| Tap No. 69 | Static Pressure= 11.826 | P/Pt0= .2389 | Mach= 1.590 |
| Tap No. 70 | Static Pressure= 11.444 | P/Pt0= .2312 | Mach= 1.612 |
| Tap No. 71 | Static Pressure= 12.223 | P/Pt0= .2469 | Mach= 1.567 |
| Tap No. 72 | Static Pressure= 16.067 | P/Pt0= .3246 | Mach= 1.377 |
| Tap No. 73 | Static Pressure= 14.363 | P/Pt0= .2902 | Mach= 1.456 |
| Tap No. 74 | Static Pressure= 11.498 | P/Pt0= .2323 | Mach= 1.609 |
| Tap No. 75 | Static Pressure= 16.193 | P/Pt0= .3271 | Mach= 1.371 |
| Tap No. 76 | Static Pressure= 16.060 | P/Pt0= .3244 | Mach= 1.377 |
| Tap No. 77 | Static Pressure= 14.771 | P/Pt0= .2984 | Mach= 1.437 |
| Tap No. 78 | Static Pressure= 14.803 | P/Pt0= .2991 | Mach= 1.435 |
| Tap No. 79 | Static Pressure= 12.856 | P/Pt0= .2597 | Mach= 1.533 |
| Tap No. 80 | Static Pressure= 14.697 | P/Pt0= .2969 | Mach= 1.440 |
| Tap No. 81 | Static Pressure= 14.749 | P/Pt0= .2980 | Mach= 1.438 |
| Tap No. 82 | Static Pressure= 14.744 | P/Pt0= .2979 | Mach= 1.438 |
| Tap No. 83 | Static Pressure= 14.745 | P/Pt0= .2979 | Mach= 1.438 |
| Tap No. 84 | Static Pressure= 11.817 | P/Pt0= .2387 | Mach= 1.590 |
| Tap No. 85 | Static Pressure= 14.686 | P/Pt0= .2967 | Mach= 1.441 |
| Tap No. 86 | Static Pressure= 14.836 | P/Pt0= .2997 | Mach= 1.433 |
| Tap No. 87 | Static Pressure= 16.235 | P/Pt0= .3280 | Mach= 1.369 |
| Tap No. 88 | Static Pressure= 14.667 | P/Pt0= .2963 | Mach= 1.441 |
| Tap No. 89 | Static Pressure= 11.579 | P/Pt0= .2339 | Mach= 1.604 |

**Table C-1. (Continued)**

AD-A091 080 NAVAL POSTGRADUATE SCHOOL MONTEREY CA F/G 14/2
TRASONIC CASCADE WIND TUNNEL MODIFICATION AND INITIAL TESTS.(U)
JUN 80 K F VOLLAND

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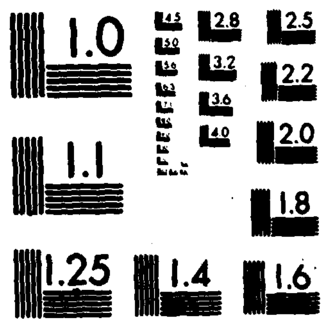


MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

************ CASCADE WIND TUNNEL TEST 1 **************************

Total Pressure = 50.728 psia
Plenum Total Temperature = 62 deg F
Ambient Pressure = 14.749 psia

| | | |
|---|---|---|
| Tap No. 1 | Static Pressure = 50.729 psia | P/Pt0=1.0000 |
| Tap No. 2 | Static Pressure = 33.355 psia | P/Pt0= .6575 |
| Tap No. 3 | Static Pressure = 33.863 psia | P/Pt0= .6675 |
| Tap No. 4 | Static Pressure = 33.928 psia | P/Pt0= .6688 |
| Tap No. 5 | Static Pressure = 33.970 psia | P/Pt0= .6696 |
| Tap No. 6 | Static Pressure = 33.449 psia | P/Pt0= .6594 |
| Tap No. 7 | Static Pressure = 33.977 psia | P/Pt0= .6698 |
| Tap No. 8 | Static Pressure = 34.040 psia | P/Pt0= .6710 |
| Tap No. 9 | Static Pressure = 34.066 psia | P/Pt0= .6715 |
| Tap No. 10 | Static Pressure = 34.075 psia | P/Pt0= .6717 |
| Tap No. 11 | Static Pressure = 33.900 psia | P/Pt0= .6683 |
| Tap No. 12 | Static Pressure = 33.847 psia | P/Pt0= .6672 |
| Tap No. 13 | Static Pressure = 33.721 psia | P/Pt0= .6647 |
| Tap No. 14 | Static Pressure = 33.578 psia | P/Pt0= .6619 |
| Tap No. 15 | Static Pressure = 33.595 psia | P/Pt0= .6622 |
| Tap No. 16 | Static Pressure = 33.986 psia | P/Pt0= .6699 |
| Tap No. 17 | Static Pressure = 34.002 psia | P/Pt0= .6703 |
| Tap No. 18 | Static Pressure = 33.761 psia | P/Pt0= .6655 |
| Tap No. 19 | Static Pressure = 33.706 psia | P/Pt0= .6644 |
| Tap No. 20 | Static Pressure = 33.706 psia | P/Pt0= .6644 |
| Tap No. 21 | Static Pressure = 33.828 psia | P/Pt0= .6668 |
| Tap No. 22 | Static Pressure = 33.408 psia | P/Pt0= .6586 |
| Tap No. 23 | Static Pressure = 33.054 psia | P/Pt0= .6516 |
| Tap No. 24 | Static Pressure = 34.652 psia | P/Pt0= .6831 |
| Tap No. 25 | Static Pressure = 34.395 psia | P/Pt0= .6780 |
| Tap No. 26 | Static Pressure = 33.497 psia | P/Pt0= .6603 |
| Tap No. 27 | Static Pressure = 33.968 psia | P/Pt0= .6696 |
| Tap No. 28 | Static Pressure = 33.941 psia | P/Pt0= .6691 |
| Tap No. 29 | Static Pressure = 33.494 psia | P/Pt0= .6603 |
| Tap No. 30 | Static Pressure = 33.180 psia | P/Pt0= .6541 |
| Tap No. 31 | Static Pressure = 33.862 psia | P/Pt0= .6675 |
| Tap No. 32 | Static Pressure = 32.642 psia | P/Pt0= .6435 |
| Tap No. 33 | Static Pressure = 34.206 psia | P/Pt0= .6743 |
| Tap No. 34 | Static Pressure = 33.751 psia | P/Pt0= .6653 |
| Tap No. 35 | Static Pressure = 34.487 psia | P/Pt0= .6798 |
| Tap No. 36 | Static Pressure = 34.031 psia | P/Pt0= .6708 |
| Tap No. 37 | Static Pressure = 33.360 psia | P/Pt0= .6576 |
| Tap No. 38 | Static Pressure = 32.817 psia | P/Pt0= .6469 |
| Tap No. 39 | Static Pressure = 32.866 psia | P/Pt0= .6479 |
| Tap No. 40 | Static Pressure = 33.141 psia | P/Pt0= .6533 |
| Tap No. 41 | Static Pressure = 31.082 psia | P/Pt0= .6127 |
| Tap No. 42 | Static Pressure = 33.469 psia | P/Pt0= .6598 |
| Tap No. 43 | Static Pressure = 33.031 psia | P/Pt0= .6511 |
| Tap No. 44 | Static Pressure = 32.508 psia | P/Pt0= .6408 |
| Tap No. 45 | Static Pressure = 32.453 psia | P/Pt0= .6397 |
| Tap No. 46 | Static Pressure = 32.444 psia | P/Pt0= .6396 |

**Table C-2. Cascade Wind Tunnel Test Data**

CASCADE WIND TUNNEL TEST 1 CONTINUED

| | | |
|---|---|---|
| Tap No. 47 | Static Pressure = 32.148 psia | P/Pt0= .6337 |
| Tap No. 48 | Static Pressure = 32.068 psia | P/Pt0= .6321 |
| Tap No. 49 | Static Pressure = 31.239 psia | P/Pt0= .6158 |
| Tap No. 50 | Static Pressure = 23.478 psia | P/Pt0= .4628 |
| Tap No. 51 | Static Pressure = 31.811 psia | P/Pt0= .6271 |
| Tap No. 52 | Static Pressure = 31.204 psia | P/Pt0= .6151 |
| Tap No. 53 | Static Pressure = 29.516 psia | P/Pt0= .5818 |
| Tap No. 54 | Static Pressure = 22.630 psia | P/Pt0= .4461 |
| Tap No. 55 | Static Pressure = 30.574 psia | P/Pt0= .6027 |
| Tap No. 56 | Static Pressure = 28.336 psia | P/Pt0= .5586 |
| Tap No. 57 | Static Pressure = 22.831 psia | P/Pt0= .4500 |
| Tap No. 58 | Static Pressure = 21.312 psia | P/Pt0= .4201 |
| Tap No. 59 | Static Pressure = 21.453 psia | P/Pt0= .4229 |
| Tap No. 60 | Static Pressure = 20.225 psia | P/Pt0= .3987 |
| Tap No. 61 | Static Pressure = 19.392 psia | P/Pt0= .3823 |
| Tap No. 62 | Static Pressure = 16.789 psia | P/Pt0= .3309 |
| Tap No. 63 | Static Pressure = 17.474 psia | P/Pt0= .3444 |
| Tap No. 64 | Static Pressure = 16.948 psia | P/Pt0= .3341 |
| Tap No. 65 | Static Pressure = 14.785 psia | P/Pt0= .2914 |
| Tap No. 66 | Static Pressure = 13.038 psia | P/Pt0= .2570 |
| Tap No. 67 | Static Pressure = 10.107 psia | P/Pt0= .1992 |
| Tap No. 68 | Static Pressure = 10.601 psia | P/Pt0= .2090 |
| Tap No. 69 | Static Pressure = 11.257 psia | P/Pt0= .2219 |
| Tap No. 70 | Static Pressure = 11.883 psia | P/Pt0= .2342 |
| Tap No. 71 | Static Pressure = 11.600 psia | P/Pt0= .2287 |
| Tap No. 72 | Static Pressure = 33.404 psia | P/Pt0= .6585 |
| Tap No. 73 | Static Pressure = 25.629 psia | P/Pt0= .5052 |
| Tap No. 74 | Static Pressure = 22.918 psia | P/Pt0= .4518 |
| Tap No. 75 | Static Pressure = 32.392 psia | P/Pt0= .6385 |
| Tap No. 76 | Static Pressure = 33.525 psia | P/Pt0= .6609 |
| Tap No. 77 | Static Pressure = 15.089 psia | P/Pt0= .2974 |
| Tap No. 78 | Static Pressure = 14.766 psia | P/Pt0= .2911 |
| Tap No. 79 | Static Pressure = 32.923 psia | P/Pt0= .6490 |
| Tap No. 80 | Static Pressure = 15.268 psia | P/Pt0= .3010 |
| Tap No. 81 | Static Pressure = 14.783 psia | P/Pt0= .2914 |
| Tap No. 82 | Static Pressure = 14.762 psia | P/Pt0= .2910 |
| Tap No. 83 | Static Pressure = 10.260 psia | P/Pt0= .2022 |
| Tap No. 84 | Static Pressure = 11.137 psia | P/Pt0= .2195 |
| Tap No. 85 | Static Pressure = 14.610 psia | P/Pt0= .2880 |
| Tap No. 86 | Static Pressure = 14.800 psia | P/Pt0= .2917 |
| Tap No. 87 | Static Pressure = 33.539 psia | P/Pt0= .6611 |
| Tap No. 88 | Static Pressure = 26.185 psia | P/Pt0= .5162 |
| Tap No. 89 | Static Pressure = 23.609 psia | P/Pt0= .4654 |

**Table C-2. (Continued)**

************* CASCADE WIND TUNNEL TEST 2 *************************

Total Pressure = 49.565 psia
Plenum Total Temperature = 65 deg F
Ambient Pressure = 14.789 psia

| | | |
|---|---|---|
| Tap No. 1 | Static Pressure = 49.561 psia | P/Pt0= .9999 |
| Tap No. 2 | Static Pressure = 16.261 psia | P/Pt0= .3281 |
| Tap No. 3 | Static Pressure = 15.999 psia | P/Pt0= .3228 |
| Tap No. 4 | Static Pressure = 16.202 psia | P/Pt0= .3269 |
| Tap No. 5 | Static Pressure = 16.416 psia | P/Pt0= .3312 |
| Tap No. 6 | Static Pressure = 16.930 psia | P/Pt0= .3416 |
| Tap No. 7 | Static Pressure = 16.244 psia | P/Pt0= .3277 |
| Tap No. 8 | Static Pressure = 16.811 psia | P/Pt0= .3392 |
| Tap No. 9 | Static Pressure = 16.694 psia | P/Pt0= .3368 |
| Tap No. 10 | Static Pressure = 16.960 psia | P/Pt0= .3422 |
| Tap No. 11 | Static Pressure = 17.656 psia | P/Pt0= .3562 |
| Tap No. 12 | Static Pressure = 18.297 psia | P/Pt0= .3691 |
| Tap No. 13 | Static Pressure = 19.156 psia | P/Pt0= .3865 |
| Tap No. 14 | Static Pressure = 19.792 psia | P/Pt0= .3993 |
| Tap No. 15 | Static Pressure = 16.109 psia | P/Pt0= .3250 |
| Tap No. 16 | Static Pressure = 17.211 psia | P/Pt0= .3472 |
| Tap No. 17 | Static Pressure = 18.849 psia | P/Pt0= .3803 |
| Tap No. 18 | Static Pressure = 19.248 psia | P/Pt0= .3883 |
| Tap No. 19 | Static Pressure = 19.190 psia | P/Pt0= .3872 |
| Tap No. 20 | Static Pressure = 19.432 psia | P/Pt0= .3920 |
| Tap No. 21 | Static Pressure = 19.137 psia | P/Pt0= .3861 |
| Tap No. 22 | Static Pressure = 20.316 psia | P/Pt0= .4099 |
| Tap No. 23 | Static Pressure = 20.610 psia | P/Pt0= .4158 |
| Tap No. 24 | Static Pressure = 18.101 psia | P/Pt0= .3652 |
| Tap No. 25 | Static Pressure = 18.899 psia | P/Pt0= .3813 |
| Tap No. 26 | Static Pressure = 18.669 psia | P/Pt0= .3767 |
| Tap No. 27 | Static Pressure = 19.383 psia | P/Pt0= .3911 |
| Tap No. 28 | Static Pressure = 20.322 psia | P/Pt0= .4100 |
| Tap No. 29 | Static Pressure = 19.683 psia | P/Pt0= .3971 |
| Tap No. 30 | Static Pressure = 19.555 psia | P/Pt0= .3945 |
| Tap No. 31 | Static Pressure = 20.279 psia | P/Pt0= .4091 |
| Tap No. 32 | Static Pressure = 22.014 psia | P/Pt0= .4441 |
| Tap No. 33 | Static Pressure = 18.676 psia | P/Pt0= .3768 |
| Tap No. 34 | Static Pressure = 19.151 psia | P/Pt0= .3864 |
| Tap No. 35 | Static Pressure = 20.436 psia | P/Pt0= .4123 |
| Tap No. 36 | Static Pressure = 19.817 psia | P/Pt0= .3998 |
| Tap No. 37 | Static Pressure = 19.448 psia | P/Pt0= .3924 |
| Tap No. 38 | Static Pressure = 19.118 psia | P/Pt0= .3857 |
| Tap No. 39 | Static Pressure = 19.083 psia | P/Pt0= .3850 |
| Tap No. 40 | Static Pressure = 19.985 psia | P/Pt0= .4032 |
| Tap No. 41 | Static Pressure = 22.030 psia | P/Pt0= .4445 |
| Tap No. 42 | Static Pressure = 19.273 psia | P/Pt0= .3888 |
| Tap No. 43 | Static Pressure = 19.035 psia | P/Pt0= .3840 |
| Tap No. 44 | Static Pressure = 18.746 psia | P/Pt0= .3782 |
| Tap No. 45 | Static Pressure = 18.524 psia | P/Pt0= .3737 |
| Tap No. 46 | Static Pressure = 18.859 psia | P/Pt0= .3805 |

**Table C-2. (Continued)**

CASCADE WIND TUNNEL TEST 2 CONTINUED

| | | |
|---|---|---|
| Tap No. 47 | Static Pressure = 18.618 psia | P/Pt0= .3756 |
| Tap No. 48 | Static Pressure = 18.492 psia | P/Pt0= .3731 |
| Tap No. 49 | Static Pressure = 19.298 psia | P/Pt0= .3893 |
| Tap No. 50 | Static Pressure = 19.478 psia | P/Pt0= .3930 |
| Tap No. 51 | Static Pressure = 18.080 psia | P/Pt0= .3648 |
| Tap No. 52 | Static Pressure = 18.528 psia | P/Pt0= .3738 |
| Tap No. 53 | Static Pressure = 19.142 psia | P/Pt0= .3862 |
| Tap No. 54 | Static Pressure = 18.556 psia | P/Pt0= .3744 |
| Tap No. 55 | Static Pressure = 18.843 psia | P/Pt0= .3802 |
| Tap No. 56 | Static Pressure = 18.621 psia | P/Pt0= .3757 |
| Tap No. 57 | Static Pressure = 17.979 psia | P/Pt0= .3627 |
| Tap No. 58 | Static Pressure = 16.939 psia | P/Pt0= .3417 |
| Tap No. 59 | Static Pressure = 17.539 psia | P/Pt0= .3539 |
| Tap No. 60 | Static Pressure = 16.677 psia | P/Pt0= .3365 |
| Tap No. 61 | Static Pressure = 16.408 psia | P/Pt0= .3310 |
| Tap No. 62 | Static Pressure = 15.377 psia | P/Pt0= .3102 |
| Tap No. 63 | Static Pressure = 15.528 psia | P/Pt0= .3133 |
| Tap No. 64 | Static Pressure = 14.600 psia | P/Pt0= .2946 |
| Tap No. 65 | Static Pressure = 13.326 psia | P/Pt0= .2689 |
| Tap No. 66 | Static Pressure = 12.496 psia | P/Pt0= .2521 |
| Tap No. 67 | Static Pressure = 11.523 psia | P/Pt0= .2325 |
| Tap No. 68 | Static Pressure = 12.335 psia | P/Pt0= .2489 |
| Tap No. 69 | Static Pressure = 12.217 psia | P/Pt0= .2465 |
| Tap No. 70 | Static Pressure = 12.111 psia | P/Pt0= .2443 |
| Tap No. 71 | Static Pressure = 11.579 psia | P/Pt0= .2336 |
| Tap No. 72 | Static Pressure = 16.502 psia | P/Pt0= .3329 |
| Tap No. 73 | Static Pressure = 15.816 psia | P/Pt0= .3191 |
| Tap No. 74 | Static Pressure = 20.636 psia | P/Pt0= .4163 |
| Tap No. 75 | Static Pressure = 16.569 psia | P/Pt0= .3343 |
| Tap No. 76 | Static Pressure = 16.753 psia | P/Pt0= .3380 |
| Tap No. 77 | Static Pressure = 14.802 psia | P/Pt0= .2986 |
| Tap No. 78 | Static Pressure = 14.792 psia | P/Pt0= .2984 |
| Tap No. 79 | Static Pressure = 19.494 psia | P/Pt0= .3933 |
| Tap No. 80 | Static Pressure = 14.921 psia | P/Pt0= .3010 |
| Tap No. 81 | Static Pressure = 14.766 psia | P/Pt0= .2979 |
| Tap No. 82 | Static Pressure = 14.777 psia | P/Pt0= .2981 |
| Tap No. 83 | Static Pressure = 11.870 psia | P/Pt0= .2395 |
| Tap No. 84 | Static Pressure = 12.035 psia | P/Pt0= .2428 |
| Tap No. 85 | Static Pressure = 14.678 psia | P/Pt0= .2961 |
| Tap No. 86 | Static Pressure = 14.918 psia | P/Pt0= .3010 |
| Tap No. 87 | Static Pressure = 16.596 psia | P/Pt0= .3348 |
| Tap No. 88 | Static Pressure = 16.397 psia | P/Pt0= .3308 |
| Tap No. 89 | Static Pressure = 21.685 psia | P/Pt0= .4375 |
| Tap No. 90 | Wall Exhaust Static Pressure = 15.017 psia | |
| Tap No. 91 | Wall Exhaust Total Pressure = 16.998 psia | |

**Table C-2. (Continued)**

*************** WAVE CANCELLATION TEST 1 ***************************

Total Pressure = 50.171 psia
Plenum Total Temperature = 60 deg F
Ambient Pressure = 14.705 psia

| | | |
|---|---|---|
| Tap No. 1 | Static Pressure = 50.155 psia | P/Pt0= .9997 |
| Tap No. 2 | Static Pressure = 16.664 psia | P/Pt0= .3321 |
| Tap No. 3 | Static Pressure = 16.449 psia | P/Pt0= .3279 |
| Tap No. 4 | Static Pressure = 16.751 psia | P/Pt0= .3339 |
| Tap No. 5 | Static Pressure = 16.683 psia | P/Pt0= .3325 |
| Tap No. 6 | Static Pressure = 17.155 psia | P/Pt0= .3419 |
| Tap No. 7 | Static Pressure = 16.615 psia | P/Pt0= .3312 |
| Tap No. 8 | Static Pressure = 17.065 psia | P/Pt0= .3401 |
| Tap No. 9 | Static Pressure = 17.053 psia | P/Pt0= .3399 |
| Tap No. 10 | Static Pressure = 17.727 psia | P/Pt0= .3533 |
| Tap No. 11 | Static Pressure = 18.142 psia | P/Pt0= .3616 |
| Tap No. 12 | Static Pressure = 18.776 psia | P/Pt0= .3742 |
| Tap No. 13 | Static Pressure = 18.358 psia | P/Pt0= .3659 |
| Tap No. 14 | Static Pressure = 17.049 psia | P/Pt0= .3398 |
| Tap No. 15 | Static Pressure = 16.644 psia | P/Pt0= .3317 |
| Tap No. 16 | Static Pressure = 17.734 psia | P/Pt0= .3535 |
| Tap No. 17 | Static Pressure = 18.945 psia | P/Pt0= .3776 |
| Tap No. 18 | Static Pressure = 18.824 psia | P/Pt0= .3752 |
| Tap No. 19 | Static Pressure = 18.590 psia | P/Pt0= .3705 |
| Tap No. 20 | Static Pressure = 18.264 psia | P/Pt0= .3640 |
| Tap No. 21 | Static Pressure = 17.685 psia | P/Pt0= .3525 |
| Tap No. 22 | Static Pressure = 17.039 psia | P/Pt0= .3396 |
| Tap No. 23 | Static Pressure = 15.517 psia | P/Pt0= .3093 |
| Tap No. 24 | Static Pressure = 18.756 psia | P/Pt0= .3738 |
| Tap No. 25 | Static Pressure = 18.487 psia | P/Pt0= .3685 |
| Tap No. 26 | Static Pressure = 17.385 psia | P/Pt0= .3465 |
| Tap No. 27 | Static Pressure = 16.840 psia | P/Pt0= .3357 |
| Tap No. 28 | Static Pressure = 16.725 psia | P/Pt0= .3334 |
| Tap No. 29 | Static Pressure = 16.454 psia | P/Pt0= .3280 |
| Tap No. 30 | Static Pressure = 16.544 psia | P/Pt0= .3298 |
| Tap No. 31 | Static Pressure = 15.517 psia | P/Pt0= .3093 |
| Tap No. 32 | Static Pressure = 14.453 psia | P/Pt0= .2881 |
| Tap No. 33 | Static Pressure = 19.093 psia | P/Pt0= .3806 |
| Tap No. 34 | Static Pressure = 17.812 psia | P/Pt0= .3550 |
| Tap No. 35 | Static Pressure = 16.537 psia | P/Pt0= .3296 |
| Tap No. 36 | Static Pressure = 16.315 psia | P/Pt0= .3252 |
| Tap No. 37 | Static Pressure = 16.092 psia | P/Pt0= .3207 |
| Tap No. 38 | Static Pressure = 16.095 psia | P/Pt0= .3208 |
| Tap No. 39 | Static Pressure = 15.583 psia | P/Pt0= .3106 |
| Tap No. 40 | Static Pressure = 15.193 psia | P/Pt0= .3028 |
| Tap No. 41 | Static Pressure = 13.884 psia | P/Pt0= .2767 |
| Tap No. 42 | Static Pressure = 15.614 psia | P/Pt0= .3112 |
| Tap No. 43 | Static Pressure = 15.853 psia | P/Pt0= .3160 |
| Tap No. 44 | Static Pressure = 15.639 psia | P/Pt0= .3117 |
| Tap No. 45 | Static Pressure = 15.432 psia | P/Pt0= .3076 |
| Tap No. 46 | Static Pressure = 15.284 psia | P/Pt0= .3046 |

**Table C-3. Wave Cancellation Test Data**

WAVE CANCELLATION TEST 1 CONTINUED

| | | |
|---|---|---|
| Tap No. 47 | Static Pressure = 15.570 psia | P/Pt0= .3103 |
| Tap No. 48 | Static Pressure = 15.085 psia | P/Pt0= .3007 |
| Tap No. 49 | Static Pressure = 14.899 psia | P/Pt0= .2970 |
| Tap No. 50 | Static Pressure = 14.580 psia | P/Pt0= .2906 |
| Tap No. 51 | Static Pressure = 14.599 psia | P/Pt0= .2910 |
| Tap No. 52 | Static Pressure = 14.492 psia | P/Pt0= .2889 |
| Tap No. 53 | Static Pressure = 14.555 psia | P/Pt0= .2901 |
| Tap No. 54 | Static Pressure = 14.243 psia | P/Pt0= .2839 |
| Tap No. 55 | Static Pressure = 14.335 psia | P/Pt0= .2857 |
| Tap No. 56 | Static Pressure = 14.245 psia | P/Pt0= .2839 |
| Tap No. 57 | Static Pressure = 14.020 psia | P/Pt0= .2795 |
| Tap No. 58 | Static Pressure = 14.182 psia | P/Pt0= .2827 |
| Tap No. 59 | Static Pressure = 13.864 psia | P/Pt0= .2763 |
| Tap No. 60 | Static Pressure = 13.773 psia | P/Pt0= .2745 |
| Tap No. 61 | Static Pressure = 13.416 psia | P/Pt0= .2674 |
| Tap No. 62 | Static Pressure = 13.113 psia | P/Pt0= .2614 |
| Tap No. 63 | Static Pressure = 12.470 psia | P/Pt0= .2486 |
| Tap No. 64 | Static Pressure = 12.745 psia | P/Pt0= .2540 |
| Tap No. 65 | Static Pressure = 12.574 psia | P/Pt0= .2506 |
| Tap No. 66 | Static Pressure = 12.887 psia | P/Pt0= .2569 |
| Tap No. 67 | Static Pressure = 12.829 psia | P/Pt0= .2557 |
| Tap No. 68 | Static Pressure = 12.550 psia | P/Pt0= .2502 |
| Tap No. 69 | Static Pressure = 12.114 psia | P/Pt0= .2415 |
| Tap No. 70 | Static Pressure = 11.676 psia | P/Pt0= .2327 |
| Tap No. 71 | Static Pressure = 9.998 psia | P/Pt0= .1993 |
| Tap No. 72 | Static Pressure = 16.368 psia | P/Pt0= .3263 |
| Tap No. 73 | Static Pressure = 15.767 psia | P/Pt0= .3143 |
| Tap No. 74 | Static Pressure = 13.778 psia | P/Pt0= .2746 |
| Tap No. 75 | Static Pressure = 16.514 psia | P/Pt0= .3292 |
| Tap No. 76 | Static Pressure = 16.422 psia | P/Pt0= .3273 |
| Tap No. 77 | Static Pressure = 14.709 psia | P/Pt0= .2932 |
| Tap No. 78 | Static Pressure = 14.764 psia | P/Pt0= .2943 |
| Tap No. 79 | Static Pressure = 16.071 psia | P/Pt0= .3203 |
| Tap No. 80 | Static Pressure = 14.792 psia | P/Pt0= .2948 |
| Tap No. 81 | Static Pressure = 14.720 psia | P/Pt0= .2934 |
| Tap No. 82 | Static Pressure = 14.733 psia | P/Pt0= .2937 |
| Tap No. 83 | Static Pressure = 11.830 psia | P/Pt0= .2358 |
| Tap No. 84 | Static Pressure = 12.269 psia | P/Pt0= .2446 |
| Tap No. 85 | Static Pressure = 14.632 psia | P/Pt0= .2916 |
| Tap No. 86 | Static Pressure = 14.835 psia | P/Pt0= .2957 |
| Tap No. 87 | Static Pressure = 16.368 psia | P/Pt0= .3263 |
| Tap No. 88 | Static Pressure = 16.315 psia | P/Pt0= .3252 |
| Tap No. 89 | Static Pressure = 14.034 psia | P/Pt0= .2797 |
| Tap No. 90 | Wall Exhaust Static Pressure = 14.707 psia | |
| Tap No. 91 | Wall Exhaust Total Pressure = 15.200 psia | |

**Table C-3. (Continued)**

*************** WAVE CANCELLATION TEST 2 ***************************

Total Pressure = 50.336 psia
Plenum Total Temperature = 61 deg F
Ambient Pressure = 14.676 psia

| | | |
|---|---|---|
| Tap No. 1 | Static Pressure = 50.349 psia | P/Pt0=1.0003 |
| Tap No. 2 | Static Pressure = 16.752 psia | P/Pt0= .3328 |
| Tap No. 3 | Static Pressure = 16.560 psia | P/Pt0= .3290 |
| Tap No. 4 | Static Pressure = 17.162 psia | P/Pt0= .3409 |
| Tap No. 5 | Static Pressure = 16.824 psia | P/Pt0= .3342 |
| Tap No. 6 | Static Pressure = 17.170 psia | P/Pt0= .3411 |
| Tap No. 7 | Static Pressure = 16.758 psia | P/Pt0= .3329 |
| Tap No. 8 | Static Pressure = 17.198 psia | P/Pt0= .3417 |
| Tap No. 9 | Static Pressure = 17.173 psia | P/Pt0= .3412 |
| Tap No. 10 | Static Pressure = 17.900 psia | P/Pt0= .3556 |
| Tap No. 11 | Static Pressure = 18.385 psia | P/Pt0= .3652 |
| Tap No. 12 | Static Pressure = 19.033 psia | P/Pt0= .3781 |
| Tap No. 13 | Static Pressure = 18.514 psia | P/Pt0= .3678 |
| Tap No. 14 | Static Pressure = 17.773 psia | P/Pt0= .3531 |
| Tap No. 15 | Static Pressure = 16.724 psia | P/Pt0= .3322 |
| Tap No. 16 | Static Pressure = 18.009 psia | P/Pt0= .3578 |
| Tap No. 17 | Static Pressure = 19.146 psia | P/Pt0= .3804 |
| Tap No. 18 | Static Pressure = 18.920 psia | P/Pt0= .3759 |
| Tap No. 19 | Static Pressure = 18.743 psia | P/Pt0= .3724 |
| Tap No. 20 | Static Pressure = 18.276 psia | P/Pt0= .3631 |
| Tap No. 21 | Static Pressure = 17.848 psia | P/Pt0= .3546 |
| Tap No. 22 | Static Pressure = 18.091 psia | P/Pt0= .3594 |
| Tap No. 23 | Static Pressure = 16.828 psia | P/Pt0= .3343 |
| Tap No. 24 | Static Pressure = 18.899 psia | P/Pt0= .3755 |
| Tap No. 25 | Static Pressure = 18.785 psia | P/Pt0= .3732 |
| Tap No. 26 | Static Pressure = 17.424 psia | P/Pt0= .3462 |
| Tap No. 27 | Static Pressure = 16.978 psia | P/Pt0= .3373 |
| Tap No. 28 | Static Pressure = 16.851 psia | P/Pt0= .3348 |
| Tap No. 29 | Static Pressure = 16.760 psia | P/Pt0= .3330 |
| Tap No. 30 | Static Pressure = 16.951 psia | P/Pt0= .3368 |
| Tap No. 31 | Static Pressure = 15.866 psia | P/Pt0= .3152 |
| Tap No. 32 | Static Pressure = 15.695 psia | P/Pt0= .3118 |
| Tap No. 33 | Static Pressure = 19.442 psia | P/Pt0= .3862 |
| Tap No. 34 | Static Pressure = 17.935 psia | P/Pt0= .3563 |
| Tap No. 35 | Static Pressure = 16.684 psia | P/Pt0= .3315 |
| Tap No. 36 | Static Pressure = 16.444 psia | P/Pt0= .3267 |
| Tap No. 37 | Static Pressure = 16.535 psia | P/Pt0= .3285 |
| Tap No. 38 | Static Pressure = 16.483 psia | P/Pt0= .3275 |
| Tap No. 39 | Static Pressure = 16.644 psia | P/Pt0= .3307 |
| Tap No. 40 | Static Pressure = 15.738 psia | P/Pt0= .3127 |
| Tap No. 41 | Static Pressure = 15.335 psia | P/Pt0= .3047 |
| Tap No. 42 | Static Pressure = 15.728 psia | P/Pt0= .3125 |
| Tap No. 43 | Static Pressure = 16.211 psia | P/Pt0= .3221 |
| Tap No. 44 | Static Pressure = 16.026 psia | P/Pt0= .3184 |
| Tap No. 45 | Static Pressure = 16.446 psia | P/Pt0= .3267 |
| Tap No. 46 | Static Pressure = 16.124 psia | P/Pt0= .3203 |

Table C-3. (Continued)

WAVE CANCELLATION TEST 2 CONTINUED

| | | |
|---|---|---|
| Tap No. 47 | Static Pressure = 15.848 psia | P/Pt0= .3148 |
| Tap No. 48 | Static Pressure = 15.859 psia | P/Pt0= .3151 |
| Tap No. 49 | Static Pressure = 15.710 psia | P/Pt0= .3121 |
| Tap No. 50 | Static Pressure = 15.425 psia | P/Pt0= .3064 |
| Tap No. 51 | Static Pressure = 14.896 psia | P/Pt0= .2959 |
| Tap No. 52 | Static Pressure = 15.249 psia | P/Pt0= .3029 |
| Tap No. 53 | Static Pressure = 15.246 psia | P/Pt0= .3029 |
| Tap No. 54 | Static Pressure = 15.099 psia | P/Pt0= .3000 |
| Tap No. 55 | Static Pressure = 15.028 psia | P/Pt0= .2986 |
| Tap No. 56 | Static Pressure = 14.890 psia | P/Pt0= .2958 |
| Tap No. 57 | Static Pressure = 14.843 psia | P/Pt0= .2949 |
| Tap No. 58 | Static Pressure = 14.459 psia | P/Pt0= .2873 |
| Tap No. 59 | Static Pressure = 14.608 psia | P/Pt0= .2902 |
| Tap No. 60 | Static Pressure = 14.004 psia | P/Pt0= .2782 |
| Tap No. 61 | Static Pressure = 13.721 psia | P/Pt0= .2726 |
| Tap No. 62 | Static Pressure = 13.776 psia | P/Pt0= .2737 |
| Tap No. 63 | Static Pressure = 12.873 psia | P/Pt0= .2557 |
| Tap No. 64 | Static Pressure = 12.900 psia | P/Pt0= .2563 |
| Tap No. 65 | Static Pressure = 13.171 psia | P/Pt0= .2617 |
| Tap No. 66 | Static Pressure = 13.469 psia | P/Pt0= .2676 |
| Tap No. 67 | Static Pressure = 12.649 psia | P/Pt0= .2513 |
| Tap No. 68 | Static Pressure = 12.940 psia | P/Pt0= .2571 |
| Tap No. 69 | Static Pressure = 12.815 psia | P/Pt0= .2546 |
| Tap No. 70 | Static Pressure = 11.841 psia | P/Pt0= .2352 |
| Tap No. 71 | Static Pressure = 9.579 psia | P/Pt0= .1903 |
| Tap No. 72 | Static Pressure = 16.434 psia | P/Pt0= .3265 |
| Tap No. 73 | Static Pressure = 15.814 psia | P/Pt0= .3142 |
| Tap No. 74 | Static Pressure = 14.184 psia | P/Pt0= .2818 |
| Tap No. 75 | Static Pressure = 16.604 psia | P/Pt0= .3299 |
| Tap No. 76 | Static Pressure = 16.639 psia | P/Pt0= .3306 |
| Tap No. 77 | Static Pressure = 14.679 psia | P/Pt0= .2916 |
| Tap No. 78 | Static Pressure = 14.679 psia | P/Pt0= .2916 |
| Tap No. 79 | Static Pressure = 16.368 psia | P/Pt0= .3252 |
| Tap No. 80 | Static Pressure = 14.712 psia | P/Pt0= .2923 |
| Tap No. 81 | Static Pressure = 14.659 psia | P/Pt0= .2912 |
| Tap No. 82 | Static Pressure = 14.663 psia | P/Pt0= .2913 |
| Tap No. 83 | Static Pressure = 12.258 psia | P/Pt0= .2435 |
| Tap No. 84 | Static Pressure = 12.840 psia | P/Pt0= .2551 |
| Tap No. 85 | Static Pressure = 14.618 psia | P/Pt0= .2904 |
| Tap No. 86 | Static Pressure = 14.763 psia | P/Pt0= .2933 |
| Tap No. 87 | Static Pressure = 16.535 psia | P/Pt0= .3285 |
| Tap No. 88 | Static Pressure = 16.398 psia | P/Pt0= .3258 |
| Tap No. 89 | Static Pressure = 14.060 psia | P/Pt0= .2793 |

**Table C-3. (Continued)**

## LIST OF REFERENCES


1. Demo, W. F., Cascade Wind Tunnel for Transonic Compressor Blading Studies, MSNE Thesis, Naval Postgraduate School, Monterey, CA, June 1978

2. Arnold, M. J., and Fjelde, J. A., Preliminary Calibration of a Cascade Wind Tunnel, AE 3815 Laboratory Report, Department of Aeronautics, Naval Postgraduate School, Sept. 23, 1978.

3. Zucker, R. D., Fundamentals of Gas Dynamics, Matrix Publishers, Inc., 1977.

4. North Atlantic Treaty Organization Advisory Group for Aerospace Research and Development Report AGARD-LS-39-70, Supersonic Cascade Performance, by H. Starken and H. Lichtfuss, August 1970.

5. Goethert, B. H., Transonic Wind Tunnel Testing, Pergamon Press, 1961.

6. Arnold Engineering Development Center Report AEDC-TR-60-9, A Summary of Perforated Wall Wind Tunnel Studies at the Arnold Engineering Development Center, by M. Pindzola and W. L. Chew, August 1960.

7. Bruhn, E. F., and others, Analysis and Design of Flight Structures, Tri State Offset Company, 1965.

8. Geopfarth, R. N., Development of a Device for the Incorporation of Multiple Scanivalves into a Computer-Controlled Data System, MSAE Thesis, Naval Postgraduate School, Monterey, CA, March 1979.

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