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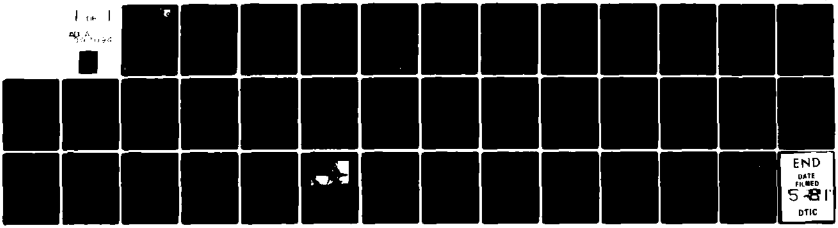

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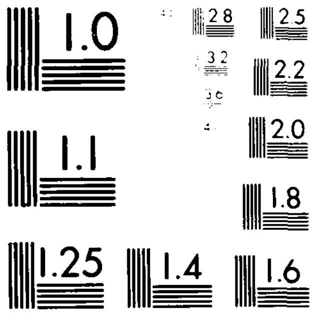

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AFWAL-TR-80-3146
Part I

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# TRANSONIC AND LOW SUPERSONIC WIND-TUNNEL TESTS ON A WING WITH INBOARD CONTROL SURFACE

## Part I. General Description

National Aerospace Laboratory
The Netherlands

DECEMBER 1980

TECHNICAL REPORT AFWAL-TR-80-3146, Part I.
Final Report for the period January 1979 through July 1980

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FLIGHT DYNAMICS LABORATORY
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A wind-tunnel investigation was carried out on a modified half-model of the F-5 wing with an oscillating in-board control surface. Detailed steady and unsteady pressure distributions were measured over the wing and over the control surface. Sectional as well as total coefficients for the wing and the control surface were obtained by integration of the measured pressure distributions. The tests covered the Mach number range between Ma = 0.6 and 1.25 with frequencies of the control surface of 20 and 40 Hz, which corresponds to a maximum reduced frequency of 0.4 at Ma = 0.6 and 0.215. (Continued on reverse)

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This report (Part I) describes the general set-up of the experiments, while the test results in tabulated form are given in Part II.

# FOREWORD

This report was prepared by the National Aerospace Laboratory (NLR) of Amsterdam, the Netherlands. The sponsor was the Flight Dynamics Laboratory (AFWAL/FIBR) of Wright-Patterson Air Force Base, Ohio. The AFOSR Grant 79-0023, "Transonic Wind Tunnel Measurements on a Wing with Oscillating Flaperon", was administered by Captain D. Wilkins of the Air Force Office of Scientific Research (AFOSR/PKN) of Bolling Air Force Base, Washington D.C. The work was performed in support of Project 2401, "Structures and Dynamics", and Task 240102, "Design and Analysis Methods for Aerospace Vehicle Structures".

The report consists of two parts. Part I contains the general description of the model and the test program. Part II presents the test data for the wing with trailing edge control surface in tabulated form. Part II will be available upon request from AFWAL/FIBRC.

The principal investigators were A. J. Persoon, R. Roos, and P. Schippers of NLR. The grant was monitored by L. J. Huttsell and Dr. J. J. Olsen of AFWAL. The assistance of Major R. Powell and Major G. Zielsdorff of the European Office of Aerospace Research Development (EOARD) is appreciated.

The National Aerospace Laboratory expresses its gratitude to the Royal Netherlands Air Force (RNLAF) for their permission to use the modified F-5 wing for this investigation.

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## LIST OF SYMBOLS

| | | |
|---|---|---|
| ALPHA | incidence | (degrees) |
| AMPL | amplitude of control surface oscillation in section of accelerometer no.1 | (degrees) |
| ARG | argument of unsteady quantity | (degrees) |
| C | chord | (m) |
| $\bar{C}$ | mean geometric chord; $\bar{C} = 0.4103$ | (m) |
| CM | pitching moment coefficient | |
| CMI | unsteady pitching moment coefficient | |
| CMIIM | imaginary part of unsteady pitching moment coefficient | |
| CMIRE | real part of unsteady pitching moment coefficient | |
| CN | hinge moment coefficient | |
| CNI | unsteady hinge moment coefficient | |
| CNIIM | imaginary part of unsteady hinge moment coefficient | |
| CNIRE | real part of unsteady hinge moment coefficient | |
| CP | pressure coefficient | |
| CPI | unsteady pressure coefficient | |
| CPIIM | imaginary part of unsteady pressure coefficient | |
| CPIRE | real part of unsteady pressure coefficient | |
| CR | control surface normal force coefficient | |
| CRI | unsteady control surface normal force coefficient | |
| CRIIM | imaginary part of unsteady control surface normal force coefficient | |
| CRIRE | real part of unsteady control surface normal force coefficient | |
| CZ | normal force coefficient | |
| CZI | unsteady normal force coefficient | |
| CZIIM | imaginary part of unsteady normal force coefficient | |
| CZIRE | real part of unsteady normal force coefficient | |
| DELTA | mean flap deflection | (degrees) |
| F | frequency of oscillation = FREQ. | (Hz) |
| i | $\sqrt{-1}$ | |

## LIST OF SYMBOLS (concluded)

| | | |
|---|---|---|
| K | reduced frequency; $K = \frac{2\pi . F. Cr}{2.V}$ | |
| M | pitching moment | (Nm) |
| Ma | Mach number | |
| MI | unsteady pitching moment | (Nm) |
| MLOC | local Mach number | |
| MOD | modulus of unsteady quantity | |
| N | hinge moment | (Nm) |
| NI | unsteady hinge moment | (Nm) |
| P | free stream static pressure | (Pa) |
| $P_o$ | stagnation pressure | (Pa) |
| PI | unsteady pressure | (Pa) |
| $P_{loc}$ | local pressure | (Pa) |
| PU | unsteady pressure in scanivalve | (Pa) |
| Q | dynamic pressure | (Pa) |
| $R_{L.E.}$ | nose radius of airfoil | (m ) |
| R | control surface normal force | (N ) |
| RE | Reynoldsnumber $\times 10^{-6}$, based on $\bar{C}$ | |
| RI | control surface unsteady normal force | (N ) |
| RUN | test point identification number | |
| S | semi-span ; S = 0.648 | (m ) |
| t | time | (s ) |
| V | free-stream velocity | (m/s) |
| x | co-ordinate in free-stream direction | (m ) |
| y | co-ordinate in spanwise direction | (m ) |
| z | co-ordinate normal to free-stream and spanwise direction | (m ) |
| Z | normal force | (N ) |
| ZI | unsteady normal force | (N ) |
| $\alpha$ | magnitude of pressure tube transfer function | |
| $\delta$ | flap deflection (positive downwards) | (rad.) |
| $\Delta$ | difference of two quantities | |
| $\varphi$ | phase of pressure tube transfer function | (rad.) |
| $\omega$ | angular velocity; $\omega = 2\pi. F$ | (rad./s) |

# SUBSCRIPTS

| | | |
|---|---|---|
| control | referring to | control surface |
| l | " " | lower surface |
| r | " " | root of the wing |
| t | " " | tip of the wing |
| u | " " | upper surface |
| wing | " " | wing |
| $\delta_o$ | " " | mean flap deflection |
| $\Delta \delta$ | " " | difference from two flap deflections |

## 1 INTRODUCTION

In January 1980 wind-tunnel tests were performed on a modified half-model of the F-5 wing with oscillating inboard control surface. The aim of these experiments was to determine unsteady airloads on a representative fighter-type wing in the transonic and low supersonic speed regimes. Such data are necessary to support future developments of calculation methods.

The present report, Part I, describes the test set-up and test techniques and gives a survey of the test program. Part II contains the test results in tabulated form.

## 2 MODEL AND TEST SET-UP

### 2.1 General description

The model investigated consisted of a wing equipped with an inboard control surface. The wing was the slightly modified half-model of the outer part of the F-5 wing (scale 1:4.5) used in earlier aeroelastic investigations (References 1 and 2).

In streamwise direction the wing possesses a modified NACA 65-A-004.8 airfoil, characterized by a droopnose, which extends from the leading edge towards the point of maximum thickness at 40 per cent of the chord. Further aft the profile is symmetrical. The line of symmetry of this rear part is chosen as a reference for the incidence. Details of the planform and the airfoil are given in Figure 1.

The model was supported at the side-wall of the test-section (Figure 2). Oscillations of the control surface about the hinge axis could be generated by means of a hydraulic actuator. This hydraulic actuator is equipped with a displacement transducer (no. 10), which controls the position of the piston rod. An additional displacement transducer (no. 9) was mounted on a lever as close as possible to the control surface root and just outside the testsection of the wind tunnel. With transducers nos. 9 and 10 the amplitude of the control surface oscillation as well as the mean steady deflection were monitored. Further details on the hydraulic test rig can be found in Reference 3.

The motions of the control surface and also any resulting motions of the wing were monitored by eight built-in accelerometers (Figure 3). The wing model, made of dural, was provided with 188 pressure orifices and connecting tubes. The pressure orifices were located on the upper and lower surface, distributed over eight spanwise sections on the wing and four on the control surface (Figure 3). From the earlier test (Reference 1), closer spacing of the measuring sections at the tip makes it possible to study tip effects in more detail. In addition twelve miniature pressure transducers were built in the wing and control surface close to the pressure points of section 2 on the upper surface. These transducers are used to provide data for the determination of the transfer function of the tubes during the test.

No use was made of transition strips.

## 2.2 Wind tunnel

The tests were performed in the transonic wind tunnel (HST) of the National Aerospace Laboratory (NLR). This wind tunnel consists of a closed circuit with a test section of 1.60 x 2.00 $m^2$. Top and bottom of the test section are slotted walls with an open ratio of 12 percent. The velocity range of this tunnel is $0 \leq Ma \leq 1.25$ and by changing the stagnation pressure from $P_o = 12.5$ kPa to $P_o = 400$ kPa a wide range of Reynolds numbers can be covered. For further details the reader is referred to Reference 4.

## 3 TEST PROCEDURES

### 3.1 Pressure measurements

The measurement of the mean steady and unsteady pressures on the model was performed with the help of pressure tubes, connecting the pressure orifices in the wing surface with scanning valves outside the model. The electrical signals from the transducers in the scanning valves were measured and then reduced to the actual aerodynamic quantities at the model surface (for definitions, see Appendix).

In the steady case, this reduction is a straight-forward procedure. However, in the unsteady case the measured pressures had to be corrected for the dynamic response characteristics of the pressure tubes.

As described in detail in Reference 5, the transfer of oscillatory pressures through pressure tubes depends on the dimensions of the tubing system, the frequency of oscillation, the mean steady pressure and the velocity of the main flow across the tube entrance. For the present wing model with control surface the dimensions of each tube in the wing as well as in the control surface were considered to be identical. This implied the existence of a common transfer function for all tubes in the wing and another transfer function for all tubes in the control surface. For a certain oscillation frequency the two transfer functions depended only on the local mean steady pressure and the flow velocity across the tube entrance. For a given stagnation pressure of the wind-tunnel, the latter two parameters are directly related and thus can be replaced by one. In practice the mean steady pressure proved to be the most suitable parameter, since this quantity was measured simultaneously with the unsteady pressures at the orifices. In principle, the transfer function can be obtained both theoretically and experimentally. In the present experiment the calibration of transfer functions was performed experimentally during the tests. For that purpose seven miniature pressure transducers were installed into the wing at section 2, very close to the entrance of each pressure tube. The same was done with five transducers in the control surface (see Figure 3). This section was chosen because it was considered to cover the full range of possible mean steady entrance pressures. The pressures measured by the transducers could be regarded as the input to the corresponding pressure tubes and so a calibration of the transfer functions during the tests was obtained. By collecting the data for these tubes and by plotting them as a function of the mean steady pressure (or the local Mach number), the required calibration curves (Figure 5) were obtained. The curves have been plotted as the real and imaginary part of the complex ratio PU/PI, in which PU is the unsteady pressure measured in the scanivalve and PI is the unsteady pressure at the model surface as measured by the corresponding miniature pressure transducers. The data reduction for all the tubes has been indicated schematically in Figure 6.

The vector PI, denoting the unsteady pressures at the model surface, is obtained from the vector PU (being the unsteady pressure measured in the scanning valve) by a counterclockwise rotation $\phi$ and a reduction in magnitude with a factor $\alpha$. Next, the vector PI is decomposed in a component in phase (real part) and a component in quadrature (imaginary part) with respect to the motion of the model. Unfortunately, during the tests the pressure orifices at 3 per cent in sections 3 and 5 on the upper surface were choked. In the unsteady measurements therefore the pressure coefficients for these two orifices were substituted by the mean value of the pressure coefficients at 3 per cent in sections 2 and 4, and 4 and 6 respectively. From the five in-situ transducers in section 2 in the control surface the one at 82 per cent was out of order during the tests.

### 3.2 Vibration modes

The vibration modes of the wing were monitored by six accelerometers (nos. 3 to 8, in Figure 3), while two accelerometers (nos. 1 and 2 in Figure 3) measured the amplitude of the control surface rotation. Two displacement transducers (nos. 9 and 10) measured the mean deflection and amplitude of rotation of the hinge axis just outside the tunnel wall.

In the tabulated results (Part II) the unsteady displacements of the accelerometers and the displacement transducers have been normalized by the unsteady displacement of accelerometer no. 1, while the amplitude of rotation in stream-wise direction of the control surface expressed in degrees, is given for the section of accelerometer no. 1. The normalized values of the displacement transducers nos. 9 and 10 were calculated as if they had the same distance from the hinge axis as accelerometer no. 1.

During the tests neither control surface nor wing appeared to be completely rigid. Due to friction in the bearings and a finite torsional stiffness of the control surface the amplitude of rotation measured by accelerometer no. 2 was 10 to 15 per cent less than the amplitude measured by accelerometer no. 1. Further, a consequence of the low bending stiffness of the wing outer part, the vibration mode depended on the unsteady airloads on that part. This is especially the case at transonic conditions. After the tests had been terminated it was found that in the last test runs accelerometers nos. 3 and 4 had failed. So the values of the normalized displacements of accelerometers nos. 3 and 4 are meaningless for test runs nos. 194 and higher.

## 4 MEASURING EQUIPMENT AND DATA REDUCTION

The wind-tunnel tests were performed by means of a processor ("PHAROS") designed for unsteady measurements (Reference 6). This computer-controlled device, performs a series of tasks. It controls the model excitation through a two-phase oscillator with variable frequency. It accepts simultaneously 48 measuring signals, which then are fed into conditioners and transfer function analyzers to obtain the steady component and the real and imaginary part of the harmonic components. In this way the time required for one test point is reduced to less than two minutes. Further it stores the data and performs a quick-look analysis with pre-determined transfer functions for the tubing system. A block-diagram of the equipment is presented in Figure 7, while a picture of it is given in Figure 8.

The final data reduction took place with the procedures described in section 3.1.

As a result, the following quantities were obtained (for definitions, see Appendix).

- the chordwise distribution of the (mean) steady pressure coefficient CP;
- the chordwise distribution of the quasi-steady pressure coefficient CPI, obtained from three steady measurements, namely (i) a run with zero mean flap deflection ($\delta_0$), (ii) a run with a mean flap deflection of + 0.5 degrees ($\delta_0 + \delta_1$) and (iii) a run with a flap deflection of -0.5 degrees ($\delta_0 + \delta_2$). The other test conditions were kept the same.
- the chordwise distribution of the unsteady pressure coefficient CPI, normalized with respect to the angular displacement of the control surface in the section of accelerometer 1;
- sectional steady, quasi-steady and unsteady lift and moment coefficients obtained by integration of the pressure distributions;
- total steady, quasi-steady and unsteady lift coefficients for the wing obtained by integration in spanwise direction of the sectional coefficients;
- total steady, quasi-steady and unsteady lift and hinge moment coefficients

for the control surface obtained by integration in spanwise direction of the sectional coefficients; and

- vibration modes of the wing and the control surface.

## 5 TEST PROGRAM

The tests on the wing with the inboard control surface covered the Mach number range between Ma = 0.6 and Ma = 1.25; the frequencies of oscillation were 20 and 40 Hz. The maximum values of the reduced frequency achieved during the tests varied from K = 0.4 at Ma = 0.6 to K = 0.215 at Ma = 1.25. The tests were performed at mean incidences of ALPHA = 0.0 and 1.5 degrees and with amplitudes of control surface oscillation AMPL. = 0.5 degrees at a mean deflection DELTA = about 0.

To determine the unsteady airloads for zero frequency ("quasi-steady" results), a series of steady measurements was carried out at control surface deflections DELTA = -0.5, 0.0 and + 0.5 degrees, respectively.

At summary of the test program for the wing with inboard control surface is shown in Table 1.

## 6 FINAL REMARK

In this report only a description has been given of the general test set-up and test procedures of the wind-tunnel tests on a wing equipped with an oscillating inboard control surface. Its already mentioned in section 1 the tabulated results will be presented in a subsequent Part II of this report.

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# APPENDIX

## Definitions of steady, quasi-steady and unsteady aerodynamic quantities for wing and control surface

## A.1 Wing

### A.1.1 Steady

Pressure coefficient:

$$CP = (P_{loc} - P)/Q$$

Sectional normal force:

$$Z = CZ.Q.C \ , \ CZ = -\int_0^1 (CP_u - CP_\ell).d(x/C)$$

Sectional pitching moment about quarter-chord point (positive nose down):

$$M = CM.Q.C^2 \ , \ CM = -\int_0^1 (CP_u - CP_\ell).(x/C - 0.25).d(x/C)$$

Total wing normal force:

$$Z_{wing} = CZ_{wing}.Q.\bar{c}.S \ , \ CZ_{wing} = \int_0^1 (CZ.C)/\bar{c}.d(y/S)$$

### A.1.2 Quasi-steady

Pressure coefficient:

$$CPI = CPIRE + i.CPIIM$$

$$CPIRE = \frac{CP_{(\delta_o + \delta_1)} - CP_{(\delta_o + \delta_2)}}{\delta_1 - \delta_2} = \Delta CP/\Delta\delta \quad ;$$

$$CPIIM = 0.0$$

Sectional normal force:

$$ZI = Q.C.CZI.\Delta\delta.e^{i\omega t} \quad ,$$

$$CZI = CZIRE + i.CZIIM$$

$$\mathrm{CZIRE} = \frac{\mathrm{CZ}_{(\delta_o + \delta_1)} - \mathrm{CZ}_{(\delta_o + \delta_2)}}{\delta_1 - \delta_2} = \Delta \mathrm{CZ}/\Delta\delta \ ; \ \mathrm{CZIIM} = 0.0$$

Sectional pitching moment (positive nose down):

$$\mathrm{MI} = \mathrm{Q.C^2.CMI}.\Delta\delta.e^{i\omega t} \quad ,$$

$$\mathrm{CMI} = \mathrm{CMIRE} + i.\mathrm{CMIIM}$$

$$\mathrm{CMIRE} = \frac{\mathrm{CM}_{(\delta_o + \delta_1)} - \mathrm{CM}_{(\delta_o + \delta_2)}}{\delta_1 - \delta_2} = \Delta \mathrm{CM}/\Delta\delta \ ; \ \mathrm{CMIIM} = 0.0$$

Total wing normal force:

$$\mathrm{ZI}_{\mathrm{wing}} = \mathrm{Q}.\bar{\mathrm{C}}.\mathrm{S}.\mathrm{CZI}_{\mathrm{wing}}.\Delta\delta.e^{i\omega t} \quad ,$$

$$\mathrm{CZI}_{\mathrm{wing}} = \mathrm{CZIRE}_{\mathrm{wing}} + i.\mathrm{CZIIM}_{\mathrm{wing}}$$

$$\mathrm{CZIRE}_{\mathrm{wing}} = \int_o^1 (\mathrm{CZIRE.C})/\bar{\mathrm{C}}.d(y/S) \ ; \ \mathrm{CZIIM} = 0.0$$

A.1.3 <u>Unsteady</u>

Pressure coefficient:

$$\mathrm{CPI} = \mathrm{CPIRE} + i.\mathrm{CPIIM} = \mathrm{PI}/(\mathrm{Q}.\Delta\delta)$$

Sectional normal force:

$$\mathrm{ZI} = \mathrm{Q.C.CZI}.\Delta\delta.e^{i\omega t} \quad ,$$

$$\mathrm{CZI} = \mathrm{CZIRE} + i.\mathrm{CZIIM} = -\int_o^1 (\mathrm{CPI}_u - \mathrm{CPI}_\ell).d(x/C)$$

Sectional pitching moment (positive nose down):

$$\mathrm{MI} = \mathrm{Q.C^2.CMI}.\Delta\delta.e^{i\omega t} \quad ,$$

$$\mathrm{CMI} = \mathrm{CMIRE} + i.\mathrm{CMIIM} = -\int_o^1 (\mathrm{CPI}_u - \mathrm{CPI}_\ell).(x/C - 0.25).d(x/C)$$

Total wing normal force:

$$\mathrm{ZI}_{\mathrm{wing}} = \mathrm{Q}.\bar{\mathrm{C}}.\mathrm{S}.\mathrm{CZI}_{\mathrm{wing}}.\Delta\delta.e^{i\omega t}$$

$$\mathrm{CZI}_{\mathrm{wing}} = \mathrm{CZIRE}_{\mathrm{wing}} + i.\mathrm{CZIIM}_{\mathrm{wing}} = \int_o^1 (\mathrm{CZI.C})/\bar{\mathrm{C}}.d(y/S)$$

## A.2 Control surface

### A.2.1 Steady

Pressure coefficient:

$$CP = (P_{loc} - P)/Q$$

Sectional normal force:

$$R = CR.Q.C \ , \ CR = -\int_{0.82}^{1} (CP_u - CP_\ell).d(x/C)$$

Sectional hinge moment:

$$N = CN.Q.C^2 \ , \ CN = -\int_{0.82}^{1} (CP_u - CP_\ell).(x/C - 0.82).d(x/C)$$

Total normal force:

$$R_{control} = CR_{control}.Q.\bar{C}.S \ , \ CR_{control} = \int_{o}^{0.5864} (CR.C)/\bar{C}.d(y/S)$$

Total hinge moment (positive control surface up):

$$N_{control} = CN_{control}.Q.\bar{C}^2.S \ , \ CN_{control} = \int_{o}^{0.5864} (CN.C^2)/\bar{C}^2.d(y/S)$$

### A.2.2 Quasi-steady

Pressure coefficient:

$$CPI = CPIRE + i.CPIIM$$

$$CPIRE = \frac{CP_{(\delta_o + \delta_1)} - CP_{(\delta_o + \delta_2)}}{\delta_1 - \delta_2} = \Delta CP/\Delta\delta \ ;$$

$$CPIIM = 0.0$$

Sectional normal force:

$$RI = Q.C.CRI.\Delta\delta.e^{i\omega t} \ ,$$

$$CRI = CRIRE + i.CRIIM$$

$$CRIRE = \frac{CR_{(\delta_o + \delta_1)} - CR_{(\delta_o + \delta_2)}}{\delta_1 - \delta_2} = \Delta CR/\Delta\delta \ ; \ CRIIM = 0.0$$

Sectional hinge moment (positive control surface up):

$$NI = Q.C^2.CNI.\Delta\delta.e^{i\omega t} \quad ,$$

$$CNI = CNIRE + i.CNIIM$$

$$CNIRE = \frac{CN_{(\delta_o + \delta_1)} - CN_{(\delta_o + \delta_2)}}{\delta_1 - \delta_2} = \Delta CN/\Delta\delta \; ; \; CNIIM = 0.0$$

Total normal force:

$$RI_{control} = Q.\bar{C}.S.CRI_{control}.\Delta\delta.e^{i\omega t} \quad ,$$

$$CRI_{control} = CRIRE_{control} + i.CRIIM_{control}$$

$$CRIRE_{control} = \int_{o}^{0.5864} (CRIRE.C)/\bar{C}.d(y/S) \; ; \; CRIIM = 0.0$$

Total hinge moment (positive control surface up):

$$NI_{control} = Q.\bar{C}^2.S.CNI_{control}.\Delta\delta.e^{i\omega t} \quad ,$$

$$CNI_{control} = CNIRE_{control} + i.CNIIM_{control}$$

$$CNIRE_{control} = \int_{o}^{0.5864} (CNIRE.C^2)/\bar{C}^2.d(y/S) \; ; \; CNIIM = 0.0$$

### A.2.3 Unsteady

Pressure coefficient:

$$CPI = CPIRE + i.CPIIM = PI/(Q.\Delta\delta)$$

Sectional normal force:

$$RI = Q.C.CRI.\Delta\delta.e^{i\omega t} \quad ,$$

$$CRI = CRIRE + i.CRIIM = - \int_{0.82}^{1} (CPI_u - CPI_\ell).d(x/C)$$

Sectional hinge moment (positive control surface up):

$$NI = Q.C^2.CNI.\Delta\delta.e^{i\omega t} \quad ,$$

$$CNI = CNIRE + i.CNIIM = - \int_{0.82}^{1} (CPI_u - CPI_\ell).(x/C - 0.82).d(x/C)$$

Total normal force:

$$RI_{control} = Q.\bar{C}.S.CRI_{control}.\Delta\delta.e^{i\omega t} \quad ,$$

$$CRI_{control} = CRIRE_{control} + i.CRIIM_{control} = \int_{0}^{0.5864} (CRI.C)/\bar{C}.d(y/S)$$

Total hinge moment (positive control surface up):

$$NI_{control} = Q.\bar{C}^2.S.CNI_{control}.\Delta\delta.e^{i\omega t} \quad ,$$

$$CNI_{control} = CNIRE_{control} + i.CNIIM = \int_{0}^{0.5864} (CNI.C^2)/\bar{C}^2.d(y/S)$$

TABLE 1

TESTPROGRAM
STEADY PRESSURE MEASUREMENTS ON
NF-5 WING WITH INBOARD CONTROL SURFACE.
( ALPHA = 0.0 degrees )

| RUN no. | P0 nom. (kPa) | MACH | DELTA (degr.) | TABLE no. | REMARKS |
|---|---|---|---|---|---|
| 10 | 100 | .600 | .488 | 2 | |
| 11 | 100 | .600 | -.505 | 3 | |
| 12 | 100 | .600 | .002 | 4 | |
| 101 | 100 | .801 | .486 | 5 | |
| 103 | 100 | .800 | -.499 | 6 | |
| 102 | 100 | .800 | -.003 | 7 | |
| 31 | 100 | .899 | .494 | 8 | |
| 32 | 100 | .899 | -.496 | 9 | |
| 33 | 100 | .899 | .002 | 10 | |
| 36 | 100 | .923 | .495 | 11 | |
| 37 | 100 | .924 | -.497 | 12 | |
| 38 | 100 | .925 | -.003 | 13 | |
| 42 | 100 | .949 | -.506 | 14 | * |
| 43 | 100 | .949 | .006 | 15 | |
| 46 | 100 | 1.000 | .484 | 16 | |
| 47 | 100 | .999 | -.501 | 17 | |
| 48 | 100 | .999 | .003 | 18 | |
| 51 | 100 | 1.046 | .492 | 19 | |
| 52 | 100 | 1.046 | -.500 | 20 | |
| 53 | 100 | 1.046 | .009 | 21 | |
| 56 | 100 | 1.096 | .482 | 22 | |
| 57 | 100 | 1.096 | -.505 | 23 | |
| 58 | 100 | 1.096 | .000 | 24 | |
| 87 | 70 | 1.049 | .493 | 25 | |
| 88 | 70 | 1.057 | -.495 | 26 | |
| 89 | 70 | 1.050 | .002 | 27 | |
| 72 | 70 | 1.096 | .492 | 28 | |
| 73 | 70 | 1.094 | -.505 | 29 | |
| 74 | 70 | 1.095 | .000 | 30 | |
| 67 | 70 | 1.192 | .489 | 31 | |
| 68 | 70 | 1.191 | -.498 | 32 | |
| 69 | 70 | 1.193 | -.005 | 33 | |
| 79 | 70 | 1.242 | .491 | 34 | |
| 80 | 70 | 1.244 | -.499 | 35 | |
| 81 | 70 | 1.244 | -.001 | 36 | |

* run with DELTA =+.5 degrees is missing.

## TABLE 2

TESTPROGRAM
STEADY PRESSURE MEASUREMENTS ON
NF-5 WING WITH INBOARD CONTROL SURFACE.
( ALPHA = 1.5 degrees )

| RUN no. | P0 nom. (kPa) | MACH | DELTA (degr.) | TABLE no. |
|---|---|---|---|---|
| 121 | 100 | .604 | .497 | 37 |
| 122 | 100 | .601 | -.499 | 38 |
| 123 | 100 | .599 | -.004 | 39 |
| 156 | 100 | .800 | .499 | 40 |
| 157 | 100 | .801 | -.501 | 41 |
| 158 | 100 | .801 | -.001 | 42 |
| 162 | 100 | .850 | .501 | 43 |
| 163 | 100 | .849 | -.501 | 44 |
| 164 | 100 | .849 | -.002 | 45 |
| 167 | 100 | .876 | .501 | 46 |
| 168 | 100 | .876 | -.502 | 47 |
| 169 | 100 | .877 | .002 | 48 |
| 173 | 100 | .901 | .496 | 49 |
| 178 | 100 | .900 | -.501 | 50 |
| 175 | 100 | .900 | -.003 | 51 |
| 179 | 100 | .926 | .502 | 52 |
| 181 | 100 | .923 | -.503 | 53 |
| 182 | 100 | .927 | -.002 | 54 |
| 185 | 100 | .950 | .503 | 55 |
| 186 | 100 | .950 | -.502 | 56 |
| 187 | 100 | .950 | -.002 | 57 |
| 190 | 100 | 1.000 | .497 | 58 |
| 191 | 100 | .998 | -.503 | 59 |
| 192 | 100 | 1.000 | -.003 | 60 |
| 195 | 100 | 1.048 | .497 | 61 |
| 196 | 100 | 1.048 | -.499 | 62 |
| 197 | 100 | 1.049 | -.004 | 63 |
| 200 | 100 | 1.097 | .498 | 64 |
| 201 | 100 | 1.098 | -.503 | 65 |
| 202 | 100 | 1.099 | .003 | 66 |
| 230 | 70 | 1.048 | .500 | 67 |
| 231 | 70 | 1.048 | -.503 | 68 |
| 232 | 70 | 1.050 | -.007 | 69 |
| 225 | 70 | 1.094 | .499 | 70 |
| 226 | 70 | 1.096 | -.501 | 71 |
| 227 | 70 | 1.094 | -.001 | 72 |
| 220 | 70 | 1.194 | .498 | 73 |
| 221 | 70 | 1.201 | -.501 | 74 |
| 222 | 70 | 1.197 | .001 | 75 |
| 215 | 70 | 1.235 | .501 | 76 |
| 216 | 70 | 1.233 | -.505 | 77 |
| 217 | 70 | 1.231 | .000 | 78 |

TABLE 3

## TESTPROGRAM
## UNSTEADY PRESSURE MEASUREMENTS ON
## NF-5 WING WITH INBOARD CONTROL SURFACE.
## ( ALPHA = 0.0 degrees )

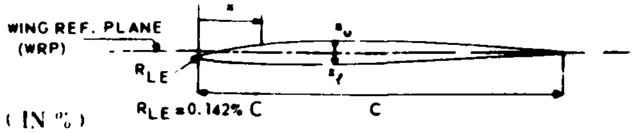
| RUN no. | PO nom. (kPa) | MACH | DELTA (degr.) | AMPL. (degr.) | FREQ. (Hz) | RED.FR. | TABLE no. |
|---|---|---|---|---|---|---|---|
| 12 | 100 | .600 | .002 | .496 | 0 | .000 | 79 |
| 109 | 100 | .599 | -.001 | .491 | 20 | .202 | 80 |
| 111 | 100 | .599 | -.004 | .527 | 40 | .404 | 81 |
| 102 | 100 | .800 | -.003 | .492 | 0 | .000 | 82 |
| 105 | 100 | .800 | -.009 | .487 | 20 | .155 | 83 |
| 108 | 100 | .800 | -.008 | .505 | 40 | .310 | 84 |
| 33 | 100 | .899 | .002 | .495 | 0 | .000 | 85 |
| 97 | 100 | .901 | -.001 | .471 | 20 | .139 | 86 |
| 100 | 100 | .900 | .000 | .503 | 40 | .279 | 87 |
| 38 | 100 | .925 | -.003 | .496 | 0 | .000 | 88 |
| 112 | 100 | .925 | -.001 | .475 | 20 | .137 | 89 |
| 114 | 100 | .925 | -.003 | .524 | 40 | .273 | 90 |
| 43 | 100 | .949 | .006 | .256 | 0 | .000 | 91 |
| 115 | 100 | .951 | -.007 | .474 | 20 | .133 | 92 |
| 116 | 100 | .950 | -.001 | .498 | 40 | .266 | 93 |
| 48 | 100 | .999 | .003 | .492 | 0 | .000 | 94 |
| 49 | 100 | 1.001 | .003 | .452 | 20 | .128 | 95 |
| 50 | 100 | 1.000 | .013 | .473 | 40 | .255 | 96 |
| 53 | 100 | 1.046 | .009 | .497 | 0 | .000 | 97 |
| 54 | 100 | 1.046 | -.004 | .444 | 20 | .123 | 98 |
| 55 | 100 | 1.047 | .003 | .466 | 40 | .245 | 99 |
| 58 | 100 | 1.096 | .000 | .494 | 0 | .000 | 100 |
| 59 | 100 | 1.096 | -.007 | .450 | 20 | .118 | 101 |
| 60 | 100 | 1.095 | .000 | .447 | 40 | .236 | 102 |
| 89 | 70 | 1.050 | .002 | .494 | 0 | .000 | 103 |
| 91 | 70 | 1.050 | -.003 | .457 | 20 | .122 | 104 |
| 92 | 70 | 1.048 | -.002 | .474 | 40 | .245 | 105 |
| 74 | 70 | 1.095 | .000 | .478 | 0 | .000 | 106 |
| 75 | 70 | 1.095 | -.005 | .453 | 20 | .118 | 107 |
| 76 | 70 | 1.096 | -.001 | .474 | 40 | .235 | 108 |
| 69 | 70 | 1.193 | -.005 | .494 | 0 | .000 | 109 |
| 70 | 70 | 1.193 | .001 | .462 | 20 | .110 | 110 |
| 71 | 70 | 1.193 | .015 | .486 | 40 | .220 | 111 |
| 81 | 70 | 1.244 | -.001 | .495 | 0 | .000 | 112 |
| 83 | 70 | 1.244 | -.001 | .452 | 20 | .107 | 113 |
| 86 | 70 | 1.244 | -.003 | .470 | 40 | .213 | 114 |

TABLE 4

TESTPROGRAM
UNSTEADY PRESSURE MEASUREMENTS ON
NF-5 WING WITH INBOARD CONTROL SURFACE.
( ALPHA = 1.5 degrees )

| RUN no. | P0 nom. (kPa) | MACH | DELTA (degr.) | AMPL. (degr.) | FREQ. (Hz) | RED.FR. | TABLE no. | REMARKS |
|---|---|---|---|---|---|---|---|---|
| 123 | 100 | .599 | -.004 | .498 | 0 | .000 | 115 | |
| 154 | 100 | .600 | .002 | .491 | 20 | .204 | 116 | |
| 155 | 100 | .600 | .010 | .513 | 40 | .407 | 117 | |
| 158 | 100 | .801 | -.001 | .500 | 0 | .000 | 118 | |
| 161 | 100 | .800 | -.002 | .477 | 20 | .156 | 119 | |
| 160 | 100 | .800 | -.005 | .441 | 40 | .213 | 120 | |
| 164 | 100 | .849 | -.002 | .501 | 0 | .000 | 121 | |
| 165 | 100 | .849 | -.003 | .457 | 20 | .148 | 122 | |
| 166 | 100 | .849 | -.004 | .492 | 40 | .295 | 123 | |
| 169 | 100 | .877 | .002 | .502 | 0 | .000 | 124 | |
| 170 | 100 | .874 | -.001 | .477 | 20 | .144 | 125 | |
| 172 | 100 | .874 | .012 | .430 | 40 | .287 | 126 | |
| 175 | 100 | .900 | -.003 | .499 | 0 | .000 | 127 | |
| 176 | 100 | .900 | -.005 | .501 | 20 | .140 | 128 | |
| 177 | 100 | .900 | .000 | .490 | 40 | .279 | 129 | |
| 182 | 100 | .927 | -.002 | .503 | 0 | .000 | 130 | |
| 183 | 100 | .926 | -.004 | .497 | 20 | .136 | 131 | |
| 184 | 100 | .925 | .008 | .484 | 40 | .273 | 132 | |
| 187 | 100 | .950 | -.002 | .503 | 0 | .000 | 133 | |
| 188 | 100 | .950 | -.004 | .481 | 20 | .133 | 134 | |
| 189 | 100 | .950 | -.003 | .491 | 40 | .266 | 135 | |
| 192 | 100 | 1.000 | -.003 | .500 | 0 | .000 | 136 | |
| 193 | 100 | 1.000 | -.007 | .500 | 20 | .127 | 137 | |
| 194 | 100 | .997 | -.004 | .485 | 40 | .255 | 138 | ** |
| 197 | 100 | 1.049 | -.004 | .498 | 0 | .000 | 139 | |
| 198 | 100 | 1.047 | -.003 | .466 | 20 | .122 | 140 | @ |
| 199 | 100 | 1.048 | -.003 | .458 | 40 | .244 | 141 | ** |
| 202 | 100 | 1.099 | .003 | .500 | 0 | .000 | 142 | |
| 203 | 100 | 1.096 | .000 | .474 | 20 | .117 | 143 | @ |
| 204 | 100 | 1.098 | -.003 | .474 | 40 | .234 | 144 | @ |
| 232 | 70 | 1.050 | -.007 | .502 | 0 | .000 | 145 | |
| 233 | 70 | 1.050 | -.002 | .481 | 20 | .122 | 146 | @ |
| 234 | 70 | 1.087 | -.002 | .498 | 40 | .237 | 147 | @ |
| 227 | 70 | 1.094 | -.001 | .500 | 0 | .000 | 148 | |
| 228 | 70 | 1.098 | -.002 | .473 | 20 | .115 | 149 | @ |
| 229 | 70 | 1.098 | .002 | .500 | 40 | .221 | 150 | @ |
| 222 | 70 | 1.197 | .001 | .499 | 0 | .000 | 151 | |
| 223 | 70 | 1.199 | -.002 | .477 | 20 | .109 | 152 | @ |
| 224 | 70 | 1.196 | -.002 | .498 | 40 | .219 | 153 | @ |
| 217 | 70 | 1.231 | .000 | .503 | 0 | .000 | 154 | |
| 218 | 70 | 1.233 | -.003 | .458 | 20 | .108 | 155 | @ |
| 219 | 70 | 1.233 | -.004 | .477 | 40 | .215 | 156 | @ |

** accelerometer 4 out of order.
@ accelerometer 3 and 4 out of order.



## AIRFOIL CO-ORDINATES (IN %)

| x/C | $z_u/C$ | $z_\ell/C$ |
|---|---|---|
| 0 | [illegible] | [illegible] |
| 0.1 | [illegible] | [illegible] |
| 0.2 | [illegible] | [illegible] |
| 0.3 | [illegible] | [illegible] |
| 0.4 | [illegible] | [illegible] |
| 0.5 | [illegible] | [illegible] |
| 0.6 | [illegible] | [illegible] |
| 0.7 | [illegible] | [illegible] |
| 0.8 | [illegible] | [illegible] |
| 0.9 | [illegible] | [illegible] |
| 1.0 | [illegible] | [illegible] |
| 1.25 | [illegible] | [illegible] |
| 1.50 | [illegible] | [illegible] |
| 1.75 | [illegible] | [illegible] |
| 2.00 | [illegible] | [illegible] |
| 2.25 | [illegible] | [illegible] |
| 2.50 | [illegible] | [illegible] |
| 3.00 | [illegible] | [illegible] |
| 4.00 | [illegible] | [illegible] |
| 5.00 | [illegible] | [illegible] |
| 6.00 | [illegible] | [illegible] |
| 7.00 | [illegible] | [illegible] |
| 8.00 | [illegible] | [illegible] |
| 9.00 | [illegible] | [illegible] |
| 10 | [illegible] | [illegible] |
| 11 | [illegible] | [illegible] |
| 12 | [illegible] | [illegible] |
| 13 | [illegible] | [illegible] |

| x/C | $z_u/C$ | $z_\ell/C$ |
|---|---|---|
| 14 | [illegible] | [illegible] |
| 15 | [illegible] | -1.99[illegible]11 |
| 16 | [illegible] | [illegible] |
| 17 | [illegible] | [illegible] |
| 18 | [illegible] | [illegible] |
| 19 | [illegible] | [illegible] |
| 20 | [illegible] | [illegible] |
| 21 | [illegible] | [illegible] |
| 22 | [illegible] | [illegible] |
| 23 | [illegible] | [illegible] |
| 24 | [illegible] | [illegible] |
| 25 | [illegible] | [illegible] |
| 26 | [illegible] | [illegible] |
| 27 | [illegible] | [illegible] |
| 28 | [illegible] | [illegible] |
| 29 | [illegible] | [illegible] |
| 30 | [illegible] | [illegible] |
| 31 | [illegible] | [illegible] |
| 32 | [illegible] | [illegible] |
| 33 | [illegible] | [illegible] |
| 34 | [illegible] | [illegible] |
| 35 | [illegible] | [illegible] |
| 36 | [illegible] | [illegible] |
| 37 | [illegible] | [illegible] |
| 38 | [illegible] | [illegible] |
| 39 | [illegible] | [illegible] |
| 40 | [illegible] | [illegible] |

| x/C | $z_u/C (= z_\ell/C)$ |
|---|---|
| 41 | [illegible] |
| 42 | [illegible] |
| 43 | [illegible] |
| 44 | [illegible] |
| 45 | [illegible] |
| 46 | [illegible] |
| 47 | [illegible] |
| 48 | [illegible] |
| 49 | [illegible] |
| 50 | [illegible] |
| 51 | [illegible] |
| 52 | [illegible] |
| 53 | [illegible] |
| 54 | [illegible] |
| 55 | [illegible] |
| 56 | [illegible] |
| 57 | [illegible] |
| 58 | [illegible] |
| 59 | [illegible] |
| 60 | [illegible] |
| 61 | [illegible] |
| 62 | [illegible] |
| 63 | [illegible] |
| 64 | [illegible] |
| 65 | [illegible] |
| 66 | [illegible] |
| 67 | [illegible] |
| 68 | [illegible] |
| 69 | [illegible] |
| 70 | [illegible] |

| x/C | $z_u/C (= z_\ell/C)$ |
|---|---|
| 71 | 1.74675 |
| 72 | 1.70213 |
| 73 | 1.65530 |
| 74 | 1.60623 |
| 75 | 1.55497 |
| 76 | 1.50161 |
| 77 | 1.44631 |
| 78 | 1.38924 |
| 79 | 1.33066 |
| 80 | 1.27087 |
| 81 | 1.21034 |
| 82 | 1.14913 |
| 83 | 1.08794 |
| 84 | 1.02680 |
| 85 | [illegible] |
| 86 | 0.90442 |
| 87 | [illegible] |
| 88 | 0.78310 |
| 89 | 0.72094 |
| 90 | [illegible] |
| 91 | [illegible] |
| 92 | 0.53740 |
| 93 | [illegible] |
| 94 | [illegible] |
| 95 | [illegible] |
| 96 | [illegible] |
| 97 | [illegible] |
| 98 | [illegible] |
| 99 | 0.10914 |
| 100 | 0.04500 |

Co–ordinates of the airfoil of the wing

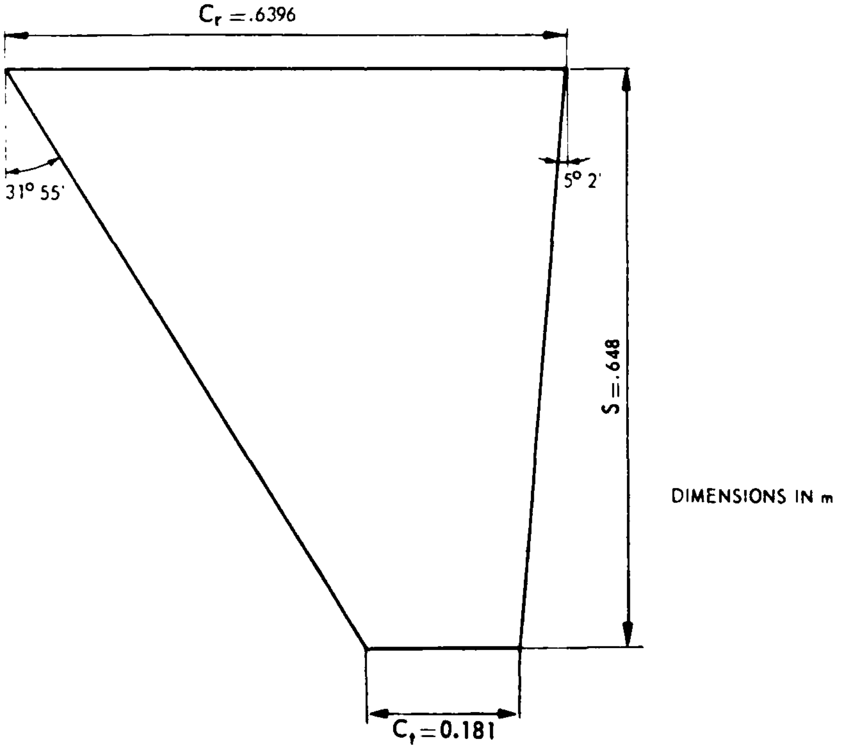


Figure 1 Dimensions of the Wing

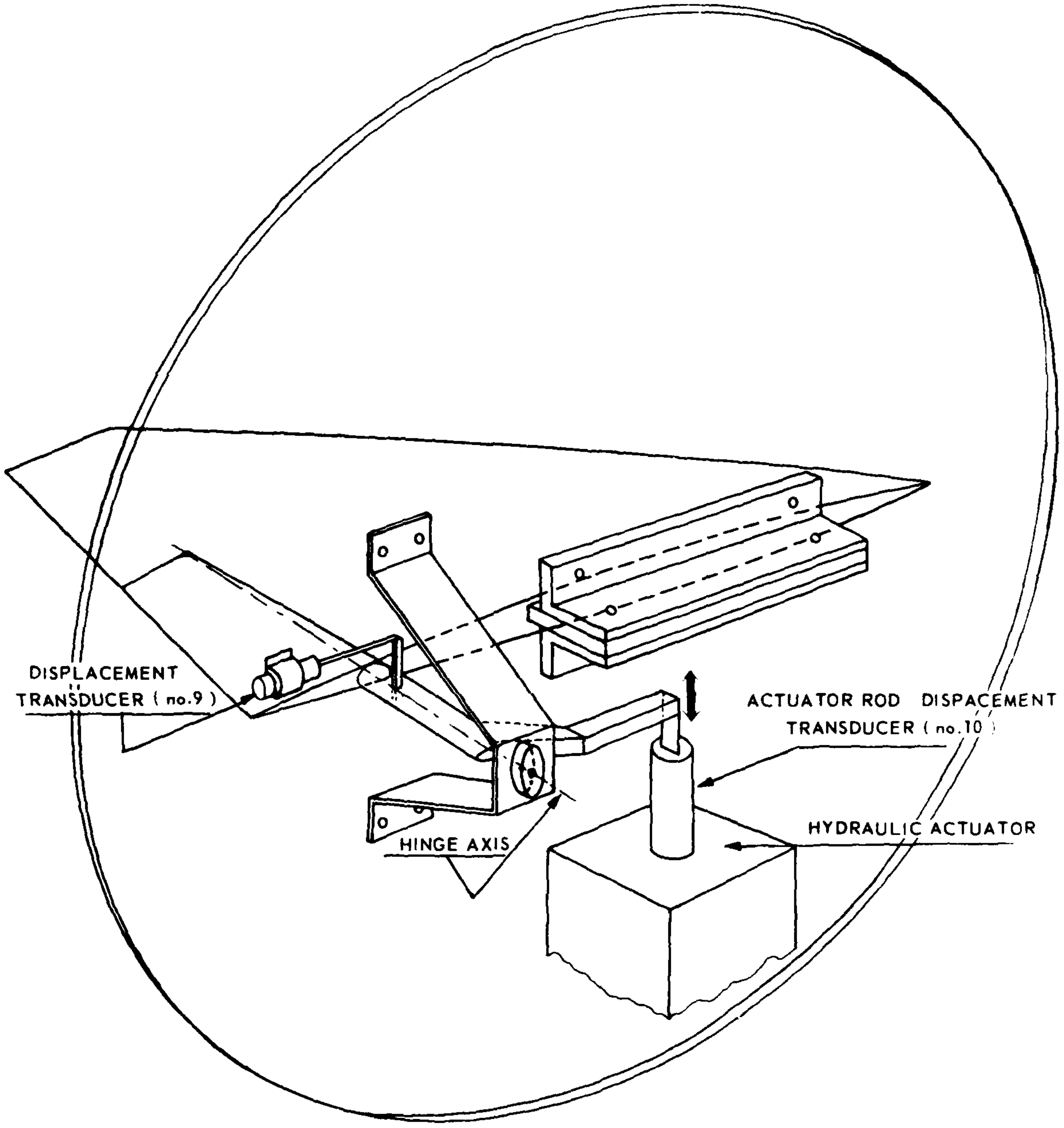


Figure 2 Schematic View of the Test Set-up

| PRESSURE ORIFICES ON UPPER AND LOWER SURFACE | | | | |
|---|---|---|---|---|
| WING SECTION | % SPAN | SECTIONS | | |
| | | 1,2,3 | 3.5 | 4,5,6,7,8 |
| 1 | 17.4 | 3 | | 3 |
| 2 | 34.1 | 10 | | 10 |
| 3 | 49.2 | 20 | | 20 |
| 3.5 | 55.7 | 30 | | 30 |
| 4 | 61.6 | 40 | | 40 |
| 5 | 69.3 | 50 | | 50 |
| 6 | 78.5 | 60 | | 60 |
| 7 | 84.1 | 70 | | 70 |
| 8 | 93.9 | 80 | | 80 |
| | | 82 | 82 | |
| | | 85.5 | 85.5 | |
| | | 89 | 89 | 90 |
| | | 92.5 | 92.5 | |
| | | 96 | 96 | |

| IN-SITU TRANSDUCERS IN WING SECTION 2 UPPER SURFACE ONLY | |
|---|---|
| % CHORD | |
| 10 | |
| 20 | |
| 30 | |
| 40 | |
| 50 | |
| 60 | |
| 70 | |
| 82 | (OUT OF ORDER) |
| 85.5 | |
| 90 | |
| 92.5 | |
| 96 | |

| ACCELEROMETERS IN WING PLANFORM | | |
|---|---|---|
| NO. | X ( m ) | Y ( m ) |
| 1 | 0.596 | 0.096 |
| 2 | 0.5745 | 0.291 |
| 3 | 0.2309 | 0.2971 |
| 4 | 0.518 | 0.252 |
| 5 | 0.3422 | 0.4772 |
| 6 | 0.5270 | 0.4772 |
| 7 | 0.4070 | 0.6176 |
| 8 | 0.5390 | 0.6176 |

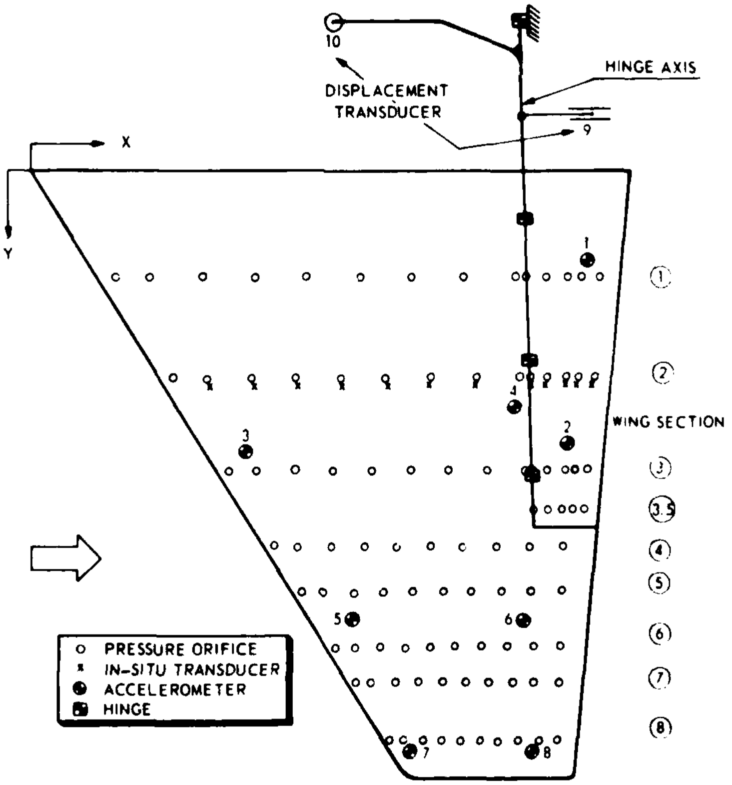


Figure 3 Location of Pressure Orifices, In-Situ Transducers and Accelerometers

Figure 4  Model in the Wind-Tunnel

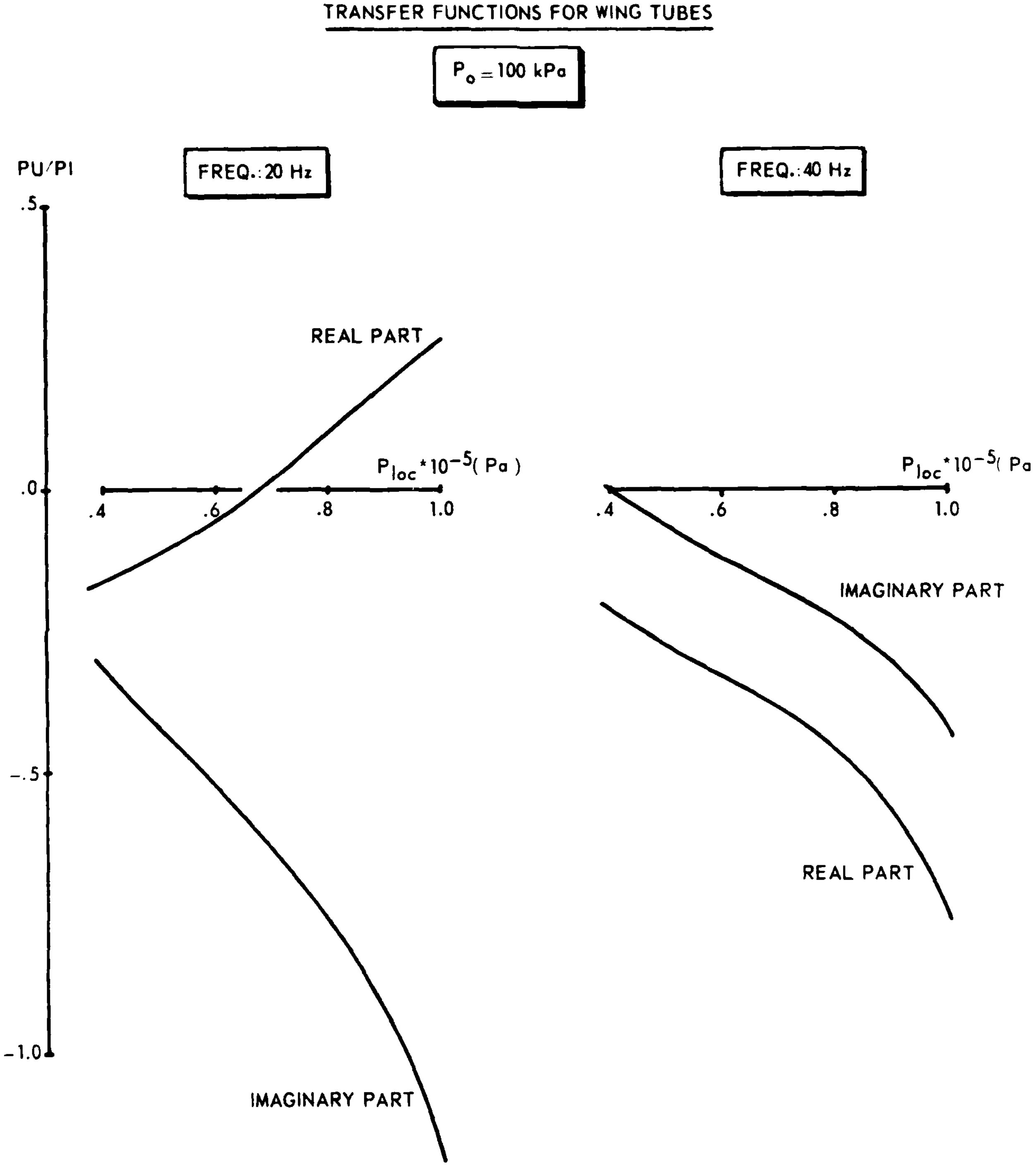


Figure 5a Transfer Functions Used for Data Reduction of the Unsteady Pressures

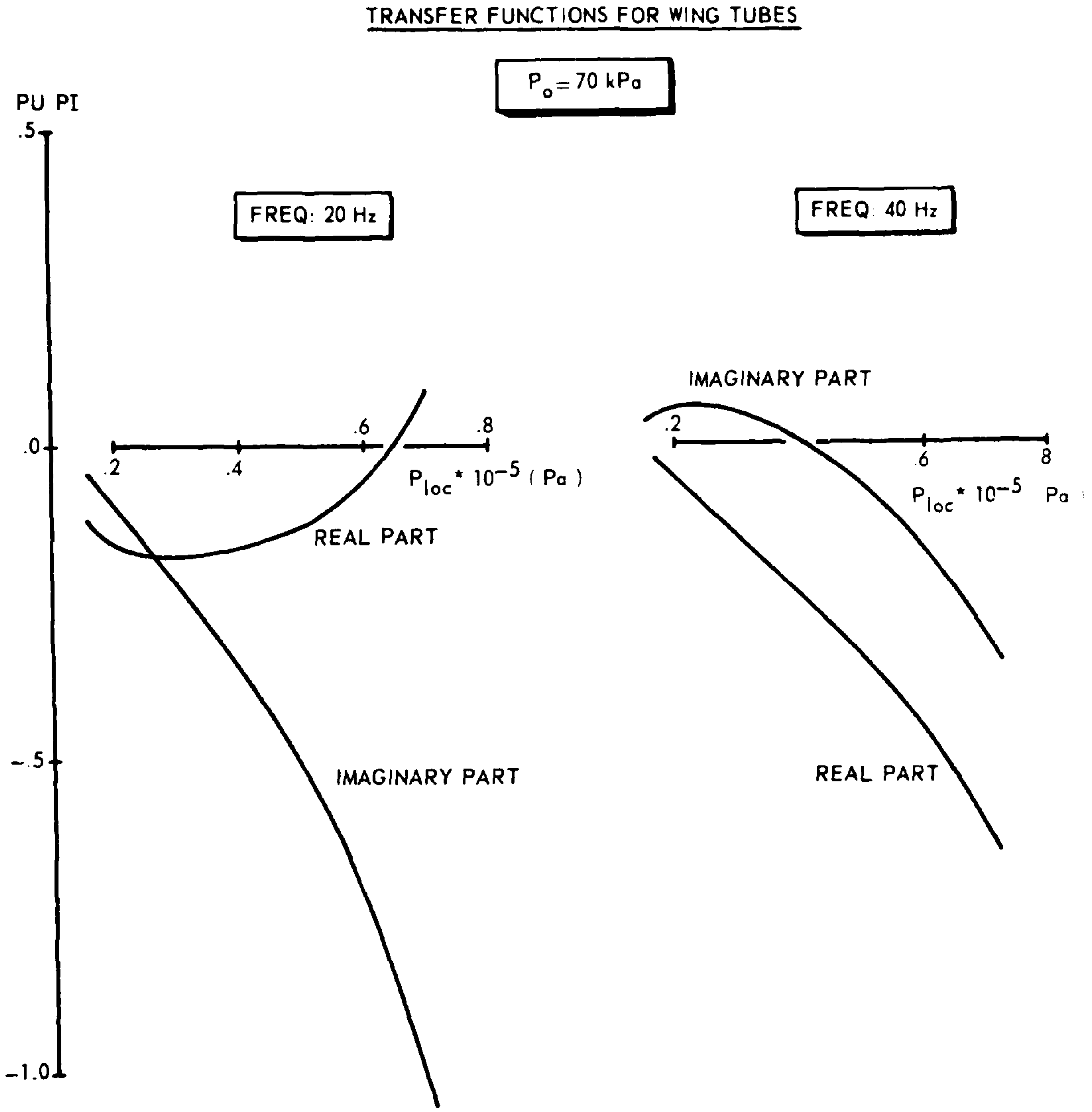


Figure 5b Transfer Functions Used for Data Reduction of the Unsteady Pressures

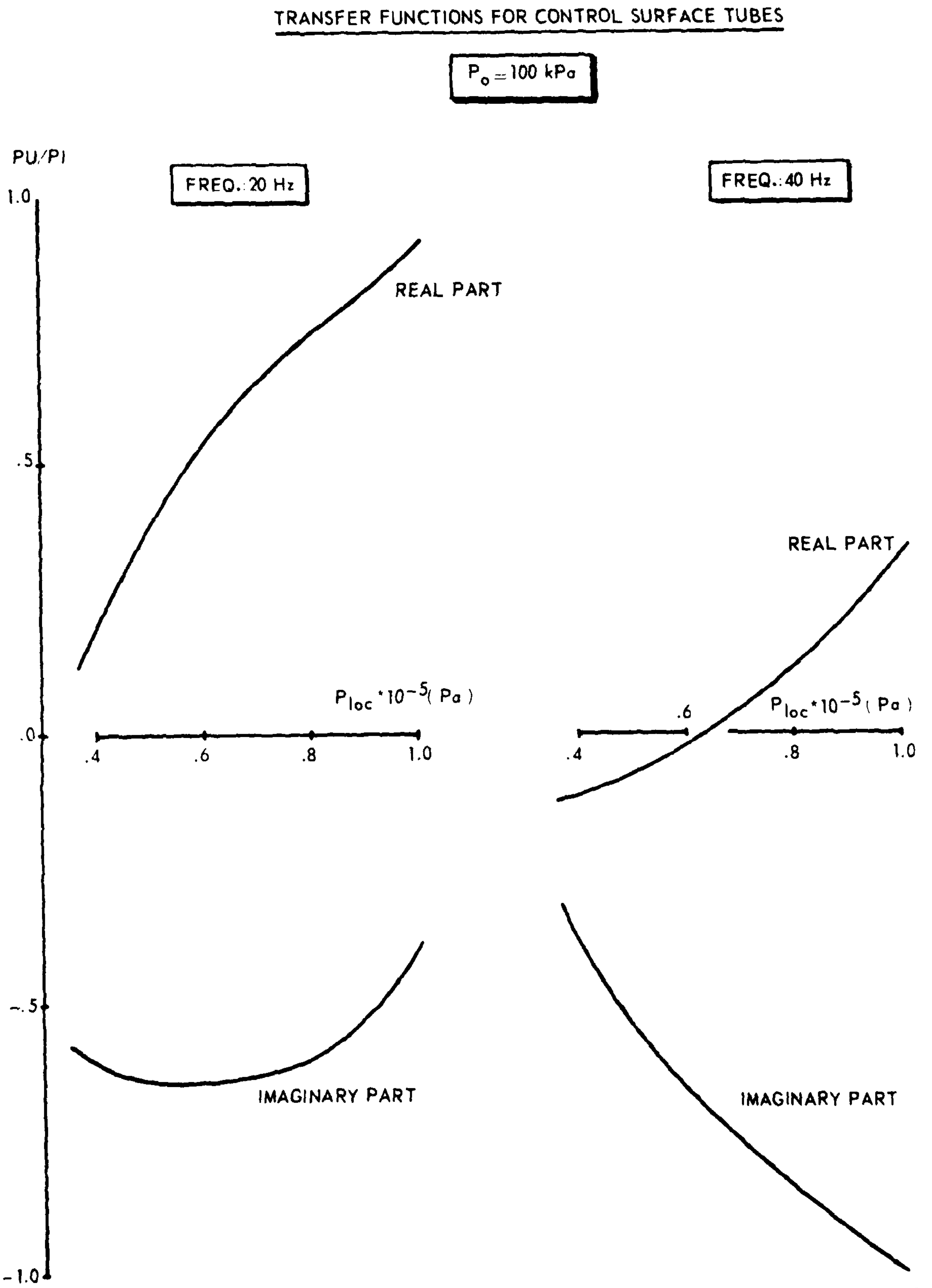


Figure 5c Transfer Functions Used for Data Reduction of the Unsteady Pressures (cont'd)

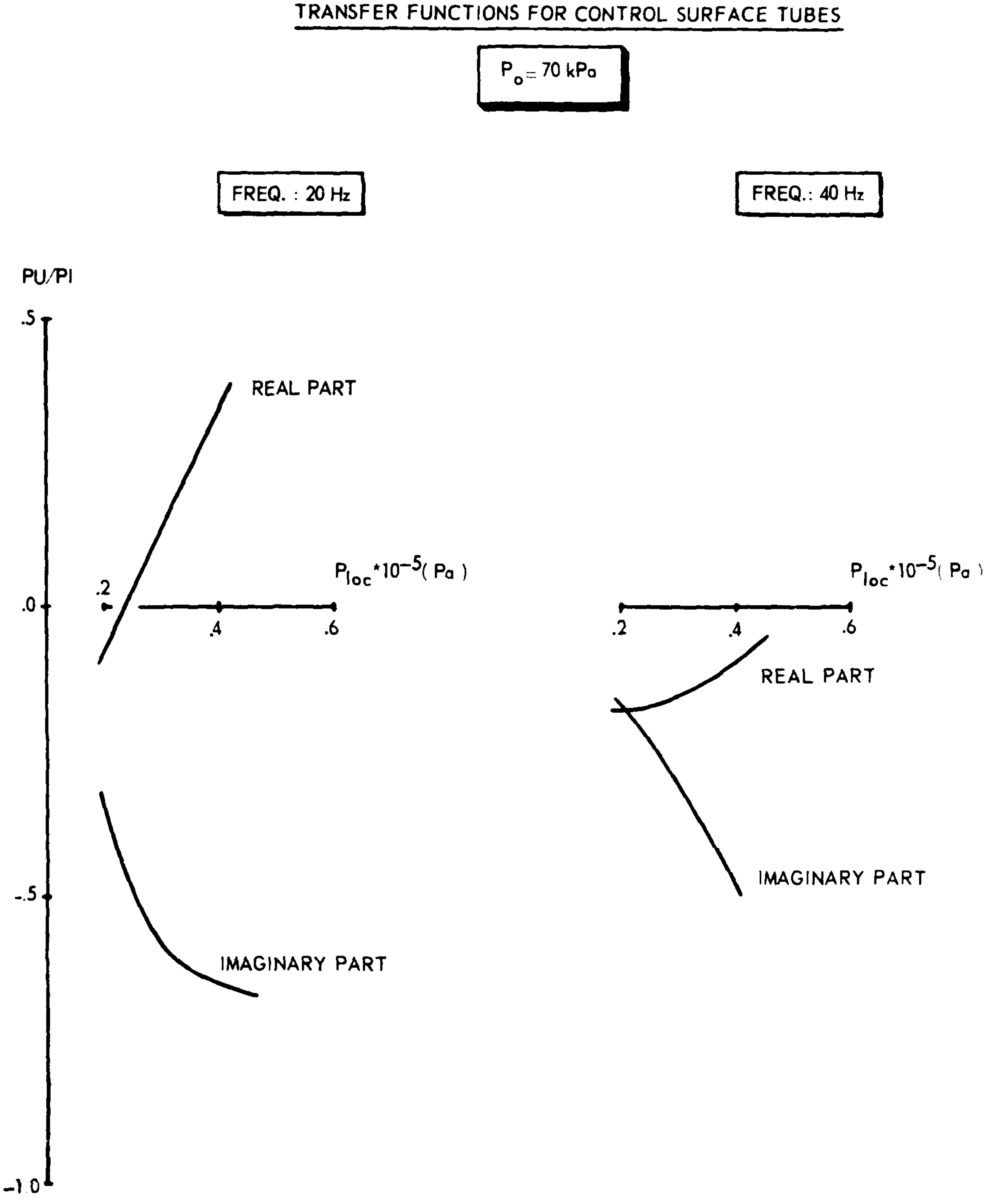


Figure 5d  Transfer Functions Used for Data Reduction of the Unsteady Pressures (cont'd)

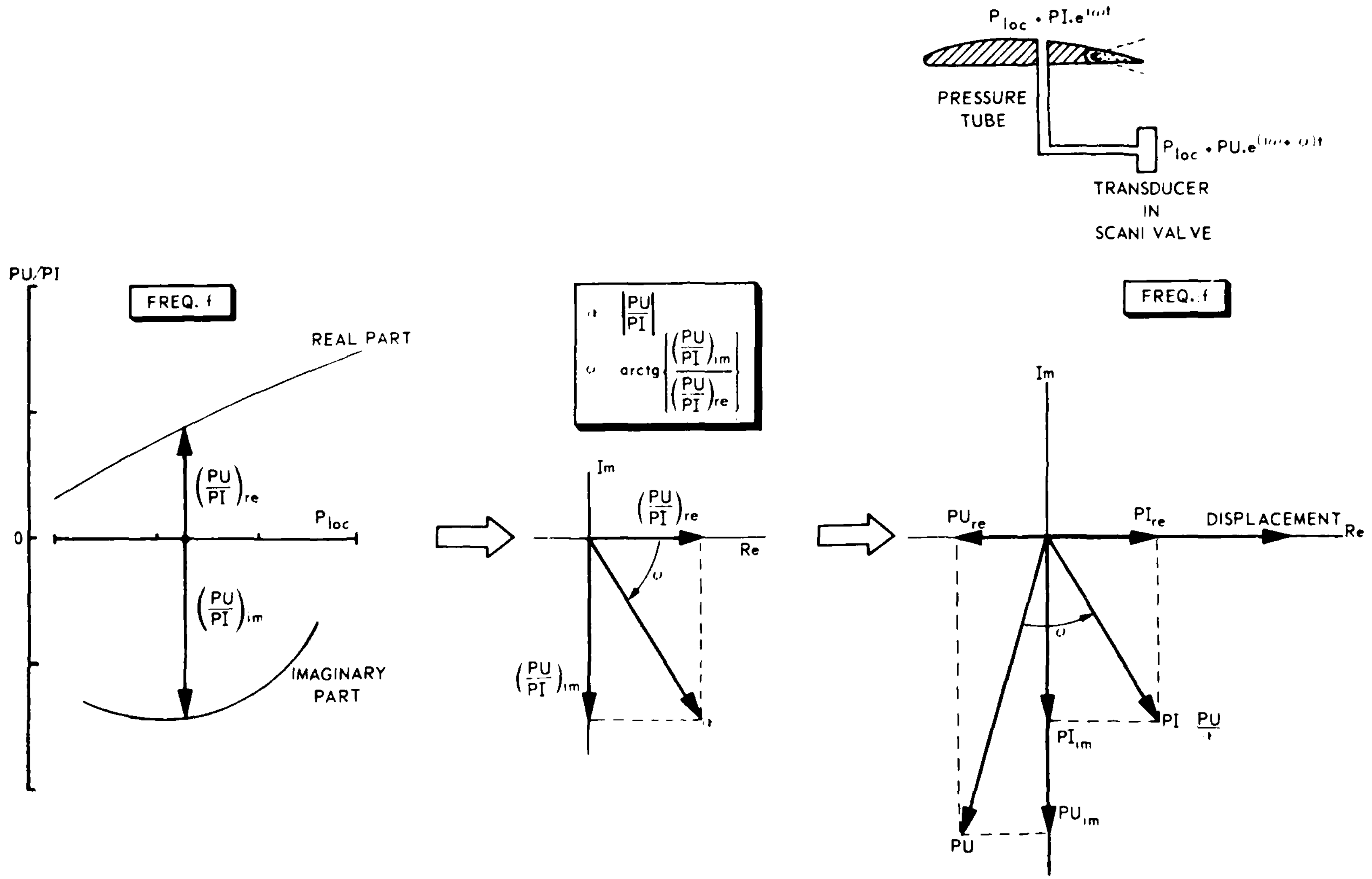


Figure 6 Principle of Unsteady Pressure Measuring Technique

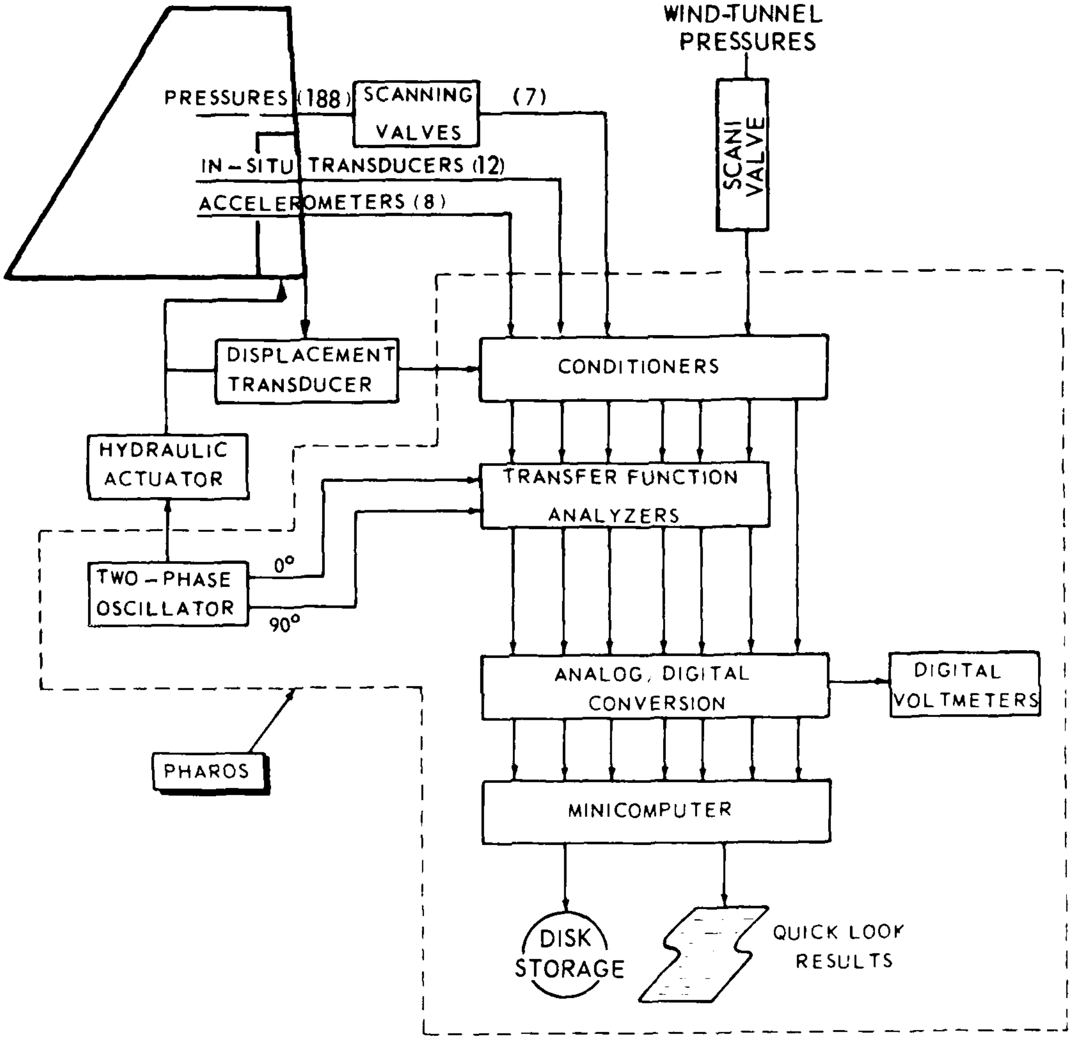


Figure 7 Block-Diagram of the Test Set-Up During Unsteady Measurements

Figure 8 Equipment for Unsteady Measurements PHAROS

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