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NORTH ATLANTIC TREATY ORGANIZATION

ADVISORY GROUP FOR AEROSPACE RESEARCH AND DEVELOPMENT

(ORGANISATION DU TRAITE DE L'ATLANTIQUE NORD)

AGARD Report No.702

COMPENDIUM OF UNSTEADY AERODYNAMIC MEASUREMENTS

This Report was sponsored by the Structures and Materials Panel of AGARD.

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14. Abstract

The Compendium is intended to assist the development of improved methods of predicting transonic unsteady aerodynamics and aeroelastic response by collecting the known unsteady aerodynamic experimental data for the standard AGARD two-dimensional and three-dimensional aeroelastic configurations published in AGARD Advisory Reports 156 and 167 respectively.

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PREFACE

The Subcommittee on Aeroelasticity of the AGARD Structures and Materials Panel (SMP) has produced two recent publications on the AGARD Standard Configurations for Aeroelastic Applications of Transonic Unsteady Aerodynamics: AGARD Advisory Report 156, "AGARD Two-Dimensional Aeroelastic Configurations" and AGARD Advisory Report 167, "AGARD Three-Dimensional Aeroelastic Configurations."

Now that the AGARD has established standard aeroelastic configurations, the next effort is to encourage aeroelasticians in the NATO countries to develop improved methods of predicting transonic unsteady aerodynamics and aeroelastic response and to evaluate them with respect to the AGARD configurations. This Compendium assists that development and evaluation by collecting the known unsteady aerodynamic experimental data for the AGARD configurations. It is due mainly to the efforts of Mr Norman Lambourne, recently of the Royal Aeronautical Establishment, with Mr H C Garner of the RAE as a major collaborator.

The next phases will come under the guidance of facilitators for aeroelasticity:

France:	Mr R. Dat ONERA 29 Avenue de la Division LeClerc 92 Chatillon Paris
Germany:	Dr W. Geissler DFVLR-AVA Bunsenstrasse 10 3400 Gottingen
Netherlands:	Mr R. Zwaan NLR Anthony Fokkerweg 2 Amsterdam 1017
United Kingdom:	Mr H C Garner RAE Farnborough, Hants GU14 6TD
United States:	Dr J. Edwards NASA Langley Research Center MS 340 Hampton VA 23665

These facilitators will encourage contributions and communications among investigators in the NATO countries for a few key two-dimensional and three-dimensional standard configurations. They will present progress reports to the AGARD Structures and Materials Panel (SMP) in the Autumn of 1983. The effort will culminate in a Specialists' Meeting on "Transonic Unsteady Aerodynamics and Aeroelastic Application" at the SMP meeting in Fall 84. We encourage scientists in the NATO countries to communicate with one of the above facilitators to coordinate their contributions.

JAMES J. OLSEN
Chairman
AGARD/SMP Subcommittee on Aeroelasticity

COMPENDIUM OF UNSTEADY AERODYNAMIC MEASUREMENTS

SUMMARY

The Compendium contains a selection of wind-tunnel measurements made on some of the AGARD Aeroelastic Configurations already chosen as computational test cases. Presentation of the numerical data in the form of separate Data Sets is preceded by a general review that discusses the various aspects concerning experimental measurements and comparisons with theoretical computations.

CONTENTS

Further Data Sets may be issued later, as addenda, when experimental results for other configurations become available.

<u>Note</u>: Although the General Review and the Data Sets are separate contributions, a consistent scheme of numbering the pages, references, tables and figures is used throughout the Compendium. Thus, for instance Table m.n is the nth table of Data Set m. For the General Review m = 0.

GENERAL REVIEW

by

N. C. Lambourne*

1 INTRODUCTION

Interest in the kind of unsteady aerodynamics considered here arises from the need for information relevant to the aeroelastic stability of aircraft. The continuing need for studies is due to design developments extending to different types of flow and to new structural configurations. At present there is special interest in transonic and separated flows, in wings specially designed for supercritical flow, and in surfaces operating as part of active control systems.

Advances in computational fluid dynamics are giving impetus to the development of new theoretical methods for unsteady aerodynamics. The development of satisfactory methods, whilst depending ultimately on comparisons with experiment, is considerably helped by comparisons between one computational method and another. To assist these developments a Working Group of the AGARD Structures and Materials Panel has already chosen a series of 2-D and 3-D configurations and for each a set of test cases, including a priority subset, to be used for comparisons. These test cases are fully identified in Refs 0.1 and 0.2, which are the documents that have set the scene for the present Compendium. The chosen configurations are known as the AGARD Aeroelastic Configurations and it is now convenient to denote the chosen cases associated with them as the Computational Test (or CT) Cases.

Although some of the configurations and some of the CT Cases were chosen purely for theoretical interest and do not have experimental counterparts, others were chosen because they had been, or were shortly to be, the subject of unsteady measurements. For the most part, these measurements had been made independently by various researchers and the resulting data are situated at separate locations or in diverse documents. The present Compendium was conceived with the idea of collecting into a single document the experimental data most important for the proposed comparisons.

Whilst the prime purpose is the presentation of numerical data, it seemed desirable to include information about the experiments themselves and to mention their more important results. Also, when experimental data are to be used for numerical comparisons, some indication of their reliability is needed: for this reason a general discussion of the various experimental procedures and the limitations of experimental data is included.

For the presentation of the material, it has been found convenient to follow the kind of arrangement already used in an AGARD document, Ref 0.3, giving a data base for steady aerodynamics.

2 GUIDE TO COMPENDIUM

The complete list of AGARD Aeroelastic Configurations is given in Table 0.1. For those configurations having Data Sets in this Compendium this table also gives the CT Case numbers (as defined in Refs 0.1 and 0.2) for which there are experimental data. For those configurations not having Data Sets the present position regarding the experiments is stated. It is intended to issue further Data Sets whenever possible.

The Compendium consists of a General Review, of which this present section is part, followed by seven self-contained Data Sets. Each Data Set provides:

- means for identifying and locating all the unsteady measurements that could be made available;
- a brief overview of the salient features of the experimental results;
- numerical data from those tests that relate directly to the CT Cases.

Also, by means of a standard form, each Data Set gives key information about the test equipment and test conditions - information that may be found important when comparing experimental and theoretical results.

It is hoped that the information contained in the Data Sets will satisfy the theoretician through the first stages of comparing calculation with experiment. At some later stage the need may arise for comparisons with experimental cases beyond those selected to correspond with the CT Cases. It is for that reason that each Set lists all the experimental tests for which data could be made available if requested from the original source.

The tables presenting the numerical data are mostly copies of computer listings from the original data banks. Therefore the forms and notations differ across the various Data Sets. To have reformatted the data to a standard notation and lay-out would

* Preparation of the Review and editing of the Compendium was funded by US Air Force Office of Scientific Research, European Office of Aerospace Research and Development.

have required much labour and incurred the risk of introducing errors - apart from which, a familiarity gained with the original form makes for easy communication if similar data are required for additional cases.

It will be seen from Table 0.1 that the present Data Sets extend over a range of 2-D section shapes and 3-D planforms. The unsteady model motions are basically either some form of rigid-body pitching or control-surface rotation; they are mostly small-amplitude oscillations, although Data Set 3 includes large-amplitude oscillatory and transient motions. The experimental cases also include a variety of types of subsonic and transonic flow, but it is necessary to refer to the Data Sets themselves for detailed specifications.

It may be noted that not every CT Case has an experimental counterpart.

2.1 Correspondence between experimental and computational cases

Although it is true that the related CT Cases were chosen from the available experimental tests, the degree of relationship between them differs over the complete series.

The type of unsteady motion is basically the same for corresponding experimental and computation cases. In some CT Cases the specification of parameters such as amplitude, frequency, Mach number, Reynolds number, model incidence and flap angle are in exact agreement with the experiments. But for Data Sets 4 and 5, which both relate to the supercritical aerofoil NLR 7301, there are differences between the experimental and CT values of model mean incidence α_m and Mach number M as shown in Table 0.2.

With regard to Data Set 4, the explanation is straightforward. The airfoil was designed by a hodograph theory which predicted shock-free flow at $M = 0.721$ and $\alpha_m = -0.19$ deg. In the NLR experiments this type of flow did not occur for those theoretical values of M and α_m but was approximated as closely as possible for a different combination: $M = 0.744$ and $\alpha_m = 0.85$ deg. The differences were mainly due to viscous effects and tunnel interference. Thus the CT specifications were chosen such that theory would produce flows similar to those observed in the experiments, on the argument that these specifications will compensate for the two effects.

The situation with regard to Data Set 5 is rather more complicated because, at the time the CT Cases were chosen, these data, generated at NASA Ames, were not available. As in the NLR tests, the experiments from which the data are abstracted were run for combinations of M and α_m which gave classes of steady flow corresponding to those predicted by the aerofoil design theory using the CT specifications. Thus the cases of Data Set 5 can be related to the CT Cases on the basis of similar flows but for this Set the values of the frequency parameters do not match the CT Cases exactly.

Data Sets 4 and 5 form a unique combination in providing independent measurements of comparable data for the same aerofoil. However, as shown in Table 0.2 there are differences between the Reynolds numbers for the two sets and also differences in regard to the use of boundary-layer transition trips. In addition there is an appreciable difference between the two ratios of tunnel to model size, which as discussed later, may be important in connection with the effects of tunnel interference. Examples of comparisons between these two Data Sets are discussed in section 7.

Certain implications arising from the differences between the experimental and CT specifications will be discussed later in section 8.

3 GENERAL NATURE OF UNSTEADY DATA

The practical requirement is for aerodynamic information for lifting surfaces and control surfaces undergoing arbitrary time-dependent displacements or deformations. Basic studies are usually centred on 2-D or 3-D model configurations performing prescribed unsteady motions in a uniform stream with steady perturbations.

In considering the general forms of the aerodynamic quantities it is convenient to restrict the discussion to pressures, the quantities that are measured. Since it is the distribution of pressure that determines the resultant forces and moments it will be readily appreciated that similar remarks can apply to quantities such as lift, pitching moment and control-surface hinge-moment. For the time being discussion will be concerned with pressure denoted by p, the introduction of non-dimensional coefficients being left until later.

For a given model configuration in a given flow, interest lies in the pressure distributions associated with an unsteady change in a model displacement parameter ϕ, which is a general coordinate to denote angle of pitch, control-surface deflection or some other quantity defining the unsteady motion. The basic problem is to determine $p(t)$ for the prescribed time-wise variation $\phi(t)$.

Experiments are sometimes made with non-harmonic forms of $\phi(t)$, and indeed Data Set 3 includes tests in which incidence is increased approximately linearly with time, but most unsteady experiments have been made for oscillatory conditions. Although there are special interests in large-amplitude motions, the main concern is with small perturbations and the most usual form of testing is with small-amplitude continuous harmonic oscillations. For this reason it is the pressure quantities relating to harmonic oscillations that will now be discussed.

We consider a rigid model undergoing oscillatory pitching motion. In addition to specifying Mach number and Reynolds number, the condition of the model is defined by

- a mean condition about which the oscillation occurs, specified by a mean incidence α_m ;
- an oscillatory motion specified by the sinusoid $\phi = \phi_0 \sin \omega t$.

Associated with this oscillatory condition will be the following classes of pressure quantity:

- steady pressure for the steady mean condition;
- unsteady pressure for the oscillatory condition: this includes a mean and an oscillatory component;
- steady pressures resulting from steady model positions which correspond to successive instantaneous positions during the unsteady excursions.

When a system can be regarded as linear (*ie* p varying linearly with ϕ) there are just four kinds of pressure quantities to be determined:

(1) steady pressure p_s for the steady mean condition identical with p_m the mean pressure during the oscillation;

(2) in-phase component normalised by motion amplitude, p'/ϕ_0 ;

(3) in-quadrature component normalised by motion amplitude, p''/ϕ_0 ;

(4) steady pressure derivative, $dp/d\phi$.

As an alternative, a modulus and a phase angle can replace the in-phase and in-quadrature components.

The distribution of p_s characterizes the type of flow, which in many respects influences the oscillatory and derivative pressures. Components p'/ϕ_0 and p''/ϕ_0 are, in general, dependent on the frequency of oscillation, and their variations with frequency give an indication of the effects of unsteady aerodynamics. In a linear system the derivative $dp/d\phi$ is the zero-frequency equivalent of p'/ϕ_0 , and provides a useful datum from which the effects of unsteadiness can be assessed.

When non-linearities are present, the pressure variation can be expressed as the Fourier series:

$$p(t) = p_m + p' \sin \omega t + p'' \cos \omega t + p_1' \sin 2\omega t + p_1'' \cos 2\omega t$$

plus higher harmonics. In the general non-linear case the Fourier coefficients are not necessarily proportional to the motion amplitude ϕ_0 , and the mean pressure p_m is not necessarily the same as the steady pressure p_s . Also the steady derivative $dp/d\phi$ needs to be replaced by another concept which will be discussed in the following section.

For attached flow serious non-linearities in pressure usually occur only for positions close to either a leading-edge, a flap hinge-line or a shockwave. Consequently being localised, the non-linearities tend to disappear when the pressures are integrated to give forces and moments. It is for this reason that even when non-linearity is present, practical interest continues to be centred on the fundamental components p'/ϕ_0 and p''/ϕ_0 . In most of the experiments included here, no attempt was made to measure any of the higher harmonics although large non-linearities were known to be occurring at a shockwave.

4 NOTATION

Various symbolic notations are used in the documents from which the information in the Data Sets has been obtained. Because the data listings are presented in their original form, it is necessary to explain the individual notations in each Data Set.

Some uniformity in notation is however desirable for future discussions and for this reason Bland, in Refs 0.1 and 0.2, has recommended a basic notation. This has been extended in this Compendium and, although the data listings retain their original forms, a move towards a standard notation has been made in preparing the diagrams and descriptive material for the Data Sets.

The following scheme is consistent with that proposed by Bland although there are a few minor changes. The sign conventions and some of the major definitions are shown in Fig 0.1 reproduced from Ref 0.2. The present scheme includes the basic notation and an extension to deal with the unsteady aerodynamic quantities.

BASIC NOTATION

Model geometry

local chord: c
root chord: c_r
model span: s
full-span aspect ratio: AR
sweepback angle: Λ
taper ratio: λ = tip chord/root chord
streamwise position aft of root leading edge: x
chordwise position aft of local leading edge: ξc
spanwise position: ηs
local position of pitching axis: x_α
local position of flap hinge: x_δ
incidence: α
flap angle: δ (measured in a streamwise section)

Stream

Mach number: M
Reynolds number based on root chord: Re
velocity: V
static pressure: p_∞
total pressure: p_t
dynamic pressure: q
total temperature: T_0
ratio of specific heats: γ

Model pressure (steady or instantaneous values)

surface pressure: p
pressure coefficient: $C_p = (p - p_\infty)/q$
pressure ratio: p/p_t
pressure resultant loading: $\Delta C_p = (C_{p\ lower} - C_{p\ upper})$

Model surface flow

local Mach number M_L determined from a measured pressure ratio by the isentropic relation:

$$M_L = \left\{\frac{2}{(\gamma - 1)}\left[\left(\frac{p}{p_t}\right)^{-(\gamma-1)/\gamma} - 1\right]\right\}^{\frac{1}{2}}$$

Section force coefficients

lift: $c_\ell = \int_0^1 \Delta C_p d(x/c)$

pitching moment: $c_m = \int_0^1 \Delta C_p (x_a/c - x/c) d(x/c)$

(Note: This definition of c_m is more general than that in Fig 0.1 because it relates to the moment about point x_a which need not be the same as x_α about which the model is pitching.)

flap lift: $c_{\ell f} = \int_{x_\delta/c}^1 \Delta C_p d(x/c)$

Section force coefficients (concluded)

flap hinge moment: $c_h = \int_{x_\delta/c}^{1} \Delta C_p(x_\delta/c - x/c)\,d(x/c)$

UNSTEADY NOTATION

Model motion

time: t

non-dimensional time: $\tau \equiv 2Vt/c$

general coordinate for model motion: ϕ

arbitrary motion: $\phi(t)$ or $\phi(\tau)$

oscillatory motion: $\phi = \phi_0 \sin \omega t$ (or $\phi_0 \cos \omega t$)

oscillatory amplitude: ϕ_0 representing α_0, δ_0 or θ_0 (Data Set 7)

mean incidence during an oscillation: α_m

mean flap angle during an oscillation: δ_m

oscillation frequency: f (Hz), or $2\pi f \equiv \omega$ (rad s^{-1})

reduced frequency: $k = \omega c/2V$, or $\omega c_r/2V$

Unsteady pressures

For an arbitrary model motion $\phi = \phi(\tau)$, the time-wise variation of instantaneous pressure is defined as

$$C_p(\tau) = \left(p(\tau) - p_\infty\right)/q \quad .$$

Oscillatory pressures

For the oscillatory motion $\phi = \phi_0 \sin \omega t$, a general equation for oscillatory pressure is

$$p(t) = p_m + p' \sin \omega t + p'' \cos \omega t + p_1' \sin 2\omega t + p_1'' \cos 2\omega t + \text{etc}$$

or the alternative,

$$p(t) = p_m \pm \left[p_0 \sin(\omega t + \varepsilon_0) + p_1 \sin(2\omega t + \varepsilon_1) + \text{etc}\right] \quad .$$

The sign outside the brackets in the last equation is a matter of choice. However, it is most convenient to choose the negative sign for the upper surface of the model and the positive for the lower, then usually the phase angles ε_0 in degrees for both surfaces will tend to zero, and not 180 deg, as the frequency tends to zero. Also this choice of signs is consistent with the usual method of plotting chordwise distributions of oscillatory pressure.

Mean pressure during oscillation: $C_{pm} = (p_m - p_\infty)/q$

Fundamental (1st harmonic) amplitude-normalised components

in-phase (or real component): $C_p'/\phi_0 = p'/q\phi_0$

in-quadrature (or imaginary component): $C_p''/\phi_0 = p''/q\phi_0$

Where an oscillatory quantity can be expressed as a complex amplitude a bar is used thus:

complex amplitude: $\bar{C}_p/\phi_0 = (C_p'/\phi_0) + i(C_p''/\phi_0) = \pm\left(|\bar{C}_p|/\phi_0\right)e^{i\varepsilon_0}$

modulus: $|\bar{C}_p|/\phi_0 = \left[(C_p'/\phi_0)^2 + (C_p''/\phi_0)^2\right]^{\frac{1}{2}}$

phase angle: $\varepsilon_0 = \tan^{-1}(C_p''/C_p')$.

Following the recommendation of Ref 0.1 the motion normalised quantities defined above are represented by a combined symbol including the normalising amplitude ϕ_0 , which in particular cases will be replaced by α_0, θ_0 or δ_0 . It should be noted that in some existing notations the normalising amplitude is omitted from the symbolic representation. Thus an existing notation may use C_p' and C_p'' respectively for the quantities C_p'/ϕ_0 and C_p''/ϕ_0 per radian as now proposed.

The (n + 1)th harmonic

in-phase component: $C'_{pn}/\phi_0 = p'_n/q\phi_0$

in-quadrature component: $C''_{pn}/\phi_0 = p''_n/q\phi_0$

complex amplitude: $\bar{C}_{pn}/\phi_0 = (C'_{pn}/\phi_0) + i(C''_{pn}/\phi_0) = \pm\left(|\bar{C}_{pn}|/\phi_0\right)e^{i\epsilon_n}$ with modulus $|\bar{C}_{pn}|/\phi_0$ and phase angle ϵ_n .

Unsteady forces and moments

The sectional unsteady forces and moments are obtained from the pressures by integration of the separate in-phase and in-quadrature components. The amplitude normalised coefficients are represented symbolically by using c_ℓ, c_m, c_h etc in place of C_p . Thus $\bar{c}_\ell/\phi_0$ represents the normalised complex amplitude of lift.

Use of p_t rather than q as a non-dimensionalising factor

In the preceding notation, apart from pressure ratio p/p_t in the expression for local Mach number M_L , all the aerodynamic pressure and force quantities have been divided by q to make them non-dimensional. An alternative which, as will be discussed in section 8, has advantages in certain circumstances is to use p_t in place of q . Thus the complex pressure amplitude $\bar{p}/p_t\phi_0$ is an alternative to $\bar{C}_p/\phi_0$. Of course the two forms are related through the stream Mach number by the relation:

$$p_t/q = \left[1 + \tfrac{1}{2}(\gamma - 1)M^2\right]^{\gamma/(\gamma-1)} \Big/ \tfrac{1}{2}\gamma M^2 \quad .$$

Units

Incidence, control angle, amplitude of angular motion and phase angle are conventionally specified in degrees. Oscillatory pressure or force when normalised by an angular motion are usually specified 'per radian'. The amplitude of a linear motion is preferably made non-dimensional by dividing by a model dimension.

Quasi-steady and steady perturbation pressures

Several kinds of steady, or quasi-steady, quantities are used as equivalent quantities to provide comparisons with the unsteady ones; the application in the linear case of the steady quantity $dC_p/d\phi$ has already been mentioned. The following discussion is intended to clarify the distinctions between the various forms these quantities can take.

The term 'quasi-steady' is usually applied to all such quantities but for the identification of experimental data it would seem preferable for this term to be applied only to those quantities that are measured in the same way as unsteady quantities but for slow rates of change. Such a quasi-steady oscillation, denoted by $k \to 0$ would yield for each in-phase component a quasi-steady value, for instance $(C'_p/\phi_0)_{qs}$. Data Sets 6 and 7 both include measurements for comparatively low-frequency oscillations which are regarded as quasi-steady.

The term 'steady perturbation pressure' is a better description of those quantities obtained by steady pressure measurements made for two or more stationary conditions of the model close to the mean condition. The simplest of these is an approximation to the derivative $dC_p/d\phi$ obtained from measured steady pressures C_{p-} and C_{p+} corresponding respectively to the two conditions $-\phi_1$ and $+\phi_1$. The quantity taken to be comparable with the unsteady in-phase component C'_p/ϕ_0 is then $\delta C_p/\delta\phi = (C_{p+} - C_{p-})/2\phi_1$ with the deflection ϕ_1 chosen to be the same as, or related to, the amplitude of oscillation ϕ_0 . Data Sets 1 and 4 contain data obtained in this manner.

More detailed information could be obtained if measurements are made for several increments of ϕ_1 so that the form of steady $C_p(\phi)$ over the oscillation amplitude is revealed. Then an average slope $dC_p/d\phi$ could be obtained, say, by 'least squares'.

To make allowance for non-linearities it is in principle possible to extend the measurements further so that they become equivalent to the steady quasi-oscillation $\phi = \phi_0 \sin\psi$, with $0 \leqslant \psi \leqslant \pi/2$. Provided the chosen values of ψ are sufficiently numerous, the measured steady pressures can be regarded as sampled data from which the fundamental and higher harmonic values can be calculated. In particular such measurements would yield a steady quantity $(C'_p/\phi_0)_s$ which is directly comparable with its unsteady counterpart C'_p/ϕ_0 . Although none of the present Data Sets contains quasi-oscillatory quantities of this nature, it may be possible to derive such quantities from data available from the original sources.

In short, under the customary generic title 'quasi-steady', three of the possible kinds of quantity comparable with the unsteady C_p'/ϕ_0 are:

(1) Low-frequency equivalent $(C_p'/\phi_0)_{qs}$ measured for $k \to 0$;

(2) Steady derivative $\delta C_p/\delta\phi$, or $dC_p/d\phi$;

(3) Steady quasi-oscillatory quantity $(C_p'/\phi_0)_s$.

In many cases a low-frequency change will become equivalent to a series of steady conditions as the rate of change is reduced. But there are special circumstances where this is not so - where even the slowest rate of change includes an unsteady event. Such a situation occurs when the motion, however slow, leads to the onset of flow separation where the actual process of shedding vorticity occupies a period of time largely independent of the rate of change. That is the condition $k \to 0$ is not always the same as the condition $k = 0$.

In addition to the fundamental differences in the form of these three quantities it may be necessary to take into account the differences between the method used to measure (1) and that used to measure the steady pressures from which (2) and (3) are derived. Sometimes different instrumentation is employed to obtain unsteady and steady measurements, in which case also, the unsteady and steady measuring positions may not be the same. Thus, whilst $(C_p'/\phi_0)_{qs}$ and the unsteady C_p'/ϕ_0 are obtained with the same instrumentation, a comparison between C_p'/ϕ_0 and a steady perturbation quantity may involve different measuring systems and different accuracies.

5 EXPERIMENTAL PROCEDURES AND INTERPRETATION OF RESULTS

The intention here is to give a brief account of some of the procedures commonly adopted in the experimental measurements and, by so doing, to draw attention to the possible limitations of the data. It is also hoped that this account will lead to an appreciation of the significance of the details of the test equipment and test conditions that are given in a standard form in each Data Set. A more extensive account of experimental techniques used in unsteady aerodynamics is contained in Ref 0.4.

Each series of tests involves a model, equipment to provide the required unsteady motion, instrumentation to measure the model motion and pressure distributions, and a wind tunnel to provide the appropriate test conditions.

The characteristics of the tunnel and the interference effects produced are of especial importance and form the subject of section 6.

5.1 Model motion

In each of the present experiments the model was designed to perform rigid-body motion. All the 2-D aerofoil models (Data Sets 1 to 5) were stiff enough to be regarded as rigid, but for the half-models of Data Sets 6 and 7, flexibility led to the basic applied motion being augmented by a small amount of elastic distortion dependent on oscillation frequency and aerodynamic loading.

The model motion, even when elastic deformation occurs, is usually defined by the output of a displacement transducer arranged to measure the motion reference coordinate ϕ , and to provide a time-varying electrical signal which is used as a phase reference for harmonic analysis. When the model cannot be regarded as rigid, some assessment of the actual motion which includes the unsteady deformation may be obtained from a distribution of accelerometers installed inside the model. By this means the true motion can be related to the measurements of ϕ .

5.2 Measurement of pressure

There are various schemes for measuring surface pressures. All of them depend on one or more pressure transducers to provide electrical outputs which are the actual quantities that are processed and eventually measured. Sometimes, as in Data Sets 2, 5, 6 and 7, two different systems are used in the same experiment: one to measure pressures in the steady state, the other for measurements in unsteady conditions. Then the steady and unsteady distributions may not be measured for the same positions, as in Data Set 7. One type of unsteady measuring system uses small transducers installed within the model and connected to orifices at the model surface. But in another system, as used for Data Sets 1 and 4, unsteady pressures are piped to a location outside the tunnel and switched in sequence to a single transducer. With any system the measurement that is sought is the surface pressure which would be acting at the position of the orifice: what is actually measured is the pressure acting at the diaphragm of the transducer. Therefore, unless the transducer is actually part of the surface there is always a question about the transfer function between the pressure acting at the orifice and that at the transducer. In systems where the unsteady pressures are piped to a distant measuring device, the determination of these transfer functions is a vital part of the calibration. When the transducer is situated very close to the orifice and the enclosed volume of air is small, the effects of transmission are usually neglected. However, a feature, which is common to all systems and very difficult to simulate in bench calibrations, is the effect of the flow across the orifice.

Whether or not the transfer function between orifice and transducer diaphragm is significant, the calibration factor relating the unsteady electrical output to unsteady pressure is of paramount importance. Whereas good standards of steady pressure are commonplace, there is no readily available definitive standard for oscillatory pressure. Although the experimenters will have taken great care over this matter, it is easily appreciated that a systematic error in the calibration could lead to undisclosed errors in all the measurements of a series.

5.2 Signal processing

In oscillatory tests, the electrical signals from the pressure transducers are usually processed in some manner to yield harmonic components phase-referenced to the signal representing the motion coordinate ϕ . However this is not so for Data Set 3 in which the pressure and motion signals are sampled to provide instantaneous values at a series of known time-intervals.

It is unnecessary to describe in detail the methods of processing the electrical signals, but it is important to be aware of the nature of the signals and to understand the kind of quantities that result from the processing. Almost inevitably the signal from a transducer sensing an aerodynamic pressure includes, in addition to the wanted signal, random-like fluctuations from various sources. Transonic tunnels with their slotted or perforated walls are prone to produce stream flows with some degree of inherent unsteadiness. Model flows which are supercritical, or separated, may themselves provide another source of unsteady disturbance. Thus even when the model is stationary the pressure signals may include fluctuations. When the model is undergoing a prescribed unsteady motion the complete pressure signal will represent a combination of random fluctuations and the response to the motion.

Depending on the type of signal processing employed, the result could be

- an instantaneous value;
- a time-average;
- a cycle-average of instantaneous samples taken at corresponding times in a number of cycles;
- a series of harmonic components obtained by Fourier analysis over either a whole number of cycles or a certain period of time.

Steady pressures are usually measured as averages over short periods of time. In general, time or cycle averaging is beneficial in reducing, if not always eliminating, the effect of random fluctuations. In some circumstances, where the unsteady process under investigation itself includes some form of randomness, averaging can obscure features of the individual cycles. Because the experiments from which Data Set 3 was extracted included an element of randomness in each cyclic onset of flow separation, both quasi-steady and unsteady pressures were measured as instantaneous values.

5.3 Occurrence and effects of extraneous fluctuations

When extraneous pressure fluctuations, independent of the applied model motion, are produced by an instability of the flow over the model they are a proper feature of the flow phenomenon and as such should appear in the results and require theoretical modelling. It is for this reason that items 5.11 or 5.12 of the test specification have been requested in each Data Set.

When the fluctuations are the result of turbulence or other unsteadiness in the tunnel flow it is desirable for their effects to be reduced by averaging. Whether they can be completely eliminated by averaging depends on whether they are linearly superposed on the pressure response to the prescribed motion or whether there is some form of non-linear interaction. In highly non-linear situations in the close vicinity of a shockwave, extraneous fluctuations can lead to erroneous data. Examples of such interference are mentioned in Refs 0.4 and 0.5.

5.4 Non-linearities

For small excursions away from the mean condition the pressure over much of the model surface will vary linearly with steady displacement ϕ . Exceptions to this become evident when measurements are made near to a leading edge or a control-surface hinge-line, or close to a shockwave. Non-linearities in the steady pressure variation are accompanied by the presence of higher harmonic components under oscillatory conditions; the manner in which these are produced in the close neighbourhood of a shockwave has been described in Refs 0.6 and 0.7.

Measurements of harmonic components are often limited to the fundamental on the grounds that this is the only component of importance in practical problems of aero-elasticity. Only Data Set 4 includes any numerical data for higher harmonics although Fig 6.6 of Data Set 6 gives graphical information on the spectral content of the pressures for transonic flow. Also Data Sets 2 and 5 include instantaneous pressures over a cycle of oscillation, which show non-linear features.

If in some circumstances the presence of higher harmonics in the oscillatory pressures is found to be independent of chordwise position, it is advisable before attributing these to non-linear aerodynamics to verify that the model motion is truly simple harmonic. This comment is relevant to any Fourier analysis that might be made on the instantaneous data presented in Data Set 3 which gives information on the harmonic distortion in the model motion.

When non-linearity is present, the values of the amplitude-normalised quantities C_p'/ϕ_0 and C_p''/ϕ_0 and the steady quantity $\delta C_p/\delta\phi$ are liable to be dependent on the displacement amplitude. This point needs to be borne in mind before placing too much emphasis on the peak values of these quantities obtained at the position of a shockwave. Interesting examples of amplitude dependence are shown in Fig 2.3 of Data Set 2 and Fig 5.7 of Data Set 5.

Irregularities in the chordwise distribution of the oscillatory pressure components are sometimes found near to the leading edge. These may be due to non-linearities associated with a local separation or with the disturbance produced by a transition-trip. Such irregularities usually appear only for small amplitudes, and disappear when the amplitude is increased.

To summarize, indications of non-linearity include:

- non-linearity in $C_p(\phi)$;
- amplitude effects on the fundamental components C_p'/ϕ_0 and C_p''/ϕ_0 ;
- non-sinusoidal time histories;
- higher harmonic components from Fourier analysis;
- irregularities in chordwise distributions of the oscillatory components.

5.5 Reduced frequency

The exact values of the test frequencies are often chosen for practical reasons such as the need to avoid unwanted resonances of the model or its supports. Almost invariably, tests are made for sets of fixed frequencies of oscillation so that for each constant frequency the reduced frequency k , varies with Mach number M and stream total temperature T_0 . For a fixed M, k varies inversely with $\sqrt{T_0}(K)$. Total temperature in a tunnel is not always closely controlled so that the value of k can vary during a tunnel run, but even in an extreme case where temperature changes from 25°C to 35°C the value of k would change by only 2%. Such a change is hardly likely to have a serious effect on the unsteady aerodynamics.

No uniform procedure has been adopted in specifying the test values of k . When either an average or a nominal value is quoted for each combination of M and f , it will be appreciated that the true value may differ by a few percent.

Tests made with substantially different values of frequency are included in most series of measurements. For rigid models the interpretation of the results is straightforward, but if model flexibility is significant, care has to be taken to eliminate any effects of changes in the oscillation mode with frequency.

5.6 Mach number and model incidence

These are the main parameters that define the basic flow from which the unsteady changes are made. In some cases the actual incidences and tunnel Mach numbers may be found to be slightly different from the specified nominal values.

For models with symmetrical sections, the datum incidence $\alpha = 0$ is usually set to align with the known flow direction of the tunnel. For models having sections that are not symmetrical the method of setting incidence is given in item 5.7 or 5.9 of the specification in each Data Set.

Where measurements of tunnel Mach number and model incidence are subject to standard corrections for wall interference, the details are given in item 9.6 of each specification.

5.7 Tunnel pressure and Reynolds number variations

The Reynolds number for a test depends on the pressure and temperature of the flow in the tunnel. Usually flow temperature is not closely controlled so that there may be small variations in Reynolds number throughout a series of tests. For those test series where tunnel total pressure remains constant, the Reynolds number is different for each Mach number. In tunnels where total pressure can be changed, variation of this quantity provides a means of obtaining data over a range of Reynolds number for each Mach number.

But as well as changing Reynolds number, alteration of total pressure can produce side-effects which, unless recognised and taken into account, may lead to apparent trends with Reynolds number that are in fact spurious.

For instance, an increase in total pressure means an increase in all the unsteady pressures, with a consequent improvement in the measurement accuracy. This in turn may mean a reduction in random errors and result in smoother pressure distributions. Also a change in total pressure alters the mean pressure level at which the transducers are operating and, in the presence of non-linearity, this can lead to a change of transducer sensitivity factor. If not accounted for in the calibration this could appear as a spurious Reynolds number effect.

An increase in the aerodynamic loading on the model is also produced by increasing the total pressure, and if the flexibility of the model is significant, this can lead to distortion of the model and to modifications to the mode of oscillatory motion. Data Sets 2 and 5 include data for a range of Reynolds numbers, but for these there is no possibility of unwanted aeroelastic effects because of the rigidity of the 2-D models.

5.8 Transition fixing and Reynolds number

Most of the tests were made for Reynolds numbers less than full-scale. To avoid unwanted effects associated with laminar boundary layers, trips to fix the transition position were fitted to some of the models. No trips were fitted for the measurements of Data Set 3 because the Reynolds numbers of the tests matched those of the full-scale helicopter blades to which the experiments were directed. Data Sets 1, 6 and 7 present numerical data for only models with transition trips, whilst for the experiments of Data Sets 2 and 5 no trips were attached. Data Set 4 gives information about the effects of fixing transition; in this Set transition was fixed for some cases and for others it was free. Data Set 6 contains a brief discussion of transition fixing in terms of increasing the thickness of the boundary layer, and provides graphical information about the effect this has on the unsteady loading produced by an oscillating control surface.

Data Sets 4 and 5 which give measurements for models having the same aerofoil shape, offer comparisons, as already shown in Table 0.2, between (a) tests with transition fixed at comparatively low Reynolds number, and (b) tests with free transition for a range of Reynolds number. Some of these comparisons will be discussed in section 7.

The desirability of fixing transition and the best position in the chord for attaching the trips are debatable matters. On the one hand if transition remains free, a laminar boundary layer may lead to types of flow separation and shockwave boundary-layer interactions that are unrepresentative of full-scale. Also it is possible that, when natural transition is delayed to a rearward position of the chord, the cyclic excursions of the transition point due to a model oscillation may engender non-typical oscillatory pressures of no practical interest. On the other hand when transition trips are used, the turbulent boundary so produced is usually too thick over the rearward part of the chord, thus over-emphasizing viscous effects which can be especially serious for a trailing-edge control, see Fig 6.4.

With regard to tests with over-thick boundary layers, Binion, Ref 0.8, points out that with modern designs of wings, even at high Reynolds number, viscous effects are likely to be so large that worthwhile calculation methods must be able to take these effects into account. The conclusion then is, albeit for steady conditions, that provided the class of flow is representative, tests with thick boundary layers do provide a useful challenge to theoretical computations. The objective of fixing transition therefore depends to some extent on whether the experiments are aimed at providing data appropriate to full-scale Reynolds numbers, or providing data to validate viscous calculations.

5.9 Accuracy of measurements

The accuracy with which the relevant quantities are measured is clearly an important matter although, as will be discussed in subsequent sections, the quality and reliability of experimental data involve wider considerations concerning the test environments.

It may be taken for granted that steady pressure, Mach number, incidence, steady deflections and oscillation frequency are measured with adequate accuracy. It is the accuracies of unsteady pressure quantities such as C_p'/ϕ_0 and C_p''/ϕ_0 that give cause for concern. Each of these quantities is derived from separate measurements of small changes in pressure and small displacements of the model. The measurements are made with instrumentation operating under dynamic, not steady conditions, and their accuracy depends crucially on the calibration procedure. It is easily seen that a systematic error in the measurement of a pressure harmonic component, or of a motion amplitude, could affect the whole set of measurements.

Whereas the resolution of the instrumentation or the day-to-day repeatability, both of which set limits to the accuracy, are fairly easy to determine, the overall accuracy of a measurement is extremely difficult to quantify. Usually the most that can be expected is a statement to the effect that the measurement of quantity A is no better than x percent. Such statements are usually made on personal, and to some extent intuitive, assessments based on the experience of the experimenter. To demand more would be unreasonable, for a thorough analysis of possible errors could easily entail as much work as the measurements themselves.

6 TUNNEL INTERFERENCE

All measurements obtained from wind tunnels are liable to suffer from the effects of tunnel interference. That is, the data obtained may differ from those which would be obtained with the same model moving in a free and uniform atmosphere. With that as a broad definition, the various sources of interference are:

(1) Wall constaint on the flow.

(2) Shockwave reflections from the walls.

(3) Side-wall boundary layers in 2-D tests.

(4) Reflection-plane boundary layer in half-model tests.

(5) Support interference in complete model tests.

(6) Flow fluctuations inherent in the tunnel flow.

(7) Curtailment of wake vorticity by tunnel corner, shockwave or fan.

(8) Reflection of acoustic disturbances at the walls.

(9) Occurrence of tunnel resonance.

(10) Acoustic disturbances propagated through a plenum chamber.

Items (1) to (6) affect both steady and unsteady measurements, whereas items (7) to (10) are peculiar to unsteady conditions. General accounts of the effects of interference on unsteady measurements are given in Refs 0.4 and 0.5. Of all the possible causes of interference, the only ones likely to be important to the present data are the constraint and reflection properties of the walls (items (1), (2) and (8)) and, if flow separation occurs at the model, the effects of the side-wall and reflection-plane boundary layers (items (3) and (4)). Tunnel resonance is known to be possible in 2-D tests (Ref 0.9) but no occurrences are reported in any of the Data Sets.

Because of its more complicated nature, interference on unsteady measurements is poorly understood in comparison with interference on steady measurements. Since some part of the total effect on an unsteady measurement can be attributed to steady interference - indeed for supercritical conditions the steady effect may be the major contribution - it is important to clarify the distinction and see how much of the total effect can be accounted for by steady considerations.

Consider for the moment a specific event in which a model initially at a steady incidence α_A is rapidly moved to a new steady incidence α_B. After sufficient time has elapsed we can assume that the flow has reached a new steady state appropriate to the new steady incidence. If the event occurs in a wind tunnel, the initial flow for α_A and the final flow for α_B are both subject to <u>steady</u> interference. The manner in which the flow changes with time, and indeed the time taken for the flow to approach its final steady state are subject to <u>unsteady</u> interference. The totality of the interference on the unsteady event is a combination of these steady and unsteady contributions.

For the more usual type of unsteady test where the model is given an oscillation of small amplitude ϕ_0 about a mean incidence α_m and conditions are linear, the aerodynamic pressure characteristics are fully described by

(1) C_p for steady α_m.

(2) $\left(|\bar{C}_p|/\phi_0\right)_{qs}$, the amplitude for a quasi-steady oscillation identical with $dC_p/d\phi$.

(3) Variations with frequency of amplitude $|\bar{C}_p|/\phi_0$ and phase angle ϵ_0.

Quantities (1) and (2) are affected by only <u>steady interference</u> and provided these effects can be accounted for, the only <u>unsteady effects</u> are those concerning the phase angle and variations with frequency, (3).

A crucial question is whether the aerodynamic measurements can be corrected for the interference effects. For supercritical flows simple forms of correction are generally impossible, but it is still helpful to approach the question from the standpoint of purely subsonic flow. Classical theory for steady subsonic flow regards wall constraint as consisting, in effect, of incremental changes in

- stream velocity due to blockage;
- model incidence due to induced upwash;
- lift and pitching moment due to streamline curvature.

On this simple basis, which neglects buoyancy effects due to the streamwise gradient of blockage, the condition of a model in a tunnel can be regarded as equivalent to the condition in free air of another model with a different camber set at a different incidence in a stream of modified velocity. For subsonic conditions values of the incremental changes can be obtained by theoretical calculations if the boundary conditions at the walls can be mathematically defined or if the wall pressures are known, or possibly by empirical means if the wall conditions are unknown.

The concept of an equivalent free-air system suggests, if the effects of streamline curvature are simplified, that the steady part of the wall constraint affecting oscillatory measurements might be equivalent to changes in stream Mach number and mean incidence. This leads to a possible basis for making comparisons between theory and experiment which will be discussed later in section 8.

For the oscillatory type of test mentioned previously a possible correction procedure would consist of applying corrections to:

(1) M and α_m - to account for steady interference on the mean condition;

(2) $\left(|\bar{C}_p|/\phi_0\right)_{qs}$ - to account for steady interference on the quasi-steady perturbation;

(3) $|\bar{C}_p|/\phi_0$ and ε_0 - to account for the unsteady interference.

The procedure is illustrated schematically in Fig 0.2 which shows a hypothetical variation of $|\bar{C}_p|/\phi_0$ and ε_0 with reduced frequency k. It is assumed that the measured steady C_p obtained for the steady condition (M,α_m) would be obtained in free air for another steady condition $(M,\alpha_m)'$. The curves labelled 1 are those measured in the tunnel for (M,α_m); those labelled 2 would be obtained in free air for the mean condition $(M,\alpha_m)'$. Steady interference is responsible for the displacement Δ_1. If curve 1A is drawn parallel to curve 1, or more strictly to give Δ_1 proportional to the modulus of total lift, then the additional and unsteady interference effects are represented by Δ_2 and Δ_3. Ability to apply corrections to the measurements requires knowledge of the translation from (M,α_m) to $(M,\alpha_m)'$ and the values of Δ_1, Δ_2 and Δ_3.

For subsonic conditions, corrections to M and α_m and corrections of the type Δ_1 applicable to lift and moment may be obtained theoretically or empirically. In principle, corrections of types Δ_2 and Δ_3 could be obtained from the extensions of classical interference theory to unsteady conditions, as described in Ref 0.10. But, as for the steady corrections, the calculations depend on an adequate definition of the wall boundary conditions which, for the unsteady case, includes time dependence.*

For the present data, any purely theoretical forms of interference corrections are liable to be unreliable because of inadequate definition of boundary conditions for the ventilated walls of the tunnels in which the data were obtained.

Broadly speaking, the steady constraint effects in a ventilated tunnel depend on the degree of ventilation; in principle at least, careful matching of the wall geometry and wall porosity to the model geometry could result in negligible interference (see for instance Ref 0.11). More usually, the measured slope of the steady lift curve for a particular model will be too large or too small depending on whether the tunnel walls are 'too closed' or 'too open'. Also it is to be expected that the larger the model is relative to the tunnel, the greater is the influence of wall constraint.

Even if the wall boundary conditions can be adequately defined, theoretical corrections to the measurements are simply not possible for supercritical flow conditions. A useful discussion of steady interference under transonic conditions is given by Binion, Ref 0.8. He points out that, where the supercritical region is no longer small with respect to the tunnel dimensions, the effect of wall constraint can no longer be regarded in the classical terms of blockage, upwash and streamline curvature; instead it must be regarded as a complicated distortion of the flow field which can strongly influence the shockwave and separation patterns. In which case, there may no longer be an equivalent free-air condition corresponding to the model in the tunnel.

It is unfortunate that the foregoing discussion has done little except describe the difficulties of making corrections to the measured unsteady data.

In none of the Data Sets are any corrections made for unsteady interference but in some Sets, steady-based corrections are either made, or the method for applying them is described. In Data Set 4, although the presented data include no interference corrections whatsoever, formulae are given for making corrections to the incidence, and to the lift and moment for steady conditions. In Data Sets 4 and 5, as already explained in section 2.1, some adjustments have been made between the experimental values of M and α_m and those chosen for the CT Cases; to some extent these adjustments are intended to account for the steady interference effects.

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* Addendum: The author's attention has been drawn to recent methods of including the effect of the walls in unsteady calculations for aerofoils and controls (see Refs 0.13, 0.14).

Data Set 5 comprises results obtained with a model having the same basic shape as the model of Data Set 4 - two examples of comparisons between the sets will be discussed in section 7. In making other comparisons between the two Sets it should be noted that, in addition to the differences shown in Table 0.2, the ratios of tunnel height to model chord are 3.1 for Data Set 4 and 6.7 for Data Set 5. However, because of the beneficial effect of wall ventilation, which to some unknown degree applies to both tunnels, it cannot without further analysis be concluded that the interference effects on Data Set 4 are necessarily larger than those on Data Set 5.

In Data Set 3 where the unsteady data are presented as instantaneous values of C_p and sectional force coefficients for instantaneous values of incidence α, the tabulated values of the incidence and the force coefficients, but not C_p, have been corrected for tunnel constraint as if each instantaneous value were obtained for a steady condition.

Data Set 7 is unique in being abstracted from an investigation into tunnel interference. In the light of the evidence obtained from several tunnels it is believed that the data for the two largest tunnels are free from any large effects due to tunnel constraint interference.

7 UNCERTAINTIES OF EXPERIMENTAL DATA

If experimental results are used only as qualitative information questions of accuracy and reliability hardly arise. But when making quantitative comparisons the user of experimental data will certainly want to know the confidence that can be placed on the measured values. Basically the question is how well do the measured unsteady aerodynamic quantities relate to the specified configuration, its motion, and to the test conditions defined by parameters such as M, Re, α_m and k. The answer is seldom straightforward. It depends not only on the accuracy of the measurements and the manufacturing accuracy of the physical model but also on the appropriateness of the wind-tunnel test conditions and the uncertainties of wind-tunnel interference. In critical situations in the presence of shockwaves or separations the answer also requires knowledge of the sensitivity of the measured data to small changes in the parameters.

A general insight into the uncertainties of measurements and an idea of the confidence that can be placed in experimental data can be obtained from a comparison of results obtained in different ways. For instance, confidence in the technique of unsteady pressure measurement was obtained when, on several occasions in the past, different organisations made comparative measurements using their own forms of instrumentation. Usually, however, such comparisons are not completely independent because they use either the same model, or the same tunnel, or both.

Examples of comparisons obtained with the same model in two different tunnels, thus providing evidence of the effects of tunnel interference, are given by Figs 7.20 and 7.21 of Data Set 7. In these comparisons the model was small in relation to the sizes of the tunnels; unfortunately the confidence gained by these comparisons does not necessarily apply to every other situation. In the same Data Set, Figs 7.16 to 7.19, also provide evidence of the sensitivity of the measured oscillatory pressures to small changes of M and α_m for some examples of transonic flow.

The two investigations from which Data Sets 4 and 5 are drawn provide a rare opportunity for comparing two independent sets of measurements. The data available for comparison relate to oscillatory pitching of the NLR 7301 supercritical airfoil. It is important to note that the two sets were obtained with different physical models in different wind tunnels by different experimenters using different instrumentation. As such the two experiments were completely independent.

At the outset, before making comparisons of the measured data, there are three points to be noted: firstly, there are differences in the degree to which each physical model represents the design shape of the NLR 7301 aerofoil; secondly, in neither case has there been any attempt to apply tunnel interference corrections to the measured unsteady data; and thirdly, there are no exact correspondences between the parametric conditions of the two tests.

Fig 0.3 provides comparisons between the measured and the design ordinates for a portion of the upper surface of each physical model. The ordinates for the NLR physical model are taken from Tables 4.1 and 4.2 of the present document; those for the Ames model are taken from Ref 5.4 which mentions that, owing to an expansion of the manufacturing mould, the model is slightly thicker than it should be. The same report also contains a suggestion, which is supported by Fig 0.3, that the surface of the model is not as smooth as the design shape.

Two examples of data comparisons will now be discussed. Not only do they provide evidence of the kind of uncertainties surrounding experimental data, but they provide a foretaste of situations requiring judgements to be made when comparing calculated and experimental results. In each example the unsteady quantities being compared are the distributions of the oscillatory pressure components, C_p'/α_0 and C_p''/α_0, for the upper surface only. The different tests are identified by the NLR Run No. or the Ames Dynamic Index.

The first example, chosen because of the aerodynamic simplicity of purely subsonic flow for M = 0.5, relates to CT Case 2. The three tests being compared are identified:

Test	M	α_m (deg)	α_0 (deg)	k	Re × 10^{-6}	Transition
NLR 1301	0.498	0.85	0.4	0.26	1.7	Fixed at 0.3c
Ames 185	0.508	0.58	0.5	0.20	2.3	Free
Ames 170	0.508	0.58	0.5	0.20	9.3	Free

The steady pressure distributions are shown in Fig 0.4a. Whilst examining these it may be noted that there is adequate agreement between the test Mach numbers and that, because the flow is subsonic, no great significance need be attached to the small difference in the values of α_m. Also it is reasonable to regard the difference between the Reynolds number of the NLR test and that of the Ames 185 test as not being too large. Although in both the Ames tests transition remained free, it was fixed in the NLR tests, but it is important to note that the roughness band was as far downstream as x = 0.3c. Since it appears from a comparison of the Ames and NLR steady pressures that fixing transition causes no dramatic changes downstream of the band, it seems reasonable to conclude that the band has no significant upstream effect. Thus the results from the Ames 185 test should be comparable with those from the NLR test at least ahead of x = 0.3c. In fact, comparison of the steady pressures shows that although there is a disagreement between the Ames and the NLR pressures at the lower surface, the three sets of results for the upper surface are in reasonable agreement in regard to the basic shape, but that there are more irregularities in the Ames distribution, possibly because of surface waviness.

Before comparing the oscillatory measurements, it should be noted that the difference between the Ames and the NLR values of k would not be expected to lead to significant changes in the real component C_p'/α_0, although it would have a small effect on the imaginary component, C_p''/α_0. The distributions of the oscillatory components are shown in Fig 0.4b and c. With regard to C_p'/α_0, in the region ahead of x = 0.3c there are considerable differences both between the two Ames sets and between the Ames and NLR sets. The dip in the region $0.1c < x < 0.2c$ is well established by three points in the Ames test at the higher Re, but is only just in evidence with a single point at the lower Re. This is mentioned in the Introduction to Data Set 5 where it is concluded that this dip is not spurious but must be attributed to a viscous effect. Interestingly the NLR distribution for an even lower Re also shows a single-point dip.

For the distribution of the imaginary component, C_p''/α_0 the main difference is the vertical displacement between the similarly shaped distributions of NLR and Ames tests. This can be ascribed partly to the known influence of changing k from 0.20 to 0.26. Another contributory factor may be differences between the unsteady effects of wall interference in the two tunnels.

The second example is a comparison of tests that relate closely to CT Case 8 which corresponds to a supercritical design case. The tests chosen for comparison are:

Test	M	α_m (deg)	α_0 (deg)	k	Re × 10^{-6}	Transition
NLR 6708	0.744	0.85	0.6	0.18	2.2	Free
Ames 191	0.752	0.37	0.5	0.20	3.3	Free
Ames 148	0.751	0.37	0.5	0.20	11.4	Free

All the tests were made without fixing transition and the Reynolds numbers for the NLR test and the Ames 191 are sufficiently close for the viscous characteristics of these two tests to be comparable. The third set, Ames 148, is included to show the effects of a large increase in Reynolds number.

There are differences between the NLR and Ames tests in regard to Mach number and mean incidence. As already explained in section 2.1 these differences are deliberate, each (M,α_m) combination having been chosen by the experimenter during preliminary trials to achieve a steady flow that matched the flow calculated by an inviscid theory for the supercritical design case. In a sense, the differences in the parametric settings in the NLR and Ames tunnels can be regarded as compensating to some extent for the differences in steady interference effects and for the differences in the shapes of the models.

The distributions of local Mach number, M_L, for the steady mean incidences, as shown in Fig 0.5a, have the same general shape, are in reasonable agreement on the general level of M_L in the supercritical region and agree on the chordwise position, $x \simeq 0.6c$, at which the deceleration from supercritical flow occurs. However, as for the subsonic example, the Ames distributions have a waviness over the forward half of the chord that is not present in the NLR distribution. Also there are significant differences in the deceleration gradients $dM_L/d(x/c)$ where the abrupt deceleration begins.

Comparisons of the oscillatory pressures are shown in Fig 0.5b and c. Each set of results include peaks in $-C_p'/\alpha_0$ and $-C_p''/\alpha_0$ close to the beginning of the deceleration from supercritical flow, the highest Re producing the highest peaks. Whilst the waviness in the Ames distributions is not unexpected in view of the waviness in the M_L distributions, there are serious differences between the Ames and NLR results in regard to the mean level of C_p'/α_0 in the region $0.3c < x < 0.6c$.

Also there are serious differences for both C_p'/α_0 and C_p''/α_0 in the region $0.6c < x < 1.0c$ where, surprisingly, it is the Ames results for the higher, and not the lower, Re that agree better with the NLR results. It is remarkable that over the rear of the chord, $0.7c < x < 1.0c$, there are such large differences between the three sets of unsteady pressures when the steady pressures there are in relatively good agreement. Probably the explanation is that the unsteady pressures over the rear part of the chord are dependent on the convection of the vorticity generated by the unsteady processes occurring upstream - in the present case the unsteady behaviour where the supercritical flow is first decelerated. In other words, over the rear of the chord, the effects of changing test conditions on the unsteady pressures are more likely to correlate with the effects of the changes on the steady pressures at more forward, rather than local, positions.

It will now be clear that both of the previous examples include discrepancies that cannot readily be attributed to differences in the models or in the test parameters. Since the ratio of tunnel height to model chord is 6.7 for the Ames tests and 3.1 for the NLR tests it is tempting to ascribe at least some of the discrepancies to differences in tunnel interference and furthermore to give more 'weight' to the data from the tunnel with the larger ratio. However, whilst interference may indeed by the reason, without further evidence and analysis it may be better to regard the differences simply as typical uncertainties inherent in unsteady wind-tunnel measurements.

8 COMPARISON BETWEEN THEORY AND EXPERIMENT

The use of experimental data as qualitative information requires no special comment - it is when the data are to be used for numerical comparisons with theoretical computations that difficulties arise.

The principal aim of computational development is naturally directed towards full-scale aircraft. One of the difficulties in making comparisons with wind-tunnel results arises because the experiments include features, particularly tunnel interference, which have no counterparts in the aircraft situation. The difficulties of applying interference corrections to the measurements have already been discussed. If no assurance can be given that the interference effects on a particular set of data are negligible, either theory must be diverted from its main aim and extended to include a mathematical representation of the tunnel boundaries in the computational model: or, if that is not possible, the probable importance of the effects must be assessed from whatever information on the subject has become available when the comparisons are being made.

A full specification of an unsteady experiment in a tunnel includes:

Model and basic flow

- Model shape;
- Oscillatory motion: mode, amplitude and frequency;
- Stream Mach number, M;
- Mean incidence, α_m (also possibly mean flap angle, δ_m);

Viscous characteristics

- Reynolds number;
- Transition position;

Tunnel boundary characteristics

- Wall geometry;
- Ventilation properties.

Comparative computations can vary in type from (a) those that include only the model and basic flow, to (b) those that include the full experimental specification. But at the start of any programme of comparison it is most likely that the chosen type of computation will omit the tunnel boundaries; furthermore the computational model may not fully represent the viscous characteristics of the experiment. In this case, apart from the shape of the model and the oscillatory motion, the main parameters entering the computation will be M and α_m. If tunnel interference (or viscosity) has had a serious effect on the measurements, then it is hardly likely that computations made for the experimental specification $(M,\alpha_m)_E$ will yield results in agreement with the experiment.

In the particular case when a shockwave is present, it is clear that the experimental and theoretical distributions of unsteady pressure will not agree unless there is already an agreement with regard to the mean position and strength of the shock. But more generally for all types of flow, it would seem that an agreement on the steady pressure distribution is a prerequisite to an agreement on the unsteady pressures.

Whilst it may be true that there is generally no free-air equivalent of the tunnel condition, it is possible that an improved comparison of unsteady pressure may result if the calculations are made for a different condition $(M,\alpha_m)_C$ which gives better agreement for the steady pressure distributions. In effect, the comparison will no longer be based on identities of stream Mach number and mean incidence but instead on similarity of the steady pressure distributions or, more aptly, on similarity of the distributions of local Mach number M_L . If such a method of comparison is adopted, steady computations would need to be made over ranges of M and α_m to seek some agreement in the distributions of M_L before any unsteady calculations are performed. As previously mentioned in section 2.1, such adjustments to the steady mean conditions have already been suggested for the supercritical design case for the NLR 7301 airfoil of Data Sets 4 and 5.

A caution is necessary here. Should a theoretical condition $(M,\alpha_m)_C$ be found that gives an M_L distribution exactly matching that of an experimental condition $(M,\alpha_m)_E$, thus supposedly compensating for the steady interference effects, it does not follow that the compensation extends to the unsteady interference or even to the interference on a quasi-steady change. This should be clear from Fig 0.2. The point needs to be kept in mind when making unsteady comparisons between theory and measurements for the steady-matched supercritical design cases of Data Sets 4 and 5.

When a comparison is made across an appreciable difference in stream Mach number, there is a question of choice concerning the form of the non-dimensional unsteady aerodynamic quantities that are to be compared. This arises because local Mach number M_L is related uniquely to p/p_t but not to C_p : obtaining identity in the values of M_L entails a difference in the values of C_p . Then, since in effect p/p_t rather than C_p is being used for the steady matching, it would seem more appropriate for the comparison of unsteady data to be made for non-dimensional quantities such as $\bar{p}/p_t\phi_0$ (already mentioned in section 4) rather than the conventional quantities typified by $\bar{C}_p/\phi_0 \equiv \bar{p}/q\phi_0$. To give an example: if the two stream Mach numbers over which the comparison is being made are $M = 0.80$ and $M = 0.85$, then an exact agreement between the values of $\bar{p}/p_t\phi_0$ would entail a difference of approximately 7% in the corresponding values of $\bar{C}_p/\phi_0$. However, for small differences in M , the matter is usually unimportant, particularly if the differences lie within the range of experimental uncertainty. Note that the unsteady measurements of Data Set 7 are presented as values of $\bar{p}/p_t\phi_0$ because they were originally used for comparisons between different tunnels.

The preceding discussion has assumed that the tunnel walls are not taken into account in the calculations. If the intention is to include the tunnel boundaries in the computational model it may be difficult to define a mathematical boundary condition sufficiently representative of the ventilated walls of the experiment. It may then be desirable to make separate calculations for each of the two extreme conditions representing closed and open boundaries, as has been done in Ref 0.12 and possibly make a third calculation for some intermediate homogeneous boundary condition.

In summary, the basis on which the experimental and computational unsteady data are compared may take any of the following forms:

- Same class of flow;
- Similarity of M_L distribution;
- Identity of basic flow parameters (M,α_m). Possibly also identity of viscous parameters, Re and transition position;
- Full experimental specification including the tunnel boundaries.

9 SUGGESTIONS FOR FUTURE EXPERIMENTS

The need for further experimental data will naturally depend on the early comparisons with the present data. If the agreement is good, the only question to arise would be whether all the significant features associated with full-scale aircraft had been catered for. In this connection it will be noted that, although a supercritical section is included in the Compendium, there are no data for a supercritical wing. However, this omission will be overcome when oscillatory pressure measurements become available for the LANN wing whose geometry and CT Cases are defined in Ref 0.2.

In the more likely event of differences being found between the computations and the experiments, there may be a need for new experiments. Before discussing what form these should take, it needs to be noted that the experimental programmes from which the present Data Sets were abstracted predate the choice of the CT Cases. Not all the experiments were specifically designed to provide data for the kind of close numerical comparisons now proposed.

In future it may be desirable to give more attention to overcoming the uncertainties of tunnel interference, say by including in any new tests the effects of changing the characteristics of the tunnel walls. The desirability of fixing transition needs to be re-examined. There could be advantages in making measurements of boundary-layer thickness under steady conditions so that these could be related to viscous calculations. Also it may be necessary to take more account of, or to place greater restraint on, the elastic distortions when 3-D configurations are being tested.

In addition there are two general matters that merit discussion and which to some extent are interrelated. These are (1) the form of the comparisons and (2) the method of communicating the experimental data.

Regarding the first of these matters, it is evident that the importance of variation of the main parameters was fully recognized when the CT Cases were selected. Completion of the computations for all cases for a configuration and their comparison with experiment is intended to demonstrate how well theory can cope with the different situations. But the intervals between consecutive values of the parameters are necessarily rather wide so that the comparisons tend to appear as a series of single-point correspondences. That is, for each case the experimental results for a particular condition $(M,\alpha_m)_E$ will be compared with computed results for the same or a related condition $(M,\alpha_m)_C$. Whilst single-point comparisons may be satisfactory for comparing one computational method with another, they may not be ideal for comparing computation with experiment: one reason being the inevitable uncertainties and sensitivities of the experimental results. It would be preferable to make comparisons of the variations of the aerodynamic quantities with the main parameters such as M and α_m , in the immediate vicinity of the corresponding condition (M,α_m), thereby taking account of the parametric sensitivities. In practice this could mean a comparison between, on the one hand the data for a pivotal condition, and on the other, data for a mesh of points surrounding the pivot point. Whether in a planned programme, the matrix of data is provided by the computations or the experiments will probably depend to some extent on the relative costs of computation and experiment. On this matter it is noted that although the capital cost of mounting an experiment is large, the running cost of additional measurements may be relatively low.

The possibility of using a greater quantity of experimental data leads to a consideration of the second matter, the means by which the data are communicated. It is obvious that printed tables cannot be used until they have been read and some manual action performed. This procedure is acceptable provided the listings are not to extensive, but the labour involved, quite apart from the amount of paper required, inhibits the use of large amounts of data in this form. Rather than printed tables it is suggested that in future the data be communicated by computer-readable magnetic tape. To give an example of the practicality of this suggestion, all the results of the NORA tests from two large tunnels, some 177 cases in all, can be made available on a standard 200 mm diameter magnetic tape. By using this means of communication, a computer available to the theoretician could present visual displays of the effects of parametric variations and indeed show the comparisons themselves.

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Table 0.1

THE AGARD AEROELASTIC CONFIGURATIONS

Configuration	Motion	Experimental data	
		Source	Present position
2-Dimensional Parabolic arc	Pitch and plunge oscillations	-	No experiments
NACA 64A006	Flap oscillation	NLR	Data Set 1. CT Cases 1,2,3,5,6,7,8*,10*,11
NACA 64A010 NASA Ames model	Pitch oscillation	Ames	Data Set 2. CT Cases 1,2,3,4,5,6*,7,8,9,10*
NACA 0012	Pitch oscillation and transient	ARA	Data Set 3. CT Cases 1*,2,3,5,6,7,8*
MBB-A3	Pitch and plunge oscillations	MBB	Steady data only
DO A1	Pitch oscillation	-	No experiments
NLR 7301	Pitch oscillation	NLR	Data Set 4. CT Cases 1,2,3,4,5,6,8*
		Ames	Data Set 5. CT Cases 1,2,3,4,5,6,7,8*,9
	Flap oscillation	NLR	Data Set 4. CT Cases 10,11,12,14
3-Dimensional Rectangular wing	Pitch oscillation about 2 axes	RAE	Experiments planned for 1984
RAE wing A	Pitch oscillation	RAE	Possibility of future experiments
	Flap oscillation	RAE	Data Set 6. CT Cases 4,5,8,9*,11
NORA model	Oscillation about swept axis	GARTEur†	Data Set 7. CT Cases 1,2*,3,4,5*,6*,7,8,9
ZKP wing	Flap oscillation	VFW	Data available in 1983
LANN wing	Pitch oscillation	NLR	Data probably available in 1983

* Denotes the priority cases for computational tests.

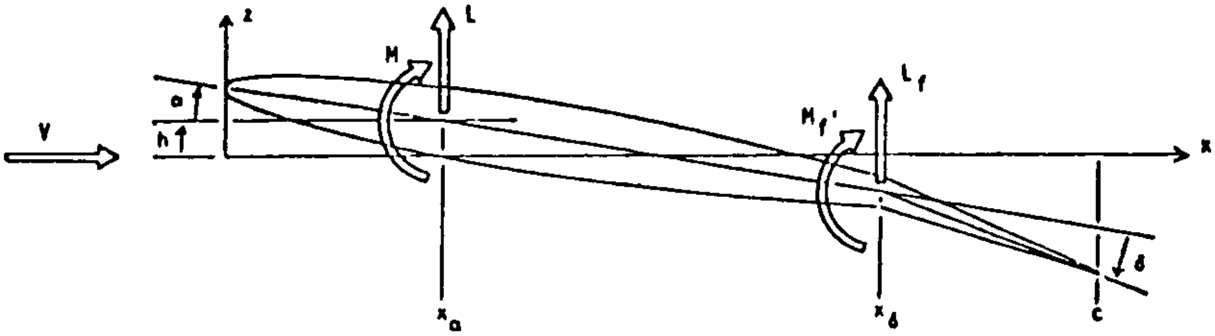
† The NORA experiments were made under the auspices of the Group for Aeronautical Research and Technology in Europe.

Table 0.2

NLR 7301 AEROFOIL PITCHING ABOUT 0.4c

Flow	Case	Run No. or DI	M	α_m	α_0	k	$Re \times 10^{-6}$	Transition
Subsonic	CT Case 1	-	0.500	0.40	0.5	0.098	-	-
	Data Set 4	1601	0.499	0.85	0.55	0.098	1.70	Fixed
	Data Set 5	184	0.508	0.58	0.50	0.050	2.53	Free
		168	0.505	0.58	0.51	0.049	9.33	Free
	CT Case 2	-	0.500	0.40	0.5	0.263	-	-
	Data Set 4	1301	0.498	0.85	0.44	0.262	1.70	Fixed
	Data Set 5	185	0.508	0.58	0.50	0.197	2.53	Free
		170	0.505	0.58	0.50	0.198	9.33	Free
Transonic with shock	CT Case 3	-	0.700	2.00	0.5	0.072	-	-
	Data Set 4	3805	0.696	3.00	0.42	0.072	2.11	Fixed
	Data Set 5	204	0.710	2.53	0.50	0.050	3.14	Free
		197	0.700	2.53	0.49	0.050	12.0	Free
	CT Case 4	-	0.700	2.00	1.0	0.072	-	-
	Data Set 4	3905	0.696	3.00	0.98	0.072	2.11	Fixed
	Data Set 5	206	0.710	2.53	1.01	0.050	3.14	Free
		199	0.700	2.53	1.01	0.050	12.0	Free
	CT Case 5	-	0.700	2.00	0.5	0.192	-	-
	Data Set 4	52705	0.695	3.00	0.55	0.192	2.12	Fixed
	Data Set 5	205	0.710	2.53	0.58	0.199	3.14	Free
		198	0.700	2.53	0.49	0.201	12.0	Free
Super-critical design	CT Case 6	-	0.721	-0.19	0.5	0.068	-	-
	Data Set 4	9608	0.744	0.85	0.46	0.068	2.23	Free
	Data Set 5	190	0.752	0.37	0.50	0.050	3.30	Free
		132	0.752	0.37	0.50	0.050	6.20	Free
		144	0.751	0.37	0.50	0.050	11.4	Free
	CT Case 7	-	0.721	-0.19	1.0	0.068	-	-
	Data Set 4	-	-	-	No measurements		-	-
	Data Set 5	136	0.752	0.37	1.01	0.050	6.20	Free
		150	0.751	0.37	1.00	0.050	11.4	Free
	CT Case 8*	-	0.721	-0.19	0.5	0.181	-	-
	Data Set 4	6708	0.744	0.85	0.61	0.181	2.22	Free
	Data Set 5	191	0.752	0.37	0.50	0.200	3.30	Free
		134	0.752	0.37	0.49	0.200	6.20	Free
		148	0.751	0.37	0.50	0.201	11.4	Free
	CT Case 9	-	0.721	-0.19	0.5	0.453	-	-
	Data Set 4	-	-	-	No measurements		-	-
	Data Set 5	135	0.752	0.37	0.50	0.300	6.20	Free
		149	0.751	0.37	0.50	0.301	11.4	Free

* Denotes a priority case for computations



$$q = 1/2\rho V^2 \qquad C_p = \frac{p - p_\infty}{q} \qquad \Delta C_p = C_{p,lower} - C_{p,upper}$$

$$L = qcc_l \qquad L_f = qcc_{l,f}$$

$$M = qc^2c_m \qquad M_f = qc^2c_h$$

$$C_L = \frac{2}{S}\int_0^s cc_l\,dy \qquad C_M = \frac{2}{Sc_r}\int_0^s c^2c_m\,dy \qquad C_H = \frac{2}{Sc_r}\int_{\text{control span}} c^2c_h\,dy$$

$$c_l = \oint_{airfoil} C_p\,d\zeta = \int_0^1 \Delta C_p\,d\zeta$$

$$c_m = \oint_{airfoil} C_p(x_\alpha/c - \zeta - z/c \cdot dz/dx)\,d\zeta = \int_0^1 \Delta C_p(x_\alpha/c - \zeta)\,d\zeta$$

$$c_{l,f} = \oint_{flap} C_p\,d\zeta = \int_{x_\delta/c}^1 \Delta C_p\,d\zeta$$

$$c_h = \oint_{flap} C_p(x_\delta/c - \zeta - z/c \cdot dz/dx)\,d\zeta = \int_{x_\delta/c}^1 \Delta C_p(x_\delta/c - \zeta)\,d\zeta$$

Fig 0.1 Wing section and total force and moment definitions from Ref 0.2

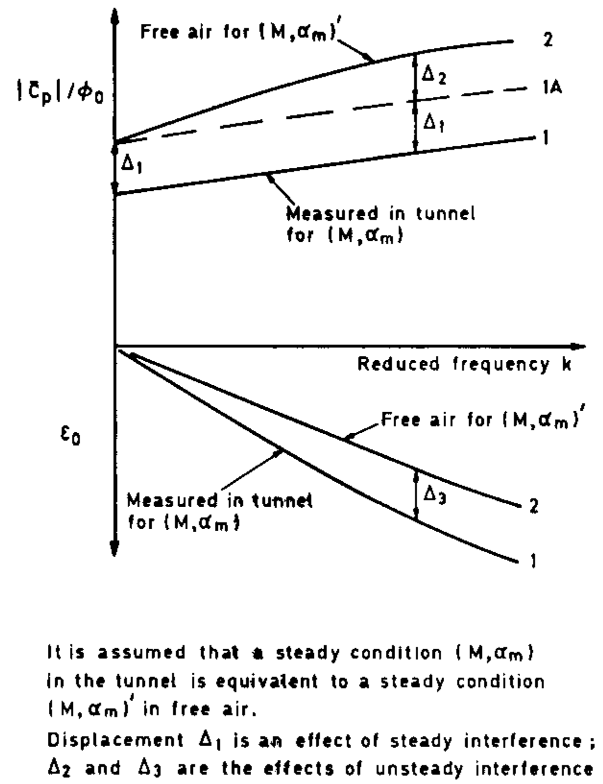


Fig 0.2 Schematic diagram illustrating tunnel interference on the modulus and phase of oscillatory pressure

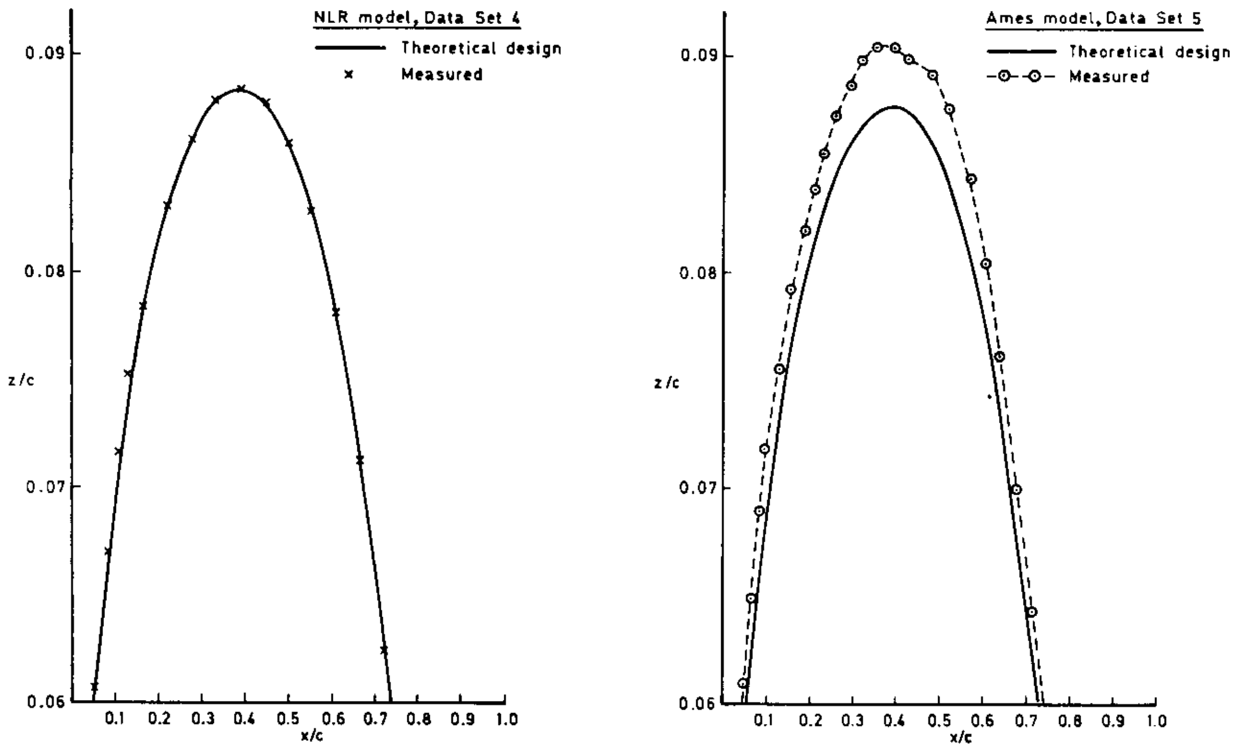


Fig 0.3 NLR 7301 Airfoil. Comparison between physical models and design shape. Profile height z/c for part of upper surface. (Note: the base line used to define z is not the same for both models; this is irrelevant to the comparisons)

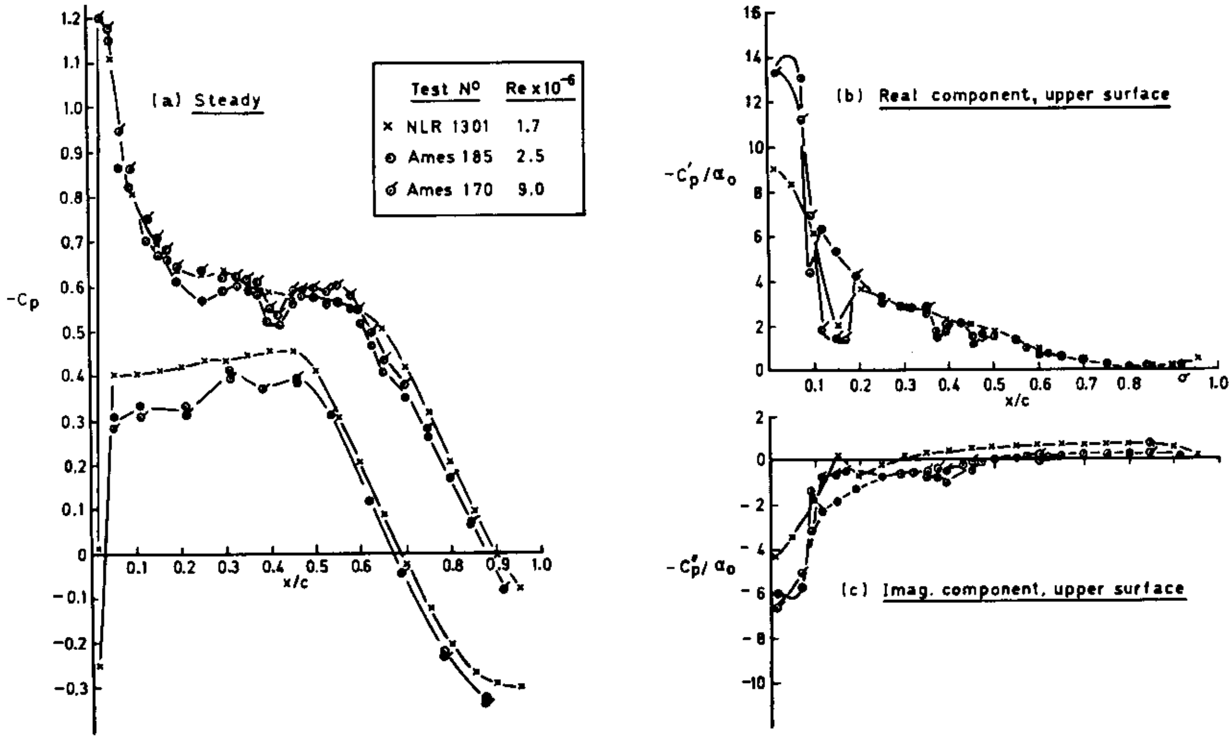


Fig 0.4 NLR 7301 Airfoil. Comparison of NLR and Ames data relating to CT Case 2 (subsonic M = 0.5)

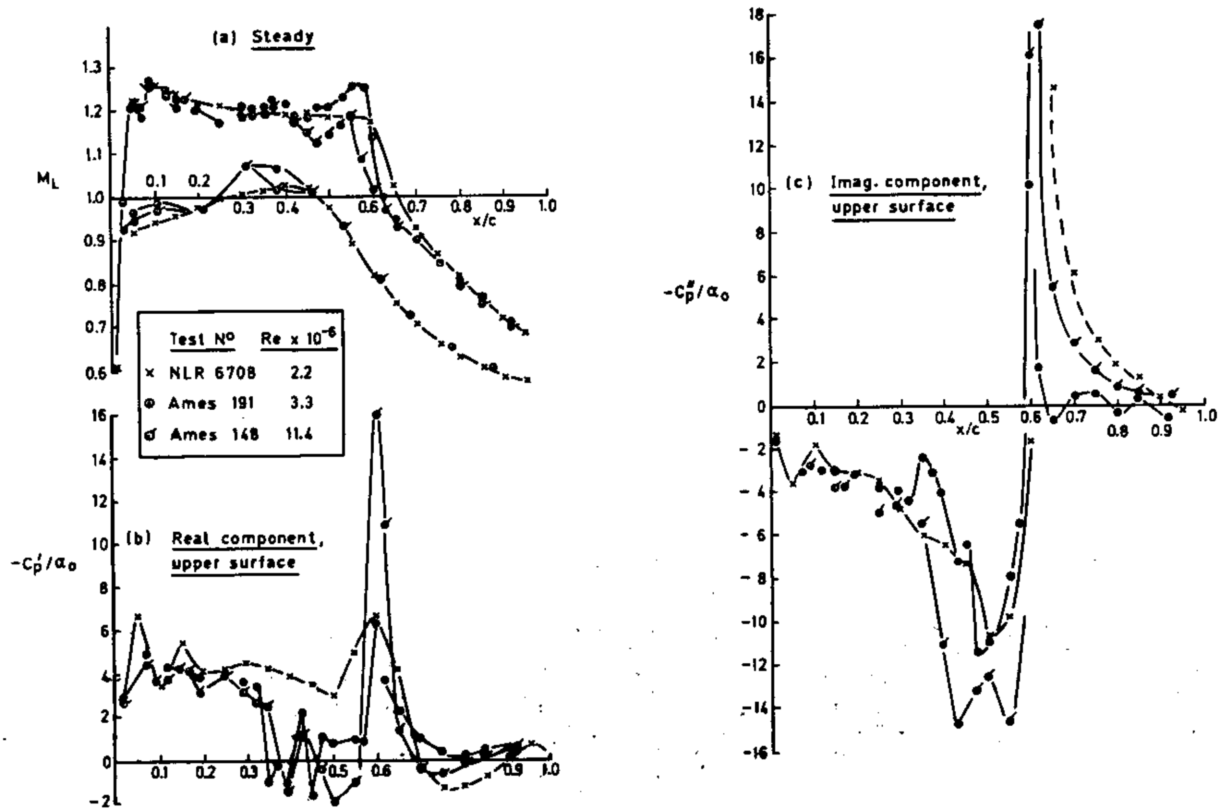


Fig 0.5 NLR 7301 Airfoil. Comparison of NLR and Ames data relating to CT Case 8 (Supercritical design case)

DATA SET 1

NACA 64A006 OSCILLATING FLAP

by

R.J. Zwaan, NLR

INTRODUCTION

The wind tunnel model which had a NACA 64A006 airfoil section, was fitted with a trailing-edge flap of 25 per cent of the chord. The maximum thickness of this symmetrical airfoil is 6 per cent and is located at about 28 per cent of the chord. During the test the main surface was clamped at the wind tunnel side walls, whereas the flap could be driven in a harmonic motion about an axis at 75 per cent of the chord. The flap had no aerodynamic balance.

In the set of two-dimensional aeroelastic configurations this airfoil represents the category of small thickness and conventional airfoils (roof-top type). The characteristics are illustrated in figure 1.1, presenting the development of the steady and unsteady pressure distributions with Mach number for a given frequency. Passing the critical Mach number, $M^* \approx 0.85$, the measured unsteady pressure distributions start to deviate from the calculated distributions under the influence of shocks at both sides. The calculated results are based on lifting surface theory.

Lift and moment coefficients are given in figure 1.2 for a frequency of 120 Hz. An at least qualitative agreement exists between experiment and theory up to $M \approx 0.85$. Results are also given for $k = 0$, see figure 1.3. The differences between experiment and theory are appreciably larger now, which can be ascribed partly to tunnel wall interference.

1 AIRFOIL

1.1	Designation	NACA 64A006
1.2	Type of airfoil	Roof top. 6 % thick, symmetrical
1.3	Geometry	See Table 1.1
1.4	Design condition	Not applicable
1.5	Additional remarks	-
1.6	References on airfoil	Ref. 1.1

2 MODEL GEOMETRY

2.1	Chord length	0.18 m
2.2	Span	0.42 m
2.3	Actual model coordinates and accuracy of measurements	See Table 1.2
2.4	Flap: hinge and gap details	Hinge axis at 0.75 c; gap width 0.1 mm
2.5	Additional remarks	-
2.6	References on model	-

3 WIND TUNNEL

3.1	Designation	NLR Pilot Tunnel
3.2	Type of tunnel	Continuous, closed circuit
3.3	Test section dimensions	Rectangular; see Fig. 1.4 height 0.55 m, width 0.42 m
3.4	Type of roof and floor	10 % slotted top and bottom walls, separate top and bottom plenums
3.5	Type of side walls	Solid side walls
3.6	Ventilation geometry	See Fig. 1.4
3.7	Thickness of side wall boundary layer	Thickness 10 % of test section semi-width, no special treatment
3.8	Thickness of boundary layers at roof and floor	Not measured; probably comparable with side wall boundary layers
3.9	Method of measuring Mach number	Derived from static pressure measured upstream of model and from total pressure measured in settling chamber
3.10	Uniformity of Mach number over test section	See Fig. 1.5
3.11	Sources and levels of noise or turbulence in empty tunnel	Turbulence/noise level, see Fig. 1.6
3.12	Tunnel resonances	No evidence

3.13	Additional remarks	For two-dimensionality of the flow see Ref. 1.3
3.14	References on tunnel	Ref. 1.2

4 MODEL MOTION

4.1	Mode of applied motion	Flap oscillation
4.2	Range of amplitude	$\delta_o \approx 1°$
4.3	Range of frequency	f = 0 to 120 Hz; k = 0 to 0.4
4.4	Method of application	Electrodynamic excitation at both sides of the flap, using adjustable spring stiffness
4.5	Purity of applied motion	Checked by spectral analysis; no data stored
4.6	Natural frequencies and normal modes of model	No interference with natural vibration modes
4.7	Static or dynamic elastic distortion during tests	Negligible
4.8	Additional remarks	-

5 TEST CONDITIONS

5.1	Tunnel height/model chord ratio	3.1
5.2	Tunnel width/model chord ratio	2.3
5.3	Range of Mach number	M = 0.5 to 1.0
5.4	Range of tunnel total pressure	Atmospheric
5.5	Range of tunnel total temperature	313 ± 1 K
5.6	Range of model steady, or mean, incidence	α_m: -4° to 0°; δ_m: -3° to 3°
5.7	Definition of model incidence	Zero incidence defined by matching upper and lower static pressure distribution (applicable because of airfoil symmetry)
5.8	Position of transition, if free	Not applicable
5.9	Position and type of trip, if transition fixed	2.5 mm strip of carborundum grains at 0.1 c
5.10	For mixed flow, position of sonic boundary in relation to roof and floor	Not measured
5.11	Flow instabilities during tests	No evidence
5.12	Additional remarks	-
5.13	References describing tests	Ref. 1.4

6 MEASUREMENTS AND OBSERVATIONS

6.1	Steady pressures for the mean conditions		✓
6.2	Steady pressures for small changes from the mean conditions		✓
6.3	Quasi-steady pressures		
6.4	Unsteady pressures		✓
6.5	Steady forces for the mean conditions	measured directly integrated press.	✓
6.6	Steady forces for small changes from the mean conditions	measured directly integrated press.	✓
6.7	Quasi-steady forces	measured directly integrated press.	
6.8	Unsteady forces	measured directly integrated press.	✓
6.9	Measurement of actual motion at points on model		✓
6.10	Observation or measurement of boundary layer properties		
6.11	Visualization of surface flow		
6.12	Visualization of shockwave movements		✓
6.13	Additional remarks		

7 INSTRUMENTATION

7.1 Steady pressures	
7.1.1 Position of orifices spanwise and chordwise	See 7.2.1
7.1.2 Type of measuring system	See 7.2.3
7.2 Unsteady pressures	
7.2.1 Position of orifices spanwise and chordwise	See Figs 1.7 and 1.8
7.2.2 Diameter of orifices	0.8 mm
7.2.3 Type of measuring system	38 pressure tubes + 6 in situ pressure transducers
7.2.4 Type of transducers	±2.5 psi and ±5 psi Statham differential pressure transducers, and ±5 psi Kulite miniature pressure transducers
7.2.5 Principle and accuracy of calibration	Calibration uses transfer functions of pressure tubes, see Ref. 1.4; for accuracy see 9.10
7.3 Model motion	
7.3.1 Method of measurement	See Fig. 1.7
7.3.2 Accuracy	See 9.10
7.4 Processing of unsteady measurements	
7.4.1 Method of acquiring and processing measurements	See Fig. 1.9
7.4.2 Type of analysis	Signal analysis of TFA over 20 cycles for f = 30 Hz and 60 cycles for f = 120 Hz
7.4.3 Unsteady pressure quantities obtained and accuracies achieved	Fundamental harmonics; for accuracy see 9.10
7.4.4 Method of integration to obtain forces	Trapezoidal rule
7.5 Additional remarks	-
7.6 References on techniques	Refs 1.4, 1.5

8 DATA PRESENTATION

8.1 Test cases for which data could be made available	Table 1.3
8.2 Test cases for which data are included in this document	Table 1.4
8.3 Steady pressures	Mean pressures in Tables 1.5 to 1.18
8.4 Quasi-steady or steady perturbation pressures	Steady pressure derivatives in Tables 1,5, 1.8, 1.11, 1.14 and 1.17
8.5 Unsteady pressures	Tables 1.6, 1.7, 1.9, 1.10, 1.12, 1.13, 1.15, 1.16 and 1.18
8.6 Steady forces or moments	-
8.7 Quasi-steady or steady perturbation forces	See 8.4
8.8 Unsteady forces and moments	See 8.5
8.9 Other forms in which data could be made available if required	-
8.10 References giving other presentations of data	Ref. 1.6

9 COMMENTS ON DATA

9.1 Accuracy	
9.1.1 Mach number	±0.002
9.1.2 Steady incidence	±0.02°
9.1.3 Reduced frequency	±0.0005
9.1.4 Steady pressure coefficients	Not known
9.1.5 Steady pressure derivatives	Not known
9.1.6 Unsteady pressure coefficients	Not known
9.2 Sensitivity to small changes of parameter	No evidence
9.3 Spanwise variations	No evidence
9.4 Non-linearities	Part of analysis of experimental results; see Ref. 1.4

9.5	Influence of tunnel total pressure	-
9.6	Wall interference corrections	No corrections included
9.7	Other relevant tests on same model	None
9.8	Relevant tests on other model of nominally the same airfoil	Unknown
9.9	Any remarks relevant to comparison between experiment and theory	Comparisons of experiment and theory including various calculation methods are given in Ref. 4
9.10	Additional remarks	No systematic investigations of separate accuracies have been performed; accuracy of lift and moment coefficients is estimated to be 5 to 10 per cent in magnitude and 3 to 6 degrees in phase angle
9.11	References on discussion of data	Refs 1.4, 1.7

10 PERSONAL CONTACT FOR FURTHER INFORMATION

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11 LIST OF REFERENCES

1.1 I.H. Abbott, A.E. von Doenhoff — Theory of wing sections. Dover Publications, Inc., New York, 1959

1.2 J. Zwaaneveld — Principal data of the NLL Pilot Tunnel. NLL Report MP 185, 1959

1.3 H.A. Dambrink — Investigation of the 2-dimensionality of the flow around a profile in the NLR 0.55x0.42 m² transonic wind tunnel. NLR Memorandum AC-72-018, 1972

1.4 H. Tijdeman — Investigations of the transonic flow around oscillating airfoils. NLR TR 77090 U, 1977

1.5 P.H. Fuykschot, L.J.M. Joosten — DYDRA - Data logger for dynamic measurements. NLR MP 69012 U, 1969

1.6 H. Tijdeman, P. Schippers — Results of pressure measurements on an airfoil with oscillating flap in two-dimensional high subsonic and transonic flow (zero incidence and zero mean flap position). NLR TR 73078 U, 1973

1.7 R. Houwink — Some remarks on boundary layer effects on unsteady airloads. AGARD-CP-296, 1981

1.8 S.R. Bland — AGARD Two-dimensional aeroelastic configurations. AGARD-AR-156, 1979

12 NOTATION AND LIST OF SYMBOLS

DATA SET	STANDARD
ALPHA	mean wing incidence, α_m, deg
C	flap amplitude, δ_o, deg; see Note 2 below
CP	steady mean pressure coefficient, C_p
DCP	oscillatory pressure coefficient ($k \neq 0$), tabulated as REal, IMaginary, MODulus and ARGument, equivalent to $-\bar{C}_p/\delta_o$, in which $\bar{C}_p/\delta_o = (C_p'/\delta_o) + i(C_p''/\delta_o)$. RE, IM, MOD in rad^{-1}, ARG in deg. If $k = 0$, then DCP = $-[C_p(+\delta_o)-C_p(-\delta_o)]/2\delta_o$
DELTA	mean flap angle, δ_m, deg
F	frequency, f, Hz
K	reduced frequency, $k = \pi fc/V$
KC, k_c	oscillatory wing lift coefficient, $\bar{C}_L/\pi\delta_o$, rad^{-1}
M	mean local Mach number, M_L
MC, m_c	oscillatory wing pitching moment coefficient (about 0.25 c), $-2\ \bar{C}_m/\pi\delta_o$, rad^{-1}
NC, n_c	oscillatory flap hinge moment coefficient, $-2\ \bar{C}_h/\pi\delta_o$, rad^{-1}
PO	total pressure, p_t, Pa
Q	dynamic pressure, q, Pa
RC	oscillatory flap lift coefficient, $\bar{C}_{\ell f}/\pi\delta$, rad^{-1}
RE	Reynolds number based on wing chord, Re
+	(suffix) upper side
-	(suffix) lower side

* (superscript) critical value

Note 1: Symbols not mentioned here conform to the notation in the General Review

Note 2: The oscillatory motion is defined as $\delta = \delta_o \sin \omega t$, in accordance with the General Review. The equation for a corresponding oscillatory pressure reads:
$p(t) = p_m + p' \sin \omega t + p'' \cos \omega t$ + etc.
Similar expressions hold for the aerodynamic coefficients.

TABLE 1.1

Contour data of the NACA 64A006 airfoil

x (% c)	z (% c)	x (% c)	z (% c)
0	0	40	2.999
0.5	0.485	45	2.945
0.75	0.585	50	2.825
1.25	0.739	55	2.653
2.5	1.016	60	2.438
5.0	1.399	65	2.188
7.5	1.684	70	1.907
10	1.919	75	1.602
15	2.283	80	1.285
20	2.557	85	0.967
25	2.757	90	0.649
30	2.896	95	0.331
35	2.977	100	0.013

L.E. radius: 0.246 % c

TABLE 1.2

Actual contour data of the NACA 64A006 airfoil
(measures per cent of chord)

x	z_{upper}	z_{lower}
1.25	0.742	-0.742
2.50	1.025	-1.025
5.00	1.405	-1.405
7.50	1.686	-1.686
10.00	1.919	-1.922
15.00	2.283	-2.283
20.00	2.558	-2.555
25.00	2.758	-2.758
30.00	2.894	-2.889
35.00	2.975	-2.969
40.00	2.991	-2.989
45.00	2.942	-2.936
50.00	2.822	-2.819
55.00	2.655	-2.642
60.00	2.430	-2.425
65.00	2.194	-2.169
70.00	1.908	-1.894
75.00	-	-
80.00	1.310	-1.310
85.00	0.989	-0.989
90.00	0.668	-0.668
95.00	0.346	-0.346
100.00	0.027	-0.027

TABLE 1.3

Test program for the NACA 64A006 airfoil with flap

Test condition	FREQ. (Hz)	MACH NUMBER												
		.50	.75	.775	.80	.825	.85	.875	.90	.92	.94	.96	.98	1.00
$\alpha_m = 0°$, $\delta_m = 0°$	0	x	x		x	x	x	x	x	x	x	x	x	x
	10	x				x	x	x	x			x		
	20	x						x						
	30	x			x	x	x	x	x			x		
	90	x				x	x	x	x			x		
	120	x	x	x	x	x	x	x	x	x	x	x	x	x
$\alpha_m = 0°$, $\delta_m = 3°$	0	x	x		x	x	x	x	x	x	x	x	x	x
	30	x				x	x	x		x				
	120	x	x	x	x	x	x	x		x	x	x		
$\alpha_m = -2°$, $\delta_m = 0°$	0	x	x		x	x	x	x	x	x	x	x		
	30	x				x	x	x	x					
	120	x	x	x	x	x	x	x	x	x	x			
$\alpha_m = -2°$, $\delta_m = 3°$	0	x	x	x	x	x	x	x	x	x	x	x		
	30	x				x	x	x	x					
	120	x	x	x	x	x	x	x	x					
$\alpha_m = -2°$, $\delta_m = -3°$	0	x	x	x	x	x	x	x	x	x	x	x		
	30	x				x	x	x						
	120	x	x	x	x	x	x	x						
$\alpha_m = -4°$, $\delta_m = 0°$	0	x	x	x	x	x	x	x	x	x				
	10	x					x							
	30	x				x	x							
	120	x	x	x	x	x	x	x	x	x				

AMPLITUDE OF OSCILLATION: $\delta_o = 1$ DEG

TABLE 1.4

Test cases for the NACA 64A006 airfoil with flap included in Data Set 1

Flow	CT Case				Data Set 1						
	No	M	δ_o	k	Run No	M	δ_o	δ_m	k	Re*10^{-6}	Table
Subsonic	z1	0.800	1.5	0	–	0.800	1.5	0	0	2.34	1.5
	1	0.800	1.0	0.064	40904	0.794	1.09	0.15	0.064	2.32	1.6
	2	0.800	1.0	0.253	40807	0.804	1.11	0.00	0.253	2.35	1.7
	z2	0.825	1.5	0	–	0.825	1.5	0	0	2.36	1.8
	3	0.825	1.0	0.062	40905	0.824	1.09	0.15	0.062	2.36	1.9
	4	0.825	2.0	0.062	No measurement						
	5	0.825	1.0	0.248	40305	0.822	0.95	0.20	0.248	2.28	1.10
Transonic	z3	0.850	1.5	0	–	0.850	1.5	0	0	2.39	1.11
	6	0.850	1.0	0.060	40906	0.853	1.10	0.16	0.060	2.40	1.12
	7	0.850	1.0	0.240	40806	0.854	1.05	0.02	0.240	2.41	1.13
	z4	0.875	1.5	0	–	0.875	1.5	0	0	2.43	1.14
	8*	0.875	1.0	0.059	40907	0.877	1.13	0.15	0.059	2.43	1.15
	9*	0.875	2.0	0.059	No measurement						
	10*	0.875	1.0	0.234	40807	0.879	1.08	0.01	0.234	2.44	1.16
	z5	0.960	1.5	0	–	0.960	1.5	0	0	2.51	1.17
	11	0.960	1.0	0.054	40911	0.966	1.03	0.00	0.054	2.53	1.18
	12	0.960	1.0	0.214	No measurement			0.18			

Remarks on Table 1.4

Cases z1 to z5 are extra to the computational cases identified in reference 1.8. They correspond to zero-frequency (k = 0) experimental data that are closely related to the CT Cases for which k ≠ 0.
The asterisks denote Priority Cases.
In all cases α_m = 0. Transition is fixed at 0.15 c.

TABLE 1.5

M = .800 F = 0 ALPHA = 0.00 KC = 1.32
DELTA = 0.00 MC = .612
C = 1.5 NC = .0372

	UPPERSIDE				LOWERSIDE			
X/C	CP +	M +	DCP + RE	DCP + IM	CP –	M –	DCP – RE	DCP – IM
.010	-.005	.802	3.552	0.0	.029	.787	-3.609	0.0
.050	-.154	.870	2.292	0.0	-.143	.865	-2.253	0.0
.100	-.192	.887	1.833	0.0	-.179	.881	-1.833	0.0
.200	-.236	.907	1.680	0.0	-.238	.908	-1.719	0.0
.300	-.268	.922	1.719	0.0	-.273	.924	-1.852	0.0
.400	-.290	.932	1.890	0.0	-.293	.933	-2.005	0.0
.450	-.276	.926	1.967	0.0	-.267	.921	-1.986	0.0
.500	-.249	.913	1.890	0.0	-.250	.914	-2.024	0.0
.550	-.216	.898	1.948	0.0	-.213	.897	-1.986	0.0
.600	-.179	.881	2.005	0.0	-.176	.880	-2.158	0.0
.650	-.150	.868	2.215	0.0	-.144	.865	-2.349	0.0
.700	-.119	.854	2.597	0.0	-.103	.847	-2.616	0.0
.725	-.104	.847	2.941	0.0	-.084	.838	-2.826	0.0
.750	-.096	.843	4.431	0.0	.007	.797	-7.086	0.0
.775	-.071	.832	3.858	0.0	-.053	.824	-3.724	0.0
.800	-.046	.821	2.807	0.0	-.034	.815	-2.769	0.0
.850	-.010	.805	1.661	0.0	-.004	.802	-1.699	0.0
.900	.023	.790	.974	0.0	.030	.786	-.974	0.0
.950	.067	.770	.458	0.0	.072	.768	-.477	0.0

TABLE 1.6

RUNNO 40904

M = .794 F= 30.0 ALPHA= 0
P0= 10429 DELTA= .15
RE= 2.32E6 K= .064 C= 1.09
Q = 3037.30

	RE	IM		RE	IM		
KC=	1.016	-0.260	RC=	.2766	.0112	X5= 1.334E-3	1
MC=	.640	.010	NC=	.0385	.0028	X6= 1.346E-3	0

X/C	CP+	M+	UPPERSIDE DCP+ RE	DCP+ IM	DCP+ MOD	DCP+ ARG	CP-	M-	LOWERSIDE DCP- RE	DCP- IM	DCP- MOD	DCP- ARG
.010	-0.035	.811	.671	-1.474	1.619	-65	.077	.759	-0.736	1.554	1.719	115
.050	-0.175	.873	.342	-0.753	.827	-66	-0.120	.847	-0.678	1.050	1.250	123
.100	-0.226	.897	.657	-0.853	1.077	-52	-0.166	.867	-0.737	.895	1.159	129
.200	-0.252	.909	.991	-0.787	1.266	-38	-0.222	.893	-1.115	.826	1.387	143
.300	-0.279	.921	1.245	-0.683	1.420	-29	-0.256	.908	-1.276	.708	1.459	151
.400	-0.304	.932	1.628	-0.554	1.719	-19	-0.279	.919	-1.578	.605	1.690	159
.450	-0.287	.925	1.744	-0.403	1.790	-13	-0.260	.910	-1.665	.490	1.736	164
.500	-0.263	.914	1.826	-0.301	1.850	-9	-0.235	.898	-1.825	.379	1.864	168
.550	-0.222	.895	1.915	-0.198	1.925	-6	-0.199	.882	-1.927	.288	1.948	172
.600	-0.190	.881	2.034	-0.113	2.038	-3	-0.165	.867	-2.105	.185	2.113	175
.650	-0.159	.866	2.155	-0.136	2.159	-4	-0.127	.850	-2.302	.118	2.305	177
.700	-0.125	.851	2.258	-0.253	2.272	-6	-0.089	.833	-2.649	.043	2.650	179
.725	-0.108	.844	2.658	-0.213	2.667	-5	-0.071	.825	-2.885	.023	2.885	180
.750	-0.068	.825	4.948	.409	4.965	5	.013	.787	-5.276	1.571	5.505	163
.775	-0.085	.833	4.097	.224	4.103	3	-0.030	.806	-3.821	-0.047	3.822	181
.800	-0.058	.821	3.038	.335	3.057	6	-0.018	.801	-2.943	-0.141	2.946	183
.850	-0.018	.803	1.751	.212	1.764	7	.006	.790	-1.738	-0.042	1.739	181
.900	.021	.786	.959	.100	.964	6	.038	.776	-1.066	-0.090	1.069	185
.950	.069	.764	.374	.013	.374	2	.080	.757	-0.501	-0.043	.503	185

TABLE 1.7

RUNNO 40807

M = .804 F= 120.0 ALPHA= 0
P0= 10484 DELTA=-0.00
RE= 2.35E6 K= .253 C= 1.11
Q = 3097.83

	RE	IM		RE	IM
KC=	.830	-0.394	RC=	.3090	.0480
MC=	.756	-0.019	NC=	.0419	.0115

X/C	CP+	M+	UPPERSIDE DCP+ RE	DCP+ IM	DCP+ MOD	DCP+ ARG	CP-	M-	LOWERSIDE DCP- RE	DCP- IM	DCP- MOD	DCP- ARG
.010	-0.031	.818	-1.001	-0.899	1.346	-138	.066	.774	1.043	.914	1.387	41
.050	-0.173	.882	-0.494	-0.510	.710	-134	-0.124	.860	.601	.704	.926	49
.100	-0.225	.906	-0.416	-0.768	.873	-118	-0.171	.882	.476	.847	.971	61
.200	-0.252	.919	-0.081	-1.121	1.124	-94	-0.225	.906	.061	1.125	1.127	87
.300	-0.280	.932	.428	-1.351	1.417	-72	-0.257	.921	-0.448	1.276	1.352	109
.400	-0.306	.944	1.240	-1.468	1.921	-50	-0.282	.933	-1.100	1.307	1.708	130
.450	-0.289	.936	1.647	-1.277	2.084	-38	-0.267	.926	-1.335	1.199	1.795	138
.500	-0.261	.923	1.943	-1.118	2.242	-30	-0.238	.912	-1.668	1.044	1.968	148
.550	-0.223	.905	2.146	-0.900	2.327	-23	-0.203	.896	-1.906	.924	2.118	154
.600	-0.188	.889	2.336	-0.629	2.420	-15	-0.168	.880	-2.217	.664	2.315	163
.650	-0.158	.875	2.582	-0.428	2.617	-9	-0.132	.864	-2.556	.523	2.609	168
.700	-0.126	.861	2.729	-0.180	2.735	-4	-0.095	.847	-2.978	.290	2.992	174
.725	-0.108	.852	3.259	-0.139	3.262	-2	-0.076	.838	-3.286	.212	3.293	176
.750	-0.045	.824	7.188	.060	7.188	0	.008	.800	-6.507	.214	6.510	178
.775	-0.083	.841	4.427	.134	4.429	2	-0.038	.821	-3.953	-0.189	3.957	183
.800	-0.055	.828	3.339	.446	3.368	8	-0.026	.816	-3.099	-0.374	3.121	187
.850	-0.017	.811	1.986	.488	2.045	14	-0.001	.804	-1.833	-0.437	1.885	193
.900	.020	.794	1.105	.407	1.178	20	.032	.789	-1.121	-0.444	1.206	202
.950	.066	.773	.431	.228	.487	28	.074	.770	-0.496	-0.273	.566	209

TABLE 1.8

M = .825   F = 0   ALPHA = 0.00   KC = 1.35
DELTA = 0.00   MC = .640
C = 1.5   NC = .0380

	UPPERSIDE				LOWERSIDE			
X/C	CP +	M +	DCP + RE	DCP + IM	CP -	M -	DCP - RE	DCP - IM
.010	.017	.817	3.132	0.0	.039	.807	-3.208	0.0
.050	-.146	.894	2.081	0.0	-.141	.891	-2.139	0.0
.100	-.188	.914	1.680	0.0	-.181	.910	-1.757	0.0
.200	-.246	.942	1.623	0.0	-.247	.942	-1.719	0.0
.300	-.283	.959	1.852	0.0	-.289	.962	-1.910	0.0
.400	-.321	.978	2.349	0.0	-.326	.980	-2.349	0.0
.450	-.300	.968	2.311	0.0	-.294	.965	-2.292	0.0
.500	-.265	.951	2.081	0.0	-.263	.950	-2.177	0.0
.550	-.225	.931	2.062	0.0	-.224	.931	-2.158	0.0
.600	-.187	.913	2.177	0.0	-.184	.912	-2.253	0.0
.650	-.151	.896	2.406	0.0	-.147	.894	-2.463	0.0
.700	-.119	.881	2.750	0.0	-.104	.874	-2.712	0.0
.725	-.103	.873	3.132	0.0	-.084	.864	-2.922	0.0
.750	-.092	.868	4.660	0.0	.007	.822	-7.219	0.0
.775	-.068	.857	3.991	0.0	-.051	.849	-3.839	0.0
.800	-.042	.845	2.845	0.0	-.032	.840	-2.884	0.0
.850	-.006	.828	1.661	0.0	.002	.824	-1.699	0.0
.900	.029	.811	.935	0.0	.036	.808	-.974	0.0
.950	.072	.791	.439	0.0	.079	.788	-.401	0.0

TABLE 1.9

RUNNO 40905

M = .824   F= 30.0   ALPHA= 0
P0= 10426   DELTA= .15
RE= 2.36E6   K= .062   C= 1.09
Q = 3175.36

	RE	IM		RE	IM
KC=	1.068	-0.260	RC=	.2863	.0195
MC=	.681	.022	NC=	.0395	.0041

	UPPERSIDE						LOWERSIDE					
X/C	CP+	M+	DCP+ RE	DCP+ IM	DCP+ MOD	DCP+ ARG	CP-	M-	DCP- RE	DCP- IM	DCP- MOD	DCP- ARG
.010	-0.011	.831	.517	-1.351	1.446	-69	.088	.782	-0.529	1.394	1.491	111
.050	-0.168	.905	.273	-0.707	.758	-69	-0.116	.878	-0.562	.999	1.147	119
.100	-0.223	.931	.559	-0.839	1.008	-56	-0.168	.902	-0.698	.915	1.151	127
.200	-0.258	.948	.908	-0.844	1.240	-43	-0.235	.934	-1.067	.901	1.396	140
.300	-0.294	.966	1.308	-0.793	1.530	-31	-0.275	.953	-1.354	.817	1.582	149
.400	-0.329	.983	1.956	-0.715	2.082	-20	-0.308	.969	-1.877	.754	2.023	158
.450	-0.312	.975	2.107	-0.467	2.158	-12	-0.284	.958	-1.940	.578	2.025	163
.500	-0.278	.958	2.113	-0.271	2.130	-7	-0.254	.943	-2.030	.391	2.067	169
.550	-0.233	.936	2.065	-0.143	2.069	-4	-0.212	.923	-2.102	.262	2.119	173
.600	-0.194	.918	2.147	-0.048	2.148	-1	-0.171	.903	-2.246	.141	2.250	176
.650	-0.162	.902	2.271	-0.053	2.272	-1	-0.134	.886	-2.447	.050	2.447	179
.700	-0.129	.887	2.346	-0.182	2.353	-4	-0.092	.866	-2.771	-0.042	2.771	181
.725	-0.112	.878	2.780	-0.133	2.783	-3	-0.072	.857	-2.994	-0.064	2.995	181
.750	-0.068	.858	5.091	.547	5.120	6	.017	.815	-5.417	1.590	5.645	164
.775	-0.086	.866	4.289	.363	4.304	5	-0.029	.836	-4.000	-0.133	4.003	182
.800	-0.058	.853	3.173	.468	3.207	8	-0.016	.831	-3.079	-0.202	3.085	184
.850	-0.014	.832	1.805	.288	1.828	9	.008	.819	-1.793	-0.092	1.795	183
.900	.024	.815	.967	.135	.977	8	.043	.803	-1.089	-0.128	1.096	187
.950	.073	.791	.381	.032	.382	5	.084	.784	-0.492	-0.061	.496	187

TABLE 1.10

RUNNO 40305

M = .822 F= 120.0 ALPHA= 0
PO= 10069 DELTA= .20
RE= 2.28E6 K= .248 C= .95
Q = 3056.41

	RE	IM		RE	IM
KC=	.865	-0.480	RC=	.3462	.0481
MC=	.861	-0.064	NC=	.0477	.0120

	UPPERSIDE						LOWERSIDE					
X/C	CP+	M+	DCP+		DCP+		CP-	M-	DCP-		DCP-	
			RE	IM	MOD	ARG			RE	IM	MOD	ARG
.010	.002	.821	-1.336	-0.490	1.423	-160	.064	.792	1.437	.496	1.521	19
.050	-0.157	.896	-0.661	-0.285	.720	-157	-0.135	.885	.978	.433	1.070	24
.100	-0.217	.925	-0.734	-0.588	.940	-141	-0.185	.909	.849	.673	1.083	38
.200	-0.257	.944	-0.566	-1.074	1.214	-118	-0.247	.938	.608	1.233	1.374	64
.300	-0.293	.961	.138	-1.765	1.770	-85	-0.285	.956	-0.048	1.690	1.691	92
.400	-0.329	.979	1.462	-2.225	2.662	-57	-0.319	.973	-1.291	2.051	2.424	122
.450	-0.307	.968	2.104	-1.836	2.792	-41	-0.296	.962	-1.683	1.754	2.431	134
.500	-0.270	.950	2.333	-1.416	2.730	-31	-0.258	.944	-2.112	1.399	2.533	146
.550	-0.229	.930	2.577	-1.087	2.797	-23	-0.220	.925	-2.314	1.165	2.591	153
.600	-0.193	.913	2.747	-0.745	2.846	-15	-0.179	.906	-2.586	.843	2.720	162
.650	-0.161	.898	2.967	-0.489	3.007	-9	-0.142	.888	-2.869	.654	2.943	167
.700	-0.126	.882	2.956	-0.230	2.965	-4	-0.104	.870	-3.307	.354	3.326	174
.725	-0.106	.872	3.445	-0.194	3.451	-3	-0.081	.859	-3.571	.248	3.580	176
.750	-0.061	.851	6.850	-0.178	6.853	-1	.017	.814	-7.104	.136	7.105	179
.775	-0.080	.860	4.901	.086	4.901	1	-0.045	.843	-4.696	-0.106	4.698	181
.800	-0.052	.847	3.740	.440	3.766	7	-0.029	.835	-3.638	-0.338	3.654	185
.850	-0.013	.829	2.224	.501	2.280	13	-0.000	.822	-2.121	-0.483	2.175	193
.900	.024	.811	1.194	.429	1.268	20	.036	.805	-1.329	-0.466	1.408	199
.950	.071	.789	.455	.246	.517	28	.081	.784	-0.607	-0.296	.675	206

TABLE 1.11

M = .850 F = 0 ALPHA = 0.00 KC = 1.41
DELTA = 0.00 MC = .745
C = 1.5 NC = .0358

	UPPERSIDE				LOWERSIDE			
X/C	CP +	M +	DCP +		CP -	M -	DCP -	
			RE	IM			RE	IM
.010	.043	.829	2.731	0.0	.062	.820	-2.654	0.0
.050	-.134	.916	1.814	0.0	-.130	.914	-1.795	0.0
.100	-.180	.938	1.451	0.0	-.175	.936	-1.489	0.0
.200	-.254	.976	1.489	0.0	-.264	.981	-1.585	0.0
.300	-.304	1.001	1.719	0.0	-.317	1.008	-1.948	0.0
.400	-.375	1.038	2.444	0.0	-.385	1.043	-2.559	0.0
.450	-.340	1.020	3.705	0.0	-.362	1.031	-4.049	0.0
.500	-.283	.990	4.794	0.0	-.282	.990	-5.042	0.0
.550	-.237	.967	1.833	0.0	-.236	.967	-2.062	0.0
.600	-.191	.944	1.986	0.0	-.190	.943	-1.986	0.0
.650	-.152	.925	2.253	0.0	-.147	.922	-2.234	0.0
.700	-.115	.906	2.654	0.0	-.105	.901	-2.674	0.0
.725	-.100	.899	3.094	0.0	-.082	.890	-2.884	0.0
.750	-.090	.894	4.660	0.0	.011	.845	-7.105	0.0
.775	-.065	.882	4.049	0.0	-.047	.873	-3.877	0.0
.800	-.039	.869	2.884	0.0	-.029	.864	-2.922	0.0
.850	0.000	.850	1.699	0.0	.007	.847	-1.680	0.0
.900	.037	.832	.955	0.0	.044	.829	-.974	0.0
.950	.082	.810	.439	0.0	.087	.808	-.401	0.0

TABLE 1.12

RUNNO 40906

M = .853 F= 30.0 ALPHA= 0
P0= 10425 DELTA= .16
RE= 2.40E6 K= .060 C= 1.10
Q = 3302.42

	RE	IM		RE	IM
KC=	1.119	-0.278	RC=	.2887	.0284
MC=	.732	.029	NC=	.0393	.0056

	UPPERSIDE						LOWERSIDE					
X/C	CP+	M+	DCP+		DCP+		CP-	M-	DCP-		DCP-	
			RE	IM	MOD	RG			RE	IM	MOD	ARG
.010	.015	.845	.292	-1.137	1.174	-76	.104	.803	-0.340	1.212	1.258	106
.050	-0.156	.929	.153	-0.602	.621	-76	-0.107	.907	-0.373	.867	.944	113
.100	-0.220	.961	.343	-0.737	.813	-65	-0.166	.937	-0.507	.867	1.005	120
.200	-0.273	.988	.621	-0.843	1.047	-54	-0.244	.976	-0.828	.979	1.282	130
.300	-0.321	1.013	.998	-0.951	1.379	-44	-0.296	1.002	-1.155	.998	1.526	139
.400	-0.392	1.050	1.721	-1.059	2.021	-32	-0.354	1.033	-2.351	1.311	2.691	151
.450	-0.377	1.042	4.088	-1.770	4.454	-23	-0.329	1.019	-3.773	1.312	3.995	161
.500	-0.311	1.008	4.276	-0.332	4.289	-4	-0.265	.986	-2.161	.170	2.167	176
.550	-0.240	.972	1.884	.334	1.913	10	-0.221	.964	-2.149	.090	2.151	178
.600	-0.198	.951	1.975	.236	1.989	7	-0.174	.941	-2.265	.023	2.265	179
.650	-0.160	.932	2.193	.161	2.199	4	-0.133	.920	-2.466	-0.047	2.466	181
.700	-0.125	.914	2.384	-0.037	2.384	-1	-0.088	.898	-2.804	-0.114	2.807	182
.725	-0.106	.905	2.837	-0.000	2.837	-0	-0.068	.888	-3.028	-0.141	3.031	183
.750	-0.064	.884	5.195	.660	5.237	7	.020	.844	-5.510	1.582	5.733	164
.775	-0.080	.892	4.426	.483	4.453	6	-0.026	.867	-4.083	-0.228	4.089	183
.800	-0.052	.878	3.235	.578	3.286	10	-0.013	.860	-3.114	-0.300	3.128	185
.850	-0.007	.856	1.812	.363	1.847	11	.014	.847	-1.796	-0.164	1.804	185
.900	.034	.836	.955	.175	.971	10	.047	.831	-1.063	-0.177	1.077	189
.950	.082	.813	.360	.040	.362	6	.092	.810	-0.465	-0.081	.472	190

TABLE 1.13

RUNNO 40806

M = .854 F= 120.0 ALPHA= 0
P0= 10479 DELTA= .02
RE= 2.41E6 K= .240 C= 1.05
Q = 3320.06

	RE	IM		RE	IM
KC=	.797	-0.551	RC=	.3514	.0651
MC=	.923	-0.147	NC=	.0475	.0146

	UPPERSIDE						LOWERSIDE					
X/C	CP+	M+	DCP+		DCP+		CP-	M-	DCP-		DCP-	
			RE	IM	MOD	ARG			RE	IM	MOD	ARG
.010	.019	.844	-1.224	.262	1.252	-192	.094	.808	1.220	-0.280	1.251	347
.050	-0.152	.929	-0.651	.181	.675	-196	-0.114	.910	.906	-0.116	.913	353
.100	-0.214	.960	-0.891	.055	.893	-184	-0.169	.937	.989	.039	.990	2
.200	-0.267	.986	-1.213	-0.339	1.260	-164	-0.245	.975	1.116	.633	1.283	30
.300	-0.314	1.011	-1.354	-1.330	1.897	-136	-0.301	1.004	1.008	1.498	1.805	56
.400	-0.372	1.041	-0.325	-3.083	3.100	-96	-0.354	1.032	-0.250	3.063	3.073	95
.450	-0.367	1.038	1.399	-4.719	4.922	-73	-0.342	1.026	-1.513	4.335	4.592	109
.500	-0.330	1.019	3.214	-5.418	6.300	-59	-0.280	.993	-3.476	2.969	4.571	140
.550	-0.236	.971	3.841	-1.564	4.147	-22	-0.220	.963	-3.243	1.189	3.454	160
.600	-0.190	.948	3.538	-0.633	3.594	-10	-0.178	.942	-3.274	.679	3.343	168
.650	-0.156	.930	3.489	-0.367	3.508	-6	-0.136	.921	-3.374	.506	3.412	171
.700	-0.124	.915	3.485	-0.060	3.486	-1	-0.093	.899	-3.587	.185	3.591	177
.725	-0.102	.903	3.856	-0.016	3.856	-0	-0.074	.890	-3.860	.089	3.861	179
.750	-0.044	.875	7.724	.194	7.726	1	.021	.843	-7.010	-0.283	7.015	182
.775	-0.079	.893	5.129	.229	5.134	3	-0.031	.869	-4.597	-0.276	4.605	183
.800	-0.051	.879	3.946	.589	3.990	8	-0.018	.862	-3.637	-0.516	3.673	188
.850	-0.008	.857	2.246	.616	2.329	15	.012	.848	-2.116	-0.586	2.196	195
.900	.032	.838	1.232	.510	1.333	22	.045	.832	-1.260	-0.570	1.383	204
.950	.082	.814	.467	.261	.535	29	.086	.811	-0.524	-0.348	.629	214

TABLE 1.14

M = .875 F = 0 ALPHA = 0.00 KC = 1.57
DELTA = 0.00 MC = 1.000
C = 1.5 NC = .0336

	UPPERSIDE				LOWERSIDE			
X/C	CP +	M +	DCP +		CP −	M −	DCP −	
			RE	IM			RE	IM
.010	.069	.840	1.948	0.0	.088	.831	−1.948	0.0
.050	−.114	.933	1.317	0.0	−.109	.930	−1.337	0.0
.100	−.163	.958	.955	0.0	−.160	.957	−.993	0.0
.200	−.251	1.004	.897	0.0	−.256	1.007	−.974	0.0
.300	−.318	1.040	1.203	0.0	−.325	1.044	−1.298	0.0
.400	−.395	1.082	1.146	0.0	−.404	1.087	−1.260	0.0
.450	−.435	1.104	1.356	0.0	−.435	1.104	−1.585	0.0
.500	−.468	1.123	5.118	0.0	−.471	1.125	−5.290	0.0
.550	−.408	1.089	6.551	0.0	−.384	1.076	−6.761	0.0
.600	−.166	.960	7.640	0.0	−.163	.958	−7.888	0.0
.650	−.124	.938	5.882	0.0	−.119	.936	−5.233	0.0
.700	−.094	.923	2.311	0.0	−.081	.916	−2.406	0.0
.725	−.081	.916	2.483	0.0	−.062	.906	−2.406	0.0
.750	−.075	.913	4.106	0.0	.029	.860	−6.436	0.0
.775	−.051	.901	3.648	0.0	−.029	.890	−3.304	0.0
.800	−.028	.889	2.654	0.0	−.011	.881	−2.502	0.0
.850	.013	.868	1.508	0.0	.022	.864	−1.528	0.0
.900	.049	.850	.802	0.0	.058	.846	−.802	0.0
.950	.094	.828	.362	0.0	.100	.825	−.286	0.0

TABLE 1.15

RUNNO 40907

M = .877 F= 30.0 ALPHA= 0
P0= 10425 DELTA= .15
RE= 2.43E6 K= .059 C= 1.13
Q = 3403.23

	RE	IM		RE	IM			
KC=	1.166	−0.397	RC=	.2719	.0604	X5=	1.375E−3	0
MC=	.866	−0.063	NC=	.0366	.0101	X6=	1.395E−3	0

	UPPERSIDE						LOWERSIDE					
X/C	CP+	M+	DCP+		DCP+		CP−	M−	DCP−		DCP−	
			RE	IM	MOD	ARG			RE	IM	MOD	ARG
.010	.048	.851	.071	−0.824	.827	−85	.127	.815	−0.084	.889	.893	95
.050	−0.130	.942	.015	−0.425	.426	−88	−0.091	.926	−0.123	.639	.651	101
.100	−0.195	.976	.117	−0.464	.479	−76	−0.151	.957	−0.224	.671	.707	108
.200	−0.263	1.011	.206	−0.516	.556	−68	−0.242	1.004	−0.380	.748	.839	117
.300	−0.334	1.050	.355	−0.778	.855	−65	−0.308	1.040	−0.522	.821	.973	122
.400	−0.406	1.089	.521	−0.832	.981	−58	−0.386	1.083	−0.695	.898	1.135	128
.450	−0.450	1.114	.656	−0.857	1.080	−53	−0.426	1.105	−0.965	.938	1.345	136
.500	−0.476	1.129	1.210	−1.040	1.596	−41	−0.364	1.071	−5.728	3.401	6.661	149
.550	−0.351	1.059	7.760	−5.047	9.257	−33	−0.291	1.031	−7.755	4.112	8.777	152
.600	−0.262	1.011	7.810	−3.794	8.683	−26	−0.178	.971	−4.027	.072	4.028	179
.650	−0.154	.955	3.871	.199	3.876	3	−0.114	.937	−2.142	−0.792	2.283	200
.700	−0.100	.927	2.265	.567	2.335	14	−0.071	.915	−2.433	−0.657	2.520	195
.725	−0.082	.917	2.560	.600	2.629	13	−0.050	.905	−2.780	−0.561	2.836	191
.750	−0.048	.900	4.891	1.172	5.029	13	.036	.861	−5.451	.965	5.536	170
.775	−0.063	.908	4.125	1.008	4.246	14	−0.009	.884	−3.889	−0.630	3.939	189
.800	−0.035	.894	3.046	.947	3.190	17	.003	.878	−2.964	−0.608	3.026	192
.850	.007	.872	1.586	.590	1.704	19	.029	.864	−1.704	−0.348	1.739	192
.900	.048	.851	.883	.304	.934	19	.062	.848	−0.958	−0.296	1.002	197
.950	.094	.828	.356	.100	.378	16	.104	.827	−0.395	−0.120	.413	197

TABLE 1.16

RUNNO 40807

M = .879 F= 120.0 ALPHA= 0
P0= 10474 DELTA= .01
RE= 2.44E6 K= .234 C= 1.08
Q = 3426.23

	RE	IM		RE	IM
KC=	.579	-0.479	RC=	.3998	.0592
MC=	.757	-0.327	NC=	.0552	.0148

	UPPERSIDE						LOWERSIDE					
X/C	CP+	M+	DCP+		DCP+		CP-	M-	DCP-		DCP-	
			RE	IM	MOD	ARG			RE	IM	MOD	ARG
.010	.052	.852	-0.375	.422	.564	-228	.118	.82[illegible]	.393	-0.441	.591	312
.050	-0.129	.945	-0.146	.213	.258	-236	-0.096	.928	.270	-0.308	.410	311
.100	-0.194	.979	-0.176	.213	.276	-230	-0.152	.958	.284	-0.312	.421	312
.200	-0.262	1.015	-0.216	.192	.289	-222	-0.243	1.006	.415	-0.312	.519	323
.300	-0.330	1.051	-0.336	.231	.408	-214	-0.311	1.042	.683	-0.228	.720	342
.400	-0.406	1.093	-0.669	.187	.695	-196	-0.385	1.083	.858	-0.087	.862	354
.450	-0.445	1.115	-0.795	.078	.799	-186	-0.424	1.104	1.211	.33[illegible]	1.255	15
.500	-0.467	1.128	-1.389	-0.752	1.579	-152	-0.363	1.071	3.179	4.753	5.718	56
.550	-0.356	1.065	-3.250	-6.962	7.683	-115	-0.292	1.032	.577	7.526	7.550	86
.600	-0.244	1.005	1.224	-7.095	7.200	-80	-0.193	.979	-3.824	4.949	6.254	128
.650	-0.148	.955	4.090	-2.598	4.846	-32	-0.118	.94[illegible]	-4.577	1.605	4.850	161
.700	-0.103	.931	4.239	-0.825	4.318	-11	-0.073	.917	-4.569	.480	4.594	174
.725	-0.083	.921	4.625	-0.489	4.651	-6	-0.054	.907	-4.564	.271	4.572	177
.750	-0.025	.891	8.368	-0.211	8.371	-1	.038	.860	-7.141	.059	7.141	180
.775	-0.064	.911	5.768	-0.015	5.768	-0	-0.013	.886	-5.277	-0.203	5.281	182
.800	-0.037	.898	4.482	.472	4.506	6	-0.000	.880	-4.239	-0.463	4.264	186
.850	.005	.876	2.628	.571	2.690	12	.026	.866	-2.490	-0.631	2.569	194
.900	.045	.856	1.391	.496	1.477	20	.060	.849	-1.480	-0.626	1.607	203
.950	.092	.832	.534	.269	.598	27	.101	.829	-0.657	-0.398	.768	211

TABLE 1.17

M = .960 F = 0 ALPHA = 0.00 KC= .07
DELTA = 0.00 MC= -.183
C = 1.5 NC= -.0219

	UPPERSIDE				LOWERSIDE			
X/C	CP +	M +	DCP +		CP -	M -	DCP -	
			RE	IM			RE	IM
.010	.178	.861	.038	0.0	.217	.839	-.152	0.0
.050	-.007	.964	0.000	0.0	.013	.953	-.114	0.0
.100	-.039	.982	-.038	0.0	-.032	.978	-.114	0.0
.200	-.175	1.062	-.019	0.0	-.127	1.033	-.133	0.0
.300	-.219	1.089	-.057	0.0	-.219	1.089	-.114	0.0
.400	-.305	1.142	-.057	0.0	-.304	1.141	-.133	0.0
.450	-.346	1.168	-.038	0.0	-.342	1.166	-.133	0.0
.500	-.381	1.191	-.076	0.0	-.378	1.189	-.152	0.0
.550	-.405	1.207	-.057	0.0	-.407	1.208	-.133	0.0
.600	-.421	1.218	-.057	0.0	-.425	1.220	-.133	0.0
.650	-.435	1.227	-.038	0.0	-.439	1.230	-.152	0.0
.700	-.447	1.235	-.038	0.0	-.450	1.237	-.152	0.0
.725	-.448	1.236	-.057	0.0	-.456	1.242	-.171	0.0
.750	-.486	1.262	.744	0.0	-.384	1.193	-1.967	0.0
.775	-.471	1.252	3.094	0.0	-.442	1.232	-3.266	0.0
.800	-.463	1.246	2.540	0.0	-.442	1.232	-3.189	0.0
.850	-.212	1.084	.038	0.0	-.374	1.186	2.081	0.0
.900	-.013	.967	.955	0.0	-.058	.993	.802	0.0
.950	.070	.921	1.146	0.0	.053	.930	.210	0.0

TABLE 1.18

RUNNO 40911

M = .966 F= 30.0 ALPHA= 0
PO= 10472 DELTA= .18
RE= 2.53E6 K= .054 C= 1.03
Q = 3759.58

	RE	IM		RE	IM
KC=	.173	.083	RC=	.1510	.0932
MC=	.178	.108	NC=	.0104	.0203

	UPPERSIDE						LOWERSIDE					
X/C	CP+	M+	DCP+ RE	DCP+ IM	DCP+ MOD	DCP+ ARG	CP-	M-	DCP- RE	DCP- IM	DCP- MOD	DCP- ARG
.010	.171	.870	.016	-0.024	.029	-56	.229	.838	-0.038	.034	.051	138
.050	-0.013	.973	.004	-0.019	.019	-78	.014	.959	-0.027	.017	.032	149
.100	-0.061	1.001	.003	-0.014	.014	-79	-0.037	.988	-0.018	.008	.019	157
.200	-0.125	1.039	-0.020	.005	.021	-195	-0.135	1.046	-0.014	-0.005	.015	200
.300	-0.236	1.106	.003	-0.005	.006	-59	-0.226	1.102	-0.019	.005	.020	165
.400	-0.313	1.155	.013	-0.019	.023	-55	-0.305	1.151	-0.011	.012	.016	132
.450	-0.354	1.181	.017	-0.024	.029	-54	-0.348	1.179	-0.040	.020	.044	154
.500	-0.388	1.204	.017	-0.015	.023	-40	-0.376	1.197	-0.025	.028	.038	131
.550	-0.412	1.220	.025	-0.023	.034	-42	-0.404	1.216	-0.030	.001	.030	179
.600	-0.430	1.232	.023	-0.019	.030	-40	-0.422	1.228	-0.036	.019	.041	152
.650	-0.448	1.245	.002	-0.010	.011	-80	-0.437	1.239	-0.033	.035	.048	133
.700	-0.460	1.253	.013	-0.023	.027	-61	-0.447	1.245	-0.049	.017	.051	161
.725	-0.465	1.257	.025	-0.029	.038	-49	-0.452	1.249	-0.064	.005	.064	176
.750	-0.456	1.250	1.498	-0.185	1.509	-7	-0.420	1.227	-1.931	.729	2.064	159
.775	-0.488	1.273	4.594	.297	4.604	4	-0.418	1.226	-4.674	-0.557	4.707	187
.800	-0.476	1.264	3.822	.419	3.845	6	-0.416	1.225	-4.717	-0.659	4.762	188
.850	-0.169	1.065	-2.897	1.024	3.072	-199	-0.246	1.114	.300	-2.052	2.073	278
.900	-0.012	.973	.833	.803	1.158	44	-0.023	.980	.669	-0.785	1.031	310
.950	.057	.934	1.307	.009	1.307	0	.063	.931	.686	-0.135	.702	[illegible]

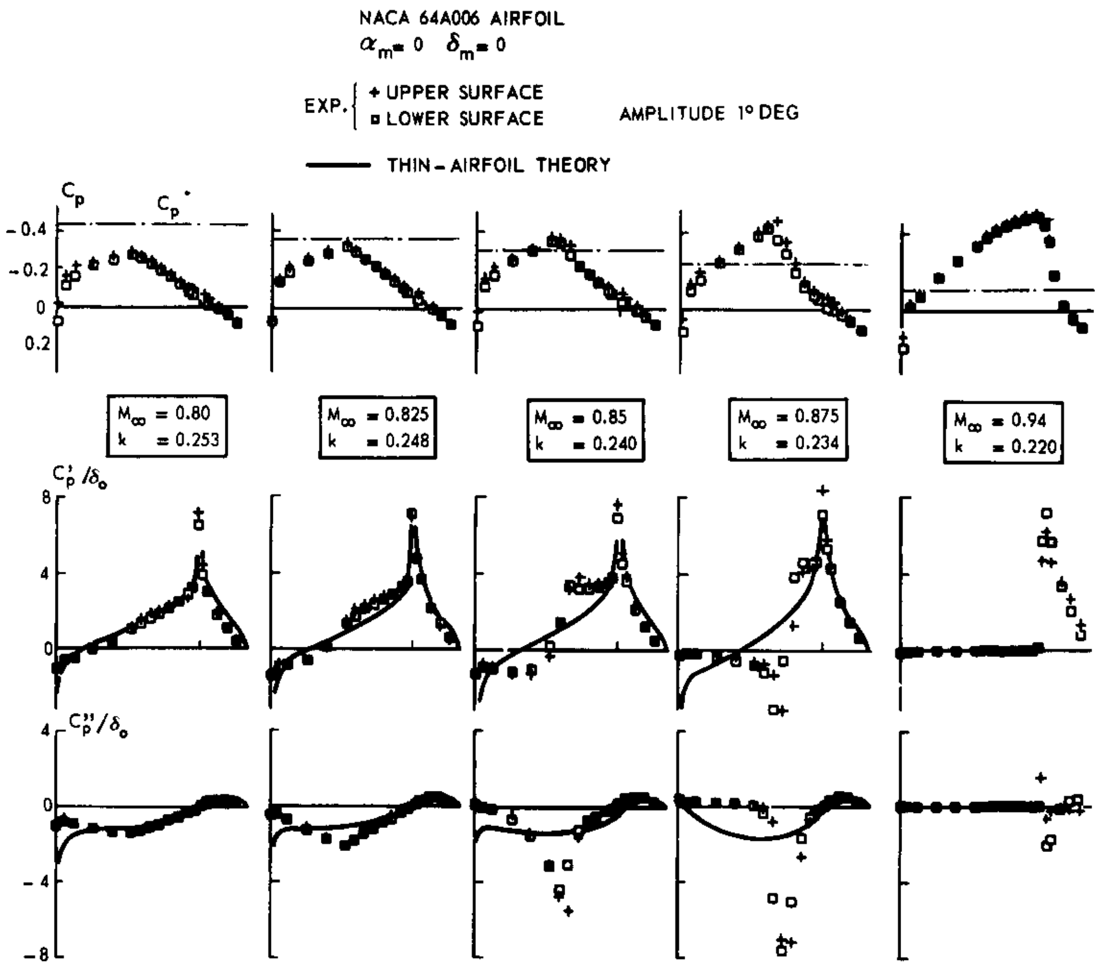


Fig. 1.1 Development of mean steady and unsteady pressure distributions with Mach number (f = 120 Hz)

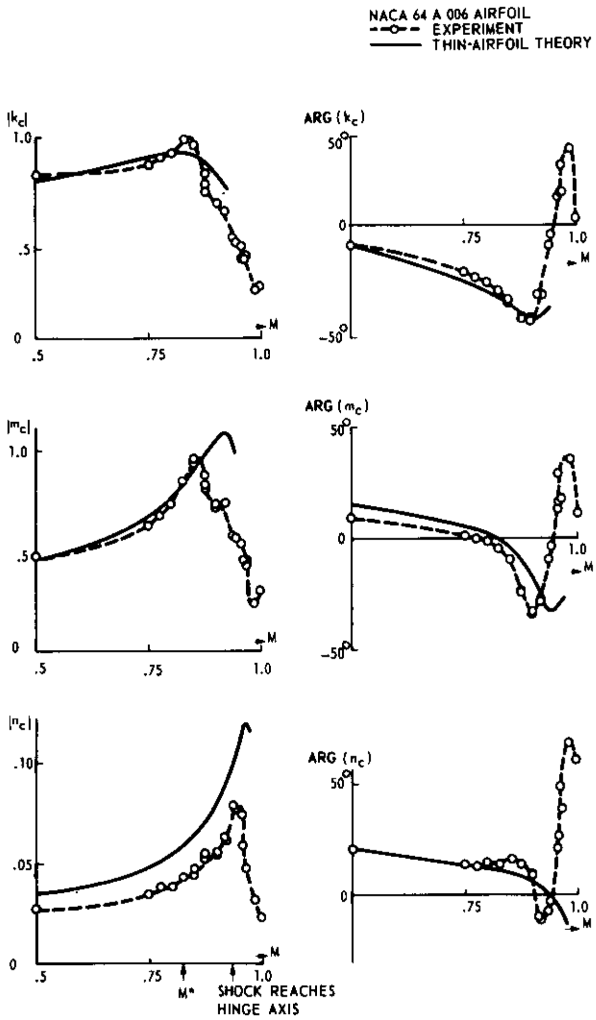


Fig. 1.2 Unsteady aerodynamic coefficients as a function of Mach number (f = 120 Hz)

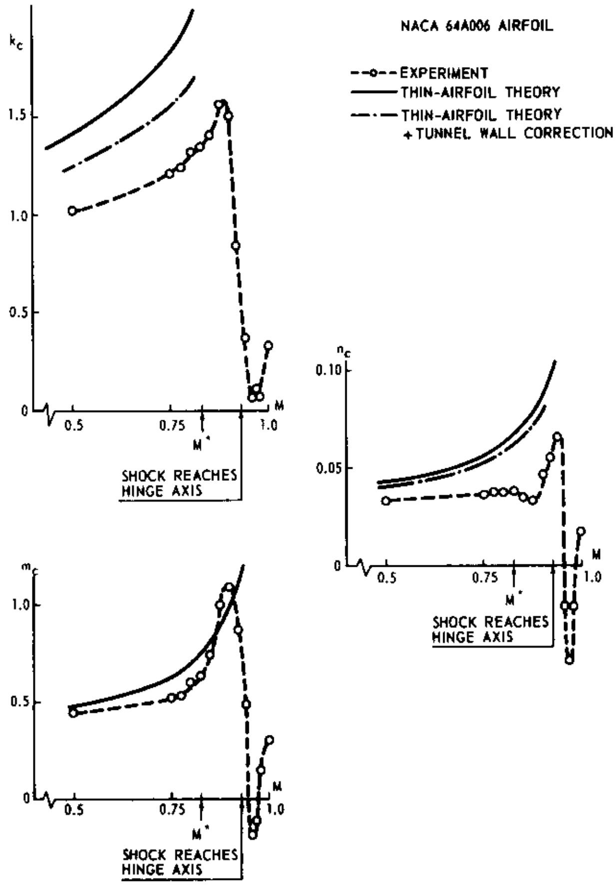


Fig. 1.3 Steady aerodynamic derivatives as a function of Mach number

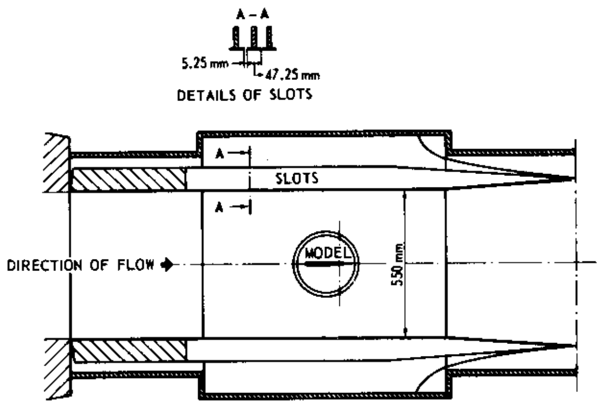


Fig. 1.4 Transonic test section of the NLR Pilot Tunnel

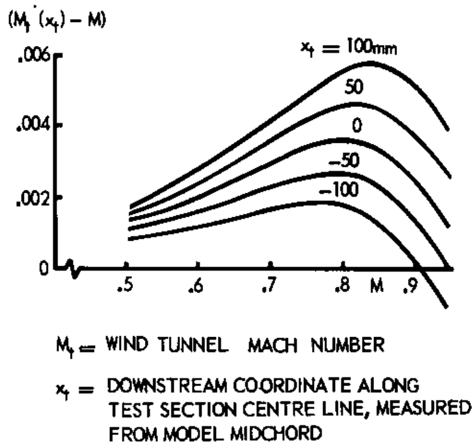


Fig. 1.5 Mach number distribution in NLR Pilot Tunnel test section

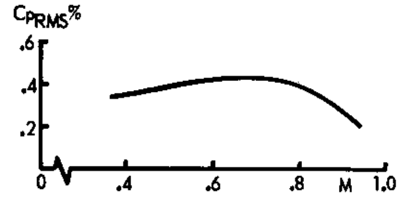


Fig. 1.6 Noise level in NLR Pilot Tunnel test section

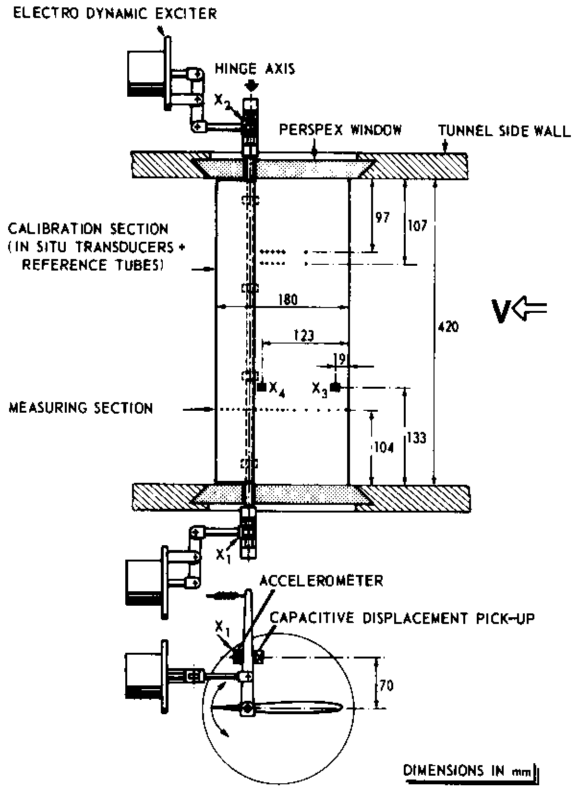
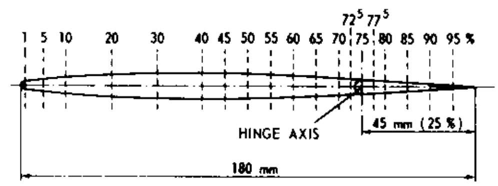


Fig. 1.7 Test set-up and instrumentation of the NACA 64A006 airfoil with flap



MEASURING SECTION (BOTH UPPER AND LOWER SURFACE)			
No.	x/c	No.	x/c
1	.01	11	.65
2	.05	12	.70
3	.10	13	.725
4	.20	14	.75
5	.30	15	.775
6	.40	16	.80
7	.45	17	.85
8	.50	18	.90
9	.55	19	.95
10	.60		

CALIBRATION SECTION (UPPER SURFACE ONLY)	
No.	x/c
1	.30
2	.50
3	.55
4	.60
5	.65
6	.70

Fig. 1.8 Location of pressure orifices on the NACA 64A006 airfoil with flap

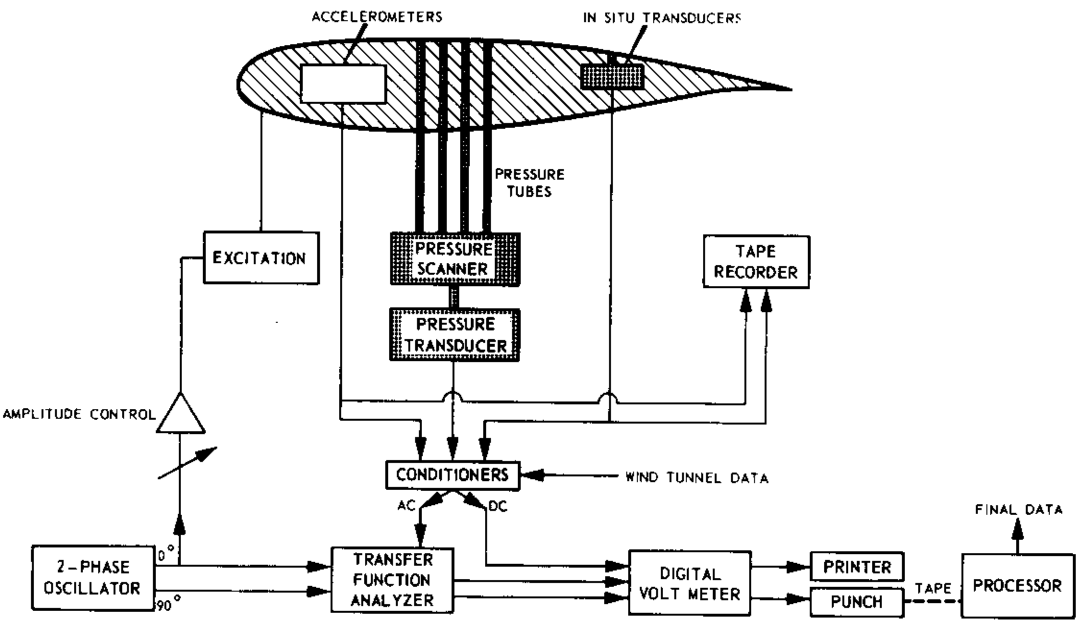


Fig. 1.9 Block diagram of measuring equipment

DATA SET 2

NACA 64A010 (NASA AMES MODEL) OSCILLATORY PITCHING

by

Sanford S. Davis, NASA Ames

INTRODUCTION AND DISCUSSION

The test program on the oscillating NACA 64A010 airfoil was designed to expand the existing unsteady aerodynamic test envelope to a higher Reynolds number and more diverse flow conditions. The data base for this airfoil, as reported in Ref. 2.1, contains 114 different combinations of Mach number, Reynolds number, mean angle of attack, oscillation frequency, and motion mode. A subset of 66 runs corresponds to the motion of pitching about a nominal axis at 0.25c. The purpose of this Data Set is to present the matrix of test conditions corresponding to these 66 runs, to tabulate numerical data belonging to the ten AGARD CT Cases supplemented by a shock-stall case (SSC) of special interest, and to present an overview of certain parametric variations of the data. The data should be useful in ascertaining the performance of those numerical codes that predict unsteady transonic flows with shock-wave boundary-layer interactions.

Each combination of motion mode and the five input parameters M, α_m, Re, α_o, and k are identified with a unique number - the dynamic index (DI). The output was the measured instantaneous chordwise pressure distribution on the airfoil. These data were digitized and processed on-line (Ref. 2.2) into a form that was suitable for interpretation and analysis. Subsequent off-line processing converted the data into the conventional normalized quantities presented in this Data Set. The notation generally follows that advocated as the AGARD standard. The nomenclature used here and an explanation of the table headings are included in Section 12 of this Data Set.

The following processed data are included for each of the AGARD CT Cases:

A. Steady upper and lower surface pressure distributions.

B. Fundamental frequency upper and lower surface pressure distributions.

C. Steady lift and moment coefficients.

D. Fundamental frequency lift and moment coefficients.

The following detailed data are presented for AGARD CT Case 6 only:

E. Instantaneous upper surface pressure distribution.

F. Instantaneous lift and moment coefficients.

Some of the data have been presented and/or discussed in previous publications. Items A, B, C, and D were included in the tabulated and graphical data of Ref. 2.1. The data were compared among themselves and with theory in Refs. 2.3 to 2.6.

Table 2.1 presents a complete list of the entire test program in chronological order. Table 2.2 shows the subset of 66 DI's considered in this Data Set. A small subset of 10 DI's, designated in Ref. 2.7 as AGARD CT Cases and the extra shock-stall case (SSC), are identified in Table 2.3 along with the relevant flow parameters. A sketch of the oscillating airfoil test apparatus is shown in Fig. 2.1. The experimental arrangement is described in detail in Refs. 2.1 and 2.8.

Tabulated data for the AGARD CT Cases and the SSC are presented in varying detail in Tables 2.4 to 2.18. Table 2.4 shows the steady values and the fundamental frequency complex amplitudes of lift and moment. (Note that the real and imaginary parts of the complex numbers in Table 2.4 are identical to the single- and double-primed quantities in the standard AGARD notation.) The mean and fundamental frequency pressure distributions are tabulated in Tables 2.5 to 2.14 and 2.17. These data are taken directly from the microfiche records enclosed in Ref. 2.1. A more basic data set, representing the instantaneous load on the airfoil, is presented in Table 2.15 for CT Case 6. Along with these data, the fundamental frequency component of the lift and moment is included for comparison and reference. The most detailed data set, from which all the previous data were derived, is the instantaneous pressure distribution. These data are presented in Table 2.16 in the form of chordwise pressure distributions at 6° phase increments for CT Case 6. The value of phase shown at the head of each column may be correlated with the nondimensional time, or the load, by cross-checking with Table 2.15.

With these AGARD CT data, one should be able to verify in detail the predictive capability of all inviscid codes and those viscous codes that include mild shock-wave/boundary-layer interactions. In Ref. 2.6 CT Case 6 was thoroughly analyzed and, being selected for priority analysis in Ref. 2.7, should be the first transonic case to compute.

Some of the first harmonic data were investigated for parametric trends. These data are presented in graphical form in Figs. 2.2 to 2.5. Fig. 2.2 shows the effect of varying Mach number with other parameters held constant. As the steady shock wave develops (uppermost row), the unsteady pressure distribution evolves into the peaked distribution usually associated with transonic flow. Although the unsteady pressure drops at M = 0.84, compared to M = 0.80, one should not consider this to be a typical response with inreasing velocity in the transonic speed range. The data in Fig. 2.2 are presented at a reduced frequency k = 0.2, which is high enough to reduce the shock motion considerably. The interaction between frequency and shock strength may be such that this dramatic drop in peak loading would not occur at lower values of k. Unfortunately, data at other frequencies were not measured at M = 0.84 so cross-trends cannot be determined experimentally.

Figure 2.3 shows the effect of varying the oscillation amplitude with other parameters held constant. Following the conventional notation, the pressure data (output) is normalized by the oscillation amplitude (input) to indicate the linearity of the response. Data presented in Ref. 2.4 showed that the force coefficients were linear functions of α_0 , but the individual pressure data do not seem to follow this trend. The shock-wave excursions, being minimal at lower oscillation amplitudes, induce peaked unsteady pressure distributions. However, at higher oscillation amplitudes the increased shock motion affects a larger portion of the airfoil. The net result is a balance in the loads even though the individual distributions vary. It is expected that this trend holds at other oscillation frequencies.

Figure 2.4 shows the frequency variation with other parameters held constant. As reported in Ref. 2.4, the pressure peaks and leading edge loading all decrease with increasing frequency. The trend is smoothly varying for this transonic flow condition, but this may not hold true for other conditions, such as shock-induced separation. For further discussions, refer to Refs. 2.3 and 2.5.

Figure 2.5 shows that scale effect is quite minimal for this flow condition. Sublimation photographs indicate that transition occurs at the shock wave at Re = 3.3×10^6, while leading edge transition was observed at Re = 12.6×10^6. Even though the point of transition varies widely, the unsteady pressure distributions are similar over the entire Reynolds number range. This benign behavior should not be considered a general rule; airfoil geometry and other mean flow conditions may be important factors (see Ref. 2.5).

The complete unsteady pressure distribution is shown in Fig. 2.6 for CT Cases 4 and 6. Certain features are common at both low and high frequencies: pure sinusoidal motion upstream of the shock wave, severe harmonic distortion at the shock, and minimal response towards the trailing edge region. The distorted wave forms in the shock region are caused by the frequency-dependent shock motion. These pressure data can be considered typical of that induced by unseparated, transonic flow over an oscillating airfoil. Although harmonic distortion is evident over part of the airfoil, the forces and moments are almost pure sinusoids.

ADDENDUM - A SHOCK-STALL CASE (SSC)

The AGARD CT Cases for this configuration refer to mean flows without separation. A more severe challenge to computational methods is the case where the airfoil pitches about a steady flow condition that supports a stronger shock wave. Some data from DI 89, a case not included in the AGARD Series but specified in Table 2.3, is presented for analysis and computational verification.

The fundamental frequency and steady pressure distributions are tabulated in Table 2.17 and the instantaneous pressure distribution in Table 2.18. Figure 2.7 depicts the complete unsteady pressure distribution on the upper surface at two frequencies. There is much more harmonic distortion, and the contrast with Fig. 2.6 is striking. The low frequency data at the shock wave in Fig. 2.7 are 180° out of phase when compared with CT Case 4 in Fig. 2.6, and a strong unsteady reponse persists to the trailing edge. Unlike the unseparated flows of the CT Cases, these complex flows require full Navier-Stokes modeling to predict both the steady shock wave position and the subsequent time-dependent motion.

1	AIRFOIL	
1.1	Designation	NACA 64A010 (NASA Ames Model)
1.2	Type of airfoil	Conventional - Laminar Flow
1.3	Geometry	Refer to Ref. 2.8 for theoretical profile
1.4	Design condition	
1.5	Additional remarks	
1.6	References on airfoil	Ref. 2.8
2	MODEL GEOMETRY	
2.1	Chord length	0.50 m (19.685 in.)
2.2	Span	1.35 m (53.2 in.)
2.3	Actual model coordinates and accuracy of measurement	Refer to AGARD-AR-156 (Ref. 2.7)
2.4	Flap: hinge and gap details	None
2.5	Additional remarks	Model mounted between splitter plates - see Fig. 2.1
2.6	References on model	Refs. 2.1, 2.2, and 2.9
3	WIND TUNNEL	
3.1	Designation	NASA Ames 11- X 11-Foot Transonic Wind Tunnel
3.2	Type of tunnel	Closed return, variable density
3.3	Test section dimensions	3.35 X 3.35 X 6.7 m (11 X 11 X 22 ft.)
3.4	Type of roof and floor	Baffled slot

3	WIND TUNNEL (Continued)		
	3.5	Type of side walls	Same as 3.4
	3.6	Ventilation geometry	1.78 cm (0.7 in.) slots, 24.4 cm (9.63 in.) slats. Open area ratio ~ 8% between splitters
	3.7	Thickness of side wall boundary layer	Very thin due to splitters
	3.8	Thickness of boundary layers at roof and floor	Approx. 7.6 cm (3 in.)
	3.9	Method of measuring Mach number	Static taps on splitters, see Refs. 2.2 and 2.9
	3.10	Uniformity of Mach number over test section	±0.002
	3.11	Sources of levels of noise or turbulence in empty tunnel	Not investigated
	3.12	Tunnel resonances	None noted
	3.13	Additional remarks	
	3.14	References on tunnel	Ref. 2.2 and 2.9
4	MODEL MOTION		
	4.1	Mode of applied motion	Pitching nominally about 0.25c and 0.50c, also plunging
	4.2	Range of amplitude	±0-2 deg; ±1 cm
	4.3	Range of frequency	0-60 Hz
	4.4	Method of application	Four graphite epoxy push-pull rods with differential motion of forward and aft pair, Fig. 2.1
	4.5	Purity of applied motion	Pure sinusoids
	4.6	Natural frequencies and normal modes of model	Lowest mode: torsion at 60 Hz
	4.7	Static or dynamic elastic distortion during tests	Not measured
	4.8	Additional remarks	
5	TEST CONDITIONS		
	5.1	Tunnel height/model chord ratio	3.35 m/0.50 m = 6.7
	5.2	Tunnel width/model chord ratio	1.35 m/0.50 m = 2.7 (between splitter plates)
	5.3	Range of Mach number	0.5-0.85
	5.4	Range of tunnel total pressure	50 kN/m^2 - 225 kN/m^2 (0.5-2.25 ATM)
	5.5	Range of tunnel total temperature	290 K - 320 K
	5.6	Range of model steady, or mean, incidence	0-4 deg
	5.7	Definition of model incidence	Chord line relative to wind tunnel
	5.8	Position of transition, if free	Limited transition studies were attempted using a sublimating material. At M = 0.5, α = 0, irregular patterns were observed without a definitive transition point. At M = 0.8, α = 0, Re = 12.6 × 10^6 transition was observed at x/c = 0.05. At M = 0.8, α = 0 , Re = 3.4 × 10^6 transition was observed at x/c = 0.5 (the shock wave).
	5.9	Position and type of trip, if transition fixed	
	5.10	For mixed flow, position of sonic boundary in relation to roof and floor	Not measured
	5.11	Flow instabilities during tests	--
	5.12	Additional remarks	--
	5.13	References describing tests	--
6	MEASUREMENTS AND OBSERVATIONS		
	6.1	Steady pressures for the mean conditions	✓
	6.2	Steady pressures for small changes from the mean conditions	–
	6.3	Quasi-steady pressures	–
	6.4	Unsteady pressures	✓

6 MEASUREMENTS AND OBSERVATIONS (Continued)

6.5	Steady forces for the mean conditions	measured directly	—
		integrated pressures	√
6.6	Steady forces for small changes from the mean conditions	measured directly	—
		integrated pressures	—
6.7	Quasi-steady forces	measured directly	—
		integrated pressures	—
6.8	Unsteady forces	measured directly	—
		integrated pressures	√
6.9	Measurement of actual motion at points on model		√
6.10	Observation or measurement of boundary layer properties		limited √
6.11	Visualization of surface flow		√
6.12	Visualization of shockwave movements		—
6.13	Additional remarks		—

7 INSTRUMENTATION

7.1	Steady pressures	
7.1.1	Position of orifices spanwise and chordwise	Mid-span, 20 upper, 20 lower; see Table 2.5 for locations
7.1.2	Type of measuring system	Pneumatic
7.2	Unsteady pressures	
7.2.1	Position of orifices spanwise and chordwise	Mid-span, 20 upper, 20 lower, see Table 2.5 for locations
7.2.2	Diameter of orifices	1.02 mm (0.040 in.)
7.2.3	Type of measuring system	Strain-gauge-type miniature pressure transducers installed close to orifice with minimum cavities.
7.2.4	Type of transducers	Kulite model XCQL-7A-093.
7.2.5	Principle and accuracy of calibration	On-line calibrations. Up to 2% change in static sensitivity before and after run allowed
7.3	Model motion	
7.3.1	Method of measurement	Motion of four push-pull rods with LVDT (reactive-type) transducers. Phase synchronism checked with wing-mounted accelerometers
7.3.2	Accuracy	~ 1%
7.4	Processing of unsteady measurements	
7.4.1	Method of acquiring and processing measurements	Real-time digitization with on-line calibration and diagnostics. Signal averaging over about 100 cycles to suppress random noise (if present). Variable sampling time adjusted to yield 60 data points per cycle.
7.4.2	Type of analysis	On-line processing for frequency content of pressure distributions and comparisons with linear theory and other data.
7.4.3	Unsteady pressure quantities obtained and accuracies achieved	Signal-averaged (essentially instantaneous) pressured distributions. Harmonic analysis of pressure distributions.
7.4.4	Method of integration to obtain forces	Numerical quadratures (see Appendix A of Ref. 2.1)
7.5	Additional remarks	
7.6	References on techniques	Ref. 2.2

8 DATA PRESENTATION

8.1	Test cases for which data could be made available	Tables 2.1 and 2.2
8.2	Test cases for which data are included in this document	Table 2.3
8.3	Steady pressures	Tables 2.5 to 2.14 and 2.17
8.4	Quasi-steady or steady perturbation pressures	N/A
8.5	Unsteady pressures	Tables 2.5 to 2.14 and 2.16 to 2.18
8.6	Steady forces or moments	None

8 DATA PRESENTATION (Continued)

8.7	Quasi-steady or steady perturbation forces	N/A
8.8	Unsteady forces and moments	Tables 2.4 and 2.15
8.9	Other forms in which data could be made available if required	Magnetic tape
8.10	References giving other presentations of data	Refs. 2.1 to 2.6

9 COMMENTS ON DATA

9.1	Accuracy	
9.1.1	Mach number	±0.002
9.1.2	Steady incidence	±0.05 deg.
9.1.3	Reduced frequency	±0.005
9.1.4	Steady pressure coefficients	1%
9.1.5	Steady pressure derivatives	N/A
9.1.6	Unsteady pressure coefficients	2%
9.2	Sensitivity to small changes of parameter	No evidence of undue sensitivity, see Figs. 2.2 to 2.5
9.3	Spanwise variations	Probably small
9.4	Nonlinearities	Depends on data set
9.5	Influence of tunnel total pressure	Minimal on model distortion
9.6	Wall interference corrections	No corrections made
9.7	Other relevant tests on *same model*	None
9.8	Relevant tests on other models of nominally the *same* aerofoil.	None
9.9	Any remarks relevant to comparison between experiment and theory	Ref. 2.4, 2.6
9.10	Additional remarks	
9.11	References on discussion of data	Refs. 2.1 to 2.6

10 PERSONAL CONTACT FOR FURTHER INFORMATION

Sanford Davis, Aerodynamics Division, NASA Ames Research Center, Moffett Field, CA 94035

11 REFERENCES

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12 NOTATION AND EXPLANATION OF TABLES*

GENERAL NOTATION

C,c	chord of airfoil, m
DI	dynamic index, data identification number
f,FREQ	frequency, Hz
k,K	reduced (nondimensional) frequency, $\frac{\omega c}{2V}$
M	free-stream Mach number
Re,RE	Reynolds number (based on chord)
t	time, s
V	free-stream velocity, m/s
X,x	distance along airfoil, m
x_α/c	pitch axis position relative to leading edge
$\alpha(t)$	Instantaneous incidence, deg $(\alpha_m + \alpha_o \cos \omega t)$
α_m	mean incidence, deg
α_o	oscillatory pitch amplitude, deg
ω	radian frequency, rad/s $(=2\pi f)$

TABLE 2.4

C_L	steady lift, +ve up $[c_\ell]$
C_M	steady moment, +ve nose up about 0.25c $[c_m]$
$C_{L,\alpha}$	normalized complex amplitude of lift coefficient, +ve up, per radian $[c_\ell'/\alpha_o + ic_\ell''/\alpha_o)]$
$C_{M,\alpha}$	normalized complex amplitude of moment coefficient, +ve noseup, about 0.25c, per radian $[c_m'/\alpha_o + ic_m''/\alpha_o]$

TABLES 2.5 to 2.14 and 2.17

ALPHA	mean incidence, deg $[\alpha_m]$
PTOT	total pressure, N/m^2 $[P_t]$
PINF	static pressure, N/m^2 $[P_\infty]$
QINF	dynamic pressure, N/m^2 $[q]$
CPU(CPL)	steady upper (lower) surface pressure coefficient $[c_p]$
CPU,A (CPL,A)	normalized complex amplitude of upper (lower) surface fundamental frequency pressure coefficient, per radian $[c_p'/\alpha_o + ic_p''/\alpha_o]$

TABLE 2.15

TAU	nondimensional time $[\tau = 2Vt/c]$
WT	phase angle re $\alpha(t)_{max}$ $[\omega t]$
ALPHA	oscillatory incidence $[\alpha_o \cos \omega t]$
CL UP	upper surface contribution to c_ℓ
CL LO	lower surface contribution to c_ℓ
CL	instantaneous lift coefficient $[c_\ell(t)]$
CLN=1	instantaneous value of fundamental frequency component of lift coefficient
CM UP	upper surface contribution to c_m
CM LO	lower surface contribution to c_m
CM	instantaneous moment coefficient, +re noseup, about 0.25c $[c_m(t)]$
CMN=1	instantaneous value of fundamental frequency component of moment coefficient

TABLES 2.16, 2.18

PHASE	phase angle re $\alpha(t)_{max}$ $[\omega t]$
ALPHA	oscillatory incidence $[\alpha_o \cos(\omega t)]$
CP	instantaneous pressure coefficient $[c_p(t)]$

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*Square-bracketed quantities indicate standard AGARD notation.

TABLE 2.1. DATA BASE FOR NACA 64A010 AIRFOIL

DI	M	α_m, deg	Re×10^{-6}	Motion	f, Hz	k
1	0.489	0.03	2.51	Plunging 0.35 cm (0.137 in.)	5.0	0.048
2	.489	.01	2.50	Pitching 0.94 deg about x_α/c = 0.236	20.8	.200
3	.488	.00	2.50	Pitching .95 deg about x_α/c = .512	20.8	.200
4	.489	.01	2.31	Plunging 1.01 cm (0.396 in.)	20.8	.200
5	.490	-.01	2.52	Pitching .96 deg about x_α/c = .507	26.0	.249
6	.490	-.01	2.52	Pitching .96 deg about x_α/c = .238	15.7	.151
7	.490	-.01	2.52	Pitching .96 deg about x_α/c = .233	10.4	.100
8	.490	-.01	2.52	Pitching .97 deg about x_α/c = .230	5.2	.050
9	.490	-.01	2.52	Pitching 1.01 deg about x_α/c = .224	2.6	.025
10	.490	-.01	2.52	Pitching 1.98 deg about x_α/c = .249	5.2	.050
11	.489	.00	2.51	Pitching 1.45 deg about x_α/c = .250	20.8	.200
12	.802	.00	3.38	Pitching .94 deg about x_α/c = .232	33.2	.200
13	.802	.00	3.38	Pitching 1.27 deg about x_α/c = .431	33.2	.200
14	.797	-.06	3.39	Plunging .89 cm (0.349 in.)	33.1	.201
15	.797	-.06	3.39	Pitching .95 deg about x_α/c = .234	41.3	.250
16	.795	.01	6.67	Pitching .96 deg about x_α/c = .252	33.3	.201
17	.795	.01	6.67	Pitching .98 deg about x_α/c = .501	33.3	.201
18	.795	.01	6.67	Plunging .38 cm (0.346 in.)	33.3	.201
19	.795	.01	6.67	Pitching 1.10 deg about x_α/c = .505	41.6	.251
20	.497	.04	5.03	Pitching .01 deg about x_α/c = .046	5.0	.047
21	.497	.04	5.03	Pitching .99 deg about x_α/c = .257	21.3	.201
22	.497	.04	5.03	Pitching 1.07 deg about x_α/c = .504	21.3	.201
23	.497	.04	5.03	Plunging 1.02 cm (0.400 in.)	21.3	.201
24	1.074	.00	6.58	Plunging .44 cm (0.173 in.)	5.0	.024
25	.497	1.98	5.00	Plunging .00 cm (0.000 in.)	5.0	.047
26	.502	-.22	9.98	Pitching .00 deg about x_α/c = .150	5.0	.046
27	.502	-.22	9.98	Pitching .24 deg about x_α/c = .234	10.8	.100
28	.502	-.22	9.98	Pitching .51 deg about x_α/c = .269	10.8	.100
29	.502	-.22	9.98	Pitching 1.02 deg about x_α/c = .269	10.8	.100
30	.499	-.21	9.90	Pitching .26 deg about x_α/c = .277	21.5	.201
31	.499	-.13	9.89	Pitching .50 deg about x_α/c = .271	21.5	.200
32	.499	-.13	9.89	Pitching 1.00 deg about x_α/c = .269	21.5	.200
33	.499	-.13	9.89	Pitching 2.01 deg about x_α/c = .267	21.5	.200
34	.499	-.13	9.89	Pitching 2.13 deg about x_α/c = .503	21.5	.200
35	.499	-.13	9.89	Pitching 1.06 deg about x_α/c = .506	21.5	.200
36	.499	-.13	9.89	Plunging 1.01 cm (0.399 in.)	21.5	.200
37	.499	-.13	9.89	Pitching 1.00 deg about x_α/c = .252	26.9	.251
38	.499	-.13	9.89	Pitching 1.07 deg about x_α/c = .506	26.9	.251
39	.499	-.13	9.89	Pitching 1.00 deg about x_α/c = .250	16.2	.151
40	.499	-.13	9.89	Plunging 1.01 cm (0.396 in.)	16.2	.151
41	.499	-.13	9.89	Plunging 1.02 cm (0.401 in.)	10.8	.101
42	.499	-.13	9.89	Plunging 1.03 cm (0.405 in.)	5.4	.050
43	.499	-.13	9.89	Pitching 1.02 deg about x_α/c = .248	5.4	.050
44	.499	-.13	9.89	Pitching 2.04 deg about x_α/c = .245	10.8	.101
45	.648	-.22	11.63	Pitching .97 deg about x_α/c = .249	27.8	.201
46	.744	-.22	12.31	Pitching 1.01 deg about x_α/c = .248	32.0	.201
47	.796	-.21	12.56	Pitching .30 deg about x_α/c = .202	17.1	.101
48	.796	-.21	12.56	Pitching .25 deg about x_α/c = .234	34.2	.201
49	.796	-.21	12.56	Pitching .51 deg about x_α/c = .247	17.1	.101
50	.796	-.21	12.56	Pitching .50 deg about x_α/c = .248	34.2	.201
51	.796	-.21	12.56	Pitching 1.03 deg about x_α/c = .249	4.2	.025
52	.796	-.21	12.56	Pitching 1.02 deg about x_α/c = .246	8.6	.051
53	.796	-.21	12.56	Pitching 1.02 deg about x_α/c = .248	17.2	.101
54	.796	-.21	12.56	Pitching 1.01 deg about x_α/c = .254	25.7	.151
55	.796	-.21	12.56	Pitching 1.01 deg about x_α/c = .248	34.4	.202
56	.796	-.21	12.56	Pitching 1.02 deg about x_α/c = .248	42.0	.247
57	.796	-.21	12.56	Pitching .99 deg about x_α/c = .252	51.5	.303
58	.796	-.21	12.56	Pitching 1.08 deg about x_α/c = .502	42.9	.252
59	.796	-.21	12.56	Pitching 1.09 deg about x_α/c = .500	34.4	.202
60	.796	-.21	12.56	Pitching 1.08 deg about x_α/c = .502	17.2	.101
61	.796	-.21	12.56	Pitching 1.09 deg about x_α/c = .501	8.6	.051
62	.796	-.21	12.56	Pitching 1.12 deg about x_α/c = .499	4.3	.025
63	.797	-.08	12.40	Pitching 1.95 deg about x_α/c = .471	34.3	.201
64	.797	-.08	12.40	Pitching 1.94 deg about x_α/c = .231	34.3	.201
65	.797	-.08	12.40	Pitching 2.00 deg about x_α/c = .239	17.2	.101
66	.797	-.08	12.40	Plunging 1.01 cm (0.396 in.)	34.3	.201
67	.797	-.08	12.40	Plunging 1.02 cm (0.401 in.)	25.8	.151
68	.797	-.08	12.40	Plunging 1.02 cm (0.400 in.)	17.4	.102
69	.797	-.08	12.40	Plunging 1.02 cm (0.400 in.)	8.6	.050
70	.797	-.08	12.40	Plunging 1.04 cm (0.409 in.)	4.3	.025
71	.842	.00	12.45	Pitching 1.01 deg about x_α/c = .248	36.4	.202
72	.842	-.22	12.43	Pitching 1.01 deg about x_α/c = .247	36.5	.202
73	.805	-.00	3.34	Pitching 1.01 deg about x_α/c = .247	25.1	.149
74	.805	-.00	3.34	Plunging .44 cm (0.173 in.)	5.0	.030
75	.805	-.00	3.34	Pitching 1.02 deg about x_α/c = .248	8.3	.049

TABLE 2.1. Continued.

DI	M	α_m, deg	Re×10^{-6}	Motion	f, Hz	k
76	0.805	0.00	3.34	Pitching 2.03 deg about x_α/c = 0.248	8.3	0.049
77	.805	.00	3.34	Pitching 2.00 deg about x_α/c = .248	33.3	.198
78	.794	.08	12.40	Pitching .64 deg about x_α/c = .328	10.0	.059
79	.782	4.00	12.01	Pitching .25 deg about x_α/c = .232	17.3	.102
80	.782	4.00	12.01	Pitching .25 deg about x_α/c = .229	34.7	.205
81	.782	4.00	12.01	Pitching .51 deg about x_α/c = .244	17.4	.103
82	.792	3.93	6.15	Pitching 1.01 deg about x_α/c = .247	34.3	.203
83	.793	4.01	6.18	Pitching 1.02 deg about x_α/c = .248	34.2	.202
84	.789	4.00	11.88	Pitching .51 deg about x_α/c = .234	34.9	.203
85	.789	4.00	11.88	Pitching 1.04 deg about x_α/c = .246	4.4	.026
86	.789	4.00	11.88	Pitching 1.03 deg about x_α/c = .246	8.8	.051
87	.789	4.00	11.88	Pitching 1.02 deg about x_α/c = .248	17.5	.102
88	.789	4.00	11.88	Pitching 1.01 deg about x_α/c = .247	26.3	.153
89	.789	4.00	11.88	Pitching 1.01 deg about x_α/c = .249	35.1	.204
90	.789	4.00	11.88	Pitching 1.01 deg about x_α/c = .248	43.9	.255
91	.789	4.00	11.88	Pitching 1.00 deg about x_α/c = .248	52.7	.306
92	.789	4.00	11.88	Pitching 1.08 deg about x_α/c = .499	35.2	.205
93	.789	4.00	11.88	Plunging .84 cm (0.330 in.)	35.2	.205
94	.789	4.00	11.88	Pitching 1.08 deg about x_α/c = .501	44.0	.256
95	.789	4.00	11.88	Pitching 2.00 deg about x_α/c = .245	17.6	.102
96	.741	4.03	11.22	Pitching 1.02 deg about x_α/c = .246	35.2	.215
97	.642	3.99	10.60	Pitching 1.01 deg about x_α/c = .247	28.8	.203
98	.504	4.00	10.20	Pitching 1.02 deg about x_α/c = .249	22.2	.199
99	.506	3.99	9.45	Pitching 1.09 deg about x_α/c = .499	22.0	.198
100	.506	3.99	9.45	Plunging 1.01 cm (0.397 in.)	22.0	.198
101	.506	3.99	9.45	Pitching 1.09 deg about x_α/c = .302	27.5	.247
102	.506	3.99	9.45	Pitching 2.14 deg about x_α/c = .502	27.5	.247
103	.790	4.00	11.72	Pitching 2.01 deg about x_α/c = .243	35.0	.203
104	.503	4.00	4.94	Pitching 1.01 deg about x_α/c = .245	21.6	.199
105	.503	4.00	4.94	Pitching 1.09 deg about x_α/c = .499	21.6	.199
106	.503	4.00	4.94	Plunging 1.02 cm (0.401 in.)	21.6	.199
107	.503	4.00	4.94	Pitching 1.08 deg about x_α/c = .502	26.9	.248
108	.642	3.78	5.92	Pitching 1.02 deg about x_α/c = .250	27.6	.203
109	.747	3.89	6.36	Pitching 1.02 deg about x_α/c = .247	31.0	.197
110	.797	4.01	6.30	Pitching 1.09 deg about x_α/c = .500	33.5	.201
111	.797	4.01	6.50	Plunging 1.01 cm (0.398 in.)	33.5	.201
112	.797	4.01	6.50	Pitching 1.08 deg about x_α/c = .502	42.0	.252
113	.848	3.89	6.59	Pitching 1.01 deg about x_α/c = .248	35.5	.201
114	.840	3.79	12.39	Pitching 1.01 deg about x_α/c = .248	36.3	.202

TABLE 2.2. DATA BASE FOR NACA 64A010 AIRFOIL, PITCHING OSCILLATION ABOUT 0.25c NOMINAL, ARRANGED IN FREQUENCY SWEEPS

M	α_m, deg	Re×10^{-6}	α_σ deg	k = 0.025	k = 0.05	k = 0.10	k = 0.15	k = 0.20	k = 0.25	k = 0.30	Type of Flow
0.50	0.0	10	±0.25			27		30			
.50	0.0	10	±0.50			28		31			
.50	0.0	2.5	±1	9	8	7	6	2			Subsonic
.50	0.0	5	±1					21			
.50	0.0	10	±1		43	29	39	32	37		
.50	0.0	2.5	±2		10			11			
.50	0.0	10	±2			44		33			
.65	0.0	11.6	±1					45			
.75	0.0	12.3	±1					46			
.80	0.0	3.3	±1		75		73	12	15		
.80	0.0	12.5	±0.25					48			
.80	0.0	12.5	±0.50		78	49		50			Transonic weak shock
.80	0.0	6.7	±1					16			
.80	0.0	12.6	±1	51	52	53	54	55	56	57	
.80	0.0	12.4	±2			65		64			
.85	0.0	12.4	±1					72			
.50	4.0	4.9	±1					104			Subsonic
.50	4.0	10.2	±1					98			
.65	4.0	5.9	±1					108			
.65	4.0	10.6	±1					97			
.75	4.0	6.4	±1					109			
.75	4.0	11.2	±1					96			
.80	4.0	12	±0.25			79		80			
.80	4.0	12	±0.50			81		84			
.80	4.0	6.2	±1					82			
.80	4.0	11.9	±1	85	86	87	88	89	90	91	Transonic shock stall
.80	4.0	11.9	±2			95		103			
.85	4.0	6.6	±1					113			

TABLE 2.3. SELECTED NASA AMES TEST DATA ASSOCIATED WITH AGARD CT CASES AND THE SHOCK STALL CASE (SSC)

CT Case	DI	M	α_m	$Re\times10^{-6}$	α_o	f	k	x_α/c
1	7	0.490	-0.01	2.52	0.96	10.4	0.100	0.233
2	29	0.502	-0.22	9.98	1.02	10.8	0.100	0.269
3	51	0.796	-0.21	12.56	1.03	4.2	0.025	0.249
4	52	0.796	-0.21	12.56	1.02	8.6	0.051	0.246
5	53	0.796	-0.21	12.56	1.02	17.2	0.101	0.248
6	55	0.796	-0.21	12.56	1.01	34.4	0.202	0.248
7	57	0.796	-0.21	12.56	0.99	51.5	0.303	0.252
8	49	0.796	-0.21	12.56	0.51	12.1	0.101	0.247
9	65	0.797	-0.08	12.40	2.00	17.2	0.101	0.239
10	12	0.802	0.00	3.38	0.94	33.2	0.200	0.232
SSC	89	0.789	4.00	11.88	1.01	35.1	0.204	0.249

TABLE 2.4. STEADY AND FUNDAMENTAL FREQUENCY LIFT AND MOMENT DATA FOE SELECTED CASES

Case	DI	Steady Data		$C_{L,\alpha}$	$C_{M,\alpha}$
		C_L	C_m		
CT1	7	0.006	-0.002	6.139 - 1.149i	0.165 - 0.163i
CT2	29	0.016	0.001	6.163 - 1.036i	0.167 - 0.201i
CT3	51	-0.029	-0.003	9.316 - 1.378i	0.000 - 0.102i
CT4	52	-0.029	-0.003	8.622 - 2.479i	-0.005 - 0.232i
CT5	53	-0.029	-0.003	6.790 - 3.387i	-0.061 - 0.388i
CT6	55	-0.029	-0.003	4.887 - 2.521i	-0.189 - 0.653i
CT7	57	-0.029	-0.003	4.635 - .905i	-0.374 - 1.023i
CT8	49	-0.029	-0.003	6.795 - 3.403i	-0.195 - 0.314i
CT9	65	-0.018	-0.002	6.141 - 3.113i	-0.239 - 0.302i
CT10	12	0.009	-0.002	5.308 - 2.471i	-0.384 - 0.546i
SSC	89	0.531	0.001	9.349 - 0.406i	-2.068 + 0.198i

TABLE 2.5. MEAN AND FUNDAMENTAL FREQUENCY PRESSURE DATA FOR AGARD CT CASE NO. 1; DYNAMIC INDEX 7

WING MODEL. NACA 64A010, CHORD= 500 METERS

WING MOTION PITCHING 96 DEG ABOUT X/C= .233

DYNAMIC INDEX 7 STATIC INDEX 5

M	490	PTOT	50964	K	.100
ALPHA	- 01	QINF	7250	FREQ	10 4
RE	2 51E 06	PINF	43169		

UPPER SURFACE

Steady data: CPU X/C	CPU	Unsteady data (CPU,A): X/C	REAL	IMAG	MAG	PHASE
.030	-.168	.033	-11 722	3 045	12 111	165 45
.052	- 185	052	-9 409	2 186	9 660	166 93
091	-.214	.091	-7 393	1 635	7 572	167 54
.142	-.259	.140	-5 434	1.178	5 560	167 78
211	-.292	.209	-4.035	725	4 100	169 83
243	- 299	243	-4.296	734	4 358	170 32
292	- 313	339	-3 369	464	3 401	172 16
341	-.326	.402	-3.254	.580	3 305	169 90
.440	- 319	.440	-1.986	.633	2 084	162 33
487	- 288	.488	-1 198	878	1.485	143 79
.537	- 251	.538	-.446	.345	.564	142 28
.585	-.197	584	-1.944	023	1.944	179 34
.634	-.143	.633	-1 412	065	1 414	-177 38
.682	- 116	682	-1.029	019	1.029	178 98
.733	- 065	.733	- 960	- 123	968	-172 73
.783	-.020	.781	- 702	- 136	.715	-169 01
927	010	829	- 370	- 025	371	-176 21
.874	.052	872	- 560	-.161	.583	-163.99
.924	.090	.941	-.113	- 045	.121	-158 30

LOWER SURFACE

Steady data: CPL X/C	CPL	Unsteady data (CPL,A): X/C	REAL	IMAG	MAG	PHASE
053	- 186	000	.608	- 180	.634	-16 53
093	- 187	034	11 555	-2 879	11 908	-13 99
.142	- 238	.054	9 500	-2 059	9 720	-12 23
.199	- 259	.094	7 299	-1 486	7 449	-11.51
.244	- 290	.141	5 840	-1.045	5 933	-10 15
.293	- 304	200	4 920	- 749	4 977	-9 66
341	- 306	243	3.973	- 728	4 039	-10.39
.393	- 312	.293	4.042	-.422	4 064	-5 96
.440	- 313	.341	1 406	-.350	1.449	-13 97
.490	- 283	394	3 133	- 058	3.134	-1.06
.537	- 237	.441	1 938	-.385	1.976	-11.24
.583	- 196	490	1 311	-.587	1 436	-24 12
625	- 153	537	1 028	- 483	1 135	-25.16
.679	- 115	.582	1 486	.263	1 509	10 02
.734	-.069	.631	1 620	.246	1.638	8 64
.789	- 022	678	1.322	.149	1.331	6.41
832	015	.733	1 055	.161	1 067	8 69
.886	065	781	781	.164	.798	11.84
.941	.114	831	.588	.050	590	4 87
		888	.432	135	.452	17 36
		923	.157	.058	.168	20.36

TABLE 2.6. MEAN AND FUNDAMENTAL FREQUENCY PRESSURE DATA FOR AGARD CT CASE NO. 2; DYNAMIC INDEX 29

WING MODEL· NACA 64A010. CHORD= 500 METERS

WING MOTION PITCHING 1 02 DEG ABOUT X/C= 269

DYNAMIC INDEX 29 STATIC INDEX 24

M	.502	PTOT	203152.	K	100
ALPHA	- 22	QINF	30199	FREQ	10 8
RE	1.00E 07	PINF	171000		

UPPER SURFACE

STEADY DATA (CPU) X/C	CPU	UNSTEADY DATA (CPU.A) X/C	REAL	IMAG	MAG	PHASE
030	- 136	.033	-10 116	2.659	10 459	165 29
091	-.177	052	-7 608	1 994	7 865	165 33
.142	-.223	091	-6 377	1 434	6 536	167 34
211	-.253	.140	-5.231	1.181	5 362	67 28
243	- 265	.209	-4.369	.791	4 440	169 75
.292	-.287	.243	-4.026	.679	4.083	170.44
.341	-.304	.294	-3 810	.576	3.853	171 41
.399	-.309	.402	-3 165	.364	3.186	173 45
.440	- 300	.440	-2.365	226	2 395	174 60
487	- 263	488	-2 020	109	2 023	176 93
.537	- 228	.538	-1 723	.023	1 723	179 25
.585	-.190	.584	-1.385	- 027	1 385	-178 90
.634	- 137	.633	-1.188	- 077	1 190	-176 32
.682	-.114	.682	-.977	- 108	983	-173 72
733	- 061	.733	-.814	- 137	.825	-170 48
827	016	.781	- 613	- 160	634	-165 39
874	055	829	-.562	-.170	587	-163 15
.924	091	872	-.333	- 148	.365	-156 08
		.941	-.097	- 110	.147	-131 23

LOWER SURFACE

STEADY DATA (CPL) X/C	CPL	UNSTEADY DATA (CPL.A) X/C	REAL	IMAG	MAG	PHASE
032	- 034	.034	11.019	-2.959	11.410	-15.03
093	- 142	.054	9 351	-2.296	9 629	-13 80
.142	- 227	.094	6.781	-1.585	6 964	-13.16
.199	-.246	.141	5.469	-1.172	5.593	-12 10
.244	- 289	.200	4.541	-.837	4 617	-10.45
.293	- 298	.243	4 075	-.692	4 133	-9.65
.341	- 285	.293	3.177	-.500	3.216	-8.94
.393	-.294	.341	3.099	-.387	3.123	-7.11
440	- 306	.394	2.647	- 275	2 662	-5 94
490	- 276	.441	2 387	- 164	2 393	-3 94
.537	-.223	.490	2 014	- 080	2.015	-2 29
583	-.183	.582	1.434	.033	1.434	1 32
.625	-.148	.631	1.203	062	1.204	2 95
.679	-.111	.678	.979	.112	.986	6 50
734	- 067	.733	.759	121	.769	9 09
789	- 016	781	.597	127	.611	11 98
832	.018	.831	410	.128	.430	17.37
886	.077	.888	.316	.110	.335	19.15
941	.121	.923	.178	.087	.198	25.95

TABLE 2.7. MEAN AND FUNDAMENTAL FREQUENCY PRESSURE DATA FOR AGARD CT CASE NO. 3; DYNAMIC INDEX 51

WING MODEL· NACA 64A010. CHORD= .500 METERS

WING MOTION PITCHING 1 03 DEG ABOUT X/C= 249

DYNAMIC INDEX 51 STATIC INDEX 30

M	.796	PTOT	203321	K	025
ALPHA	- 21	QINF	59395	FREQ	4 2
RE	1.30E 07	PINF	133912		

UPPER SURFACE

STEADY DATA (CPU) X/C	CPU	UNSTEADY DATA (CPU.A) X/C	REAL	IMAG	MAG	PHASE
.030	- 086	033	-10 450	1.860	10 614	169 92
.091	-.193	052	-9 661	1 700	9 809	170 03
.142	-.292	.091	-8 526	1 479	8 653	170 17
.211	-.378	140	-7 580	1 433	7 714	169.31
.243	- 418	.209	-6 812	1 192	6 915	170 08
.292	-.481	243	-6 912	1 229	7 020	169 93
.341	- 544	.294	-6 732	1 247	6 846	169 52
.399	- 635	402	-8.202	1 440	8 327	170 06
440	- 703	440	-8 717	1 477	8 842	170 40
487	-.594	.488	-14 522	2 131	14 678	171 67
.537	- 322	538	-2.656	- 123	2.659	-177 35
585	-.258	.584	.992	- 557	1 138	-29 30
634	-.181	633	337	- 389	515	-49 13
.682	-.132	733	- 056	- 293	298	-100 78
.733	-.061	.781	026	- 227	229	-83 40
827	.041	829	.092	- 210	229	-65 41
874	092	872	.108	- 144	180	-53 02
924	141	941	045	- 080	092	-60 67

LOWER SURFACE

STEADY DATA (CPL) X/C	CPL	UNSTEADY DATA (CPL.A) X/C	REAL	IMAG	MAG	PHASE
.053	-.207	034	12.103	-2.329	12.325	-10 99
.093	- 175	.054	10 371	-1.880	10.540	-10 28
.142	-.316	.094	8 826	-1 607	8 971	-10 32
.199	-.320	.141	8.098	-1.510	8 237	-10 57
.244	-.457	.200	7.405	-1.371	7.531	-10.49
.293	- 500	.243	6.293	-1.113	6 391	-10 03
.341	- 536	.293	5 256	-.981	5.346	-10 58
393	- 629	.341	6 343	-1.149	6 446	-10 27
.440	-.713	.394	6.194	-1.117	6.294	-10.22
.490	-.777	490	13 771	-2.269	13.957	-9.36
.537	- 334	582	.791	.332	.858	22 78
.583	- 255	.631	- 302	.402	.503	126 92
625	- 198	.678	-.368	.341	502	137 20
.679	-.137	.733	-.283	.273	.393	136 04
.734	-.070	.781	- 177	.208	.273	130 41
789	-.006	831	- 325	.166	.365	152 99
832	043	888	- 212	.116	.242	151.28
886	113	923	- 161	062	172	158 80
941	170					

TABLE 2.8. MEAN AND FUNDAMENTAL FREQUENCY PRESSURE DATA FOR AGARD CT CASE NO. 4; DYNAMIC INDEX 52

WING MODEL NACA 64A010, CHORD= .500 METERS

WING MOTION PITCHING 1.02 DEG ABOUT X/C= .246

DYNAMIC INDEX 52 STATIC INDEX 30

M	.796	PTOT	203321	K	.051
ALPHA	-.21	QINF	59395	FREQ	8.6
RE	1.30E 07	PINF	133912		

UPPER SURFACE

STEADY DATA (CPU)		UNSTEADY DATA (CPU,A)				
X/C	CPU	X/C	REAL	IMAG	MAG	PHASE
.030	-.086	.033	-9.518	3.334	10.086	160.71
.091	-.193	.052	-8.589	2.979	9.091	160.88
.142	-.292	.091	-7.723	2.634	8.160	161.18
.211	-.378	.140	-6.821	2.449	7.247	160.26
.243	-.418	.209	-6.132	2.094	6.480	161.16
.292	-.481	.243	-6.282	2.192	6.654	160.78
.341	-.544	.294	-6.270	2.245	6.660	160.31
.399	-.635	.402	-7.275	2.494	7.690	161.09
.440	-.703	.440	-7.936	2.648	8.356	161.56
.497	-.594	.488	-13.828	3.754	14.328	164.82
.537	-.322	.538	-2.389	-.208	2.398	-175.03
.585	-.258	.584	.860	-1.073	1.376	-51.30
.634	-.181	.633	.153	-.717	.733	-77.97
.682	-.132	.733	-.111	-.473	.486	-103.25
.733	-.061	.781	-.009	-.398	.398	-91.26
.827	.041	.829	.033	-.376	.377	-84.95
.874	.092	.872	.083	-.284	.296	-73.78
.924	.141	.941	.031	-.117	.121	-75.09

LOWER SURFACE

STEADY DATA (CPL)		UNSTEADY DATA (CPL,A)				
X/C	CPL	X/C	REAL	IMAG	MAG	PHASE
.053	-.207	.034	10.999	-3.944	11.685	-19.73
.093	-.175	.054	9.286	-3.301	9.856	-19.57
.142	-.316	.094	7.994	-2.835	8.481	-19.53
.199	-.320	.141	7.267	-2.615	7.723	-19.79
.244	-.457	.200	6.540	-2.340	6.946	-19.69
.293	-.500	.243	5.766	-1.987	6.099	-19.01
.341	-.536	.293	4.808	-1.754	5.117	-20.04
.393	-.629	.341	5.825	-2.031	6.169	-19.22
.440	-.713	.394	5.638	-1.968	5.972	-19.24
.490	-.777	.490	13.385	-3.652	13.874	-15.26
.537	-.334	.582	.675	.591	.897	41.19
.583	-.255	.631	-.272	.746	.794	110.07
.625	-.198	.678	-.368	.681	.774	118.35
.679	-.137	.733	-.225	.514	.561	113.70
.734	-.070	.781	-.168	.390	.424	113.31
.789	-.006	.831	-.275	.363	.455	127.18
.832	.043	.888	-.206	.244	.319	130.22
.886	.113	.923	-.147	.130	.196	138.40
.941	.170					

TABLE 2.9. MEAN AND FUNDAMENTAL FREQUENCY PRESSURE DATA FOR AGARD CT CASE NO. 5; DYNAMIC INDEX 53

WING MODEL NACA 64A010, CHORD= .500 METERS

WING MOTION PITCHING 1.02 DEG ABOUT X/C= .248

DYNAMIC INDEX 53 STATIC INDEX 30

M	.796	PTOT	203321	K	.101
ALPHA	-.21	QINF	59395	FREQ	17.2
RE	1.30E 07	PINF	133912		

UPPER SURFACE

STEADY DATA (CPU)		UNSTEADY DATA (CPU,A)				
X/C	CPU	X/C	REAL	IMAG	MAG	PHASE
.030	-.086	.033	-7.014	4.842	8.523	145.39
.091	-.193	.052	-6.369	4.387	7.734	145.45
.142	-.292	.091	-5.781	3.898	6.972	146.02
.211	-.378	.140	-5.065	3.541	6.180	145.06
.243	-.418	.209	-4.629	3.136	5.591	145.89
.292	-.481	.243	-4.724	3.282	5.752	145.23
.341	-.544	.294	-4.650	3.301	5.702	144.64
.399	-.635	.402	-5.478	3.653	6.584	146.31
.440	-.703	.440	-6.159	3.873	7.275	147.85
.487	-.594	.488	-12.060	5.962	13.453	153.71
.537	-.322	.538	-1.901	-.638	2.005	-161.47
.585	-.258	.584	.394	-1.808	1.850	-77.70
.634	-.181	.633	-.105	-1.176	1.181	-95.13
.682	-.132	.733	-.235	-.763	.799	-107.13
.733	-.061	.781	-.097	-.664	.671	-98.34
.827	.041	.829	-.053	-.600	.602	-95.05
.874	.092	.872	-.008	-.459	.459	-91.00
.924	.141	.941	.015	-.175	.175	-85.02

LOWER SURFACE

STEADY DATA (CPL)		UNSTEADY DATA (CPL,A)				
X/C	CPL	X/C	REAL	IMAG	MAG	PHASE
.053	-.207	.034	8.191	-5.798	10.035	-35.29
.093	-.175	.054	6.926	-4.843	8.451	-34.96
.142	-.316	.094	5.942	-4.122	7.232	-34.75
.199	-.320	.141	5.396	-3.756	6.574	-34.84
.244	-.457	.200	4.347	-2.854	5.200	-33.29
.293	-.500	.243	4.575	-3.123	5.540	-34.32
.341	-.536	.293	3.649	-2.604	4.483	-35.52
.393	-.629	.341	4.466	-2.943	5.349	-33.38
.440	-.713	.394	4.232	-2.731	5.037	-32.84
.490	-.777	.490	11.946	-4.497	12.764	-20.63
.537	-.334	.582	.461	1.336	1.414	70.98
.583	-.255	.631	-.156	1.404	1.413	96.33
.625	-.198	.678	-.204	1.201	1.218	99.65
.679	-.137	.733	-.150	.915	.927	99.29
.734	-.070	.781	-.117	.735	.744	99.08
.789	-.006	.831	-.251	.658	.704	110.92
.832	.043	.888	-.174	.473	.504	110.24
.886	.113	.923	-.147	.274	.311	118.17
.941	.170					

TABLE 2.10. MEAN AND FUNDAMENTAL FREQUENCY PRESSURE DATA
FOR AGARD CT CASE NO. 6; DYNAMIC INDEX 55

WING MODEL · NACA 64A010, CHORD= 500 METERS

WING MOTION· PITCHING I 01 DEG ABOUT X/C= 248

DYNAMIC INDEX 55 STATIC INDEX 30

M	.796	PTOT	203321	K	202
ALPHA	- 21	QINF	59395.	FREQ	34 4
RE	I 30E 07	PINF	133912		

UPPER SURFACE

STEADY DATA		UNSTEADY DATA				
----CPU-----		CPU,A				
X/C	CPU	X/C	REAL	IMAG	MAG	PHASE
.030	- 086	.033	-4.346	4 572	6 308	133 56
.091	- 193	.052	-3.397	4 217	5 810	133 48
.142	- 292	.091	-3 469	3 557	4 969	134 29
211	- 378	.140	-3 036	3 205	4 415	133 46
.243	- 418	.209	-2 880	2 974	4 140	134 09
292	- 481	.243	-3 023	3 176	4 385	133 60
.341	- 544	.294	-3 002	3 079	4 300	134 28
399	- 635	.402	-4.081	3 723	5 524	137 64
.440	- 703	.440	-4.988	4.046	6 423	140 96
487	- 594	.488	-11.922	4 745	12 832	158 31
.537	- 322	.538	-1 672	-2 138	2 714	-128 03
.585	-.258	584	.128	-2 800	2 803	-87 39
634	- 181	.633	-.120	-2 064	2 068	-93 32
682	- 132	733	-.052	-1 338	1 339	-92 22
.733	- 061	781	.066	-1 202	1 204	-86.85
.827	041	829	.161	-1 085	1 097	-81 55
874	092	872	.156	- 714	731	-77 69
.924	141	941	097	- 264	281	-69 84

LOWER SURFACE

STEADY DATA		UNSTEADY DATA				
----CPL-----		CPL,A				
X/C	CPL	X/C	REAL	IMAG	MAG	PHASE
053	- 207	.034	4.663	-5 537	7 239	-49 90
093	-.175	054	3 979	-4 675	6 139	-49 60
.142	- 316	.094	3 497	-4 034	5 339	-49 09
199	- 320	.141	3 236	-3 767	4 966	-49 34
244	- 457	.200	2 666	-2 792	3 861	-46 32
.293	- 500	243	3 075	-3 485	4 648	-48 57
.341	- 536	.293	2 362	-2 726	3 607	-49 10
.393	- 629	.341	3.173	-3 084	4 424	-44 19
.440	-.713	.394	3.210	-2 982	4 381	-42 89
.490	-.777	.490	11.825	-3 337	12.287	-15.76
.537	- 334	582	.616	2 691	2 761	77 12
.583	-.255	.631	.007	2 460	2.460	89 85
625	- 198	.678	-.168	2 091	2 097	94 60
.679	-.137	.733	-.208	1 491	1.505	97 95
.734	-.070	781	-.171	1 316	1 327	97 42
789	-.006	831	- 396	1.119	1.187	109 48
.832	043	888	- 246	708	.749	109 16
886	.113	923	- 170	463	.494	110 21
.941	.170					

TABLE 2.11. MEAN AND FUNDAMENTAL FREQUENCY PRESSURE DATA
FOR AGARD CT CASE NO. 7; DYNAMIC INDEX 57

WING MODEL · NACA 64A010. CHORD= 500 METERS

WING MOTION· PITCHING .99 DEG ABOUT X/C= .252

DYNAMIC INDEX 57 STATIC INDEX 30

M	796	PTOT	203321	K	303
ALPHA	- 21	QINF	59395	FREQ	51 5
RE	1 30E 07	PINF	133912		

UPPER SURFACE

STEADY DATA		UNSTEADY DATA				
----CPU-----		CPU,A				
X/C	CPU	X/C	REAL	IMAG	MAG	PHASE
.030	- 086	033	-4 071	3 040	5 081	143 26
091	- 193	.052	-4 071	3 496	5 366	139 35
142	- 292	.091	-3 341	2 997	4 488	138 12
211	-.378	.140	-3 272	2 850	4 340	138 96
.243	- 418	.209	-3 110	2 974	4 303	136 29
292	-.481	.243	-3.626	3 313	4 912	137 59
.341	- 544	.402	-7 213	4 219	8 357	149 69
399	- 635	.440	-7.972	3 340	8 643	157 28
.440	-.703	.488	-13 300	- 288	13 304	-178 77
487	- 594	.538	-1 358	-4 719	4 911	-106 06
537	- 322	584	.528	-4 838	4 867	-83 78
.585	- 258	633	-3.354	-3 778	5 052	-131 61
634	- 181	733	766	-2 966	3 063	-75 52
682	- 132	781	736	-2 393	2 504	-72 92
.733	- 061	829	.411	-2 428	2 462	-80 40
827	.041	.872	792	-1 393	1 602	-60 38
874	092	941	.499	- 521	721	-46 29
924	.141					

LOWER SURFACE

STEADY DATA		UNSTEADY DATA				
----CPL-----		CPL,A				
X/C	CPL	X/C	REAL	IMAG	MAG	PHASE
053	- 207	.034	116	-4 311	4 312	-88 47
093	- 175	054	3 831	-3 861	5 439	-45 23
142	- 316	.094	2 813	-3 368	4 388	-50 13
199	- 320	.141	2 867	-3 478	4 507	-50 50
244	- 457	.200	2 374	-2 490	3 441	-46 37
293	- 500	.243	2 506	-3 182	4 050	-51.78
.341	- 536	.293	2.164	-2.746	3 497	-51.76
393	- 629	.341	2 660	-3 281	4 224	-50 97
440	- 713	394	2.559	-3 361	4 224	-52 71
490	- 777	.490	11 999	-6 060	13 442	-26 80
.537	-.334	582	3 288	5.074	6 046	57 06
583	- 256	631	-.231	4 500	4 506	92 94
625	- 198	.678	- 892	3 384	3 500	104 78
679	- 137	.733	-1 522	2 582	2 997	120 52
734	- 070	.781	- 608	2 258	2 338	105 08
789	- 006	831	-1 485	1.880	2 395	128 32
832	043	888	- 976	1 106	1 475	131 43
886	.113	923	- 655	.603	.891	137 37
941	170					

TABLE 2.12. MEAN AND FUNDAMENTAL FREQUENCY PRESSURE DATA
FOR AGARD CT CASE NO. 8; DYNAMIC INDEX 49

WING MODEL. NACA 64A010. CHORD= .500 METERS

WING MOTION. PITCHING .51 DEG ABOUT X/C= 247

DYNAMIC INDEX 49 STATIC INDEX 30

M	.796	PTOT	203321	K	101
ALPHA	-.21	QINF	59395.	FREQ	17.1
RE	1.30E 07	PINF	133912		

----------------------UPPER SURFACE----------------------

STEADY DATA		UNSTEADY DATA				
----CPU-----		-----------------CPU,A-----------------				
X/C	CPU	X/C	REAL	IMAG	MAG	PHASE
030	- 086	.033	-5 969	4 221	7 311	144 75
091	- 193	.052	-6 089	4 153	7 371	145 71
.142	- 292	.091	-5 759	3 944	6 980	145 60
.211	-.378	.140	-4 902	3 538	6 045	144 19
243	- 418	.209	-4 689	3 255	5 708	145 24
.292	- 481	243	-4 851	3 434	5 943	144 71
.341	-.544	294	-4 535	3 142	5 517	145 30
.399	- 635	.402	-5 050	3 330	6 049	146 61
.440	- 703	.440	-4 941	3 414	6 006	145.37
.487	- 594	.488	-18 650	10 071	21 195	151 64
537	- 322	.538	- 803	-1 572	1 765	-117 06
.585	-.258	.584	.593	-1 987	2 073	-73 39
.634	-.181	.633	- 058	-1.149	1.151	-92.89
.682	-.132	.733	- 222	-.752	784	-106 45
.733	-.061	784	- 114	- 642	.652	-100 07
.827	.041	.829	- 030	- 593	599	-98 67
.874	.092	.872	- 018	-.431	432	-92 40
.924	.141	.941	-.018	-.175	176	-95.86

----------------------LOWER SURFACE----------------------

STEADY DATA		UNSTEADY DATA				
----CPL-----		-----------------CPL,A-----------------				
X/C	CPL	X/C	REAL	IMAG	MAG	PHASE
053	- 207	.034	8 689	-5 674	10.377	-33 15
093	-.175	.054	6 979	-4 989	8 578	-35 56
.142	- 316	.094	6.041	-4.167	7 339	-34.60
.199	- 320	.141	5 340	-3.828	6.571	-35 64
244	- 457	.200	4.130	-2 819	5 000	-34 32
293	- 500	.243	5 142	-3.708	6 340	-35 80
341	-.536	293	3.526	-2.578	4 368	-36 18
.393	-.629	.341	4.290	-2.832	5 141	-33 43
.440	-.713	.394	4.538	-2 983	5.431	-33.32
.490	-.777	.490	10 913	-4 639	11.858	-23 03
537	- 334	582	- 115	1 710	1.714	93 84
.583	-.255	.631	- 402	1.502	1.555	105 00
.625	-.198	.678	- 284	1 190	1 224	103 42
.679	- 137	.733	- 194	943	962	101 61
.734	-.070	.781	-.091	.718	.724	97 25
.789	- 006	831	- 267	.660	.712	112 08
832	.043	888	-.164	.458	.486	109 70
.886	.113	.923	-.148	.270	.308	118 78
.941	.170					

TABLE 2.13. MEAN AND FUNDAMENTAL FREQUENCY PRESSURE DATA
FOR AGARD CT CASE NO. 9; DYNAMIC INDEX 65

WING MODEL. NACA 64A010. CHORD= 500 METERS

WING MOTION. PITCHING 2 00 DEG ABOUT X/C= .239

DYNAMIC INDEX 65 STATIC INDEX 31

M	.797	PTOT	203186	K	101
ALPHA	- 09	QINF	59423.	FREQ	17 2
RE	1.24E 07	PINF	133724		

----------------------UPPER SURFACE----------------------

STEADY DATA		UNSTEADY DATA				
----CPU-----		-----------------CPU,A-----------------				
X/C	CPU	X/C	REAL	IMAG	MAG	PHASE
030	- 099	033	-6 824	4 616	8 239	145 93
091	-.200	052	-6.621	4 530	8 025	145 64
142	- 298	.091	-5 300	3 507	6 355	146 52
211	- 385	.140	-4 806	3.234	5 793	146 07
243	- 425	.209	-4 557	3 064	5 491	146 10
292	-.488	243	-4 448	3.039	5 387	145 67
.341	-.551	.294	-3.123	2 919	4.274	136 96
399	-.643	.402	-4.844	3 184	5 797	146 69
440	-.716	.440	-5.167	3 031	5 990	149 62
487	- 729	488	-8 226	4 227	9 248	152 81
.537	-.323	.538	-7 658	3 392	8 375	156 12
585	-.254	.584	-1 227	-.746	1 436	-148 73
634	-.180	.633	-.087	- 862	.866	-95 74
.682	- 130	.733	- 160	- 930	943	-99 78
733	- 060	.781	.002	-.851	.851	-89 85
827	042	829	.112	- 740	748	-81 43
874	092	.872	.103	- 531	541	-79 00
924	.140	.941	.085	- 224	.239	-69 32

----------------------LOWER SURFACE----------------------

STEADY DATA		UNSTEADY DATA				
----CPL-----		-----------------CPL,A-----------------				
X/C	CPL	X/C	REAL	IMAG	MAG	PHASE
000	- 021	034	6 553	-5 203	8.367	-38 46
053	- 187	054	6.738	-4 585	8.150	-34.23
.142	- 309	094	5 618	-3 745	6 752	-33 69
244	- 450	.141	5 340	-3 573	6 425	-33 79
293	- 497	200	4 880	-3.279	5 879	-33 90
341	- 523	243	4.535	-2.901	5.384	-32.61
.393	- 627	.293	3 465	-2 211	4.111	-32.55
440	-.713	341	2.981	-1.824	3.495	-31.47
490	-.786	.394	4 334	-2.487	4 997	-29 85
537	- 358	490	8 028	-2.483	8.404	-17.19
583	- 254	582	2 184	.225	2.196	5 89
625	- 197	631	.711	.836	1.098	49 63
679	- 137	.678	260	.957	.991	74 81
.734	- 071	733	- 003	.825	825	90 19
789	- 008	781	009	713	.713	89 30
332	042	888	- 133	446	.466	106.65
886	111	923	- 150	.277	.315	118.56
941	167					

TABLE 2.14. MEAN AND FUNDAMENTAL FREQUENCY PRESSURE DATA FOR AGARD CT CASE NO. 10; DYNAMIC INDEX 12

WING MODEL: NACA 64A010, CHORD= .500 METERS

WING MOTION: PITCHING .94 DEG ABOUT X/C= .232

DYNAMIC INDEX 12 STATIC INDEX 13

M	.802	PTOT	50763	K	.200
ALPHA	-.00	QINF	14953	FREQ	33.2
RE	3.40E 06	PINF	33251		

UPPER SURFACE

STEADY DATA		UNSTEADY DATA				
----CPU----		----CPU,A----				
X/C	CPU	X/C	REAL	IMAG	MAG	PHASE
.030	-.121	.033	-3.850	4.490	5.915	130.62
.052	-.169	.052	-4.211	3.919	5.752	137.06
.091	-.242	.091	-3.825	3.394	5.114	138.42
.142	-.339	.140	-3.325	2.834	4.369	139.58
.211	-.426	.209	-2.990	2.804	4.099	136.86
.243	-.465	.243	-3.110	3.128	4.411	134.85
.292	-.522	.339	-3.189	2.987	4.370	136.89
.341	-.576	.402	-4.394	3.759	5.782	139.46
.440	-.693	.440	-5.819	3.668	6.879	147.78
.487	-.659	.488	-6.677	4.318	7.952	147.12
.537	-.396	.538	-11.290	3.568	11.841	162.47
.585	-.224	.584	-.470	-2.720	2.760	-99.81
.634	-.160	.633	.055	-2.592	2.593	-88.80
.682	-.115	.682	.309	-2.120	2.142	-81.72
.733	-.053	.733	.256	-1.560	1.580	-80.67
.783	-.001	.781	.086	-1.494	1.497	-86.72
.827	.039	.829	.082	-1.181	1.184	-86.05
.874	.088	.872	.088	-1.029	1.033	-85.12
.924	.135	.941	.009	-.543	.543	-89.05

LOWER SURFACE

STEADY DATA		UNSTEADY DATA				
----CPL----		----CPL,A----				
X/C	CPL	X/C	REAL	IMAG	MAG	PHASE
.053	-.186	.000	.345	-.322	.472	-43.03
.093	-.223	.034	4.863	-4.966	6.950	-45.61
.142	-.315	.054	4.415	-4.477	6.298	-45.40
.199	-.358	.094	3.797	-3.665	5.277	-43.99
.244	-.448	.141	3.528	-3.349	4.865	-43.52
.293	-.503	.200	3.291	-2.883	4.375	-41.23
.341	-.551	.243	3.365	-2.925	4.459	-41.00
.393	-.627	.293	3.196	-2.883	4.304	-42.06
.440	-.672	.341	3.578	-3.096	4.731	-40.87
.490	-.673	.394	3.637	-2.697	4.527	-36.56
.537	-.399	.441	6.015	-2.916	6.684	-25.86
.583	-.244	.490	8.838	-3.331	9.445	-20.65
.625	-.179	.537	12.947	2.056	13.109	9.02
.679	-.124	.582	.946	2.606	2.772	70.06
.734	-.061	.631	-.459	2.321	2.366	101.20
.789	-.004	.678	-.449	2.024	2.073	102.52
.832	.043	.733	-.433	1.191	1.268	110.00
.886	.106	.781	-.163	1.086	1.098	98.55
.941	.160	.831	-.862	.712	1.118	140.46
		.888	-.389	.069	.395	169.89
		.923	-.219	.484	.531	114.40

TABLE 2.15. INSTANTANEOUS LIFT AND MOMENT DATA; CT CASE NO. 6, DYNAMIC INDEX 55

	TAU	WT,DEG	ALPHA	CL UP	CL LO	CL	CLN=1	CM UP	CM LO	CM	CMN=1
1	-.5	-5.49	1.02	-.0386	.0520	.0907	.0822	.0014	-.0045	-.0057	-.0044
2	.0	.51	1.02	-.0404	.0531	.0935	.0969	.0010	-.0030	-.0041	-.0031
3	.6	6.51	1.01	-.0413	.0530	.0944	.0907	.0003	-.0017	-.0020	-.0019
4	1.1	12.51	.99	-.0429	.0530	.0958	.0935	-.0003	-.0005	-.0001	-.0006
5	1.6	18.51	.96	-.0435	.0529	.0964	.0952	-.0012	.0004	.0016	.0007
6	2.1	24.51	.91	-.0444	.0521	.0965	.0950	-.0019	.0012	.0031	.0019
7	2.6	30.51	.86	-.0444	.0503	.0947	.0956	-.0024	.0023	.0047	.0032
8	3.1	36.51	.80	-.0431	.0483	.0913	.0942	-.0027	.0033	.0061	.0044
9	3.7	42.51	.73	-.0418	.0466	.0884	.0918	-.0031	.0039	.0070	.0056
10	4.2	48.51	.65	-.0404	.0439	.0843	.0888	-.0034	.0043	.0077	.0067
11	4.7	54.51	.57	-.0397	.0468	.0865	.0840	-.0035	.0049	.0084	.0077
12	5.2	60.51	.46	-.0384	.0366	.0751	.0787	-.0034	.0056	.0090	.0087
13	5.7	66.51	.39	-.0369	.0312	.0681	.0725	-.0034	.0066	.0099	.0095
14	6.3	72.51	.29	-.0347	.0254	.0601	.0655	-.0032	.0074	.0106	.0103
15	6.8	78.51	.19	-.0308	.0212	.0520	.0578	-.0037	.0075	.0114	.0109
16	7.3	84.51	.09	-.0281	.0174	.0455	.0495	-.0038	.0075	.0113	.0110
17	7.8	90.51	-.01	-.0256	.0134	.0390	.0406	-.0038	.0075	.0113	.0118
18	8.3	96.51	-.12	-.0231	.0086	.0316	.0313	-.0036	.0074	.0110	.0121
19	8.8	102.51	-.22	-.0192	.0050	.0242	.0217	-.0034	.0069	.0104	.0122
20	9.4	108.51	-.31	-.0154	.0010	.0144	.0118	-.0040	.0067	.0107	.0122
21	9.9	114.51	-.41	-.0078	-.0030	.0048	.0018	-.0045	.0065	.0110	.0121
22	10.4	120.51	-.50	-.0010	-.0076	-.0067	-.0043	-.0050	.0066	.0116	.0117
23	10.9	126.51	-.58	.0063	-.0116	-.0179	-.0192	-.0058	.0060	.0122	.0119
24	11.4	132.51	-.66	.0141	-.0128	-.0269	-.0280	-.0062	.0059	.0121	.0119
25	11.9	138.51	-.74	.0203	-.0186	-.0389	-.0374	-.0055	.0050	.0105	.0102
26	12.5	144.51	-.81	.0254	-.0223	-.0477	-.0464	-.0056	.0044	.0100	.0095
27	13.0	150.51	-.87	.0310	-.0256	-.0566	-.0550	-.0055	.0035	.0090	.0086
28	13.5	156.51	-.92	.0353	-.0292	-.0644	-.0625	-.0051	.0029	.0080	.0077
29	14.0	162.51	-.96	.0371	-.0323	-.0693	-.0701	-.0040	.0026	.0066	.0061
30	14.5	168.51	-.99	.0392	-.0356	-.0708	-.0766	-.0035	.0022	.0056	.0055
31	15.0	174.51	-1.01	.0401	-.0384	-.0785	-.0822	-.0026	.0016	.0042	.0049
32	15.6	180.51	-1.02	.0426	-.0411	-.0837	-.0869	-.0022	.0011	.0033	.0031
33	16.1	186.51	-1.01	.0446	-.0439	-.0885	-.0907	-.0012	.0008	.0020	.0019
34	16.6	192.51	-1.00	.0454	-.0463	-.0917	-.0935	-.0003	.0001	.0004	.0006
35	17.1	198.51	-.97	.0461	-.0466	-.0928	-.0952	.0001	-.0007	-.0009	-.0007
36	17.6	204.51	-.93	.0473	-.0473	-.0946	-.0959	.0009	-.0014	-.0023	-.0015
37	18.1	210.51	-.87	.0470	-.0474	-.0944	-.0956	.0019	-.0020	-.0039	-.0032
38	18.7	216.51	-.81	.0463	-.0466	-.0929	-.0942	.0027	-.0030	-.0057	-.0048
39	19.2	222.51	-.70	.0442	-.0452	-.0894	-.0918	.0032	-.0033	-.0066	-.0056
40	19.7	228.51	-.67	.0438	-.0435	-.0872	-.0880	.0036	-.0040	-.0076	-.0067
41	20.2	234.51	-.58	.0413	-.0418	-.0831	-.0846	.0041	-.0044	-.0084	-.0077
42	20.7	240.51	-.50	.0387	-.0396	-.0782	-.0787	.0044	-.0047	-.0091	-.0087
43	21.3	246.51	-.40	.0349	-.0366	-.0715	-.0725	.0044	-.0050	-.0095	-.0095
44	21.8	252.51	-.30	.0311	[illegible]	[illegible]	-.0655	.0046	-.0052	-.0098	-.0105
45	22.3	258.51	-.20	.0276	-.0310	-.0586	-.0570	.0047	-.0054	-.0101	-.0109
46	22.8	264.51	-.10	.0234	-.0274	-.0508	-.0435	.0047	-.0050	-.0101	-.0114
47	23.3	270.51	.01	.0196	-.0239	-.0435	-.0407	.0049	-.0053	-.0101	-.0118
48	23.8	276.51	.11	.0164	-.0205	-.0369	-.0314	.0050	-.0055	-.0109	-.0121
49	24.4	282.51	.22	.0110	-.0170	-.0279	-.0217	.0049	-.0055	-.0104	-.0122
50	24.9	288.51	.32	.0051	-.0126	-.0187	-.0113	.0053	-.0055	-.0107	-.0122
51	25.4	294.51	.42	.0011	-.0087	-.0099	-.0019	.0057	-.0065	-.0108	-.0121
52	25.9	300.51	.51	-.0041	-.0029	.0062	.0162	.0058	-.0064	-.0106	-.0113
53	26.4	306.51	.60	-.0058	.0055	.0113	.0182	.0060	-.0053	-.0112	-.0110
54	26.9	312.51	.68	-.0114	.0124	.0238	.0279	.0050	-.0063	-.0119	-.0109
55	27.5	318.51	.76	-.0166	.0209	.0370	.0374	.0054	-.0061	-.0115	-.0102
56	28.0	324.51	.82	-.0229	.0277	.0506	.0464	.0052	-.0063	-.0115	-.0095
57	28.5	330.51	.88	-.0276	.0340	.0616	.0549	.0047	-.0062	-.0109	-.0084
58	29.0	336.51	.93	-.0309	.0402	.0711	.0629	.0037	-.0062	-.0100	-.0077
59	29.5	342.51	.97	-.0339	.0458	.0797	.0701	.0026	-.0060	-.0088	-.0066
60	30.0	348.51	1.00	-.0361	.0499	.0855	.0766	.0018	-.0052	-.0071	-.0055
61	30.6	354.51	1.02	-.0376	.0521	.0896	.0822	.0012	-.0043	-.0056	-.0044

TABLE 2.16. INSTANTANEOUS PRESSURES AT UPPER-SURFACE; CT CASE NO. 6, DYNAMIC INDEX 55

	J=	1	2	3	4	5	6	7	8	9	10	11	12	13
	PHASE,DEG=	-5.5	.5	6.5	12.5	18.5	24.5	30.5	36.5	42.5	48.5	54.5	60.5	66.5
	ALPHA,DEG=	1.019	1.021	1.012	.991	.958	.915	.862	.800	.730	.653	.570	.481	.387
I	X/C	* *	* *	* *	* *	* *	* *	CP *	* *	* *	* *	* *	* *	* *
1	.033	-.161	-.167	-.173	-.182	-.191	-.198	-.202	-.203	-.202	-.201	-.200	-.198	-.195
2	.052	-.187	-.196	-.204	-.210	-.214	-.218	-.222	-.225	-.225	-.224	-.222	-.219	-.217
3	.091	-.254	-.259	-.265	-.269	-.272	-.275	-.277	-.277	-.278	-.277	-.275	-.271	-.268
4	.140	-.339	-.346	-.350	-.355	-.358	-.360	-.362	-.364	-.364	-.363	-.361	-.358	-.356
5	.209	-.422	-.429	-.433	-.438	-.439	-.442	-.443	-.443	-.443	-.442	-.440	-.439	-.437
6	.243	-.468	-.474	-.480	-.484	-.486	-.488	-.490	-.490	-.490	-.488	-.487	-.486	-.484
7	.294	-.530	-.535	-.541	-.546	-.549	-.551	-.554	-.555	-.554	-.553	-.552	-.550	-.549
8	.402	-.709	-.715	-.720	-.721	-.723	-.726	-.727	-.724	-.723	-.722	-.724	-.723	-.716
9	.440	-.777	-.782	-.785	-.788	-.790	-.791	-.791	-.790	-.790	-.789	-.790	-.789	-.786
10	.488	-.777	-.786	-.792	-.795	-.796	-.795	-.794	-.792	-.792	-.795	-.793	-.789	-.784
11	.538	-.349	-.350	-.352	-.346	-.342	-.340	-.337	-.334	-.328	-.322	-.313	-.304	-.299
12	.584	-.262	-.259	-.247	-.240	-.238	-.233	-.229	-.223	-.219	-.215	-.213	-.213	-.217
13	.633	-.187	-.181	-.176	-.172	-.168	-.165	-.160	-.157	-.154	-.153	-.150	-.153	-.155.
14	.733	-.059	-.056	-.053	-.055	-.050	-.048	-.045	-.044	-.042	-.039	-.040	-.043	-.042
15	.781	-.008	-.004	-.002	-.000	.003	.006	.008	.007	.009	.009	.008	.007	.009
16	.829	.043	.047	.049	.055	.060	.064	.065	.067	.067	.066	.064	.061	.060
17	.872	.092	.094	.096	.098	.100	.101	.101	.102	.102	.103	.102	.102	.102
18	.941	.160	.159	.160	.161	.160	.160	.160	.160	.160	.160	.161	.162	.162

	J=	14	15	16	17	18	19	20	21	22	23	24	25	26
	PHASE,DEG=	72.5	78.5	84.5	90.5	96.5	102.5	108.5	114.5	120.5	126.5	132.5	138.5	144.5
	ALPHA,DEG=	.290	.190	.088	-.014	-.116	-.216	-.313	-.407	-.497	-.583	-.664	-.738	-.806
I	X/C	* *	* *	* *	* *	* *	* *	CP *	* *	* *	* *	* *	* *	* *
1	.033	-.190	-.185	-.179	-.171	-.164	-.157	-.146	-.137	-.126	-.113	-.099	-.087	-.072
2	.052	-.213	-.208	-.202	-.196	-.188	-.181	-.173	-.163	-.153	-.142	-.132	-.122	-.111
3	.091	-.264	-.260	-.255	-.250	-.248	-.242	-.237	-.229	-.218	-.209	-.200	-.191	-.183
4	.140	-.353	-.349	-.345	-.340	-.337	-.332	-.327	-.321	-.314	-.306	-.298	-.289	-.281
5	.209	-.435	-.431	-.428	-.423	-.419	-.416	-.411	-.405	-.399	-.392	-.385	-.377	-.370
6	.243	-.481	-.477	-.474	-.470	-.466	-.464	-.459	-.453	-.446	-.437	-.428	-.420	-.413
7	.294	-.544	-.541	-.538	-.537	-.536	-.532	-.523	-.515	-.509	-.502	-.493	-.484	-.475
8	.402	-.715	-.707	-.703	-.700	-.696	-.689	-.682	-.676	-.666	-.658	-.651	-.642	-.634
9	.440	-.783	-.781	-.778	-.774	-.769	-.763	-.757	-.749	-.742	-.738	-.733	-.725	-.718
10	.488	-.777	-.768	-.761	-.745	-.724	-.696	-.651	-.596	-.543	-.486	-.434	-.397	-.370
11	.538	-.297	-.293	-.285	-.278	-.273	-.266	-.262	-.261	-.259	-.259	-.259	-.261	-.263
12	.584	-.219	-.216	-.213	-.213	-.213	-.215	-.218	-.221	-.222	-.223	-.226	-.232	-.234
13	.633	-.153	-.148	-.147	-.150	-.151	-.155	-.150	-.148	-.151	-.153	-.148	-.158	-.161
14	.733	-.043	-.041	-.042	-.042	-.043	-.043	-.045	-.047	-.042	-.038	-.039	-.043	-.046
15	.781	.009	.009	.009	.008	.007	.010	.010	.008	.005	.007	.007	.006	.005
16	.829	.057	.056	.055	.055	.056	.058	.056	.054	.052	.052	.052	.053	.054
17	.872	.101	.101	.101	.101	.101	.101	.100	.099	.098	.098	.098	.096	.095
18	.941	.162	.164	.163	.162	.160	.158	.157	.157	.158	.156	.158	.161	.159

	J=	27	28	29	30	31	32	33	34	35	36	37	38	39
	PHASE,DEG=	150.5	156.5	162.5	168.5	174.5	180.5	186.5	192.5	198.5	204.5	210.5	216.5	222.5
	ALPHA,DEG=	-.866	-.918	-.960	-.991	-1.010	-1.018	-1.013	-.996	-.966	-.925	-.874	-.814	-.744
I	X/C	* *	* *	* *	* *	* *	* *	CP *	* *	* *	* *	* *	* *	* *
1	.033	-.057	-.043	-.032	-.025	-.018	-.012	-.008	-.001	.007	.012	.016	.019	.018
2	.052	-.099	-.088	-.077	-.068	-.060	-.052	-.045	-.037	-.031	-.027	-.024	-.021	-.021
3	.091	-.177	-.169	-.158	-.148	-.141	-.132	-.125	-.118	-.113	-.109	-.106	-.103	-.103
4	.140	-.274	-.265	-.258	-.250	-.243	-.235	-.228	-.222	-.218	-.214	-.210	-.209	-.208
5	.209	-.362	-.354	-.346	-.339	-.332	-.325	-.317	-.311	-.307	-.303	-.300	-.299	-.298
6	.243	-.403	-.394	-.386	-.379	-.373	-.363	-.355	-.349	-.346	-.342	-.340	-.338	-.337
7	.294	-.467	-.461	-.452	-.442	-.432	-.424	-.419	-.415	-.410	-.407	-.405	-.403	-.403
8	.402	-.626	-.615	-.609	-.598	-.587	-.578	-.568	-.560	-.549	-.535	-.526	-.518	-.514
9	.440	-.707	-.695	-.681	-.659	-.632	-.609	-.584	-.554	-.524	-.519	-.524	-.529	-.542
10	.488	-.346	-.340	-.346	-.352	-.364	-.369	-.371	-.379	-.392	-.404	-.411	-.419	-.420
11	.538	-.267	-.273	-.277	-.286	-.289	-.291	-.294	-.307	-.314	-.314	-.317	-.321	-.330
12	.584	-.237	-.241	-.247	-.250	-.252	-.253	-.261	-.271	-.274	-.280	-.284	-.290	-.301
13	.633	-.165	-.167	-.172	-.172	-.175	-.178	-.184	-.185	-.189	-.192	-.198	-.205	-.211
14	.733	-.049	-.048	-.050	-.055	-.057	-.057	-.060	-.060	-.065	-.068	-.073	-.075	-.079
15	.781	.003	.002	-.001	-.003	-.006	-.008	-.010	-.014	-.017	-.020	-.023	-.026	-.029
16	.829	.057	.057	.055	.053	.050	.047	.042	.037	.031	.029	.025	.022	.021
17	.872	.096	.094	.093	.092	.091	.091	.088	.086	.083	.083	.080	.078	.076
18	.941	.161	.159	.156	.156	.159	.158	.156	.154	.154	.153	.152	.150	.150

	J=	40	41	42	43	44	45	46	47	48	49	50	51	52
	PHASE,DEG=	228.5	234.5	240.5	246.5	252.5	258.5	264.5	270.5	276.5	282.5	288.5	294.5	300.5
	ALPHA,DEG=	-.668	-.585	-.496	-.402	-.303	-.202	-.098	.007	.112	.217	.319	.417	.511
I	X/C	* *	* *	* *	* *	* *	* *	CP *	* *	* *	* *	* *	* *	* *
1	.033	.018	.016	.015	.010	.003	-.003	-.009	-.016	-.024	-.033	-.041	-.048	-.055
2	.052	-.021	-.023	-.025	-.028	-.032	-.036	-.042	-.049	-.056	-.066	-.076	-.086	-.097
3	.091	-.103	-.104	-.106	-.109	-.114	-.118	-.125	-.130	-.136	-.145	-.154	-.162	-.171
4	.140	-.207	-.209	-.210	-.213	-.217	-.221	-.227	-.231	-.238	-.246	-.254	-.261	-.269
5	.209	-.297	-.298	-.301	-.303	-.306	-.311	-.317	-.322	-.330	-.338	-.344	-.352	-.359
6	.243	-.336	-.337	-.338	-.341	-.346	-.352	-.356	-.362	-.370	-.378	-.384	-.391	-.400
7	.294	-.403	-.406	-.408	-.411	-.415	-.420	-.424	-.430	-.439	-.446	-.453	-.460	-.468
8	.402	-.510	-.513	-.524	-.536	-.548	-.558	-.573	-.587	-.596	-.607	-.617	-.627	-.637
9	.440	-.554	-.571	-.587	-.604	-.622	-.638	-.652	-.664	-.677	-.687	-.699	-.710	-.719
10	.488	-.430	-.442	-.459	-.478	-.484	-.493	-.503	-.510	-.521	-.540	-.566	-.588	-.612
11	.538	-.340	-.354	-.352	-.354	-.353	-.356	-.356	-.352	-.354	-.357	-.356	-.354	-.356
12	.584	-.309	-.306	-.309	-.306	-.310	-.310	-.305	-.309	-.308	-.306	-.303	-.305	-.300
13	.633	-.213	-.216	-.215	-.215	-.215	-.212	-.216	-.217	-.217	-.216	-.218	-.216	-.217
14	.733	-.080	-.082	-.084	-.084	-.083	-.085	-.086	-.086	-.085	-.085	-.083	-.082	-.083
15	.781	-.029	-.029	-.029	-.030	-.030	-.030	-.028	-.029	-.029	-.028	-.028	-.029	-.029
16	.829	.022	.023	.026	.027	.026	.028	.029	.027	.027	.028	.028	.028	.028
17	.872	.077	.078	.077	.077	.077	.078	.078	.078	.079	.080	.080	.079	.081
18	.941	.150	.151	.151	.150	.151	.152	.153	.153	.155	.153	.150	.149	.152

TABLE 2.16 CONCLUDED.

J=		53	54	55	56	57	58	59	60	61	62	63	64	65
PHASE,DEG=		306.5	312.5	318.5	324.5	330.5	336.5	342.5	348.5	354.5	360.5	366.5	372.5	378.5
ALPHA,DEG=		.599	.681	.756	.823	.882	.931	.971	1.000	1.017	1.021	1.014	.994	.963
I	X/C	* *	* *	* *	* *	* *	* *	CP *	* *	* *	* *	* *	* *	* *
1	.033	-.062	-.074	-.089	-.104	-.118	-.129	-.142	-.152	-.160	-.167	-.173	-.181	-.190
2	.052	-.107	-.117	-.128	-.138	-.149	-.158	-.168	-.177	-.186	-.195	-.204	-.210	-.213
3	.091	-.181	-.189	-.200	-.210	-.219	-.228	-.236	-.245	-.253	-.259	-.265	-.269	-.271
4	.140	-.277	-.286	-.295	-.303	-.310	-.318	-.326	-.333	-.339	-.345	-.350	-.354	-.357
5	.209	-.367	-.376	-.384	-.391	-.398	-.405	-.411	-.417	-.422	-.428	-.432	-.435	-.439
6	.243	-.409	-.420	-.428	-.434	-.440	-.447	-.454	-.462	-.468	-.473	-.478	-.482	-.486
7	.294	-.478	-.485	-.493	-.499	-.506	-.513	-.519	-.524	-.530	-.533	-.538	-.544	-.548
8	.402	-.648	-.656	-.665	-.673	-.683	-.689	-.695	-.700	-.706	-.712	-.718	-.722	-.724
9	.440	-.727	-.735	-.743	-.750	-.758	-.762	-.765	-.771	-.775	-.779	-.785	-.789	-.790
10	.488	-.636	-.657	-.681	-.705	-.720	-.733	-.748	-.762	-.774	-.784	-.793	-.796	-.795
11	.538	-.354	-.352	-.352	-.353	-.352	-.351	-.352	-.351	-.348	-.347	-.348	-.345	-.342
12	.584	-.297	-.292	-.291	-.287	-.284	-.280	-.272	-.267	-.263	-.259	-.251	-.243	-.238
13	.633	-.215	-.214	-.210	-.206	-.204	-.201	-.198	-.191	-.187	-.183	-.178	-.173	-.169
14	.733	-.083	-.081	-.080	-.077	-.076	-.071	-.068	-.064	-.059	-.055	-.053	-.052	-.051
15	.781	-.025	-.023	-.021	-.022	-.020	-.016	-.015	-.012	-.008	-.004	-.003	-.000	.004
16	.829	.029	.030	.031	.029	.031	.034	.036	.040	.044	.047	.049	.055	.059
17	.872	.082	.084	.084	.083	.086	.087	.088	.092	.093	.094	.095	.098	.099
18	.941	.155	.158	.158	.154	.153	.155	.158	.160	.161	.159	.160	.161	.160

TABLE 2.17. STEADY AND FUNDAMENTAL FREQUENCY PRESSURE DATA; SHOCK-STALL CASE

WING MODEL· NACA 64A010, CHORD= 500 METERS

WING MOTION PITCHING 1 01 DEG ABOUT X/C= 249

DYNAMIC INDEX 89 STATIC INDEX 44

M	789	PTOT	203:69	K	204
ALPHA	4 00	QINF	58714	FREQ	35 1
RE	1 20E 07	PINF	134741		

------------------------UPPER SURFACE------------------------

STEADY DATA		UNSTEADY DATA				
----CPU-----		----------------CPU,A----------------				
X/C	CPU	X/C	REAL	IMAG	MAG	PHASE
000	- 957	052	-3 932	3 115	5 017	141 62
.091	- 947	.091	-3 834	3 334	5 080	139 00
.142	- 969	.140	-3 779	3 908	5 436	134 05
211	- 970	209	-2 688	3 398	4 332	129 35
243	- 997	243	-2 405	3 587	4 319	123 85
.292	-1.049	.294	-2 030	4.143	4 613	116 11
.341	-1 073	339	-3 139	.388	3 163	172 97
.399	-1.109	.402	-12.419	-18 554	22 326	-123 81
.440	- 649	.440	-12.228	-16 425	20 [illegible]	-126 67
487	- 534	.439	-13 076	-15 031	19 923	-131 03
.537	- 487	.538	-6 693	-3 861	7 727	-150 03
585	- 449	584	-7 341	-1 110	7 425	-171 36
.634	- 397	.633	-8 079	1 800	8 276	167 45
.682	- 337	.733	-6.750	7 405	10 019	132 36
.733	- 274	.781	-5.424	9 110	10 602	120 78
.783	- 212	.829	-4.112	10 248	11 695	110 59
.827	- 153	872	-2 369	11 049	11 305	102 21
.874	- 099	941	- 094	10 483	10 483	90 52
.924	- 045					

------------------------LOWER SURFACE------------------------

STEADY DATA		UNSTEADY DATA				
----CPL-----		----------------CPL,A----------------				
X/C	CPL	X/C	REAL	IMAG	MAG	PHASE
053	331	034	4 331	-2 837	5 178	-33 22
.093	.272	.054	4 151	-2 662	4 931	-32 67
.142	114	.094	3 763	-2.271	4 396	-31.11
.199	- 016	141	3 962	-2 219	4 454	-29 88
244	- 062	.200	3.102	-1.535	3.483	-27 07
293	- 136	243	3 841	-1.621	4 169	-22 88
341	- 183	.293	3 542	-1.189	3.736	-18.55
393	- 265	.341	4 331	- 979	4 440	-12 74
.430	- 339	394	5 119	- 536	5 147	-5 98
537	- 256	.490	6 032	1.339	6 179	12 51
583	- 251	.582	5 072	2.800	5.794	28 91
625	- 217	631	7 415	2 512	7.829	18 72
.679	- 178	.678	3 895	3.742	5.401	43 85
.734	- 128	.733	3 628	4 011	5.409	47 87
789	- 076	.781	3.555	4 657	5 859	52 85
.832	- 048	888	2 356	5 449	5 937	66.63
.886	- 002	923	2 323	6 536	6 937	70.44
941	016					

TABLE 2.18. INSTANTANEOUS PRESSURES AT UPPER-SURFACE; SHOCK STALL CASE, DYNAMIC INDEX 89

	J=	1	2	3	4	5	6	7	8	9	10	11	12	13
	PHASE,DEG=	-11.2	-5.2	.8	6.8	12.8	18.8	24.8	30.8	36.8	42.8	48.8	54.8	60.8
	ALPHA,DEG=	1.009	1.025	1.028	1.019	.998	.966	.923	.870	.809	.739	.662	.577	.487
I	X/C	* *	* *	* *	* *	* *	* *	* CP *	* *	* *	* *	* *	* *	* *
1	.052	-1.013	-1.022	-1.028	-1.033	-1.037	-1.040	-1.041	-1.041	-1.040	-1.039	-1.036	-1.033	-1.030
2	.091	-1.009	-1.017	-1.023	-1.027	-1.032	-1.036	-1.037	-1.038	-1.039	-1.037	-1.035	-1.032	-1.028
3	.140	-1.033	-1.042	-1.049	-1.054	-1.058	-1.061	-1.063	-1.064	-1.064	-1.063	-1.061	-1.059	-1.055
4	.209	-1.014	-1.021	-1.028	-1.034	-1.039	-1.043	-1.045	-1.047	-1.047	-1.047	-1.046	-1.045	-1.042
5	.243	-1.037	-1.045	-1.050	-1.056	-1.062	-1.066	-1.069	-1.071	-1.072	-1.072	-1.071	-1.071	-1.068
6	.294	-1.084	-1.092	-1.100	-1.109	-1.117	-1.121	-1.122	-1.126	-1.128	-1.126	-1.128	-1.128	-1.124
7	.339	-1.139	-1.147	-1.155	-1.162	-1.168	-1.172	-1.176	-1.179	-1.181	-1.182	-1.183	-1.182	-1.172
8	.402	-1.402	-1.412	-1.422	-1.429	-1.437	-1.444	-1.447	-1.424	-1.325	-1.119	-.910	-.803	-.744
9	.440	-.991	-.997	-1.000	-1.005	-.987	-.888	-.715	-.580	-.504	-.462	-.436	-.420	-.404
10	.488	-.853	-.728	-.632	-.564	-.521	-.485	-.457	-.431	-.408	-.392	-.373	-.355	-.343
11	.538	-.623	-.610	-.596	-.581	-.569	-.557	-.539	-.527	-.513	-.497	-.483	-.471	-.455
12	.584	-.595	-.591	-.585	-.578	-.572	-.564	-.548	-.536	-.519	-.504	-.490	-.475	-.461
13	.633	-.562	-.566	-.561	-.565	-.554	-.543	-.534	-.524	-.510	-.495	-.480	-.466	-.447
14	.733	-.414	-.429	-.446	-.455	-.464	-.471	-.464	-.454	-.448	-.437	-.429	-.417	-.405
15	.781	-.321	-.340	-.364	-.386	-.400	-.413	-.421	-.412	-.411	-.405	-.400	-.387	-.381
16	.829	-.207	-.233	-.268	-.300	-.329	-.345	-.362	-.365	-.364	-.370	-.363	-.361	-.354
17	.872	-.093	-.126	-.163	-.188	-.226	-.257	-.285	-.295	-.306	-.318	-.316	-.319	-.314
18	.941	.052	.024	-.001	-.038	-.077	-.119	-.153	-.180	-.200	-.215	-.226	-.229	-.231

	J=	14	15	16	17	18	19	20	21	22	23	24	25	26
	PHASE,DEG=	66.8	72.8	78.8	84.8	90.8	96.8	102.8	108.8	114.8	120.8	126.8	132.8	138.8
	ALPHA,DEG=	.392	.294	.192	.088	-.016	-.120	-.223	-.324	-.421	-.514	-.602	-.684	-.759
I	X/C	* *	* *	* *	* *	* *	* *	* CP *	* *	* *	* *	* *	* *	* *
1	.052	-1.024	-1.019	-1.012	-1.006	-.998	-.991	-.983	-.974	-.966	-.958	-.950	-.941	-.933
2	.091	-1.024	-1.019	-1.014	-1.008	-1.000	-.993	-.987	-.979	-.971	-.964	-.955	-.946	-.936
3	.140	-1.051	-1.047	-1.042	-1.037	-1.031	-1.024	-1.016	-1.008	-1.000	-.991	-.982	-.973	-.964
4	.209	-1.039	-1.035	-1.032	-1.027	-1.022	-1.016	-1.010	-1.004	-.998	-.991	-.984	-.976	-.969
5	.243	-1.066	-1.063	-1.060	-1.056	-1.052	-1.047	-1.041	-1.036	-1.030	-1.024	-1.018	-1.012	-1.005
6	.294	-1.123	-1.121	-1.119	-1.116	-1.111	-1.108	-1.104	-1.098	-1.095	-1.089	-1.081	-1.077	-1.073
7	.339	-1.139	-1.099	-1.051	-1.010	-.982	-.964	-.963	-.966	-.968	-.977	-.988	-.995	-1.010
8	.402	-.714	-.694	-.683	-.674	-.664	-.657	-.655	-.653	-.651	-.653	-.655	-.658	-.661
9	.440	-.393	-.381	-.375	-.371	-.363	-.359	-.357	-.355	-.352	-.348	-.351	-.350	-.351
10	.488	-.335	-.328	-.325	-.314	-.311	-.299	-.301	-.295	-.294	-.296	-.290	-.288	-.290
11	.538	-.445	-.433	-.428	-.424	-.413	-.412	-.406	-.402	-.399	-.389	-.389	-.386	-.385
12	.584	-.447	-.438	-.426	-.421	-.415	-.404	-.402	-.399	-.395	-.387	-.388	-.382	-.372
13	.633	-.435	-.425	-.413	-.408	-.400	-.391	-.384	-.375	-.375	-.368	-.366	-.351	-.345
14	.733	-.399	-.382	-.373	-.365	-.358	-.351	-.338	-.332	-.325	-.318	-.304	-.295	-.266
15	.781	-.371	-.356	-.346	-.338	-.332	-.323	-.303	-.304	-.290	-.288	-.274	-.264	-.251
16	.829	-.344	-.334	-.319	-.311	-.301	-.300	-.282	-.274	-.258	-.255	-.244	-.225	-.223
17	.872	-.308	-.298	-.287	-.279	-.265	-.263	-.255	-.240	-.224	-.209	-.210	-.166	-.177
18	.941	-.231	-.229	-.219	-.210	-.199	-.191	-.169	-.176	-.168	-.149	-.143	-.134	-.113

	J=	27	28	29	30	31	32	33	34	35	36	37	38	39
	PHASE,DEG=	144.8	150.8	156.8	162.8	168.8	174.8	180.8	186.8	192.8	198.8	204.8	210.8	216.8
	ALPHA,DEG=	-.827	-.886	-.936	-.975	-1.003	-1.019	-1.022	-1.013	-.995	-.961	-.918	-.865	-.804
I	X/C	* *	* *	* *	* *	* *	* *	* CP *	* *	* *	* *	* *	* *	* *
1	.052	-.923	-.914	-.905	-.897	-.890	-.885	-.880	-.875	-.871	-.868	-.866	-.865	-.866
2	.091	-.925	-.914	-.907	-.898	-.891	-.885	-.880	-.874	-.870	-.866	-.863	-.861	-.862
3	.140	-.954	-.945	-.936	-.928	-.919	-.911	-.904	-.898	-.892	-.888	-.884	-.882	-.881
4	.209	-.961	-.954	-.948	-.941	-.935	-.929	-.924	-.919	-.915	-.912	-.910	-.908	-.906
5	.243	-.998	-.991	-.985	-.976	-.970	-.963	-.958	-.953	-.948	-.944	-.940	-.937	-.934
6	.294	-1.065	-1.058	-1.049	-1.040	-1.033	-1.026	-1.019	-1.013	-1.007	-1.002	-1.001	-.995	-.990
7	.339	-1.031	-1.043	-1.061	-1.067	-1.068	-1.075	-1.079	-1.076	-1.074	-1.071	-1.068	-1.065	-1.060
8	.402	-.668	-.681	-.694	-.717	-.747	-.793	-.859	-.946	-1.053	-1.168	-1.262	-1.320	-1.339
9	.440	-.348	-.349	-.348	-.357	-.365	-.375	-.387	-.405	-.425	-.454	-.494	-.550	-.629
10	.488	-.288	-.290	-.290	-.290	-.293	-.292	-.299	-.307	-.316	-.331	-.348	-.365	-.386
11	.538	-.378	-.371	-.367	-.369	-.373	-.371	-.372	-.373	-.375	-.377	-.384	-.391	-.403
12	.584	-.369	-.359	-.355	-.349	-.342	-.335	-.328	-.325	-.323	-.321	-.321	-.317	-.324
13	.633	-.340	-.331	-.321	-.309	-.303	-.295	-.281	-.276	-.265	-.257	-.246	-.238	-.229
14	.733	-.273	-.271	-.249	-.239	-.221	-.205	-.185	-.175	-.160	-.139	-.121	-.105	-.091
15	.781	-.236	-.228	-.209	-.198	-.182	-.160	-.147	-.134	-.110	-.089	-.069	-.054	-.039
16	.829	-.200	-.193	-.180	-.159	-.136	-.113	-.090	-.065	-.044	-.020	.005	.022	.027
17	.872	-.164	-.148	-.145	-.122	-.096	-.080	-.067	-.038	-.025	-.009	.021	.037	.050
18	.941	-.108	-.092	-.081	-.067	-.046	-.036	-.017	-.003	.017	.031	.049	.070	.082

	J=	40	41	42	43	44	45	46	47	48	49	50	51	52
	PHASE,DEG=	222.8	228.8	234.8	240.8	246.8	252.8	258.8	264.8	270.8	276.8	282.8	288.8	294.8
	ALPHA,DEG=	-.735	-.658	-.575	-.486	-.395	-.295	-.194	-.091	.013	.117	.219	.320	.417
I	X/C	* *	* *	* *	* *	* *	* *	* CP *	* *	* *	* *	* *	* *	* *
1	.052	-.868	-.869	-.870	-.870	-.872	-.877	-.881	-.886	-.893	-.899	-.906	-.913	-.920
2	.091	-.863	-.864	-.863	-.863	-.866	-.870	-.874	-.879	-.885	-.893	-.901	-.909	-.917
3	.140	-.880	-.878	-.875	-.874	-.876	-.878	-.882	-.886	-.892	-.899	-.907	-.916	-.925
4	.209	-.904	-.899	-.894	-.893	-.894	-.895	-.896	-.898	-.902	-.906	-.911	-.917	-.925
5	.243	-.931	-.924	-.919	-.918	-.917	-.917	-.918	-.919	-.923	-.928	-.933	-.940	-.949
6	.294	-.984	-.974	-.967	-.965	-.963	-.960	-.960	-.959	-.963	-.966	-.972	-.981	-.991
7	.339	-1.052	-1.042	-1.037	-1.036	-1.032	-1.029	-1.026	-1.025	-1.026	-1.025	-1.029	-1.035	-1.043
8	.402	-1.334	-1.327	-1.323	-1.319	-1.313	-1.307	-1.301	-1.299	-1.297	-1.296	-1.299	-1.305	-1.311
9	.440	-.740	-.849	-.904	-.919	-.918	-.916	-.916	-.916	-.915	-.915	-.919	-.925	-.929
10	.488	-.410	-.439	-.466	-.500	-.543	-.603	-.678	-.775	-.876	-.947	-.976	-.986	-.990
11	.538	-.416	-.432	-.452	-.470	-.487	-.503	-.519	-.534	-.553	-.573	-.592	-.611	-.626
12	.584	-.333	-.341	-.357	-.374	-.394	-.415	-.433	-.452	-.473	-.492	-.512	-.532	-.549
13	.633	-.233	-.240	-.240	-.257	-.271	-.287	-.311	-.330	-.350	-.371	-.395	-.420	-.446
14	.733	-.081	-.075	-.072	-.072	-.076	-.086	-.095	-.106	-.117	-.133	-.144	-.159	-.178
15	.781	-.026	-.020	-.018	-.018	-.021	-.030	-.035	-.043	-.050	-.057	-.061	-.069	-.076
16	.829	.037	.044	.045	.042	.044	.036	.031	.027	.022	.020	.017	.014	.012
17	.872	.065	.075	.081	.081	.082	.078	.074	.070	.064	.060	.056	.058	.053
18	.941	.095	.111	.120	.126	.129	.132	.132	.132	.130	.131	.127	.125	.126

TABLE 2.18 CONCLUDED.

	J=	53	54	55	56	57	58	59	60	61	62	63	64	65
	PHASE,DEG=	[illegible]	[illegible]	[illegible]	[illegible]	524.8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	ALPHA,DEG=	[illegible]	[illegible]	[illegible]	.757	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1.125	[illegible]	[illegible]	[illegible]
I	X/C	* *	* *	* *	* *	* *	* *	* CP *	* *	* *	* *	* *	* *	* *
1	.032	-.925	-.938	-.947	-.958	-.970	-.981	-.992	-1.002	-1.012	-1.021	-1.028	-1.033	-1.037
2	.091	-.927	-.936	-.946	-.956	-.967	-.980	-.990	-.998	-1.007	-1.015	-1.021	-1.027	-1.032
3	.140	-.937	-.948	-.960	-.973	-.986	-.998	-1.010	-1.021	-1.031	-1.040	-1.047	-1.054	-1.058
4	.209	-.932	-.940	-.950	-.961	-.972	-.983	-.993	-1.003	-1.012	-1.021	-1.027	-1.034	-1.039
5	.243	-.959	-.968	-.977	-.987	-.996	-1.008	-1.017	-1.027	-1.035	-1.043	-1.049	-1.056	-1.061
6	.294	-.999	-1.009	-1.019	-1.029	-1.041	-1.052	-1.062	-1.072	-1.082	-1.091	-1.100	-1.107	-1.115
7	.359	-1.050	-1.060	-1.071	-1.084	-1.096	-1.108	-1.118	-1.129	-1.139	-1.147	-1.154	-1.161	-1.167
8	.402	-1.317	-1.326	-1.336	-1.347	-1.359	-1.370	-1.380	-1.391	-1.400	-1.410	-1.421	-1.428	-1.435
9	.440	-.933	-.939	-.946	-.954	-.961	-.968	-.976	-.984	-.991	-.996	-1.011	-1.001	-.970
10	.488	-.994	-1.003	-1.012	-1.021	-1.025	-1.031	-1.031	-.990	-.865	-.726	-.625	-.559	-.517
11	.536	-.642	-.653	-.659	-.659	-.654	-.644	-.635	-.629	-.619	-.608	-.594	-.579	-.569
12	.584	-.563	-.576	-.586	-.590	-.594	-.596	-.592	-.594	-.593	-.587	-.580	-.576	-.568
13	.653	-.471	-.493	-.513	-.526	-.538	-.549	-.552	-.560	-.562	-.562	-.562	-.560	-.556
14	.733	-.203	-.230	-.261	-.291	-.318	-.353	-.378	-.405	-.416	-.434	-.443	-.455	-.462
15	.781	-.087	-.102	-.122	-.149	-.190	-.218	-.265	-.300	-.320	-.345	-.369	-.377	-.398
16	.829	.011	.005	-.007	-.021	-.044	-.080	-.118	-.162	-.210	-.239	-.270	-.296	-.323
17	.872	.057	.057	.054	.048	.038	.021	-.012	-.050	-.084	-.124	-.159	-.197	-.224
18	.941	.126	.127	.128	.127	.124	.113	.101	.083	.057	.028	-.003	-.038	-.075

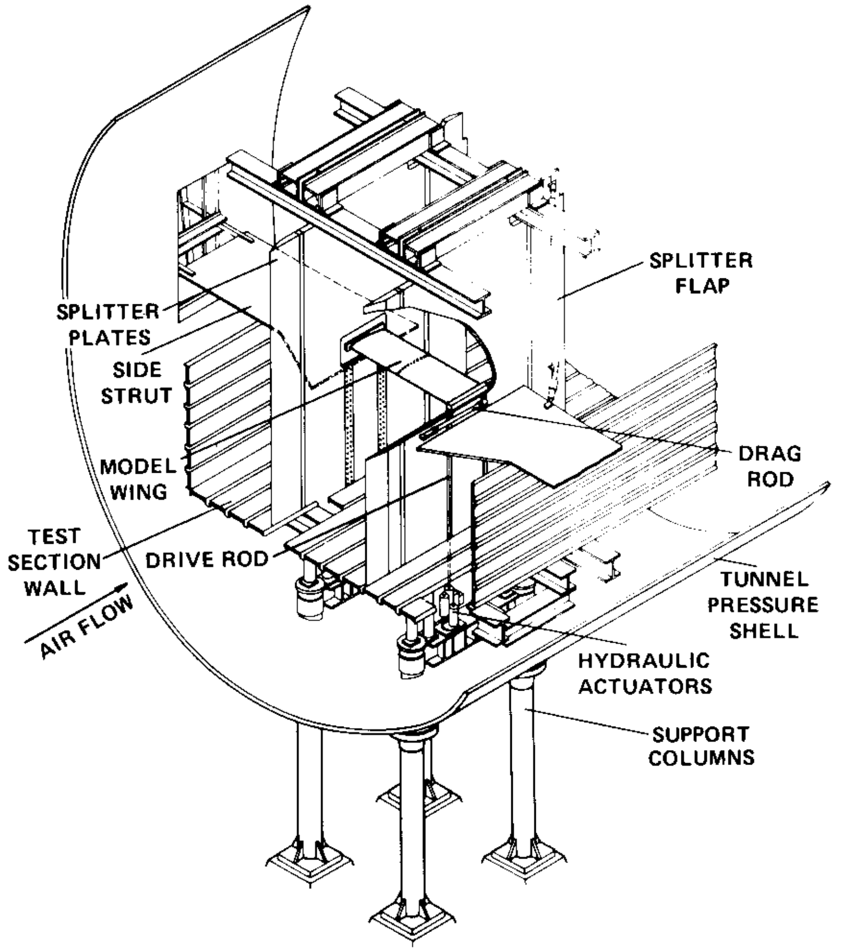


Fig. 2.1. General arrangement of oscillating airfoil test apparatus in NASA Ames 11- by 11-Foot Transonic Wind Tunnel.

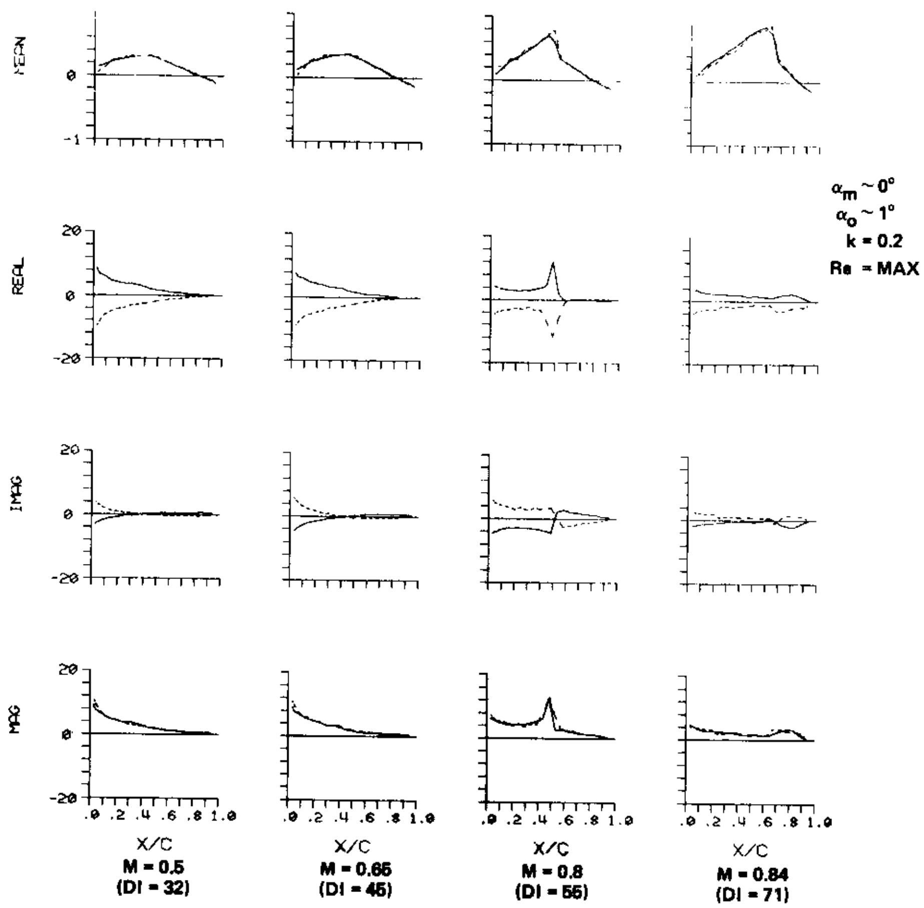


Fig. 2.2. Effect of varying Mach number.

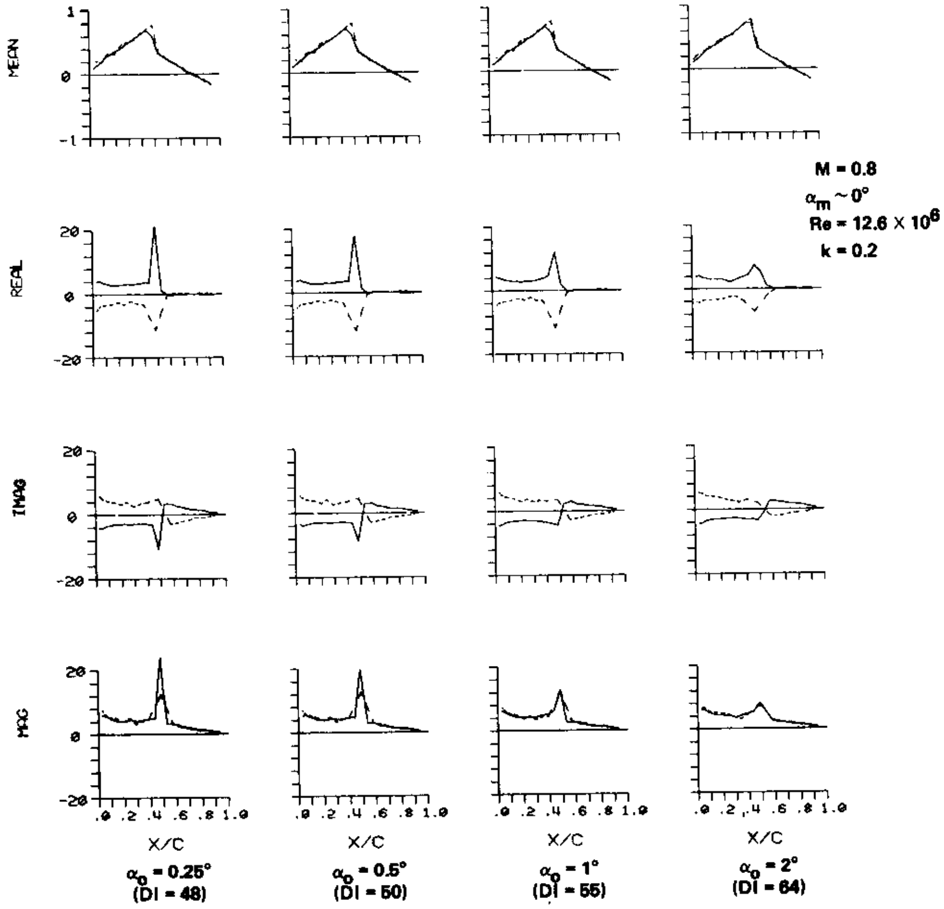


Fig. 2.3. Effect of varying oscillation amplitude.

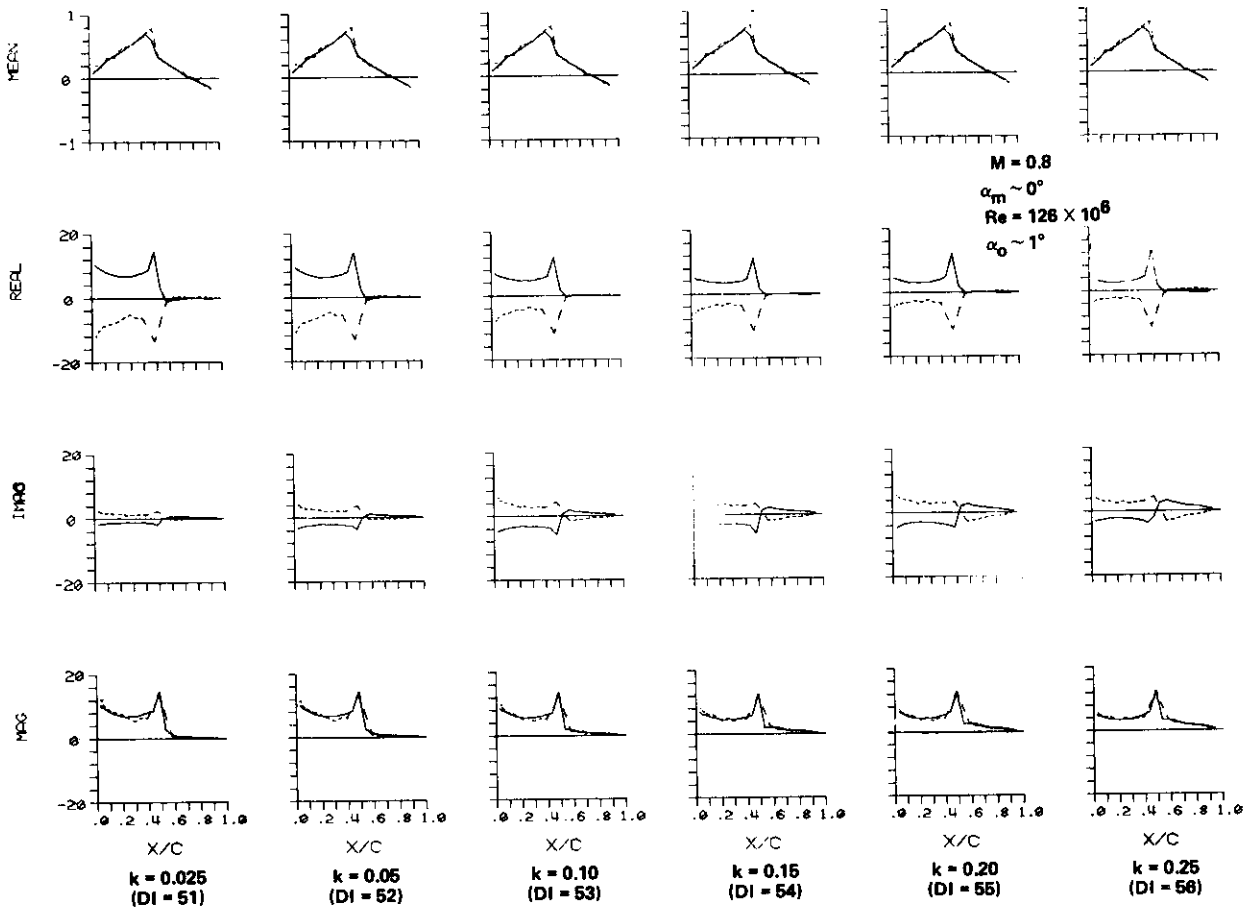


Fig. 2.4. Effect of varying frequency parameter.

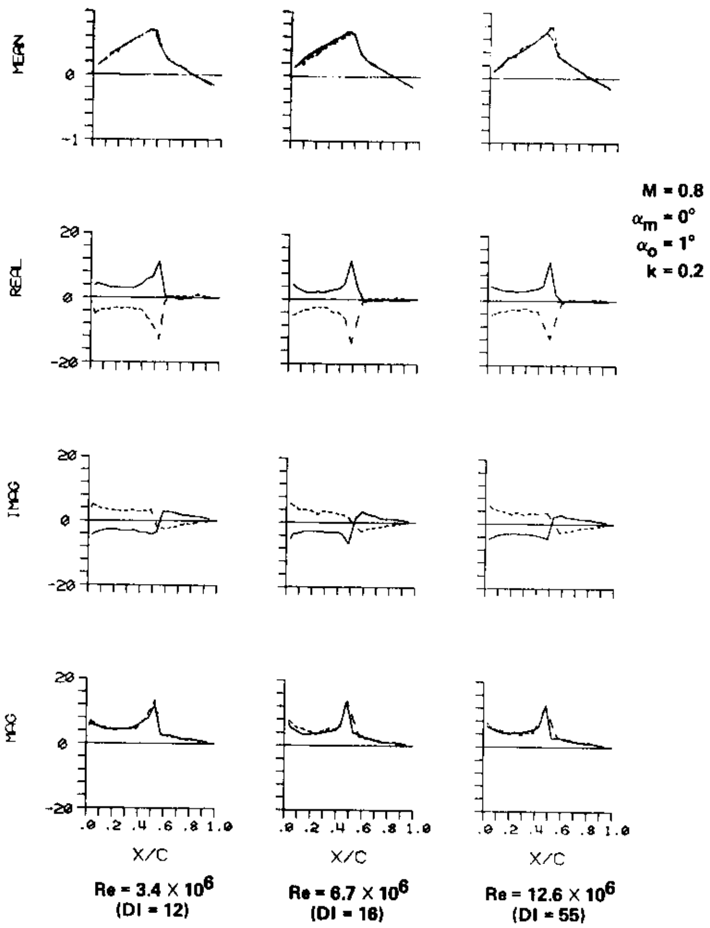


Fig. 2.5. Effect of varying Reynolds number.

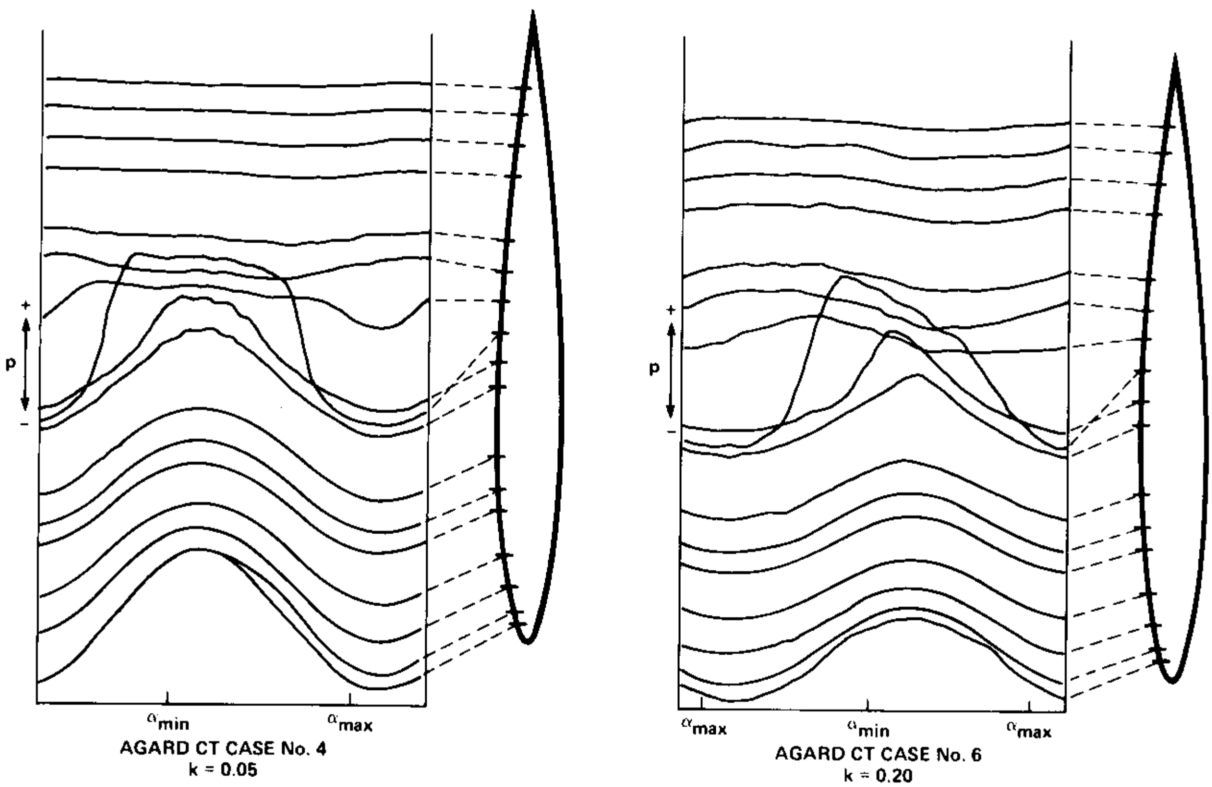


Fig. 2.6. Unsteady pressure time-histories for AGARD CT Cases 4 and 6.
$M = 0.8$, $\alpha_m = 0°$.

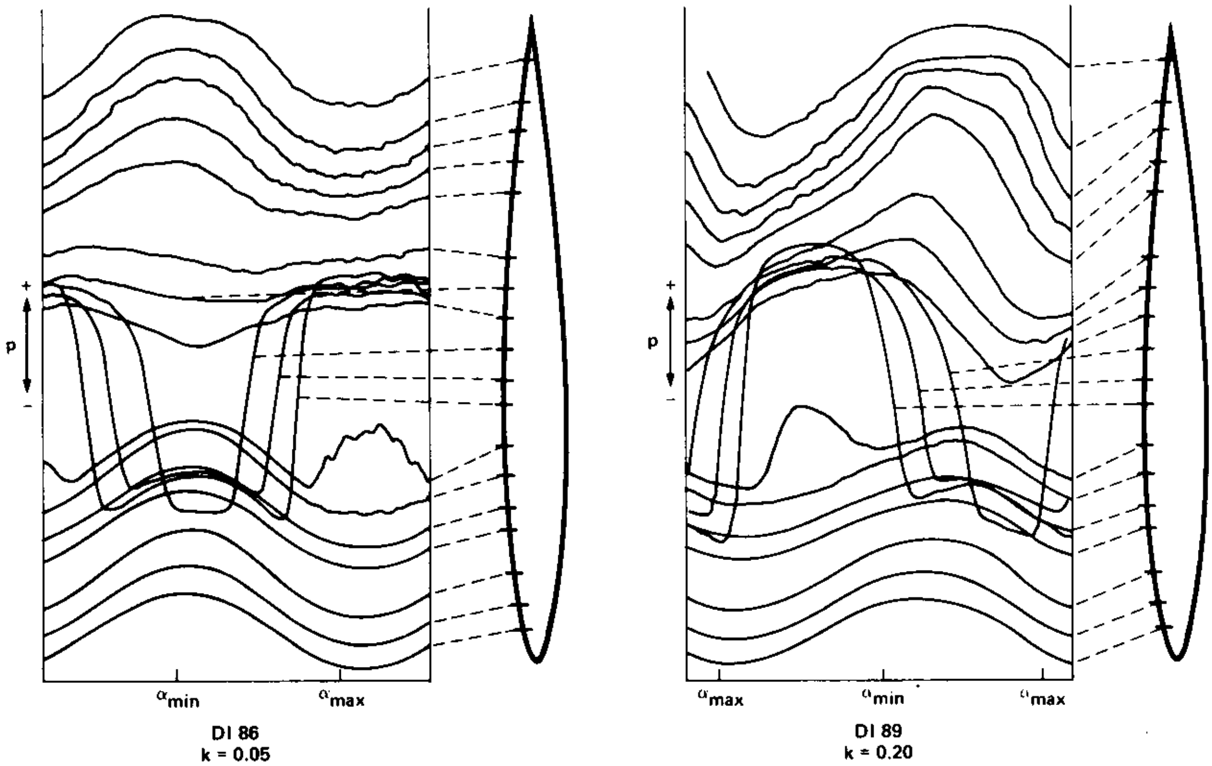


Fig. 2.7. Unsteady pressure time-histories for shock-stall case.
$M = 0.8$, $\alpha_m = 4.0°$.

DATA SET 3

NACA 0012. OSCILLATORY AND TRANSIENT PITCHING

by

R. H. Landon, ARA

INTRODUCTION

These results are extracted from tabulations of wing pressures resulting from the 3rd series of pitching tests about 0.25c axis made in the ARA 2-dimensional tunnel, using the pitching and heaving rig, Ref 3.1.

The main purpose of these tests was to examine the conditions of dynamic stall and recovery at scaled time rates similar to those of a typical helicopter application. Dynamic similarity was maintained also in Reynolds number; the approximately quarter scale blade section was therefore run, for all the cases reported here, at a tunnel stagnation pressure of 4 bar to match low altitude flight of the helicopter. Consequently, no artificial boundary layer transition trips were applied to the test wing.

The output of dynamic pressure transducers was sampled at fixed intervals, the instantaneous pressures and reference conditions having a matched and filtered response within 3 dB up to 460 Hz.

The results represent one specific cycle, and are not averaged over a number of cycles. The data bank at ARA contains at least 4 cycles of each dynamic condition. Ramp motions have only a single transient.

Up to 6 increments of mean incidence and amplitude, singly or in combination, could be run: the present programme called for 3 increments (called programme steps or PSTEP) of mean incidence, α_m as shown in Table 3.4.

The time-dependent results are presented without harmonic or spectral analysis. Note that the harmonic content of the pitching motion is relatively high, due to the intrusion of other modes of the drive system:

AGARD case	f (Hz)	Harmonic content and phase angle relative to the fundamental			
		First	Second	Third	Fourth
1,2,3	50.32	2.44%,-10°	2.45%,-39°	0.5%, -51°	0.38%, 0°
5	62.5	0.22%,-13°	2.60%,-44°	0.37%,-61°	0.07%,-76°

The instantaneous Mach number varies in sympathy with the drag of the wing: the flow momentum loss changes the effective area of the choked throat that controls the flow downstream of the model, thus making speed dependent on drag. Mach number is thus given for each data point in the results.

The heave mode (no results presented here) allowed the wing to be placed up to 63.5 mm (2.5 in) above and below the tunnel centre line. Some pitching tests are reported in Ref 3.2 to show possible effects on dynamic readings of wall proximity: there has been no analysis of *unsteady* tunnel interference, but corrections appropriate to steady interference have been applied to some of the measured quantities.

Notes on the data

The ordinates of the NACA 0012 airfoil are given in Table 3.1. The chordwise and spanwise locations of the 30 pressure holes and their channel numbers are given in Table 3.2, and the arrangement of the data is explained in Table 3.3.

Ten data sets are presented to provide experimental comparison with AGARD CT Cases. These are extracted from the full set of tests identified in Tables 3.4 and 3.5.

For the priority CT Case 1 the tabulated data are presented as 32 sets of pressure coefficients at equal time intervals during a cycle of oscillation, extracted from 64 sets in the original data. For the other CT Cases of oscillatory pitch the number is reduced to 8 sets. The ramp motion and quasi-steady data have 16 points, chosen to give approximately equal incidence increments, again taken from more closely spaced original data. Tables 3.7 to 3.10 include a pitch damping factor which is irrelevant for the present purpose and its value is also shown in each of the oscillatory plots. Note also that the ramp incidence rate is an approximate or nominal value: the incidence rate $\dot{\alpha} = d\alpha/dt$ is not constant, and when calculated from different ranges of incidences, will give different values. Approximate representations of the motions in Ref 3.6 are recommended for comparative calculations at given α . No measurements were made for strictly steady conditions, but instantaneous pressures were measured for very slow oscillations of incidence. The results of three of these quasi-steady tests are given in Tables 3.14 to 3.16.

Oscillatory pitch about 0.25c:

Related AGARD CT Case	Run No. and P step	Experimental conditions							Data table
		M	α_m (deg)	α_0 (deg)	f (Hz)	k	Re $\times 10^{-6}$	Sets	
1	87-1	0.600	2.89	2.41	50.32	0.0808	4.8	32	3.7
2	89-1	0.600	3.16	4.59	50.32	0.0811	4.8	8	3.8
3	87-3	0.600	4.86	2.44	50.32	0.0810	4.8	8	3.9
5	128-1	0.755	0.016	2.51	62.5	0.0814	5.5	8	3.10

Ramp motion about 0.25c:

Related AGARD CT Case	Run No.	Experimental conditions					Data table
		M	α range (deg)	Re $\times 10^{-6}$	Approx $\dot{\alpha}$ (deg/s)	Sets	
6	218	0.30	-0.03 to 15.54	2.7	1280	16	3.11
7	227	0.57	-0.01 to 14.80	4.6	425	16	3.12
8	230	0.56	-0.01 to 14.97	4.5	1380	16	3.13

Quasi-steady:

Run No.	M	α range in table (deg)	Re $\times 10^{-6}$	Sets	Data table
6	0.30	-0.12 to 15.55	2.6	16	3.14
11	0.58	-0.13 to 11.56	4.6	16	3.15
151	0.75	-3.27 to 3.35	5.5	16	3.16

Figs 3.2 to 3.4 show typical results extracted from Ref 3.2 for oscillatory pitching at M = 0.6 and 0.75, showing the effect of reduced frequency parameter on normal force, pitching moment and a damping factor DF. The related AGARD CT cases 1, 2, 3 and 5 are included in these figures. Figs 3.2 and 3.3 are for respective amplitudes $\alpha_0 = 2.5^\circ$ and 5.0°.

Fig 3.5 shows curves of C_N against α from the quasi-steady data and for the two ramp rates at M = 0.57 to illustrate the lag in the growth of C_N and the delayed stall under dynamic conditions.

1 AIRFOIL

1.1	Designation	NACA 0012
1.2	Type of airfoil	Symmetrical 12% thick
1.3	Geometry	See Table 3.1 and formula in Ref 3.6
1.4	Design condition	-
1.5	Additional remarks	-
1.6	References on airfoil	Refs 3.6, 3.7

2 MODEL GEOMETRY

2.1	Chord length	101.6 mm (4 in)
2.2	Span	203.2 mm (8 in)
2.3	Actual model coordinates and accuracy of measurements	See Fig 3.1 and Table 3.1. TE thickness = 0.383 mm, ie approximately 0.127 mm too thick
2.4	Flap: hinge and gap details	-
2.5	Additional remarks	-
2.6	References on model	-

3 WIND TUNNEL

3.1	Designation	ARA 2-dimensional tunnel
3.2	Type of tunnel	Intermittent blow down
3.3	Test section dimensions	h = 457.2, b = 203.2, length = 1251 mm
3.4	Type of roof and floor	Slotted, 3.2% open area ratio
3.5	Type of side walls	Solid
3.6	Ventilation geometry	Roof and floor each have 6 slots and 2 half slots at corners. Plenum chambers 133 mm deep connected by large ducts. Top and bottom walls diverge.
3.7	Thickness of side wall boundary layer	$2\delta^*/b = 0.015$
3.8	Thickness of boundary layers at roof and floor	Not known
3.9	Method of measuring Mach number	Static hole in side wall 5 chords ahead of model
3.10	Uniformity of Mach number over test section	Centre line distribution within ±0.0015 in region of model
3.11	Sources and levels of noise or turbulence in empty tunnel	No serious disturbances
3.12	Tunnel resonances	No evidence
3.13	Additional remarks	
3.14	References on tunnel	Ref 3.8

4 MODEL MOTION

4.1	Mode of applied motion	Pitching about 0.25c, oscillation or ramp. No heave results
4.2	Range of amplitude	Oscillation $\pm 9.5^{\circ}$; ramp 0 to 30° (limit 44°)
4.3	Range of frequency	0 to 60 Hz (limit 100 Hz)
4.4	Method of application	Hydraulic actuator
4.5	Purity of applied motion	See Introduction
4.6	Natural frequencies and normal modes of model	Lowest is bending at 600 Hz
4.7	Static or dynamic elastic distortion during tests	No significant distortion
4.8	Additional remarks	-

5 TEST CONDITIONS

5.1	Tunnel height/model chord ratio	4.5
5.2	Tunnel width/model chord ratio	2.0
5.3	Range of Mach number	0.3 to 0.87
5.4	Range of tunnel total pressure	1½-4 bar
5.5	Range of tunnel total temperature	280 K approximately, uncontrolled
5.6	Range of model steady, or mean, incidence	±11 deg (limit 44°)
5.7	Definition of model incidence	On chordline: datum matched on chordwise pressure distributions
5.8	Position of transition, if free	Not known
5.9	Position and type of trip, if transition fixed	No trips in presented data because model Re consistent with full-scale helicopter blade
5.10	For mixed flow, position of sonic boundary in relation to roof and floor	-
5.11	Flow instabilities during tests	No simple answer: refer to ARA
5.12	Additional remarks	Position of model 0.25c is 6 chords downstream of start of slots
5.13	References describing tests	Refs 3.1, 3.2

6 MEASUREMENTS AND OBSERVATIONS

6.1	Steady pressures for the mean conditions		-
6.2	Steady pressures for small changes from the mean conditions		-
6.3	Quasi-steady pressures		√
6.4	Unsteady pressures		√
6.5	Steady forces for the mean conditions	measured directly	-
		integrated pressures	-
6.6	Steady forces for small changes from the mean conditions	measured directly	-
		integrated pressures	-
6.7	Quasi-steady forces	measured directly	-
		integrated pressures	√
6.8	Unsteady forces	measured directly	-
		integrated pressures	√
6.9	Measurement of actual motion at points on model		-
6.10	Observation or measurement of boundary layer properties		-
6.11	Visualization of surface flow		-
6.12	Visualization of shockwave movements		-
6.13	Additional remarks		-

7 INSTRUMENTATION

7.1	Steady pressures	Pressures for quasi-steady conditions measured with same system used for unsteady pressures
7.1.1	Position of orifices spanwise and chordwise	-
7.1.2	Type of measuring system	-
7.2	Unsteady pressures	
7.2.1	Position of orifices spanwise and chordwise	See Table 3.2
7.2.2	Diameter of orifices	0.25 mm
7.2.3	Type of measuring system	30 transducers in model (see Ref 3.1)
7.2.4	Type of transducers	Kulite XCQL absolute
7.2.5	Principle and accuracy of calibration	Calibrated under steady conditions against Texas Quartz Pressure Test Set. Accuracy: ±2.7 mb
7.3	Model motion	
7.3.1	Method of measurement	Shaft encoder
7.3.2	Accuracy	Resolution: ±0.1 deg
7.4	Processing of unsteady measurements	
7.4.1	Method of acquiring and processing measurements	Signals sampled at known time intervals, same points in cycle
7.4.2	Type of analysis	Instantaneous pressures reduced to non-dimensional coefficients
7.4.3	Unsteady pressure quantities obtained and accuracies achieved	Approximately ±0.01 in C_p
7.4.4	Method of integration to obtain forces	Standard curve fitting procedure
7.5	Additional remarks	Tabulated C_N and C_m are corrected for wall constraint
7.6	References on techniques	Refs 3.1, 3.9, 3.10

8 DATA PRESENTATION

8.1	Test cases for which data could be made available	Tables 3.4, 3.5, 3.6
8.2	Test cases for which data are included in this document	See Introduction
8.3	Steady pressures	-
8.4	Quasi-steady or steady perturbation pressures	Tables 3.14, 3.15, 3.16
8.5	Unsteady pressures	Tables 3.7 to 3.13
8.6	Steady forces or moments	-
8.7	Quasi-steady or steady perturbation forces	Tables 3.14, 3.15, 3.16
8.8	Unsteady forces and moments	Tables 3.7 to 3.13
8.9	Other forms in which data could be made available if required	None
8.10	References giving other presentations of data	Ref 3.1

9 COMMENTS ON DATA

9.1	Accuracy	
9.1.1	Mach number	±0.0015
9.1.2	Steady incidence	Instantaneous incidence to ±0.1 deg
9.1.3	Reduced frequency	Within about 1%
9.1.4	Steady pressure coefficients	-
9.1.5	Steady pressure derivatives	-
9.1.6	Unsteady pressure coefficients	Instantaneous C_p to ±0.01 (see Ref 3.10)
9.2	Sensitivity to small changes of parameter	-
9.3	Spanwise variations	Not serious for data presented here (for other cases see Ref 3.1)
9.4	Non-linearities	-
9.5	Influence of tunnel total pressure	-
9.6	Wall interference corrections	Values of α, α_m, α_0, C_N and C_m have been corrected on the basis of steady calibrations (see para 12). No corrections appear to be necessary for M .
9.7	Other relevant tests on *same model*	-
9.8	Relevant tests on other models of nominally the *same* aerofoil	Ref 3.11 gives steady measurements on another model of NACA 0012 in same tunnel
9.9	Any remarks relevant to comparison between experiment and theory	-
9.10	Additional remarks	-
9.11	References on discussion of data	Ref 3.2

10 PERSONAL CONTACT FOR FURTHER INFORMATION

Mr R.H. Landon, Aircraft Research Association Ltd, Manton Lane, Bedford MK41 7PF, England

11 LIST OF REFERENCES

3.1 R.H. Landon — A description of the ARA 2-dimensional pitch and heave rig and some results from the NACA 0012 wing. ARA Memo 199, September 1977

3.2 Mrs M.E. Wood — Results of oscillatory pitch and ramp tests on the NACA 0012 blade section. ARA Memo 220, December 1979

3.3	A. Harris	Calibration of ARA's 2-dimensional facility using 2.8% open area liners. April 1971, unpublished Memorandum
3.4	A. Harris A.B. Haines	Evidence on wall interference effects in the ARA 2-dimensional tunnel. ARA Memo 147, 1972
3.5	A.B. Haines	An evaluation of wall interference effects in ARA's 2-dimensional tunnel. Item 5, Tech Comm., June 1973
3.6	Ed. S.R. Bland	AGARD two-dimensional aeroelastic configurations. AGARD-AR-156, 1979
3.7	I.H. Abbott A.E. von Doenhoff	Theory of wing sections: including a summary of airfoil data. McGraw-Hill, New York, 1949
3.8	B.L.F. Hammond	Some notes on model testing in the ARA 2-dimensional facility. ARA Memo 170, 1975
3.9	R.H. Landon Mrs M.E. Wood	Some sources of error with Kulite pressure transducers in the ARA pitch/heave rig. ARA Memo 204, 1978
3.10	R.H. Landon Mrs M.E. Wood	The pitch/heave rig data selection and reduction program, and Corrigendum. ARA Memo 182, 1976
3.11	Mrs J. Sawyer	Results of tests on aerofoil M.102/9 (NACA 0012) in the ARA 2-dimensional tunnel. ARA Model Test Note M.102/9, 1978

12 DEFINITIONS AND EXPLANATION OF DATA TABLES

b	airfoil span and tunnel width
c	chord
C_N	normal force coefficient
C_m	pitching moment coefficient (about 0.25c)
f	frequency (Hz)
h	tunnel height
k	reduced frequency, $\omega c/2V$
M	Mach number
q	dynamic pressure
R,Re	Reynolds number
t	time (seconds)
V	velocity
x,y,z	airfoil coordinates
α	incidence
α_m	mean incidence
α_0	pitch amplitude
δ^*	displacement thickness of boundary layer
ω	frequency (rad/s)

For each chosen case, experimental data are presented as sets of instantaneous values of the quantities C_p C_N C_m α and M for particular times t (in seconds) in Tables 3.7 to 3.16.

Uncorrected coefficients C_N' and C_m' are evaluated by a curve fitting procedure from the integrals

$$C_N' = \int_0^1 (C_{pL} - C_{pU})\, d(x/c)$$

$$C_m' = \int_0^1 (C_{pL} - C_{pU})\left(0.25 - (x/c)\right) d(x/c)$$

where $C_p = (p - p_\infty)/q$ is uncorrected and the suffices L and U denote lower and upper surfaces respectively.

Oscillatory motion is defined by

$$\alpha = \alpha_m + \alpha_0 \sin(\omega t + \epsilon)$$

where ϵ is a phase angle dependent on the time datum.

The quantities α α_m α_0 C_N and C_m (but not C_p) have each been corrected for tunnel constraint effects. The corrections, as derived for steady conditions in Refs 3.3, 3.4 and 3.5, are applied to each instantaneous condition as if it were steady.

Table 3.1

NACA 0012 SECTION ORDINATES

x/c	z/c
0	0
0.0050	±0.01221
0.0125	±0.01894
0.0250	±0.02615
0.0500	±0.03555
0.0750	±0.04200
0.1000	±0.04683
0.1500	±0.05345
0.2000	±0.05738
0.2500	±0.05941
0.3000	±0.06002
0.3500	±0.05949
0.4000	±0.05803
0.4500	±0.05581
0.5000	±0.05294
0.5500	±0.04952
0.6000	±0.04563
0.6500	±0.04132
0.7000	±0.03664
0.7500	±0.03160
0.8000	±0.02623
0.8500	±0.02053
0.9000	±0.01448
0.9500	±0.00807
1.0000	±0.00126

Table 3.2

NACA 0012 WING PRESSURE LOCATIONS AND CHANNEL NUMBER IDENTITIES

Upper surface			Lower surface		
Channel No.	x/c	y/b	Channel No.	x/c	y/b
1	1.0 TE	0.52	21	0 LE	0.44
2	0.9	0.51	22	0.01	0.46
3	0.8	0.48	23	0.02	0.48
4	0.7	0.49	24	0.04	0.48
5	0.6	0.5	25	0.10	0.48
6	0.5	0.5	26	0.22	0.5
7	0.4	0.5	27	0.34	0.5
8	0.3	0.5	28	0.46	0.5
9	0.2	0.51	29	0.57	0.5
10	0.15	0.48	30	0.68	0.5
11	0.125	0.48	31	0.79	0.54
12	0.1	0.49	32	0.90	0.55
13	0.075	0.5			
14	0.05	0.51			
15	0.03	0.52			
16	0.02	0.53			
17	0.01	0.55			
18	0.005	0.56			

Table 3.3

LAYOUT OF RESULTS IN TABLES 3.7 TO 3.16

C_{p1}	C_{p2}	C_{p3}	C_{p4}	C_{p5}	C_{p6}	C_{p7}	C_{p8}	C_{p9}	C_{p10}	Data point	
C_{p11}	C_{p12}	C_{p13}	C_{p14}	C_{p15}	C_{p16}	C_{p17}	C_{p18}	C_{p21}	C_{p22}	M	C_N
C_{p23}	C_{p24}	C_{p25}	C_{p26}	C_{p27}	C_{p28}	C_{p29}	C_{p30}	C_{p31}	C_{p32}	t (second)	C_m
										q (lb/ft^2)	α (deg)

where, in the arrangement above, C_{pn} is the instantaneous value of C_p for channel n (see Table 3.2). Corresponding x/c locations can be identified from the following key:

Upper									
1.00	0.90	0.80	0.70	0.60	0.50	0.40	0.30	0.10	0.15
Upper								Lower	
0.125	0.10	0.075	0.05	0.03	0.02	0.01	0.005	0	0.01
Lower									
0.02	0.04	0.10	0.22	0.34	0.46	0.57	0.68	0.79	0.90

Table 3.4

PARAMETERS OF OSCILLATORY PITCH CASES

ARA run No.	M	α_0 (deg)	α_m (deg)	f (Hz)	k	Re × 10^{-6}
152	0.288	8.5	4,5,6	30	0.099	2.7
153	0.286	8.5	7,8,9	30	0.099	2.7
183	0.287	8.5	10,11,12	30	0.101	2.7
184	0.286	7.5	6	30	0.102	2.7
156	0.292	9.5	6	30	0.096	2.7
185	0.287	9.5	6	30	0.102	2.7
186	0.285	Max	6	30	0.102	2.7
157	0.290	2.5	9,10,11	30	0.097	2.7
158	0.286	2.5	12,14,16	30	0.099	2.7
159	0.288	5.0	9,10,11	30	0.098	2.7
160	0.286	5.0	12,15,18	30	0.099	2.7
199	0.305	2.5	9,10,11	50	0.155	2.8
200	0.298	2.5	9,10,11	50	0.159	2.8
188	0.285	2.5	12,14,16	50	0.168	2.6
39	0.290	5.0	9,10,11	50	0.170	2.7
40	0.287	5.0	12,15,18	50	0.172	2.7
116	0.287	2.5	9,10,11	70	0.238	2.7
43	0.289	2.5	12,14,16	70	0.245	2.7
117	0.292	5.0	9,10,11	70	0.231	2.7
44	0.287	5.0	12,15,18	70	0.245	2.7
161	0.382	8.5	2,3,4	30	0.075	3.5
162	0.380	8.5	5,6,7	30	0.075	3.5
163	0.379	8.5	8,9,10	30	0.076	3.5
164	0.380	7.5	4	30	0.076	3.5
165	0.380	9.5	4	30	0.076	3.5
166	0.380	Max	4	30	0.076	3.5
201	0.398	2.5	7,8,9	30	0.073	3.6
168	0.377	2.5	10,12,14	30	0.077	3.4
169	0.379	5.0	6,8,10	30	0.076	3.4
170	0.377	5.0	9,12,15	30	0.077	3.4
59	0.377	2.5	7,8,9	50	0.126	3.3
60	0.383	2.5	10,12,14	50	0.128	3.3
61	0.380	5.0	6,8,10	50	0.127	3.4
62	0.380	5.0	9,12,15	50	0.128	3.4
63	0.381	2.5	7,8,9	70	0.182	3.5
64	0.378	2.5	10,12,14	70	0.184	3.4
65	0.378	5.0	6,8,10	70	0.184	3.4
66	0.378	5.0	9,12,15	70	0.184	3.4
171	0.483	8.5	0,1,2	30	0.060	4.2
172	0.482	8.5	3,4,5	30	0.060	4.2
173	0.482	8.5	6,7,8	30	0.060	4.2
174	0.483	2.5	5,6,7	30	0.060	4.2
175	0.481	2.5	8,10,12	30	0.061	4.2
176	0.483	5.0	5,6,7	30	0.060	4.2
177	0.479	5.0	9,12,15	30	0.061	4.2
107	0.484	2.5	5,6,7	50	0.100	4.2
108	0.481	2.5	8,10,12	50	0.101	4.2
119	0.489	5.0	5,6,7	50	0.099	4.2
109	0.479	5.0	9,12,15	50	0.101	4.1
78	0.480	2.5	5,6,7	70	0.147	4.2
118	0.488	2.5	8,10,12	70	0.141	4.2
80	0.480	5.0	5,6,7	70	0.147	4.2
81	0.476	5.0	9,12,15	70	0.149	4.2

ARA run No.	M	α_0 (deg)	α_m (deg)	f (Hz)	k	Re × 10^{-6}
178	0.598	2.5	3,4,5	30	0.050	4.9
179	0.593	2.5	6,8,10	30	0.050	4.9
180	0.597	5.0	3,4,5	30	0.050	4.9
202	0.600	5.0	6,9,12	30	0.049	5.0
87	0.600	2.5	3,4,5	50	0.081	4.9
88	0.595	2.5	6,8,10	50	0.082	4.9
89	0.598	5.0	3,4,5	50	0.082	4.9
90	0.592	5.0	6,9,12	50	0.083	4.9
91	0.599	2.5	3,4,5	70	0.115	4.9
92	0.594	2.5	6,8,10	70	0.116	4.9
93	0.599	5.0	3,4,5	70	0.115	4.9
94	0.591	5.0	6,9,12	70	0.117	4.9
103	0.699	2.5	1,2,3	29	0.041	5.4
96	0.688	2.5	4,6,8	29	0.042	5.4
104	0.697	5.0	1,2,3	29	0.041	5.4
98	0.686	5.0	4,6,8	29	0.042	5.4
105	0.699	2.5	1,2,3	58	0.081	5.5
100	0.686	2.5	4,6,8	58	0.083	5.4
106	0.696	5.0	1,2,3	58	0.082	5.4
102	0.685	5.0	4,6,8	58	0.083	5.4
122	0.700	2.5	1,2,3	80	0.115	5.5
123	0.691	2.5	4,6,8	80	0.116	5.4
124	0.698	5.0	1,2,3	70	0.101	5.5
125	0.691	5.0	4,6,8	70	0.101	5.4
95	0.699	2.5	0,1,2	29	0.041	5.4
97	0.696	5.0	0,1,2	29	0.041	5.4
99	0.697	2.5	0,1,2	58	0.082	5.4
101	0.693	5.0	0,1,2	58	0.082	5.4
126	0.754	2.5	0,1,2	31	0.042	5.7
127	0.744	2.5	3,4,5	31	0.042	5.6
128	0.753	2.5	0,1,2	62	0.082	5.7
129	0.743	2.5	3,4,5	62	0.083	5.6
130	0.753	2.5	0,1,2	80	0.108	5.7
131	0.744	2.5	3,4,5	80	0.109	5.6
138	0.805	2.5	0,½,1	33	0.041	5.9
203	0.816	2.5	0,½,1	33	0.041	6.0
204	0.802	2.5	0,½,1	33	0.041	6.0
139	0.794	2.5	2,2½,3	33	0.041	5.8
134	0.785	2.5	0,½,1	66	0.082	5.8
135	0.792	2.5	2,2½,3	66	0.081	5.8
136	0.799	2.5	0,½,1	80	0.101	5.9
137	0.794	2.5	2,2½,3	80	0.102	5.9
142	0.814	2.5	0,1,2	80	0.100	5.9
141	0.821	2.5	0,1,2	80	0.099	5.9
143	0.829	2.5	0,1,2	80	0.098	6.0
144	0.840	2.5	0,1,2	80	0.097	5.9
145	0.866	2.5	0,1,2	80	0.094	6.0
146	0.878	2.5	0,1,2	80	0.093	6.0
147	0.896	2.5	0,1,2	80	0.092	6.0

Table 3.5

PARAMETERS OF RAMP PITCH CASES

ARA run No.		α^o range	$\frac{d\alpha}{dt}$ (deg/s)	Re × 10^{-6}
215	0.296	0-30	400	2.7
216	0.298	0-30	800	2.7
242	0.299	0-30	1200	2.7
218	0.294	0-30	1600	2.7
214	0.406	0-30	400	3.5
243	0.410	0-30	800	3.5
222	0.410	0-30	1200	3.6
219	0.412	0-30	1600	3.6
223	0.504	0-30	400	4.2
224	0.501	0-30	800	4.2
225	0.503	0-30	1200	4.2
226	0.496	0-30	1600	4.2
227	0.613	0-30	400	4.8
228	0.615	0-30	800	4.8
229	0.614	0-30	1200	4.8
230	0.611	0-30	1600	4.7
231	0.707	0-30	800	5.2
232	0.706	0-30	1600	5.2
233	0.761	0-30	1600	5.3
234	0.760	0-30	800	5.3
235	0.806	0-30	800	5.5
237	0.809	0-30	1600	5.5
239	0.834	0-30	800	5.7
238	0.838	0-30	1600	5.4
240	0.900	0-30	800	5.9
241	0.902	0-30	1600	5.9
236	0.812	0-30	800	5.5

Table 3.6

PARAMETERS OF QUASI-STEADY CASES

M	ARA run No.	α_0 (deg)	α_m (deg)	M	ARA run No.	α_0 (deg)	α_m (deg)
0.3	6	11	11	0.75	14	5	5
0.3	189	11	11	0.75	192	5	5
0.3	278	11	11	0.8	15	4	4
0.4	7	11	11	0.8	193	4	4
0.4	245	11	11	0.8	296	4	4
0.45	190	11	11				
0.5	9	10	10	0.4	148	0	11
0.5	279	10	10	0.6	149	0	9
0.55	46	10	10	0.7	150	0	7
0.6	11	9	9	0.75	151	0	5
0.6	280	9	9	0.3	244	0	11
0.65	12	8	8	0.5	246	0	10
0.65	191	8	8	0.6	247	0	8
0.7	13	7	7	0.7	248	0	7
0.7	281	7	7	0.8	249	0	4

Table 3.7

ARA RUN 87 PSTEP 1 AGARD CASE 1 - OSC. PITCH
M=0.6 $R=4.8*10^6$ $\omega c/2V=0.0808$ $\alpha_m=2.89$ $\alpha_o=2.41$ Damping +0.06708

0.1647	-0.0007	-0.1408	-0.2437	-0.3383	-0.4547	-0.5712	-0.7231	-0.8666	-0.9290	2	
-1.0117	-1.0640	-1.1383	-1.1316	-1.1096	-0.9442	-0.7231	-0.5408	0.9766	0.6306	0.602	0.3719
0.3993	0.1580	-0.1897	-0.2488	-0.2454	-0.1948	-0.1560	-0.1070	-0.0530	0.0263	0.00000	0.0014
										1706.3	2.97
0.1562	-0.0024	-0.1493	-0.2539	-0.3501	-0.4716	-0.5965	-0.7535	-0.9172	-0.9965	4	
-1.0894	-1.1484	-1.2615	-1.2683	-1.2582	-1.0928	-0.8683	-0.6860	0.9191	0.7031	0.602	0.4267
0.4752	0.2254	-0.1358	-0.2151	-0.2134	-0.1746	-0.1391	-0.0986	-0.0497	0.0263	0.00062	0.0022
										1706.3	3.42
0.1645	0.0044	-0.1439	-0.2518	-0.3512	-0.4760	-0.6057	-0.7760	-0.9597	-1.0507	6	
-1.1519	-1.2277	-1.3979	-1.4097	-1.4148	-1.2328	-1.0103	-0.8316	0.8674	0.7747	0.602	0.4777
0.5455	0.2977	-0.0731	-0.1759	-0.1810	-0.1473	-0.1203	-0.0815	-0.0343	0.0348	0.00124	0.0043
										1708.7	3.84
0.1657	0.0078	-0.1416	-0.2519	-0.3571	-0.4879	-0.6304	-0.8070	-1.0107	-1.1024	8	
-1.2161	-1.3044	-1.5827	-1.5929	-1.5963	-1.3689	-1.1516	-0.9699	0.8158	0.8277	0.600	0.5285
0.6036	0.3558	-0.0312	-0.1348	-0.1568	-0.1314	-0.1059	-0.0720	-0.0261	0.0367	0.00187	0.0070
										1696.6	4.23
0.1594	0.0044	-0.1473	-0.2586	-0.3681	-0.4996	-0.6445	-0.8299	-1.0406	-1.1434	10	
-1.2446	-1.4333	-1.7570	-1.7772	-1.7182	-1.4772	-1.2581	-1.0878	0.7460	0.8572	0.602	0.5731
0.6449	0.4005	0.0094	-0.0968	-0.1389	-0.1187	-0.0984	-0.0647	-0.0260	0.0398	0.00249	0.0083
										1708.7	4.56
0.1632	0.0094	-0.1394	-0.2530	-0.3616	-0.4954	-0.6441	-0.8296	-1.0419	-1.1271	12	
-1.2191	-1.6887	-1.9077	-1.9043	-1.8024	-1.5817	-1.3528	-1.1940	0.6830	0.8936	0.605	0.6049
0.6880	0.4540	0.0529	-0.0641	-0.1143	-0.0976	-0.0825	-0.0558	-0.0173	0.0378	0.00311	0.0124
										1723.1	4.83
0.1537	-0.0008	-0.1571	-0.2721	-0.3871	-0.5211	-0.6807	-0.8730	-1.0791	-1.1237	14	
-1.4293	-1.9393	-2.0835	-2.0577	-1.9461	-1.7401	-1.4929	-1.3194	0.6413	0.9229	0.596	0.6485
0.7186	0.4782	0.0627	-0.0661	-0.1193	-0.1038	-0.0953	-0.0643	-0.0283	0.0301	0.00373	0.0149
										1677.4	4.98
0.1479	0.0043	-0.1495	-0.2675	-0.3803	-0.5205	-0.6778	-0.8710	-1.0556	-1.1018	16	
-1.8471	-2.0318	-2.1514	-2.1138	-1.9976	-1.8078	-1.5616	-1.3719	0.6010	0.9395	0.597	0.6717
0.7343	0.5001	0.0830	-0.0521	-0.1085	-0.0948	-0.0880	-0.0640	-0.0264	0.0300	0.00435	0.0189
										1684.6	5.11
0.1559	0.0111	-0.1387	-0.2548	-0.3659	-0.5005	-0.6520	-0.8389	-0.9887	-1.0863	18	
-2.0255	-2.0675	-2.1551	-2.1130	-2.0002	-1.8218	-1.5761	-1.3707	0.5750	0.9402	0.603	0.6725
0.7433	0.5127	0.1003	-0.0326	-0.0949	-0.0781	-0.0781	-0.0545	-0.0158	0.0364	0.00497	0.0208
										1711.1	5.09
0.1533	0.0094	-0.1429	-0.2580	-0.3697	-0.5119	-0.6643	-0.8504	-0.9926	-1.1213	20	
-2.0945	-2.1233	-2.1994	-2.1571	-2.0471	-1.8643	-1.6223	-1.3971	0.5646	0.9369	0.601	0.6756
0.7440	0.5087	0.0940	-0.0414	-0.1057	-0.1006	-0.0888	-0.0685	-0.0261	0.0297	0.00559	0.0236
										1701.5	5.05
0.1553	0.0061	-0.1430	-0.2545	-0.3642	-0.5065	-0.6591	-0.8443	-0.9918	-1.0792	22	
-2.1234	-2.1594	-2.2365	-2.1902	-2.0839	-1.8936	-1.6484	-1.4015	0.5737	0.9389	0.597	0.6694
0.7400	0.5034	0.0833	-0.0522	-0.1207	-0.1122	-0.0967	-0.0710	-0.0333	0.0301	0.00621	0.0254
										1679.7	4.82
0.1552	0.0077	-0.1381	-0.2482	-0.3567	-0.4940	-0.6432	-0.8313	-0.9906	-0.9923	24	
-1.9992	-2.1144	-2.1924	-2.1551	-2.0534	-1.8619	-1.6110	-1.3296	0.6027	0.9128	0.600	0.6422
0.7145	0.4755	0.0653	-0.0686	-0.1313	-0.1177	-0.1025	-0.0770	-0.0364	0.0247	0.00683	0.0262
										1699.1	4.54
0.1494	0.0009	-0.1426	-0.2523	-0.3603	-0.4936	-0.6354	-0.8244	-1.0101	-1.0320	26	
-1.4118	-2.0548	-2.1358	-2.1172	-2.0295	-1.8134	-1.5637	-1.2784	0.6237	0.8785	0.601	0.6039
0.6743	0.4363	0.0313	-0.0936	-0.1510	-0.1392	-0.1189	-0.0903	-0.0447	0.0194	0.00745	0.0238
										1706.4	4.17
0.1597	0.0112	-0.1373	-0.2449	-0.3524	-0.4873	-0.6256	-0.8168	-1.0216	-1.1070	28	
-1.0848	-1.9657	-2.0698	-2.0784	-2.0067	-1.7472	-1.4945	-1.2077	0.6889	0.8665	0.598	0.5738
0.6582	0.4124	0.0095	-0.1151	-0.1698	-0.1527	-0.1271	-0.0947	-0.0486	0.0231	0.00807	0.0238
										1687.0	3.80
0.1583	0.0077	-0.1328	-0.2411	-0.3427	-0.4747	-0.6067	-0.7878	-0.9892	-1.0857	30	
-1.1991	-1.5613	-1.9049	-1.9574	-1.9134	-1.6290	-1.3667	-1.0891	0.7338	0.8201	0.601	0.5269
0.6052	0.3598	-0.0380	-0.1446	-0.1903	-0.1649	-0.1396	-0.1023	-0.0532	0.0179	0.00869	0.0220
										1701.5	3.40
0.1601	0.0094	-0.1294	-0.2309	-0.3342	-0.4611	-0.5898	-0.7658	-0.9588	-1.0485	32	
-1.1923	-1.2651	-1.6663	-1.7644	-1.8068	-1.4953	-1.2279	-0.9486	0.7914	0.7796	0.601	0.4768
0.5544	0.3107	-0.0786	-0.1734	-0.2106	-0.1785	-0.1514	-0.1091	-0.0549	0.0179	0.00931	0.0192
										1701.5	3.01

(continued overleaf)

Table 3.7 (concluded)

ARA RUN 87 PSTEP 1 AGARD CASE 1 - OSC. PITCH
M=0.6 R=4.8*10^6 $\omega c/2v$=0.0808 α_m=2.89 α_0=2.41 Damping +0.06708

0.1600	0.0043	-0.1328	-0.2360	-0.3308	-0.4493	-0.5695	-0.7370	-0.9131	-0.9943	34	
-1.1162	-1.2482	-1.4767	-1.5715	-1.6476	-1.3464	-1.0840	-0.8132	0.8472	0.7287	0.601	0.4294
0.4969	0.2582	-0.1209	-0.2089	-0.2326	-0.1988	-0.1649	-0.1209	-0.0634	0.0145	0.00994	0.0166
										1701.5	2.62
0.1698	0.0162	-0.1205	-0.2167	-0.3079	-0.4243	-0.5476	-0.7028	-0.8649	-0.9307	36	
-1.0556	-1.1653	-1.3290	-1.3881	-1.3949	-1.1467	-0.9020	-0.6421	0.9192	0.6761	0.602	0.3774
0.4432	0.2052	-0.1593	-0.2336	-0.2488	-0.2100	-0.1678	-0.1222	-0.0614	0.0213	0.01056	0.0152
										1706.3	2.24
0.1622	0.0078	-0.1280	-0.2231	-0.3097	-0.4251	-0.5405	-0.6848	-0.8342	-0.8953	38	
-1.0056	-1.0973	-1.2178	-1.2517	-1.2195	-1.0175	-0.7663	-0.5167	0.9600	0.6138	0.600	0.3342
0.3761	0.1368	-0.2112	-0.2740	-0.2808	-0.2350	-0.1908	-0.1348	-0.0686	0.0163	0.01118	0.0121
										1696.6	1.87
0.1621	0.0060	-0.1281	-0.2181	-0.2995	-0.4133	-0.5185	-0.6611	-0.7867	-0.8410	40	
-0.9530	-1.0311	-1.1177	-1.1245	-1.0718	-0.8716	-0.6271	-0.3861	0.9972	0.5440	0.599	0.2803
0.2996	0.0671	-0.2639	-0.3148	-0.3131	-0.2588	-0.2113	-0.1502	-0.0857	0.0043	0.01180	0.0128
										1696.8	1.48
0.1647	0.0094	-0.1188	-0.2083	-0.2876	-0.3973	-0.4969	-0.6252	-0.7383	-0.7855	42	
-0.8784	-0.9375	-0.9982	-0.9796	-0.9088	-0.7147	-0.4716	-0.2353	1.0340	0.4753	0.602	0.2361
0.2289	0.0044	-0.3045	-0.3450	-0.3281	-0.2657	-0.2100	-0.1475	-0.0783	0.0128	0.01242	0.0090
										1706.3	1.16
0.1712	0.0129	-0.1182	-0.2016	-0.2799	-0.3854	-0.4808	-0.5982	-0.7106	-0.7565	44	
-0.8314	-0.8876	-0.9285	-0.8910	-0.8127	-0.6084	-0.3616	-0.1216	1.0564	0.4129	0.599	0.1965
0.1678	-0.0552	-0.3497	-0.3769	-0.3480	-0.2782	-0.2237	-0.1590	-0.0858	0.0129	0.01304	0.0086
										1691.8	0.85
0.1649	0.0111	-0.1123	-0.1951	-0.2711	-0.3743	-0.4605	-0.5703	-0.6684	-0.7224	46	
-0.7748	-0.8205	-0.8492	-0.8036	-0.7089	-0.5078	-0.2661	-0.0311	1.0641	0.3525	0.601	0.1606
0.1007	-0.1072	-0.3895	-0.3996	-0.3590	-0.2897	-0.2272	-0.1613	-0.0869	0.0128	0.01366	0.0068
										1703.9	0.62
0.1669	0.0144	-0.1079	-0.1900	-0.2621	-0.3593	-0.4448	-0.5470	-0.6359	-0.6878	48	
-0.7247	-0.7582	-0.7750	-0.7197	-0.6174	-0.4096	-0.1699	0.0429	1.0670	0.2960	0.604	0.1309
0.0463	-0.1532	-0.4146	-0.4163	-0.3694	-0.2923	-0.2303	-0.1616	-0.0845	0.0161	0.01428	0.0051
										1718.3	0.50
0.1664	0.0078	-0.1183	-0.2019	-0.2752	-0.3689	-0.4593	-0.5530	-0.6349	-0.6860	50	
-0.7116	-0.7406	-0.7525	-0.6894	-0.5871	-0.3843	-0.1354	0.0658	1.0835	0.2584	0.599	0.1245
0.0095	-0.1899	-0.4422	-0.4354	-0.3826	-0.2990	-0.2325	-0.1609	-0.0876	0.0129	0.01490	0.0019
										1689.4	0.44
0.1672	0.0128	-0.1131	-0.1954	-0.2675	-0.3582	-0.4454	-0.5411	-0.6233	-0.6703	52	
-0.6972	-0.7190	-0.7240	-0.6619	-0.5596	-0.3615	-0.1131	0.0917	1.0668	0.2410	0.604	0.1166
0.0010	-0.1954	-0.4387	-0.4303	-0.3783	-0.2944	-0.2306	-0.1584	-0.0829	0.0161	0.01552	0.0019
										1715.9	0.53
0.1613	0.0044	-0.1222	-0.2066	-0.2809	-0.3720	-0.4615	-0.5560	-0.6387	-0.6809	54	
-0.7096	-0.7265	-0.7299	-0.6691	-0.5644	-0.3687	-0.1172	0.0887	1.0711	0.2525	0.602	0.1286
0.0094	-0.1914	-0.4362	-0.4277	-0.3737	-0.2927	-0.2286	-0.1594	-0.0851	0.0111	0.01614	0.0000
										1706.3	0.70
0.1647	0.0061	-0.1205	-0.2083	-0.2842	-0.3821	-0.4682	-0.5729	-0.6623	-0.6910	56	
-0.7349	-0.7484	-0.7535	-0.6944	-0.5965	-0.4108	-0.1627	0.0263	1.0711	0.2829	0.602	0.1479
0.0432	-0.1644	-0.4159	-0.4125	-0.3670	-0.2809	-0.2201	-0.1543	-0.0817	0.0128	0.01676	0.0002
										1706.3	0.96
0.1582	0.0044	-0.1292	-0.2171	-0.2931	-0.3928	-0.4892	-0.6024	-0.6920	-0.7174	58	
-0.7731	-0.7884	-0.7968	-0.7427	-0.6565	-0.4807	-0.2357	-0.0447	1.0675	0.3390	0.601	0.1846
0.1024	-0.1140	-0.3810	-0.3844	-0.3421	-0.2610	-0.2103	-0.1444	-0.0785	0.0145	0.01738	-0.0010
										1703.9	1.29
0.1689	0.0095	-0.1231	-0.2154	-0.2943	-0.3967	-0.4974	-0.6199	-0.7173	-0.7425	60	
-0.8079	-0.8314	-0.8449	-0.8012	-0.7290	-0.5545	-0.3229	-0.1298	1.0602	0.4123	0.604	0.2205
0.1773	-0.0459	-0.3296	-0.3480	-0.3161	-0.2473	-0.1936	-0.1315	-0.0660	0.0263	0.01800	-0.0005
										1715.8	1.68
0.1577	0.0010	-0.1355	-0.2282	-0.3159	-0.4238	-0.5266	-0.6547	-0.7726	-0.8080	62	
-0.8822	-0.9159	-0.9412	-0.9075	-0.8485	-0.6816	-0.4575	-0.2687	1.0325	0.4830	0.602	0.2720
0.2487	0.0161	-0.2872	-0.3193	-0.2923	-0.2316	-0.1844	-0.1254	-0.0648	0.0195	0.01862	-0.0004
										1708.7	2.12
0.1603	0.0010	-0.1397	-0.2380	-0.3279	-0.4397	-0.5482	-0.6906	-0.8177	-0.8720	64	
-0.9516	-0.9991	-1.0381	-1.0177	-0.9771	-0.8076	-0.5855	-0.4092	1.0163	0.5603	0.600	0.3211
0.3247	0.0857	-0.2397	-0.2821	-0.2719	-0.2143	-0.1719	-0.1211	-0.0634	0.0213	0.01925	0.0011
										1699.1	2.57

Table 3.8

ARA RUN 89 PSTEP 1 AGARD CASE 2 - OSC. PITCH
M=0.60 R=$4.8*10^6$ $\omega c/2v$=0.0811 α_m=3.16 α_o=4.59 Damping +0.2455

0.1627	0.0061	-0.1505	-0.2646	-0.3838	-0.5182	-0.6697	-0.8723	-1.0902	-1.1889	8	
-1.3285	-1.5651	-1.8937	-1.8920	-1.7677	-1.5430	-1.3200	-1.1634	0.7517	0.9185	0.599	0.6384
0.7057	0.4725	0.0622	-0.0501	-0.0978	-0.0773	-0.0654	-0.0348	-0.0024	0.0520	0.00000	0.0049
										1691.9	5.32
0.1378	-0.0078	-0.1567	-0.2800	-0.4015	-0.5419	-0.6754	-0.9253	-1.6769	-2.5089	16	
-2.5277	-2.4832	-2.5465	-2.4917	-2.3959	-2.2264	-1.9491	-1.7933	0.3312	1.0639	0.596	0.9280
0.9047	0.6958	0.2696	0.1018	0.0145	0.0008	-0.0112	-0.0026	0.0128	0.0470	0.00248	0.0258
										1682.3	7.36
0.0812	-0.0198	-0.1464	-0.2560	-0.3570	-0.4922	-0.6138	-0.7935	-1.6529	-2.3086	24	
-2.6732	-2.6578	-2.6800	-2.6355	-2.5499	-2.3770	-2.1117	-1.9662	0.2113	1.0484	0.596	0.8720
0.8910	0.6821	0.2490	0.0727	-0.0266	-0.0523	-0.0626	-0.0557	-0.0352	-0.0009	0.00496	0.0457
										1682.4	6.00
0.1562	0.0094	-0.1287	-0.2323	-0.3359	-0.4741	-0.6122	-0.8091	-0.9956	-0.9921	32	
-1.5205	-2.2389	-2.3028	-2.2873	-2.2113	-1.9557	-1.6950	-1.3254	0.6052	0.8935	0.594	0.5878
0.6811	0.4359	0.0180	-0.1218	-0.1823	-0.1719	-0.1529	-0.1132	-0.0648	0.0042	0.00745	0.0373
										1667.8	3.88
0.1677	0.0196	-0.1081	-0.1932	-0.2749	-0.3804	-0.4774	-0.6102	-0.7396	-0.7804	40	
-0.8860	-0.9711	-1.0630	-1.0306	-0.9728	-0.7651	-0.5370	-0.2698	1.0086	0.5098	0.599	0.2327
0.2596	0.0366	-0.2902	-0.3413	-0.3276	-0.2698	-0.2221	-0.1506	-0.0825	0.0111	0.00993	0.0150
										1691.9	0.86
0.1788	0.0349	-0.0802	-0.1462	-0.2072	-0.2833	-0.3510	-0.4289	-0.4678	-0.4949	48	
-0.5169	-0.5169	-0.4949	-0.3764	-0.2275	-0.0040	0.2363	0.4310	1.0877	-0.0430	0.601	-0.0525
-0.2833	-0.4374	-0.6134	-0.5559	-0.4645	-0.3527	-0.2698	-0.1835	-0.0955	0.0146	0.01241	0.0047
										1701.4	-1.30
0.1680	0.0144	-0.1054	-0.1763	-0.2421	-0.3164	-0.3856	-0.4598	-0.4835	-0.4902	56	
-0.4987	-0.4750	-0.4328	-0.3215	-0.1831	0.0195	0.2676	0.4515	1.0676	-0.1426	0.601	-0.0376
-0.3738	-0.5054	-0.6489	-0.5594	-0.4565	-0.3333	-0.2573	-0.1712	-0.0885	0.0178	0.01490	-0.0073
										1706.4	-0.57
0.1692	0.0129	-0.1272	-0.2218	-0.3078	-0.4159	-0.5154	-0.6454	-0.7484	-0.7855	64	
-0.8446	-0.8699	-0.8834	-0.8378	-0.7703	-0.6049	-0.3838	-0.1964	1.0644	0.4787	0.602	0.2686
0.2374	0.0112	-0.2842	-0.3095	-0.2758	-0.2116	-0.1610	-0.1070	-0.0479	0.0348	0.01738	-0.0044
										1706.3	2.38

Table 3.9

ARA RUN 87 PSTEP 3 AGARD CASE 3 - OSC PITCH
M=0.60 R=$4.8*10^6$ $\omega c/2v$=0.0810 α_m=4.86 α_o=2.44 Damping +0.26392

0.1458	-0.0008	-0.1559	-0.2735	-0.3894	-0.5377	-0.6929	-0.8855	-1.0492	-1.4651	8	
-2.1453	-2.1623	-2.2748	-2.2049	-2.0993	-1.9169	-1.6748	-1.4941	0.5072	0.9846	0.598	0.7502
0.7953	0.5669	0.1475	0.0112	-0.0553	-0.0553	-0.0519	-0.0349	-0.0059	0.0436	0.00000	0.0168
										1689.4	5.95
0.1243	-0.0077	-0.1620	-0.2786	-0.3900	-0.5272	-0.6729	-0.8083	-1.6879	-2.5365	16	
-2.5640	-2.5434	-2.5691	-2.5160	-2.4320	-2.2622	-1.9965	-1.8130	0.2821	1.0450	0.596	0.9064
0.8873	0.6747	0.2512	0.0849	-0.0008	-0.0180	-0.0265	-0.0180	0.0043	0.0420	0.00248	0.0297
										1679.8	6.97
0.1163	-0.0110	-0.1485	-0.2588	-0.3657	-0.5032	-0.6373	-0.7731	-1.5573	-1.9307	24	
-2.5893	-2.5893	-2.6012	-2.5537	-2.4824	-2.3109	-2.0410	-1.8238	0.2708	1.0329	0.600	0.8480
0.8768	0.6612	0.2318	0.0654	-0.0262	-0.0415	-0.0517	-0.0449	-0.0212	0.0213	0.00496	0.0378
										1696.7	6.57
0.1428	-0.0025	-0.1427	-0.2539	-0.3564	-0.5017	-0.6453	-0.8265	-0.9274	-1.2044	32	
-2.3378	-2.4062	-2.4369	-2.3925	-2.3241	-2.1070	-1.8796	-1.5360	0.4761	0.9480	0.597	0.6985
0.7616	0.5274	0.1103	-0.0402	-0.1085	-0.1068	-0.1017	-0.0812	-0.0402	0.0197	0.00745	0.0333
										1684.7	5.11
0.1620	0.0112	-0.1278	-0.2346	-0.3295	-0.4634	-0.5990	-0.7804	-0.9906	-1.0957	40	
-1.2279	-1.5517	-1.9331	-1.9839	-1.9500	-1.6602	-1.3940	-1.1110	0.7197	0.8384	0.601	0.5402
0.6248	0.3807	-0.0126	-0.1261	-0.1702	-0.1516	-0.1278	-0.0905	-0.0397	0.0298	0.00993	0.0215
										1699.0	3.49
0.1715	0.0129	-0.1286	-0.2291	-0.3195	-0.4456	-0.5616	-0.7184	-0.8906	-0.9605	48	
-1.0781	-1.1753	-1.3304	-1.3918	-1.4071	-1.1787	-0.9281	-0.6775	0.9131	0.6932	0.599	0.4013
0.4613	0.2175	-0.1473	-0.2223	-0.2377	-0.1967	-0.1592	-0.1098	-0.0535	0.0300	0.01241	0.0111
										1689.4	2.43
0.1704	0.0078	-0.1310	-0.2325	-0.3205	-0.4424	-0.5626	-0.7116	-0.8673	-0.9316	56	
-1.0332	-1.1077	-1.2075	-1.2312	-1.2312	-1.0518	-0.8131	-0.5998	0.9524	0.6697	0.601	0.3876
0.4395	0.1940	-0.1580	-0.2241	-0.2308	-0.1834	-0.1496	-0.1022	-0.0463	0.0349	0.01490	0.0050
										1701.4	2.67
0.1667	0.0045	-0.1443	-0.2525	-0.3556	-0.4908	-0.6345	-0.8086	-1.0081	-1.1078	64	
-1.2177	-1.3056	-1.5895	-1.6064	-1.6267	-1.4019	-1.1855	-1.0030	0.7888	0.8327	0.602	0.5433
0.6164	0.3679	-0.0141	-0.1105	-0.1460	-0.1189	-0.0970	-0.0632	-0.0226	0.0467	0.01738	0.0048
										1703.8	4.28

Table 3.10

ARA RUN 128 PSTEP 1 AGARD CASE 5 - OSC. PITCH
M=0.755 R=$5.5*10^6$ $\omega c/2v$=0.0814 $\bar{\alpha}_m$=0.016 α_0=2.51 Damping +0.07790

0.2056	0.0453	-0.0990	-0.2050	-0.2999	-0.4158	-0.5256	-0.8831	-0.8399	-0.8005	4	
-0.7376	-0.6636	-0.5773	-0.4466	-0.2851	-0.0681	0.1784	0.3634	1.1623	0.2413	0.754	0.1008
-0.0003	-0.2284	-0.6316	-0.7290	-0.4183	-0.3517	-0.2555	-0.1594	-0.0718	0.0416	0.00000	-0.0074
										2336.0	1.09
0.2089	0.0551	-0.0803	-0.1751	-0.2600	-0.4778	-1.1719	-1.1411	-1.0537	-1.0242	8	
-0.9639	-0.8741	-0.7965	-0.6698	-0.5504	-0.3326	-0.0889	0.0944	1.1565	0.5129	0.755	0.3436
0.2729	0.0341	-0.3424	-0.4249	-0.3818	-0.2735	-0.2071	-0.1295	-0.0532	0.0514	0.00200	-0.0056
										2340.2	2.34
0.1996	0.0807	-0.0370	-0.1204	-0.3522	-0.5938	-1.2510	-1.1995	-1.1272	-1.0794	12	
-1.0303	-0.9616	-0.8967	-0.7470	-0.6563	-0.4184	-0.1609	0.0267	1.1426	0.5700	0.757	0.4001
0.3357	0.1015	-0.2786	-0.3779	-0.3595	-0.2713	-0.2124	-0.1388	-0.0567	0.0488	0.00399	-0.0013
										2348.6	2.01
0.2072	0.0713	-0.0460	-0.1152	-0.1794	-0.4018	-1.2010	-1.1442	-1.0602	-0.9984	16	
-0.9688	-0.9095	-0.8280	-0.7057	-0.5364	-0.2807	-0.0127	0.1899	1.1547	0.4308	0.753	0.2592
0.1825	-0.0399	-0.4265	-0.5167	-0.4697	-0.3586	-0.2746	-0.1831	-0.0831	0.0330	0.00599	0.0126
										2331.5	0.52
0.2139	0.0613	-0.0618	-0.1480	-0.2243	-0.3154	-0.3400	-0.8619	-0.8471	-0.7695	20	
-0.7412	-0.6982	-0.6108	-0.4434	-0.2403	0.0010	0.2730	0.4749	1.1617	0.1758	0.755	-0.0021
-0.0766	-0.2821	-0.6502	-0.7412	-0.6083	-0.4384	-0.3178	-0.2033	-0.0926	0.0404	0.00799	0.0138
										2339.8	-1.25
0.2057	0.0589	-0.0621	-0.1410	-0.2064	-0.2953	-0.3792	-0.4742	-0.4903	-0.4915	24	
-0.4606	-0.3989	-0.3187	-0.1472	0.0515	0.2933	0.5303	0.6981	1.1251	-0.1065	0.753	-0.2425
-0.3582	-0.5088	-0.8679	-1.0357	-1.0739	-0.4668	-0.3076	-0.2040	-0.0991	0.0391	0.00999	0.0044
										2333.9	-2.41
0.2138	0.0634	-0.0565	-0.1408	-0.2093	-0.2839	-0.3634	-0.4417	-0.4283	-0.4258	28	
-0.3793	-0.3072	-0.2301	-0.0711	0.1148	0.3422	0.5856	0.7410	1.1066	-0.1788	0.758	-0.2911
-0.4307	-0.5506	-0.9321	-1.0862	-1.1694	-0.5848	-0.2815	-0.1494	-0.0589	0.0573	0.01199	-0.0017
										2354.8	-2.00
0.2183	0.0562	-0.0763	-0.1709	-0.2519	-0.3488	-0.4458	-0.5624	-0.5600	-0.5428	32	
-0.5072	-0.4237	-0.3464	-0.1954	-0.0174	0.1937	0.4478	0.6111	1.1413	-0.0371	0.757	-0.1525
-0.2924	-0.4605	-0.8239	-1.0154	-1.0645	-0.3366	-0.2187	-0.1463	-0.0567	0.0538	0.01399	-0.0108
										2346.3	-0.54

Table 3.11

ARA RUN 218 AGARD CASE 6 - RAMP
M=0.3 $R=2.7*10^6$ $\dot{\alpha}c/V=0.02545$ Rad

0.1542	0.0110	-0.1266	-0.1432	-0.1927	-0.2973	-0.3414	-0.4184	-0.4405	-0.4350	136	
-0.4515	-0.4790	-0.4680	-0.4129	-0.2973	-0.1597	-0.0165	0.1982	1.0186	0.0330	0.304	0.0232
-0.2478	-0.3524	-0.4460	-0.3799	-0.3469	-0.2698	-0.1982	-0.1542	-0.0661	-0.0165	0.00000	0.0009
										523.1	-0.03
0.1486	0.0057	-0.1486	-0.1772	-0.2344	-0.3430	-0.4001	-0.5087	-0.5430	-0.5316	145	
-0.5716	-0.6002	-0.6116	-0.5659	-0.4744	-0.3658	-0.2401	-0.0229	1.0632	0.2458	0.298	0.1331
-0.0629	-0.2001	-0.3544	-0.3087	-0.2915	-0.2286	-0.1601	-0.1315	-0.0457	-0.0114	0.00352	-0.0028
										503.8	1.08
0.1406	-0.0056	-0.1519	-0.1856	-0.2362	-0.3656	-0.4162	-0.5230	-0.5961	-0.5849	148	
-0.6355	-0.6805	-0.7086	-0.6974	-0.6468	-0.5680	-0.4724	-0.2643	1.0348	0.4218	0.300	0.2097
0.1125	-0.0450	-0.2475	-0.2418	-0.2475	-0.1856	-0.1350	-0.1012	-0.0394	-0.0056	0.00469	-0.0024
										512.1	1.86
0.1454	-0.0168	-0.1790	-0.2126	-0.2741	-0.4084	-0.4867	-0.5986	-0.6825	-0.6937	151	
-0.7664	-0.8279	-0.8671	-0.8950	-0.8894	-0.8615	-0.8279	-0.6265	0.9845	0.5986	0.301	0.3253
0.2853	0.1063	-0.1454	-0.1846	-0.1790	-0.1343	-0.1007	-0.0895	-0.0112	0.0056	0.00586	-0.0058
										514.8	2.94
0.1494	-0.0057	-0.1839	-0.2299	-0.2989	-0.4541	-0.5403	-0.6782	-0.7932	-0.8276	154	
-0.9139	-0.9828	-1.0748	-1.1495	-1.2012	-1.2185	-1.2587	-1.0805	0.9139	0.7932	0.297	0.4500
0.4943	0.2816	-0.0287	-0.0920	-0.1264	-0.0977	-0.0632	-0.0460	0.0172	0.0230	0.00703	-0.0051
										501.1	4.14
0.1352	-0.0353	-0.2057	-0.2703	-0.3526	-0.5172	-0.6053	-0.7640	-0.9050	-0.9638	156	
-1.0637	-1.1342	-1.2635	-1.3575	-1.4751	-1.5515	-1.6338	-1.4868	0.8463	0.8933	0.294	0.5494
0.5994	0.3702	0.0353	-0.0588	-0.1058	-0.0764	-0.0529	-0.0411	0.0118	0.0118	0.00782	-0.0061
										490.1	4.97
0.1463	-0.0054	-0.1843	-0.2331	-0.3252	-0.4770	-0.5637	-0.7318	-0.8781	-0.9486	158	
-1.0624	-1.1437	-1.2901	-1.4201	-1.5990	-1.7399	-1.8917	-1.7562	0.6938	0.9377	0.306	0.5959
0.6830	0.4824	0.1409	0.0325	-0.0217	-0.0054	-0.0000	-0.0000	0.0488	0.0434	0.00860	-0.0048
										531.3	5.84
0.1510	-0.0112	-0.1958	-0.2573	-0.3524	-0.5203	-0.6265	-0.8056	-0.9846	-1.0685	160	
-1.1971	-1.3146	-1.4768	-1.6670	-1.9244	-2.1313	-2.3495	-2.2600	0.5818	1.0797	0.301	0.7064
0.7832	0.5986	0.2294	0.0951	0.0224	0.0224	0.0336	0.0280	0.0615	0.0503	0.00938	-0.0045
										514.8	6.72
0.1258	-0.0229	-0.2058	-0.2801	-0.3944	-0.5773	-0.7145	-0.9089	-1.1375	-1.2404	163	
-1.4119	-1.5605	-1.7949	-2.0692	-2.4236	-2.7666	-3.1439	-3.1324	0.3087	1.0861	0.298	0.8499
0.9089	0.7259	0.3315	0.1715	0.0686	0.0572	0.0572	0.0400	0.0686	0.0457	0.01055	0.0005
										503.8	8.02
0.1086	-0.0343	-0.2172	-0.3029	-0.4230	-0.6116	-0.7602	-0.9717	-1.2347	-1.3604	165	
-1.5319	-1.7205	-1.9835	-2.3093	-2.7265	-3.1152	-3.6925	-3.6983	0.0915	1.0975	0.298	0.9454
0.9431	0.8060	0.4058	0.2286	0.1086	0.0857	0.0743	0.0572	0.0743	0.0457	0.01133	0.0013
										503.8	8.91
0.0966	-0.0398	-0.2388	-0.3184	-0.4377	-0.6424	-0.7959	-1.0347	-1.3189	-1.4553	167	
-1.6543	-1.8647	-2.1603	-2.5582	-3.0642	-3.5076	-4.2523	-4.3376	-0.1251	1.0574	0.298	1.0353
0.9664	0.8527	0.4718	0.2729	0.1478	0.1194	0.0966	0.0682	0.0910	0.0512	0.01212	0.0018
										506.6	9.85
0.0848	-0.0339	-0.2205	-0.3223	-0.4523	-0.6615	-0.8199	-1.0743	-1.3966	-1.5493	169	
-1.7698	-2.0129	-2.3352	-2.7875	-3.3812	-3.9184	-4.8004	-4.9531	-0.3675	1.0404	0.299	1.1270
0.9725	0.9103	0.5428	0.3506	0.2092	0.1640	0.1357	0.1018	0.1131	0.0622	0.01290	0.0034
										509.4	10.80
0.0747	-0.0460	-0.2414	-0.3448	-0.4770	-0.6954	-0.8736	-1.1552	-1.5058	-1.6783	171	
-1.9312	-2.2070	-2.5749	-3.0979	-3.8278	-4.4658	-5.4486	-5.7302	-0.6265	0.9943	0.297	1.2531
1.0460	0.9828	0.6322	0.4138	0.2701	0.2184	0.1782	0.1322	0.1322	0.0747	0.01369	0.0020
										501.1	11.76
0.0615	-0.0392	-0.2238	-0.3300	-0.4699	-0.6936	-0.8950	-1.1803	-1.5551	-1.7565	173	
-2.0138	-2.3158	-2.7242	-3.3115	-4.0947	-4.8610	-5.9574	-6.3042	-0.8838	0.8726	0.301	1.3046
0.9342	0.9789	0.6713	0.4531	0.2909	0.2349	0.2014	0.1510	0.1510	0.0783	0.01447	0.0066
										514.9	12.83
0.0455	-0.0512	-0.2445	-0.3411	-0.4832	-0.7277	-0.9380	-1.2507	-1.6771	-1.8988	175	
-2.1830	-2.5241	-2.9675	-3.6440	-4.5423	-5.4291	-6.6286	-7.6235	-1.1995	0.7959	0.298	1.4453
0.9437	1.0403	0.7618	0.5458	0.3638	0.3127	0.2558	0.1876	0.1705	0.0910	0.01525	0.0069
										506.6	13.88
-0.0234	-0.0935	-0.2630	-0.3857	-0.5610	-0.8240	-1.0577	-1.3908	-1.8700	-2.1272	178	
-2.4603	-2.8810	-3.4595	-4.3069	-5.2419	-6.2938	-8.0937	-8.7015	-1.7006	0.6194	0.294	1.6368
0.8707	1.0694	0.8532	0.6194	0.4324	0.3565	0.2863	0.2162	0.1928	0.0935	0.01642	0.0036
										492.8	15.54

Table 3.12

ARA RUN 227 AGARD CASE 7 - RAMP
M=0.57 R=4.6*10⁶ $\dot{\alpha}$c/v=0.0044 Rad

0.1899	0.0429	-0.0776	-0.1552	-0.2279	-0.3072	-0.3881	-0.4822	-0.5450	-0.5334	151	
-0.5979	-0.5648	-0.5599	-0.4806	-0.3501	-0.1354	0.0661	0.2874	1.1082	0.1107	0.613	0.0282
-0.1453	-0.3154	-0.5202	-0.4905	-0.4129	-0.3055	-0.2345	-0.1552	-0.0694	0.0347	0.00000	0.0018
										1743.8	-0.01
0.1933	0.0413	-0.0859	-0.1751	-0.2544	-0.3370	-0.4294	-0.5418	-0.6343	-0.6425	169	
-0.7235	-0.6871	-0.7069	-0.6557	-0.5434	-0.3551	-0.1553	0.0611	1.1133	0.3138	0.613	0.1363
0.0512	-0.1454	-0.3931	-0.3981	-0.3436	-0.2593	-0.1966	-0.1272	-0.0529	0.0429	0.00698	0.0014
										1743.6	0.98
0.1919	0.0410	-0.0935	-0.1854	-0.2723	-0.3707	-0.4790	-0.6184	-0.7382	-0.7693	180	
-0.8743	-0.8514	-0.9088	-0.8924	-0.8251	-0.6496	-0.4708	-0.2264	1.0826	0.5216	0.615	0.2540
0.2641	0.0377	-0.2575	-0.3035	-0.2789	-0.2116	-0.1624	-0.1066	-0.0344	0.0476	0.01126	0.0043
										1755.7	1.97
0.1885	0.0347	-0.1058	-0.2084	-0.3076	-0.4134	-0.5391	-0.7012	-0.8533	-0.9178	189	
-1.0468	-1.0501	-1.1527	-1.1725	-1.1510	-0.9823	-0.8136	-0.5689	1.0286	0.6946	0.612	0.3798
0.4432	0.2067	-0.1406	-0.2166	-0.2150	-0.1703	-0.1306	-0.0827	-0.0215	0.0496	0.01475	0.0059
										1741.5	2.93
0.1921	0.0331	-0.1143	-0.2219	-0.3295	-0.4488	-0.5945	-0.7733	-0.9737	-1.0664	197	
-1.2271	-1.2486	-1.4722	-1.4788	-1.5450	-1.3016	-1.1509	-0.9141	0.9356	0.8330	0.612	0.5050
0.5962	0.3511	-0.0265	-0.1292	-0.1507	-0.1225	-0.0927	-0.0546	-0.0050	0.0580	0.01786	0.0083
										1739.2	3.94
0.1805	0.0331	-0.1159	-0.2318	-0.3444	-0.4720	-0.6276	-0.8230	-1.0317	-1.1128	203	
-1.3496	-1.7586	-1.8216	-1.8696	-1.7901	-1.5699	-1.3993	-1.1724	0.8462	0.9191	0.612	0.6105
0.6988	0.4587	0.0696	-0.0530	-0.0977	-0.0828	-0.0629	-0.0348	0.0083	0.0613	0.02019	0.0129
										1739.2	4.79
0.1755	0.0315	-0.1176	-0.2335	-0.3544	-0.4852	-0.6376	-0.8214	-1.1377	-1.7603	210	
-2.1528	-2.1114	-2.1561	-2.1213	-2.0236	-1.8497	-1.6692	-1.4341	0.7203	0.9952	0.612	0.7425
0.7949	0.5746	0.1656	0.0199	-0.0364	-0.0381	-0.0315	-0.0116	0.0232	0.0662	0.02291	0.0212
										1739.2	5.79
0.1648	0.0250	-0.1232	-0.2398	-0.3580	-0.4845	-0.6211	-0.8925	-1.5152	-2.3228	216	
-2.4027	-2.3544	-2.3544	-2.3128	-2.2412	-2.0514	-1.8699	-1.6184	0.6094	1.0540	0.610	0.8628
0.8792	0.6694	0.2514	0.0899	0.0117	0.0017	-0.0017	0.0083	0.0366	0.0699	0.02523	0.0263
										1729.7	6.70
0.0747	-0.0000	-0.1279	-0.2408	-0.3753	-0.6027	-0.9083	-1.2254	-1.5575	-1.6854	223	
-1.7983	-2.5272	-2.5239	-2.4873	-2.4159	-2.2482	-2.0324	-1.9245	0.4666	1.0843	0.610	0.9573
0.9315	0.7356	0.3254	0.1461	0.0598	0.0349	0.0183	0.0199	0.0315	0.0465	0.02795	0.0153
										1734.5	7.75
-0.0616	-0.1082	-0.2664	-0.3912	-0.6026	-0.7075	-0.8224	-1.0421	-1.3784	-1.5898	229	
-1.7397	-2.0410	-2.6353	-2.6054	-2.5404	-2.3873	-2.1958	-2.1492	0.3446	1.1037	0.609	0.9878
0.9706	0.7774	0.3662	0.1798	0.0749	0.0383	0.0183	0.0017	0.0033	-0.0050	0.03028	-0.0102
										1730.0	8.73
-0.0789	-0.1527	-0.2467	-0.3256	-0.4163	-0.6143	-0.8325	-1.1749	-1.4704	-1.5912	235	
-1.6265	-1.7893	-2.1182	-2.6117	-2.6470	-2.5060	-2.3331	-2.3079	0.2383	1.1229	0.606	0.9587
0.9970	0.8107	0.3978	0.2031	0.0839	0.0436	0.0117	-0.0117	-0.0201	-0.0420	0.03261	0.0026
										1715.8	9.68
-0.1892	-0.2250	-0.3068	-0.3886	-0.5642	-0.7159	-0.9443	-1.1932	-1.4267	-1.4727	241	
-1.5512	-1.6483	-1.7847	-2.2671	-2.6063	-2.5245	-2.4716	-2.4563	0.1398	1.1386	0.601	0.9823
1.0176	0.8404	0.4261	0.2131	0.0938	0.0426	-0.0034	-0.0358	-0.0563	-0.0972	0.03493	-0.0147
										1689.6	10.63
-0.2864	-0.3000	-0.4330	-0.4892	-0.5455	-0.6529	-0.7654	-1.0466	-1.5018	-1.3944	248	
-1.5103	-1.6961	-2.0694	-2.7410	-2.8075	-2.6848	-2.4444	-2.5859	0.0324	1.1455	0.601	1.0090
1.0483	0.8847	0.4739	0.2506	0.1210	0.0545	0.0034	-0.0409	-0.0733	-0.1381	0.03765	-0.0170
										1689.5	11.74
-0.4212	-0.4505	-0.5644	-0.5506	-0.5783	-0.7388	-0.8389	-1.0132	-1.1030	-1.2221	254	
-1.4275	-1.6830	-1.9988	-2.3044	-2.8464	-2.8533	-2.6997	-2.6910	-0.0742	1.1479	0.595	0.9920
1.0581	0.8959	0.4799	0.2537	0.1053	0.0328	-0.0242	-0.0829	-0.1329	-0.2158	0.03999	-0.0340
										1668.5	12.70
-0.3785	-0.4944	-0.5791	-0.6050	-0.6655	-0.7917	-0.8418	-1.0440	-1.1391	-1.2463	260	
-1.5989	-1.7631	-1.9342	-2.2471	-2.8434	-2.8227	-2.7725	-2.5012	-0.1590	1.1443	0.595	1.0459
1.0665	0.9282	0.5237	0.2904	0.1383	0.0622	-0.0069	-0.0674	-0.1210	-0.2109	0.04232	-0.0466
										1666.2	13.72
-0.5402	-0.6507	-0.6910	-0.6682	-0.6349	-0.7822	-0.7857	-0.8910	-1.1909	-1.1347	266	
-1.2014	-1.4767	-1.6065	-1.8433	-2.2344	-2.6045	-2.8710	-2.4063	-0.2578	1.1610	0.590	1.0192
1.0979	0.9734	0.5682	0.3227	0.1649	0.0772	-0.0018	-0.0754	-0.1368	-0.2420	0.04464	-0.0725
										1642.1	14.80

Table 3.13

ARA RUN 230 AGARD CASE 8 - RAMP
M=0.56 R=4.5*10^{6} $\dot{\alpha}$ c/v=0.01492 Rad

0.1932	0.0446	-0.0710	-0.1486	-0.2246	-0.2973	-0.3766	-0.4724	-0.5351	-0.5285	64	
-0.5814	-0.5533	-0.5533	-0.4691	-0.3353	-0.1156	0.0826	0.2940	1.1099	0.1090	0.613	0.0250
-0.1470	-0.3122	-0.5170	-0.4905	-0.4113	-0.2973	-0.2246	-0.1486	-0.0628	0.0380	0.00000	0.0014
										1743.7	-0.01
0.1896	0.0316	-0.0931	-0.1829	-0.2611	-0.3476	-0.4390	-0.5504	-0.6336	-0.6452	74	
-0.7018	-0.6668	-0.6885	-0.6253	-0.5105	-0.3226	-0.1231	0.0815	1.1125	0.2877	0.610	0.1305
0.0216	-0.1680	-0.4157	-0.4174	-0.3492	-0.2627	-0.1979	-0.1280	-0.0532	0.0349	0.00388	-0.0009
										1731.9	1.08
0.1805	0.0248	-0.1076	-0.1987	-0.2848	-0.3776	-0.4769	-0.6061	-0.7088	-0.7336	77	
-0.8065	-0.7767	-0.8131	-0.7717	-0.6806	-0.5084	-0.3213	-0.0927	1.1045	0.4372	0.612	0.2184
0.1755	-0.0397	-0.3179	-0.3428	-0.2997	-0.2236	-0.1722	-0.1093	-0.0431	0.0348	0.00505	-0.0013
										1739.1	1.90
0.1832	0.0266	-0.1132	-0.2148	-0.3147	-0.4196	-0.5345	-0.6894	-0.8293	-0.8859	80	
-0.9758	-0.9609	-1.0208	-1.0058	-0.9625	-0.7977	-0.6228	-0.4163	1.0924	0.6328	0.610	0.3458
0.3747	0.1365	-0.1865	-0.2498	-0.2331	-0.1732	-0.1349	-0.0799	-0.0200	0.0466	0.00621	-0.0006
										1729.5	2.96
0.1850	0.0330	-0.1140	-0.2213	-0.3270	-0.4393	-0.5731	-0.7333	-0.9017	-0.9827	82	
-1.0884	-1.0884	-1.1776	-1.1825	-1.1776	-1.0223	-0.8621	-0.6639	1.0553	0.7481	0.613	0.4342
0.5054	0.2626	-0.0941	-0.1767	-0.1784	-0.1321	-0.0974	-0.0545	-0.0050	0.0562	0.00699	0.0005
										1743.8	3.83
0.1794	0.0266	-0.1229	-0.2391	-0.3504	-0.4716	-0.6161	-0.8021	-1.0064	-1.1127	84	
-1.2422	-1.2638	-1.4099	-1.4548	-1.4797	-1.2704	-1.1127	-0.9283	1.0230	0.8602	0.611	0.5422
0.6277	0.3853	0.0017	-0.0996	-0.1229	-0.0913	-0.0681	-0.0332	0.0083	0.0648	0.00776	0.0011
										1734.2	4.70
0.1730	0.0266	-0.1281	-0.2478	-0.3675	-0.5006	-0.6569	-0.8581	-1.0727	-1.2124	86	
-1.4618	-1.6348	-1.7213	-1.8510	-1.7346	-1.5417	-1.3604	-1.1874	0.9762	0.9546	0.611	0.6552
0.7434	0.5106	0.1081	-0.0233	-0.0665	-0.0466	-0.0333	-0.0083	0.0249	0.0682	0.00854	0.0049
										1731.7	5.67
0.1671	0.0278	-0.1245	-0.2474	-0.3702	-0.5029	-0.6618	-0.8470	-1.1746	-1.6873	88	
-2.0281	-1.9380	-1.9839	-2.0232	-1.9167	-1.7512	-1.5514	-1.3826	0.9092	1.0075	0.616	0.7628
0.8158	0.6094	0.1933	0.0475	-0.0033	-0.0016	0.0033	0.0213	0.0426	0.0754	0.00931	0.0104
										1758.0	6.60
0.1613	0.0200	-0.1314	-0.2561	-0.3825	-0.5122	-0.6569	-0.9446	-1.5782	-2.3116	90	
-2.3066	-2.2234	-2.2284	-2.2484	-2.1586	-1.9823	-1.7777	-1.5898	0.8498	1.0776	0.611	0.9000
0.9063	0.7068	0.2827	0.1214	0.0499	0.0382	0.0333	0.0399	0.0565	0.0815	0.01009	0.0155
										1731.8	7.57
0.1478	0.0183	-0.1295	-0.2408	-0.3504	-0.5215	-0.8752	-1.4116	-1.6740	-2.1705	92	
-2.4246	-2.4030	-2.4014	-2.4279	-2.3316	-2.1722	-1.9513	-1.8567	0.7805	1.1143	0.611	1.0335
0.9715	0.7805	0.3620	0.1877	0.1030	0.0830	0.0681	0.0664	0.0731	0.0880	0.01086	0.0126
										1734.2	8.55
0.0743	-0.0000	-0.1602	-0.3220	-0.5631	-0.9049	-1.2319	-1.4366	-1.5506	-1.5753	94	
-1.7240	-2.2590	-2.3993	-2.5678	-2.4968	-2.3515	-2.1566	-2.1450	0.6952	1.1295	0.612	1.1289
1.0089	0.8356	0.4310	0.2444	0.1453	0.1123	0.0859	0.0710	0.0760	0.0710	0.01164	-0.0192
										1744.1	9.55
-0.0766	-0.2198	-0.4196	-0.5345	-0.8209	-1.0123	-1.2105	-1.3420	-1.3437	-1.2954	96	
-1.3570	-1.5435	-1.6933	-2.0846	-2.2195	-2.5208	-2.3610	-2.3593	0.6260	1.1472	0.609	1.1567
1.0506	0.8924	0.4912	0.2947	0.1815	0.1349	0.0932	0.0649	0.0516	0.0117	0.01241	-0.0758
										1729.7	10.56
-0.2721	-0.2838	-0.3272	-0.4140	-0.5576	-0.8414	-1.1136	-1.2688	-1.5827	-1.6745	98	
-1.7013	-1.6228	-1.6211	-1.6512	-1.8482	-2.6629	-2.5110	-2.5143	0.5476	1.1637	0.608	1.0933
1.0802	0.9333	0.5309	0.3172	0.1853	0.1219	0.0668	0.0217	-0.0100	-0.0902	0.01319	-0.0403
										1725.0	11.63
-0.2467	-0.3117	-0.4418	-0.6251	-0.7685	-0.8435	-0.8602	-1.3886	-1.5637	-1.5770	100	
-1.5803	-1.5820	-1.5753	-1.5537	-1.6454	-2.7373	-2.6056	-2.6072	0.4668	1.1436	0.608	1.1169
1.0719	0.9385	0.5418	0.3217	0.1834	0.1167	0.0617	0.0133	-0.0300	-0.1050	0.01396	-0.0599
										1727.6	12.69
-0.5488	-0.5842	-0.7003	-0.6885	-0.7121	-0.7643	-0.8249	-1.0185	-1.4478	-1.4915	102	
-1.5235	-1.6700	-1.6111	-1.5993	-1.6582	-2.7541	-2.7070	-2.7121	0.4040	1.1717	0.605	1.1387
1.1111	0.9831	0.5926	0.3636	0.2172	0.1448	0.0758	0.0135	-0.0438	-0.1566	0.01474	-0.0917
										1710.8	13.77
-0.4878	-0.5932	-0.6578	-0.6765	-0.7071	-0.7581	-0.8703	-0.9893	-1.1524	-1.2391	104	
-1.3972	-1.6709	-1.6760	-1.6590	-1.6947	-2.5837	-2.6380	-2.7978	0.3230	1.1711	0.602	1.0878
1.1235	1.0063	0.6136	0.3773	0.2227	0.1343	0.0544	-0.0204	-0.0884	-0.2159	0.01552	-0.0775
										1694.3	14.97

Table 3·14

ARA RUN 6 QUASI-STATIC
M=0.3 R=2.6*10^6 α_m=10.75 α_o=11.16 1.8 Hz

0.1349	-0.0066	-0.1537	-0.1877	-0.2443	-0.3405	-0.3801	-0.4424	-0.4594	-0.4707	80	
-0.4933	-0.5046	-0.4877	-0.4367	-0.3179	-0.1764	0.0160	0.2254	1.0008	-0.0292	0.299	0.0140
-0.2783	-0.3858	-0.5103	-0.4480	-0.3914	-0.3065	-0.2500	-0.1764	-0.1198	-0.0292	0.00000	-0.0013
										508.9	-0.12
0.1233	-0.0306	-0.1962	-0.2317	-0.2908	-0.3973	-0.4447	-0.5275	-0.5571	-0.5926	84	
-0.6221	-0.6517	-0.6576	-0.6340	-0.5334	-0.4328	-0.2554	-0.0483	1.0461	0.2002	0.293	0.1125
-0.0779	-0.2435	-0.4328	-0.4032	-0.3559	-0.2968	-0.2554	-0.1784	-0.1252	-0.0424	0.01110	-0.0012
										486.8	0.69
0.1092	-0.0412	-0.2031	-0.2610	-0.3304	-0.4460	-0.5097	-0.6138	-0.6716	-0.7121	88	
-0.7699	-0.8335	-0.8740	-0.9029	-0.8798	-0.8220	-0.6947	-0.4981	0.9247	0.4851	0.296	0.2514
0.1901	-0.0007	-0.2841	-0.3015	-0.2899	-0.2436	-0.2147	-0.1569	-0.1164	-0.0470	0.02220	0.0016
										498.0	2.04
0.1232	-0.0344	-0.1976	-0.2595	-0.3270	-0.4564	-0.5127	-0.6365	-0.7153	-0.7547	90	
-0.8391	-0.9179	-0.9686	-1.0361	-1.0473	-1.0473	-0.9573	-0.7941	0.7929	0.6128	0.300	0.3288
0.3258	0.1232	-0.1807	-0.2201	-0.2370	-0.2088	-0.1694	-0.1075	-0.0794	-0.0287	0.02775	0.0010
										511.8	2.84
0.1259	-0.0351	-0.2077	-0.2824	-0.3515	-0.4952	-0.5758	-0.7023	-0.7943	-0.8806	92	
-0.9438	-1.0704	-1.1624	-1.2602	-1.3292	-1.3694	-1.3464	-1.2026	0.6435	0.7643	0.297	0.4340
0.4767	0.2582	-0.0869	-0.1617	-0.1904	-0.1502	-0.1387	-0.0984	-0.0696	-0.0179	0.03330	0.0011
										500.8	3.65
0.0977	-0.0585	-0.2377	-0.3245	-0.3997	-0.5385	-0.6368	-0.7756	-0.9028	-0.9895	94	
-1.0763	-1.1572	-1.3654	-1.4985	-1.6488	-1.7413	-1.7934	-1.6719	0.3348	0.8668	0.296	0.5268
0.6066	0.3753	-0.0064	-0.1163	-0.1626	-0.1510	-0.1452	-0.1047	-0.0758	-0.0353	0.03885	0.0034
										498.0	4.62
0.1025	-0.0405	-0.2349	-0.3093	-0.4065	-0.5552	-0.6639	-0.8240	-0.9784	-1.0814	96	
-1.1957	-1.3158	-1.4417	-1.7505	-1.9507	-2.1222	-2.2538	-2.1851	-0.0062	0.9546	0.298	0.6326
0.7259	0.5085	0.1025	-0.0119	-0.0977	-0.0977	-0.0862	-0.0576	-0.0405	-0.0119	0.04441	0.0040
										503.6	5.61
0.0881	-0.0716	-0.2609	-0.3614	-0.4619	-0.6334	-0.7576	-0.9410	-1.1361	-1.2663	98	
-1.3964	-1.5560	-1.7512	-1.9878	-2.4491	-2.6975	-2.9518	-2.9577	-0.5388	1.0284	0.293	0.7745
0.8392	0.6381	0.1886	0.0526	-0.0420	-0.0598	-0.0775	-0.0539	-0.0539	-0.0243	0.04995	0.0051
										487.0	6.59
0.1066	-0.0539	-0.2501	-0.3512	-0.4702	-0.6545	-0.7794	-0.9934	-1.2254	-1.3740	100	
-1.5346	-1.7427	-1.9865	-2.2957	-2.7833	-3.2412	-3.5861	-3.6634	-1.1243	1.0878	0.292	0.8889
0.9273	0.7548	0.3029	0.1364	0.0234	-0.0063	-0.0301	-0.0063	-0.0123	0.0056	0.05551	0.0072
										484.3	7.67
0.0820	-0.0650	-0.2707	-0.3766	-0.5000	-0.6764	-0.8293	-1.0527	-1.3231	-1.4936	102	
-1.6758	-1.9051	-2.1932	-2.5871	-3.0692	-3.8217	-4.2391	-4.4155	-1.7523	1.0462	0.294	0.9937
0.9580	0.8169	0.3877	0.1996	0.0702	0.0350	0.0056	0.0056	-0.0062	0.0056	0.06106	0.0075
										489.9	8.72
0.0899	-0.0394	-0.2307	-0.3488	-0.4613	-0.6525	-0.8100	-1.0519	-1.3388	-1.5188	104	
-1.7269	-1.9687	-2.2837	-2.7450	-3.3131	-3.8924	-4.7755	-5.0512	-2.4019	0.9843	0.301	1.0381
0.9337	0.8549	0.4612	0.2643	0.1237	0.0787	0.0506	0.0449	0.0281	0.0225	0.06662	0.0124
										512.0	9.79
0.0582	-0.0581	-0.2441	-0.3719	-0.5056	-0.7090	-0.8892	-1.1449	-1.4878	-1.6971	106	
-1.9295	-2.2143	-2.5921	-3.1442	-3.8591	-4.4984	-5.7771	-6.2362	-3.2721	0.9474	0.296	1.1814
0.9590	0.9358	0.5464	0.3313	0.1860	0.1221	0.0872	0.0640	0.0349	0.0175	0.07216	0.0148
										495.5	10.83
0.0624	-0.0450	-0.2147	-0.3391	-0.4804	-0.6896	-0.8818	-1.1532	-1.5151	-1.7469	108	
-1.9957	-2.3123	-2.7138	-3.3188	-4.1330	-4.8680	-6.6660	-7.3445	-3.9011	0.8709	0.300	1.2479
0.9501	0.9614	0.6108	0.4016	0.2433	0.1755	0.1246	0.1076	0.0737	0.0398	0.07772	0.0192
										509.4	11.93
-0.0508	-0.1412	-0.2600	-0.3505	-0.4918	-0.7180	-0.9216	-1.2269	-1.6114	-1.8772	111	
-2.1486	-2.5048	-2.9572	-3.6357	-4.5404	-5.3094	-8.4364	-9.1262	-4.9871	0.6673	0.300	1.3487
0.8539	0.9557	0.6617	0.4468	0.2659	0.1811	0.1302	0.0962	0.0567	0.0001	0.08605	0.0214
										509.3	13.54
-0.0764	-0.2586	-0.4114	-0.4466	-0.4819	-0.7523	-0.9932	-1.3694	-1.7044	-1.9101	113	
-2.1687	-2.5037	-2.9445	-3.6087	-4.4903	-5.2073	-6.9411	-8.1577	-5.3660	0.6877	0.294	1.4063
0.8934	1.0168	0.7053	0.4761	0.2880	0.1940	0.1293	0.0941	0.0294	-0.0411	0.09159	0.0008
										490.0	14.55
-0.2278	-0.3739	-0.6077	-0.8356	-0.9934	-1.2505	-1.5836	-1.2271	-1.3382	-1.5836	115	
-1.5252	-1.6070	-1.8349	-2.3726	-3.1557	-3.7810	-4.3420	-5.1427	-4.8271	0.7540	0.295	1.3783
0.9235	0.9936	0.6897	0.4501	0.2573	0.1696	0.0878	0.0469	-0.0408	-0.1109	0.09715	-0.0991
										492.8	15.55

Table 3.15

ARA RUN 11 QUASI-STATIC
M=0.58 R=4.6*10^6 α_m=8.99 α_0=9.55 1.8 Hz

0.1774	0.0287	-0.0935	-0.1643	-0.2298	-0.3183	-0.3892	-0.4741	-0.5237	-0.5467	82	
-0.5680	-0.5680	-0.5503	-0.4741	-0.3396	-0.1448	0.0960	0.2872	1.0981	0.0730	0.585	0.0255
-0.1643	-0.3431	-0.5220	-0.4812	-0.4069	-0.3113	-0.2387	-0.1590	-0.0811	0.0198	0.00000	0.0009
										1626.6	-0.13
0.1730	0.0196	-0.1055	-0.1795	-0.2500	-0.3364	-0.4175	-0.5127	-0.5743	-0.6078	84	
-0.6413	-0.6396	-0.6308	-0.5743	-0.4545	-0.2589	-0.0156	0.1677	1.0860	0.1747	0.585	0.0747
-0.0632	-0.2589	-0.4686	-0.4510	-0.3910	-0.3012	-0.2342	-0.1637	-0.0826	0.0179	0.00537	0.0019
										1634.0	0.26
0.1804	0.0301	-0.1027	-0.1778	-0.2494	-0.3455	-0.4311	-0.5307	-0.6093	-0.6425	86	
-0.6932	-0.7054	-0.7106	-0.6687	-0.5691	-0.3927	-0.1481	0.0458	1.0836	0.3009	0.589	0.1350
0.0686	-0.1463	-0.3892	-0.3962	-0.3420	-0.2651	-0.2005	-0.1324	-0.0625	0.0336	0.01074	0.0014
										1648.5	0.76
0.1733	0.0197	-0.1162	-0.2009	-0.2751	-0.3757	-0.4745	-0.5840	-0.6881	-0.7340	88	
-0.7905	-0.8188	-0.8382	-0.8188	-0.7464	-0.5822	-0.3474	-0.1391	1.0665	0.4169	0.585	0.2044
0.1804	-0.0509	-0.3157	-0.3580	-0.3174	-0.2486	-0.1921	-0.1303	-0.0615	0.0215	0.01611	0.0036
										1631.5	1.34
0.1814	0.0268	-0.1121	-0.2017	-0.2843	-0.3915	-0.4969	-0.6252	-0.7553	-0.8063	90	
-0.8941	-0.9398	-0.9838	-0.9873	-0.9521	-0.8045	-0.5795	-0.3827	1.0285	0.5523	0.587	0.2881
0.3238	0.0830	-0.2193	-0.2878	-0.2614	-0.2052	-0.1613	-0.1068	-0.0435	0.0356	0.02148	0.0053
										1638.7	2.00
0.1740	0.0196	-0.1243	-0.2173	-0.3085	-0.4244	-0.5384	-0.6841	-0.8332	-0.8876	92	
-1.0140	-1.0894	-1.1631	-1.2017	-1.2070	-1.0578	-0.8332	-0.6349	0.9338	0.6776	0.587	0.3753
0.4460	0.1933	-0.1383	-0.2313	-0.2243	-0.1769	-0.1401	-0.0927	-0.0366	0.0371	0.02685	0.0063
										1641.3	2.71
0.1710	0.0197	-0.1317	-0.2285	-0.3271	-0.4503	-0.5787	-0.7495	-0.9219	-0.9976	94	
-1.1085	-1.2634	-1.3813	-1.4622	-1.5291	-1.3707	-1.1472	-0.9290	0.8169	0.7976	0.586	0.4725
0.5740	0.3206	-0.0419	-0.1599	-0.1739	-0.1440	-0.1141	-0.0754	-0.0243	0.0373	0.03222	0.0096
										1636.4	3.49
0.1712	0.0179	-0.1354	-0.2394	-0.3470	-0.4809	-0.6184	-0.8088	-1.0132	-1.1137	96	
-1.2424	-1.2335	-1.7077	-1.8875	-1.9227	-1.6900	-1.4715	-1.2706	0.6683	0.8904	0.585	0.5795
0.6806	0.4374	0.0461	-0.0720	-0.1178	-0.0967	-0.0808	-0.0508	-0.0068	0.0461	0.03759	0.0113
										1634.0	4.32
0.1583	0.0214	-0.1313	-0.2418	-0.3559	-0.4998	-0.6402	-0.8420	-1.0543	-1.1227	98	
-1.1227	-2.1019	-2.2195	-2.2405	-2.1616	-1.9878	-1.7457	-1.5246	0.5005	0.9585	0.587	0.6808
0.7725	0.5391	0.1320	-0.0014	-0.0628	-0.0593	-0.0505	-0.0277	0.0056	0.0512	0.04296	0.0176
										1641.2	5.21
0.1532	0.0145	-0.1403	-0.2559	-0.3715	-0.5226	-0.6791	-0.8712	-1.0010	-1.1398	100	
-2.3847	-2.5110	-2.5626	-2.5128	-2.4541	-2.2673	-2.0415	-1.7925	0.3328	1.0264	0.583	0.7996
0.8593	0.6316	0.2137	0.0554	-0.0175	-0.0264	-0.0264	-0.0104	0.0145	0.0483	0.04832	0.0252
										1619.3	6.10
0.1342	0.0091	-0.1427	-0.2517	-0.3804	-0.5286	-0.6733	-0.8520	-1.1450	-1.9739	102	
-2.6742	-2.7457	-2.7743	-2.7350	-2.6707	-2.4956	-2.2223	-2.0865	0.1520	1.0739	0.581	0.9017
0.9345	0.7184	0.2932	0.1199	0.0288	0.0073	-0.0034	0.0037	0.0198	0.0466	0.05371	0.0327
										1612.1	7.01
0.0962	-0.0123	-0.1475	-0.2613	-0.3787	-0.5191	-0.6650	-0.8517	-1.3763	-1.9650	104	
-2.7262	-2.7884	-2.8898	-2.8489	-2.7848	-2.6195	-2.3989	-2.3474	0.0339	1.0779	0.582	0.9428
0.9552	0.7506	0.3363	0.1389	0.0499	0.0233	0.0037	0.0019	0.0108	0.0250	0.05908	0.0369
										1619.4	7.94
0.0393	-0.0499	-0.1765	-0.2782	-0.3870	-0.5350	-0.6760	-0.9221	-1.4465	-1.8514	106	
-2.1886	-2.8343	-2.9092	-2.9377	-2.8878	-2.7255	-2.5221	-2.4829	-0.0659	1.0899	0.581	0.9565
0.9811	0.7849	0.3693	0.1660	0.0607	0.0250	-0.0017	-0.0124	-0.0106	-0.0088	0.06445	0.0353
										1614.6	8.79
-0.1562	-0.2046	-0.2638	-0.3051	-0.3895	-0.5474	-0.7179	-1.0157	-1.5344	-1.8448	108	
-1.9381	-2.0907	-2.3850	-2.7833	-2.9430	-2.8390	-2.6649	-2.6416	-0.1544	1.0928	0.579	0.9632
0.9959	0.8057	0.3911	0.1812	0.0681	0.0287	-0.0090	-0.0306	-0.0431	-0.0665	0.06982	0.0150
										1604.9	9.74
-0.2378	-0.2612	-0.3242	-0.3476	-0.4322	-0.5870	-0.7868	-1.0477	-1.5463	-1.6867	110	
-1.7983	-1.8991	-1.9729	-1.9837	-2.2015	-2.8764	-2.7720	-2.7648	-0.2396	1.0995	0.577	0.9387
1.0059	0.8295	0.4138	0.1942	0.0682	0.0214	-0.0200	-0.0524	-0.0776	-0.1154	0.07520	0.0001
										1600.1	10.63
-0.3974	-0.4787	-0.5509	-0.5491	-0.5906	-0.6646	-0.8307	-1.0275	-1.2406	-1.2333	112	
-1.1557	-1.1358	-1.0943	-1.1792	-2.5892	-2.6686	-2.7715	-2.7625	-0.1754	1.1064	0.576	0.9087
1.0144	0.8447	0.4330	0.2110	0.0792	0.0160	-0.0364	-0.0797	-0.1176	-0.1916	0.08057	-0.0508
										1595.2	11.56

Table 3.16

ARA RUN 151 QUASI-STATIC
M=0.745 R=5.5*10^6 α_m=0.09 α_0=5. 1.8 Hz

0.1715	0.0418	-0.0567	-0.1228	-0.1689	-0.2313	-0.2799	-0.3223	-0.2811	-0.2599	15	
-0.2151	-0.1427	-0.0604	0.0904	0.2949	0.5019	0.7239	0.8623	0.9994	-0.4644	0.746	-0.4703
-0.7250	-0.8061	-1.1777	-1.2787	-1.3560	-0.6964	-0.4146	-0.1689	-0.0592	0.0543	0.00000	-0.0020
										2309.7	-3.27
0.1906	0.0482	-0.0605	-0.1305	-0.1830	-0.2529	-0.3079	-0.3566	-0.3266	-0.3154	16	
-0.2654	-0.1980	-0.1180	0.0257	0.2331	0.4417	0.6741	0.8240	1.0327	-0.3866	0.745	-0.4168
-0.6477	-0.7514	-1.1313	-1.2425	-1.3187	-0.6340	-0.3179	-0.1642	-0.0743	0.0419	0.00555	-0.0029
										2305.1	-2.85
0.1968	0.0519	-0.0593	-0.1342	-0.1942	-0.2692	-0.3329	-0.3916	-0.3716	-0.3629	17	
-0.3167	-0.2492	-0.1717	-0.0268	0.1681	0.3843	0.6204	0.7766	1.0527	-0.3167	0.745	-0.3653
-0.5740	-0.6940	-1.0775	-1.1987	-1.2699	-0.5565	-0.2779	-0.1730	-0.0818	0.0407	0.01109	-0.0033
										2305.1	-2.40
0.2022	0.0530	-0.0639	-0.1435	-0.2082	-0.2928	-0.3587	-0.4370	-0.4271	-0.4096	18	
-0.3748	-0.3102	-0.2318	-0.0888	0.1089	0.3265	0.5665	0.7245	1.0801	-0.2306	0.747	-0.3010
-0.4867	-0.6310	-1.0003	-1.1421	-1.2117	-0.4159	-0.2729	-0.1871	-0.0913	0.0380	0.01663	-0.0040
										2315.9	-1.98
0.2095	0.0542	-0.0688	-0.1521	-0.2254	-0.3111	-0.3906	-0.4851	-0.4925	-0.4764	19	
-0.4515	-0.3844	-0.3136	-0.1682	0.0269	0.2592	0.5003	0.6680	1.1104	-0.1297	0.748	-0.2322
-0.3844	-0.5571	-0.9100	-1.0740	-1.0802	-0.3658	-0.2912	-0.1955	-0.0937	0.0356	0.02217	-0.0021
										2317.8	-1.54
0.2145	0.0530	-0.0713	-0.1620	-0.2427	-0.3384	-0.4291	-0.5360	-0.5596	-0.5522	20	
-0.5298	-0.4652	-0.3943	-0.2527	-0.0563	0.1698	0.4233	0.5998	1.1329	-0.0303	0.749	-0.1589
-0.2862	-0.4764	-0.8231	-0.9660	-0.9274	-0.3968	-0.3049	-0.1930	-0.0924	0.0406	0.02772	-0.0004
										2317.6	-1.06
0.2026	0.0454	-0.0834	-0.1775	-0.2592	-0.3607	-0.4622	-0.6008	-0.6627	-0.6565	21	
-0.6281	-0.5525	-0.4882	-0.3433	-0.1552	0.0726	0.3301	0.5009	1.1384	0.0590	0.750	-0.0538
-0.1911	-0.4003	-0.7556	-0.9152	-0.5166	-0.4077	-0.3012	-0.1960	-0.0933	0.0342	0.03327	-0.0022
										2326.6	-0.59
0.2095	0.0512	-0.0788	-0.1745	-0.2616	-0.3708	-0.4873	-0.6112	-0.7965	-0.7511	22	
-0.6971	-0.6296	-0.5695	-0.4272	-0.2444	-0.0187	0.2389	0.4192	1.1406	0.1678	0.755	0.0137
-0.0764	-0.2972	-0.6701	-0.7167	-0.5437	-0.3855	-0.2874	-0.1831	-0.0825	0.0414	0.03881	0.0018
										2347.7	-0.06
0.2091	0.0474	-0.0836	-0.1840	-0.2721	-0.3738	-0.4582	-0.9492	-0.8806	-0.8182	23	
-0.7558	-0.7178	-0.6517	-0.5097	-0.3334	-0.1105	0.1515	0.3413	1.1396	0.2593	0.755	0.0973
0.0144	-0.2085	-0.5880	-0.6345	-0.5121	-0.3750	-0.2734	-0.1766	-0.0811	0.0401	0.04436	0.0033
										2352.2	0.40
0.2049	0.0427	-0.0876	-0.1884	-0.2695	-0.3580	-0.4759	-1.0449	-0.9565	-0.8926	24	
-0.8594	-0.8151	-0.7303	-0.5951	-0.4219	-0.1970	0.0685	0.2553	1.1402	0.3401	0.754	0.1610
0.0968	-0.1355	-0.5079	-0.5706	-0.4636	-0.3432	-0.2584	-0.1675	-0.0753	0.0415	0.04990	0.0049
										2343.4	0.86
0.2115	0.0527	-0.0803	-0.1727	-0.2441	-0.3377	-0.8894	-1.1135	-1.0187	-0.9731	25	
-0.9362	-0.8820	-0.7958	-0.6652	-0.5089	-0.2774	-0.0101	0.1795	1.1486	0.4258	0.754	0.2535
0.1894	-0.0458	-0.4202	-0.5015	-0.4214	-0.3118	-0.2355	-0.1505	-0.0668	0.0465	0.05545	0.0034
										2338.8	1.31
0.2011	0.0516	-0.0794	-0.1635	-0.2364	-0.4317	-1.2239	-1.1732	-1.1015	-1.0570	26	
-1.0076	-0.9532	-0.8889	-0.7394	-0.6072	-0.3711	-0.1128	0.0812	1.1342	0.5002	0.752	0.3481
0.2654	0.0244	-0.3489	-0.4403	-0.3785	-0.2908	-0.2216	-0.1449	-0.0646	0.0466	0.06098	-0.0004
										2330.3	1.79
0.1925	0.0543	-0.0689	-0.1486	-0.2731	-0.5619	-1.3014	-1.2417	-1.1707	-1.1246	27	
-1.0761	-1.0325	-0.9703	-0.8047	-0.7051	-0.4598	-0.2021	-0.0092	1.1200	0.5598	0.748	0.4134
0.3257	0.0842	-0.2943	-0.3976	-0.3528	-0.2743	-0.2121	-0.1399	-0.0677	0.0406	0.06653	-0.0012
										2313.3	2.21
0.1847	0.0675	-0.0484	-0.1360	-0.3568	-0.6307	-1.3276	-1.2647	-1.2018	-1.1488	28	
-1.1155	-1.0760	-1.0032	-0.8404	-0.7762	-0.5160	-0.2705	-0.0855	1.1049	0.6189	0.752	0.4723
0.3956	0.1551	-0.2224	-0.3322	-0.3050	-0.2446	-0.1878	-0.1200	-0.0521	0.0453	0.07208	-0.0043
										2334.7	2.61
0.1596	0.0671	-0.0455	-0.2269	-0.4720	-0.6759	-1.3939	-1.3464	-1.2726	-1.2201	29	
-1.1876	-1.1450	-1.0687	-0.9324	-0.8636	-0.5921	-0.3457	-0.1593	1.0890	0.6637	0.746	0.5356
0.4461	0.1959	-0.1894	-0.3044	-0.2932	-0.2419	-0.1881	-0.1293	-0.0630	0.0258	0.07762	-0.0086
										2302.4	2.95
0.1177	0.0543	-0.0764	-0.2544	-0.4860	-0.6814	-1.1096	-1.3797	-1.3025	-1.2751	30	
-1.2191	-1.1755	-1.0996	-0.9863	-0.9092	-0.6304	-0.3889	-0.2047	1.0700	0.6978	0.747	0.5413
0.4837	0.2385	-0.1524	-0.2768	-0.2756	-0.2271	-0.1822	-0.1287	-0.0702	0.0132	0.08317	-0.0066
										2313.7	3.35

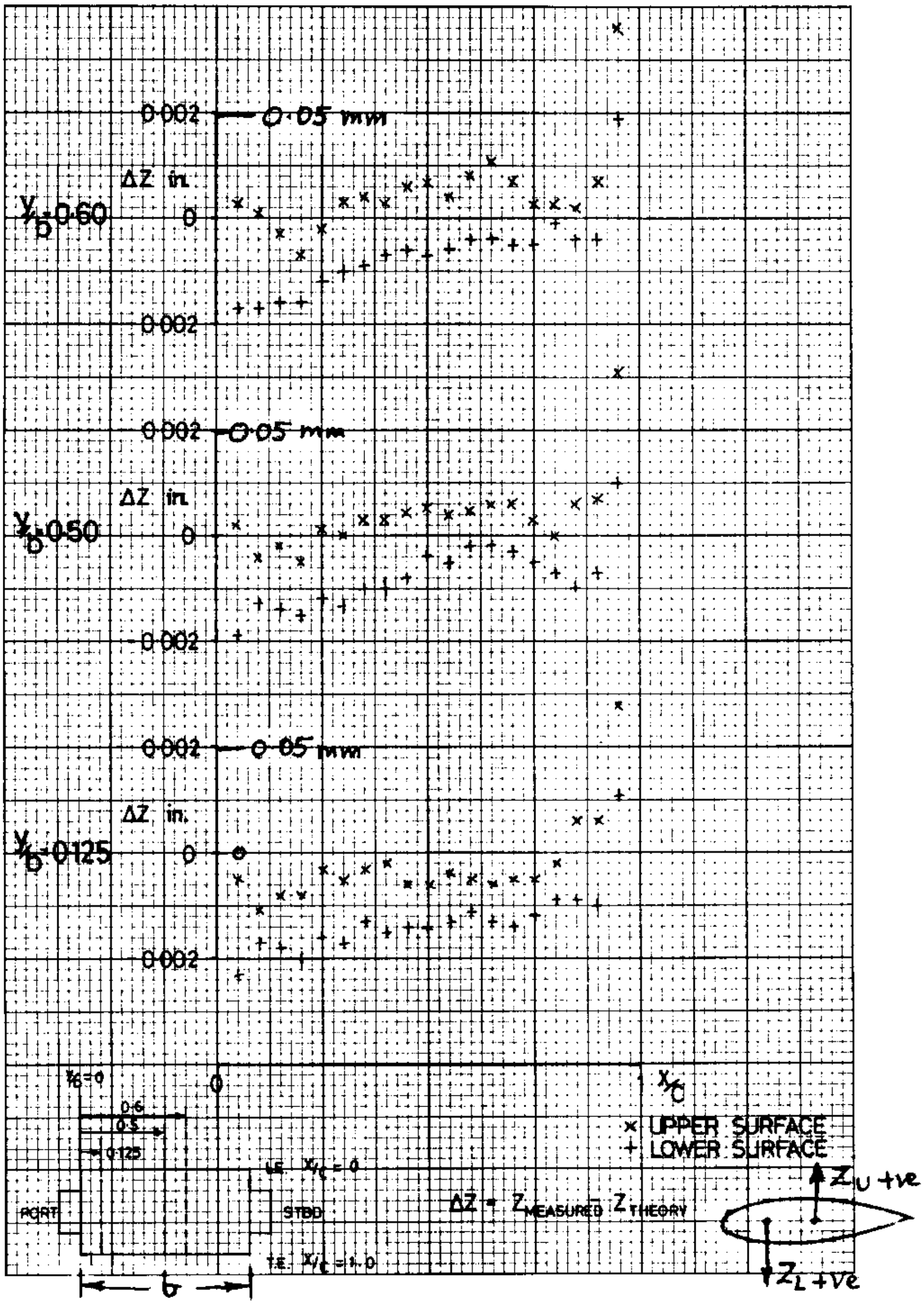


Fig 3.1 Profile inspection of NACA 0012 wing: $Z_m - Z_t$

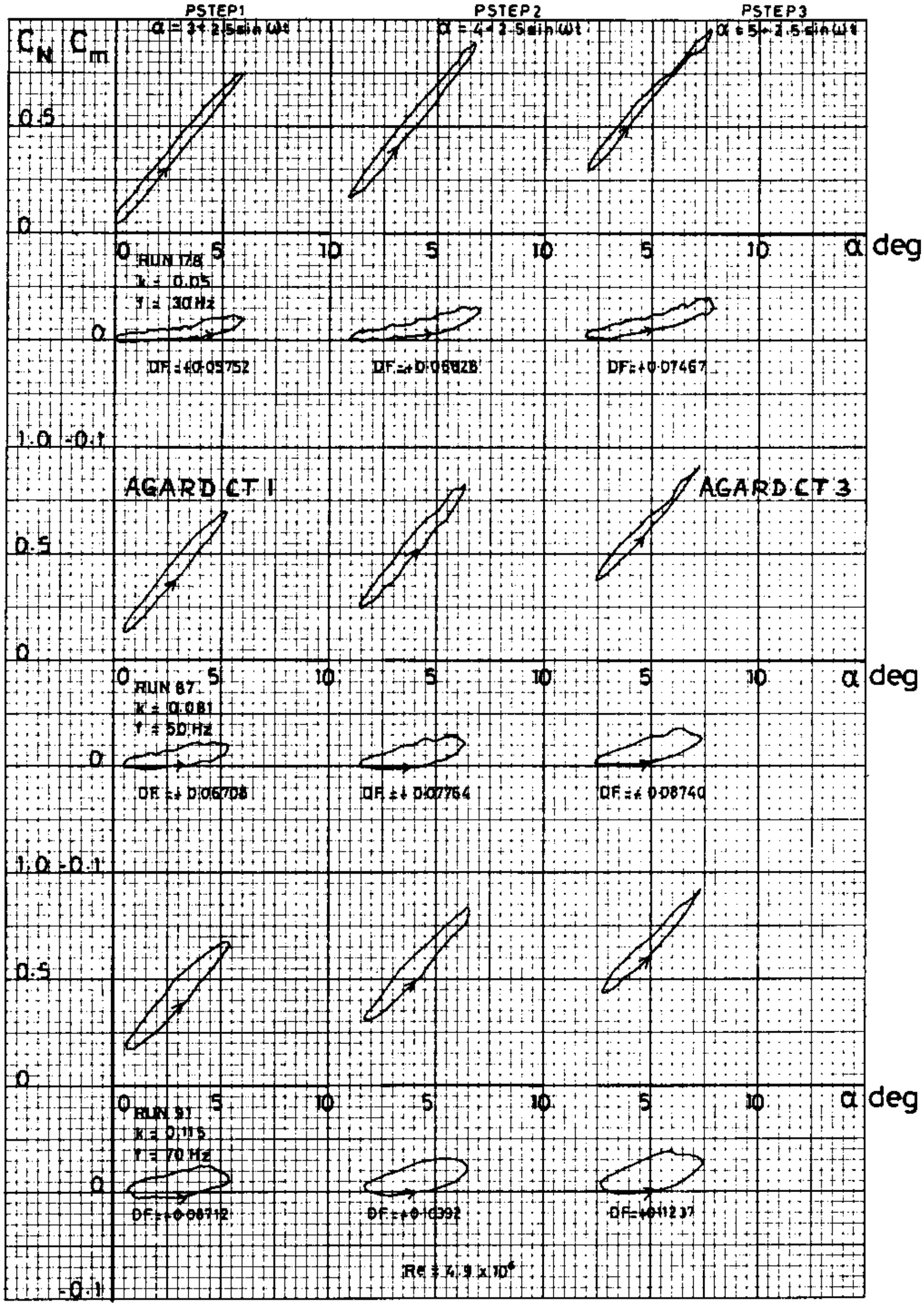


Fig 3.2 C_N, C_m *v.* incidence over range of $\alpha_m = 3^0, 4^0, 5^0$; $\alpha_0 = 2.5^0$.
Effect of frequency k = 0.05, 0.08, 0.12; M = 0.6

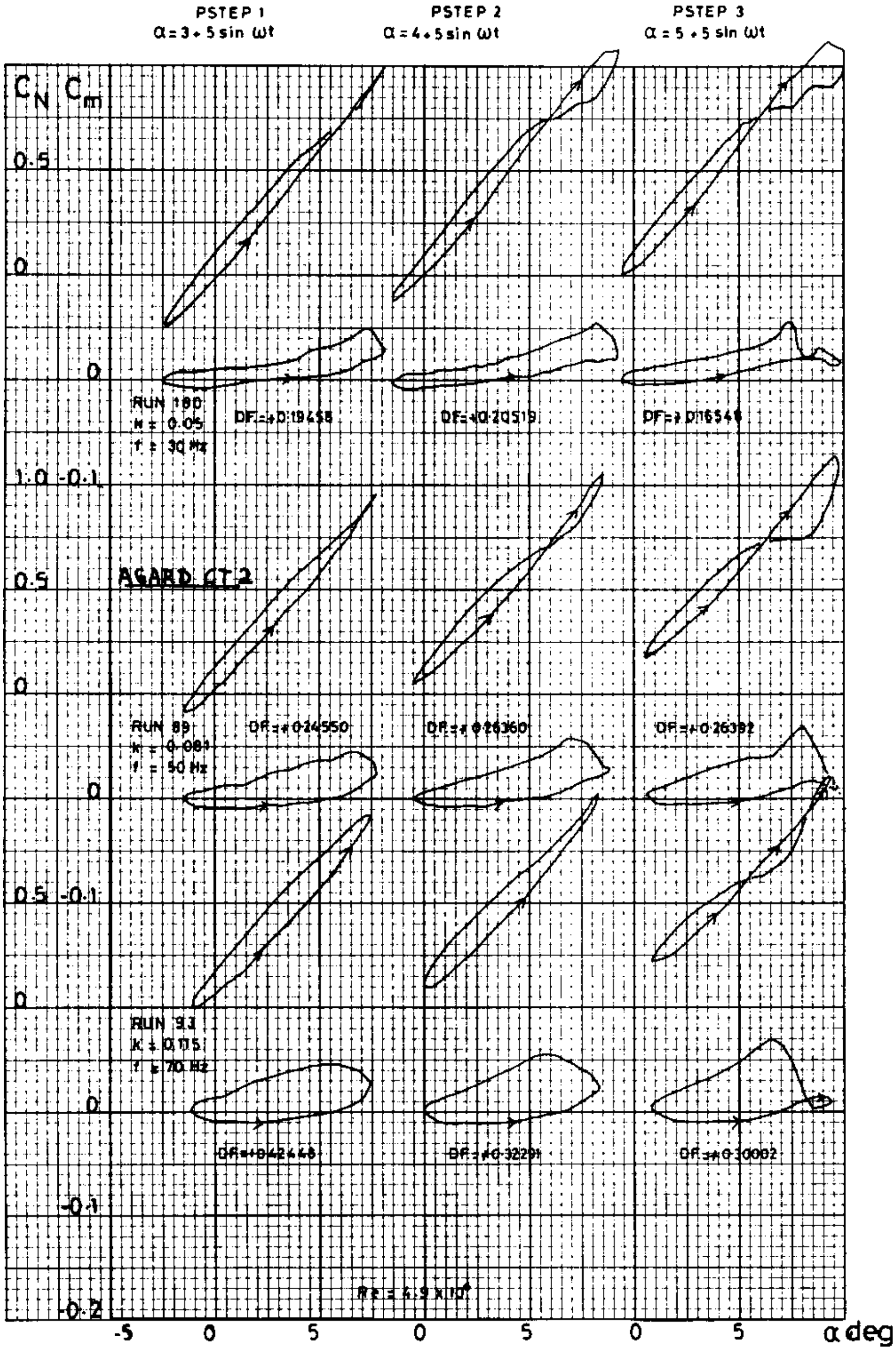


Fig 3.3 C_N, C_m *v.* incidence over range of $\alpha_m = 3^0, 4^0, 5^0$; $\alpha_0 = 5^0$.
Effect of frequency k = 0.05, 0.08, 0.12; M = 0.6

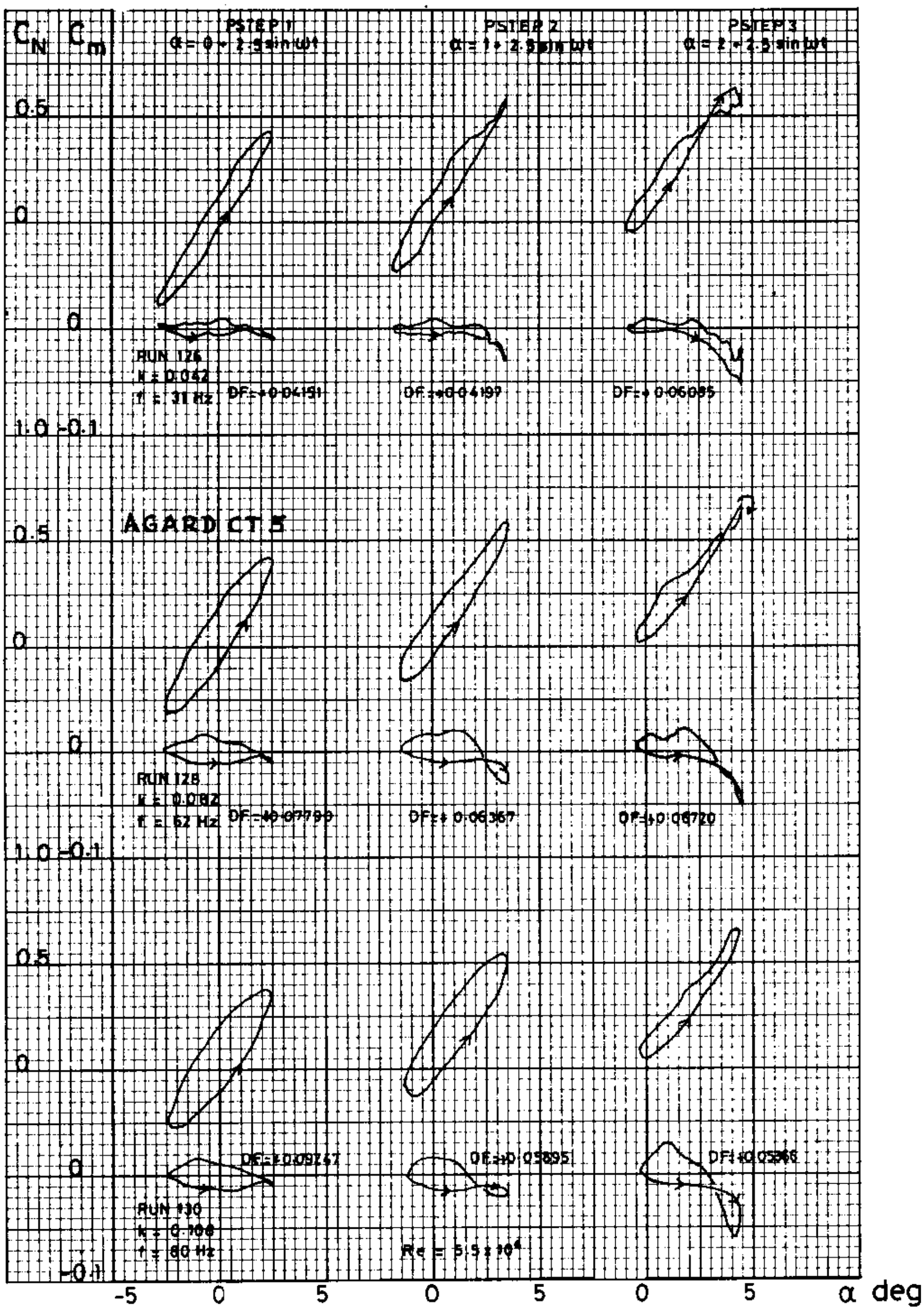


Fig 3.4 C_N, C_m *v.* incidence over range of $\alpha_m = 0^0, 1^0, 2^0$; $\alpha_0 = 2.5^0$.
Effect of frequency k = 0.04, 0.08, 0.10; M = 0.75

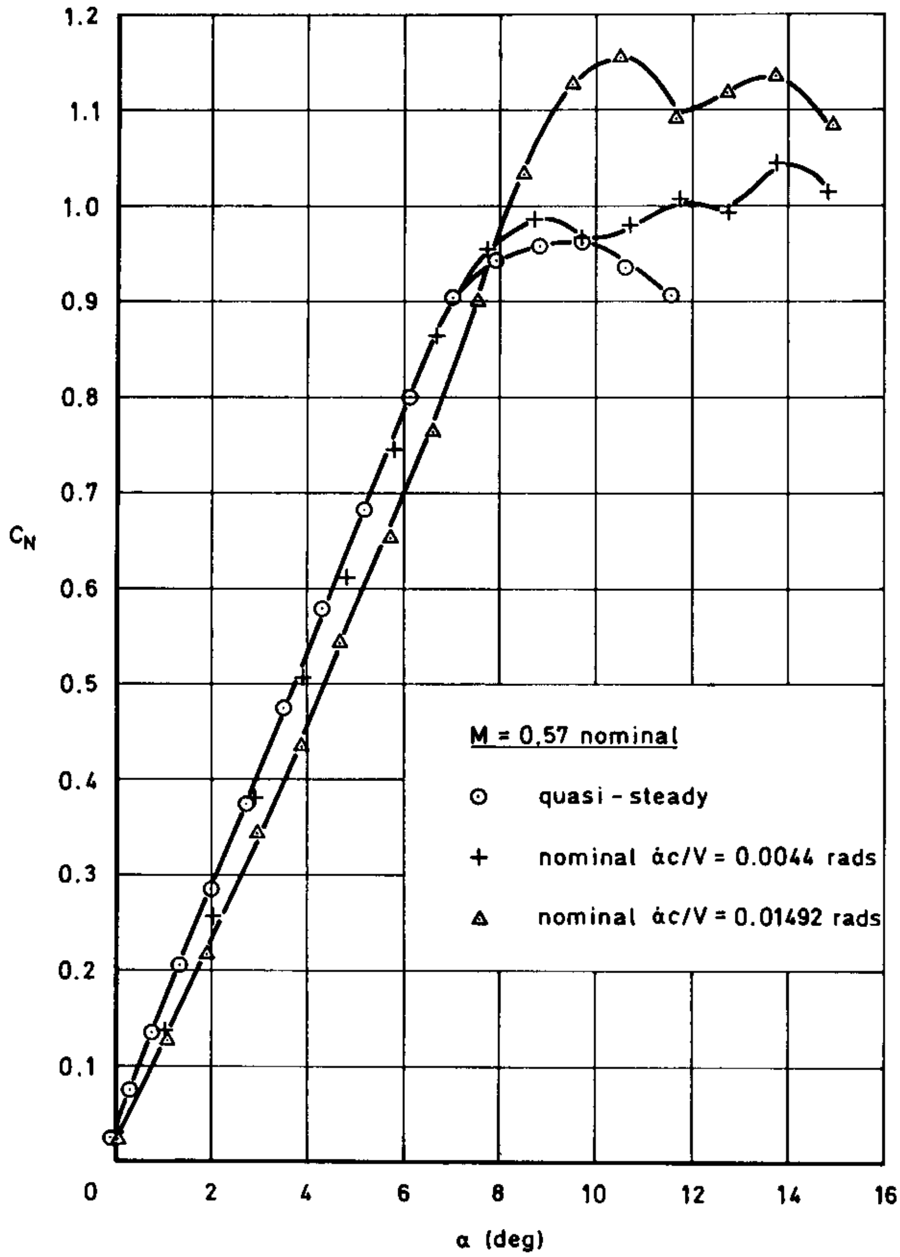


Fig 3.5 Lift *v.* incidence for different rates of change

DATA SET 4

NLR 7301 SUPERCRITICAL AIRFOIL OSCILLATORY PITCHING AND OSCILLATING FLAP

by

R.J. Zwaan, NLR

INTRODUCTION

The supercritical airfoil NLR 7301 has a maximum thickness of 16.5 per cent of the chord. In the set of two-dimensional aeroelastic configurations this airfoil represents the category of thick and blunt-nosed airfoils.

The airfoil was investigated in two wind-tunnel tests with different models. In the first test the model could be driven harmonically in a pitching motion about an axis at 40 per cent of the chord. Information about this configuration is designated with the letter "A". In the second test harmonic rotation of a trailing-edge flap was considered. The flap axis was located at 75 per cent of the chord; the flap had no aerodynamic balance. Information about this configuration is designated with the letter "B".

In transonic flow the contribution of the shock to the aerodynamic loading can of course be very different. As an illustration, pressure distributions on the upper surface are compared for a flow with a strong shock and a shock-free flow. Also results of thin-airfoil theory have been added. In the strong shock cases (A: Fig. 4.1, B: Fig. 4.5) the pressure peak due to the moving shock dominates in the pressure distribution, with a strength which diminishes with frequency. Although the flow conditions are the same for both configurations, the mean pressure distributions differ slightly. The cause of these differences could not be traced. In the shock-free cases (A: Fig. 4.2, B: Fig. 4.6) the pressure distribution shows a wide bulge. The pressure distributions of configuration A show very clearly that with increasing frequency the bulge decreases while at the same time a weak shock develops. Also here the mean pressure distributions should be the same. For unexplained reasons, however, shock-free flow could only be realized at slightly different Mach numbers.

Lift and moment coefficients are presented in figures 4.3 and 4.4 for configuration A and in figures 4.7 and 4.8 for configuration B. The influence of fixing boundary layer transition is remarkable. Configuration A shows only minor differences. Forced transition at 0.3 c is obviously not so effective in this case. The differences are larger for configuration B, which includes also fixed transition at 0.07 c. Characteristic changes occur in particular in the lift coefficient at low frequencies. Transition fixing has obviously the effect of reducing both the lift magnitude and the phase lag.

An aspect that emerges especially in the present case of a supercritical airfoil is the difference in the specification of theoretical and experimental shock-free flow. In the General Review it was pointed out that this difference is mainly due to viscous effects and tunnel interference. It was further proposed to choose the CT specification such that theory would produce a flow similar to that observed in the experiment. This is illustrated in figure 4.9 where the theoretical design pressure distribution calculated with a hodograph theory is compared with a shock-free pressure distribution measured at free transition.

1	AIRFOIL	
1.1	Designation	NLR 7301 (also NLR HT 7310810)
1.2	Type of airfoil	Thick, aft-loaded, shock-free supercritical; designed by means of Boerstoel hodograph method
1.3	Geometry	See Table 4.1
	Nose radius	0.05 c
	Maximum thickness	t/c = 16.5 %
	Base thickness	Zero
1.4	Design condition	
	Design condition	Potential flow (hodograph theory): $M = 0.721$ $C_\ell = 0.595$
	Design pressure distribution	Steady experiment (free transition, NLR Pilot Tunnel): $M = 0.747$, $C_\ell = 0.455$; see Fig. 4.9
1.5	Additional remarks	"Shock-free" pressure distributions for configuration A shown in Fig. 4.2 and for configuration B shown in Fig. 4.6
1.6	References on airfoil	
2	MODEL GEOMETRY	
2.1	Chord length	0.18 m
2.2	Span	0.42 m
2.3	Actual model coordinates and accuracy of measurements	See Table 4.2
2.4	Flap: hinge and gap details	A: not applicable B: hinge axis at 0.75 c; gap width 0.35 mm

2.5	Additional remarks	-
2.6	References on model	-

3 WIND TUNNEL

3.1	Designation	NLR Pilot Tunnel
3.2	Type of tunnel	Continuous, closed circuit
3.3	Test section dimensions	Rectangular; see Fig. 4.10 height 0.55 m, width 0.42 m
3.4	Type of roof and floor	10 % slotted top and bottom walls, separate top and bottom plenums
3.5	Type of side walls	Solid side walls
3.6	Ventilation geometry	See Fig. 4.10
3.7	Thickness of side wall boundary layer	Thickness 10 % of test section semi-width, no special treatment
3.8	Thickness of boundary layers at roof and floor	Not measured; probably comparable with side wall boundary layers
3.9	Method of measuring Mach number	Derived from static pressure measured upstream of model and from total pressure measured in settling chamber
3.10	Uniformity of Mach number over test section	See Fig. 4.11 (empty test section)
3.11	Sources and levels of noise or turbulence in empty tunnel	Turbulence/noise level, see Fig. 4.12
3.12	Tunnel resonances	No evidence
3.13	Additional remarks	For two-dimensionality of the flow see Ref. 4.3
3.14	References on tunnel	Ref. 4.2

4 MODEL MOTION

4.1	Mode of applied motion	A: pitching oscillation of airfoil B: oscillation of trailing-edge flap
4.2	Range of amplitude	A: α_o= 0.1° to 1.5° B: δ_o= 0.1° to 2.0°
4.3	Range of frequency	A: f = 0 to 80 Hz; k = 0 to 0.26 B: f = 0 to 200 Hz; k = 0 to 0.65
4.4	Method of application	A, B} hydraulic excitation at one side of the model
4.5	Purity of applied motion	Checked by spectral analysis; no data stored
4.6	Natural frequencies and normal modes of model	No interference with natural vibration modes
4.7	Static or dynamic elastic distortion during tests	Negligible
4.8	Additional remarks	-

5 TEST CONDITIONS

5.1	Tunnel height/model chord ratio	3.1
5.2	Tunnel width/model chord ratio	2.3
5.3	Range of Mach number	A: M = 0.5 to 0.8 B: M = 0.5 to 0.82
5.4	Range of tunnel total pressure	Atmospheric
5.5	Range of tunnel total temperature	313 ±1 K
5.6	Range of model steady mean incidence	A: α_m= 0° to 3° B: α_m= 0° to 3°; δ_m= 0°
5.7	Definition of model incidence	Incidence datum line α = 0 relates to the x-axis as used in Tables 4.1 and 4.2. Datum line is parallel to test section centre line for α_m= 0
5.8	Position of transition, if free	A, B} part of the test performed with natural transition; position of transition not measured
5.9	Position and type of trip, if transition fixed	A: strip of carborundum grains at 0.3 c B: strip of carborundum grains at 0.07 c or 0.3 c
5.10	For mixed flow, position of sonic boundary in relation to roof and floor	Not measured
5.11	Flow instabilities during tests	No evidence

5.12	Additional remarks	-
5.13	References describing tests	A: Ref. 4.4 B: not available

6 MEASUREMENTS AND OBSERVATIONS

6.1	Steady pressures for the mean conditions		✓
6.2	Steady pressures for small changes from the mean conditions		✓
6.3	Quasi-steady pressures		
6.4	Unsteady pressures		✓
6.5	Steady forces for the mean conditions	measured directly	
		integrated press.	✓
6.6	Steady forces for small changes from the mean conditions	measured directly	
		integrated press.	✓
6.7	Quasi-steady forces	measured directly	
		integrated press.	
6.8	Unsteady forces	measured directly	
		integrated press.	✓
6.9	Measurement of actual motion at points on model		✓
6.10	Observation or measurement of boundary layer properties		
6.11	Visualization of surface flow		
6.12	Visualization of shockwave movements		✓
6.13	Additional remarks		

7 INSTRUMENTATION

7.1	Steady pressures	
7.1.1	Position of orifices spanwise and chordwise	See 7.2.1
7.1.2	Type of measuring system	See 7.2.3
7.2	Unsteady pressures	
7.2.1	Position of orifices spanwise and chordwise	A: see Figs 4.13 and 4.14 B: see Figs 4.15 and 4.16
7.2.2	Diameter of orifices	0.8 mm
7.2.3	Type of measuring system	A: 40 pressure tubes + 13 in situ pressure transducers B: 46 pressure tubes + 12 in situ pressure transducers
7.2.4	Type of transducers	±7.5 psi Statham differential pressure transducers, and ±5 psi Kulite miniature pressure transducers
7.2.5	Principle and accuracy of calibration	Calibration uses transfer functions of pressure tubes, see Ref. 4.4; for accuracy see 9.10
7.3	Model motion	
7.3.1	Method of measurement	A: with accelerometers, see Fig. 4.13 B: with accelerometers, see Fig. 4.15
7.3.2	Accuracy	See 9.10
7.4	Processing of unsteady measurements	
7.4.1	Method of acquiring and processing measurements	See Fig. 4.17
7.4.2	Type of analysis	A: signal analysis of TFA over 20 cycles for f = 30, 80 Hz and 60 cycles for f = 200 Hz B: signal length during TFA analysis was 1 s
7.4.3	Unsteady pressure quantities obtained and accuracies achieved	A: Fundamental harmonics B: Fundamental harmonics and occasionally second and third harmonics For accuracy see 9.10
7.4.4	Method of integration to obtain forces	Trapezoidal rule
7.5	Additional remarks	-
7.6	References on techniques	A: Refs 4.4, 4.5 B: Ref. 4.6

8 DATA PRESENTATION

8.1 Test cases for which data could be made available	A: see Table 4.3 B: not available
8.2 Test cases for which data are included in this document	A, B : see Table 4.4
8.3 Steady pressures	Mean pressures for: A: Tables 4.5 to 4.14 B: Tables 4.15 to 4.23
8.4 Quasi-steady or steady perturbation pressures	Steady pressure derivatives for: A: Tables 4.5, 4.8, 4.12 B: Tables 4.15, 4.17, 4.19
8.5 Unsteady pressures	A: Tables 4.6, 4.7, 4.9 to 4.11, 4.13, 4.14 B: Tables 4.16, 4.18, 4.20 to 4.23
8.6 Steady forces or moments	See 8.3
8.7 Quasi-steady or steady perturbation forces	See 8.4
8.8 Unsteady forces and moments	See 8.5
8.9 Other forms in which data could be made available if required	-
8.10 References giving other presentations of data	-

9 COMMENTS ON DATA

9.1 Accuracy	
9.1.1 Mach number	±0.002. No corrections made for Mach number nonuniformity
9.1.2 Steady incidence	±0.02°
9.1.3 Reduced frequency	±0.0005
9.1.4 Steady pressure coefficients	Not known
9.1.5 Steady pressure derivatives	Not applicable
9.1.6 Unsteady pressure coefficients	Not known
9.2 Sensitivity to small changes of parameter	No evidence
9.3 Spanwise variations	No evidence
9.4 Non-linearities	Part of analysis of experimental results; see Ref. 4.4
9.5 Influence of tunnel total pressure	-
9.6 Wall interference corrections	No corrections included, but under steady conditions it is normal to make the following corrections to measurements made in this tunnel: steady corrections: $\Delta\alpha_m = -1.4\ C_\ell + 0.56\ (C_m + 0.25\ C_\ell)/\sqrt{1-M^2}$, (deg) (±15 %) $\Delta C_\ell = -0.015\ C_\ell/(1-M^2)$, (±30 %) $\Delta C_m = -0.25\ \Delta C_\ell$, (±30 %)
9.7 Other relevant tests on <u>same model</u>	-
9.8 Relevant tests on other models of nominally the <u>same</u> airfoil	See Data Set 5
9.9 Any remarks relevant to comparison between experiment and theory	-
9.10 Additional remarks	No systematic investigations of separate accuracies have been performed; accuracy of lift and moment coefficients is estimated to be 5 to 10 per cent in magnitude and 3 to 6 degrees in phase angle
9.11 References on discussion of data	A: Ref. 4.4

10 PERSONAL CONTACT FOR FURTHER INFORMATION

R.J. Zwaan, National Aerospace Laboratory (NLR), Anthony Fokkerweg 2, 1059 CM Amsterdam, The Netherlands

11 LIST OF REFERENCES

4.1	J. Barche c.s.	Experimental data base for computer program assessment AGARD-AR-138, 1979
4.2	J. Zwaaneveld	Principal data of the NLL Pilot Tunnel NLL Report MP 185, 1959
4.3	H.A. Dambrink	Investigation of the 2-dimensionality of the flow around a profile in the NLR 0.55x0.42 m^2 transonic wind tunnel NLR Memorandum AC-72-018, 1972
4.4	H. Tijdeman	Investigations of the transonic flow around oscillating airfoils NLR TR 77090 U, 1977
4.5	P.H. Fuykschot L.J.M. Joosten	DYDRA-Data logger for dynamic measurements NLR MP 69012 U, 1969
4.6	P.H. Fuykschot	PHAROS, processor for harmonic analysis of the response of oscillating surfaces NLR MP 77012 U, 1977
4.7	S.R. Bland	AGARD Two-dimensional aeroelastic configurations AGARD-AR-156, 1979

12 NOTATION AND LIST OF SYMBOLS

DATA SET	STANDARD
ALPHA	mean wing incidence, α_m, deg
AMPL.	flap amplitude, δ_o, deg; see Note 2 below
C2	pitch amplitude, α_o, deg; see Note 2 below
CL	mean wing lift coefficient, C_ℓ
CLIM	k''_α in Tables 4.5 to 4.14; k''_c in Tables 4.15 to 4.23
CLRE	k'_α in Tables 4.5 to 4.4; k'_c in Tables 4.15 to 4.23
CM	mean wing moment coefficient (about 0.25 c), C_m
CMIM	m''_α in Tables 4.5 to 4.14; m''_c in Tables 4.15 to 4.23
CMRE	m'_α in Tables 4.5 to 4.14; m'_c in Tables 4.15 to 4.23
CP	mean pressure coefficient, C_p
CPIM	imaginary component of oscillatory pressure coefficient, rad^{-1}. In Tables 4.5 to 4.14 it represents C''_p/α_o, in Tables 4.15 to 4.23 it represents C''_p/δ_o
CPRE	real component of oscillatory pressure coefficient, rad^{-1}. In Tables 4.5 to 4.14 it represents C'_p/α_o, in Tables 4.15 to 4.23 it represents C'_p/δ_o. If k = 0, then CPRE = $[C_p(+\alpha_o) - C_p(-\alpha_o)]/2\alpha_o$ and CPRE = $[C_p(+\delta_o) - C_p(-\delta_o)]/2\delta_o$, resp.
DELTA	mean flap angle, δ_m, deg
FREQ.	frequency, f, Hz
HARM	order of harmonic
k_α	oscillatory wing lift coefficient, $\bar{C}_L/\pi\alpha_o$, rad^{-1}
k_c	oscillatory wing lift coefficient, $\bar{C}_L/\pi\delta_o$, rad^{-1}
M	mean local Mach number, M_L
MACH	free-stream Mach number, M
m_α	oscillatory wing moment coefficient, $-2\ \bar{C}_m/\pi\alpha_o$, rad^{-1}
m_c	oscillatory wing moment coefficient, $-2\ \bar{C}_m/\pi\delta_o$, rad^{-1}
MEETRUNNR.	run number
NCRE, NCIM	real and imaginary components of oscillatory flap moment coefficient, $-2\ \bar{C}_h/\pi\delta_o$, rad^{-1}
PO	total pressure, p_t, Pa
Q	dynamic pressure, q, Pa
RCRE, RCIM	real and imaginary components of oscillatory flap lift coefficient, $\bar{C}_{\ell f}/\pi\delta_o$, rad^{-1}
RE	Reynolds number based on wing chord, Re
RFREQ	reduced frequency, $k = \pi fc/V$
+	(suffix) upper side
-	(suffix) lower side
*	(superscript) critical value

Note 1: Symbols not mentioned here conform to the notation in the General Review.

Note 2: The oscillatory motions are defined as $\alpha = \alpha_o \sin \omega t$ and $\delta = \delta_o \sin \omega t$. The equation for a corresponding oscillatory pressure (including higher harmonics, if available) reads:

$p(t) = p_m + p' \sin \omega t + p'' \cos \omega t + p_1' \sin 2\omega t + p_1'' \cos 2\omega t \div$ etc.

Similar expressions hold for the aerodynamic coefficients.

TABLE 4.1

Contour data of the NLR 7301 airfoil

UPPER PART

X	Z
0.0000012	-.0004162
0.0002895	+.0052191
0.0005870	+.0076759
0.0008861	+.0095965
0.0011758	+.0112217
0.0014662	+.0126337
0.0017468	+.0138934
0.0020176	+.0150413
0.0022988	+.0160878
0.0025701	+.0170734
0.0028314	+.0179879
0.0042208	+.0220524
0.0056121	+.0254172
0.0069239	+.0281722
0.0081862	+.0305312
0.0094795	+.0326872
0.0107530	+.0346503
0.0119867	+.0363594
0.0131194	+.0378449
0.0141918	+.0391576
0.0153049	+.0404096
0.0164386	+.0416005
0.0175319	+.0426834
0.0185343	+.0436187
0.0194052	+.0443882
0.0202255	+.0450753
0.0211270	+.0457913
0.0223832	+.0467230
0.0240550	+.0478651
0.0255447	+.0488004
0.0265278	+.0493759
0.0274908	+.0499059
0.0276023	+.0499651
0.0276429	+.0499865
0.0279647	+.0501553
0.0281700	+.0502615
0.0285818	+.0504716
0.0291330	+.0507471
0.0296602	+.0510052
0.0300455	+.0511909
0.0304510	+.0513850
0.0310492	+.0516694
0.0316879	+.0519702
0.0331276	+.0526347
0.0378375	+.0546577
0.0425480	+.0564729
0.0472590	+.0581064
0.0519705	+.0595825
0.0566824	+.0609237
0.0613946	+.0621505
0.0661071	+.0632814
0.0708199	+.0643330
0.0764002	+.0654949
0.0808464	+.0663708
0.0848828	+.0671354
0.0888097	+.0678502
0.0926554	+.0685253
0.0967347	+.0692169
0.1028790	+.0702150
0.1090235	+.0711645
0.1174463	+.0723954
0.1225001	+.0730979
0.1298374	+.0740738
0.1371749	+.0750008
0.1451619	+.0759587
0.1531492	+.0768671
0.1620297	+.0778222
0.1703103	+.0787225
0.1757515	+.0791914
0.1830136	+.0798669
0.1902757	+.0805103
0.1956374	+.0809654
0.2009991	+.0814040
0.2063603	+.0818267
0.2117226	+.0822338
0.2175970	+.0826623
0.2234714	+.0830729
0.2293459	+.0834659
0.2352205	+.0838418
0.2417117	+.0842377
0.2482030	+.0846135
0.2546944	+.0849698
0.2611858	+.0853068
0.2683650	+.0856577
0.2755442	+.0859859
0.2827234	+.0862918
0.2899029	+.0865757
0.2977752	+.0868622
0.3056476	+.0871229
0.3135200	+.0873584
0.3213925	+.0875690
0.3300667	+.0877723
0.3387010	+.0879461
0.3473554	+.0880910
0.3560099	+.0882071
0.3651415	+.0882986
0.3742734	+.0883584
0.3834053	+.0883847
0.3925373	+.0883833
0.4018445	+.0883475
0.4111518	+.0882789
0.4204592	+.0881775

X	Z
0.4297567	+.0880434
0.4386049	+.0878957
0.4474429	+.0876992
0.4562811	+.0874305
0.4651193	+.0872324
0.4728611	+.0869899
0.4806030	+.0867235
0.4883450	+.0864327
0.4960870	+.0861171
0.5026310	+.0858307
0.5091750	+.0855260
0.5157191	+.0852026
0.5222632	+.0848603
0.5302975	+.0844135
0.5383313	+.0839359
0.5435882	+.0836020
0.5525071	+.0830195
0.5613261	+.0823476
0.5686577	+.0814492
0.5759893	+.0812713
0.5822243	+.0807557
0.5884591	+.0802173
0.5938567	+.0797321
0.5992541	+.0792287
0.6040016	+.0787704
0.6087491	+.0782972
0.6130854	+.0778517
0.6174213	+.0773334
0.6254041	+.0765152
0.6329293	+.0755459
0.6401197	+.0747769
0.6470765	+.0739003
0.6539319	+.0730023
0.6606756	+.0720459
0.6674601	+.0711319
0.6742447	+.0701454
0.6811995	+.0691019
0.6881543	+.0680253
0.6951093	+.0669196
0.7020644	+.0657827
0.7093750	+.0645558
0.7166857	+.0632973
0.7239965	+.0620092
0.7313074	+.0606892
0.7390044	+.0592694
0.7467015	+.0578191
0.7543987	+.0563396
0.7620959	+.0548323
0.7703087	+.0531951
0.7785216	+.0515298
0.7867346	+.0498392
0.7949477	+.0481221
0.8038922	+.0462276
0.8128369	+.0443096
0.8217815	+.0423675
0.8307263	+.0404068
0.8406234	+.0382174
0.8505207	+.0360190
0.8604179	+.0337880
0.8703152	+.0315565
0.8804741	+.0292535
0.8906331	+.0269475
0.9007920	+.0246399
0.9137643	+.0216959
0.9239239	+.0193996
0.9340827	+.0171138
0.9442415	+.0148440
0.9538193	+.0116237
0.9636815	+.0105616
0.9685437	+.0095059
0.9734059	+.0084610
0.9782680	+.0074251
0.9831300	+.0064005
0.9879921	+.0053944
0.9928541	+.0043901
0.9977161	+.0034069
0.9999052	+.0029695
1.0020942	+.0025354
1.0042633	+.0021046
1.0064723	+.0016772
1.0086614	+.0012530
1.0108504	+.0008329
1.0130394	+.0004144
1.0152284	+.0000000

LOWER PART

X	Z
0.0000012	-.0004162
0.0002395	-.0056237
0.0004787	-.0076027
0.0007164	-.0090435
0.0009431	-.0102206
0.0011795	-.0112149
0.0014054	-.0121076
0.0016514	-.0129243
0.0017744	-.0133248
0.0018974	-.0137103
0.0021635	-.0144608
0.0024397	-.0151909
0.0031756	-.0169046
0.0039110	-.0184354
0.0046153	-.0197634
0.0052785	-.0209290
0.0059313	-.0219726
0.0066246	-.0230063
0.0073992	-.0240599
0.0082348	-.0251336
0.0091007	-.0261567
0.0099563	-.0271155
0.0108218	-.0280297
0.0117280	-.0289408
0.0127561	-.0298945
0.0134978	-.0304576
0.0154631	-.0321417
0.0170910	-.0333505
0.0179506	-.0339546
0.0188101	-.0345367
0.0197713	-.0351686
0.0207325	-.0357755
0.0219376	-.0365060
0.0231427	-.0372055
0.0245498	-.0379864
0.0259567	-.0387330
0.0268947	-.0392137
0.0296142	-.0405379
0.0323335	-.0417721
0.0341073	-.0425358
0.0358810	-.0432701
0.0376546	-.0439771
0.0394281	-.0446591
0.0423271	-.0457248
0.0452260	-.0467344
0.0481247	-.0476930
0.0510232	-.0486058
0.0565381	-.0502310
0.0620525	-.0517267
0.0675667	-.0531110
0.0730805	-.0544013
0.0771059	-.0552931
0.0811312	-.0561467
0.0851564	-.0569652
0.0891815	-.0577513
0.0929399	-.0584584
0.0966982	-.0591412
0.1004565	-.0598010
0.1042147	-.0604391
0.1078915	-.0610431
0.1115683	-.0616267
0.1152451	-.0621901
0.1189218	-.0627346
0.1264630	-.0638076
0.1340040	-.0648412
0.1417023	-.0658428
0.1494005	-.0667871
0.1581394	-.0677937
0.1668782	-.0687354
0.1756167	-.0696163
0.1843551	-.0704393
0.1895240	-.0708995
0.1946928	-.0713408
0.1998615	-.0717630
0.2050302	-.0721684
0.2110365	-.0726163
0.2170428	-.0730405
0.2230491	-.0734416
0.2290552	-.0738200
0.2363154	-.0742478
0.2435754	-.0746437
0.2508353	-.0750084
0.2580952	-.0753426
0.2673729	-.0757257
0.2766505	-.0760604
0.2859280	-.0763472
0.2952053	-.0765865
0.3053582	-.0767946
0.3155109	-.0769474
0.3256635	-.0770445
0.3358159	-.0770861
0.3460392	-.0770716
0.3561913	-.0770007
0.3663432	-.0768720
0.3764950	-.0766837
0.3866465	-.0764334
0.3967979	-.0761186
0.4069491	-.0757362
0.4171001	-.0752827
0.4272508	-.0747544
0.4374014	-.0741469
0.4475517	-.0734558

X	Z
0.4594475	-.0725326
0.4688157	-.0717156
0.4745806	-.0711708
0.4856332	-.0700287
0.4933971	-.0691512
0.5001765	-.0683376
0.5067021	-.0675138
0.5133493	-.0666367
0.5202298	-.0656939
0.5274553	-.0646685
0.5351272	-.0635414
0.5431744	-.0623191
0.5516579	-.0609873
0.5545499	-.0605234
0.5636167	-.0590373
0.5726834	-.0575037
0.5821558	-.0558514
0.5916280	-.0541483
0.6011052	-.0523934
0.6105822	-.0505882
0.6197243	-.0487996
0.6288662	-.0469661
0.6376225	-.0451694
0.6463786	-.0433366
0.6550535	-.0414889
0.6637283	-.0396149
0.6727886	-.0376348
0.6818488	-.0356373
0.6915939	-.0334759
0.7013389	-.0313082
0.7118449	-.0289699
0.7223508	-.0266371
0.7279285	-.0254030
0.7335062	-.0241734
0.7390839	-.0229494
0.7446616	-.0217322
0.7506223	-.0204404
0.7565831	-.0191598
0.7625439	-.0178924
0.7685048	-.0166403
0.7752698	-.0152405
0.7820349	-.0138661
0.7888000	-.0125201
0.7955653	-.0112058
0.8040480	-.0096069
0.8125308	-.0080674
0.8210139	-.0065919
0.8294972	-.0051848
0.8396449	-.0035977
0.8497929	-.0021236
0.8599413	-.0007717
0.8700901	+.0004496
0.8763318	+.0011324
0.8864812	+.0021265
0.8966310	+.0029712
0.9067813	+.0036605
0.9169321	+.0041886
0.9270833	+.0045505
0.9372351	+.0047413
0.9473873	+.0047565
0.9575401	+.0045921
0.9676934	+.0042446
0.9748111	+.0038900
0.9839296	+.0032994
0.9884890	+.0029450
0.9930485	+.0025507
0.9971651	+.0021591
0.9999096	+.0018774
1.0026541	+.0015787
1.0040264	+.0014231
1.0073270	+.0010317
1.0106277	+.0006148
1.0143956	+.0001129
1.0152284	+.0000000

Note: See note at the end of table 4.2

TABLE 4.2

Actual contour data of the NLR 7301 airfoil (conf. B) (measures in mm)

x	z_{upper}	z_{lower}
000.000	000.000	-000.000
000.500	003.250	-002.820
001.000	004.595	-003.780
002.000	006.360	-005.025
003.000	007.750	-005.880
004.000	008.415	-006.525
005.000	009.030	-007.065
006.000	009.520	-007.520
007.000	009.940	-007.930
008.000	010.315	-008.290
009.000	010.640	-008.620
010.000	010.935	-008.920
015.000	012.045	-010.110
020.000	012.880	-010.990
025.000	013.545	-011.695
030.000	014.105	-012.275
040.000	014.945	-013.125
050.000	015.500	-013.620
060.000	015.815	-013.795
070.000	015.910	-013.665
080.000	015.800	-013.190
090.000	015.480	-012.245
100.000	014.910	-010.810
110.000	014.055	-009.030
120.000	012.835	-006.945
130.000	011.240	-004.760
134.500	010.410	-003.785
137.500	009.940	-003.165
140.000	009.450	-002.645
150.000	007.335	-000.780
160.000	005.135	000.495
170.000	002.935	000.975
175.000	001.855	000.860
180.000	000.775	000.465

TABLE 4.3

Test program for the NLR 7301 airfoil (conf. A)

Basic program: amplitude of oscillation: α_o= 0.5 degree
frequencies: 0, 10 and 80 Hz
transition strip at x/c= 0.3

Incidence	MACH NUMBER										
	.5	.6	.65	.675	.70	.725	.74	.75	.76	.775	.80
α_m= 0°	x				x			x			
0.85	x	x	x	x	x	x	x	x	x	x	x
1.50	x				x			x			
3.00	x	x	x	x	x	x		x			

Influence of amplitude and frequency transition strip at x/c= 0.3

Incidence	amplitude α_o	freq.	MACH NUMBER		
			.5	.7	.75
α_m= 0.85°	0.1; 0.25; 0.75; 1.0; 1.5°	10; 80 Hz	x	x	x
3.00	0.1; 0.25; 0.75; 1.0	10; 80		x	
0.85°	0.5; 1.0°	10; 30; 60; 80 Hz	x	x	x
3.00	0.5; 1.0	10; 30; 60; 80		x	

Additional tests with natural transition

Incidence	amplitude α_o	freq.	MACH NUMBER		
			.5	.7	.75
α_m= 0.85°	0.5; 1.0°	10 Hz	x	x	x
	0.5; 0.75	80	x	x	x
3.00	0.5; 1.0	10		x	
	0.5; 0.75	80		x	
0.85	0.5	30; 60	x		x

Note regarding Tables 4.1 and 4.2: In Ref. 4.7 the contour coordinates have been transformed to unit chord. The model was designed to shape given by Table 4.1, but the trailing edge was cut off at x/c= 1.0. The actual measured shape of the model is given in the table above.

TABLE 4.4

Test cases for the NLR 7301 airfoil (confs A and B) included in Data Set 4

Motion	Flow	CT Case					Data Set 4									
		No	M	α_m	α_o,δ_o	k	Run No	M	α_m	δ_m	α_o,δ_o	k	$Re*10^{-6}$	Trans.	Harm.	Table
Pitching about 0.4 c (conf. A)	Subsonic	z1	0.500	0.40	0.5	0	12201	0.499	0.85		0.50	0	1.70	0.3 c	1	4.5
		1	0.500	0.40	0.5	0.098	1601	0.499	0.85		0.55	0.098	1.70	0.3 c	1	4.6
		2	0.500	0.40	0.5	0.262	1301	0.498	0.85		0.44	0.262	1.70	0.3 c	1	4.7
	Transonic with shock	z2	0.700	2.00	0.5	0	14405	0.696	3.00		0.50	0	2.11	0.3 c	1	4.8
		3	0.700	2.00	0.5	0.072	3805	0.696	3.00		0.42	0.072	2.11	0.3 c	1	4.9
		4	0.700	2.00	1.0	0.072	3905	0.696	3.00		0.98	0.072	2.11	0.3 c	1	4.10
		5	0.700	2.00	0.5	0.192	52705	0.695	3.00		0.55	0.192	2.12	0.3 c	1	4.11
	Supercritical design	z3	0.721	-0.19	0.5	0	16908	0.744			0.50	0	2.22	free	1	4.12
		6	0.721	-0.19	0.5	0.068	9608	0.744	0.85		0.46	0.068	2.23	free	1	4.13
		7	0.721	-0.19	1.0	0.068			No measurement							
		8*	0.721	-0.19	0.5	0.181	6708	0.744	0.85		0.61	0.181	2.22	free	1	4.14
		9	0.721	-0.19	0.5	0.453			No measurement							
Flap rotation (conf. B)	Subsonic	z4	0.500	0.40	1.0	0	250	0.503	0	0.02	0.95	0	1.69	0.07 c	1	4.15
		10	0.500	0.40	1.0	0.098	253	0.502	0	0.02	0.97	0.098	1.69	0.07 c	1	4.16
	Transonic with shock	z5	0.700	2.00	1.0	0	129	0.702	3.00	-0.08	0.95	0	2.14	0.3 c	1	4.17
		11	0.700	2.00	1.0	0.071	120	0.701	3.00	0.03	0.97	0.071	2.14	0.3 c	1	4.18
	Supercritical design	z6	0.721	-0.19	1.0	0	160	0.754	0.85	0.01	0.96	0	2.23	free	1	4.19
		12	0.721	-0.19	1.0	0.067	148-150	0.755	0.85	0.01	0.95	0.067	2.23	free	1,2,3	4.20-4.22
		13*	0.721	-0.19	1.0	0.181			No measurement							
		14	0.721	-0.19	1.0	0.445	162	0.756	0.85	-0.01	0.90	0.445	2.23	free	1	4.23

Remarks on Table 4.4

Cases z1 to z6 are extra to the computational cases identified in Ref. 4.7. They correspond to zero-frequency (k = 0) experimental data that are closely related to the CT Cases for which k ≠ 0.
The asterisks denote Priority Cases.

TABLE 4.5

RUN 12201

M	.499	C2	.50		STAT.	QUASI-INSTAT.	
ALPHA	.85	FREQ	0.			RE	IM
P0	10376.	K	0.000	CL	.303	1.835	0.000
RE	1.70E6			CM	.068	-.076	0.000
Q	1524.						

X/C	CP+	M+	CPRE+	CPIM+	CP-	M-	CPRE-	CPIM-
	UPPERSIDE				LOWERSIDE			
.01	-.068	.516	-12.204	0.000	.284	.420	11.230	0.000
.05	-1.148	.771	-12.834	0.000	-.369	.591	9.511	0.000
.10	-.859	.705	-9.225	0.000	-.372	.591	6.417	0.000
.15	-.683	.665	-5.214	0.000	-.386	.595	5.099	0.000
.20	-.647	.657	-5.099	0.000	-.403	.599	4.469	0.000
.25	-.626	.652	-4.183	0.000	-.421	.603	3.953	0.000
.30	-.635	.654	-3.495	0.000	-.417	.602	3.151	0.000
.35	-.594	.644	-2.979	0.000	-.429	.605	2.922	0.000
.40	-.587	.643	-2.636	0.000	-.444	.609	2.693	0.000
.45	-.579	.641	-2.235	0.000	-.445	.609	2.177	0.000
.50	-.570	.639	-2.063	0.000	-.397	.597	1.833	0.000
.55	-.556	.635	-1.776	0.000	-.300	.574	1.318	0.000
.60	-.539	.631	-1.261	0.000	-.203	.550	1.089	0.000
.65	-.491	.620	-.859	0.000	-.086	.521	.688	0.000
.70	-.408	.600	-.458	0.000	.029	.491	.630	0.000
.75	-.307	.576	-.286	0.000	.129	.464	.458	0.000
.80	-.193	.548	-.115	0.000	.208	.442	.401	0.000
.85	-.086	.521	.057	0.000	.269	.425	.458	0.000
.90	.012	.496	-.057	0.000	.298	.416	.286	0.000
.95	.089	.475	-.516	0.000	.301	.415	.115	0.000

TABLE 4.6

RUN 1601

M	.499	C2	.55		STAT.	INSTAT.	
ALPHA	.85	FREQ	30.			RE	IM
P0	10398.	K	.098	CL	.311	1.481	-.170
RE	1.70E6			CM	.069	-.028	.151
Q	1529.						

X/C	CP+	M+	CPRE+	CPIM+	CP-	M-	CPRE-	CPIM-
	UPPERSIDE				LOWERSIDE			
.01	-.070	.518	-10.560	2.296	.296	.417	6.804	-3.146
.05	-1.163	.776	-11.456	2.389	-.351	.586	7.090	-2.048
.10	-.846	.703	-8.108	1.833	-.373	.592	4.808	-1.920
.15	-.707	.672	-3.138	.552	-.383	.594	4.104	-1.096
.20	-.654	.659	-4.080	.853	-.400	.598	3.403	-.864
.25	-.633	.655	-3.339	.514	-.415	.602	2.854	-.738
.30	-.642	.657	-2.972	.213	-.413	.601	2.725	-.614
.35	-.599	.647	-2.920	.004	-.426	.604	2.671	.011
.40	-.594	.645	-2.413	.024	-.440	.608	2.356	.164
.45	-.582	.643	-2.089	-.054	-.440	.608	1.963	.091
.50	-.571	.640	-1.804	-.181	-.393	.597	1.688	.237
.55	-.562	.638	-1.398	-.139	-.297	.573	1.492	.238
.60	-.542	.633	-1.045	-.155	-.201	.550	1.089	.164
.65	-.494	.622	-.705	-.200	-.084	.520	.852	.296
.70	-.410	.602	-.412	-.227	.030	.491	.259	-.067
.75	-.307	.577	-.191	-.277	.130	.464	.547	.422
.80	-.195	.549	.054	-.279	.212	.441	.571	.457
.85	-.085	.522	.091	-.256	.269	.425	.562	.533
.90	.011	.497	-.090	-.152	.300	.416	.440	.431
.95	.086	.477	-.466	-.092	.302	.415	.250	.284

TABLE 4.7

RUN 1301

M	.498	C2	.44		STAT.	INSTAT.	
ALPHA	.85	FREQ	80.			RE	IM
PO	10398.	K	.262	CL	.290	1.355	.015
RE	1.70E6			CM	.071	.096	.310
Q	1524.						

	UPPERSIDE				LOWERSIDE			
X/C	CP+	M+	CPRE+	CPIM+	CP-	M-	CPRE-	CPIM-
.01	-.014	.502	-9.118	4.392	.248	.431	5.363	-3.002
.05	-1.106	.760	-8.298	3.528	-.400	.598	5.742	-2.356
.10	-.806	.692	-6.065	1.829	-.402	.598	3.390	-1.596
.15	-.693	.666	-2.099	-.165	-.408	.600	3.630	-1.041
.20	-.637	.653	-3.772	.745	-.418	.602	3.043	-.636
.25	-.620	.649	-3.161	.289	-.436	.606	2.558	-.359
.30	-.635	.653	-2.886	-.023	-.431	.605	2.217	-.317
.35	-.594	.643	-2.839	-.250	-.441	.608	2.911	.124
.40	-.588	.642	-2.251	-.357	-.452	.610	2.829	.443
.45	-.576	.639	-1.996	-.462	-.451	.610	2.216	.503
.50	-.570	.638	-1.819	-.556	-.402	.598	2.062	.727
.55	-.562	.636	-1.352	-.610	-.304	.575	1.573	.807
.60	-.544	.631	-1.034	-.643	-.206	.551	1.132	.821
.65	-.499	.621	-.663	-.645	-.089	.521	1.005	1.079
.70	-.415	.601	-.526	-.690	.026	.491	.177	.151
.75	-.313	.577	-.321	-.748	.128	.464	.999	1.244
.80	-.200	.549	-.102	-.749	.209	.442	1.125	1.202
.85	-.091	.521	-.057	-.714	.266	.425	1.367	1.166
.90	.007	.496	-.158	-.561	.299	.416	.932	.836
.95	.085	.475	-.481	-.048	.301	.415	.488	.450

TABLE 4.8

RUN 14405

M	.696	C2	.50		STAT.	QUASI-INSTAT.	
ALPHA	3.00	FREQ	0.			RE	IM
PO	10220.	K	0.000	CL	.715	3.250	0.000
RE	2.11E6			CM	.074	.373	0.000
Q	2509.						

	UPPERSIDE				LOWERSIDE			
X/C	CP+	M+	CPRE+	CPIM+	CP-	M-	CPRE-	CPIM-
.01	.004	.695	-5.500	0.000	.601	.449	6.474	0.000
.05	-1.661	1.398	-7.219	0.000	-.092	.731	7.907	0.000
.10	-1.671	1.403	-7.850	0.000	-.201	.773	6.704	0.000
.15	-1.607	1.368	-8.021	0.000	-.258	.794	5.844	0.000
.20	-1.562	1.344	-8.308	0.000	-.312	.814	5.386	0.000
.25	-1.536	1.331	-9.969	0.000	-.356	.831	5.042	0.000
.30	-1.508	1.316	-11.803	0.000	-.373	.837	4.813	0.000
.35	-1.518	1.321	-22.746	0.000	-.409	.851	4.183	0.000
.40	-1.406	1.266	-57.640	0.000	-.453	.868	3.896	0.000
.45	-.585	.918	-49.790	0.000	-.465	.872	3.323	0.000
.50	-.576	.915	1.318	0.000	-.412	.852	2.922	0.000
.55	-.631	.936	9.626	0.000	-.290	.806	2.177	0.000
.60	-.645	.941	8.652	0.000	-.169	.760	1.604	0.000
.65	-.589	.920	5.214	0.000	-.044	.713	1.261	0.000
.70	-.471	.875	2.693	0.000	.079	.666	1.089	0.000
.75	-.337	.824	1.318	0.000	.184	.625	.974	0.000
.80	-.200	.772	.458	0.000	.267	.592	.917	0.000
.85	-.075	.725	-.057	0.000	.324	.569	.859	0.000
.90	.032	.684	-.286	0.000	.356	.556	.745	0.000
.95	.114	.653	-.286	0.000	.354	.557	.630	0.000

TABLE 4.9

RUN 3805

M	.696	C2	.42		STAT.	INSTAT.	
ALPHA	3.00	FREQ	30.			RE	IM
PO	10220.	K	.072	CL	.705	2.82	-.90
RE	2.11E6			CM	.072	.296	.106
ω	2505.						

	UPPERSIDE				LOWERSIDE			
X/C	CP+	M+	CPRE+	CPIM+	CP-	M-	CPRE-	CPIM-
.01	.001	.695	-4.068	1.563	.605	.447	4.478	-2.328
.05	-1.669	1.398	-6.156	1.863	-.084	.728	6.187	-2.665
.10	-1.682	1.405	-9.320	1.586	-.200	.772	4.633	-2.476
.15	-1.622	1.372	-9.811	1.036	-.259	.794	4.308	-2.078
.20	-1.572	1.346	-9.316	2.170	-.315	.815	3.680	-2.034
.25	-1.534	1.326	-8.715	2.920	-.364	.833	3.468	-1.909
.30	-1.478	1.298	-10.091	5.812	-.385	.841	2.353	-2.017
.35	-1.463	1.290	-19.295	8.129	-.413	.852	3.845	-1.367
.40	-1.122	1.134	-74.021	40.662	-.448	.865	4.448	-1.226
.45	-.720	.969	-34.136	3.267	-.466	.872	3.831	-1.196
.50	-.620	.930	-.667	-6.649	-.410	.851	3.454	-.855
.55	-.622	.931	10.303	-6.919	-.289	.805	2.530	-.647
.60	-.631	.934	8.852	-5.420	-.170	.760	2.305	-.552
.65	-.579	.914	5.066	-3.002	-.044	.713	1.858	-.322
.70	-.464	.871	2.838	-1.691	.079	.666	.353	-.393
.75	-.333	.821	1.978	-1.062	.183	.625	1.675	.065
.80	-.198	.770	1.026	-.487	.264	.593	1.795	.192
.85	-.073	.723	.435	-.362	.323	.569	1.826	.310
.90	.033	.683	.022	-.473	.354	.556	1.565	.068
.95	.112	.652	-.369	-.596	.353	.557	1.153	-.261

TABLE 4.10

RUN 3905

M	.696	C2	.98		STAT.	INSTAT.	
ALPHA	3.00	FREQ	30.			RE	IM
PO	10220.	K	.072	CL	.702	2.853	-.988
RE	2.11E6			CM	.072	.306	.003
ω	2509.						

	UPPERSIDE				LOWERSIDE			
X/C	CP+	M+	CPRE+	CPIM+	CP-	M-	CPRE-	CPIM-
.01	.013	.691	-4.005	1.351	.604	.447	3.921	-2.109
.05	-1.666	1.399	-5.628	1.316	-.084	.728	5.863	-2.194
.10	-1.686	1.411	-8.972	1.172	-.202	.773	4.267	-2.127
.15	-1.622	1.375	-7.543	1.655	-.263	.796	4.323	-1.770
.20	-1.554	1.339	-6.761	2.275	-.319	.817	3.697	-1.785
.25	-1.512	1.317	-8.630	2.748	-.367	.835	3.240	-1.686
.30	-1.453	1.288	-9.328	3.526	-.384	.841	3.033	-1.784
.35	-1.229	1.183	-31.991	17.920	-.416	.854	3.533	-1.288
.40	-1.110	1.130	-34.780	18.621	-.452	.867	3.728	-1.081
.45	-.931	1.055	-23.733	10.022	-.468	.873	3.395	-1.059
.50	-.746	.981	-7.737	-1.004	-.413	.853	3.030	-.752
.55	-.669	.950	2.002	-3.133	-.292	.807	2.311	-.556
.60	-.610	.927	6.394	-4.290	-.172	.762	1.798	-.410
.65	-.552	.905	5.093	-2.865	-.046	.714	1.468	-.248
.70	-.446	.865	3.157	-1.810	.077	.667	.312	-.349
.75	-.320	.817	1.579	-.900	.182	.626	1.271	-.002
.80	-.190	.768	.796	-.447	.262	.594	1.331	.130
.85	-.070	.723	.141	-.279	.320	.571	1.368	.171
.90	.031	.684	-.086	-.333	.351	.558	1.191	.037
.95	.107	.655	-.119	-.558	.351	.558	1.024	-.280

TABLE 4.11

RUN 52705

M	.695	C2	.55		STAT.	INSTAT.	
ALPHA	3.00	FREQ	80.			RE	IM
PO	10265.	K	.192	CL	.694	1.541	-.989
RE	2.12E6			CM	.072	.210	.087
Q	2511.						

	UPPERSIDE				LOWERSIDE			
X/C	CP+	M+	CPRE+	CPIM+	CP-	M-	CPRE-	CPIM-
.01	.010	.691	-2.639	1.667	.599	.448	2.724	-1.662
.05	-1.657	1.389	-4.196	2.153	-.095	.730	3.438	-1.706
.10	-1.667	1.395	-3.680	1.892	-.206	.772	2.436	-.983
.15	-1.604	1.361	-6.735	3.486	-.267	.795	2.347	-.805
.20	-1.557	1.336	-5.944	3.449	-.323	.816	2.223	-.693
.25	-1.520	1.317	-5.168	3.809	-.368	.833	1.997	-.502
.30	-1.468	1.291	-3.517	5.595	-.390	.841	1.267	.136
.35	-1.454	1.284	-6.493	12.094	-.417	.852	2.171	-.180
.40	-1.098	1.122	-19.161	42.695	-.453	.865	2.266	-.372
.45	-.687	.953	-12.598	9.450	-.473	.872	2.020	-.199
.50	-.608	.924	-2.708	-5.711	-.415	.851	1.870	-.002
.55	-.626	.931	1.611	-7.332	-.294	.805	1.507	.163
.60	-.639	.936	1.749	-5.694	-.173	.760	1.210	.254
.65	-.585	.916	1.457	-3.256	-.044	.711	1.104	.418
.70	-.468	.871	.874	-2.002	.078	.665	.225	.067
.75	-.334	.821	.739	-1.362	.182	.624	1.358	.411
.80	-.199	.770	.690	-.849	.264	.592	1.582	.293
.85	-.074	.723	.385	-.510	.324	.567	1.870	.247
.90	.032	.682	.125	-.354	.355	.555	1.404	.036
.95	.112	.652	-.284	-.290	.354	.555	.788	-.166

TABLE 4.12

RUN 16908

M	.744	O2	.50		STAT.	QUASI-INSTAT.	
ALPHA	.85	FREQ	0.			RE	IM
PO	10332.	K	0.000	CL	.481	3.522	0.000
RE	2.22E6			CM	.108	1.239	0.000
Q	2772.						

	UPPERSIDE				LOWERSIDE			
X/C	CP+	M+	CPRE+	CPIM+	CP-	M-	CPRE-	CPIM-
.01	.325	.607	-5.214	0.000	.332	.604	8.193	0.000
.05	-1.101	1.229	-11.230	0.000	-.439	.926	11.001	0.000
.10	-1.160	1.259	-8.652	0.000	-.484	.945	9.683	0.000
.15	-1.113	1.235	-10.943	0.000	-.516	.959	7.964	0.000
.20	-1.079	1.217	-14.897	0.000	-.564	.979	7.735	0.000
.25	-1.060	1.208	-19.022	0.000	-.612	1.000	8.652	0.000
.30	-1.047	1.201	-21.944	0.000	-.624	1.005	7.047	0.000
.35	-1.037	1.197	-18.335	0.000	-.651	1.017	7.907	0.000
.40	-1.039	1.197	-18.392	0.000	-.676	1.028	7.047	0.000
.45	-1.046	1.201	-19.194	0.000	-.660	1.021	5.157	0.000
.50	-1.062	1.209	-17.762	0.000	-.557	.977	4.125	0.000
.55	-1.045	1.201	-16.157	0.000	-.358	.892	2.235	0.000
.60	-1.001	1.179	-12.777	0.000	-.184	.820	2.005	0.000
.65	-.788	1.078	-14.610	0.000	-.034	.758	1.662	0.000
.70	-.443	.927	2.349	0.000	.099	.703	1.662	0.000
.75	-.307	.871	1.375	0.000	.205	.658	2.005	0.000
.80	-.178	.817	-.286	0.000	.281	.626	1.891	0.000
.85	-.054	.766	-.516	0.000	.342	.600	1.891	0.000
.90	.063	.718	.401	0.000	.385	.581	2.120	0.000
.95	.162	.677	2.005	0.000	.395	.576	2.177	0.000

TABLE 4.13

RUN 9608

					STAT.	INSTAT. RE	INSTAT. IM
M	.744	C2	.46				
ALPHA	.85	FREQ	30.				
PO	10380.	K	.068	CL	.463	2.710	-.914
RE	2.23E6			CM	.105	.157	.074
Q	2785.						

	UPPERSIDE				LOWERSIDE			
X/C	CP+	M+	CPRE+	CPIM+	CP-	M-	CPRE-	CPIM-
.01	.329	.605	-3.845	1.210	.332	.604	4.500	-2.394
.05	-1.093	1.225	-8.934	2.739	-.435	.924	7.494	-2.975
.10	-1.153	1.257	-8.638	1.809	-.486	.945	6.085	-2.661
.15	-1.111	1.234	-8.954	1.699	-.517	.959	6.092	-2.130
.20	-1.062	1.210	-7.623	3.184	-.566	.980	5.631	-2.170
.25	-1.041	1.199	-8.752	3.917	-.619	1.003	5.684	-2.346
.30	-1.023	1.190	-10.687	4.692	-.627	1.006	6.345	-1.730
.35	-1.009	1.184	-12.728	6.138	-.652	1.017	6.361	-1.423
.40	-1.012	1.185	-12.752	7.085	-.687	1.032	5.064	-1.614
.45	-1.011	1.185	-14.213	8.315	-.665	1.023	3.797	-1.090
.50	-1.007	1.182	-18.586	11.621	-.564	.979	2.687	-.537
.55	-1.030	1.194	-13.956	5.802	-.360	.892	.816	.038
.60	-1.030	1.194	-9.447	1.031	-.187	.821	.393	.102
.65	-.722	1.049	20.134	-12.438	-.035	.758	.049	.119
.70	-.449	.931	6.371	-4.040	.096	.704	.111	-.043
.75	-.297	.867	3.078	-1.595	.200	.660	1.217	.352
.80	-.168	.813	1.813	-.455	.276	.628	1.495	.433
.85	-.048	.764	.563	-.076	.337	.602	1.636	.497
.90	.061	.719	-.686	-.127	.375	.585	1.032	.167
.95	.150	.682	-1.429	-.302	.387	.580	.319	-.168

TABLE 4.14

RUN 6708

					STAT.	INSTAT. RE	INSTAT. IM
M	.744	C2	.61				
ALPHA	.85	FREQ	80.				
PO	10333.	K	.181	CL	.471	1.498	-.586
RE	2.22E6			CM	.104	.238	.255
Q	2770.						

	UPPERSIDE				LOWERSIDE			
X/C	CP+	M+	CPRE+	CPIM+	CP-	M-	CPRE-	CPIM-
.01	.323	.608	-2.483	1.472	.338	.601	2.747	-1.772
.05	-1.107	1.231	-6.763	3.710	-.428	.921	3.809	-2.291
.10	-1.167	1.263	-3.525	1.841	-.484	.944	3.170	-1.587
.15	-1.125	1.240	-5.456	2.970	-.511	.956	3.285	-1.459
.20	-1.077	1.216	-4.065	3.026	-.563	.978	3.051	-1.256
.25	-1.059	1.207	-4.067	3.493	-.607	.997	2.954	-1.079
.30	-1.041	1.198	-4.510	4.794	-.622	1.003	3.645	-.763
.35	-1.032	1.193	-4.300	6.034	-.642	1.012	3.599	-.252
.40	-1.032	1.193	-3.802	6.416	-.677	1.028	2.839	.183
.45	-1.031	1.193	-3.531	7.356	-.657	1.019	2.138	.471
.50	-1.015	1.185	-2.966	10.747	-.558	.976	1.385	1.235
.55	-1.014	1.184	-5.064	9.904	-.359	.892	.357	1.266
.60	-.994	1.175	-6.754	1.791	-.187	.820	.239	1.134
.65	-.675	1.027	-4.213	-14.659	-.035	.758	.135	1.316
.70	-.450	.930	.572	-6.041	.096	.704	.092	.222
.75	-.303	.869	1.383	-2.949	.202	.659	1.319	.944
.80	-.171	.814	1.351	-1.849	.278	.627	1.716	.483
.85	-.050	.764	.889	-1.202	.339	.601	1.907	.359
.90	.060	.719	-.004	-.405	.380	.583	1.053	.295
.95	.149	.682	-.771	.330	.388	.579	.302	.269

TABLE 4.15

Pressure distributions for NLR 7301 with control surface and transition strip at x/c = .07

ZERO FREQUENCY TEST DATA NLR 7301 WITH OSCILLATING FLAP

	UPPERSIDE				LOWERSIDE			
X/C	CP+	M+	CPRE+	CPIM+	CP-	M-	CPRE-	CPIM-
.010	.121	.470	-2.816	.000	.067	.485	3.157	.000
.030	-.940	.730	-4.084	.000	-.467	.619	3.189	.000
.050	-.873	.715	-3.457	.000	-.535	.636	2.607	.000
.100	-.627	.657	-2.129	.000	-.465	.619	2.207	.000
.150	-.568	.644	-1.839	.000	-.468	.620	1.846	.000
.200	-.544	.638	-1.718	.000	-.474	.621	1.706	.000
.250	-.533	.635	-1.670	.000	-.481	.623	1.646	.000
.300	-.523	.633	-1.622	.000	-.489	.625	1.645	.000
.350	-.511	.630	-1.597	.000	-.485	.624	1.645	.000
.400	-.509	.630	-1.621	.000	-.496	.626	1.685	.000
.450	-.504	.628	-1.597	.000	-.483	.623	1.786	.000
.500	-.500	.627	-1.693	.000	-.430	.611	1.807	.000
.550	-.489	.625	-1.766	.000	-.328	.586	1.768	.000
.600	-.469	.620	-1.958	.000	-.222	.560	1.770	.000
.650	-.421	.608	-2.102	.000	-.109	.531	1.812	.000
.700	-.340	.589	-2.389	.000	.008	.501	1.854	.000
.725	-.286	.576	-2.509	.000	.053	.489	1.854	.000
.760	-.271	.572	-3.496	.000	.115	.472	1.975	.000
.775	-.235	.563	-2.580	.000	.138	.465	1.635	.000
.800	-.171	.547	-1.761	.000	.174	.455	1.355	.000
.850	-.067	.520	-1.013	.000	.227	.440	.955	.000
.900	.020	.498	-.361	.000	.259	.431	1.016	.000
.950	.097	.477	-.408	.000	.269	.428	.575	.000

TEST DATA		MODEL DATA		OVERALL DATA		STEADY	UNSTEADY RE	UNSTEADY IM
MEETRUNNR.	250	ALPHA	.00 DEG.					
MACH	.503	DELTA	.02 DEG.	NORMAL FORCE	CL	.173	1.090	.000
Q [PA]	15004	AMPL.	.95 DEG.	MOMENT(1/4C)	CM	.058	.393	.000
RE	1.69E6	FREQ.	.0 HZ	FLAP FORCE	RC	.0625	.1634	.0000
HARM	1	RFREQ	.000	HINGE MOMENT	NC	.0059	.0246	.0000
IDENTNR.	10							

TABLE 4.16

FUNDAMENTAL FREQUENCY TEST DATA NLR 7301 WITH OSCILLATING FLAP

	UPPERSIDE				LOWERSIDE			
X/C	CP+	M+	CPRE+	CPIM+	CP-	M-	CPRE-	CPIM-
.010	.126	.469	-2.159	1.234	.069	.484	2.243	-1.519
.030	-.935	.728	-3.015	1.557	-.464	.618	2.675	-1.422
.050	-.867	.713	-.883	1.411	-.531	.634	.973	-1.323
.100	-.629	.658	-1.950	.987	-.472	.620	1.900	-.860
.150	-.570	.643	-1.384	.755	-.471	.620	1.389	-.839
.200	-.545	.638	-1.238	.629	-.474	.621	1.321	-.673
.250	-.534	.635	-1.237	.629	-.483	.623	1.201	-.568
.300	-.522	.632	-1.363	.483	-.488	.624	.976	-.584
.350	-.512	.630	-1.362	.484	-.488	.624	1.306	-.447
.400	-.509	.629	-1.290	.421	-.497	.626	1.419	-.439
.450	-.503	.628	-1.425	.411	-.483	.623	1.418	-.439
.500	-.501	.627	-1.551	.266	-.431	.610	1.521	-.320
.550	-.487	.624	-1.550	.266	-.328	.585	1.622	-.201
.600	-.470	.620	-1.820	.247	-.222	.559	1.776	-.024
.650	-.421	.608	-1.954	.239	-.107	.530	1.929	.152
.700	-.340	.588	-2.347	.078	.009	.500	1.970	.319
.725	-.283	.574	-2.416	.144	.057	.487	1.975	.205
.760	-.269	.571	-3.494	.072	.117	.471	2.123	.492
.775	-.233	.562	-2.728	-.215	.140	.465	1.788	.471
.800	-.172	.547	-1.711	-.213	.174	.455	1.565	.456
.850	-.067	.520	-.901	-.159	.228	.440	1.119	.429
.900	.022	.497	-.568	-.069	.261	.430	.955	.362
.950	.097	.476	-.425	-.194	.270	.428	.517	.225

TEST DATA		MODEL DATA		OVERALL DATA		STEADY	UNSTEADY RE	UNSTEADY IM
MEETRUNNR.	253	ALPHA	.00 DEG.					
MACH	.502	DELTA	.02 DEG.	NORMAL FORCE	CL	.172	.927	-.197
Q [PA]	15024	AMPL.	.97 DEG.	MOMENT(1/4C)	CM	.058	.418	.065
RE	1.69E6	FREQ.	30.0 HZ	FLAP FORCE	RC	.0625	.1705	.0376
HARM	1	RFREQ	.098	HINGE MOMENT	NC	.0059	.0255	.0077
IDENTNR.	10							

TABLE 4.17

ZERO FREQUENCY TEST DATA NLR 7301 WITH OSCILLATING FLAP

	UPPERSIDE				LOWERSIDE			
X/C	CP+	M+	CPRE+	CPIM+	CP-	M-	CPRE-	CPIM-
.010	.009	.699	-.832	.000	.583	.461	1.305	.000
.030	-1.467	1.312	-.984	.000	.055	.681	1.750	.000
.050	-1.597	1.381	-1.214	.000	-.107	.743	1.775	.000
.100	-1.562	1.361	-1.078	.000	-.208	.782	1.574	.000
.150	-1.501	1.329	-1.345	.000	-.259	.801	1.550	.000
.200	-1.459	1.307	-1.522	.000	-.312	.821	1.614	.000
.250	-1.430	1.293	-2.411	.000	-.356	.838	1.644	.000
.300	-1.302	1.230	-10.641	.000	-.380	.847	1.683	.000
.350	-.857	1.035	-23.199	.000	-.424	.864	1.890	.000
.400	-.633	.945	-3.794	.000	-.466	.880	2.258	.000
.450	-.616	.939	.741	.000	-.476	.884	2.263	.000
.500	-.641	.949	.823	.000	-.423	.864	2.263	.000
.550	-.638	.947	-.449	.000	-.304	.818	1.914	.000
.600	-.605	.934	-1.202	.000	-.188	.774	1.957	.000
.650	-.506	.896	-1.699	.000	-.062	.726	1.971	.000
.700	-.381	.848	-1.984	.000	.063	.678	2.034	.000
.725	-.307	.819	-2.121	.000	.117	.657	2.063	.000
.760	-.252	.799	-2.488	.000	.178	.633	2.235	.000
.775	-.217	.785	-1.813	.000	.205	.622	1.847	.000
.800	-.152	.760	-1.168	.000	.245	.606	1.503	.000
.850	-.042	.718	-.743	.000	.305	.582	1.110	.000
.900	.044	.685	-.785	.000	.338	.568	.874	.000
.950	.106	.661	-1.093	.000	.337	.568	.423	.000

TEST DATA		MODEL DATA		OVERALL DATA	STEADY	UNSTEADY RE	UNSTEADY IM
MEETRUNNR.	129	ALPHA	3.00 DEG.				
MACH	.702	DELTA	-.08 DEG.	NORMAL FORCE CL	.593	1.410	.000
Q [PA]	25035	AMPL.	.95 DEG.	MOMENT(1/4C) CM	.052	.484	.000
RE	2.14E6	FREQ.	.0 HZ	FLAP FORCE RC	.0745	.1615	.0000
HARM	1	RFREQ	.000	HINGE MOMENT NC	.0073	.0282	.0000
IDENTNR.	5						

TABLE 4.18

FUNDAMENTAL FREQUENCY TEST DATA NLR 7301 WITH OSCILLATING FLAP

	UPPERSIDE				LOWERSIDE			
X/C	CP+	M+	CPRE+	CPIM+	CP-	M-	CPRE-	CPIM-
.010	.006	.699	-.709	.568	.584	.460	.940	-.829
.030	-1.472	1.312	-.982	.945	.059	.679	1.855	-.894
.050	-1.600	1.380	-1.121	.835	-.105	.742	.646	-1.057
.100	-1.559	1.358	-.887	.705	-.207	.781	.762	-.933
.150	-1.500	1.326	-1.116	.992	-.258	.800	.985	-.926
.200	-1.457	1.305	-1.220	1.009	-.310	.820	1.000	-.886
.250	-1.426	1.289	-1.726	1.507	-.356	.837	1.097	-.854
.300	-1.272	1.215	-5.784	4.585	-.379	.846	1.193	-.853
.350	-.880	1.043	-17.495	10.740	-.422	.863	1.421	-.861
.400	-.652	.952	-5.238	.628	-.462	.878	1.519	-.885
.450	-.622	.940	-.373	-1.670	-.474	.883	1.744	-.846
.500	-.640	.947	-.030	-1.932	-.422	.863	1.871	-.679
.550	-.636	.946	-.898	-1.355	-.301	.816	1.933	-.495
.600	-.599	.931	-1.503	-.841	-.181	.771	1.990	-.339
.650	-.503	.894	-1.768	-.536	-.058	.724	2.068	-.186
.700	-.379	.846	-2.052	-.540	.066	.676	2.186	-.030
.725	-.307	.819	-2.146	-.419	.118	.656	2.181	-.070
.760	-.255	.799	-2.621	-.252	.173	.634	2.488	.089
.775	-.217	.784	-1.908	-.640	.202	.622	2.150	.254
.800	-.151	.759	-1.136	-.595	.243	.606	1.763	.289
.850	-.042	.718	-.629	-.342	.304	.582	1.381	.284
.900	.040	.686	-.824	-.189	.337	.568	1.025	.219
.950	.098	.663	-1.304	-.159	.334	.569	.451	.078

TEST DATA		MODEL DATA		OVERALL DATA	STEADY	UNSTEADY RE	UNSTEADY IM
MEETRUNNR.	120	ALPHA	3.00 DEG.				
MACH	.701	DELTA	.03 DEG.	NORMAL FORCE CL	.595	1.213	-.350
Q [PA]	25006	AMPL.	.97 DEG.	MOMENT(1/4C) CM	.053	.516	.069
RE	2.14E6	FREQ.	30.0 HZ	FLAP FORCE RC	.0746	.1783	.0384
HARM	1	RFREQ	.071	HINGE MOMENT NC	.0073	.0316	.0068
IDENTNR.	5						

TABLE 4.19

ZERO FREQUENCY TEST DATA NLR 7301 WITH OSCILLATING FLAP

	UPPERSIDE				LOWERSIDE			
X/C	CP+	M+	CPRE+	CPIM+	CP-	M-	CPRE-	CPIM-
.010	.329	.613	-.993	.000	.312	.621	1.591	.000
.030	-.958	1.178	-1.801	.000	-.287	.874	2.148	.000
.050	-1.016	1.207	-1.983	.000	-.451	.945	2.308	.000
.100	-1.092	1.246	-1.542	.000	-.512	.971	2.319	.000
.150	-1.034	1.216	-2.036	.000	-.531	.979	2.167	.000
.200	-1.008	1.203	-2.465	.000	-.582	1.002	2.383	.000
.250	-.976	1.186	-3.181	.000	-.623	1.020	2.458	.000
.300	-.956	1.177	-4.652	.000	-.671	1.042	3.444	.000
.350	-.937	1.167	-8.831	.000	-.690	1.051	3.920	.000
.400	-.918	1.158	-8.427	.000	-.732	1.070	4.483	.000
.450	-.872	1.136	-8.701	.000	-.701	1.055	7.333	.000
.500	-.748	1.077	-9.521	.000	-.584	1.003	3.770	.000
.550	-.762	1.083	-7.920	.000	-.376	.912	2.504	.000
.600	-.626	1.022	-5.886	.000	-.204	.839	2.268	.000
.650	-.519	.974	-1.835	.000	-.058	.778	2.313	.000
.700	-.380	.914	-2.003	.000	.077	.721	2.401	.000
.725	-.299	.880	-2.145	.000	.132	.698	2.607	.000
.760	-.249	.859	-2.340	.000	.201	.669	2.467	.000
.775	-.214	.844	-1.779	.000	.228	.657	2.142	.000
.800	-.143	.814	-1.193	.000	.268	.640	1.850	.000
.850	-.024	.764	-.710	.000	.330	.613	1.482	.000
.900	.073	.723	-.917	.000	.369	.596	1.169	.000
.950	.142	.694	-1.268	.000	.372	.594	.670	.000

TEST DATA		MODEL DATA		OVERALL DATA				
						STEADY	UNSTEADY	
MEETRUNNR.	160	ALPHA	.85 DEG.				RE	IM
MACH	.754	DELTA	.01 DEG.	NORMAL FORCE	CL	.352	2.043	.000
Q [PA]	27504	AMPL.	.96 DEG.	MOMENT(1/4C)	CM	.076	.814	.000
RE	2.23E6	FREQ.	.0 HZ	FLAP FORCE	RC	.0761	.1870	.0000
HARM	1	RFREQ	.000	HINGE MOMENT	NC	.0073	.0345	.0000
IDENTNR.	6							

TABLE 4.20

FUNDAMENTAL FREQUENCY TEST DATA NLR 7301 WITH OSCILLATING FLAP

	UPPERSIDE				LOWERSIDE			
X/C	CP+	M+	CPRE+	CPIM+	CP-	M-	CPRE-	CPIM-
.010	.329	.614	-.452	.624	.314	.621	.938	-1.128
.030	-.956	1.178	-.579	1.044	-.287	.875	1.420	-1.568
.050	-1.017	1.209	-.284	.925	-.452	.946	.265	-1.187
.100	-1.090	1.247	-.330	.919	-.512	.972	.404	-1.290
.150	-1.033	1.217	-.479	1.215	-.530	.980	.586	-1.325
.200	-1.001	1.201	-.534	1.459	-.575	1.000	.680	-1.378
.250	-.975	1.188	-.699	1.853	-.621	1.020	.858	-1.467
.300	-.951	1.176	-.877	2.524	-.672	1.044	.939	-1.819
.350	-.928	1.165	-1.392	4.194	-.689	1.051	1.909	-2.222
.400	-.871	1.137	-3.247	8.476	-.728	1.069	2.414	-2.168
.450	-.834	1.119	-4.806	9.156	-.720	1.065	5.145	-2.934
.500	-.800	1.103	-7.826	6.778	-.583	1.004	3.172	-1.336
.550	-.763	1.085	-10.508	1.371	-.377	.914	2.132	-.490
.600	-.679	1.047	-8.004	-3.403	-.207	.842	1.983	-.359
.650	-.513	.972	-2.092	-1.180	-.059	.779	2.122	-.282
.700	-.371	.911	-2.063	-.648	.078	.722	2.323	-.229
.725	-.295	.879	-2.294	-.385	.131	.700	2.299	-.277
.760	-.238	.855	-2.377	-.176	.201	.669	2.342	-.176
.775	-.205	.841	-1.704	-.615	.227	.658	2.177	-.028
.800	-.137	.812	-.909	-.563	.267	.641	1.921	-.000
.850	-.022	.764	-.514	-.296	.330	.614	1.551	.026
.900	.068	.726	-1.028	-.251	.369	.596	1.122	-.073
.950	.136	.698	-1.804	-.264	.372	.595	.447	-.195

TEST DATA		MODEL DATA		OVERALL DATA				
						STEADY	UNSTEADY	
MEETRUNNR.	148	ALPHA	.85 DEG.				RE	IM
MACH	.755	DELTA	.01 DEG.	NORMAL FORCE	CL	.350	1.325	-.826
Q [PA]	27538	AMPL.	.95 DEG.	MOMENT(1/4C)	CM	.076	.781	-.120
RE	2.23E6	FREQ.	30.0 HZ	FLAP FORCE	RC	.0759	.1877	.0195
HARM	1	RFREQ	.067	HINGE MOMENT	NC	.0074	.0362	.0032
IDENTNR.	6							

TABLE 4.21

FIRST HARMONIC TEST DATA NLR 7301 WITH OSCILLATING FLAP

	UPPERSIDE				LOWERSIDE			
X/C	CP+	M+	CPRE+	CPIM+	CP-	M-	CPRE-	CPIM-
.010	.329	.614	-.015	.015	.313	.621	-.047	-.066
.030	-.956	1.178	-.048	.042	-.288	.875	-.045	-.018
.050	-1.014	1.207	-.007	-.005	-.452	.946	.016	.011
.100	-1.090	1.247	.008	.005	-.512	.972	-.043	.001
.150	-1.033	1.217	-.027	.026	-.531	.980	-.033	-.010
.200	-.999	1.199	-.030	.063	-.574	.999	-.058	-.012
.250	-.974	1.186	-.105	.153	-.621	1.020	-.111	-.015
.300	-.954	1.177	-.139	.242	-.674	1.044	-.039	-.088
.350	-.930	1.165	-.507	.848	-.690	1.051	-.149	-.191
.400	-.873	1.137	-2.026	2.922	-.727	1.068	-.182	-.189
.450	-.830	1.117	-2.427	-.632	-.719	1.064	.968	-.052
.500	-.795	1.100	-1.356	-4.594	-.582	1.003	.159	.015
.550	-.761	1.084	2.920	-3.489	-.374	.912	.012	.044
.600	-.674	1.044	2.237	2.641	-.202	.839	.031	.001
.650	-.510	.971	.267	.514	-.056	.778	.067	.029
.700	-.371	.911	-.110	.211	.078	.721	.105	.012
.725	-.295	.879	-.182	.029	.131	.699	-.016	-.010
.760	-.239	.855	-.202	-.082	.202	.669	.092	.003
.775	-.206	.841	-.339	-.126	.227	.658	.076	-.015
.800	-.137	.812	-.250	-.159	.267	.641	.058	-.009
.850	-.021	.763	-.062	-.020	.330	.613	.008	.000
.900	.069	.725	.162	.196	.369	.596	-.001	.020
.950	.135	.697	.237	.257	.372	.595	.040	.014

TEST DATA		MODEL DATA		OVERALL DATA		STEADY	UNSTEADY	
							RE	IM
MEETRUNNR.	149	ALPHA	.85 DEG.					
MACH	.754	DELTA	.02 DEG.	NORMAL FORCE	CL	.350	.037	.007
Q [PA]	27528	AMPL.	.95 DEG.	MOMENT(1/4C)	CM	.076	-.004	.013
RE	2.23E6	FREQ.	30.0 HZ	FLAP FORCE	RC	.0759	.0033	-.0034
HARM	2	RFREQ	.067	HINGE MOMENT	NC	.0074	-.0013	-.0021
IDENTNR.	6							

TABLE 4.22

SECOND HARMONIC TEST DATA NLR 7301 WITH OSCILLATING FLAP

	UPPERSIDE				LOWERSIDE			
X/C	CP+	M+	CPRE+	CPIM+	CP-	M-	CPRE-	CPIM-
.010	.329	.614	.022	.026	.313	.621	.025	-.057
.030	-.955	1.178	-.032	.091	-.286	.875	.068	-.051
.050	-1.014	1.207	-.008	.046	-.452	.946	.025	-.030
.100	-1.091	1.247	-.000	.024	-.511	.972	.025	.005
.150	-1.034	1.217	-.017	.030	-.530	.980	.038	-.003
.200	-1.001	1.201	.001	.062	-.575	1.000	.023	-.001
.250	-.972	1.186	-.007	.043	-.620	1.020	.026	.018
.300	-.951	1.175	-.005	.118	-.671	1.043	.031	.007
.350	-.928	1.164	-.139	.317	-.689	1.051	.087	.060
.400	-.870	1.136	-1.110	1.159	-.727	1.068	.152	.107
.450	-.829	1.116	.502	-2.189	-.719	1.065	.338	-.033
.500	-.805	1.105	1.079	-.719	-.582	1.003	.047	.135
.550	-.755	1.082	-.963	2.435	-.373	.912	.004	.108
.600	-.671	1.043	-.322	-1.877	-.201	.839	.021	.106
.650	-.511	.972	-.117	-.489	-.057	.779	.006	.111
.700	-.371	.911	.001	-.211	.078	.722	.020	.112
.725	-.295	.879	-.004	-.119	.132	.699	.017	.113
.760	-.239	.855	.060	-.062	.201	.669	.011	.102
.775	-.206	.841	.043	-.015	.228	.658	.011	.114
.800	-.136	.812	.054	-.009	.268	.641	.026	.100
.850	-.022	.764	.022	-.056	.330	.613	.011	.093
.900	.069	.725	.013	-.155	.369	.596	-.006	.054
.950	.136	.697	-.078	-.150	.372	.595	-.028	.037

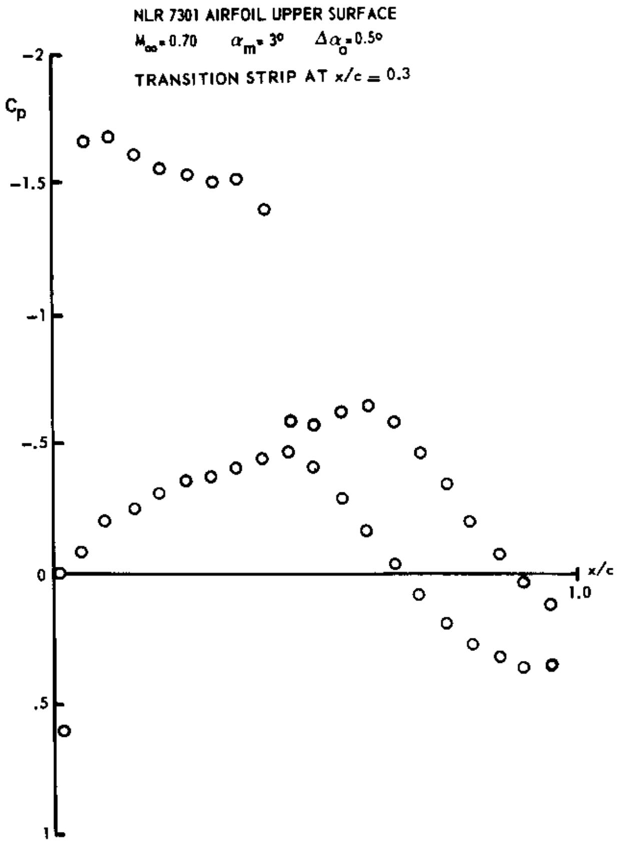
TEST DATA		MODEL DATA		OVERALL DATA		STEADY	UNSTEADY	
							RE	IM
MEETRUNNR.	150	ALPHA	.85 DEG.					
MACH	.755	DELTA	.02 DEG.	NORMAL FORCE	CL	.350	.031	.043
Q [PA]	27537	AMPL.	.95 DEG.	MOMENT(1/4C)	CM	.076	.011	.044
RE	2.23E6	FREQ.	30.0 HZ	FLAP FORCE	RC	.0759	-.0005	.0117
HARM	3	RFREQ	.067	HINGE MOMENT	NC	.0074	.0001	.0029
IDENTNR.	6							

TABLE 4.23

FUNDAMENTAL FREQUENCY TEST DATA NLR 7301 WITH OSCILLATING FLAP

	UPPERSIDE				LOWERSIDE			
X/C	CP+	M+	CPRE+	CPIM+	CP-	M-	CPRE-	CPIM-
.010	.334	.613	.154	-.688	.316	.621	-1.050	1.042
.030	-.946	1.177	.465	-1.072	-.285	.877	-1.841	1.397
.050	-1.006	1.207	.190	-.692	-.452	.948	-.922	.636
.100	-1.083	1.247	.122	-.703	-.511	.974	-1.242	.505
.150	-1.026	1.217	.099	-.809	-.530	.982	-1.559	.244
.200	-.993	1.200	-.103	-.925	-.573	1.001	-1.835	-.147
.250	-.966	1.187	-.332	-1.094	-.616	1.021	-2.146	-.784
.300	-.945	1.176	-.560	-1.161	-.670	1.045	-2.018	-1.425
.350	-.925	1.166	-.959	-1.320	-.680	1.050	-1.886	-3.774
.400	-.896	1.152	-1.049	-1.833	-.712	1.065	.422	-5.230
.450	-.788	1.100	-.505	-5.948	-.733	1.074	5.262	-6.610
.500	-.695	1.057	7.227	-1.821	-.572	1.001	6.297	-1.647
.550	-.687	1.053	7.596	3.866	-.365	.911	4.839	.422
.600	-.661	1.041	.002	10.300	-.199	.840	3.657	.954
.650	-.545	.989	-7.826	7.013	-.057	.781	3.378	.856
.700	-.369	.913	-6.432	.319	.070	.727	3.207	.975
.725	-.299	.883	-5.431	-.581	.122	.705	2.887	1.038
.760	-.229	.853	-5.075	-1.452	.196	.673	2.809	1.223
.775	-.198	.840	-4.991	-1.792	.222	.662	2.675	1.415
.800	-.132	.812	-3.286	-2.022	.263	.644	2.336	1.535
.850	-.020	.765	-1.446	-1.301	.326	.617	1.657	1.782
.900	.070	.727	-1.047	-.845	.364	.600	1.301	1.543
.950	.135	.699	-1.397	-.102	.367	.598	.711	1.049

TEST DATA		MODEL DATA		OVERALL DATA		STEADY	UNSTEADY RE	UNSTEADY IM
MEETRUNNR.	162	ALPHA	.85 DEG.					
MACH	.756	DELTA	-.01 DEG.	NORMAL FORCE	CL	.339	.611	-.102
Q [PA]	27637	AMPL.	.90 DEG.	MOMENT(1/4C)	CM	.073	.740	-.024
RE	2.23E6	FREQ.	200.0 HZ	FLAP FORCE	RC	.0743	.2801	.1832
HARM	1	RFREQ	.445	HINGE MOMENT	NC	.0073	.0443	.0340
IDENTNR.	6							



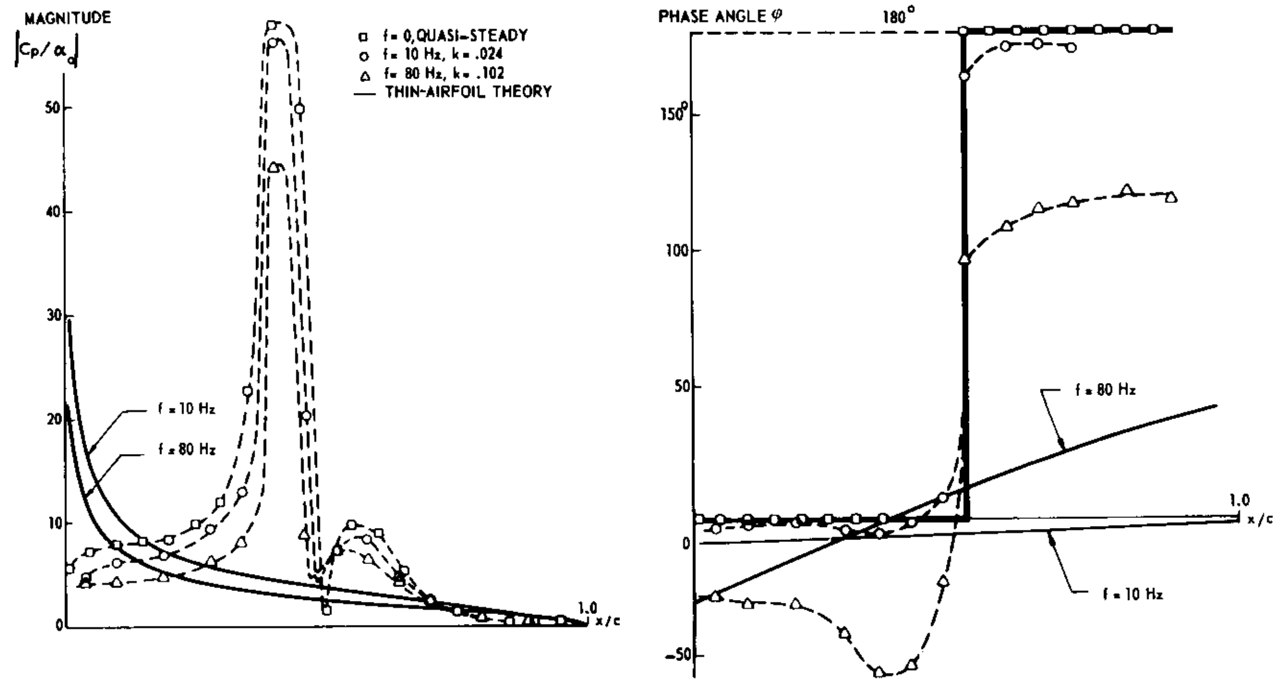


Fig. 4.1 Effect of shock wave on the unsteady pressure distributions; pitching oscillation

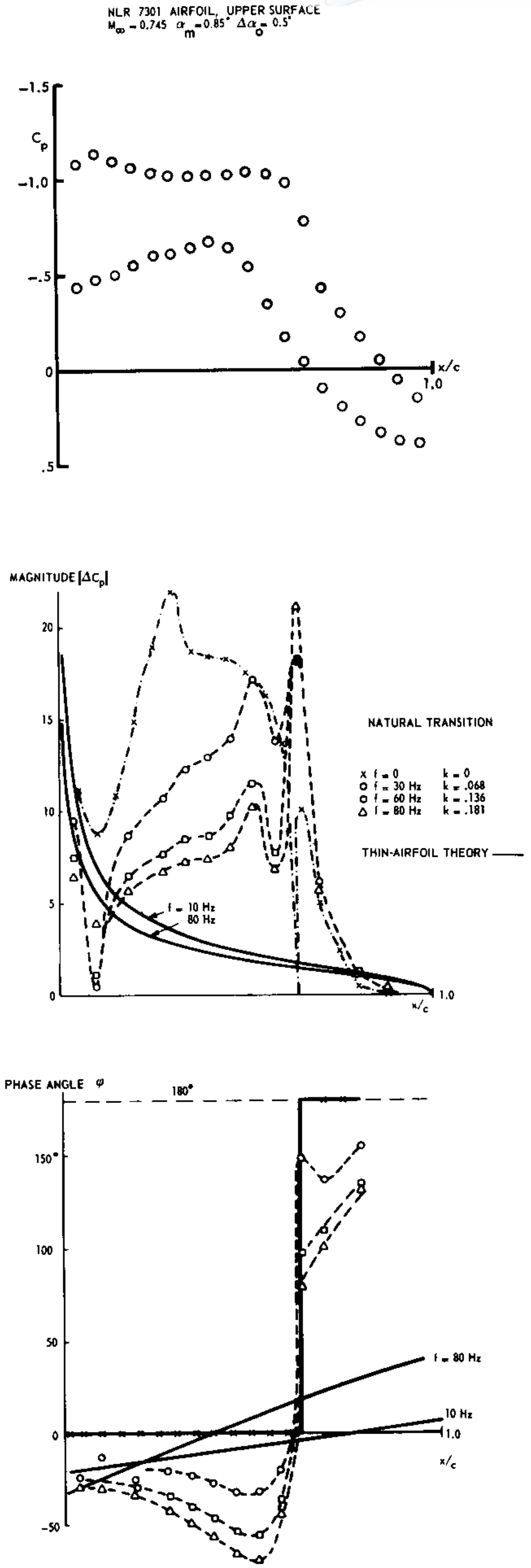


Fig. 4.2 Unsteady pressure distributions for the "shock-free" design point; pitching oscillation

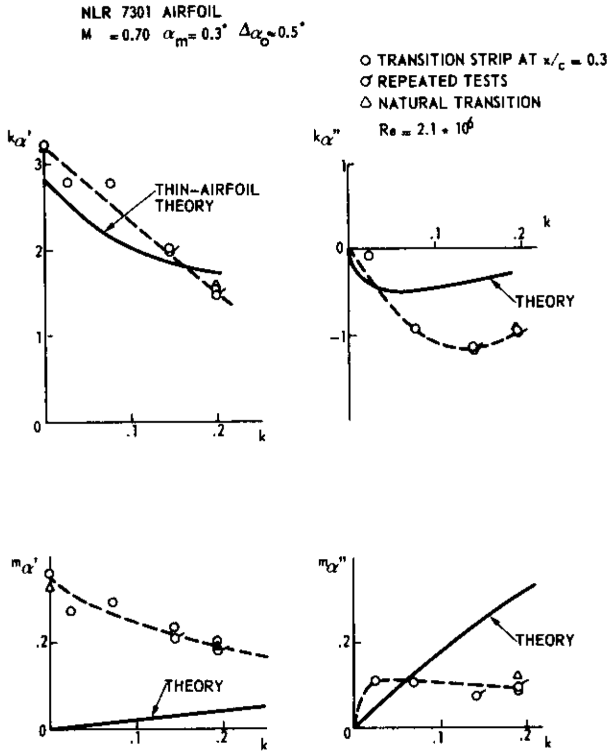


Fig. 4.3 Unsteady normal-force and moment coefficients as a function of frequency in transonic flow with a well-developed shock wave; pitching oscillation

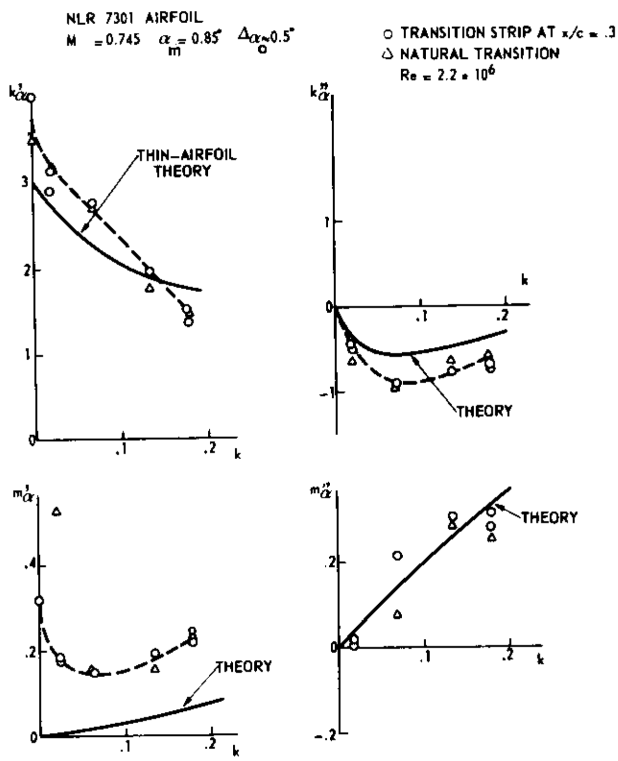


Fig. 4.4 Unsteady normal-force and moment coefficients as a function of frequency for the "shock-free" design point; pitching oscillation

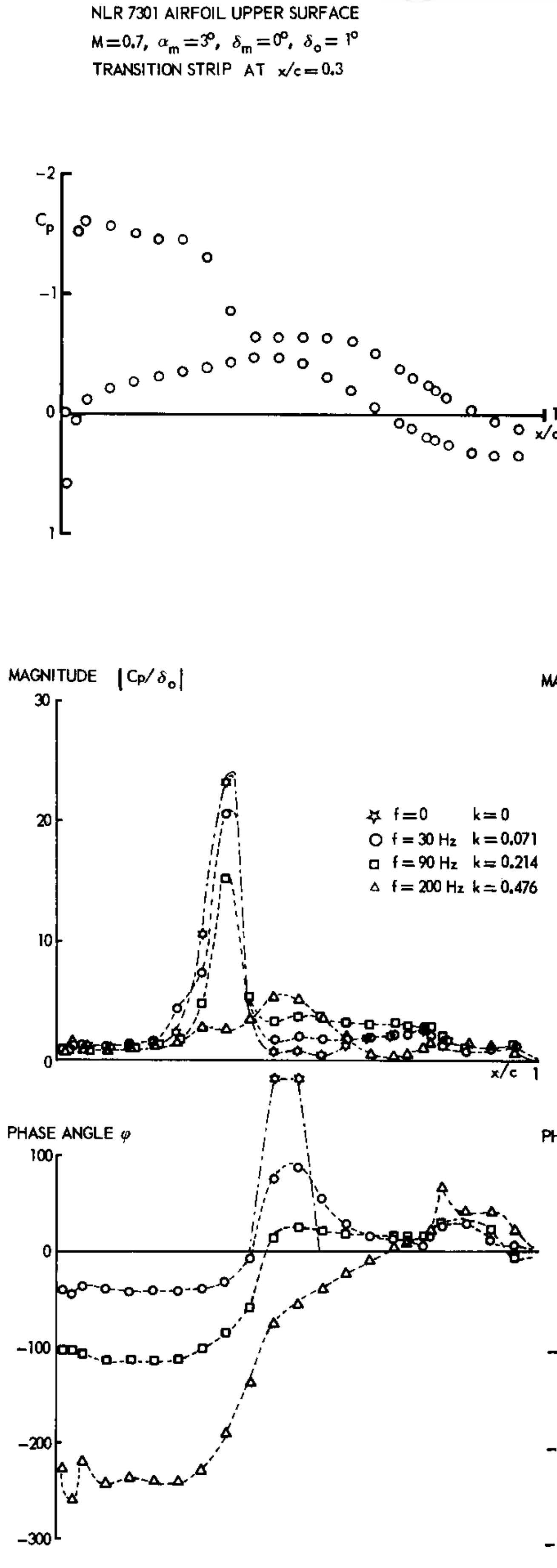


Fig. 4.5 Effect of shock wave on the unsteady pressure distributions; flap oscillation

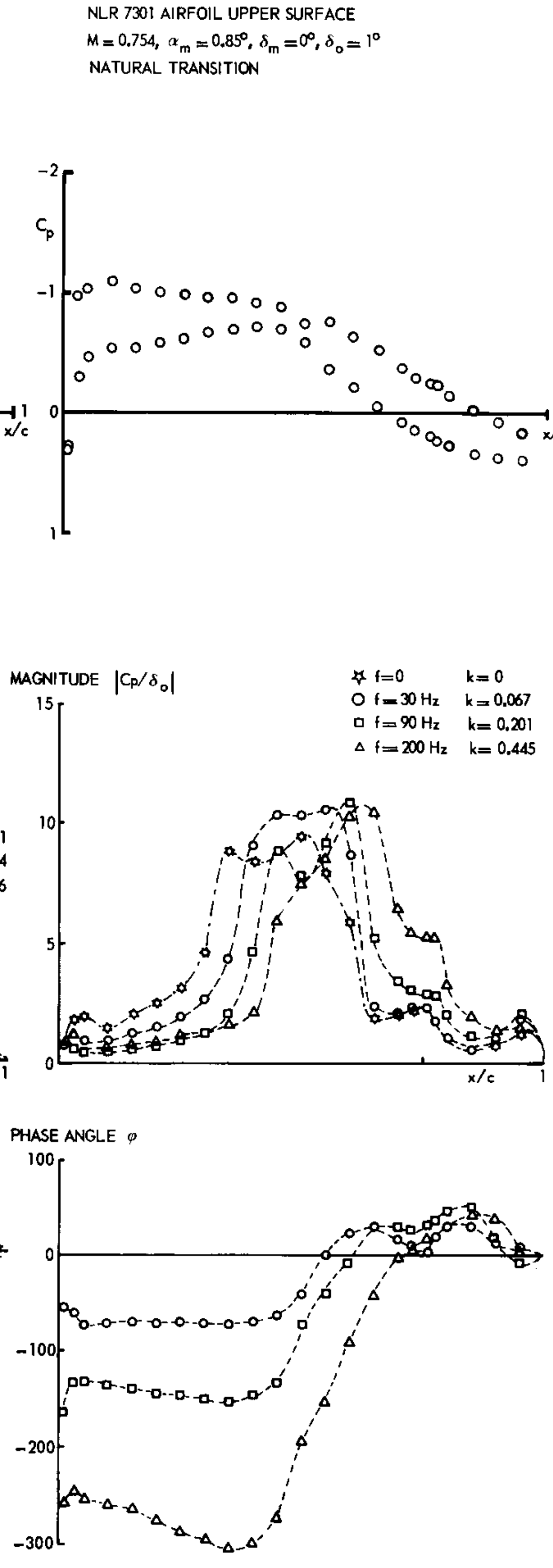


Fig. 4.6 Unsteady pressure distributions for the "shock-free" design point; flap oscillation

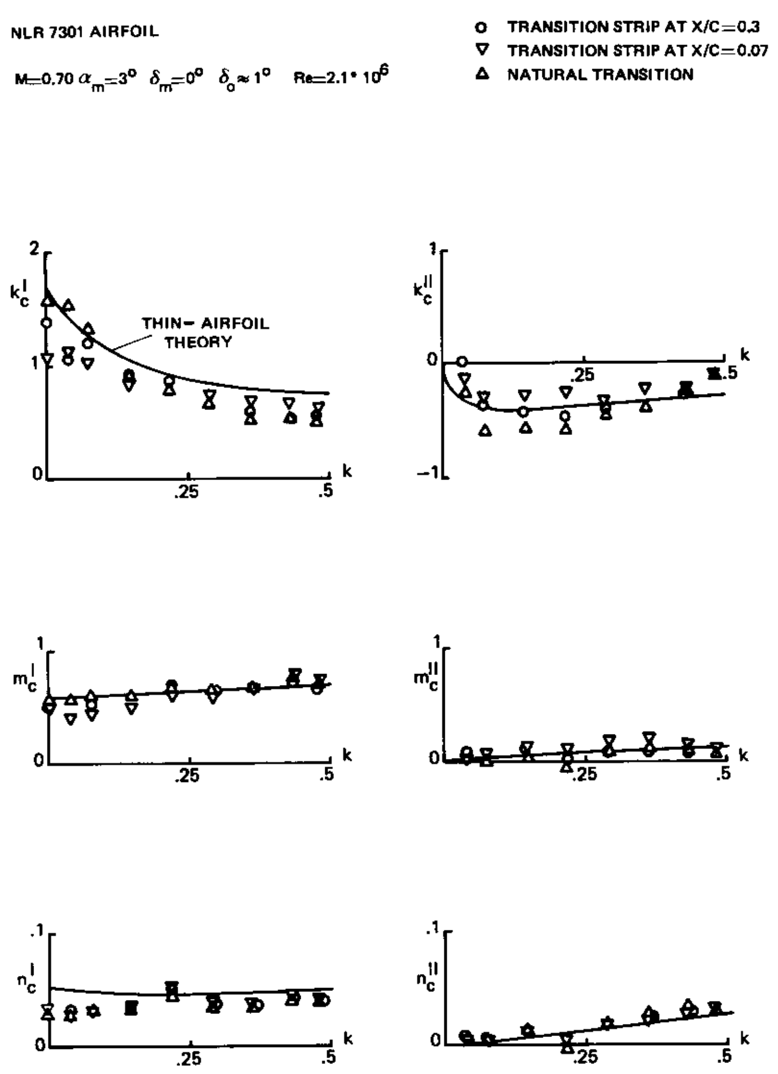


Fig. 4.7 Unsteady aerodynamic coefficients as functions of frequency in transonic flow with a well-developed shock wave; flap oscillation

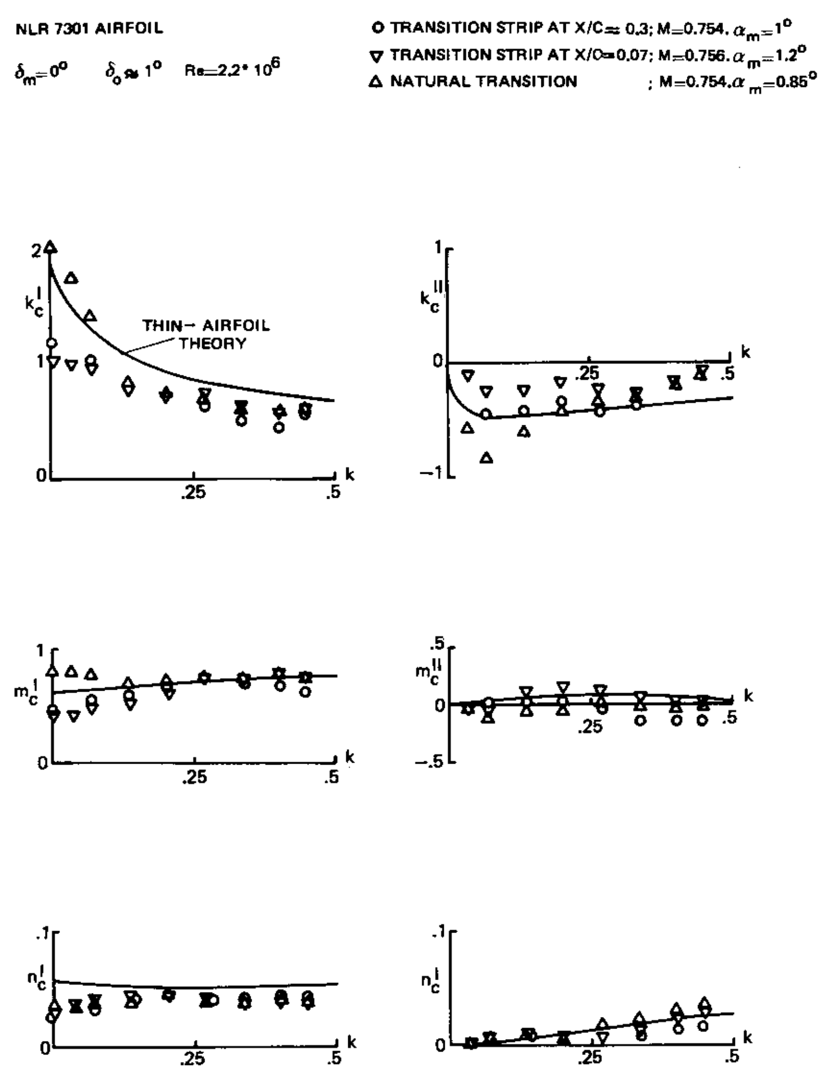


Fig. 4.8 Unsteady aerodynamic coefficients as functions of frequency for best "shock-free" steady flow; flap oscillation

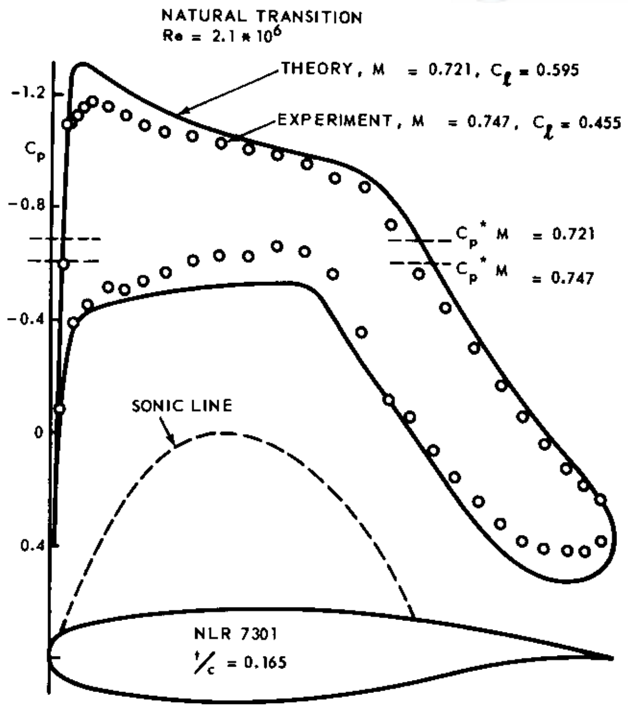


Fig. 4.9 Theoretical and experimental "shock-free" pressure distributions of the NLR 7301 airfoil (free transition)

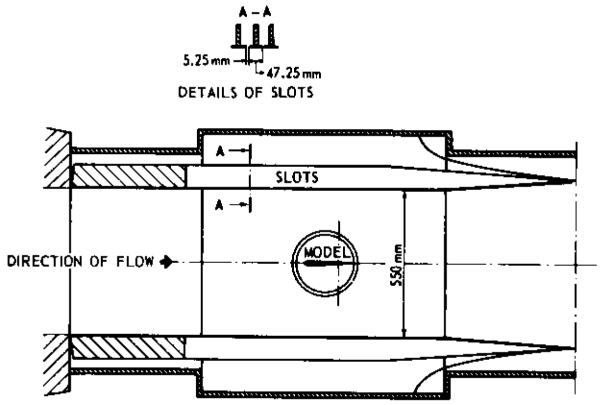


Fig. 4.10 Transonic test section of the NLR Pilot Tunnel

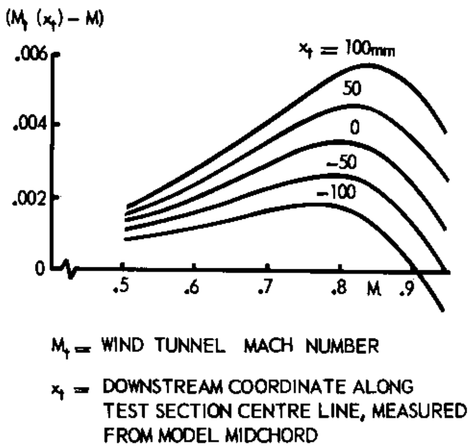


Fig. 4.11 Mach number distribution in NLR Pilot Tunnel test section

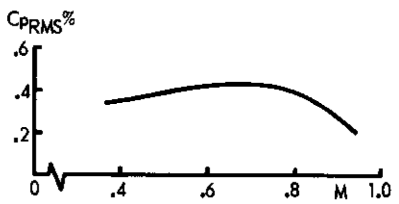


Fig. 4.12 Noise level in NLR Pilot Tunnel test section

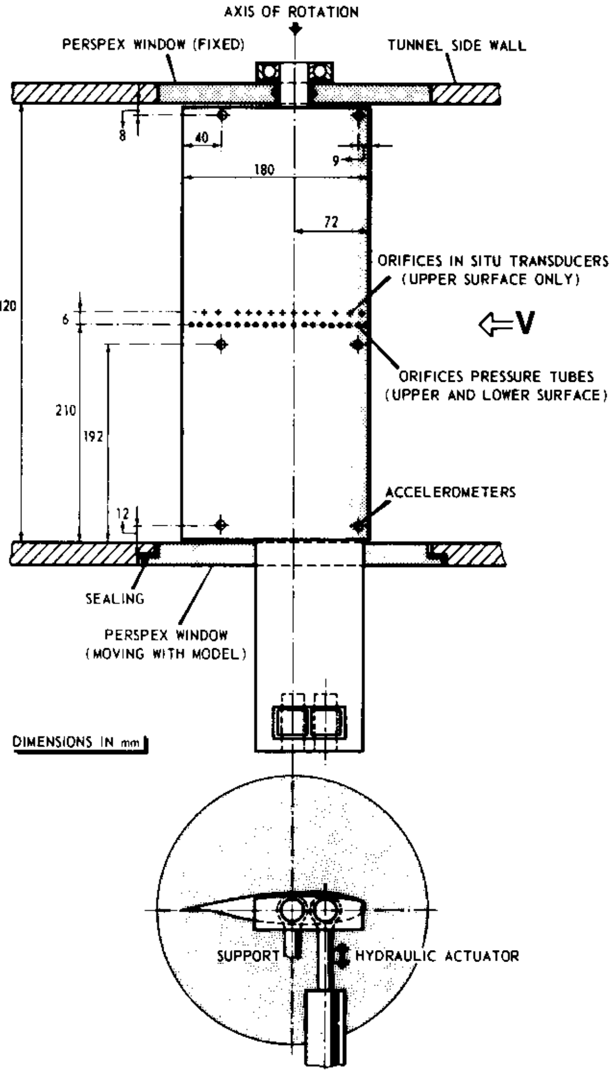
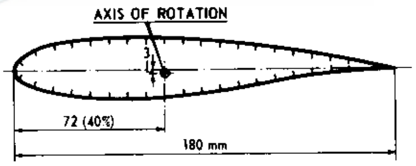


Fig. 4.13 Test set-up and instrumentation of the NLR 7301 airfoil (Conf. A)



PRESSURE ORIFICES TUBING SYSTEM (BOTH UPPER AND LOWER SURFACE)				IN SITU TRANSDUCERS (UPPER SURFACE ONLY)			
No.	x/c	No.	x/c	No.	x/c	No.	x/c
1	.01	11	.50	1	.04	11	.70
2	.05	12	.55	2	.10	12	.80
3	.10	13	.60	3	.19	13	.88
4	.15	14	.65	4	.28		
5	.20	15	.70	5	.34		
6	.25	16	.75	6	.40		
7	.30	17	.80	7	.46		
8	.35	18	.85	8	.52		
9	.40	19	.90	9	.58		
10	.45	20	.95	10	.64		

Fig. 4.14 Location of pressure orifices of the NLR 7301 airfoil (Conf. A)

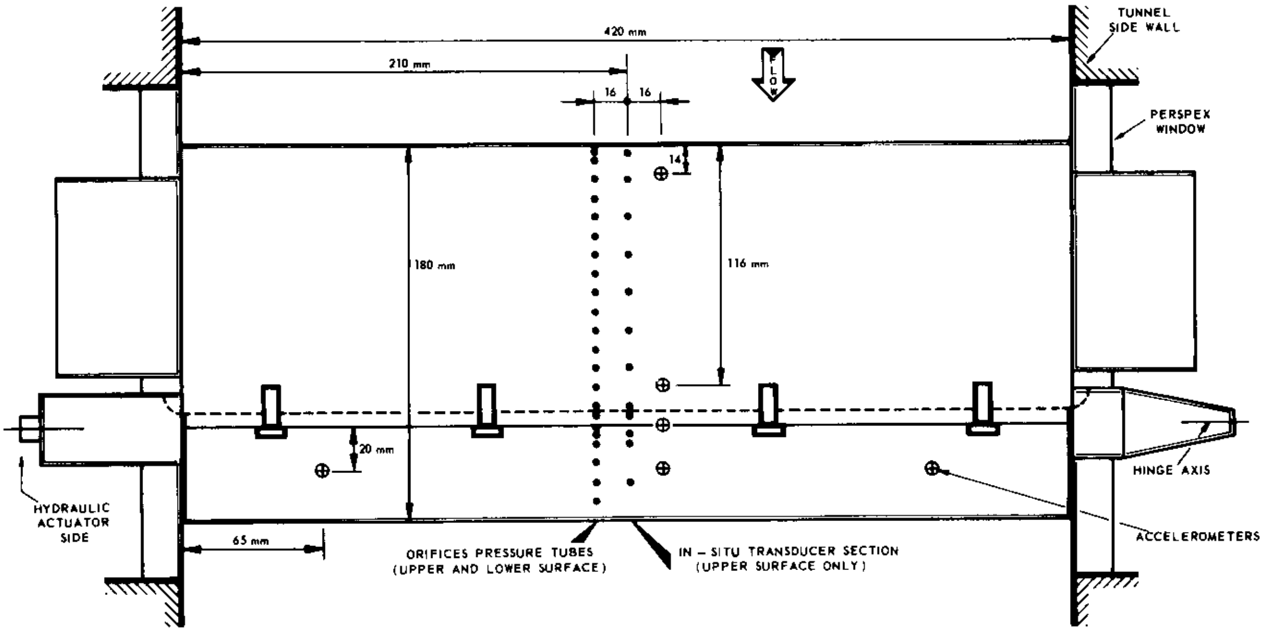
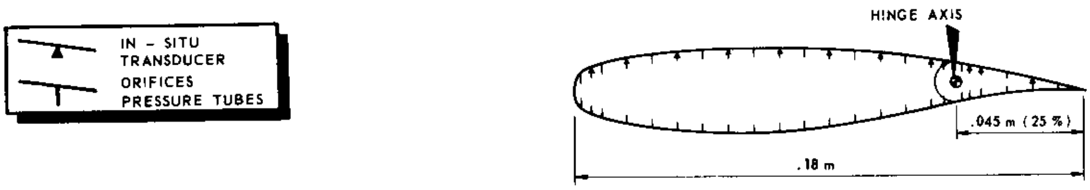


Fig. 4.15 Test set-up and instrumentation of the NLR 7301 airfoil with control surface (Conf. B)



PRESSURE ORIFICES TUBING SYSTEM (both upper and lower surface)				IN SITU TRANSDUCERS (upper surface only)	
no.	x/c	no.	x/c	no.	x/c
1	.01	13	.55	1	.03
2	.03	14	.60	2	.10
3	.05	15	.65	3	.20
4	.10	16	.70	4	.30
5	.15	17	.725	5	.40
6	.20	18	.76	6	.50
7	.25	19	.775	7	.60
8	.30	20	.8	8	.70
9	.35	21	.85	9	.725
10	.40	22	.90	10	.775
11	.45	23	.95	11	.80
12	.50			12	.90

Fig. 4.16 Location of pressure orifices of the NLR 7301 airfoil with control surface (Conf. B)

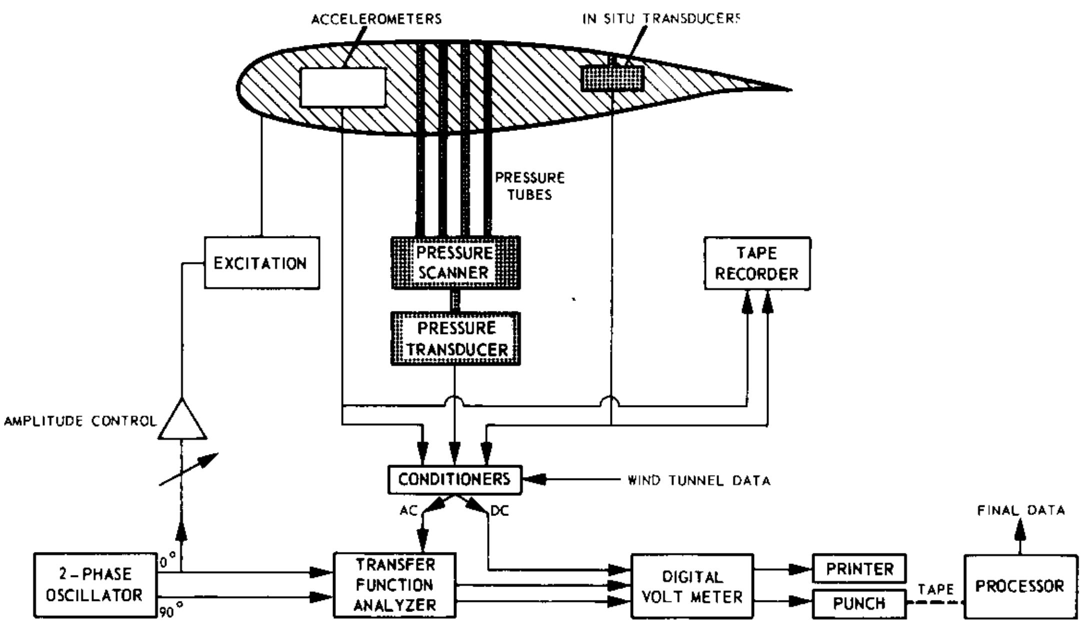


Fig. 4.17 Block diagram of measuring equipment (Conf. A). Similar equipment essentially for Conf. B

R-702

DATA SET 5

NLR 7301 SUPERCRITICAL AIRFOIL OSCILLATORY PITCHING

by

Sanford S. Davis, NASA Ames

INTRODUCTION AND DISCUSSION

Test data on the NLR 7301 supercritical airfoil were acquired concurrently with the NACA 64A010 data previously described in Data Set 2. The purpose of this Data Set is to tabulate numerical data from those tests that can be associated with the AGARD CT Cases and to present an overview of certain parametric data trends. The test arrangement for this airfoil is the same as that described in Data Set 2 and is reproduced in Fig. 5-1.

Users of these data sould be aware of some differences in the methods of specifying the geometry of the NLR supercritical airfoil whose general properties are described in Ref. 5.1. The differences between the original coordinates which, as given by Table 4.1 of Data Set 4, locate the sharp trailing edge at $X/C \cong 1.015$, and the transformed coordinates given by Table 5 of Ref. 5.2 are explained in Data Set 4. However, the coordinates used to construct the model of the present tests were derived from the original specification in yet another manner. As for the model of Data Set 4, the physical model of the present tests was obtained by truncating the trailing edge of the original design at $X/C = 1.0$. But unlike the model of Data Set 4, the chord was redefined as the line connecting the nose of the airfoil with the bisection point of the truncated trailing edge. In effect, the design shape of the present model is the same as that of the NLR model of Data Set 4 and, apart from the trailing-edge truncation, is the same shape, as that defined in Ref. 5.2 for the AGARD Computation Tests. However, because of the method of defining the chord line, there is a slight difference in the definitions of incidence. The sensitivity of the computed flow to the minor variations listed above is not expected to be a major problem, but the analyst should be aware of their existence.

The data base for this airfoil is presented in Table 5.1 and consists of 95 parametric combinations. The data subset corresponding to a pitching axis at 0.40c is listed in Table 5.2. The AGARD CT Cases advocated in Ref. 5.2 do not precisely match the current data set. In Table 5.3 tests from the current series are correlated with the AGARD CT Cases by matching similar mean flow conditions. The three flow regimes selected are: (1) a subcritical Mach number, (2) an off-design flow condition with a strong shock wave, and (3) the supercritical design point.

In these tests lower surface unsteady pressure data were sacrificed for the sake of increased upper surface resolution. For this reason lift and moment data are not available. In Tables 5.4 to 5.23 first harmonic upper surface and steady pressure data for the 20 runs identified in Table 5.3 are reproduced from Ref. 5.3. Complete instantaneous pressure distributions are presented in Tables 5.24 and 5.25 for the high Reynolds number data associated with AGARD CT Cases 6 and 8.

In Figs. 5.2 to 5.10 the steady pressure distributions are shown, and certain parametric trends are presented concerning the upper surface fundamental frequency pressure distribution. The picture that emerges is one of a complex dynamic flow pattern that is sensitive to many parameters. More coordinated research needs to be done before definitive data suitable for aeroelastic applications become available. Other supercritical airfoil data may be found in Data Set 4 and the references cited herein.

The effect of varying the frequency parameter alone is shown in Figs. 5.2 to 5.4. Figure 5.2 depicts a subsonic flow condition where the classical thin airfoil theory should remain valid. The general trend confirms the flat plate theory -- decreasing real portion and increasing imaginary portion as frequency increases -- except for the curious dip just upstream of the 0.2c station. This phenomenon is consistent with the full time-histories and comparison with other data (see Fig. 5.8) will show that it is actually a viscous effect. (The dip in the mean pressure distribution at approximately 0.4c was traced to a surface wave in the airfoil contour.) In Fig. 5.3 the Mach number and mean angle of attack were increased enough to induce a strong shock wave with possible separation at the trailing edge. The pressure distributions are dramatically different at the two frequencies shown. An especially important point, one that cannot be stressed too strongly, is that the variation of unsteady lift and moment (not shown) may show erratic trends with frequency because of the balancing of positive and negative lobes in the pressure distributions. More examples of this phenomenon are described in Refs. 5.4, 5.5 and 5.6. Figure 5.4 completes this series by showing the variation of unsteady pressure distributions with frequency at the supercritical design point. Unlike conventional airfoils, a broad, high level of unsteady loading persists over the forward portion of the airfoil at low frequencies. The net effect is larger unsteady loads on supercritical airfoils than that usually found on conventional airfoils.

The next series of three figures shows data trends with varying oscillation amplitude. Figure 5.5 indicates that the normalized oscillatory pressure distribution remains relatively invariant in subsonic flow. This is a good indication of a linear response over the range indicated. Figure 5.6 shows only minor departures from linearity up to $\alpha_o = 1°$, even with a strong shock wave present. Figure 5.7 shows progressive changes with amplitude α_o at the supercritical design point that cast doubt on the linearity assumption. Whether or not the response curves are "sufficiently linear" must await aeroelastic sensitivity calculations.

The next series of figures shows the scale effect on the steady and oscillatory pressures. In this connection, it should be noted that the model did not have a boundary layer transition trip. The trends on the unsteady pressures are disconcerting because the Reynolds number seems to be an important parameter, especially at and near the supercritical design point. In Fig. 5.8 the major effect of increasing Reynolds number is to induce the leading edge dip in the unsteady pressure distribution. In Fig. 5.9 the first harmonic pressures aft of the shock wave seem to be most affected. This may cause major changes in the unsteady moment as well as the lift. In Fig. 5.10 the unsteady loading at the design point seems to be significantly affected by changing the Reynolds number. At this stage it is impossible to trace the root causes of the relatively severe scale effects on a supercritical airfoil (see Ref. 5.3 for other data). A computational model that includes all of the significant physical effects is surely necessary.

The higher harmonic content of the unsteady pressure distributions is also significantly affected by flow condition. Figure 5.11 shows the complete space-time pressure distributions at the supercritical design point (CT Cases 6 and 8) when Re = 11.5×10^6. The harmonic distortion is significantly affected by the frequency parameter, but is concentrated near the end of the region where the steady flow is supersonic. General trends should not be deduced from this special choice of parameters, just as harmonic distortion in the overall loads cannot be inferred from the harmonic content of the pressure distributions themselves (Ref. 5.4).

1	AIRFOIL	
1.1	Designation	NLR
1.2	Type of airfoil	Supercritical - t/c = 16.5%
1.3	Geometry	Table 2 of Ref. 5.3
1.4	Design condition	M = 0.721, α_m = -0.19° (theoretical, quoted in Ref. 5.2)
1.5	Additional remarks	
1.6	References on airfoil	See Introduction of this Data Set.
2	MODEL GEOMETRY	
2.1	Chord length	0.50 m (19.685 in.)
2.2	Span	1.35 m (53.2 in.)
2.3	Actual model coordinates and accuracy of measurement	Ref. 5.3
2.4	Flap: hinge and gap details	None
2.5	Additional remarks	Model mounted between splitter plates - see Fig. 5.1
2.6	References on model	Ref. 5.3
3	WIND TUNNEL	
3.1	Designation	NASA Ames 11- X 11-Foot Transonic Wind Tunnel
3.2	Type of tunnel	Closed return, variable density
3.3	Test section dimensions	3.35 X 3.35 X 6.7 m (11 X 11 X 22 ft.)
3.4	Type of roof and floor	Baffled slat
3.5	Type of side walls	Same as 3.4
3.6	Ventilation geometry	1.78 cm (0.7 in.) slots, 24.4 cm (9.63 in.) slats. Open area ratio ~ 8% between splitters.
3.7	Thickness of side wall boundary layer	Very thin due to splitters
3.8	Thickness of boundary layers at roof and floor	Approx. 7.6 cm (3 in.)
3.9	Method or measuring Mach number	Static taps and splitters, see Ref. 5.6.
3.10	Uniformity of Mach number over test section	±0.002
3.11	Sources and levels of noise or turbulence in empty tunnel	Not investigated
3.12	Tunnel resonances	None noted
3.13	Additional remarks	
3.14	References on tunnel	Ref. 5.3
4	MODEL MOTION	
4.1	Mode of applied motion	Pitching about nominal 0.40c, also plunging
4.2	Range of amplitude	±0-2 deg; ±1 cm
4.3	Range of frequency	0-60 Hz
4.4	Method of application	Four graphite epoxy push-pull rods with differential motion of forward and aft pair, see Fig. 5.1.

4	MODEL MOTION (Continued)	
4.5	Purity of applied motion	Pure sinusoids
4.6	Natural frequencies and normal modes of model	Lowest mode: torsion at 60 Hz
4.7	Static or dynamic elastic distortion during tests	Not measured
4.8	Additional remarks	
5	TEST CONDITIONS	
5.1	Tunnel height/model chord ratio	3.35 m/0.50 m = 6.7
5.2	Tunnel width/model chord ratio	1.35 m/0.50 m = 2.7 (between splitter plates)
5.3	Range of Mach number	0.40 - 0.85
5.4	Range of tunnel total pressure	50 kN/M^2 - 225 kN/m^2 (0.5-2.25 ATM)
5.5	Range of tunnel total temperature	290 K - 320 K
5.6	Range of model steady, or mean, incidence	0 - 2.5 deg.
5.7	Definition of model incidence	Chord line relative to wind tunnel.
5.8	Position of transition, if free	Transition was observed using a sublimating material at two flow conditions. At M = 0.453, α_m = 0.57°, Re = 4.5 × 10^6 a definite transition point was not observed. At M = 0.708, α_m = 0.58°, Re = 6.2 × 10^6, transition occurred at x/c ~ 0.10.
5.9	Position and type of trip, if transition fixed	
5.10	For mixed flow, position of sonic boundary in relation to roof and floor	Not measured
5.11	Flow instabilities during tests	--
5.12	Additional remarks	--
5.13	References describing tests	--

6	MEASUREMENTS AND OBSERVATIONS		
6.1	Steady pressures for the mean conditions		✓
6.2	Steady pressures for small changes from the mean conditions		–
6.3	Quasi-steady pressures		–
6.4	Unsteady pressures		✓
6.5	Steady forces for the mean conditions	measured directly	–
		integrated pressures	✓
6.6	Steady forces for small changes from the mean conditions	measured directly	–
		integrated pressures	–
6.7	Quasi-steady forces	measured directly	–
		integrated pressures	–
6.8	Unsteady forces	measured directly	–
		integrated pressure	–
6.9	Measurement of actual motion at points on model		✓
6.10	Observation or measurement of boundary layer properties		✓
6.11	Visualization of surface flow		✓
6.12	Visualization of shockwave movements		–
6.13	Additional remarks		–

7	INSTRUMENTATION	
7.1	Steady pressures	
7.1.1	Position of orifices spanwise and chordwise	Mid-span 29 upper, 12 lower. (May vary with data, see Table 5.4 for locations.)
7.1.2	Type of measuring system	Pneumatic
7.2	Unsteady pressures	
7.2.1	Position of orifices spanwise and chordwise	Mid-span, 29 upper, none on lower. (May vary with data, see Table 5.4 for locations.)
7.2.2	Diameter of orifices	0.102 cm (0.040 in.)

7	INSTRUMENTATION (Continued)	
7.2.3	Type of measuring system	Strain-gauge-type miniature pressure transducers installed close to orifice with minimum cavities.
7.2.4	Type of transducers	Kulite model XCQL-7A-093.
7.2.5	Principle and accuracy of calibration	On-line calibrations. Up to 2% change in static sensitivity before and after run allowed.
7.3	Model motion	
7.3.1	Method of measurement	Motion of four push-pull rods with LVDT (reactive-type) transducers. Phase synchronism checked with wing-mounted accelerometers.
7.3.2	Accuracy	~ 1%
7.4	Processing of unsteady measurements	
7.4.1	Method of acquiring and processing measurements	Real-time digitization with on-line calibration and diagnostics. Signal averaging over approx. 100 cycles to suppress random noise (if present). Variable sampling time adjusted to yield 60 data points per cycle.
7.4.2	Type of analysis	On-line processing for frequency content of pressure distributions and comparisons with linear theory and other data.
7.4.3	Unsteady pressure quantities obtained and accuracies achieved	Signal averaged (essentially instantaneous) pressured distributions. Harmonic analysis of pressure distributions.
7.4.4	Method of integration to obtain forces	Numerical quadratures (see Appendix A of Ref. 5.3).
7.5	Additional remarks	
7.6	References on techniques	Ref. 5.6
8	DATA PRESENTATION	
8.1	Test cases for which data could be made available	Table 5.1
8.2	Test cases for which data are included in this document	Table 5.3
8.3	Steady pressures	Tables 5.4 to 5.23
8.4	Quasi-steady or steady perturbation pressures	Not available
8.5	Unsteady pressures	Tables 5.4 to 5.25
8.6	Steady forces or moments	Not available
8.7	Quasi-steady or steady perturbation forces	Not available
8.8	Unsteady forces and moments	Not available
8.9	Other forms in which data could be made available if required	Magnetic tape
8.10	References giving other presentations of data	Refs. 5.3 to 5.5
9	COMMENTS ON DATA	
9.1	Accuracy	
9.1.1	Mach number	±0.002
9.1.2	Steady incidence	±0.05 deg
9.1.3	Reduced frequency	±0.005
9.1.4	Steady pressure coefficients	1%
9.1.5	Steady pressure derivatives	N/A
9.1.6	Unsteady pressure coefficients	2%
9.2	Sensitivity to small changes of parameter	No evidence of undue sensitivity
9.3	Spanwise variations	Probably small
9.4	Nonlinearities	Depends on parametric conditions
9.5	Influence of tunnel total pressure	Minimal on model distortion, probably all Reynolds number effect.
9.6	Wall interference corrections	No corrections made
9.7	Other relevant tests on *same model*	None

9 COMMENTS ON DATA (Continued)

9.8	Relevant tests on other models of nominally the *same* aerofoil.	See Data Set 4 of this Compendium
9.9	Any remarks relevant to comparison between experiment and theory	
9.10	Additional remarks	
9.11	References on discussion of data	Refs. 5.4 and 5.5

10 PERSONAL CONTACT FOR FURTHER INFORMATION

Sanford Davis, Aerodynamics Division, NASA Ames Research Center, Moffett Field, CA 94035

11 REFERENCES

5.1	H. Tijdeman	Investigations of the Transonic Flow Around Oscillating Airfoils. NLR TR 77090U, 1977.
5.2	S. R. Bland	AGARD Two-Dimensional Aeroelastic Configurations. AGARD-AR-156, August 1979.
5.3	S. Davis and G. Malcolm	Experimental Unsteady Aerodynamics of Conventional and Supercritical Airfoils. NASA TM-81221, August 1980.
5.4	S. Davis and G. Malcolm	Unsteady Aerodynamics of Conventional and Supercritical Airfoils. AIAA Paper 80-734, Seattle, WA, May 1980.
5.5	S. Davis	Experimental Studies of Scale Effects on Oscillating Airfoils at Transonic Speeds. AGARD-CP-296, February 1981, pp. 9-1 to 9-5.
5.6	S. Davis	Computer/Experiment Integration for Unsteady Aerodynamic Research. Intl. Congress on Instrumentation in Aerospace Simulation Facilities. ICIASF '79 Record, September 1979, pp. 237-250.

12 NOTATION AND EXPLANATION OF TABLES*

GENERAL NOTATION

C,c	chord of airfoil, m
DI	dynamic index, data identification number
f,FREQ	frequency, Hz
k,K	reduced (nondimensional) frequency, $\frac{\omega c}{2V}$
M	free-stream Mach number
Re,RE	Reynolds number (based on chord)
t	time, s
V	free-stream velocity, m/s
X,x	distance along airfoil, m
x_α/c	pitch axis position relative to leading edge
$\alpha(t)$	instantaneous incidence, deg $(\alpha_m + \alpha_o \cos \omega t)$
α_m	mean incidence, deg
α_o	oscillatory pitch amplitude, deg
ω	radian frequency, rad/s $(=2\pi f)$

TABLES 5.4 to 5.23

ALPHA	mean incidence, deg [α_m]
PTOT	total pressure, N/m^2 [P_t]
PINF	static pressure, N/m^2 [P_∞]
QINF	dynamic pressure, N/m^2 [q]
CPU(CPL)	steady upper (lower) surface pressure coefficient [c_p]
CPU,A	normalized complex amplitude of upper surface fundamental frequency pressure coefficient, per radian [$c_p'/\alpha_o + ic_p''/\alpha_o$]

TABLES 5.24 and 5.25

PHASE	phase angle re $\alpha(t)_{max}$ [ωt]
ALPHA	oscillatory incidence [$\alpha_o \cos(\omega t)$]
CP	instantaneous pressure coefficient [$c_p(t)$]

*Square-bracketed quantities indicate standard AGARD notation

TABLE 5.1. DATA BASE FOR NLR 7301 AIRFOIL

DI	M	α_m, deg	Re×10^{-6}	Motion	f, Hz	k
115	0.453	0.57	4.47	Pitching 0.52 deg about x_α/c = 0.394	2.7	0.028
116	.453	.57	4.47	Pitching .50 deg about x_α/c = .404	5.4	.055
117	.453	.57	4.47	Pitching .48 deg about x_α/c = .400	10.7	.110
118	.453	.57	4.47	Pitching .49 deg about x_α/c = .391	21.5	.221
119	.453	.57	4.47	Pitching .49 deg about x_α/c = .394	32.2	.331
120	.453	.57	4.47	Pitching 1.04 deg about x_α/c = .384	5.4	.055
121	.453	.57	4.47	Pitching 1. deg about x_α/c = .389	21.5	.221
122	.453	.57	4.47	Pitching 2. deg about x_α/c = .393	5.4	.055
123	.453	.57	4.47	Pitching 2.00 deg about x_α/c = .403	21.5	.221
124	.708	.58	6.15	Pitching .52 deg about x_α/c = .394	3.7	.025
125	.708	.58	6.15	Pitching .50 deg about x_α/c = .401	7.5	.050
126	.708	.58	6.15	Pitching .49 deg about x_α/c = .402	29.9	.200
127	.708	.58	6.15	Pitching 1.01 deg about x_α/c = .397	7.5	.050
128	.708	.58	6.15	Pitching 1.00 deg about x_α/c = .398	29.9	.200
129	.708	.58	6.15	Pitching 2.02 deg about x_α/c = .401	7.5	.050
130	.708	.58	6.15	Pitching 2.00 deg about x_α/c = .399	29.9	.200
131	.752	.37	6.21	Pitching .51 deg about x_α/c = .401	4.0	.025
132	.752	.37	6.21	Pitching .50 deg about x_α/c = .401	8.0	.050
133	.752	.37	6.21	Pitching 0.50 deg about x_α/c = .402	16.0	0.100
134	.752	.37	6.21	Pitching .49 deg about x_α/c = .403	32.0	.200
135	.752	.37	6.21	Pitching .50 deg about x_α/c = .403	48.0	.300
136	.752	.37	6.21	Pitching 1.01 deg about x_α/c = .398	8.0	.050
137	.752	.37	6.21	Pitching 1.00 deg about x_α/c = .397	32.0	.200
138	.752	.37	6.21	Pitching 2.02 deg about x_α/c = .400	8.0	.050
139	.752	.37	6.21	Pitching 2.01 deg about x_α/c = .399	32.0	.200
140	.808	.36	6.26	Pitching .50 deg about x_α/c = .402	8.5	.050
141	.808	.36	6.26	Pitching .50 deg about x_α/c = .407	34.0	.199
142	.807	.36	11.78	Pitching .49 deg about x_α/c = .404	8.7	.050
143	.807	.36	11.78	Pitching .49 deg about x_α/c = .398	35.0	.200
144	.751	.37	11.48	Pitching .50 deg about x_α/c = .403	8.2	.050
145	.751	.37	11.48	Pitching .51 deg about x_α/c = .399	4.1	.025
146	.751	.37	11.48	Pitching .49 deg about x_α/c = .400	16.5	.100
147	.751	.37	11.48	Pitching .49 deg about x_α/c = .401	24.7	.150
148	.751	.37	11.48	Pitching .50 deg about x_α/c = .403	33.0	.201
149	.751	.37	11.48	Pitching .50 deg about x_α/c = .400	49.5	.301
150	.751	.37	11.48	Pitching 1.00 deg about x_α/c = .398	8.2	.050
151	.751	.37	11.48	Pitching 1.00 deg about x_α/c = .400	32.8	.200
152	.751	.37	11.48	Pitching 2.02 deg about x_α/c = .399	8.2	.050
153	.751	.37	11.48	Pitching 2.00 deg about x_α/c = .402	32.8	.200
154	.751	.37	11.48	Plunging 1.00 cm (0.395 in.)	8.2	.050
155	.751	.37	11.48	Plunging .98 cm (0.386 in.)	32.8	.200
156	.706	.59	11.22	Pitching .51 deg about x_α/c = .400	3.9	.025
157	.706	.59	11.22	Pitching .50 deg about x_α/c = .402	7.7	.050
158	.706	.59	11.22	Pitching .50 deg about x_α/c = .399	15.4	.099
159	.706	.59	11.22	Pitching .49 deg about x_α/c = .401	30.8	.199
160	.706	.59	11.22	Pitching .49 deg about x_α/c = .404	46.2	.298
161	.706	.59	11.22	Pitching 1.01 deg about x_α/c = .398	7.7	.050
162	.706	.59	11.22	Pitching 1.00 deg about x_α/c = .398	30.8	.199
163	.706	.59	11.22	Pitching 2.01 deg about x_α/c = .401	7.7	.050
164	.706	.59	11.22	Pitching 2.00 deg about x_α/c = .402	30.8	.199
165	.706	.59	11.22	Plunging 1.00 cm (0.393 in.)	7.7	.050
166	.706	.59	11.22	Plunging 1.00 cm (0.392 in.)	30.8	0.199
167	.505	.58	9.34	Pitching .53 deg about x_α/c = .396	2.8	.025
168	.505	.58	9.34	Pitching .51 deg about x_α/c = .401	5.5	.049
169	.505	.58	9.34	Pitching .50 deg about x_α/c = .403	11.0	.099
170	.505	.58	9.34	Pitching .50 deg about x_α/c = .404	22.0	.198
171	.505	.58	9.34	Pitching .50 deg about x_α/c = .404	33.0	.297
172	.505	.58	9.34	Pitching 1.02 deg about x_α/c = .399	5.5	.049
173	.505	.58	9.34	Pitching 1.01 deg about x_α/c = .399	22.0	.198
174	.505	.58	9.34	Pitching 2.04 deg about x_α/c = .400	5.5	.049
175	.505	.58	9.34	Pitching 2.01 deg about x_α/c = .402	22.0	.198
176	.505	.58	9.34	Plunging 1.01 cm (0.396 in.)	5.5	.049
177	.505	.58	9.34	Plunging .99 cm (0.389 in.)	22.0	.198
178	.712	.58	3.09	Pitching .50 deg about x_α/c = .403	7.4	.049
179	.712	.58	3.09	Pitching .49 deg about x_α/c = .403	29.7	.197
180	.712	.58	3.09	Pitching 2.02 deg about x_α/c = .402	7.4	.049
181	.712	.58	3.09	Pitching 2.00 deg about x_α/c = .402	29.7	.197
182	.712	.58	3.09	Plunging 1.00 cm (0.394 in.)	7.4	.049
183	.712	.58	3.09	Plunging .98 cm (0.388 in.)	29.7	.197
184	.508	.58	2.54	Pitching .50 deg about x_α/c = .402	5.4	.050
185	.508	.58	2.54	Pitching .50 deg about x_α/c = .405	21.4	.197
186	.508	.58	2.54	Pitching 2.03 deg about x_α/c = .400	5.4	.050
187	.508	.58	2.54	Pitching 2.00 deg about x_α/c = .401	21.4	.197
188	.508	.58	2.54	Plunging 1.01 cm (0.396 in.)	5.4	.050
189	.508	.58	2.54	Plunging .99 cm (0.389 in.)	21.4	.197
190	.752	.37	3.25	Pitching .50 deg about x_α/c = .403	7.8	.050
191	.752	.37	3.25	Pitching .50 deg about x_α/c = .401	31.4	.200

TABLE 5.1. CONCLUDED

DI	M	α_m, deg	Re×10^{-6}	Motion	f, Hz	k
192	0.752	0.37	3.25	Pitching 2.02 deg about x_α/c = 0.401	7.8	0.050
193	.752	.37	3.25	Pitching 2.00 deg about x_α/c = .401	31.4	.200
194	.752	.37	3.25	Plunging 1.00 cm (0.394 in.)	7.8	.050
195	.812	.35	3.29	Pitching .50 deg about x_α/c = .403	8.4	.050
196	.812	.35	3.29	Pitching .50 deg about x_α/c = .404	33.4	.198
197	.700	2.53	11.80	Pitching .49 deg about x_α/c = .406	7.5	.050
198	.700	2.53	11.80	Pitching .49 deg about x_α/c = .405	30.2	.201
199	.700	2.53	11.80	Pitching 1.01 deg about x_α/c = 0.398	7.5	0.050
200	.700	2.53	11.80	Pitching 1.00 deg about x_α/c = .399	30.2	.201
201	.700	2.53	11.80	Pitching 1.31 deg about x_α/c = .403	7.5	.050
202	.700	2.54	11.69	Plunging 1.00 cm (0.395 in.)	7.5	.050
203	.700	2.54	11.69	Plunging .86 cm (0.339 in.)	30.2	.201
204	.710	2.53	3.15	Pitching .50 deg about x_α/c = .403	7.4	.050
205	.710	2.53	3.15	Pitching .50 deg about x_α/c = .403	29.5	.199
206	.710	2.53	3.15	Pitching 1.01 deg about x_α/c = .400	7.4	.050
207	.710	2.53	3.15	Pitching 1.00 deg about x_α/c = .399	29.5	.199
208	.710	2.53	3.15	Plunging 1.01 cm (0.398 in.)	7.4	.050
209	.710	2.53	3.15	Plunging .87 cm (0.341 in.)	29.5	.199

TABLE 5.2. DATA BASE FOR NLR 7301 AIRFOIL, PITCHING OSCILLATION ABOUT 0.40c, ARRANGED IN FREQUENCY SWEEPS

M	α_m, deg	Re×10^{-6}	α_o deg	k = 0.025	k = 0.05	k = 0.10	k = 0.15	k = 0.20	k = 0.25	k = 0.30
0.75	0.37	3.3	±0.50		190			191		
.75	.37	6.2	±0.50	131	132	133		134		135
.75	.37	11.5	±0.50	145	144	146	147	148		149
.75	.37	6.2	±1		136			137		
.75	.37	11.5	±1		150			151		
.75	.37	3.3	±2		192			193		
.75	.37	6.2	±2		138			139		
.75	.37	11.5	±2		152			153		
.80	.37	3.3	±0.50		195			196		
.80	.37	6.3	±0.50		140			141		
.80	.37	11.7	±0.50		142			143		
.50	.57	2.5	±0.50		184			185		
.45	.57	4.5	±0.50	115	116	117		118		119
.50	.57	9.3	±0.50	167	168	169		170		171
.45	.57	4.5	±1		120			121		
.50	.57	9.5	±1		172			173		
.50	.57	2.5	±2		186			187		
.45	.57	4.5	±2		122			123		
.50	.57	9.3	±2		174			175		
.71	.57	3.1	±0.50		178			179		
.70	.57	6.2	±0.50	124	125			126		
.70	.57	11.2	±0.50	156	157	158		159		160
.70	.57	6.2	±1		127			128		
.70	.57	11.2	±1		161			162		
.71	.57	3.1	±2		180			181		
.70	.57	6.2	±2		129			130		
.70	.57	11.2	±2		163			164		
.70	2.5	3.2	±0.5		204			205		
.70	2.5	11.8	±0.5		197			198		
.70	2.5	3.2	±1		206			207		
.70	2.5	11.8	±1		199			200		

TABLE 5.3. NASA AMES TEST DATA ASSOCIATED WITH AGARD CT CASES

Flow	CT case					Data set 5						
	No.	M	α_m	α_o	k	DI no.	M	α_m	α_o	k	$Re \times 10^{-6}$	Data table no.
Subsonic	1	0.500	0.40	0.5	0.098	184	0.508	0.58	0.50	0.050	2.53	5.4
						168	0.505	0.58	0.51	0.049	9.33	5.5
	2	0.500	0.40	0.5	0.263	185	0.508	0.58	0.50	0.197	2.53	5.6
						170	0.505	0.58	0.50	0.198	9.33	5.7
Transonic with shock	3	0.700	2.00	0.5	0.072	204	0.710	2.53	0.50	0.050	3.14	5.8
						197	0.700	2.53	0.49	0.050	12.0	5.9
	4	0.700	2.00	1.0	0.072	206	0.710	2.53	1.01	0.050	3.14	5.10
						199	0.700	2.53	1.01	0.050	12.0	5.11
	5	0.700	2.00	0.5	0.192	205	0.710	2.53	0.58	0.199	3.14	5.12
						198	0.700	2.53	0.49	0.201	12.0	5.13
Supercritical design	6	0.721	-0.19	0.5	0.068	190	0.752	0.37	0.50	0.050	3.30	5.14
						132	0.752	0.37	0.50	0.050	6.20	5.15
						144	0.751	0.37	0.50	0.050	11.4	5.16 & 5.24
	7	0.721	-0.19	1.0	0.068	136	0.752	0.37	1.01	0.050	6.20	5.17
						150	0.751	0.37	1.00	0.050	11.4	5.18
	8*	0.721	-0.19	0.5	0.181	191	0.752	0.37	0.50	0.200	3.30	5.19
						134	0.752	0.37	0.49	0.200	6.20	5.20
						148	0.751	0.37	0.50	0.201	11.4	5.21 & 5.25
	9	0.721	-0.19	0.5	0.453	135	0.752	0.37	0.50	0.300	6.20	5.22
						149	0.751	0.37	0.50	0.301	11.4	5.23

* denotes priority case.

TABLE 5.4. MEA. AND FUNDAMENTAL FREQUENCY PRESSURE FOR AGARD CT CASE NO. 1; DYNAMIC INDEX 184

WING MODEL: NLR 7301 SUPERCRITICAL, CHORD= .500 METERS

WING MOTION: PITCHING .50 DEG ABOUT X/C= .402

DYNAMIC INDEX 184 STATIC INDEX 80

M	.508	PTOT	50864	K	.050
ALPHA	.58	QINF	7699	FREQ	5.4
RE	2.53E 06	PINF	42656		

UPPER SURFACE

STEADY DATA CPU X/C	CPU	UNSTEADY DATA CPU,A X/C	REAL	IMAG	MAG	PHASE
045	-1 146	016	-17 487	[illegible]	17 731	170 90
070	- 066	067	[illegible]	2 760	17 502	170 87
094	- 826	092	-5 154	693	5 200	172 36
122	-.704	.117	-8 250	1 209	8 338	171 68
147	- 676	.142	-6 941	1 017	7 015	171 68
.168	-.663	.191	-5 657	785	5.711	172 11
.195	-.612	.245	-4 194	.527	4.227	172 86
249	- 565	294	-4 227	470	4 253	173 66
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
321	- 601	343	-3 644	512	3 680	172 02
348	-.594	.366	[illegible]	544	2 931	169 32
369	- 580	393	[illegible]	584	3 059	169 00
396	- 524	.424	-2 855	255	2 86	174 91
420	-.515	.448	-2 304	327	2 327	171 93
450	- 560	470	-2 414	200	2 423	175 27
473	- 579	497	-2 226	184	2 234	175 30
499	- 572	.547	-2 047	160	2 053	175 53
.524	-.599	569	-1 698	109	1 701	176 34
.550	- 560	.595	-1 444	101	1 447	176.00
578	- 548	.618	-1 372	063	1.373	177 38
.600	- 519	647	-1 139	049	1 140	177 53
.624	-.467	.697	- 708	014	708	178 86
652	- 406	.746	- 395	- 043	397	-173 83
.703	-.353	796	- 227	- 075	239	-161 83
.749	- 260	841	- 082	- 071	108	-138 82
797	-.165	916	- 292	- 050	296	-170 29
842	- 061					
.914	.081					

LOWER SURFACE

STEADY DATA CPL X/C	CPL	UNSTEADY DATA CPL,A X/C	REAL	IMAG	MAG	PHASE
053	- 316					
106	- 337					
209	-.337					
.309	-.416					
381	- 374					
460	-.385					
.532	-.316					
614	- 122					
[illegible]	044					
779	.216					
.874	.334					

TABLE 5.5. MEAN AND FUNDAMENTAL FREQUENCY PRESSURE FOR AGARD CT CASE NO. 1; DYNAMIC INDEX 168

WING MODEL: NLR 7301 SUPERCRITICAL, CHORD= .500 METERS

WING MOTION: PITCHING .51 DEG ABOUT X/C= .401

DYNAMIC INDEX 168 STATIC INDEX 78

M	.505	PTOT	203067.	K	.049
ALPHA	.58	QINF	30419.	FREQ	5.5
RE	9.33E 06	PINF	170663.		

UPPER SURFACE							LOWER SURFACE						
STEADY DATA		UNSTEADY DATA					STEADY DATA		UNSTEADY DATA				
CPU		CPU,A					CPL		CPL,A				
X/C	CPU	X/C	REAL	IMAG	MAG	PHASE	X/C	CPL	X/C	REAL	IMAG	MAG	PHASE
.023	-1.201	.016	-18.059	3.167	18.335	170.07	.053	-.284					
.045	-1.178	.067	-16.240	2.509	16.442	171.02	.106	-.313					
.070	-.953	.092	-8.348	1.623	8.505	169.01	.209	-.317					
.094	-.869	.117	-2.668	.418	2.700	171.10	.309	-.399					
.122	-.753	.142	-2.074	.347	2.103	170.50	.381	-.370					
.147	-.715	.164	-2.154	.303	2.175	172.01	.460	-.390					
.168	-.682	.191	-6.073	.849	6.132	172.05	.532	-.315					
.195	-.645	.245	-4.041	.669	4.096	170.61	.614	-.117					
.249	-.635	.294	-4.131	.518	4.163	172.87	.684	.059					
.297	-.619	.319	-3.786	.484	3.817	172.72	.779	.230					
.321	-.622	.343	-3.631	.460	3.660	172.79	.874	.339					
.348	-.616	.366	-2.569	.379	2.597	171.63							
.369	-.608	.393	-2.554	.434	2.590	170.36							
.396	-.550	.424	-3.012	.304	3.027	174.25							
.420	-.535	.448	-1.784	.249	1.802	172.06							
.450	-.584	.470	-2.436	.268	2.451	173.73							
.473	-.593	.497	-2.093	.266	2.109	172.78							
.499	-.597	.547	-2.075	.281	2.094	172.30							
.524	-.587	.569	-1.847	.207	1.858	173.63							
.550	-.598	.595	-1.511	.173	1.521	173.49							
.578	-.579	.618	-1.769	.154	1.776	175.04							
.600	-.545	.647	-1.196	.107	1.201	174.89							
.624	-.498	.697	-.563	.057	.566	174.23							
.652	-.432	.746	-.736	.037	.737	177.17							
.700	-.379	.796	-.386	-.000	.386	-179.99							
.749	-.281	.841	-.281	-.015	.281	-177.01							
.797	-.170	.916	1.483	-.081	1.485	-3.13							
.842	-.065												
.914	.078												

TABLE 5.6. MEAN AND FUNDAMENTAL FREQUENCY PRESSURE FOR AGARD CT CASE NO. 2; DYNAMIC INDEX 185

WING MODEL: NLR 7301 SUPERCRITICAL, CHORD= .500 METERS

WING MOTION: PITCHING .50 DEG ABOUT X/C= .405

DYNAMIC INDEX 185 STATIC INDEX 80

M	.508	PTOT	50864.	K	.197
ALPHA	.58	QINF	7699.	FREQ	21.4
RE	2.53E 06	PINF	42656.		

UPPER SURFACE							LOWER SURFACE						
STEADY DATA		UNSTEADY DATA					STEADY DATA		UNSTEADY DATA				
CPU		CPU,A					CPL		CPL,A				
X/C	CPU	X/C	REAL	IMAG	MAG	PHASE	X/C	CPL	X/C	REAL	IMAG	MAG	PHASE
.045	-1.146	.016	-13.312	5.910	14.565	156.07	.053	-.316					
.070	-.865	.067	-13.205	5.623	14.353	156.95	.106	-.337					
.094	-.826	.092	-4.410	1.341	4.609	163.09	.209	-.337					
.122	-.704	.117	-6.369	2.261	6.759	160.47	.309	-.416					
.147	-.676	.142	-5.276	1.797	5.573	161.21	.381	-.374					
.168	-.663	.191	-4.270	1.253	4.450	163.66	.460	-.385					
.195	-.612	.245	-3.396	.713	3.470	168.16	.532	-.316					
.249	-.565	.294	-3.054	.676	3.128	167.54	.614	-.122					
.297	-.590	.319	-3.056	.526	3.101	170.25	.684	.044					
.321	-.601	.343	-2.567	.818	2.694	162.34	.779	.216					
.348	-.594	.366	-1.878	.792	2.039	157.14	.874	.334					
.369	-.580	.393	-2.019	.877	2.201	156.55							
.396	-.524	.424	-2.177	.095	2.179	177.51							
.420	-.515	.448	-1.619	.397	1.667	166.25							
.450	-.560	.470	-1.785	.044	1.786	178.62							
.473	-.579	.497	-1.638	.004	1.638	179.86							
.499	-.572	.547	-1.423	-.072	1.425	-177.13							
.524	-.559	.569	-1.126	-.180	1.140	-170.94							
.550	-.560	.595	-.907	.037	.908	177.68							
.578	-.548	.618	-.910	-.220	.937	-166.43							
.600	-.519	.647	-.780	-.246	.818	-162.49							
.624	-.467	.697	-.463	-.347	.579	-143.21							
.652	-.406	.746	-.212	-.364	.422	-120.26							
.700	-.353	.796	-.147	-.399	.425	-110.28							
.749	-.260	.841	-.268	-.831	.874	-107.90							
.797	-.165	.916	-.274	-.238	.363	-139.00							
.842	-.061												
.914	.081												

TABLE 5.7. MEAN AND FUNDAMENTAL FREQUENCY PRESSURE FOR AGARD CT CASE NO. 2; DYNAMIC INDEX 170

WING MODEL· NLR 7301 SUPERCRITICAL, CHORD= 500 METERS

WING MOTION· PITCHING 50 DEG ABOUT X/C= 404

DYNAMIC INDEX 170 STATIC INDEX 78

M	.505	PTOT	203067	K	198
ALPHA	56	QINF	30419.	FREQ	22 0
RE	9 33E 06	PINF	170663		

----------UPPER SURFACE----------

STEADY DATA		UNSTEADY DATA				
----CPU----		----CPU.A----				
X/C	CPU	X/C	REAL	IMAG	MAG	PHASE
.023	-1 201	.016	-13.384	6 528	14 891	154 01
.045	-1 178	.067	-11.267	5 092	12 350	155 73
070	- 953	.092	-6 923	3 157	7 608	155 50
.094	-.869	117	-1 933	755	2 075	158 67
.122	- 753	142	-1 591	615	1 706	158 87
.147	-.715	.164	-1 512	502	1 593	161 63
168	-.682	.191	-4 265	1 353	4 474	162 41
.195	- 645	245	-3 217	977	3 362	163 12
.249	-.635	294	-3 078	672	3 151	167 69
.297	- 619	.319	-2 814	567	2 875	168 22
.321	- 622	.343	-2.669	517	2 719	169 04
348	-.616	366	-1 720	456	1 780	165 15
.369	- 608	393	-1 998	478	2 054	166 55
396	- 550	.424	-2 100	226	2 112	173 86
420	- 535	448	-1.279	184	1 293	171 84
450	- 584	470	-1 764	133	1 769	175 71
473	-.593	.497	-1 552	135	1 557	175 05
499	- 597	.547	-1 460	079	1 462	176 91
524	- 587	569	-1 215	- 038	1 216	-178 20
550	-.598	.595	- 984	-.028	.984	-178 35
.578	- 579	.618	-1 002	- 103	1 008	-174 14
.600	- 545	.647	-.778	- 148	792	-169 23
624	- 498	697	- 461	- 305	553	-146 54
.652	- 432	746	-.372	- 232	438	-147 98
.700	-.379	.796	- 229	- 273	361	-129 44
.749	-.281	.841	- 129	- 333	357	-111 24
.797	- 170	.916	.332	- 255	418	-37 53
.842	- 065					
914	078					

----------LOWER SURFACE----------

STEADY DATA		UNSTEADY DATA				
----CPL----		----CPL.A----				
X/C	CPL	X/C	REAL	IMAG	MAG	PHASE
053	-.284					
106	- 313					
209	- 317					
309	- 399					
.391	- 370					
.460	- 390					
532	- 315					
614	- 117					
684	059					
779	230					
874	339					

TABLE 5.8. MEAN AND FUNDAMENTAL FREQUENCY PRESSURE FOR AGARD CT CASE NO. 3; DYNAMIC INDEX 204

WING MODEL· NLR 7301 SUPERCRITICAL, CHORD= .500 METERS

WING MOTION· PITCHING 50 DEG ABOUT X/C= 403

DYNAMIC INDEX 204 STATIC INDEX 85

M	.710	PTOT	50966	K	.050
ALPHA	2 53	QINF	12840.	FREQ	7 4
RE	3 14E 06	PINF	36427.		

----------UPPER SURFACE----------

STEADY DATA		UNSTEADY DATA				
----CPU----		----CPU.A----				
X/C	CPU	X/C	REAL	IMAG	MAG	PHASE
.023	-1 006	.016	-5.230	1.054	5.335	168 61
.045	-1.550	067	-7 294	1 396	7 426	169 18
.070	-1.324	117	-6 342	1 219	6 458	169 13
094	-1 667	.142	-6 009	1 181	6 124	168 89
122	-1 634	.191	-6 836	1 335	6 965	168 96
.147	-1.593	.245	-6 740	1 463	6 897	167 77
.168	-1.588	.294	-7 074	1.315	7 195	169 48
195	-1 519	319	-7 499	1 497	7 646	168 72
249	-1.454	366	-4 759	2 347	5 307	153 75
.297	-1 501	393	-6 543	3 147	7 260	154 33
.321	-1 504	424	-1 206	1 957	2 298	121.66
.348	-1.516	.448	-5.532	1 808	5 820	161.91
.369	-1 554	470	-7 992	1.626	8 156	168 52
.396	-1 546	497	-25 934	3 731	26 201	171 83
420	-1.512	547	-19 277	1 970	19 377	174 18
450	-1.496	.569	-16 171	1 432	16 235	174 95
473	-1 518	595	-8 789	- 560	8 807	-176 37
499	-1 449	618	-2 478	-1 924	3 138	-142 18
.524	-1 021	.647	2 733	-2 222	3 523	-39 12
550	- 772	.697	5.340	-2.175	5 766	-22 16
578	- 648	.746	4 361	-1 529	4 622	-19 32
600	-.565	.796	1 124	-1 098	1 572	-44 33
624	- 476	841	179	- 509	539	-70 63
652	- 395	.916	-4.166	- 409	4 186	-174 41
.700	-.334					
749	-.248					
.797	- 152					
842	- 047					
914	.098					

----------LOWER SURFACE----------

STEADY DATA		UNSTEADY DATA				
----CPL----		----CPL.A----				
X/C	CPL	X/C	REAL	IMAG	MAG	PHASE
053	- 101					
106	- 194					
209	- 272					
309	- 414					
381	- 396					
460	- 427					
532	-.355					
614	- 030					
694	.101					
779	287					
874	410					

TABLE 5.9. MEAN AND FUNDAMENTAL FREQUENCY PRESSURE FOR AGARD CT CASE NO. 3; DYNAMIC INDEX 197

WING MODEL: NLR 7301 SUPERCRITICAL, CHORD= 500 METERS

WING MOTION: PITCHING 49 DEG ABOUT X/C= 406

DYNAMIC INDEX 197 STATIC INDEX 83

M	.700	PTOT	203135.	K	050
ALPHA	2 53	QINF	50262.	FREQ	7.5
RE	1 20E 07	PINF	146405.		

-----UPPER SURFACE-----

STEADY DATA		UNSTEADY DATA				
----CPU----		--------CPU.A--------				
X/C	CPU	X/C	REAL	IMAG	MAG	PHASE
.023	-1.052	.016	-5 838	1.440	6.013	166 16
045	-1.623	.067	-7.653	1 768	7 854	167 01
.070	-1 418	.117	-6 752	1.598	6 939	166 70
.094	-1.692	.142	-6 320	1 588	6 516	165 91
122	-1 659	.191	-7 634	1 838	7 652	166 48
147	-1.606	245	-7 350	2 004	7 6'B	164 76
.168	-1.601	294	-7 813	1 949	8 053	166 00
195	-1 554	319	-8 195	2 083	6 456	165 75
249	-1.485	.366	-3.526	1 446	3 811	157.71
297	-1 489	393	-21 396	8 238	22 927	158 95
.321	-1 491	.424	-44 699	11 855	46 244	165 16
.348	-1 497	448	-20 83ʁ	4 302	21 278	168 35
369	-1 528	.470	-18 632	3 017	18 8'5	170 82
.396	-1 432	497	-9 312	791	9 345	175 16
.420	-1 236	.547	2.855	-2.514	3 805	-41 37
450	-.905	569	5 088	-2 788	5 802	-28 72
473	- 758	.595	5 650	-2.784	6 299	-26 24
499	- 688	.618	5 465	-2 440	5 985	-24 06
524	- 649	.647	13 730	-5 900	14 944	-23 26
550	- 627	697	11 433	-5 013	12 484	-23 68
.578	- 501	.746	2 514	-1 086	2 739	-23 36
.600	- 561	.796	1 243	- 642	1 399	-27 33
624	-.506	.841	.660	- 177	683	-15 02
652	-.436	.916	-.216	869	895	103 98
.700	- 365					
749	-.254					
797	- 139					
.842	-.036					
.914	096					

-----LOWER SURFACE-----

STEADY DATA		UNSTEADY DATA				
----CPL----		--------CPL.A--------				
X/C	CPL	X/C	REAL	IMAG	MAG	PHASE
053	- 078					
106	-.170					
209	- 250					
309	- 402					
381	- 392					
.4?0	- 433					
532	- 354					
614	- 114					
684	.083					
779	263					
.874	.376					

TABLE 5.10. MEAN AND FUNDAMENTAL FREQUENCY PRESSURE FOR AGARD CT CASE NO. 4; DYNAMIC INDEX 206

WING MODEL: NLR 7301 SUPERCRITICAL, CHORD= 500 METERS

WING MOTION: PITCHING 1.01 DEG ABOUT X/C= 400

DYNAMIC INDEX 206 STATIC INDEX 85

M	710	PTOT	50966	K	050
ALPHA	2.53	QINF	12840.	FREQ	7 4
RE	3 14E 06	PINF	36427.		

-----UPPER SURFACE-----

STEADY DATA		UNSTEADY DATA				
----CPU----		--------CPU.A--------				
X/C	CPU	X/C	REAL	IMAG	MAG	PHASE
023	-1 006	.016	-5 260	1 149	5 384	167 69
.045	-1.550	.067	-7 522	1.556	7 681	168 32
070	-1.324	117	-6 520	1 348	6 658	168 33
.094	-1 667	142	-6 250	1 376	6 407	167 82
122	-1 634	191	-7 050	1 521	7 212	167 84
147	-1.593	.245	-6 877	1 663	7.075	166 42
.168	-1.581	294	-7 345	1 677	7 534	167 15
.195	-1.519	.319	-7.796	1 852	8 013	166 65
249	-1 454	366	-4 896	2 623	5 555	151 83
297	-1.501	.393	-6 762	3 638	7 679	151 73
.321	-1.504	.424	-1 750	2 938	3 420	120 79
.348	-1 516	.448	-11 736	5 972	13 168	153 04
.369	-1.554	.470	-24 279	8 480	25 718	160 76
.396	-1.546	.497	-29.460	7.667	30 441	165 43
.420	-1.512	.547	-10 767	.517	10 779	177.26
.450	-1.496	.569	-6.861	- 252	6 866	-177 91
.473	-1.518	.595	-3.263	-1 752	3 704	-151 78
499	-1 449	.618	-1 039	-2 726	2 917	-110 87
.524	-1.021	.647	1 143	-3 118	3 321	-69 87
.550	772	.697	3 443	-2.054	4.009	-30 82
.578	- 648	746	2.240	-2 126	3 089	-43 51
600	-.565	.796	1.130	-.968	1.487	-40 59
.624	-.476	.841	.920	-.378	.994	-22 36
.652	-.395	.916	.622	124	.634	11 28
.700	-.334					
.749	-.248					
.797	-.152					
842	-.047					
914	.098					

-----LOWER SURFACE-----

STEADY DATA		UNSTEADY DATA				
----CPL----		--------CPL.A--------				
X/C	CPL	X/C	REAL	IMAG	MAG	PHASE
053	-.101					
.106	- 194					
209	- 272					
309	- 414					
381	- 396					
.460	- 427					
532	- 355					
614	- 080					
684	101					
779	287					
874	410					

TABLE 5.11. MEAN AND FUNDAMENTAL FREQUENCY PRESSURE FOR AGARD CT CASE NO. 5; DYNAMIC INDEX 199

WING MODEL. NLR 7301 SUPERCRITICAL, CHORD= 500 METERS

WING MOTION PITCHING 1 01 DEG ABOUT X/C= 398

DYNAMIC INDEX 199 STATIC INDEX 83

M	.700	PTOT	203135.	K	050
ALPHA	2 53	QINF	50262.	FREQ	7 5
RE	1 20E 07	PINF	146405		

UPPER SURFACE							LOWER SURFACE						
STEADY DATA		UNSTEADY DATA					STEADY DATA		UNSTEADY DATA				
CPU		CPU.A					CPL		CPL.A				
X/C	CPU	X/C	REAL	IMAG	MAG	PHASE	X/C	CPL	X/C	REAL	IMAG	MAG	PHASE
.023	-1 052	.016	-5 541	1 319	5 695	166 62	053	-.078					
.045	-1.623	.067	-7.513	1 718	7 707	167 13	.106	- 170					
070	-1 418	.117	-6.739	1.565	6.918	166 94	.209	- 250					
094	-1 682	.142	-6 736	1 648	6 935	165 26	.309	- 402					
122	-1 659	.191	-7 533	1.853	7 757	166 19	.381	- 392					
.147	-1.606	.245	-7 737	2 099	8 017	164 83	.460	- 433					
168	-1 601	.294	-8 139	2 107	8 407	165 50	532	- 354					
.195	-1 554	319	-8.613	2.306	8 917	165 02	614	- 114					
249	-1 485	366	-9 969	4 609	10 982	155 20	694	063					
297	-1 489	.393	-28.255	11 958	30 681	157 07	779	263					
.321	-1 491	424	-28 498	8 377	29 704	163 63	874	376					
348	-1 497	.448	-12 714	1 556	12 809	173 03							
369	-1.528	470	-10 319	429	10 328	177 63							
.396	-1 432	.497	-4.491	- 847	4 571	-169 33							
420	-1 236	.547	2 280	-2 753	3 574	-50 37							
.450	-.905	.569	3 473	-2.604	4 341	-36 87							
473	- 758	.595	3.758	-2 329	4 421	-31 80							
499	- 688	618	3 821	-1 960	4 294	-27 16							
524	-.649	647	10 247	-4 805	11 318	-25 12							
550	- 627	697	9 098	-4 155	10 002	-24 55							
.578	- 601	746	2.212	-.917	2 394	-22 51							
.600	- 561	.796	1 003	-.502	1.121	-26 61							
624	- 506	.841	.758	- 158	775	-11 77							
652	- 436	916	1 022	492	1 134	25 74							
.700	-.365												
749	- 254												
.797	- 139												
842	- 036												
914	096												

TABLE 5.12. MEAN AND FUNDAMENTAL FREQUENCY PRESSURE FOR AGARD CT CASE NO. 5; DYNAMIC INDEX 205

WING MODEL. NLR 7301 SUPERCRITICAL, CHORD= 500 METERS

WING MOTION. PITCHING 50 DEG ABOUT X/C= 403

DYNAMIC INDEX 205 STATIC INDEX 85

M	.710	PTOT	50966	K	199
ALPHA	2 53	QINF	12840	FREQ	29 5
RE	3.14E 06	PINF	36427		

UPPER SURFACE							LOWER SURFACE						
STEADY DATA		UNSTEADY DATA					STEADY DATA		UNSTEADY DATA				
CPU		CPU.A					CPL		CPL.A				
X/C	CPU	X/C	REAL	IMAG	MAG	PHASE	X/C	CPL	X/C	REAL	IMAG	MAG	PHASE
.023	-1 006	.016	-3.557	1 820	3 996	152 92	053	- 101					
.045	-1 550	.067	-4 982	2 705	5 669	151 51	106	- 194					
070	-1 324	117	-4 233	2 465	4 898	149 80	209	- 272					
094	-1 667	.142	-3 926	2 473	4 640	147 81	309	- 414					
.122	-1 634	.191	-4 377	2 824	5 209	147 19	381	-.396					
.147	-1 593	.245	-3 801	3 185	4 959	140 05	460	- 427					
.168	-1 588	.294	-4 042	3 105	5 097	142 48	532	- 355					
.195	-1 519	.319	-4 202	3 473	5 451	140 44	614	- 080					
249	-1 454	.366	- 369	2 607	2 633	98 06	654	101					
297	-1 501	393	- 312	3 666	3 679	94 87	779	287					
321	-1 504	424	394	517	650	52 70	874	410					
348	-1 516	448	-.729	3 609	3 878	100 84							
369	-1 554	.470	-4 161	4 990	6 498	129 83							
.396	-1 546	.497	-19 466	27 930	34 044	124 88							
420	-1 512	547	-14 788	15 908	21 764	132 81							
.450	-1.496	569	-12 090	12 636	17 489	133 74							
473	-1 518	595	-8 770	6 507	10 920	143 44							
499	-1 449	618	-6 060	1 569	6 260	165 50							
.524	-1.021	.647	-3 094	-3.000	4 310	-135 89							
550	-.772	.697	- 026	-5.790	5 790	-90 27							
578	-.648	746	-1 592	-3 420	3 773	-114 97							
600	-.565	.796	-.919	- 991	1 352	-132 86							
624	-.476	.841	075	-2 299	2 300	-88 13							
652	- 395	916	- 162	- 301	342	-118 33							
.700	-.334												
749	- 248												
797	-.152												
842	-.047												
.914	.098												

TABLE 5.13. MEAN AND FUNDAMENTAL FREQUENCY PRESSURE FOR AGARD CT CASE NO. 5; DYNAMIC INDEX 198

WING MODEL: NLR 7301 SUPERCRITICAL, CHORD= .500 METERS

WING MOTION: PITCHING .49 DEG ABOUT X/C= .405

DYNAMIC INDEX 198   STATIC INDEX 83

M	.700	PTOT	203135	K	.201
ALPHA	2.53	QINF	50262.	FREQ	30.2
RE	1.20E 07	PINF	146405		

UPPER SURFACE									LOWER SURFACE				
STEADY DATA		UNSTEADY DATA					STEADY DATA		UNSTEADY DATA				
CPU		CPU,A					CPL		CPL,A				
X/C	CPU	X/C	REAL	IMAG	MAG	PHASE	X/C	CPL	X/C	REAL	IMAG	MAG	PHASE
023	-1 052	.016	-3 555	2 036	4 097	150 21	053	- 078					
045	-1 623	067	-4 831	2 905	5 637	148 99	106	- 170					
070	-1 418	.117	-4 130	2 703	4 936	146 80	209	- 250					
094	-1 682	.142	-3 726	2 717	4 611	143 91	309	- 402					
122	-1 659	.191	-4 489	3 350	5 601	143 28	381	- 392					
147	-1 606	.245	-3 881	3 529	5 246	137 72	460	- 433					
.168	-1 601	294	-4 144	3 737	5 580	137 97	532	- 354					
.195	-1 554	.319	-4 309	4 130	5 969	136 23	614	- 114					
249	-1 485	366	- 869	2 295	2 462	111 19	684	083					
.297	-1 489	393	-3 946	19 845	20 233	101 25	779	.263					
321	-1 491	.424	-16 477	39 796	43 072	112 50	874	376					
348	-1 497	448	-9 232	20 443	22 431	114 31							
369	-1 528	470	-13 026	15 224	20 036	130 56							
.396	-1 432	497	-8 117	5.943	10 061	143 80							
420	-1.236	.547	-2 929	-5 039	5 829	-120 17							
450	- 905	.569	-1.182	-6 552	6 658	-100 24							
.473	- 758	.595	-.411	-6 717	6 729	-93 51							
.499	- 688	618	111	-6 167	6 168	-88 98							
524	- 649	647	863	-15 701	15 725	-86 86							
550	- 627	.697	.375	-12 892	12 897	-88 34							
.578	- .601	.746	073	-2 909	2 910	-88 58							
.600	- .561	.796	-.155	-1 696	1 703	-95 22							
624	- .506	841	085	-1 196	1 199	-85 96							
652	- 436	916	.850	- 209	.875	-13 82							
700	- 365												
.749	- 254												
797	- 139												
.842	- .036												
.914	096												

TABLE 5.14. MEAN AND FUNDAMENTAL FREQUENCY PRESSURE FOR AGARD CT CASE NO. 6; DYNAMIC INDEX 190

WING MODEL: NLR 7301 SUPERCRITICAL, CHORD= 500 METERS

WING MOTION: PITCHING .50 DEG ABOUT X/C= .403

DYNAMIC INDEX 190   STATIC INDEX 81

M	.752	PTOT	50966.	K	050
ALPHA	37	QINF	13866.	FREQ	7 8
RE	3.30E 06	PINF	35026.		

UPPER SURFACE									LOWER SURFACE				
STEADY DATA		UNSTEADY DATA					STEADY DATA		UNSTEADY DATA				
CPU		CPU,A					CPL		CPL,A				
X/C	CPU	X/C	REAL	IMAG	MAG	PHASE	X/C	CPL	X/C	REAL	IMAG	MAG	PHASE
023	- 565	.016	-5 397	2 088	5 787	158 86	053	- 526					
045	-1.029	067	-8 955	3 414	9 584	159 14	106	- 565					
070	- 987	.117	-8 380	3 286	9 001	158 60	.209	- 533					
094	-1 152	142	-8 406	3 414	9 073	157 91	309	- 753					
122	-1 112	191	-8 406	3 530	9 117	157 23	381	- 734					
.147	-1 077	245	-9 067	4 111	9 956	155 62	460	- 611					
.168	-1.077	.294	-9.823	4 718	10 897	154.35	532	- 442					
.195	-1 015	.319	-10 473	5 251	11 716	153 38	614	- 133					
.249	- 959	.343	-6 951	8 762	11 184	128 44	654	059					
297	-1 013	366	-7 184	6 403	9 623	138 30	779	231					
321	-1 019	393	-11 187	11 173	15 807	135 03	874	349					
.348	-1 029	424	-15 644	9 988	18 561	147 46							
.369	-1 072	448	-10 411	8 540	13 465	140 65							
.396	-1 047	470	-13.646	8 662	16 163	147 61							
420	- 994	.497	-13 296	8 370	15 711	147.82							
450	- 988	.547	-14 752	9 636	17 620	146 86							
473	-1 022	.569	-11 791	8 495	14 532	144 24							
499	-1 026	595	12 638	-7 262	14 576	-29 89							
524	-1 072	.618	5 441	-5 464	7 712	-45 12							
550	-1 118	.647	-2 498	555	2 559	167 49							
578	-1.113	.697	-1 664	339	1 698	158 50							
.600	- 869	746	-1 427	647	1 567	155 60							
624	- 597	796	-1 945	1.066	2 218	151 29							
.652	- .467	841	-2 199	1 252	2 530	150 35							
.700	- 356	.916	-1 182	040	1 183	178 06							
.749	- 242												
.797	- 132												
.842	- 028												
914	102												

TABLE 5.15. MEAN AND FUNDAMENTAL FREQUENCY PRESSURE FOR AGARD CT CASE NO. 6; DYNAMIC INDEX 132

WING MODEL: NLR 7301 SUPERCRITICAL, CHORD= .500 METERS

WING MOTION: PITCHING .50 DEG ABOUT X/C= .401

DYNAMIC INDEX 132 STATIC INDEX 73

M	.752	PTOT	101661.	K	.050
ALPHA	.37	QINF	27671.	FREQ	8.0
RE	6.20E 06	PINF	69850.		

----------UPPER SURFACE----------

STEADY DATA		UNSTEADY DATA				
----CPU----		----CPU,A----				
X/C	CPU	X/C	REAL	IMAG	MAG	PHASE
.023	-.564	.016	-5.217	1.972	5.577	159.30
.045	-1.095	.067	-8.618	3.247	9.209	159.37
.070	-1.064	.092	-6.838	2.756	7.373	159.06
.094	-1.136	.117	-7.952	3.046	8.516	159.04
.122	-1.105	.142	-8.721	3.526	9.407	159.00
.147	-1.062	.164	-8.699	3.487	9.372	158.17
.168	-1.065	.191	-8.007	3.337	8.674	157.39
.195	-1.026	.245	-8.859	4.008	9.723	155.67
.249	-.970	.294	-9.900	4.553	10.897	155.31
.297	-1.004	.319	-9.363	4.405	10.348	154.82
.321	-1.007	.343	-9.807	4.984	11.001	153.07
.348	-1.015	.393	-11.767	9.664	15.227	140.61
.369	-1.052	.424	-15.856	9.453	18.460	149.21
.396	-1.044	.470	-14.543	8.621	16.906	149.35
.420	-.991	.497	-14.666	9.139	17.298	148.12
.450	-.980	.547	-17.800	12.269	21.454	145.13
.473	-1.015	.595	5.924	-10.688	12.220	-61.01
.499	-1.016	.618	5.193	-9.932	11.208	-62.40
.524	-1.045	.647	-3.277	-.540	3.321	-170.65
.550	-1.085	.697	-1.904	.099	1.906	177.02
.578	-1.003	.746	-.921	-.011	.921	-179.33
.600	-.808	.796	-1.033	.205	1.054	168.61
.624	-.639	.841	-.416	.057	.420	172.27
.652	-.492	.916	.592	-.555	.811	-43.14
.700	-.365					
.749	-.243					
.797	-.128					
.842	-.023					
.914	.109					

----------LOWER SURFACE----------

STEADY DATA		UNSTEADY DATA				
----CPL----		----CPL,A----				
X/C	CPL	X/C	REAL	IMAG	MAG	PHASE
.033	.258					
.053	-.502					
.106	-.532					
.209	-.498					
.309	-.721					
.381	-.667					
.460	-.602					
.532	-.430					
.614	-.128					
.684	.068					
.779	.245					
.874	.357					

TABLE 5.16. MEAN AND FUNDAMENTAL FREQUENCY PRESSURE FOR AGARD CT CASE NO. 6; DYNAMIC INDEX 144

WING MODEL: NLR 7301 SUPERCRITICAL, CHORD= .500 METERS

WING MOTION: PITCHING .50 DEG ABOUT X/C= .403

DYNAMIC INDEX 144 STATIC INDEX 76

M	.751	PTOT	203236.	K	.050
ALPHA	.37	QINF	55173.	FREQ	8.2
RE	1.14E 07	PINF	139846.		

----------UPPER SURFACE----------

STEADY DATA		UNSTEADY DATA				
----CPU----		----CPU,A----				
X/C	CPU	X/C	REAL	IMAG	MAG	PHASE
.023	-.562	.016	-5.222	1.939	5.571	159.65
.045	-1.048	.067	-8.563	3.183	9.138	159.59
.070	-1.036	.092	-7.428	2.963	7.997	158.27
.094	-1.131	.117	-7.958	3.015	8.510	159.26
.122	-1.097	.142	-9.410	3.793	10.146	158.06
.147	-1.043	.164	-8.922	3.560	9.606	158.26
.168	-1.059	.191	-8.103	3.400	8.788	157.25
.195	-1.021	.245	-10.687	4.973	11.787	155.06
.249	-.956	.294	-13.807	7.932	15.924	150.13
.297	-.991	.319	-14.089	8.466	16.437	149.01
.321	-1.000	.343	-16.577	9.924	19.320	149.10
.348	-1.009	.393	-15.377	10.391	18.559	145.96
.369	-1.052	.424	-17.606	9.485	19.998	151.70
.396	-1.052	.470	-18.015	8.911	20.099	153.69
.420	-.973	.497	-17.658	8.644	19.840	154.18
.450	-.920	.547	-16.346	7.972	18.186	154.01
.473	-.866	.595	17.824	-18.372	25.597	-45.87
.499	-.905	.618	18.269	-14.417	23.273	-38.28
.524	-.949	.647	5.023	-2.967	5.834	-30.57
.550	-.999	.697	1.726	-.687	1.858	-21.71
.578	-.784	.746	1.010	-.328	1.062	-18.01
.600	-.633	.796	.393	-.293	.490	-36.74
.624	-.525	.841	.216	-.320	.386	-55.90
.652	-.440	.916	.998	-.510	1.121	-27.06
.700	-.353					
.749	-.234					
.797	-.110					
.842	-.006					
.914	.122					

----------LOWER SURFACE----------

STEADY DATA		UNSTEADY DATA				
----CPL----		----CPL,A----				
X/C	CPL	X/C	REAL	IMAG	MAG	PHASE
.033	-.434					
.053	-.474					
.106	-.531					
.209	-.516					
.309	-.750					
.381	-.627					
.460	-.626					
.532	-.440					
.614	-.133					
.694	.066					
.779	.238					
.874	.348					

TABLE 5.17. MEAN AND FUNDAMENTAL FREQUENCY PRESSURE FOR AGARD CT CASE NO. 7; DYNAMIC INDEX 136

WING MODEL: NLR 7301 SUPERCRITICAL, CHORD= .500 METERS

WING MOTION: PITCHING 1.01 DEG ABOUT X/C= .398

DYNAMIC INDEX 136 STATIC INDEX 73

M	.752	PTOT	101661	K	.050
ALPHA	.37	QINF	27671	FREQ	8.0
RE	6.20E 06	PINF	69850		

UPPER SURFACE

STEADY DATA		UNSTEADY DATA				
CPU		CPU, A				
X/C	CPU	X/C	REAL	IMAG	MAG	PHASE
.023	-.564	.016	-5.250	1.829	5.559	160.80
.045	-1.095	.067	-8.951	3.233	9.517	160.15
.070	-1.064	.092	-7.442	2.988	8.020	158.14
.094	-1.136	.117	-8.540	3.232	9.131	159.28
.122	-1.105	.142	-9.309	3.747	10.035	158.09
.147	-1.052	.164	-8.939	3.579	9.629	158.19
.168	-1.065	.191	-11.194	5.325	12.396	154.57
.195	-1.026	.245	-12.405	7.029	14.253	150.47
.249	-.970	.294	-11.832	6.325	13.470	152.00
.297	-1.004	.319	-11.182	5.757	12.577	152.77
.321	-1.007	.343	-10.897	5.444	12.181	153.47
.348	-1.015	.393	-8.422	5.538	10.080	146.68
.369	-1.052	.424	-10.100	4.298	10.977	156.96
.396	-1.044	.470	-9.429	3.637	10.107	158.92
.420	-.991	.497	-7.073	2.419	7.475	161.14
.450	-.980	.547	3.398	-3.441	4.836	-45.36
.473	-1.015	.595	8.073	-8.710	11.876	-47.18
.499	-1.016	.618	6.052	-3.930	7.216	-33.00
.524	-1.045	.647	.109	-.892	.099	-83.05
.550	-1.085	.697	-1.603	-.262	1.624	-170.74
.578	-1.003	.746	-2.295	.239	2.308	174.10
.600	-.808	.796	-3.069	.732	3.155	165.60
.624	-.639	.841	-3.634	1.131	3.806	162.72
.652	-.492	.916	-4.023	1.493	4.291	159.65
.700	-.365					
.749	-.243					
.797	-.128					
.842	-.023					
.914	.109					

LOWER SURFACE

STEADY DATA		UNSTEADY DATA				
CPL		CPL, A				
X/C	CPL	X/C	REAL	IMAG	MAG	PHASE
.033	.258					
.053	-.502					
.106	-.532					
.209	-.498					
.309	-.721					
.381	-.667					
.460	-.602					
.532	-.420					
.614	-.128					
.684	.068					
.779	.245					
.874	.357					

TABLE 5.18. MEAN AND FUNDAMENTAL FREQUENCY PRESSURE FOR AGARD CT CASE NO. 7; DYNAMIC INDEX 150

WING MODEL: NLR 7301 SUPERCRITICAL, CHORD= .500 METERS

WING MOTION: PITCHING 1.00 DEG ABOUT X/C= .398

DYNAMIC INDEX 150 STATIC INDEX 76

M	.751	PTOT	203236	K	.050
ALPHA	.37	QINF	55173	FREQ	8.2
RE	1.14E 07	PINF	139846		

UPPER SURFACE

STEADY DATA		UNSTEADY DATA				
CPU		CPU, A				
X/C	CPU	X/C	REAL	IMAG	MAG	PHASE
.023	-.562	.016	-5.240	1.663	5.497	162.41
.045	-1.048	.067	-9.033	2.991	9.516	161.69
.070	-1.036	.092	-8.040	2.951	8.564	159.85
.094	-1.131	.117	-8.847	3.080	9.368	160.82
.122	-1.097	.142	-10.254	3.809	10.939	159.63
.147	-1.043	.164	-10.601	3.611	11.265	160.24
.168	-1.059	.191	-13.624	6.011	14.891	156.20
.195	-1.021	.245	-12.861	6.248	14.298	154.10
.249	-.956	.294	-11.470	5.284	12.628	155.28
.297	-.991	.319	-10.284	4.583	11.259	155.99
.321	-1.000	.343	-10.195	4.330	11.100	156.71
.348	-1.009	.393	-8.545	4.016	9.442	154.84
.369	-1.052	.424	-9.878	2.894	10.293	163.68
.396	-1.052	.470	-10.645	2.416	10.915	167.23
.420	-.973	.497	-10.522	2.459	10.806	166.86
.450	-.920	.547	-9.497	.630	9.518	176.22
.473	-.866	.595	8.459	-8.668	12.112	-45.70
.499	-.905	.618	7.797	-1.814	8.005	-13.10
.524	-.949	.647	1.358	-.433	1.425	-17.68
.550	-.999	.697	.778	-.464	.906	-30.82
.578	-.784	.746	.673	-.349	.758	-27.44
.600	-.633	.796	.175	-.235	.293	-53.36
.624	-.525	.841	-.062	-.143	.156	-113.27
.652	-.440	.916	-.322	-.298	.439	-137.19
.700	-.353					
.749	-.234					
.797	-.110					
.842	-.006					
.914	.122					

LOWER SURFACE

STEADY DATA		UNSTEADY DATA				
CPL		CPL, A				
X/C	CPL	X/C	REAL	IMAG	MAG	PHASE
.033	-.434					
.053	-.474					
.106	-.531					
.209	-.516					
.309	-.750					
.381	-.627					
.460	-.626					
.532	-.440					
.614	-.133					
.684	.066					
.779	.238					
.874	.348					

TABLE 5.19. MEAN AND FUNDAMENTAL FREQUENCY PRESSURE FOR AGARD CT CASE NO. 8; DYNAMIC INDEX 191

WING MODEL· NLR 7301 SUPERCRITICAL, CHORD= 500 METERS

WING MOTION· PITCHING 50 DEG ABOUT X/C= 401

DYNAMIC INDEX 191 STATIC INDEX 81

M	.752	PTOT	50966.	K	200
ALPHA	.37	QINF	13866.	FREQ	31 4
RE	3 30E 06	PINF	35026		

UPPER SURFACE							LOWER SURFACE						
STEADY DATA		UNSTEADY DATA					STEADY DATA		UNSTEADY DATA				
CPU		CPU.A					CPL		CPL.A				
X/C	CPU	X/C	REAL	IMAG	MAG	PHASE	X/C	CPL	X/C	REAL	IMAG	MAG	PHASE
.023	- .565	.016	-2.891	1 629	3 318	150 60	053	- 526					
045	-1 029	.067	-4 852	2 994	5 701	148 33	106	- 565					
.070	- .987	.117	-4 301	2 872	5.172	146 28	.209	- 533					
094	-1.152	.142	-4 159	3.130	5 206	143 04	.309	- 753					
122	-1 112	.191	-3.908	3 193	5.046	140 76	.381	- 734					
147	-1 077	.245	-3.880	3 844	5 452	135 28	460	- 611					
168	-1 077	294	-3 610	3 970	5 356	132 29	.532	- 442					
.195	-1 015	.319	-3.442	4 435	5.614	127 82	.614	- 133					
.249	- 959	.343	.999	2 381	2.562	67 24	684	059					
297	-1 013	366	354	3 003	3 024	83 29	779	231					
321	-1 019	.393	1 011	3 976	4 102	75 75	.874	349					
348	-1 029	424	-2 236	7 215	7 553	107 23							
369	-1 072	.448	1 666	6 464	6 675	75 56							
396	-1.047	.470	-1.130	11 378	11 433	95 68							
420	- 994	.497	- .914	11 162	11 199	94 69							
450	- .988	547	-1.044	7 947	8 016	97 49							
473	-1 022	569	- 857	5 515	5 581	98 04							
.499	-1 026	.595	-6 341	-10.238	12.042	-121 78							
.524	-1 072	.618	-3 671	-1 746	4.055	-154 57							
550	-1 118	.647	-2 298	.735	2 413	162 27							
578	-1 113	.697	-1 104	- 442	1 189	-158 20							
600	- 889	746	- 389	- 420	572	-132 30							
624	- .597	.796	- 293	.283	407	136 06							
652	- 467	.841	- 503	- .393	.638	-141 95							
.700	- 356	.916	- 452	.713	844	122 40							
.749	- 242												
797	- .132												
842	- 028												
.914	102												

TABLE 5.20. MEAN AND FUNDAMENTAL FREQUENCY PRESSURE FOR AGARD CT CASE NO. 8; DYNAMIC INDEX 134

WING MODEL· NLR 7301 SUPERCRITICAL, CHORD= 500 METERS

WING MOTION· PITCHING .49 DEG ABOUT X/C= .403

DYNAMIC INDEX 134 STATIC INDEX 73

M	.752	PTOT	101661.	K	200
ALPHA	.37	QINF	27671.	FREQ	32 0
RE	6.20E 06	PINF	69850.		

UPPER SURFACE							LOWER SURFACE						
STEADY DATA		UNSTEADY DATA					STEADY DATA		UNSTEADY DATA				
CPU		CPU.A					CPL		CPL.A				
X/C	CPU	X/C	REAL	IMAG	MAG	PHASE	X/C	CPL	X/C	REAL	IMAG	MAG	PHASE
.023	- .564	.016	-2 655	1.470	3.034	151.04	033	.258					
045	-1 095	067	-4 519	2 862	5 349	147 66	053	- 502					
.070	-1.064	.092	-3 840	2 511	4 588	146 83	106	- 532					
.094	-1.136	.117	-3 949	2.735	4 804	145.30	.209	- .498					
122	-1.105	.142	-4 125	3.248	5 250	141 80	.309	- 721					
147	-1.052	.164	-4 179	3.299	5 324	141 72	.381	- 667					
.168	-1.065	.191	-3 373	2.914	4 457	139 19	460	- .602					
.195	-1 026	245	-3 575	3.609	5 080	134 74	532	- 430					
.249	- .970	294	-3 390	4 081	5 305	129 73	.614	- 128					
297	-1 004	.319	-3 004	3 959	4 970	127 20	684	069					
321	-1.007	.343	-2 534	3 802	4 569	123 69	779	.245					
.349	-1.015	393	268	4 433	4 442	86.54	874	357					
369	-1.052	.424	-2 176	6.940	7 273	107 42							
.396	-1.044	.470	- 990	11 189	11 233	95 06							
420	- 991	.497	- 462	11 464	11 474	92.32							
.450	- 980	.547	- 363	8 298	8 306	92 51							
.473	-1 015	595	-11 982	929	12 018	175 58							
499	-1 016	.618	-4 737	2 650	5 428	150 79							
.524	-1 045	.647	-2 681	2 619	3.747	135 68							
550	-1.085	.697	-1.302	.012	1 302	179 47							
.578	-1.003	.746	- .633	- .693	939	-132 43							
.600	- .808	.796	- 451	- 302	542	-146.22							
624	- 639	841	- 556	- 974	1 122	-119 73							
.652	- .492	.916	- 393	- 689	794	-119 72							
700	- .365												
.749	- .243												
.797	- .128												
842	- .023												
914	.109												

TABLE 5.21. MEAN AND FUNDAMENTAL FREQUENCY PRESSURE FOR AGARD CT CASE NO. 8; DYNAMIC INDEX 148

WING MODEL: NLR 7301 SUPERCRITICAL, CHORD= .500 METERS

WING MOTION: PITCHING .50 DEG ABOUT X/C= .403

DYNAMIC INDEX 148 STATIC INDEX 76

M	.751	PTOT	203236.	K	.201
ALPHA	.37	QINF	55173.	FREQ	33.0
RE	1.14E 07	PINF	139846.		

UPPER SURFACE: STEADY DATA (CPU)		UPPER SURFACE: UNSTEADY DATA (CPU,A)					LOWER SURFACE: STEADY DATA (CPL)		LOWER SURFACE: UNSTEADY DATA (CPL,A)				
X/C	CPU	X/C	REAL	IMAG	MAG	PHASE	X/C	CPL	X/C	REAL	IMAG	MAG	PHASE
.023	-.562	.016	-2.693	1.646	3.156	148.57	.033	-.434					
.045	-1.048	.067	-4.533	3.206	5.552	144.74	.053	-.474					
.070	-1.036	.092	-3.694	2.880	4.684	142.06	.106	-.531					
.094	-1.131	.117	-3.781	2.920	4.777	142.33	.209	-.515					
.122	-1.097	.142	-4.270	3.843	5.748	137.98	.309	-.750					
.147	-1.043	.164	-4.101	3.709	5.529	137.88	.381	-.627					
.168	-1.059	.191	-3.204	3.157	4.498	135.43	.460	-.626					
.195	-1.021	.245	-3.931	4.951	6.322	128.46	.532	.440					
.249	-.956	.294	-3.251	4.744	5.751	124.43	.614	-.133					
.297	-.991	.319	-2.725	4.542	5.296	120.97	.684	.066					
.321	-1.000	.343	-2.449	5.465	6.007	114.07	.779	.238					
.348	-1.009	.393	1.524	11.058	11.162	82.16	.874	.348					
.369	-1.052	.424	-1.157	14.791	14.837	94.48							
.396	-1.052	.470	.461	13.193	13.201	88.01							
.420	-.973	.497	2.004	12.564	12.722	80.94							
.450	-.920	.547	1.023	14.689	14.725	86.02							
.473	-.866	.595	-15.984	-16.220	22.772	-134.59							
.499	-.905	.618	-10.856	-17.504	20.597	-121.82							
.524	-.949	.647	-1.345	-5.369	5.535	-104.07							
.550	-.999	.697	.502	-2.949	2.991	-80.35							
.578	-.784	.746	.628	-1.586	1.706	-68.40							
.600	-.633	.796	.141	-.826	.838	-80.30							
.624	-.525	.841	-.135	-.677	.690	-101.27							
.652	-.440	.916	-.617	-.460	.769	-143.31							
.700	-.353												
.749	-.234												
.797	-.110												
.842	-.006												
.914	.122												

TABLE 5.22. MEAN AND FUNDAMENTAL FREQUENCY PRESSURE FOR AGARD CT CASE NO. 9; DYNAMIC INDEX 135

WING MODEL: NLR 7301 SUPERCRITICAL, CHORD= .500 METERS

WING MOTION: PITCHING .50 DEG ABOUT X/C= .403

DYNAMIC INDEX 135 STATIC INDEX 73

M	.752	PTOT	101661.	K	.300
ALPHA	.37	QINF	27671.	FREQ	48.0
RE	6.20E 06	PINF	69850.		

UPPER SURFACE: STEADY DATA (CPU)		UPPER SURFACE: UNSTEADY DATA (CPU,A)					LOWER SURFACE: STEADY DATA (CPL)		LOWER SURFACE: UNSTEADY DATA (CPL,A)				
X/C	CPU	X/C	REAL	IMAG	MAG	PHASE	X/C	CPL	X/C	REAL	IMAG	MAG	PHASE
.023	-.564	.016	-2.848	.783	2.954	164.64	.033	.258					
.045	-1.095	.067	-4.842	2.041	5.255	157.16	.053	-.502					
.070	-1.064	.092	-4.359	2.089	4.833	154.41	.106	-.532					
.094	-1.136	.117	-4.169	1.884	4.575	155.69	.209	-.498					
.122	-1.105	.142	-4.319	2.359	4.921	151.37	.309	-.721					
.147	-1.052	.164	-4.332	2.299	4.904	152.05	.381	-.667					
.168	-1.055	.191	-3.426	1.839	3.888	151.79	.460	-.602					
.195	-1.026	.245	-3.633	2.414	4.404	146.76	.532	-.430					
.249	-.970	.294	-3.410	2.603	4.290	142.66	.614	-.128					
.297	-1.004	.319	-2.741	2.260	3.552	140.50	.684	.068					
.321	-1.007	.343	-2.366	1.972	3.080	140.21	.779	.245					
.348	-1.015	.393	-.013	2.175	2.175	90.34	.874	.357					
.369	-1.052	.424	-1.350	3.648	3.890	110.31							
.396	-1.044	.470	-.025	4.548	4.548	90.33							
.420	-.991	.497	2.392	7.452	7.827	72.21							
.450	-.980	.547	2.404	4.961	5.512	64.15							
.473	-1.015	.595	5.338	3.118	6.182	30.29							
.499	-1.016	.618	1.766	2.768	3.284	57.46							
.524	-1.045	.647	1.058	2.248	2.485	64.81							
.550	-1.085	.697	-.157	.374	.406	112.72							
.578	-1.003	.746	-.236	-.192	.304	-140.89							
.600	-.808	.796	-.038	-.159	.163	-103.52							
.624	-.639	.841	-.580	-.992	1.149	-120.31							
.652	-.492	.916	-.201	-.423	.469	-115.46							
.700	-.365												
.749	-.243												
.797	-.128												
.842	-.023												
.914	.109												

TABLE 5.23. MEAN AND FUNDAMENTAL FREQUENCY PRESSURE FOR AGARD CT CASE NO. 9; DYNAMIC INDEX 149

WING MODEL NLR 7301 SUPERCRITICAL, CHORD= 500 METERS

WING MOTION PITCHING 50 DEG ABOUT X/C= 400

DYNAMIC INDEX 149 STATIC INDEX 76

M	751	PTOT	203236	K	301
ALPHA	.37	QINF	55173	FREQ	49 5
RE	1.14E 07	PINF	139346		

UPPER SURFACE

STEADY DATA		UNSTEADY DATA				
CPU		CPU, A				
X/C	CPU	X/C	REAL	IMAG	MAG	PHASE
.023	-.562	.016	-2.473	.918	2 658	159.66
.045	-1.048	.067	-4.268	2 360	4 877	151 07
.070	-1.036	.092	-3.426	2 121	4 030	148 25
094	-1 131	.117	-3 423	2 076	4 003	148 77
122	-1 097	142	-3 770	2 815	4 705	143 26
147	-1.043	.164	-3 641	2 704	4 535	143 41
.168	-1 059	.191	-2 727	2 056	3 415	143 00
.195	-1.021	245	-3 196	3 397	4 [illegible]	133 27
249	-.956	294	-2.441	2 774	3 695	131 36
.297	- 991	.319	-1 867	2 535	3 148	126 38
321	-1 000	.343	-1.420	2 [illegible]7	3 145	116 85
348	-1 009	.393	1 182	3 937	4 110	73 29
369	-1 052	424	3 147	10 268	10 739	72 97
.396	-1 052	470	3 626	7 643	8 460	64 62
420	-.973	.497	1.944	3 175	3 723	58 52
450	- 920	.547	5 093	2 708	5 768	28 00
473	- 866	595	-8.421	062	8 422	179 59
499	-.905	618	-4 367	-2 372	4 970	-151 51
524	- 949	647	-2 029	-2 051	2 00[illegible]	-134 70
550	- 999	.697	-1.378	-2 142	2 547	-122 76
578	- 784	.746	- 288	-1 095	1 132	-104 75
600	- 633	.796	-.065	- 575	578	-96 49
624	- 525	84[illegible]	- 170	- 648	659	-104 69
.652	- 440	.916	- 356	- 173	396	-154 12
700	- 353					
.749	-.22[illegible]					
797	- 110					
842	- 006					
914	.122					

LOWER SURFACE

STEADY DATA		UNSTEADY DATA				
CPL		CPL, A				
X/C	CPL	X/C	REAL	IMAG	MAG	PHASE
.033	- 434					
.053	- 474					
106	-.531					
209	- 516					
.309	- 750					
.381	- 627					
460	- 626					
532	- 440					
614	-.133					
684	.066					
779	.238					
874	348					

TABLE 5.24. INSTANTANEOUS PRESSURES AT THE UPPER SURFACE, HIGH REYNOLDS NUMBER DATA; CT CASE 6; DYNAMIC INDEX 144

I	J=	1	2	3	4	5	6	7	8	9	10	11	12	13
	PHASE,DEG=	38.7	44.7	50.7	56.7	62.7	68.7	74.7	80.7	86.7	92.7	98.7	104.7	110.7
	ALPHA,DEG=	.398	.365	.327	.282	.233	.181	.129	.076	.024	-.029	-.082	-.134	-.184
I	X/C	* *	* * *	* *	* *	* *	* * *	CP *	* *	* * *	* *	* *	* *	* *
1	.016	-.267	-.266	-.263	-.260	-.257	-.254	-.249	-.246	-.242	-.237	-.232	-.228	-.222
2	.067	-1.104	-1.102	-1.098	-1.094	-1.089	-1.085	-1.079	-1.073	-1.066	-1.058	-1.050	-1.041	-1.031
3	.092	-1.190	-1.188	-1.186	-1.183	-1.179	-1.175	-1.170	-1.164	-1.158	-1.151	-1.144	-1.138	-1.130
4	.117	-1.172	-1.170	-1.167	-1.163	-1.159	-1.154	-1.148	-1.142	-1.136	-1.128	-1.121	-1.113	-1.104
5	.142	-1.128	-1.125	-1.122	-1.118	-1.113	-1.107	-1.100	-1.093	-1.086	-1.077	-1.069	-1.062	-1.054
6	.164	-1.137	-1.134	-1.131	-1.127	-1.122	-1.116	-1.109	-1.103	-1.094	-1.086	-1.078	-1.070	-1.061
7	.191	-1.102	-1.099	-1.096	-1.092	-1.087	-1.081	-1.074	-1.069	-1.062	-1.056	-1.049	-1.042	-1.034
8	.245	-1.047	-1.045	-1.043	-1.038	-1.034	-1.028	-1.021	-1.015	-1.007	-.999	-.990	-.982	-.972
9	.294	-1.101	-1.099	-1.096	-1.091	-1.086	-1.080	-1.073	-1.065	-1.056	-1.047	-1.038	-1.030	-1.021
10	.319	-1.111	-1.108	-1.106	-1.101	-1.096	-1.091	-1.085	-1.077	-1.070	-1.062	-1.053	-1.046	-1.038
11	.343	-1.131	-1.128	-1.126	-1.121	-1.116	-1.111	-1.105	-1.098	-1.092	-1.084	-1.077	-1.071	-1.062
12	.393	-1.188	-1.187	-1.184	-1.182	-1.178	-1.174	-1.169	-1.163	-1.157	-1.150	-1.142	-1.134	-1.125
13	.424	-1.113	-1.111	-1.108	-1.105	-1.100	-1.095	-1.087	-1.080	-1.071	-1.060	-1.048	-1.035	-1.022
14	.470	-1.030	-1.027	-1.025	-1.020	-1.016	-1.009	-1.002	-.992	-.981	-.971	-.957	-.937	-.910
15	.497	-1.073	-1.070	-1.067	-1.062	-1.058	-1.050	-1.041	-1.030	-1.019	-1.002	-.976	-.932	-.873
16	.547	-1.187	-1.182	-1.178	-1.174	-1.164	-1.152	-1.128	-1.094	-1.038	-1.012	-1.015	-1.018	-1.017
17	.595	-.519	-.518	-.516	-.513	-.505	-.495	-.489	-.480	-.480	-.479	-.479	-.481	-.478
18	.618	-.424	-.423	-.422	-.417	-.412	-.406	-.403	-.398	-.399	-.396	-.398	-.402	-.404
19	.647	-.420	-.420	-.417	-.415	-.412	-.408	-.408	-.407	-.407	-.409	-.409	-.414	-.419
20	.697	-.342	-.342	-.342	-.340	-.340	-.340	-.342	-.343	-.347	-.349	-.351	-.356	-.361
21	.746	-.229	-.230	-.230	-.231	-.230	-.232	-.232	-.234	-.235	-.236	-.239	-.241	-.243
22	.796	-.109	-.108	-.108	-.107	-.107	-.107	-.108	-.108	-.109	-.109	-.110	-.110	-.110
23	.841	-.007	-.006	-.006	-.006	-.005	-.006	-.006	-.005	-.006	-.005	-.005	-.006	-.005
24	.916	.135	.137	.129	.138	.135	.137	.124	.129	.132	.140	.138	.138	.140

TABLE 5.24. CONTINUED.

	J=	14	15	16	17	18	19	20	21	22	23	24	25	26
	PHASE,DEG=	116.7	122.7	128.7	134.7	140.7	146.7	152.7	158.7	164.7	170.7	176.7	182.7	188.7
	ALPHA,DEG=	-.232	-.276	-.315	-.349	-.382	-.413	-.439	-.460	-.474	-.475	-.487	-.487	-.483
I	X/C							CP						
1	.016	-.217	-.213	-.208	-.204	-.199	-.194	-.190	-.187	-.184	-.181	-.178	-.176	-.175
2	.067	-1.023	-1.015	-1.006	-1.001	-.995	-.988	-.982	-.976	-.971	-.964	-.959	-.957	-.954
3	.092	-1.123	-1.117	-1.111	-1.105	-1.099	-1.091	-1.084	-1.078	-1.073	-1.067	-1.064	-1.061	-1.059
4	.117	-1.096	-1.091	-1.085	-1.079	-1.074	-1.066	-1.059	-1.052	-1.047	-1.041	-1.037	-1.034	-1.031
5	.142	-1.045	-1.037	-1.028	-1.018	-1.010	-1.001	-.993	-.986	-.980	-.973	-.968	-.964	-.960
6	.164	-1.052	-1.044	-1.035	-1.028	-1.021	-1.014	-1.007	-1.001	-.996	-.990	-.986	-.983	-.979
7	.191	-1.027	-1.020	-1.013	-1.007	-1.001	-.993	-.987	-.980	-.975	-.968	-.963	-.959	-.955
8	.245	-.961	-.950	-.939	-.929	-.919	-.908	-.899	-.891	-.884	-.876	-.869	-.864	-.858
9	.294	-1.011	-1.002	-.992	-.983	-.976	-.965	-.953	-.944	-.934	-.922	-.914	-.901	-.886
10	.319	-1.030	-1.022	-1.013	-1.004	-.997	-.986	-.976	-.966	-.954	-.937	-.922	-.902	-.867
11	.343	-1.053	-1.044	-1.033	-1.021	-1.011	-.997	-.980	-.962	-.944	-.907	-.852	-.811	-.786
12	.393	-1.114	-1.101	-1.087	-1.069	-1.050	-1.024	-.972	-.926	-.906	-.900	-.901	-.897	-.892
13	.424	-1.006	-.984	-.955	-.898	-.846	-.830	-.849	-.846	-.833	-.815	-.790	-.760	-.750
14	.470	-.854	-.804	-.787	-.796	-.792	-.787	-.779	-.752	-.710	-.682	-.659	-.650	-.646
15	.497	-.857	-.860	-.859	-.859	-.854	-.838	-.815	-.739	-.686	-.663	-.671	-.687	-.704
16	.547	-1.005	-.997	-.984	-.948	-.858	-.797	-.798	-.801	-.819	-.841	-.860	-.893	-.909
17	.595	-.485	-.499	-.513	-.552	-.608	-.682	-.752	-.794	-.835	-.857	-.867	-.892	-.899
18	.618	-.414	-.432	-.441	-.459	-.479	-.527	-.585	-.680	-.758	-.793	-.808	-.784	-.790
19	.647	-.425	-.436	-.441	-.450	-.460	-.461	-.470	-.481	-.496	-.511	-.531	-.525	-.531
20	.697	-.364	-.371	-.374	-.376	-.381	-.381	-.378	-.380	-.376	-.374	-.372	-.370	-.372
21	.746	-.246	-.249	-.251	-.251	-.252	-.253	-.254	-.254	-.251	-.248	-.248	-.247	-.247
22	.796	-.112	-.113	-.113	-.113	-.113	-.115	-.114	-.115	-.115	-.115	-.116	-.115	-.116
23	.841	-.006	-.006	-.007	-.006	-.006	-.008	-.007	-.007	-.008	-.010	-.010	-.011	-.012
24	.916	.129	.108	.131	.119	.120	.139	.089	.106	.110	.115	.124	.095	.101

	J=	27	28	29	30	31	32	33	34	35	36	37	38	39
	PHASE,DEG=	194.7	200.7	206.7	212.7	218.7	224.7	230.7	236.7	242.7	248.7	254.7	260.7	266.7
	ALPHA,DEG=	-.475	-.464	-.448	-.426	-.397	-.362	-.321	-.278	-.229	-.183	-.134	-.084	-.031
I	X/C							CP						
1	.016	-.173	-.173	-.172	-.173	-.174	-.176	-.178	-.182	-.186	-.189	-.194	-.199	-.203
2	.067	-.951	-.950	-.949	-.950	-.952	-.955	-.959	-.965	-.972	-.979	-.986	-.993	-1.000
3	.092	-1.056	-1.056	-1.055	-1.055	-1.056	-1.059	-1.062	-1.066	-1.071	-1.078	-1.085	-1.094	-1.101
4	.117	-1.029	-1.028	-1.027	-1.027	-1.029	-1.032	-1.035	-1.041	-1.046	-1.054	-1.062	-1.071	-1.079
5	.142	-.957	-.956	-.955	-.954	-.956	-.960	-.964	-.970	-.977	-.984	-.993	-1.003	-1.012
6	.164	-.977	-.976	-.975	-.975	-.976	-.979	-.982	-.987	-.993	-1.000	-1.007	-1.015	-1.024
7	.191	-.952	-.950	-.949	-.949	-.949	-.953	-.956	-.962	-.968	-.976	-.984	-.992	-1.001
8	.245	-.853	-.848	-.844	-.841	-.840	-.843	-.850	-.860	-.870	-.878	-.888	-.900	-.911
9	.294	-.867	-.840	-.796	-.759	-.746	-.742	-.751	-.769	-.811	-.878	-.925	-.947	-.963
10	.319	-.826	-.798	-.781	-.776	-.776	-.776	-.779	-.793	-.803	-.831	-.896	-.952	-.979
11	.343	-.777	-.769	-.772	-.784	-.792	-.795	-.798	-.799	-.796	-.799	-.818	-.897	-.959
12	.393	-.885	-.883	-.891	-.901	-.912	-.919	-.924	-.927	-.923	-.919	-.910	-.900	-.901
13	.424	-.759	-.789	-.807	-.829	-.840	-.848	-.854	-.853	-.852	-.841	-.833	-.822	-.831
14	.470	-.646	-.660	-.693	-.741	-.772	-.785	-.791	-.793	-.790	-.783	-.772	-.760	-.747
15	.497	-.713	-.723	-.731	-.762	-.805	-.836	-.846	-.850	-.849	-.844	-.833	-.811	-.786
16	.547	-.914	-.909	-.905	-.899	-.891	-.902	-.920	-.938	-.946	-.939	-.929	-.906	-.885
17	.595	-.906	-.898	-.896	-.892	-.881	-.879	-.878	-.875	-.876	-.879	-.881	-.882	-.880
18	.618	-.794	-.804	-.812	-.795	-.790	-.757	-.729	-.718	-.705	-.705	-.714	-.738	-.758
19	.647	-.530	-.534	-.532	-.519	-.508	-.492	-.480	-.479	-.475	-.477	-.479	-.481	-.483
20	.697	-.370	-.372	-.369	-.368	-.369	-.367	-.366	-.369	-.366	-.365	-.366	-.366	-.368
21	.746	-.247	-.248	-.245	-.246	-.245	-.244	-.245	-.246	-.245	-.245	-.246	-.244	-.246
22	.796	-.116	-.117	-.117	-.117	-.116	-.116	-.116	-.115	-.115	-.115	-.117	-.115	-.116
23	.841	-.013	-.013	-.014	-.015	-.013	-.012	-.013	-.011	-.015	-.011	-.013	-.012	-.012
24	.916	.104	.115	.125	.114	.124	.122	.113	.123	.118	.123	.126	.127	.127

	J=	40	41	42	43	44	45	46	47	48	49	50	51	52
	PHASE,DEG=	272.7	278.7	284.7	290.7	296.7	302.7	308.7	314.7	320.7	326.7	332.7	338.7	344.7
	ALPHA,DEG=	.024	.076	.131	.181	.229	.274	.315	.353	.386	.416	.440	.459	.473
I	X/C							CP						
1	.016	-.208	-.213	-.219	-.224	-.230	-.234	-.238	-.243	-.247	-.251	-.255	-.258	-.261
2	.067	-1.008	-1.016	-1.025	-1.036	-1.045	-1.054	-1.063	-1.070	-1.076	-1.082	-1.086	-1.091	-1.095
3	.092	-1.109	-1.115	-1.122	-1.131	-1.138	-1.145	-1.152	-1.159	-1.165	-1.171	-1.175	-1.179	-1.183
4	.117	-1.086	-1.093	-1.099	-1.107	-1.116	-1.123	-1.131	-1.139	-1.145	-1.151	-1.155	-1.160	-1.164
5	.142	-1.023	-1.033	-1.043	-1.053	-1.062	-1.070	-1.079	-1.087	-1.094	-1.102	-1.107	-1.113	-1.118
6	.164	-1.032	-1.042	-1.051	-1.061	-1.071	-1.079	-1.088	-1.097	-1.104	-1.111	-1.117	-1.122	-1.126
7	.191	-1.008	-1.016	-1.024	-1.032	-1.040	-1.048	-1.056	-1.063	-1.069	-1.075	-1.080	-1.085	-1.090
8	.245	-.924	-.936	-.949	-.961	-.973	-.984	-.994	-1.003	-1.011	-1.018	-1.024	-1.030	-1.035
9	.294	-.977	-.990	-1.002	-1.011	-1.021	-1.032	-1.041	-1.050	-1.059	-1.068	-1.076	-1.082	-1.087
10	.319	-.994	-1.007	-1.019	-1.029	-1.038	-1.046	-1.056	-1.064	-1.072	-1.080	-1.086	-1.092	-1.097
11	.343	-.995	-1.017	-1.033	-1.047	-1.058	-1.069	-1.078	-1.084	-1.091	-1.099	-1.105	-1.111	-1.116
12	.393	-.915	-.952	-1.009	-1.052	-1.081	-1.101	-1.117	-1.129	-1.140	-1.150	-1.157	-1.164	-1.169
13	.424	-.849	-.857	-.864	-.909	-.967	-1.008	-1.032	-1.048	-1.062	-1.075	-1.085	-1.092	-1.098
14	.470	-.771	-.793	-.805	-.814	-.811	-.819	-.876	-.927	-.961	-.981	-.992	-1.002	-1.009
15	.497	-.767	-.802	-.850	-.868	-.873	-.876	-.875	-.893	-.952	-.999	-1.016	-1.038	-1.043
16	.547	-.873	-.861	-.853	-.902	-.979	-1.025	-1.039	-1.041	-1.042	-1.043	-1.042	-1.077	-1.117
17	.595	-.874	-.855	-.811	-.749	-.668	-.594	-.562	-.556	-.548	-.534	-.535	-.532	-.533
18	.618	-.743	-.687	-.623	-.529	-.472	-.444	-.433	-.425	-.420	-.418	-.417	-.418	-.423
19	.647	-.476	-.465	-.453	-.443	-.440	-.434	-.428	-.425	-.421	-.419	-.417	-.416	-.419
20	.697	-.363	-.365	-.363	-.365	-.367	-.364	-.360	-.358	-.356	-.352	-.350	-.347	-.346
21	.746	-.243	-.243	-.243	-.243	-.244	-.244	-.242	-.240	-.239	-.236	-.237	-.236	-.234
22	.796	-.114	-.113	-.112	-.112	-.111	-.112	-.112	-.111	-.112	-.110	-.111	-.112	-.110
23	.841	-.011	-.010	-.008	-.008	-.010	-.007	-.008	-.006	-.008	-.007	-.007	-.008	-.008
24	.916	.114	.114	.124	.128	.126	.130	.123	.133	.137	.126	.131	.130	.118

TABLE 5.24. CONCLUDED

I	X/C	J= 53	54	55	56	57	58	59	60	61	62	63	64	65
	PHASE,DEG=	350.7	356.7	362.7	368.7	374.7	380.7	386.7	392.7	398.7	404.7	410.7	416.7	422.7
	ALPHA,DEG=	.482	.486	.467	.483	.476	.465	.448	.427	.403	.372	.335	.291	.242
		CP												
1	.016	-.264	-.266	-.267	-.268	-.269	-.269	-.270	-.268	-.267	-.265	-.264	-.262	-.258
2	.067	-1.099	-1.102	-1.104	-1.106	-1.108	-1.108	-1.108	-1.107	-1.105	-1.102	-1.099	-1.096	-1.091
3	.092	-1.186	-1.188	-1.190	-1.191	-1.192	-1.193	-1.193	-1.192	-1.191	-1.190	-1.187	-1.185	-1.181
4	.117	-1.168	-1.171	-1.172	-1.174	-1.175	-1.175	-1.174	-1.174	-1.173	-1.171	-1.168	-1.165	-1.161
5	.142	-1.122	-1.125	-1.127	-1.129	-1.130	-1.131	-1.130	-1.130	-1.128	-1.126	-1.123	-1.120	-1.115
6	.164	-1.131	-1.134	-1.136	-1.138	-1.139	-1.140	-1.139	-1.138	-1.137	-1.135	-1.132	-1.128	-1.123
7	.191	-1.095	-1.098	-1.101	-1.103	-1.104	-1.105	-1.104	-1.103	-1.101	-1.099	-1.097	-1.093	-1.088
8	.245	-1.039	-1.043	-1.045	-1.047	-1.048	-1.049	-1.049	-1.048	-1.046	-1.044	-1.043	-1.039	-1.034
9	.294	-1.092	-1.096	-1.099	-1.101	-1.102	-1.103	-1.104	-1.102	-1.100	-1.098	-1.095	-1.091	-1.086
10	.319	-1.101	-1.105	-1.108	-1.110	-1.112	-1.113	-1.113	-1.112	-1.110	-1.108	-1.106	-1.101	-1.097
11	.343	-1.120	-1.125	-1.128	-1.130	-1.132	-1.133	-1.133	-1.132	-1.130	-1.129	-1.126	-1.121	-1.117
12	.393	-1.174	-1.178	-1.181	-1.184	-1.186	-1.188	-1.188	-1.189	-1.188	-1.187	-1.185	-1.182	-1.179
13	.424	-1.104	-1.107	-1.110	-1.113	-1.114	-1.114	-1.116	-1.115	-1.113	-1.112	-1.108	-1.105	-1.101
14	.470	-1.018	-1.021	-1.026	-1.029	-1.031	-1.032	-1.032	-1.032	-1.030	-1.028	-1.025	-1.021	-1.017
15	.497	-1.053	-1.061	-1.066	-1.070	-1.073	-1.074	-1.075	-1.075	-1.074	-1.071	-1.068	-1.063	-1.058
16	.547	-1.147	-1.165	-1.174	-1.180	-1.184	-1.186	-1.189	-1.187	-1.186	-1.183	-1.180	-1.174	-1.165
17	.595	-.531	-.529	-.532	-.530	-.529	-.529	-.528	-.522	-.523	-.519	-.514	-.508	-.499
18	.618	-.422	-.424	-.428	-.434	-.430	-.429	-.429	-.428	-.425	-.424	-.420	-.415	-.408
19	.647	-.417	-.421	-.423	-.426	-.425	-.425	-.425	-.424	-.420	-.420	-.417	-.412	-.410
20	.697	-.344	-.343	-.344	-.347	-.345	-.344	-.343	-.345	-.342	-.343	-.340	-.339	-.340
21	.746	-.232	-.230	-.232	-.233	-.231	-.232	-.230	-.232	-.231	-.230	-.228	-.229	-.229
22	.796	-.109	-.109	-.109	-.110	-.110	-.109	-.108	-.108	-.109	-.107	-.106	-.107	-.106
23	.841	-.006	-.007	-.006	-.006	-.006	-.007	-.007	-.008	-.007	-.006	-.004	-.005	-.005
24	.916	.124	.136	.128	.117	.132	.137	.136	.125	.138	.138	.133	.137	.140

TABLE 5.25. INSTANTANEOUS PRESSURES AT THE UPPER SURFACE, HIGH REYNOLDS NUMBER DATA; CT CASE 8; DYNAMIC INDEX 148

I	X/C	J= 1	2	3	4	5	6	7	8	9	10	11	12	13
	PHASE,DEG=	1.5	7.5	13.5	19.5	25.5	31.5	37.5	43.5	49.5	55.5	61.5	67.5	73.5
	ALPHA,DEG=	.490	.483	.471	.456	.437	.414	.388	.358	.323	.285	.244	.199	.151
		CP												
1	.016	-.246	-.247	-.248	-.249	-.249	-.249	-.250	-.249	-.248	-.247	-.246	-.244	-.242
2	.067	-1.074	-1.075	-1.077	-1.078	-1.078	-1.078	-1.078	-1.078	-1.078	-1.077	-1.075	-1.073	-1.070
3	.092	-1.161	-1.163	-1.165	-1.166	-1.167	-1.167	-1.167	-1.167	-1.167	-1.167	-1.165	-1.163	-1.161
4	.117	-1.140	-1.142	-1.143	-1.145	-1.145	-1.146	-1.146	-1.146	-1.146	-1.145	-1.143	-1.141	-1.139
5	.142	-1.087	-1.090	-1.092	-1.094	-1.095	-1.096	-1.097	-1.096	-1.096	-1.096	-1.094	-1.092	-1.090
6	.164	-1.098	-1.100	-1.103	-1.105	-1.106	-1.107	-1.107	-1.107	-1.107	-1.106	-1.105	-1.103	-1.100
7	.191	-1.061	-1.064	-1.065	-1.067	-1.068	-1.068	-1.069	-1.069	-1.069	-1.069	-1.067	-1.066	-1.064
8	.245	-.995	-.998	-1.003	-1.005	-1.007	-1.008	-1.009	-1.009	-1.010	-1.009	-1.008	-1.007	-1.005
9	.294	-1.021	-1.025	-1.029	-1.031	-1.033	-1.036	-1.038	-1.039	-1.041	-1.039	-1.039	-1.038	-1.037
10	.319	-1.027	-1.030	-1.035	-1.037	-1.040	-1.042	-1.044	-1.044	-1.046	-1.045	-1.045	-1.044	-1.043
11	.343	-1.034	-1.038	-1.041	-1.042	-1.046	-1.048	-1.050	-1.051	-1.053	-1.052	-1.052	-1.051	-1.050
12	.393	-1.079	-1.088	-1.097	-1.104	-1.110	-1.116	-1.120	-1.124	-1.127	-1.130	-1.132	-1.133	-1.134
13	.424	-1.014	-1.032	-1.042	-1.050	-1.057	-1.062	-1.067	-1.071	-1.074	-1.075	-1.076	-1.077	-1.076
14	.470	-.825	-.836	-.866	-.902	-.934	-.954	-.968	-.979	-.983	-.986	-.989	-.990	-.991
15	.497	-.883	-.889	-.894	-.896	-.905	-.924	-.955	-.983	-1.001	-1.015	-1.025	-1.029	-1.033
16	.547	-1.015	-1.046	-1.066	-1.078	-1.092	-1.102	-1.108	-1.105	-1.103	-1.100	-1.097	-1.095	-1.098
17	.595	-.809	-.773	-.735	-.692	-.657	-.629	-.612	-.598	-.584	-.574	-.567	-.562	-.557
18	.618	-.573	-.534	-.503	-.482	-.468	-.461	-.457	-.451	-.445	-.444	-.441	-.438	-.438
19	.647	-.449	-.443	-.435	-.433	-.430	-.429	-.426	-.421	-.420	-.419	-.417	-.416	-.418
20	.697	-.352	-.349	-.348	-.347	-.347	-.345	-.341	-.341	-.341	-.338	-.336	-.338	-.340
21	.746	-.234	-.232	-.231	-.233	-.232	-.229	-.228	-.229	-.229	-.227	-.228	-.229	-.230
22	.796	-.108	-.108	-.108	-.109	-.106	-.105	-.106	-.106	-.106	-.105	-.108	-.107	-.107
23	.841	-.007	-.006	-.006	-.005	-.003	-.004	-.004	-.005	-.005	-.006	-.006	-.006	-.005
24	.916	.118	.118	.117	.121	.123	.124	.126	.127	.129	.127	.128	.128	.129

I	X/C	J= 14	15	16	17	18	19	20	21	22	23	24	25	26
	PHASE,DEG=	79.5	85.5	91.5	97.5	103.5	109.5	115.5	121.5	127.5	133.5	139.5	145.5	151.5
	ALPHA,DEG=	.101	.049	-.003	-.057	-.110	-.163	-.213	-.261	-.307	-.349	-.387	-.420	-.448
		CP												
1	.016	-.240	-.238	-.236	-.233	-.231	-.227	-.224	-.222	-.219	-.216	-.214	-.211	-.207
2	.067	-1.068	-1.064	-1.060	-1.057	-1.052	-1.046	-1.040	-1.034	-1.028	-1.023	-1.017	-1.012	-1.007
3	.092	-1.158	-1.155	-1.152	-1.148	-1.145	-1.140	-1.135	-1.131	-1.127	-1.122	-1.117	-1.113	-1.110
4	.117	-1.136	-1.134	-1.130	-1.126	-1.122	-1.117	-1.112	-1.107	-1.102	-1.097	-1.092	-1.088	-1.085
5	.142	-1.087	-1.083	-1.079	-1.076	-1.072	-1.067	-1.062	-1.057	-1.052	-1.047	-1.042	-1.037	-1.031
6	.164	-1.097	-1.094	-1.090	-1.086	-1.082	-1.078	-1.072	-1.068	-1.062	-1.056	-1.051	-1.046	-1.041
7	.191	-1.062	-1.060	-1.056	-1.054	-1.051	-1.046	-1.042	-1.038	-1.034	-1.030	-1.026	-1.022	-1.018
8	.245	-1.003	-1.000	-.997	-.994	-.990	-.984	-.980	-.975	-.969	-.964	-.959	-.953	-.947
9	.294	-1.035	-1.031	-1.029	-1.024	-1.021	-1.015	-1.012	-1.007	-1.002	-.998	-.995	-.987	-.979
10	.319	-1.041	-1.036	-1.036	-1.032	-1.029	-1.024	-1.021	-1.017	-1.012	-1.007	-1.003	-.998	-.994
11	.343	-1.049	-1.046	-1.045	-1.042	-1.039	-1.034	-1.032	-1.029	-1.025	-1.021	-1.018	-1.013	-1.009
12	.393	-1.134	-1.134	-1.133	-1.132	-1.131	-1.129	-1.127	-1.124	-1.121	-1.118	-1.115	-1.111	-1.106
13	.424	-1.074	-1.072	-1.071	-1.069	-1.064	-1.060	-1.056	-1.051	-1.046	-1.041	-1.034	-1.026	-1.021
14	.470	-.989	-.989	-.988	-.986	-.981	-.978	-.973	-.969	-.964	-.959	-.950	-.941	-.931
15	.497	-1.033	-1.034	-1.034	-1.031	-1.027	-1.024	-1.017	-1.011	-1.003	-.993	-.979	-.962	-.937
16	.547	-1.102	-1.103	-1.100	-1.097	-1.099	-1.090	-1.086	-1.083	-1.077	-1.071	-1.070	-1.072	-1.072
17	.595	-.554	-.552	-.548	-.542	-.535	-.527	-.523	-.518	-.512	-.508	-.505	-.498	-.495
18	.618	-.437	-.438	-.434	-.430	-.427	-.426	-.425	-.424	-.421	-.422	-.422	-.422	-.423
19	.647	-.417	-.417	-.413	-.410	-.410	-.411	-.411	-.409	-.410	-.410	-.413	-.414	-.417
20	.697	-.339	-.339	-.335	-.334	-.334	-.337	-.336	-.335	-.336	-.338	-.340	-.344	-.345
21	.746	-.230	-.227	-.226	-.227	-.229	-.229	-.230	-.230	-.231	-.232	-.234	-.236	-.240
22	.796	-.106	-.105	-.105	-.106	-.106	-.106	-.107	-.106	-.107	-.107	-.107	-.110	-.110
23	.841	-.003	-.001	-.001	-.000	-.000	-.002	-.001	-.002	-.003	-.004	-.006	-.007	-.007
24	.916	.130	.131	.132	.131	.132	.131	.132	.115	.132	.133	.125	.132	.133

TABLE 5.25. CONCLUDED.

	J=	27	28	29	30	31	32	33	34	35	36	37	38	39
	PHASE,DEG=	157.5	163.5	169.5	175.5	181.5	187.5	193.5	199.5	205.5	211.5	217.5	223.5	229.5
	ALPHA,DEG=	-.470	-.486	-.495	-.498	-.495	-.487	-.474	-.457	-.437	-.413	-.386	-.355	-.320
I	X/C	* *	* *	* *	* *	* *	* *	* CP *	* *	* *	* *	* *	* *	* *
1	.016	-.205	-.203	-.201	-.199	-.198	-.197	-.196	-.195	-.196	-.196	-.195	-.196	-.197
2	.067	-1.003	-1.000	-.997	-.994	-.992	-.990	-.989	-.988	-.988	-.986	-.987	-.987	-.988
3	.092	-1.107	-1.104	-1.101	-1.098	-1.096	-1.094	-1.092	-1.090	-1.089	-1.088	-1.087	-1.087	-1.087
4	.117	-1.082	-1.080	-1.077	-1.075	-1.072	-1.070	-1.069	-1.067	-1.066	-1.065	-1.065	-1.065	-1.065
5	.142	-1.026	-1.022	-1.017	-1.013	-1.009	-1.006	-1.004	-1.002	-1.001	-.999	-.998	-.998	-.999
6	.164	-1.037	-1.033	-1.029	-1.026	-1.023	-1.021	-1.019	-1.018	-1.016	-1.014	-1.014	-1.013	-1.013
7	.191	-1.014	-1.011	-1.008	-1.006	-1.003	-1.001	-.998	-.997	-.995	-.993	-.993	-.992	-.992
8	.245	-.941	-.937	-.931	-.927	-.922	-.919	-.915	-.912	-.908	-.906	-.904	-.903	-.902
9	.294	-.976	-.974	-.969	-.965	-.961	-.959	-.956	-.953	-.949	-.947	-.944	-.942	-.940
10	.319	-.991	-.988	-.985	-.980	-.977	-.974	-.972	-.969	-.965	-.963	-.959	-.957	-.955
11	.343	-1.005	-1.001	-.997	-.991	-.987	-.983	-.980	-.975	-.970	-.966	-.961	-.957	-.954
12	.393	-1.102	-1.097	-1.092	-1.086	-1.080	-1.074	-1.068	-1.062	-1.054	-1.046	-1.038	-1.030	-1.020
13	.424	-1.015	-1.008	-.999	-.989	-.977	-.965	-.952	-.924	-.892	-.857	-.836	-.832	-.836
14	.470	-.918	-.901	-.874	-.833	-.804	-.797	-.794	-.798	-.801	-.802	-.804	-.806	-.806
15	.497	-.906	-.882	-.867	-.869	-.873	-.877	-.878	-.879	-.881	-.879	-.878	-.879	-.876
16	.547	-1.072	-1.070	-1.067	-1.063	-1.052	-1.040	-1.023	-1.007	-.984	-.960	-.941	-.909	-.882
17	.595	-.496	-.497	-.500	-.502	-.505	-.513	-.531	-.538	-.556	-.578	-.597	-.624	-.652
18	.618	-.429	-.431	-.437	-.442	-.450	-.460	-.469	-.478	-.491	-.502	-.516	-.526	-.538
19	.647	-.420	-.426	-.427	-.433	-.439	-.446	-.452	-.457	-.465	-.464	-.470	-.475	-.479
20	.697	-.353	-.353	-.359	-.363	-.366	-.371	-.375	-.378	-.377	-.381	-.384	-.383	-.385
21	.746	-.241	-.241	-.244	-.245	-.249	-.251	-.252	-.251	-.253	-.256	-.256	-.255	-.258
22	.796	-.110	-.111	-.111	-.113	-.115	-.115	-.115	-.115	-.117	-.117	-.117	-.119	-.119
23	.841	-.007	-.009	-.009	-.009	-.009	-.009	-.006	-.007	-.009	-.010	-.009	-.010	-.011
24	.916	.127	.134	.133	.118	.125	.134	.111	.130	.124	.123	.130	.129	.128

	J=	40	41	42	43	44	45	46	47	48	49	50	51	52
	PHASE,DEG=	235.5	241.5	247.5	253.5	259.5	265.5	271.5	277.5	283.5	289.5	295.5	301.5	307.5
	ALPHA,DEG=	-.281	-.240	-.194	-.147	-.096	-.044	.009	.062	.114	.167	.216	.263	.307
I	X/C	* *	* *	* *	* *	* *	* *	* CP *	* *	* *	* *	* *	* *	* *
1	.016	-.197	-.199	-.201	-.202	-.204	-.207	-.209	-.211	-.214	-.217	-.219	-.222	-.225
2	.067	-.989	-.991	-.992	-.995	-.997	-1.001	-1.004	-1.008	-1.012	-1.017	-1.021	-1.025	-1.032
3	.092	-1.088	-1.090	-1.093	-1.095	-1.098	-1.101	-1.104	-1.108	-1.111	-1.114	-1.117	-1.121	-1.126
4	.117	-1.067	-1.068	-1.070	-1.072	-1.075	-1.078	-1.081	-1.084	-1.087	-1.091	-1.093	-1.097	-1.102
5	.142	-1.000	-1.001	-1.003	-1.005	-1.007	-1.011	-1.015	-1.019	-1.024	-1.030	-1.034	-1.039	-1.045
6	.164	-1.015	-1.016	-1.017	-1.019	-1.022	-1.025	-1.028	-1.031	-1.035	-1.039	-1.043	-1.048	-1.054
7	.191	-.993	-.993	-.995	-.996	-.999	-1.002	-1.004	-1.006	-1.010	-1.014	-1.016	-1.020	-1.024
8	.245	-.902	-.901	-.903	-.904	-.908	-.910	-.913	-.917	-.922	-.927	-.931	-.937	-.942
9	.294	-.940	-.938	-.938	-.940	-.943	-.944	-.947	-.951	-.956	-.959	-.962	-.968	-.973
10	.319	-.954	-.952	-.951	-.953	-.954	-.955	-.957	-.960	-.964	-.966	-.970	-.975	-.980
11	.343	-.951	-.947	-.945	-.945	-.945	-.945	-.947	-.951	-.955	-.958	-.964	-.971	-.978
12	.393	-1.006	-.990	-.973	-.958	-.946	-.936	-.928	-.923	-.922	-.923	-.925	-.932	-.943
13	.424	-.839	-.842	-.847	-.848	-.849	-.851	-.852	-.853	-.851	-.849	-.852	-.854	-.857
14	.470	-.807	-.807	-.806	-.800	-.793	-.784	-.779	-.772	-.766	-.767	-.764	-.767	-.771
15	.497	-.873	-.862	-.845	-.837	-.827	-.807	-.792	-.782	-.779	-.776	-.778	-.786	-.790
16	.547	-.864	-.852	-.844	-.838	-.843	-.852	-.860	-.866	-.872	-.881	-.891	-.899	-.900
17	.595	-.679	-.712	-.747	-.779	-.803	-.821	-.835	-.844	-.854	-.863	-.874	-.876	-.878
18	.618	-.557	-.580	-.602	-.632	-.667	-.696	-.724	-.753	-.777	-.798	-.805	-.809	-.809
19	.647	-.483	-.486	-.488	-.493	-.493	-.495	-.499	-.502	-.503	-.504	-.506	-.505	-.506
20	.697	-.388	-.387	-.388	-.386	-.384	-.384	-.384	-.382	-.379	-.378	-.377	-.376	-.372
21	.746	-.258	-.259	-.256	-.256	-.255	-.255	-.254	-.252	-.252	-.250	-.250	-.248	-.247
22	.796	-.120	-.119	-.119	-.119	-.119	-.120	-.118	-.119	-.119	-.119	-.119	-.117	-.117
23	.841	-.010	-.012	-.013	-.011	-.013	-.014	-.013	-.014	-.013	-.015	-.015	-.017	-.018
24	.916	.129	.127	.126	.125	.122	.123	.122	.121	.120	.120	.121	.119	.119

	J=	53	54	55	56	57	58	59	60	61	62	63	64	65
	PHASE,DEG=	313.5	319.5	325.5	331.5	337.5	343.5	349.5	355.5	361.5	367.5	373.5	379.5	385.5
	ALPHA,DEG=	.347	.383	.415	.438	.463	.479	.488	.492	.491	.484	.473	.458	.439
I	X/C	* *	* *	* *	* *	* *	* *	* CP *	* *	* *	* *	* *	* *	* *
1	.016	-.227	-.230	-.233	-.235	-.238	-.240	-.242	-.244	-.245	-.247	-.248	-.249	-.250
2	.067	-1.037	-1.044	-1.050	-1.056	-1.060	-1.064	-1.067	-1.070	-1.073	-1.075	-1.076	-1.078	-1.078
3	.092	-1.130	-1.135	-1.140	-1.144	-1.149	-1.152	-1.155	-1.158	-1.161	-1.163	-1.164	-1.166	-1.167
4	.117	-1.106	-1.112	-1.117	-1.122	-1.126	-1.130	-1.133	-1.136	-1.139	-1.142	-1.143	-1.145	-1.146
5	.142	-1.050	-1.056	-1.061	-1.067	-1.071	-1.075	-1.079	-1.083	-1.086	-1.089	-1.091	-1.094	-1.095
6	.164	-1.059	-1.065	-1.071	-1.077	-1.081	-1.086	-1.090	-1.094	-1.097	-1.100	-1.102	-1.104	-1.107
7	.191	-1.028	-1.034	-1.039	-1.043	-1.047	-1.052	-1.055	-1.058	-1.061	-1.064	-1.065	-1.067	-1.068
8	.245	-.949	-.957	-.964	-.970	-.976	-.981	-.987	-.990	-.995	-.999	-1.002	-1.005	-1.007
9	.294	-.980	-.985	-.991	-.996	-1.002	-1.007	-1.010	-1.014	-1.020	-1.025	-1.028	-1.031	-1.033
10	.319	-.987	-.994	-.999	-1.004	-1.008	-1.013	-1.017	-1.022	-1.027	-1.030	-1.034	-1.037	-1.040
11	.343	-.987	-.995	-1.001	-1.007	-1.013	-1.020	-1.025	-1.029	-1.034	-1.037	-1.040	-1.043	-1.045
12	.393	-.958	-.975	-.992	-1.007	-1.024	-1.040	-1.054	-1.067	-1.078	-1.087	-1.096	-1.103	-1.110
13	.424	-.856	-.858	-.862	-.876	-.897	-.926	-.955	-.984	-1.010	-1.029	-1.041	-1.049	-1.056
14	.470	-.776	-.780	-.785	-.793	-.800	-.803	-.811	-.819	-.824	-.837	-.865	-.900	-.930
15	.497	-.797	-.803	-.814	-.826	-.837	-.849	-.862	-.877	-.881	-.886	-.890	-.895	-.906
16	.547	-.901	-.906	-.911	-.920	-.931	-.949	-.971	-.994	-1.021	-1.046	-1.065	-1.080	-1.091
17	.595	-.880	-.880	-.881	-.877	-.873	-.865	-.850	-.834	-.808	-.777	-.739	-.701	-.665
18	.618	-.809	-.798	-.789	-.768	-.742	-.704	-.664	-.621	-.580	-.540	-.506	-.487	-.471
19	.647	-.501	-.499	-.495	-.489	-.482	-.473	-.467	-.459	-.452	-.444	-.438	-.435	-.430
20	.697	-.371	-.371	-.369	-.364	-.362	-.360	-.358	-.356	-.353	-.351	-.350	-.347	-.346
21	.746	-.245	-.245	-.243	-.241	-.240	-.239	-.238	-.236	-.234	-.234	-.232	-.232	-.231
22	.796	-.117	-.115	-.116	-.115	-.114	-.113	-.112	-.111	-.110	-.109	-.107	-.108	-.106
23	.841	-.020	-.018	-.017	-.014	-.012	-.010	-.009	-.007	-.008	-.007	-.005	-.004	-.004
24	.916	.117	.117	.117	.108	.117	.116	.116	.115	.117	.118	.119	.121	.122

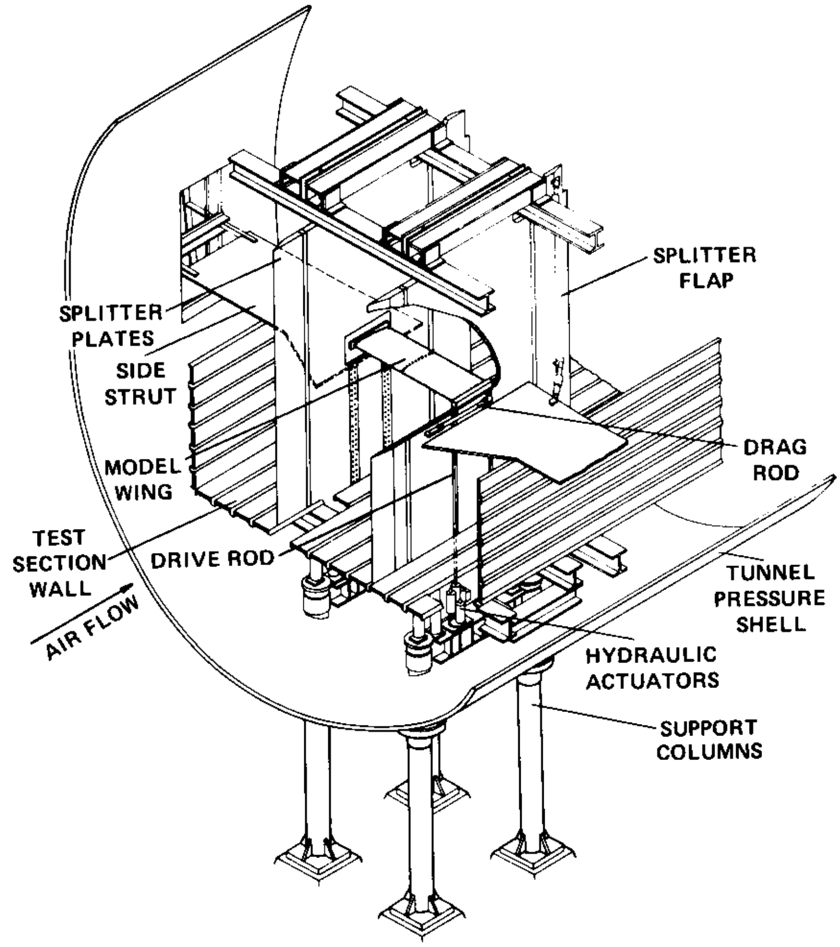


Fig. 5.1. General arrangement of oscillating airfoil test apparatus in NASA AMES 11- by 11-Foot Transonic Wind Tunnel.

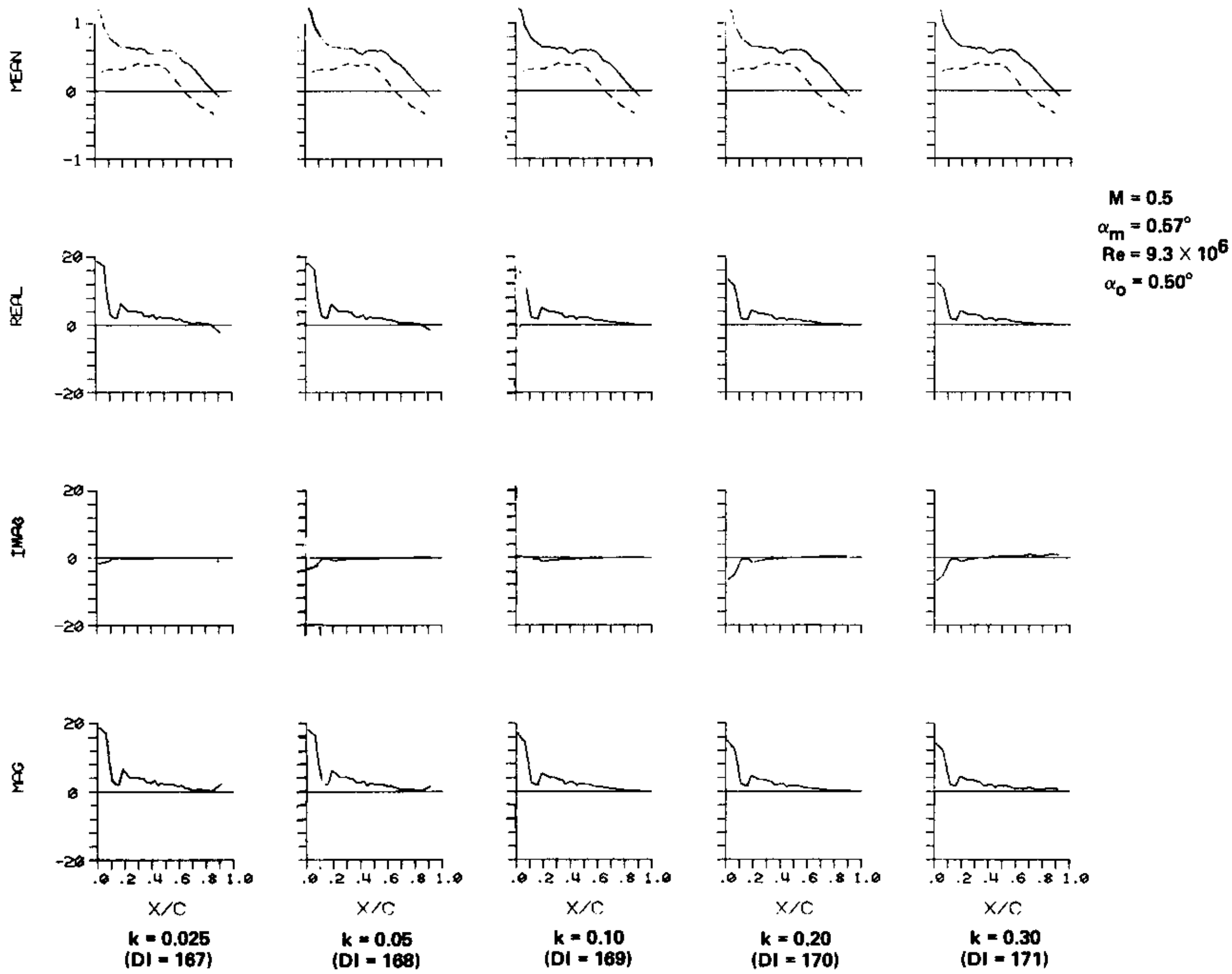


Fig. 5.2. Effect of varying frequency - subsonic flow.

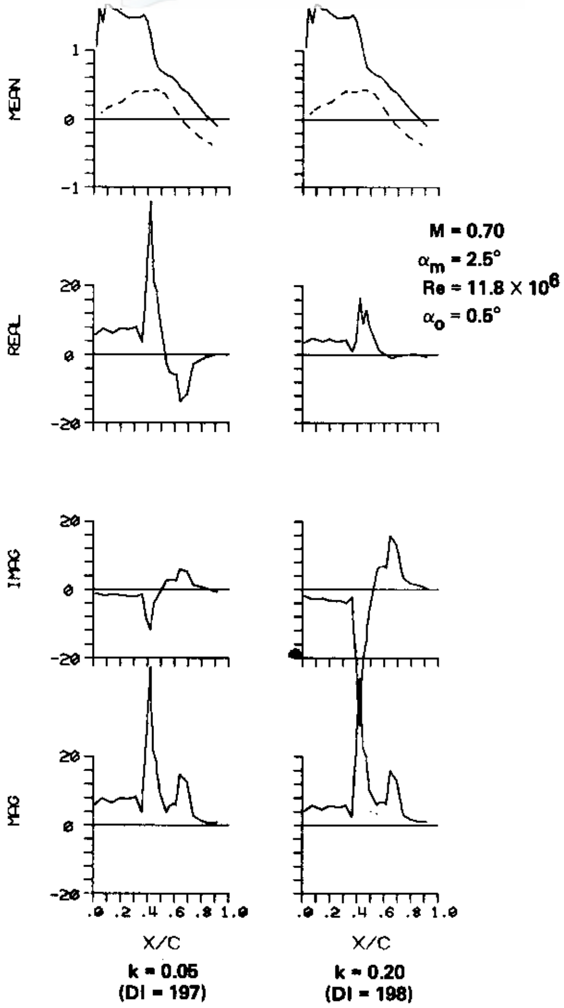


Fig. 5.3. Effect of varying frequency - transonic flow.

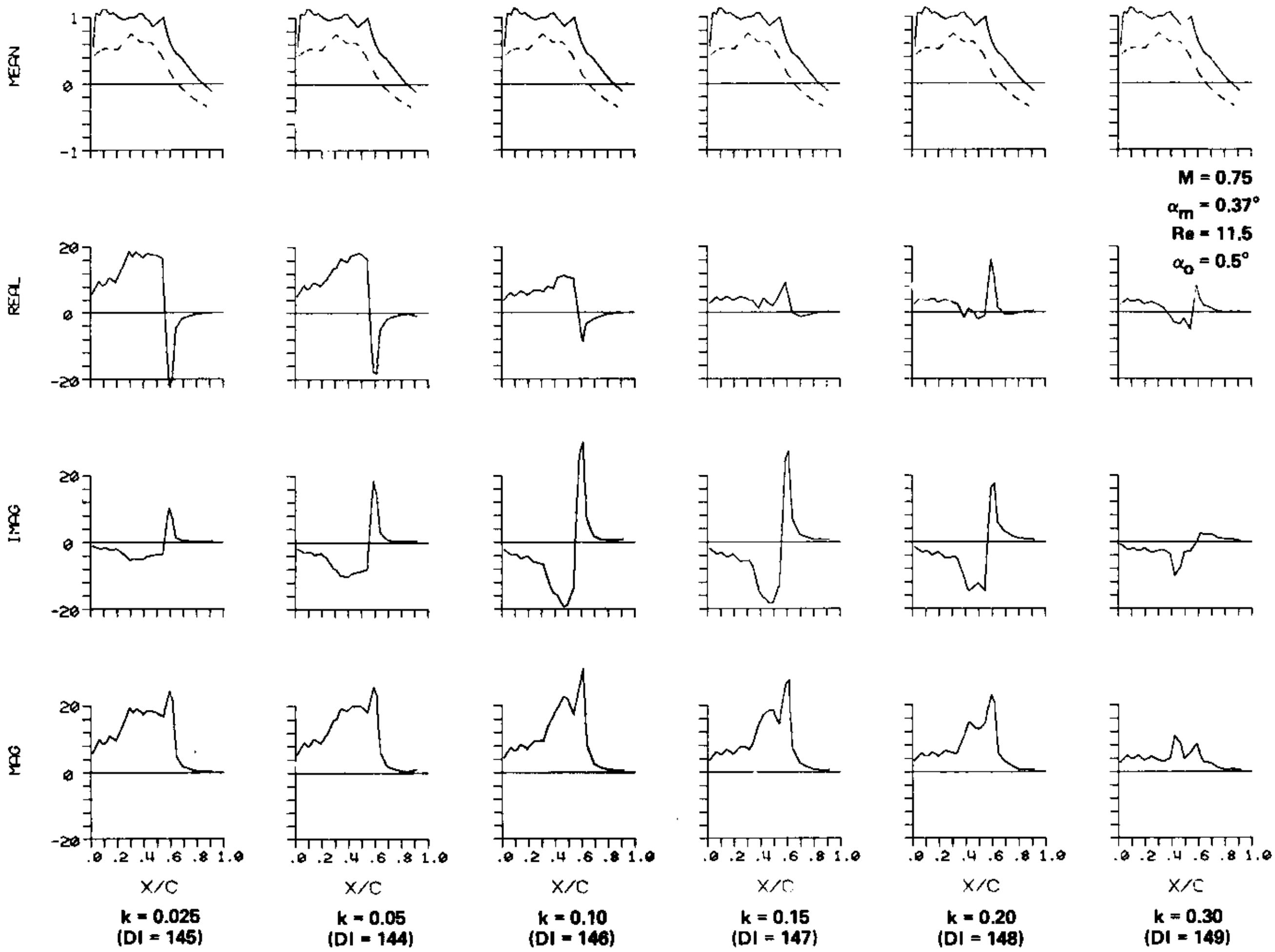


Fig. 5.4. Effect of varying frequency - supercritical design point.

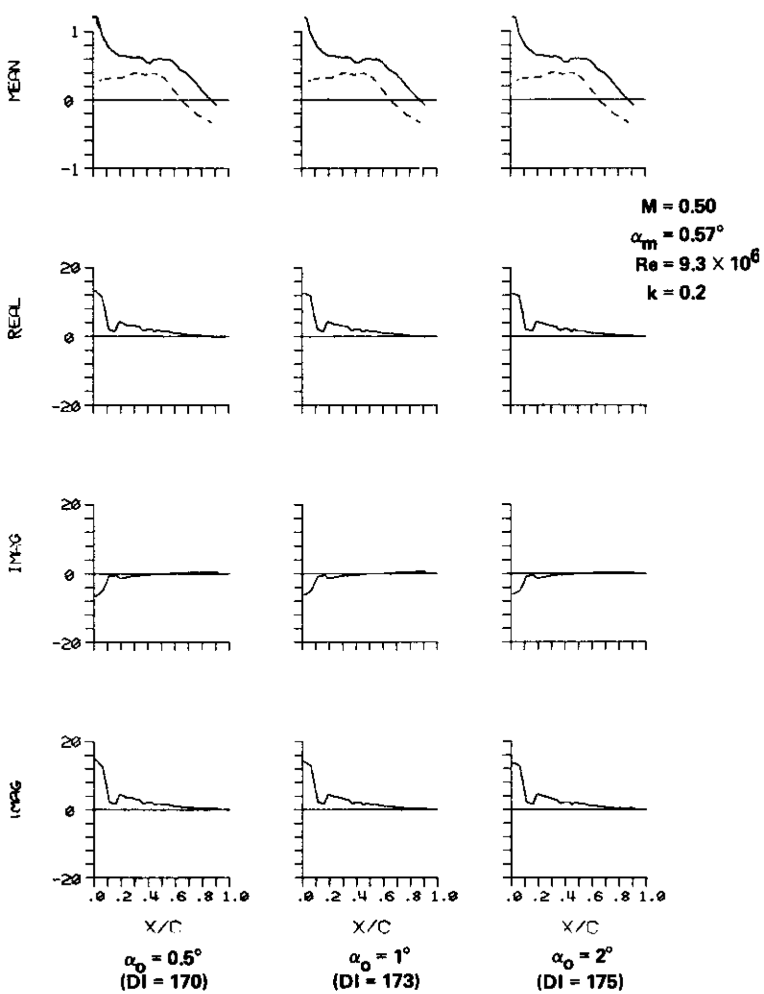


Fig. 5.5. Effect of varying amplitude - subsonic flow.

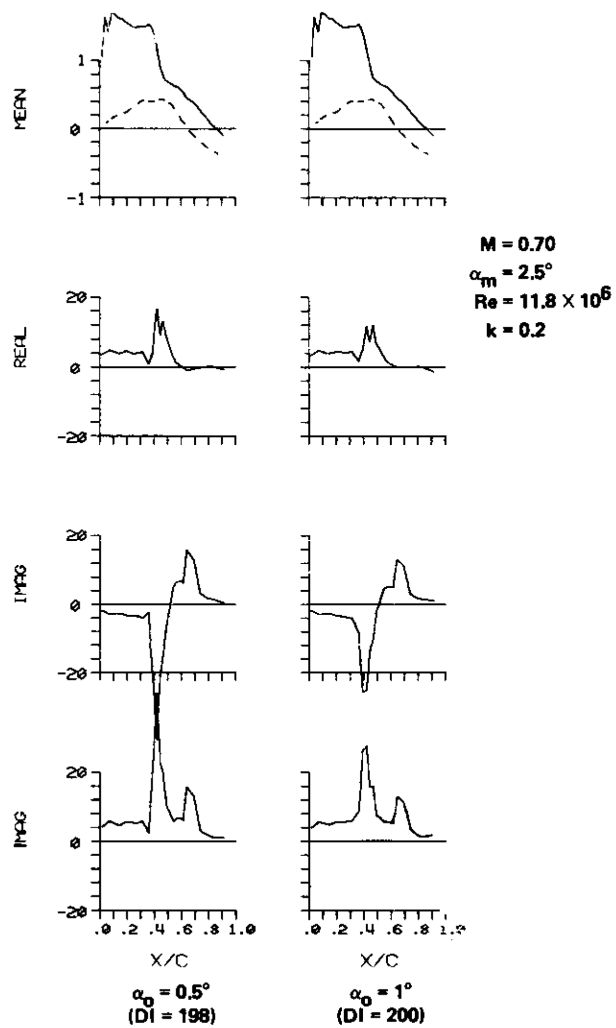


Fig. 5.6. Effect of varying amplitude - transonic flow.

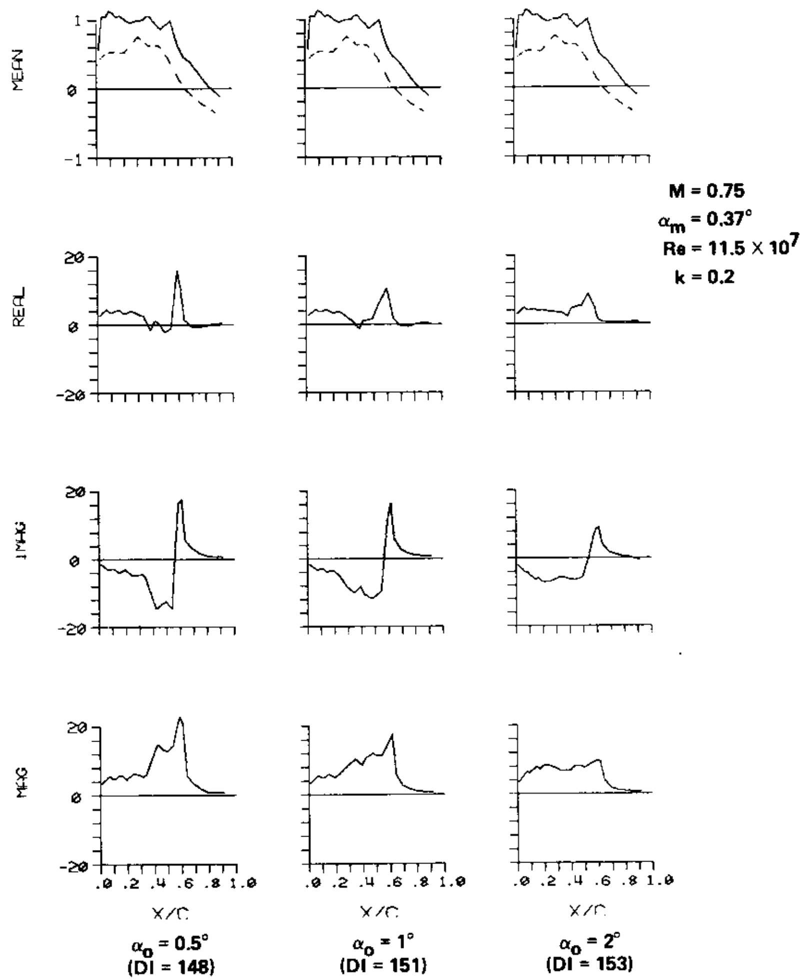


Fig. 5.7. Effect of varying amplitude - supercritical design point.

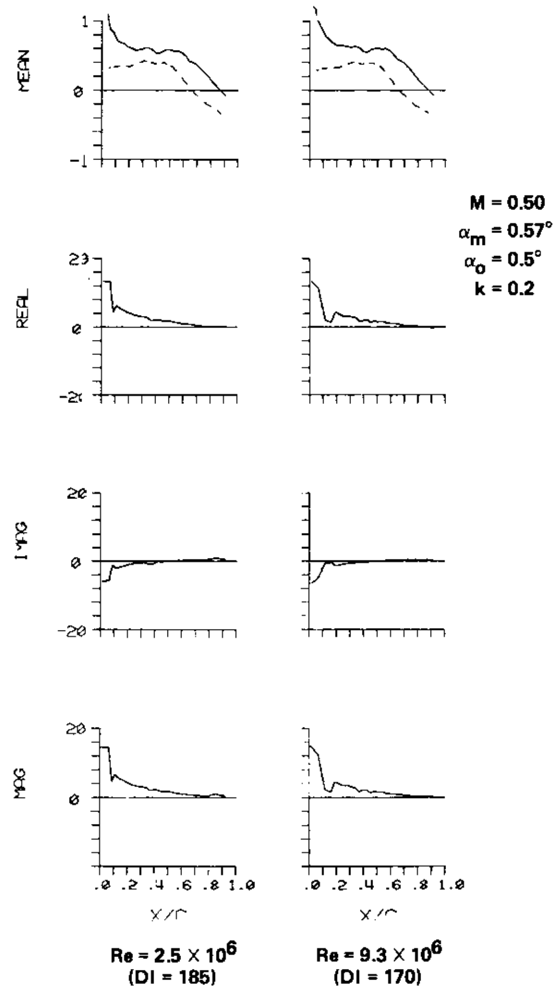


Fig. 5.8. Effect of varying Reynolds number - subsonic flow.

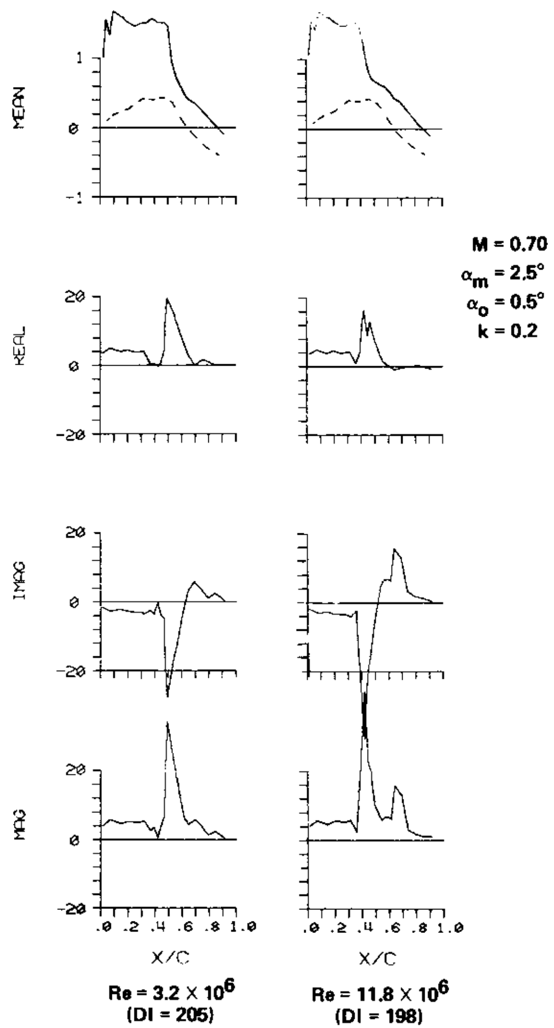


Fig. 5.9. Effect of varying Reynolds number - transonic flow.

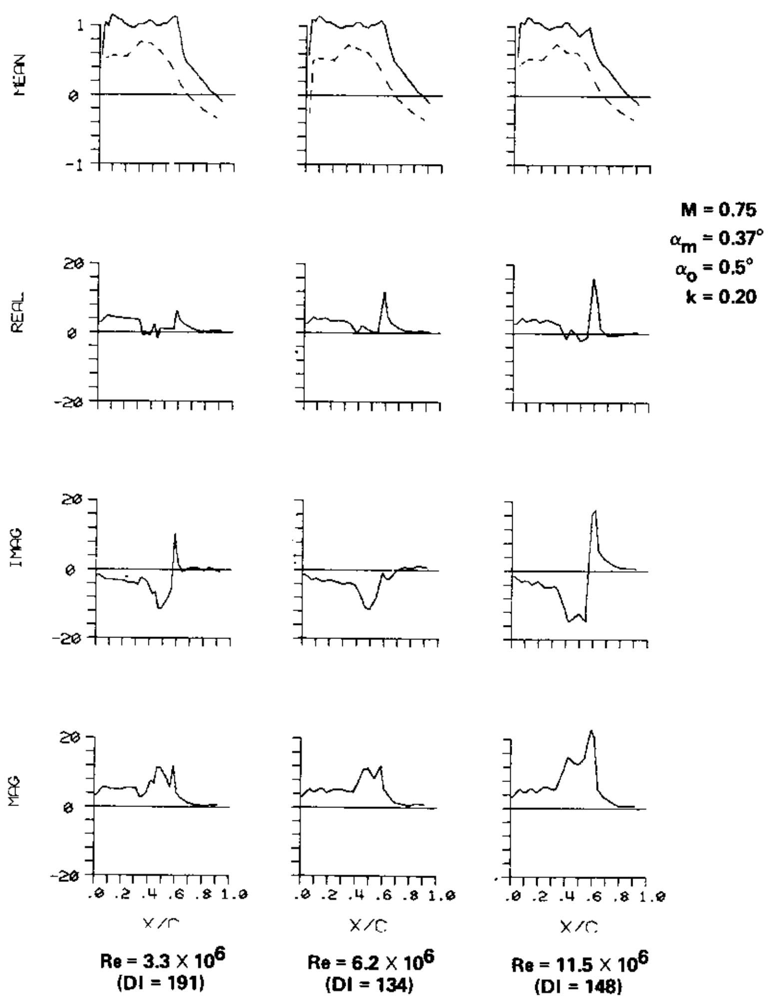


Fig. 5.10. Effect of varying Reynolds number - supercritical design point.

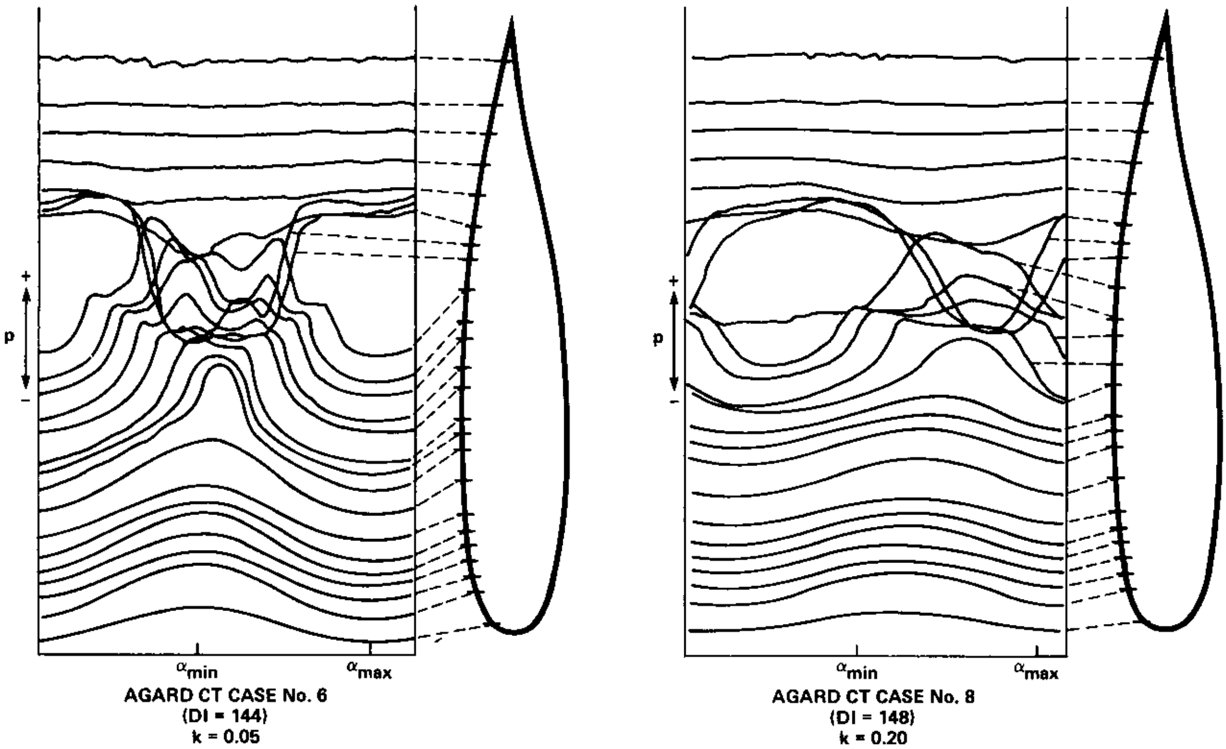


Fig. 5.11. Unsteady pressure time-histories for supercritical design case. M = 0.721, α_m = 0.19°.

DATA SET 6

RAE WING A. OSCILLATING FLAP

by

D. G. Mabey, RAE Bedford

INTRODUCTION AND DISCUSSION

An extensive series of oscillatory pressure measurements[6.1,2] was made on a half model of a swept wing with a part-span trailing-edge flap (Fig 6.1), to highlight the uncertainties in linearised theory at transonic speeds and moderately high frequencies and to provide evidence of the importance of boundary-layer thickness. The model thickness-to-chord ratio was selected to ensure that at zero incidence, even at transonic Mach numbers up to M = 0.9, the local Mach number, M_e , would be less than 1.2, so that boundary-layer separations were avoided (Fig 6.2). The mean isomach contours are given in Figs 6.2 and 6.3 which illustrates some measurements made for angles of incidence other than zero.

The magnitude of the oscillatory pressures decreases significantly as the boundary-layer displacement thickness, δ_1 , at the flap hinge line increases. consistent with the reduced lift-curve slope of the flap. However, the phase lag of the oscillatory pressure with respect to the flap motion decreases as the boundary-layer thickness increases (Fig 6.4). This large change in phase angle, ϕ , is now attributed to the displacement effect of the time-dependent turbulent boundary layer[6.3].

The major uncertainty in the original experiment[6.1,2] was the absolute value of the flap deflection, which could only be specified to about 5% accuracy because of aeroelastic distortion (both static and dynamic). In the subsequent tests a stiff flap was used made of carbon fibre[6.3], together with a new form of optical transducer to measure the flap amplitude[6.4]. There were also improvements in the measurement of pressures. None of these measurements is included here, for other reasons discussed fully in Ref 6.3.

In the original experiment good comparisons with inviscid linearised theory were obtained at subsonic speeds (Fig 6.4). The principle of superposition of flap frequencies was valid at both subsonic and transonic speeds (Fig 6.5a&b). However, at transonic speeds sinusoidal flap movements do develop significant pressures at harmonic frequencies behind the shock waves, owing to the non-linearity of transonic flows[6.1] and small aero-elastic distortions (Fig 6.6).

Ref 6.1 gives some details of the original experiment while Ref 6.2 reviews the principal results. Ref 6.3 gives some preliminary measurements on the same model fitted with a modified flap and drive system capable of much higher frequencies. Amongst other results, these tests established that in the original experiments[6.1,2] the effects of the unwanted wing motion on the oscillatory pressures were small.

The data presented correspond with some of the CT cases in Ref 6.9 chosen for RAE Wing A with an oscillating flap and relate to both subsonic and transonic flows. Of the CT cases, 4 and 5 are for subcritical flow and 11 is for supercritical flow. For CT Cases 8 and 9 the unsteady flow is termed 'critical' because a local supersonic region is present intermittently. (See Table 6.1 and discussion in Ref 6.1.)

No data for the CT Cases with heaving or pitching or for CT Cases 10, 12 and 13 are yet available.

1 GENERAL DESCRIPTION OF MODEL

1.1	Designation	RAE Wing A
1.2	Type	Half model with part-span trailing-edge flap
1.3	Derivation	-
1.4	Additional remarks	-
1.5	References	Ref 6.5

2 MODEL GEOMETRY

2.1	Planform	Straight tapered
2.2	Aspect ratio	6
2.3	Leading-edge sweep	36.65°
2.4	Trailing-edge sweep	22.34°

2.5	Taper ratio	1/3
2.6	Twist	0
2.7	Root chord	240 mm
2.8	Span of model	s = 480 mm
2.9	Area of planform	0.0768 m^2
2.10	Location of reference sections and definition of profiles	RAE 101 - 9% streamwise
2.11	Lofting procedure between reference sections	Straight line generators
2.12	Form of wing-body, or wing-root junction	No body: 0.6 mm gap at root
2.13	Form of wing tip	Straight streamwise chord: no radius
2.14	Control surface details	Trailing-edge flap from η = 0.40 to 0.70. Hinge line at x/c = 0.70 swept 27.05°. Small chordwise and spanwise gaps (see Ref 6.1)
2.15	Additional remarks	-
2.16	References	-

3 WIND TUNNEL

3.1	Designation	RAE 3 ft × 3 ft
3.2	Type of tunnel	Continuous and pressurised
3.3	Test section dimensions	Height = 640 mm, width = 910 mm, length = 1370 mm
3.4	Type of roof and floor	Slotted
3.5	Type of side walls	Closed
3.6	Ventilation geometry	Four complete slots and two corner half slots in roof and floor, covered with perforated plates. Open area ratio of slots = 8%
3.7	Thickness of side wall boundary layer	δ^* = 7 mm
3.8	Thickness of boundary layers at roof and floor	δ^* less than 7 mm
3.9	Method of measuring Mach number	Plenum chamber pressure
3.10	Flow angularity	About 0.1°
3.11	Uniformity of Mach number over test section	±0.002
3.12	Sources and levels of noise or turbulence in empty tunnel	Mixing region at ends of working section. Typical levels at transonic speeds $\sqrt{nF(n)}$ = 0.004 (Ref 6.6)
3.13	Tunnel resonances	Tunnel resonance frequencies well above flap frequencies
3.14	Additional remarks	-
3.15	References on tunnel	Ref 6.6

4 MODEL MOTION

4.1	General description	Sinusoidal pitching of flap about swept hinge line
4.2	Reference coordinate and definition of motion	Flap deflection relative to wing chord at η = 0.55 (mid-flap)
4.3	Range of amplitude	0 to 2°

4.4	Range of frequency	0, 1 Hz, 90 Hz and limited data available at 131 Hz
4.5	Method of applying motion	Semi-resonant motion
4.6	Timewise purity of motion	Good. First overtone 40 dB lower than fundamental
4.7	Natural frequencies and normal modes of model and support system	First bending frequency at 60 Hz, second bending frequency at 143 Hz, minimum model motion at 90 Hz
4.8	Actual mode of applied motion including any elastic deformation	Elastic deformations were not measured but were subsequently shown not to alter the pressures at 1 and 90 Hz
4.9	Additional remarks	Influence of wing motion discussed in Ref 6.3

5 TEST CONDITIONS

5.1	Model planform area/tunnel area	0.13
5.2	Model span/tunnel width	0.53
5.3	Blockage	1.2%
5.4	Position of model in tunnel	685 mm from start of working section
5.5	Range of Mach number	0.40, 0.65, 0.80, 0.85, 0.90, 0.95
5.6	Range of tunnel total pressure	0.95 bar
5.7	Range of tunnel total temperature	278 K to 298 K
5.8	Range of model steady, or mean, incidence	0 to 2°
5.9	Definition of model incidence	Model set to zero geometric incidence (NB up to 0.1° flow deflection)
5.10	Position of transition, if free	Limited data with free transition in Ref 6.2
5.11	Position and type of trip, if transition fixed	x/c = 0.05, roughness elements 0.13 mm high and 2 mm apart
5.12	Flow instabilities during tests	No periodic shock oscillation but some random oscillation associated with unsteadiness in tunnel flow
5.13	Changes to mean shape of model due to steady aerodynamic load	Negligible
5.14	Additional remarks	-
5.15	References describing tests	Refs 6.1, 6.2

6 MEASUREMENTS AND OBSERVATIONS

6.1	Steady pressures for the mean conditions	✓
6.2	Steady pressures for small changes from the mean conditions	-
6.3	Quasi-steady pressures	✓
6.4	Unsteady pressures	✓
6.5	Steady section forces for the mean conditions by integration of pressures	-
6.6	Steady section forces for small changes from the mean conditions by integration	-
6.7	Quasi-steady section forces by integration	-
6.8	Unsteady section forces by integration	-
6.9	Measurement of actual motion at points on model	-

6.10	Observation or measurement of boundary layer properties	✓
6.11	Visualization of surface flow	✓
6.12	Visualization of shockwave movements	-
6.13	Additional remarks	-

7 INSTRUMENTATION

7.1 Steady pressures

7.1.1	Position of orifices spanwise and chordwise	See data tables
7.1.2	Type of measuring system	Capsule manometers

7.2 Unsteady pressures

7.2.1	Position of orifices spanwise and chordwise	See data tables
7.2.2	Diameter of orifices	0.5 mm
7.2.3	Type of measuring system	Individual in situ transducers
7.2.4	Type of transducers	Kulite type XCQL 093 25A
7.2.5	Principle and accuracy of calibration	Steady calibration and tests with oscillatory pressure generator (see Ref 6.7)

7.3 Model motion

7.3.1	Method of measuring motion reference coordinates	Foil strain gauges on steel flexures at η = 0.52 and 0.66. Average motion at η = 0.55
7.3.2	Method of determining spatial mode of motion	Not measured
7.3.3	Accuracy of measured motions	5%

7.4 Processing of unsteady measurements

7.4.1	Method of acquiring and processing measurements	Serial logger to Digital Transfer Function Analyser (DTFA); paper tape input to remote computer; parallel magnetic tape
7.4.2	Type of analysis	Harmonic
7.4.3	Unsteady pressure quantities obtained and accuracies achieved	Fundamental only
7.4.4	Method of integration to obtain forces	Not integrated

7.5	Additional remarks	-
7.6	References on techniques	Refs 6.1, 6.3 and 6.4

8 DATA PRESENTATION

8.1	Test cases for which data could be made available	Table 6.1
8.2	Test cases for which data are included in this document	Table 6.1
8.3	Steady pressures	Tables 6.2 to 6.5
8.4	Quasi-steady or steady perturbation pressures	Tables 6.2 to 6.5
8.5	Unsteady pressures	Tables 6.2 to 6.5
8.6	Steady forces or moments	-
8.7	Quasi-steady or steady perturbation forces	-
8.8	Unsteady forces and moments	-
8.9	Other forms in which data could be made available	-

8.10	References giving other presentations of data	Refs 6.1, 6.2, 6.3 and 6.8

9 COMMENTS ON DATA

9.1	Accuracy	
9.1.1	Mach number	±0.002
9.1.2	Steady incidence	$\pm 0.1^{\circ}$
9.1.3	Reduced frequency	Variations up to ±2% from nominal values due to temperature variations
9.1.4	Steady pressure coefficients	C_p better than ±0.006
9.1.5	Steady pressure derivatives	-
9.1.6	Unsteady pressure coefficients	Magnitude of $\bar{C}_p/\delta_0$ to $\pm\left(0.05\lvert\bar{C}_p/\delta_0\rvert + 0.02\right)$. Phase to $\pm 3^{\circ}$
9.2	Sensitivity to small changes of parameter	-
9.3	Non-linearities	Small (discussed in Refs 6.1 and 6.2)
9.4	Influence of tunnel total pressure	Not known
9.5	Effects on data of uncertainty, or variation, in mode of model motion	See Introduction
9.6	Wall interference corrections	None
9.7	Other relevant tests on same model	Ref 6.3
9.8	Relevant tests on other models of nominally the same shape	Ref 6.5 for relevant steady tests
9.9	Any remarks relevant to comparison between experiment and theory	Some interesting comparisons with subsonic inviscid linearised theory in Ref 6.2
9.10	Additional remarks	-
9.11	References on discussion of data	Refs 6.1, 6.2 and 6.3

10 PERSONAL CONTACT FOR FURTHER INFORMATION

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11 LIST OF REFERENCES

6.1	D.M. McOwat B.L. Welsh B.E. Cripps	Time-dependent pressure measurements on a swept wing with an oscillating trailing-edge flap. RAE Technical Report 81033 (1981)
6.2	D.G. Mabey B.L. Welsh D.M. McOwat	Aerodynamic characteristics of moving trailing-edge controls at subsonic speeds. AGARD CP 262, Paper 20, May 1979; RAE Technical Memorandum Structures 947 (1979)
6.3	D.G. Mabey B.L. Welsh B.E. Cripps	Further aerodynamic characteristics of moving trailing-edge controls at subsonic and transonic speeds. RAE Technical Report 80134 (1980)
6.4	B.L. Welsh	A new angular displacement transducer. RAE Technical Report 79026 (1979)
6.5	D.A. Treadgold A.F. Jones K.H. Wilson	Pressure distribution measured in the RAE 8ft × 6ft transonic tunnel on RAE Wing 'A' in combination with an axisymmetric body at Mach numbers of 0.4, 0.8 and 0.9. AGARD AR 138, Paper B4 (1979)

6.6 D.G. Mabey — Flow unsteadiness of model vibration in wind tunnels at subsonic and transonic speeds. CP 1155 (1971)

6.7 B.L. Welsh — Some notes on the measurement of oscillatory pressures. RAE Technical Memorandum Structures 869 (1975)

6.8 D.M. McOwat — Dynamics Lab Memo 1 (1982)

6.9 S.R. Bland — AGARD three-dimensional aeroelastic configurations. AGARD-AR-167 (1982)

12 NOTATION

c_r	root chord
C_p	steady pressure coefficient
$\bar{C}_p$	complex pressure coefficient
$R(\bar{C}_p)$	real part of $\bar{C}_p$
$I(\bar{C}_p)$	imaginary part of $\bar{C}_p$
f	frequency (Hz)
k	frequency parameter $f\pi c_r/U$
M	free stream Mach number
M_e	local external Mach number
Re	Reynolds number based on free stream conditions and root chord
U	free stream velocity
α	angle of incidence
δ_0	flap amplitude in streamwise direction (see Note below)
δ_1	boundary-layer displacement thickness at hinge line
δ^*	boundary-layer displacement thickness at wall
η	dimensionless spanwise coordinate y/s
Λ	sweepback angle
ξ	dimensionless chordwise coordinate (fraction of local chord)
ϕ	phase angle of pressure with respect to flap motion

NOTE: For consistency with the standard notation suggested by Bland, the symbol δ represents the flap deflection angle measured streamwise. In Refs 6.1 to 6.3, which give other information about the tests, the symbol δ represents the flap deflection measured normal to the hinge line. Thus

$$(\delta \text{, as used here}) = (\delta \text{ of Refs}) \times \cos \Lambda_{HL} , \quad \text{where} \quad \Lambda_{HL} = 27.05^{\circ}$$

$$= (\delta \text{ of Refs}) \times 0.891 .$$

$$(\bar{C}_p/\delta \text{, as used here}) = (\bar{C}_p/\delta \text{ of Refs}) \times 1.122 .$$

Table 6.1

SUMMARY OF DATA GIVEN AND DATA AVAILABLE

M	Re × 10^{-6}	k	δ_0 (deg)	α (deg)	η 0.35	η 0.45	η 0.60	η 0.75	CT or data given	Time-dependent flow	Test No.
0.40	1.91	Steady	-	0	1	1	1	1			1
		0.0055	1.78	0	1	1	1	0		A	
		0.50	1.71	0	1	1	1	1		A	
0.65	2.78	Steady	-	0	1	1	1	1			2
		0.0035	1.75	0	1	1	1	0		A	
		0.32	1.63	0	1	1	1	1		A	
0.80	3.14	Steady	-	+2	1	1	1	1	✓		9
				+1	1	1	1	1	-		7
				0	1	1	1	1	✓		3
				-1	1	0	1	0	-		8
				-2	1	1	1	1	✓		10
		0.0029	1.75	+2	1	1	1	0	✓	A	9
				+1	0	1	0	0	-	A	7
				0	1	1	1	0	✓	A	3
				-1	0	1	0	0	-	A	8
				-2	1	1	1	0	✓	A	10
		0.26	1.60	+2	1	1	1	1	5	A	9
				+1	1	1	1	1	-	A	7
				0	1	1	1	1	4	A	3
				-1	1	1	0	1	-	A	8
				-2	1	1	1	1	5	A	10
0.85	3.23	Steady	-	+2	1	1	1	1			13
				+1	1	1	1	1			11
				0	1	1	1	1			4
				-1	1	1	1	1			12
				-2	1	1	1	1			14
		0.0028	1.75	+2	1	1	1	0		B	13
				+1	0	1	1	0		A	11
				0	1	1	1	0		A	4
				-1	0	1	1	0		A	12
				-2	1	1	1	0		A	14
		0.25	1.58	+2	1	1	1	1		B	13
				+1	1	1	1	1		A	11
				0	1	1	1	1		A	4
				-1	1	1	1	1		A	12
				-2	1	1	1	1		A	14
0.90	3.32	Steady	-	+1	1	1	1	1	✓		15
				0	1	1	1	1	✓		5
				-1	1	1	1	1	✓		16
		0.0026	1.76	+1	0	1	1	0	✓	C	15
				0	1	1	1	0	8	B	5
				-1	0	1	1	0	✓	A	16
		0.24	1.58	+1	1	1	1	1	11	C	15
				0	1	1	1	1	9	B	5
				-1	1	1	1	1	11	A	16
0.95	3.38	Steady	-	+1	1	1	1	1			17
				0	1	1	1	1			6
				-1	1	1	1	1			18
		0.0036	1.80	+1	0	1	1	0		C	17
				0	1	1	1	0		C	6
				-1	0	1	1	0		C	18
		0.23	1.58	+1	1	1	1	1		C	17
				0	1	1	1	1		C	6
				-1	1	1	1	1		C	18

Type of flow: A Subcritical
B Critical
C Supercritical

Data available: 1
No data: 0
Data given: ✓

All tests made with fixed transition.
Results for lower surface are obtained from negative incidences.

Table 6.2

CASE 4

Test	M	α	δ_0	Surface	
3	0.80	0.0	1.75(f=1) 1.60(f=90)	upper	$k = 2.9 \times 10^{-3}$ f

η = 0.35

f	data														
	ξ	0.012	0.025	0.049	0.099	0.199	0.299	0.399	0.498	0.574	0.623	0.661	0.733	0.758	0.824
-	Cp	0.046	-0.114	-0.247	-0.301	-0.372	-0.363	-0.279	-0.206	-0.148	-0.114	-0.088	-0.039	-0.021	0.012
1.	-0.89 $\bar{C}p/\delta_0$	0.027	0.020	0.035	0.094	0.205	0.186	0.097	0.125	0.163	0.323	0.254	0.310	0.335	0.236
90.	-0.89R($\bar{C}p/\delta_0$)	0.018	0.000	0.011	0.017	0.097	0.141	0.220	0.267	0.293	0.332	0.355	0.425	0.440	0.437
	-0.89I($\bar{C}p/\delta_0$)	-0.257	-0.271	-0.216	-0.208	-0.208	-0.197	-0.168	-0.138	-0.116	-0.094	-0.077	-0.065	-0.025	-0.042

η = 0.45

f	data														
	ξ	0.012	0.026	0.049	0.099	0.199	0.299	0.398	0.498	0.573	0.623	0.660	0.723	0.759	0.824
-	Cp	-0.007	-0.186	-0.226	-0.313	-0.349	-0.353	-0.281	-0.195	-0.139	-0.099	-0.080	-0.080	-0.043	-0.004
1.	-0.89 $\bar{C}p/\delta_0$	0.088	0.038	0.175	0.175	0.150	0.138	0.332	0.438	0.576	0.750	0.872	2.583	1.470	0.700
90.	-0.89R($\bar{C}p/\delta_0$)	0.026	0.002	0.056	0.101	0.159	0.285	0.441	0.545	0.754	0.975	0.982	3.023	1.813	0.895
	-0.89I($\bar{C}p/\delta_0$)	-0.317	-0.331	-0.289	-0.287	-0.296	-0.275	-0.221	-0.163	-0.137	-0.111	-0.110	-0.052	0.146	0.254

η = 0.60

f	data														
	ξ	0.012	0.024	0.049	0.098	0.198	0.298	0.398	0.498	0.572	0.622	0.660	0.724	0.759	0.825
-	Cp	0.037	-0.128	-0.195	-0.288	-0.351	-0.356	-0.300	-0.217	-0.168	-0.139	-0.086	-0.062	-0.049	-0.018
1.	-0.89 $\bar{C}p/\delta_0$	0.226	0.289	0.208	0.232	0.350	0.554	0.682	0.902	1.138	1.233	1.406	2.400	1.526	0.742
90.	-0.89R($\bar{C}p/\delta_0$)	0.281	0.318	0.000	0.297	0.479	0.671	0.878	1.133	1.374	1.566	1.775	0.000	1.841	0.905
	-0.89I($\bar{C}p/\delta_0$)	-0.529	-0.528	0.000	-0.412	-0.377	-0.355	-0.240	-0.186	-0.160	-0.126	-0.084	0.000	0.188	0.256

η = 0.75

f	data														
	ξ	0.012	0.024	0.048	0.098	0.198	0.297	0.397	0.497	0.572	0.622	0.660	0.723	0.758	0.823
-	Cp	0.013	-0.156	-0.278	-0.344	-0.378	-0.346	-0.276	-0.193	-0.131	-0.099	-0.070	0.000	0.000	0.000
1.	-0.89 $\bar{C}p/\delta_0$	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
90.	-0.89R($\bar{C}p/\delta_0$)	0.832	0.890	0.743	0.697	0.829	0.880	0.833	0.767	0.692	0.633	0.502	0.659	0.485	0.316
	-0.89I($\bar{C}p/\delta_0$)	-0.645	-0.666	-0.608	-0.432	-0.332	-0.185	-0.054	0.011	0.022	0.057	0.050	0.119	0.091	0.066

Table 6.3

CASE 5

Test	M	α	δ_0	Surface	
9	0.80	2.0	1.75(f=1) 1.60(f=90)	upper	$k = 2.9 \times 10^{-3}\ f$

$\eta = 0.35$

f	data														
	ξ	0.012	0.025	0.049	0.099	0.199	0.299	0.399	0.498	0.574	0.623	0.661	0.733	0.758	0.824
–	C_p	-0.386	-0.529	-0.576	-0.549	-0.544	-0.478	-0.354	-0.255	-0.184	-0.137	-0.104	-0.065	-0.039	0.004
1.	-0.89 $\bar{C}_p/\delta_0$	0.080	0.009	0.132	0.139	0.000	0.211	0.226	0.255	0.208	0.273	0.292	0.260	0.306	0.290
90.	-0.89R($\bar{C}_p/\delta_0$)	-0.073	-0.101	-0.028	-0.007	0.084	0.159	0.261	0.314	0.338	0.382	0.406	0.467	0.485	0.465
	-0.89I($\bar{C}_p/\delta_0$)	-0.308	-0.305	-0.261	-0.241	-0.273	-0.264	-0.209	-0.165	-0.120	-0.104	-0.084	-0.060	-0.018	-0.034

$\eta = 0.45$

f	data														
	ξ	0.012	0.026	0.049	0.099	0.199	0.299	0.398	0.498	0.573	0.623	0.660	0.723	0.759	0.824
–	C_p	-0.330	-0.526	-0.510	-0.553	-0.493	-0.461	-0.351	-0.241	-0.174	-0.123	-0.093	-0.103	-0.061	-0.015
1.	-0.89 $\bar{C}_p/\delta_0$	0.053	0.120	0.010	0.068	0.121	0.296	0.286	0.364	0.548	0.626	0.592	1.078	1.091	0.558
90.	-0.89R($\bar{C}_p/\delta_0$)	-0.055	-0.064	0.042	0.043	0.176	0.367	0.505	0.633	0.842	1.032	1.066	3.065	1.845	0.938
	-0.89I($\bar{C}_p/\delta_0$)	-0.390	-0.336	-0.639	-0.278	-0.369	-0.376	-0.249	-0.197	-0.149	-0.122	-0.121	-0.035	0.191	0.263

$\eta = 0.60$

f	data														
	ξ	0.012	0.024	0.049	0.098	0.198	0.298	0.398	0.498	0.572	0.622	0.660	0.724	0.759	0.825
–	C_p	-0.337	-0.479	-0.475	-0.489	-0.494	-0.464	-0.361	-0.256	-0.183	-0.145	-0.106	-0.067	-0.061	-0.027
1.	-0.89 $\bar{C}_p/\delta_0$	0.211	0.220	0.466	0.374	0.374	0.502	0.633	0.801	0.911	0.000	1.126	1.734	1.148	0.589
90.	-0.89R($\bar{C}_p/\delta_0$)	0.241	0.272	0.301	0.377	0.535	0.902	1.091	1.337	1.532	0.000	1.792	2.710	1.822	0.947
	-0.89I($\bar{C}_p/\delta_0$)	-0.681	-0.725	-1.096	-0.703	-0.517	-0.441	-0.219	-0.126	-0.057	0.000	-0.056	0.218	0.387	0.330

$\eta = 0.75$

f	data														
	ξ	0.012	0.024	0.048	0.098	0.198	0.297	0.397	0.497	0.572	0.622	0.660	0.723	0.758	0.823
–	C_p	-0.344	-0.590	-0.540	-0.562	0.000	-0.450	-0.349	-0.242	-0.165	-0.124	-0.086	0.000	0.000	0.000
1.	-0.89 $\bar{C}_p/\delta_0$	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
90.	-0.89R($\bar{C}_p/\delta_0$)	0.949	0.758	1.133	1.300	1.221	1.096	0.970	0.714	0.530	0.000	0.377	0.884	0.616	0.368
	-0.89I($\bar{C}_p/\delta_0$)	-0.991	-0.996	-1.309	-1.296	-0.608	-0.164	0.023	0.090	0.085	0.000	0.081	0.215	0.160	0.111

Table 6.3 (concluded)

CASE 5

Test	M	α	δ_0	Surface	
10	0.80	2.0	1.75(f=1) 1.60(f=90)	lower	$k = 2.9 \times 10^{-3}$ f

η = 0.35

f	data														
	ξ	0.012	0.025	0.049	0.099	0.199	0.299	0.399	0.498	0.574	0.623	0.661	0.733	0.758	0.824
-	C_p/δ_0	0.315	0.152	0.002	-0.122	-0.234	-0.259	-0.211	-0.158	-0.111	-0.085	-0.065	-0.008	0.005	0.029
1.	0.89 $\bar{C}_p/\delta_0$	0.006	0.035	0.043	0.043	0.083	0.138	0.110	0.198	0.234	0.230	0.210	0.291	0.304	0.295
90.	0.89R($\bar{C}_p/\delta_0$)	0.030	0.000	0.018	0.019	0.096	0.122	0.180	0.221	0.250	0.291	0.314	0.392	0.414	0.407
	0.89I($\bar{C}_p/\delta_0$)	-0.162	-0.012	-0.153	-0.142	-0.159	-0.159	-0.129	-0.128	-0.114	-0.101	-0.087	-0.084	-0.044	-0.067

η = 0.45

f	data														
	ξ	0.012	0.026	0.049	0.099	0.199	0.299	0.398	0.498	0.573	0.623	0.660	0.723	0.759	0.824
-	C_p/δ_0	0.264	0.094	-0.001	-0.127	-0.213	-0.247	-0.208	-0.144	-0.104	-0.070	-0.054	-0.055	-0.028	0.007
1.	0.89 $\bar{C}_p/\delta_0$	0.072	0.064	0.064	0.051	0.059	0.144	0.191	0.281	0.385	0.535	0.629	1.742	1.075	0.501
90.	0.89R($\bar{C}_p/\delta_0$)	0.051	0.062	0.051	0.084	0.166	0.216	0.320	0.474	0.618	0.821	0.882	2.543	1.540	0.769
	0.89I($\bar{C}_p/\delta_0$)	-0.231	-0.209	-0.214	-0.203	-0.191	-0.224	-0.190	-0.178	-0.194	-0.176	-0.164	-0.252	0.044	0.154

η = 0.60

f	data														
	ξ	0.012	0.024	0.049	0.098	0.198	0.298	0.398	0.498	0.572	0.622	0.660	0.724	0.759	0.825
-	C_p/δ_0	0.269	0.105	0.001	-0.132	-0.231	-0.271	-0.226	-0.165	-0.117	-0.088	-0.060	-0.042	-0.032	-0.008
1.	0.89 $\bar{C}_p/\delta_0$	0.152	0.166	0.179	0.184	0.309	0.422	0.561	0.731	0.852	0.000	1.081	1.995	1.273	0.605
90.	0.89R($\bar{C}_p/\delta_0$)	0.201	0.241	0.248	0.259	0.398	0.550	0.746	0.990	1.199	0.000	1.456	2.645	1.705	0.841
	0.89I($\bar{C}_p/\delta_0$)	-0.344	-0.303	-0.326	-0.320	-0.299	-0.300	-0.214	-0.196	-0.149	0.000	-0.177	-0.158	0.109	0.162

η = 0.75

f	data														
	ξ	0.012	0.024	0.048	0.098	0.198	0.297	0.397	0.497	0.572	0.622	0.660	0.723	0.758	0.823
-	C_p/δ_0	0.331	0.131	0.023	-0.146	-0.216	-0.230	-0.201	-0.146	-0.101	-0.079	-0.054	0.000	0.000	0.000
1.	0.89 $\bar{C}_p/\delta_0$	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
90.	0.89R($\bar{C}_p/\delta_0$)	0.478	0.548	0.537	0.516	0.613	0.680	0.686	0.647	0.586	0.545	0.446	0.538	0.377	0.232
	0.89I($\bar{C}_p/\delta_0$)	-0.330	-0.383	-0.391	-0.312	-0.245	-0.164	-0.079	-0.028	-0.007	0.017	0.015	0.066	0.046	0.038

Table 6.4

CASES 8 and 9

Test	M	α	δ_0	Surface	
5	0.90	0.0	1.76(f=1) 1.58(f=90)	upper	$k = 2.7 \times 10^{-3}$ f

η = 0.35

f	data														
	ξ	0.012	0.025	0.049	0.099	0.199	0.299	0.399	0.498	0.574	0.623	0.661	0.733	0.758	0.824
-	C_p	0.069	-0.099	-0.226	-0.345	-0.464	-0.531	-0.299	-0.220	-0.154	-0.111	-0.080	-0.028	-0.006	0.032
1.	-0.89 C_p/δ_0	-0.069	-0.066	-0.062	-0.012	-0.025	0.014	0.153	0.235	0.220	0.258	0.290	0.309	0.367	0.436
90.	-0.89R($\bar{C}_p/\delta_0$)	-0.043	-0.048	-0.045	-0.060	-0.063	-0.127	-0.631	0.380	0.400	0.455	0.000	0.551	0.597	0.584
	-0.89I($\bar{C}_p/\delta_0$)	-0.044	-0.039	-0.032	-0.034	-0.046	-0.053	-0.689	-0.545	-0.313	-0.244	0.000	-0.119	-0.067	-0.065

η = 0.45

f	data														
	ξ	0.012	0.026	0.049	0.099	0.199	0.299	0.398	0.498	0.573	0.623	0.660	0.723	0.759	0.824
-	C_p	0.022	-0.186	-0.249	-0.389	-0.425	-0.522	-0.379	-0.283	-0.142	-0.098	-0.075	-0.076	-0.043	0.009
1.	-0.89 C_p/δ_0	-0.042	0.000	-0.031	-0.016	-0.073	0.000	0.364	0.438	0.545	0.711	0.837	2.856	1.669	0.000
90.	-0.89R($\bar{C}_p/\delta_0$)	-0.034	-0.029	0.000	-0.024	-0.057	-0.175	-0.324	0.774	0.935	1.152	1.171	3.435	2.098	1.027
	-0.89I($\bar{C}_p/\delta_0$)	-0.052	-0.046	0.000	-0.035	-0.043	-0.075	-1.463	-0.561	-0.316	-0.215	-0.180	-0.019	0.229	0.341

η = 0.60

f	data														
	ξ	0.012	0.024	0.049	0.098	0.198	0.298	0.398	0.498	0.572	0.622	0.660	0.724	0.759	0.825
-	C_p	0.069	-0.098	-0.167	-0.290	-0.418	-0.488	-0.441	-0.251	-0.174	-0.136	-0.081	-0.050	-0.035	-0.003
1.	-0.89 C_p/δ_0	-0.007	-0.028	0.042	0.011	0.005	1.022	0.546	1.152	1.344	1.476	1.516	2.495	1.529	0.667
90.	-0.89R($\bar{C}_p/\delta_0$)	-0.094	-0.075	0.000	-0.109	-0.267	-0.033	1.581	1.739	1.833	1.920	2.012	3.055	1.930	0.847
	-0.89I($\bar{C}_p/\delta_0$)	-0.122	-0.132	0.000	-0.126	-0.333	-2.397	-0.421	-0.272	-0.143	-0.066	-0.017	0.240	0.338	0.374

η = 0.75

f	data														
	ξ	0.012	0.024	0.048	0.098	0.198	0.297	0.397	0.497	0.572	0.622	0.660	0.723	0.758	0.823
-	C_p	0.059	-0.144	-0.399	-0.334	-0.478	-0.476	-0.317	-0.219	-0.146	-0.101	-0.064	0.000	0.000	0.000
1.	-0.89 C_p/δ_0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
90.	-0.89R($\bar{C}_p/\delta_0$)	-0.028	0.019	-0.048	0.009	0.138	1.927	1.787	0.858	0.486	0.416	0.354	0.684	0.419	0.182
	-0.89I($\bar{C}_p/\delta_0$)	-0.441	-0.524	-0.555	-0.866	-1.191	-0.609	0.106	0.216	0.188	0.159	0.132	0.313	0.221	0.134

Table 6.5

CASE 11

Test	M	α	δ_0	Surface	$k = 2.7 \times 10^{-3} f$
15	0.90	1.0	1.76(f=1) 1.58(f=90)	upper	

η = 0.35

f	data														
	ξ	0.012	0.025	0.049	0.099	0.199	0.299	0.399	0.498	0.574	0.623	0.661	0.733	0.758	0.824
-	C_p	-0.081	-0.253	-0.387	-0.474	-0.570	-0.677	-0.435	-0.224	-0.159	-0.119	-0.088	-0.040	-0.014	0.027
1.	-0.89 $\bar{C}_p/\delta_0$	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
90.	-0.89R($\bar{C}_p/\delta_0$)	-0.018	-0.031	-0.018	-0.015	-0.010	-0.018	-0.129	-0.065	0.229	0.343	0.399	0.516	0.542	0.547
	-0.89I($\bar{C}_p/\delta_0$)	-0.043	-0.032	-0.032	-0.022	-0.020	-0.015	-0.041	-0.523	-0.373	-0.309	-0.262	-0.178	-0.138	-0.125

η = 0.45

f	data														
	ξ	0.012	0.026	0.049	0.099	0.199	0.299	0.398	0.498	0.573	0.623	0.660	0.723	0.759	0.824
-	C_p	-0.077	-0.278	-0.450	-0.435	-0.491	-0.600	-0.523	-0.212	-0.148	-0.104	-0.076	-0.079	-0.045	0.007
1.	-0.89 $\bar{C}_p/\delta_0$	-0.024	-0.033	0.024	-0.024	0.000	0.024	-0.052	0.387	0.505	0.657	0.661	2.362	1.497	0.732
90.	-0.89R($\bar{C}_p/\delta_0$)	-0.031	-0.008	-0.070	-0.005	-0.014	0.001	-0.680	0.308	0.776	1.007	1.004	3.194	2.059	1.076
	-0.89I($\bar{C}_p/\delta_0$)	-0.014	-0.027	-0.103	-0.006	-0.023	-0.005	-0.511	-0.626	-0.451	-0.310	-0.220	-0.193	0.163	0.235

η = 0.60

f	data														
	ξ	0.012	0.024	0.049	0.098	0.198	0.298	0.398	0.498	0.572	0.622	0.660	0.724	0.759	0.825
-	C_p	-0.073	-0.241	-0.296	-0.392	-0.511	-0.563	-0.548	-0.278	-0.177	-0.130	-0.092	-0.053	-0.041	-0.006
1.	-0.89 $\bar{C}_p/\delta_0$	-0.065	-0.048	-0.017	-0.052	-0.009	0.026	2.452	0.969	0.995	0.000	1.348	1.995	1.348	0.648
90.	-0.89R($\bar{C}_p/\delta_0$)	-0.094	-0.084	-0.063	0.042	-0.100	-2.097	1.090	1.639	1.952	0.000	1.963	2.844	1.925	0.965
	-0.89I($\bar{C}_p/\delta_0$)	-0.054	-0.059	-0.011	0.027	-0.038	-0.920	-2.110	-0.581	-0.240	0.000	-0.197	0.061	0.287	0.333

η = 0.75

f	data														
	ξ	0.012	0.024	0.048	0.098	0.198	0.297	0.397	0.497	0.572	0.622	0.660	0.723	0.758	0.823
-	C_p	-0.075	-0.337	-0.459	-0.391	-0.584	-0.426	-0.319	-0.210	-0.153	-0.109	-0.071	0.000	0.000	0.000
1.	-0.89 $\bar{C}_p/\delta_0$	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
90.	-0.89R($\bar{C}_p/\delta_0$)	0.003	-0.016	-0.075	-0.067	-0.138	0.044	4.265	1.348	0.672	0.512	0.437	0.780	0.519	0.255
	-0.89I($\bar{C}_p/\delta_0$)	-0.359	-0.324	-0.283	-0.118	-0.302	-0.441	-3.837	0.471	0.433	0.389	0.304	0.532	0.400	0.245

Table 6.5 (concluded)

CASE 11

Test	M	α	δ_0	Surface	
16	0.90	1.0	1.76(f=1) 1.58(f=90)	lower	$k = 2.7 \times 10^{-3} f$

$\eta = 0.35$

f	data															
		ξ	0.012	0.025	0.049	0.099	0.199	0.299	0.399	0.498	0.574	0.623	0.661	0.733	0.758	0.824
-		C_p	0.182	0.019	-0.124	-0.255	-0.381	-0.395	-0.305	-0.208	-0.142	-0.106	-0.077	-0.018	0.000	0.034
1.	0.89	$\bar{C}_p/\delta_0$	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
90.	0.89R($\bar{C}_p/\delta_0$)		-0.068	-0.078	-0.068	-0.083	-0.151	-0.316	0.230	0.397	0.354	0.375	0.400	0.477	0.525	0.533
	0.89I($\bar{C}_p/\delta_0$)		-0.071	-0.074	-0.066	-0.081	-0.125	-0.323	-0.532	-0.324	-0.184	-0.147	-0.125	-0.101	-0.054	-0.069

$\eta = 0.45$

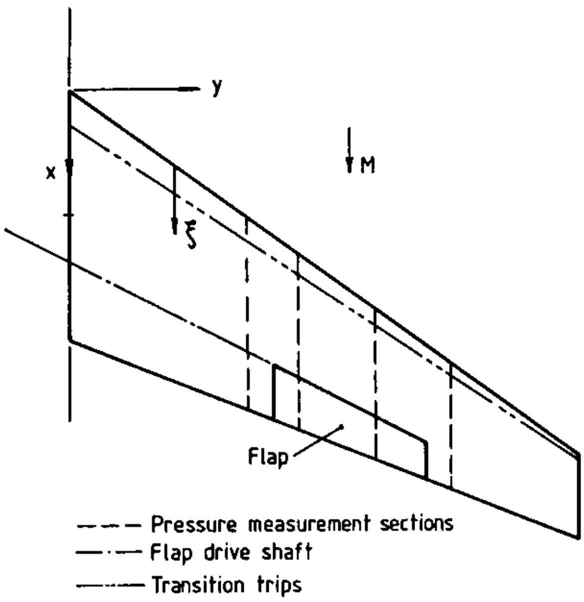
f	data															
		ξ	0.012	0.026	0.049	0.099	0.199	0.299	0.398	0.498	0.573	0.623	0.660	0.723	0.759	0.824
-		C_p	0.128	-0.069	-0.119	-0.271	-0.351	-0.429	-0.317	-0.193	-0.134	-0.090	-0.066	-0.065	-0.034	0.013
1.	0.89	$\bar{C}_p/\delta_0$	-0.113	0.000	0.000	0.000	0.066	0.141	0.353	0.368	0.500	0.688	0.792	2.597	1.527	0.726
90.	0.89R($\bar{C}_p/\delta_0$)		0.059	-0.067	-0.071	-0.089	-0.142	-0.349	0.579	0.550	0.699	0.892	0.923	2.866	1.755	0.846
	0.89I($\bar{C}_p/\delta_0$)		0.010	-0.073	-0.082	-0.092	-0.160	-0.542	-0.696	-0.245	-0.216	-0.200	-0.150	-0.222	0.124	0.210

$\eta = 0.60$

f	data															
		ξ	0.012	0.024	0.049	0.098	0.198	0.298	0.398	0.498	0.572	0.622	0.660	0.724	0.759	0.825
-		C_p	0.166	-0.001	-0.086	-0.223	-0.357	-0.427	-0.350	-0.234	-0.155	-0.116	-0.081	-0.048	-0.040	-0.006
1.	0.89	$\bar{C}_p/\delta_0$	-0.028	0.000	0.084	0.019	0.340	0.312	0.837	1.139	1.302	0.000	1.530	2.456	1.558	0.698
90.	0.89R($\bar{C}_p/\delta_0$)		-0.092	-0.075	-0.146	-0.126	-0.366	1.197	1.005	1.350	1.539	0.000	1.672	2.692	1.733	0.788
	0.89I($\bar{C}_p/\delta_0$)		-0.211	-0.247	-0.294	-0.263	-0.836	-0.745	-0.204	-0.333	-0.160	0.000	-0.167	0.003	0.268	0.307

$\eta = 0.75$

f	data															
		ξ	0.012	0.024	0.048	0.098	0.198	0.297	0.397	0.497	0.572	0.622	0.660	0.723	0.758	0.823
-		C_p	0.190	-0.015	-0.200	-0.259	-0.370	-0.380	-0.277	-0.200	-0.134	-0.097	-0.062	0.000	0.000	0.000
1.	0.89	$\bar{C}_p/\delta_0$	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
90.	0.89R($\bar{C}_p/\delta_0$)		0.266	0.291	0.240	0.385	0.652	1.269	1.162	0.061	0.653	0.000	0.422	0.535	0.341	0.164
	0.89I($\bar{C}_p/\delta_0$)		-0.372	-0.429	-0.406	-0.492	-0.557	-0.529	-0.040	0.126	0.126	0.000	0.108	0.197	0.139	0.082



Aspect ratio	AR	6
Taper ratio	λ	1/3
Section		RAE 101
Thickness/chord ratio	t/c	0·09
Sweepback: Leading edge	Λ(0)	36·65°
Mid-chord	Λ(0·5)	30·00°
Flap LE	Λ(0·7)	27·05°
Trailing edge	Λ(1·0)	22·33°
Semi-span	s	0·48m
Root chord	c_r	0·24m
First mean chord	$\bar{c}$	0·16m
Wing area	S/2	0·0768m²
Flap: Span		$0.4 \leq \eta \leq 0.7$
Chord		$0.7 \leq \xi \leq 1.0$
Transition trips: Position	ξ	0·05
Height	—	0·127mm

Fig 6.1 Model geometry: RAE Wing A

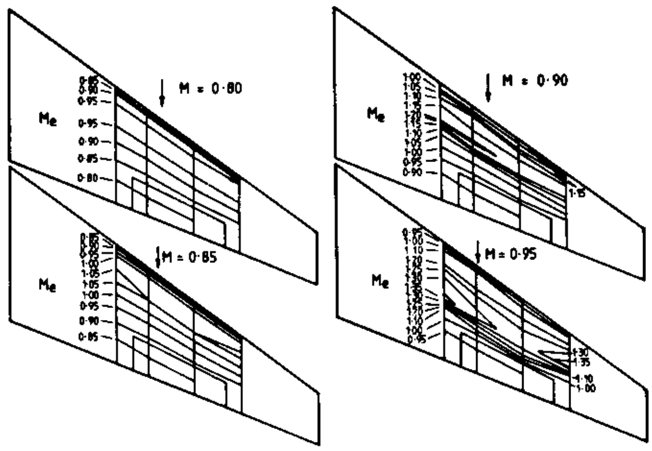


Fig 6.2 Mean isomach contours: α = 0

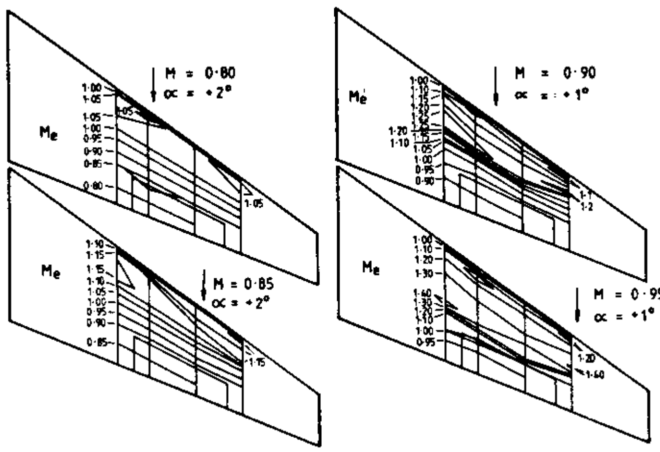


Fig 6.3 Mean isomach contours: suction surface

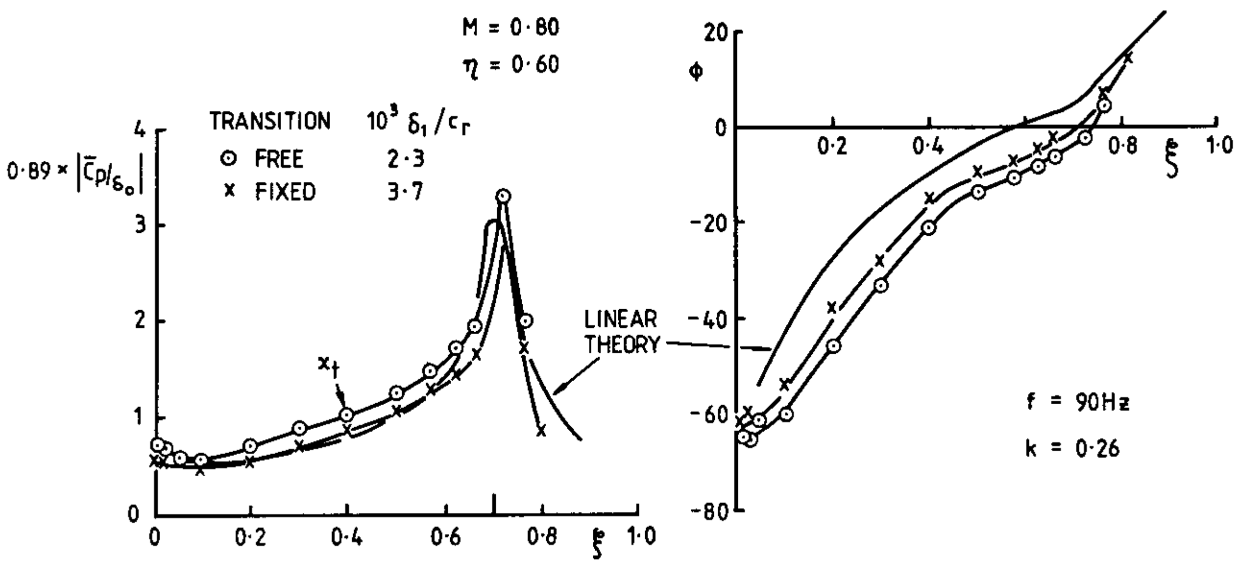
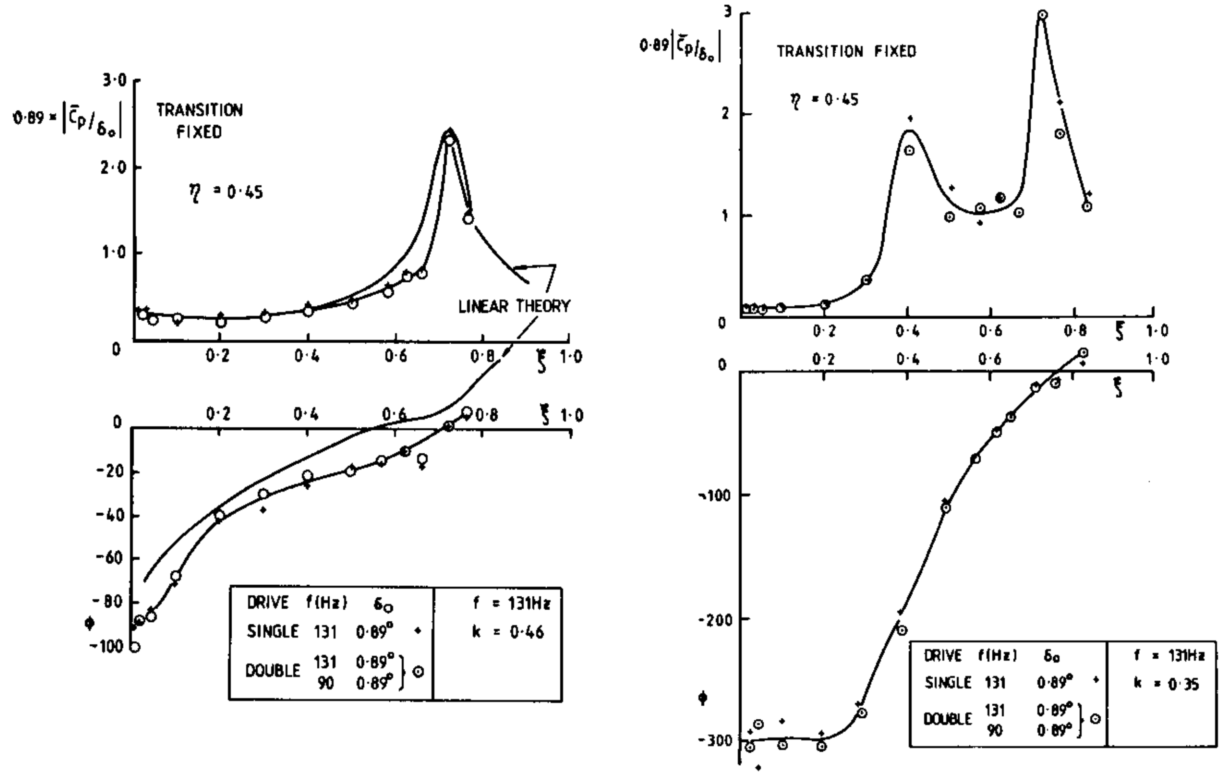
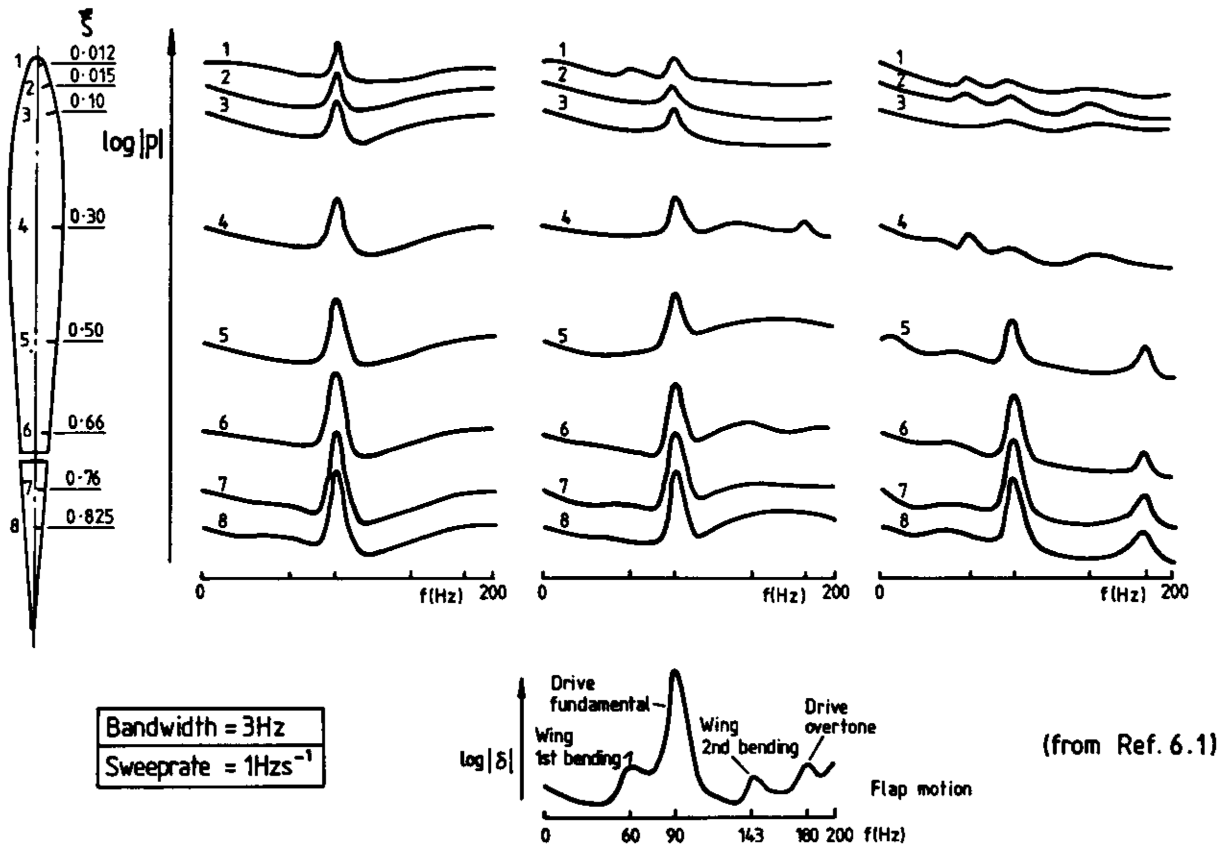


Fig 6.4 Magnitude and phase of subsonic pressure distribution



(a) Subsonic M = 0.65 (b) Transonic M = 0.90

Fig 6.5 Superposition of two frequencies



(a) Subcritical: M = 0.85 (b) Critical: M = 0.90 (c) Supercritical: M = 0.95

Fig 6.6 Typical spectra: $\alpha = 0$, $\eta = 0.60$

DATA SET 7

NORA MODEL. OSCILLATION ABOUT A SWEPT AXIS

by

N. C. Lambourne (formerly with RAE)

INTRODUCTION

This Data Set relates to a low-aspect-ratio model oscillating as a rigid body about a sweptback axis as shown in Fig 7.1. The data were obtained during an international cooperative investigation of wind-tunnel interference on unsteady measurements*. Comparative measurements were made in four different tunnels two of which, the NLR High Speed Tunnel (HST) and the ONERA Modane S2 tunnel, were large in comparison with the model. The results from those tunnels are considered to be free of large interference effects.

The numerical data included here correspond closely with the AGARD CT Cases and come mainly from the HST in which the most extensive tests were made. Where nominally identical conditions were tested in the S2 tunnel, the corresponding data from that source are also included.

Fig 7.2 and Table 7.1 show the parametric combinations for which data could be made available if required. The cases for which data are included here are detailed in Table 7.2; they comprise not only all the CT Cases, but in addition a low-frequency (5 Hz) set of data for every Mach number and mean incidence combination of the CT Cases.

Fig 7.1 and Table 7.3 show the positions at which the steady and unsteady pressures were measured. Because no steady pressures were obtained at the two spanwise positions at which the oscillatory pressures were measured, direct comparisons between unsteady and zero-frequency ($k = 0$) equivalents are not possible. However, oscillatory pressures were measured for an oscillation frequency of 5 Hz ($k \approx 0.035$) and it is considered that the in-phase component of pressure for this frequency is sufficiently close to that which would be obtained for a quasi-steady condition, $k \to 0$.

For the unsteady measurements, attention was directed mainly to the upper surface (the extrados, denoted throughout by E) whilst only a few measuring positions were provided at the lower surface (the intrados denoted by I).

It should be noted that the measured steady pressures are not expressed as pressure coefficients C_p, but as local Mach numbers M_L. Also the oscillatory pressures have not been converted from their original form of R and I, the real and imaginary components non-dimensionalised using tunnel total pressure, and not dynamic pressure. Multiplying factors for the conversion of these quantities to the more usual C_p'/θ_0 and C_p''/θ_0 are included in the tables.

Mode of oscillation

The oscillation imposed on the model was basically rigid-body rotation about the axis shown in Fig 7.1. The motion was defined by the output of a transducer attached to the driving shaft rigidly fixed to the root of the model. The transducer output was calibrated to read angular displacement θ in a streamwise plane parallel to the plane $y = 0$. The oscillatory signal, $\theta = \theta_0 \sin \omega t$, acted as a phase and amplitude reference for all the other oscillatory quantities.

Due to model flexibility, there were slight departures from the design mode of rigid-body motion, and these differences tended to increase with oscillation frequency. Information about the actual motion was obtained from the six accelerometers installed within the model as shown in Fig 7.1 and detailed in Table 7.4.

Because displacements deduced from accelerometers tend to be unrealiable for low frequencies, no measurements were made for 5 Hz. However, for this frequency it can be confidently concluded that the differences between the actual motion and the design mode were negligible.

For the 40 Hz tests corresponding to the CT Cases, the complex amplitudes of the normal displacements, z, at each of the accelerometer positions are given in Table 7.5. The severity of the departures from the design mode is more readily appreciated from Table 7.6 which gives, for the three spanwise positions containing accelerometers, local pitching and wing bending (*ie* the rotation about, and the normal displacements of, the design axis) as deduced on the basis that each chordwise section remains rigid. Not surprisingly, the deformations in twist and bending tend to increase with spanwise position.

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* The letters of the acronym NORA refer to the names of the organisations involved: NLR, ONERA, RAE and AVA (a branch of DFVLR).

The bending deformation if it were exactly in phase with the pitching motion would simply amount to a small change in the local position of the pitching axis. A few theoretical calculations made at the time of the experiments to examine the effect of changes of axis position on the unsteady aerodynamics showed that the measured amount of superimposed bending motion for 40 Hz is not likely to produce significant contributions to the oscillatory pressures.

With regard to the effects of the twisting deformation of the model, it can be inferred from Table 7.6 that the actual pitching motion at the sections η = 0.524 and 0.712, where the unsteady pressures were measured, has (1) an amplitude rather larger than the reference θ_0 and (2) a small phase lead. The phase lead is never larger than 4^o and its effect is probably negligible within the general accuracy of the measurements. Since no corrections for the model deformations have been applied to the tabulated data, which are normalised using the reference θ_0, the increase in pitching amplitude at the unsteady measuring sections suggests that a user of the 40 Hz data would be justified in reducing the values of the normalised quantities R and I by a few percent.

No numerical data for 60 Hz are presented here but could be made available if required. For this frequency the bending motion of the wing is larger than for 40 Hz, and without an analysis it is not possible to conclude that its effect is insignificant. In the absence of such analysis, the 60 Hz data should be regarded as only qualitatively relating to the design mode of motion.

Steady flow

The steady flow at the upper surface can be inferred from the distributions of M_L shown in Figs 7.3 to 7.6.

When the incidence is near to zero, for all M, there is a small region of high suction and a recompression situated close to the leading edge. With increase of incidence, for each subsonic M the high suction region extends backwards over the chord and is terminated by a steep pressure gradient - the forward recompression. For higher subsonic M this is followed by another expansion region, which for M = 0.95 is terminated by a shock wave - the rear shock, aft of mid-chord. The three-dimensional nature of the flow when the model is at incidence can be seen in the isomachs of Fig 7.7.

Whereas there is no doubt about the existence of the rear shock, the exact nature of the flow over the more forward part of the chord is not absolutely clear. Although for some of the test conditions the local Mach numbers in this forward region are supersonic, it is not obvious that the forward recompression involves a shock wave. Certainly there is no possibility of a shock wave for M = 0.80 even at the highest incidence. It is therefore important to note that the general shape of the forward recompression remains essentially the same as M is increased up to its highest subsonic value M = 0.95. Furthermore, the high angle of sweepback of the isomachs in the forward recompression region, as seen in Fig 7.7, suggests that a shock wave will not be present. Instead it is probable that for much of the incidence range and for all subsonic Mach numbers, a leading-edge separation vortex extends across the upper surface.

Influence of incidence on the oscillatory pressures

An example of the influence of mean incidence on the oscillatory pressures for M = 0.90 is shown in Fig 7.8 which gives results for the upper surface (E) at sections 2 and 4 and for the lower surface (I) at section 2. It is the upper surface that is most affected by increasing positive incidence, the lower surface tending to retain the pattern it has for the non-lifting condition. Also, whereas for a non-lifting condition the distributions for the two spanwise positions are basically similar, with increase of incidence the characteristics for the upper surface become more three-dimensional and the leading-edge peaks in R(X) and I(X) move to the rear and broaden. These changes are doubtless related to the rearward displacement with incidence of the steady-flow recompression region, as already seen in Fig 7.4. For $\alpha_m = 3^o$, R(X) and I(X) at section 2E each consists of a leading-edge peak followed by several subsidiary peaks or 'crinkles', lying ahead of the rear shock peak which is situated at about 55% chord. With further increase of incidence to $\alpha_m = 5^o$, the crinkles have almost disappeared and have been replaced by a more regular distribution of forward and rear peaks. It would seem that this evolution is associated with successive stages in the development locally of high subsonic and eventually supersonic flow.

At section 4E with increase of incidence, R(X) becomes negative over nearly all of the rearward half of the chord. At the highest incidence, $\alpha_m = 5^o$, the forward peak extends over much of the fore-chord as a result of the fanning-out of the forward recompression, possibly associated with the separated vortex flow suggested previously.

Influence of oscillation frequency

The effects of changing oscillation frequency are shown, at least qualitatively, for each of the CT combinations of M and α_m in Figs 7.9 to 7.15. For the non-lifting cases, Figs 7.9 to 7.12, results are shown for section 2E only; for the lifting cases, Figs 7.13 to 7.15, results are shown for both sections 2E and 4E.

Changing frequency is generally expected to affect the imaginary component and phase angle. For the non-lifting cases the frequency effects on the real component are not large when the flow is either completely subsonic (Fig 7.9 for M = 0.8) or completely supersonic (Fig 7.12 for M = 1.10). Greater sensitivity to frequency appears in both real and imaginary components where the local flow is close to sonic (Fig 7.10 for M = 0.9, near mid chord) or in the vicinity of the rear shock wave (Fig 7.12 for M = 0.95).

For the lifting cases (Figs 7.13 to 7.15) the real and imaginary components show considerable changes, not only at the rear shock wave, but also at the forward peaks.

Sensitivity to small changes in M and α_m

When comparisons between experimental and computational results are being made, it is helpful to be aware of the sensitivity to small variations in the parameters and of the uncertainties in the measurements. For the present model with sonic or near-sonic flow the real and imaginary distributions R(X) and I(X) are sensitive not only to frequency but also to small changes of M and α_m .

As shown in Fig 7.2 the tests for the mean conditions M = 0.90, $\alpha_m = 4^\circ$ and M = 0.95, $\alpha_m = 4.75^\circ$ corresponding to CT Cases 5 and 7 or 8 are each surrounded by eight neighbouring test cases with small differences in M and α_m . It is from these matrices of tests that information on sensitivity can be obtained.

Fig 7.16 shows for the initial condition M = 0.90, $\alpha_m = 4^\circ$, the separate effects of making changes of $\pm 0.2^\circ$ in α_m and ± 0.01 in M . Whilst the forward peaks in R(X) and I(X) show some sensitivity to the incidence change, it is the rear peaks that show most sensitivity to the Mach number change. The increase from M = 0.89 to M = 0.90 changes the mid-chord crinkles to a distribution with well-defined peaks. A further increase to M = 0.91 displaces the peaks to the rear.

For the initial condition M = 0.95, $\alpha_m = 4.75^\circ$ the distributions are relatively insensitive to incidence changes of 0.25°, but quite sensitive to the Mach number changes of ± 0.01 as shown in Fig 7.17. The distributions for section 2E demonstrate an important point: when a peak has become very sharp, it may just be detectable from only a single point, as for M = 0.95, or may even be 'lost' between measuring positions as we believe has happened for M = 0.96. Section 4E shows a highly sensitive negative peak in R(X) .

Figs 7.18 and 7.19 may be of special interest when assessing the significance of any differences between computational and experimental data. They show the measurements corresponding to the 40 Hz CT Cases for M = 0.90, $\alpha_m = 4^\circ$ and M = 0.95, $\alpha_m = 4.75^\circ$ within envelopes that enclose all the data measured for the surrounding test matrices. It is suggested the envelopes could be a help in deciding on the tolerances to be accepted when judging the results of computations.

For CT Cases 1, 4 and 6, as seen in Table 7.2, numerical data obtained in the ONERA S2 tunnel are included for comparison with the data obtained from the main source, the HST of NLR. For the conditions M = 0.90, $\alpha_m = 4^\circ$ and M = 0.95, $\alpha_m = 4.75^\circ$ corresponding to CT Cases 5 and 7 no measurements are available from the S2 tunnel. However comparisons between the two tunnels are available for the two nearby conditions, M = 0.90, $\alpha_m = 5^\circ$ and M = 0.95, $\alpha_m = 5^\circ$ and are shown in Figs 7.20 and 7.21. It must be emphasised that the results from both tunnels were obtained using the same techniques and with the same instrumentation, so that from these comparisons it is impossible to draw conclusions about any uncertainties arising from the instrumentation itself. The comparisons do however give some idea of the likely spread in the data from items such as tunnel interference, the character of the tunnel flow and the consistency of the parameter settings.

Since the results from the two tunnels are regarded as having equal 'weight', a theoretical result which, when compared with the results from one tunnel, shows similar discrepancies to those in Figs 7.20 and 7.21 could be regarded as being in general agreement with experiment.

1 GENERAL DESCRIPTION OF MODEL

1.1	Designation	NORA model
1.2	Type	Half model
1.3	Derivation	Horizontal tail surface of Mirage F1
1.4	Additional remarks	-
1.5	References	Ref 7.1

2 MODEL GEOMETRY

2.1	Planform	For the actual model, see Fig 7.1. For the computational model, see Ref 7.2 for modififed planform with streamwise tip
2.2	Aspect ratio	2.01
2.3	Leading-edge sweep	50°
2.4	Trailing-edge sweep	13° 26'
2.5	Taper ratio	0.3515 (for the computational model)
2.6	Twist	None
2.7	Root chord	650 mm
2.8	Span of model	442.5 mm
2.9	Area of planform	0.1944 m^2 (for the computational model)
2.10	Location of reference sections and definition of profiles	The profile is based on the symmetric NACA 63006 modified to a thickness ratio of about 5% and with a small updroop near the nose. For details of actual model, see Figs 45 and 46 of Ref 7.1. For the computational model, see Ref 7.2
2.11	Lofting procedure between reference sections	(see 2.10)
2.12	Form of wing-body, or wing-root junction	Clearance between root and tunnel wall. Small fillet attached to model to cover shaft aperture, see Fig 4a of Ref 7.1
2.13	Form of wing tip	Actual model: sharp Computational model: square cut
2.14	Control surface details	None
2.15	Additional remarks	-
2.16	References	Refs 7.1, 7.2

3 WIND TUNNELS

3.1	Designation	HST: NLR High Speed Tunnel (HST) S2: ONERA Modane S2
3.2	Type of tunnel	HST: Continuous, variable pressure S2: Continuous, variable pressure
3.3	Test section dimensions	HST: Height = 1.60 m, width = 2.00 m, length = 2.50 m S2: Height = 1.77 m, width = 1.75 m, length = 5.40 m (of perforated part)
3.4	Type of roof and floor	HST: Slotted, each having four whole slots and a ½-slot at each corner S2: Perforated plates, with holes inclined 60° to the normal. Each plate is backed by a perforated sheet which can be slid to vary porosity
3.5	Type of side walls	HST: Solid S2: Solid
3.6	Ventilation geometry	HST: Roof and floor are 12% open S2: Porosity of roof and floor chosen according to Mach number. 1% open for M = 0.80 and M = 1.10; 6% open for M = 0.9 and M = 0.95
3.7	Thickness of side wall boundary layer	HST: 7 mm approximately S2: 90 to 170 mm
3.8	Thickness of boundary layers at roof and floor	HST: - S2: -
3.9	Method of measuring Mach number	HST: Derived from settling chamber stagnation and plenum chamber static pressures S2: -
3.10	Flow angularity	HST: - S2: -

3.11	Uniformity of Mach number over test section	HST: - S2: $\Delta M/\Delta x = \pm 3 \times 10^{-3}\ m^{-1}$ for $0.70 < M < 0.92$
3.12	Sources and levels of noise or turbulence in empty tunnel	HST: Less than 1% in rms p/q for M = 0.8 S2: Velocity turbulence: 0.2%
3.13	Tunnel resonances	HST: } S2: } No evidence of resonance in present tests
3.14	Additional remarks	HST: Information about flow angularity and Mach number uniformity available only along test section centre-line S2: Accuracy of Mach number, $\Delta M = \pm 0.001$
3.15	References on tunnel	HST: Ref 7.3 S2: Refs 7.4, 7.5, 7.6

4 MODEL MOTION

4.1	General description	Rigid-body oscillation about swept axis shown in Fig 7.1. Sinusoidal in time
4.2	Reference coordinate and definition of motion	Rotation $\theta = \theta_0 \sin \omega t$ measured in streamwise plane $y = 0$ at the root
4.3	Range of amplitude	$0.25^\circ \leqslant \theta_0 \leqslant 1.00^\circ$
4.4	Range of frequency	Standard frequencies for main data: 5, 40 and 60 Hz. A few special tests at other frequencies up to 95 Hz, see Ref 7.1
4.5	Method of applying motion	Forced by hydraulic rotary actuator
4.6	Timewise purity of motion	Purity of sinusoid considered to be adequate
4.7	Natural frequencies and normal modes of model and support system	Lowest natural frequency of system: torsion of drive shaft at 100 Hz approximately
4.8	Actual mode of applied motion including any elastic deformation	See Introduction and Tables 7.5 and 7.6
4.9	Additional remarks	-

5 TEST CONDITIONS

5.1	Model planform area/ tunnel area	HST: 0.06 S2: 0.06
5.2	Model span/tunnel width	HST: 0.22 S2: 0.25
5.3	Blockage	HST: } S2: } 0.3% for zero incidence
5.4	Position of model in tunnel	HST: Standard side-wall position S2: Standard wall mounting position
5.5	Range of Mach number	HST: $0.60 \leqslant M \leqslant 1.10$, see Table 7.1 S2: $0.80 \leqslant M \leqslant 0.95$
5.6	Range of tunnel total pressure	$0.46 \leqslant p_t \leqslant 0.9$ bar, see Table 7.1
5.7	Range of tunnel total temperature	HST: $30^\circ C \leqslant T_0 \leqslant 38^\circ C$ S2: $18^\circ C \leqslant T_0 \leqslant 20^\circ C$
5.8	Range of model steady, or mean, incidence	HST: $0.5^\circ \leqslant \alpha_m \leqslant 5.0^\circ$ S2: $-1.0^\circ \leqslant \alpha_m \leqslant 5.0^\circ$
5.9	Definition of model incidence	Chord line of basic symmetrical section was datum for incidence
5.10	Position of transition, if free	-

5.11	Position and type of trip, if transition fixed	Metal tapes with 'coronets' about 0.09 mm high fixed at 5% local chord on both surfaces
5.12	Flow instabilities during tests	None encountered
5.13	Changes to mean shape of model due to steady aerodynamic load	Not measured, but considered negligible
5.14	Additional remarks	-
5.15	References describing tests	Ref 7.1

6 MEASUREMENTS AND OBSERVATIONS

6.1	Steady pressures for the mean conditions	✓
6.2	Steady pressures for small changes from the mean conditions	-
6.3	Quasi-steady pressures	✓ (5Hz)
6.4	Unsteady pressures	✓
6.5	Steady section forces for the mean conditions by integration of pressures	✓
6.6	Steady section forces for small changes from the mean conditions by integration	-
6.7	Quasi-steady section forces by integration	✓ (5Hz)
6.8	Unsteady section forces by integration	✓
6.9	Measurement of actual motion at points on model	✓
6.10	Observation or measurement of boundary layer properties	-
6.11	Visualization of surface flow	-
6.12	Visualization of shock wave movements	-
6.13	Additional remarks	-

7 INSTRUMENTATION

7.1	Steady pressure	
7.1.1	Position of orifices spanwise and chordwise	See Fig 7.1 and Table 7.3
7.1.2	Type of measuring system	Orifices connected by tubes to conventional tunnel-based system
7.2	Unsteady pressures	
7.2.1	Position of orifices spanwise and chordwise	See Fig 7.1 and Table 7.3
7.2.2	Diameter of orifices	0.8 mm
7.2.3	Type of measuring system	Each orifice closely connected to its own transducer installed within model
7.2.4	Type of transducers	Kulite XCQL 093
7.2.5	Principle and accuracy of calibration	Daily calibration using portable oscillatory pressure generator. Accuracy probably a few percent
7.3	Model motion	
7.3.1	Method of measuring motion reference coordinate	Rotary potentiometer attached to drive shaft, calibrated to give deflection θ
7.3.2	Method of determining spatial mode of motion	Six accelerometers installed within model; see Fig 7.1 and Table 7.4
7.3.3	Accuracy of measured motions	Resolution of θ, about 0.01°. Accelerometers readings, accurate to a few percent

7.4	Processing of unsteady measurements	
7.4.1	Method of acquiring and processing measurements	Pressure and accelerometer signals processed sequentially in groups by ten parallel channels. Each channel consisted of analogue circuitry giving output voltages proportional to Fourier fundamental components. Output voltages digitized and fed to computer for conversion to coefficients, display and disc-storage
7.4.2	Type of analysis	Components in phase and in quadrature with θ, averaged over 8 seconds
7.4.3	Unsteady pressure quantities obtained and accuracies achieved	Fundamental harmonic coefficients of pressure, accurate to a few percent. Chordwise integration to give section lift and moment contributions from upper and lower surfaces, but accuracy low because of wide spacing
7.4.4	Method of integration to obtain forces	Polygonal summation, see Appendix C of Ref 7.1
7.5	Additional remarks	-
7.6	References on techniques	-

8 DATA PRESENTATION

8.1	Test cases for which data could be made available	Table 7.1
8.2	Test cases for which data are included in this document	Table 7.2
8.3	Steady pressures	Tables 7.7 to 7.13
8.4	Quasi-steady or steady perturbation pressures	Data for 5 Hz in Tables 7.14 to 7.27
8.5	Unsteady pressures	Tables 7.14 to 7.30
8.6	Steady forces or moments	Not included
8.7	Quasi-steady or steady perturbation forces	Not included
8.8	Unsteady forces and moments	Not included
8.9	Other forms in which data could be made available	Unsteady pressures measured at tunnel roof
8.10	References giving other presentations of data	Ref 7.1

9 COMMENTS ON DATA

9.1	Accuracy	
9.1.1	Mach number	±0.005
9.1.2	Steady incidence	$\pm 0.01^{\circ}$
9.1.3	Reduced frequency	Better than ±2% of nominal values due to temperature variations
9.1.4	Steady pressure coefficients	M_L to ±0.005
9.1.5	Steady pressure derivatives	-
9.1.6	Unsteady pressure coefficients	The uncertainties in the coefficients R and I are probably $\pm(0.02 + 0.04Q)$, where $Q = \lvert R \rvert$ or $\lvert I \rvert$
9.2	Sensitivity to small changes of parameter	See Introduction and Figs 7.15 to 7.19
9.3	Non-linearities	Normalised pressure coefficients not sensitive to oscillation amplitude except for positions near the leading edge or a shock wave
9.4	Influence of tunnel total pressure	Effects of Reynolds number not examined

9.5	Effects on data of uncertainty, or variation, in mode of model motion	Not large for 5 Hz and 40 Hz. See Introduction and Tables 7.5 and 7.6
9.6	Wall interference corrections	No corrections applied to any data. Values of M and α_m are tunnel settings
9.7	Other relevant tests on same model	-
9.8	Relevant tests on other models of nominally the same shape	-
9.9	Any remarks relevant to comparison between experiment and theory	-
9.10	Additional remarks	-
9.11	References on discussion of data	Ref 7.1

10 PERSONAL CONTACT FOR FURTHER INFORMATION

Mr B.L. Welsh, Royal Aircraft Establishment, Bedford MK41 6AE, England (or, if convenient, any of the authors of Ref 7.1).

11 LIST OF REFERENCES

7.1	N. Lambourne R. Destuynder K. Kienappel R. Roos	Comparative measurements in four European wind tunnels of the unsteady pressures on an oscillating model (the NORA experiments). (1980) Issued in each of the following forms: RAE Technical Report 80016 ONERA 1589/OR; Note Technique 10/5115 RY DFVLR-FB 80-30 NLR TR 80066 U Also published as AGARD-R-673, but this does not contain the Appendices giving full details of the model and tests.
7.2	S.R. Bland	AGARD three-dimensional aeroelastic configurations. AGARD-AR-167
7.3	-	Users guide to the high speed wind tunnel. HST of NLR (revised edition) (1977)
7.4	M. Pierre G. Fasso	The aerodynamic test center of Modane Avrieux. ONERA Technical Note 166E (1972)
7.5	M. Pierre G. Fasso	Exploitation du centre d'essai aerothermodynamique de Modane Avrieux. ONERA Note Technique 181 (1971)
7.6	V. Schmitt F. Charpin	Experimental data base for computer program assessment. AGARD AR 138, pp.B1-1 to B1-44 (1979)

12 NOTATION

General

c	local chord
c_r	root chord
C'_p/θ_0, C''_p/θ_0	normalised fundamental in-phase and in-quadrature components of oscillatory pressure, respectively $p'/q\theta_0$ and $p''/q\theta_0$ (rad^{-1})
E	as in 2E, 4E, denotes extrados, or upper surface
f	oscillation frequency (Hz), $\omega/2\pi$
I	as in 2I, 4I, denotes intrados, or lower surface
I	normalised fundamental in-quadrature component of pressure, $-p''/p_t\theta_0$ (rad^{-1})
I(X)	chordwise distribution of I
k	reduced frequency, $\omega c_r/2V$
M	stream Mach number

M_L	local Mach number at surface of model, $M_L = \left\{5\left[(p/p_t)^{-2/7} - 1\right]\right\}^{-1/2}$
p	pressure
p_t	stream total pressure
p', p"	fundamental components of pressure respectively in phase and in quadrature with oscillatory motion θ
q	stream dynamic pressure
R	normalised fundamental in-phase component of pressure $-p'/p_t\theta_0$ (rad^{-1})
R(X)	chordwise distribution of R
s	span of model
t	time
T_0	stream total temperature
V	stream velocity
x, y	coordinates in plane of model, see Fig 7.1
$x_{LE}(y)$	coordinate of local leading edge
$x_\alpha(y)$	local chordwise position of oscillation axis
X	local chordwise position, ξ
z	upward displacement normal to plane of model
α	incidence of model (deg)
α_m	steady, or mean, incidence (deg)
η	non-dimensional spanwise position, y/s
θ	coordinate for specifying angular oscillatory motion, positive nose up, measured in planes parallel to plane y = 0 . Reference at drive shaft $\theta = \theta_0 \sin \omega t$ (deg)
θ_0	reference amplitude of motion, identical to α_0 of Ref 7.2 (deg)
ξ	non-dimensional chordwise position, $(x - x_{LE})/c$
ω	oscillation frequency (rad^{-1})

Chordwise sections are identified 0E ... 6E and 0I ... 6I ; see Table 7.3 for positions.

Tables 7.7 to 7.13

MLOC	local Mach number, M_L
EXTR	extrados = upper surface
INTR	intrados = lower surface

Tables 7.14 to 7.30

PRESSURE stream total pressure, p_t

The factor $(C'_p/R) \equiv (C''_p/I)$, whose value F is given at the head of each table can be used to obtain C'_p/θ_0 and C''_p/θ_0 , but note that a change of sign is required, thus:

$$C'_p/\theta_0 = - R \times F$$

$$C''_p/\theta_0 = - I \times F \ .$$

Figures 7.8 to 7.12

Modulus $= (R^2 + I^2)^{\frac{1}{2}}$

tan ϕ $= I/R$.

Table 7.1

TEST NUMBERS OF DATA THAT CAN BE MADE AVAILABLE

Test numbers are necessarily different for different frequencies, but for the steady pressures they are often the same as those for one of the frequencies, usually 40 Hz. Data are included in this document for those numbers underlined

M	α_m (deg)	p_t (bars)	Steady	5 Hz	40 Hz	60 Hz
0.60	0.4	0.9	2006	2192	2006	2182
	4.5	0.9	2007	2193	2007	2183
0.79	0.4	0.9	2008	2186	2008	2175
	3.8	0.9	2009	2191	2009	2181
0.80	0	0.9	2010	2185/2194	2010	2174/2184
	1.0	0.9	2011	2187	2011	2176
	2.0	0.9	2012	2188	2012	2177
	3.0	0.9	1061	2189	2013	2178
	4.0	0.9	2014	2190	2014	2180
0.89	3.5	0.6	2019	2142	2019	2169
	3.8	0.6	2044	2141	2017/2044	2168
	4.0	0.6	2041	2143	2042	2170
	4.2	0.6	2043	2144	2043	2171
0.90	-0.5	0.6	2024	2122	2024	2157
	-0.3	0.6	2023	2139	2023	2166
	0	0.6	2029	2124	2029	2158
	0.3	0.6	2020	2125	2020	2159
	1.0	0.6	2030	2126	2030	2160
	2.0	0.6	2031	2127	2031	2161
	3.0	0.6	2032	2128	2032	2162
	3.8	0.6	2034	2129/2135	2034	2163
	4.0	0.6	2035	2136	2035	2164
	4.2	0.6	2036	2138	2036	2165
	4.75	0.46	2200	2197	2200	2203
	5.0	0.46	2201	2199	2201	2204/2224
0.91	3.8	0.6	2037	2119	2037	2154
	4.0	0.6	2038	2120	2038	2155
	4.2	0.6	2040	2121	2040	2156
0.92	4.75	0.46	2092	2109	2092	2205
0.93	5.0	0.46	2093	2110	2093	2206
0.94	0	0.6	2027	2134	2027	2153
	4.5	0.46	2085	2102	2085	2207
	4.75	0.46	2086	2103	2086	2208
	5.0	0.46	2087	2104	2087	2211
0.95	0	0.6	2046	2114	2046	2149
	0.5	0.6	2028	2135	2028	2152
	1.0	0.6	2047	2115	2047	2150
	2.0	0.6	2048	2116	2048	2151
	2.0	0.46	2079	2096	2079	2212
	3.0	0.6	2051	2117	2118	-
	3.0	0.46	2080	2097	2080	2213
	4.0	0.46	2081	2098	2081	2214
	4.5	0.46	2082	2099	2082	2218
	4.75	0.46	2083	2100	2083	2219
	5.0	0.46	2084	2101	2084	2220
0.96	4.5	0.46	2088	2105	2088	2221
	4.75	0.46	2089	2106	2089	2222
	5.0	0.46	2090	2107	2090	2223
1.10	0.6	0.6	2045	2113	2045	2148

Each set of measurements comprises:

Steady local Mach numbers, as in Tables 7.7 to 7.13
Oscillatory pressures, as in Tables 7.14 to 7.30
Accelerometer displacements, as in Table 7.5

Frequency parameter: k (nominal) $= 5.8f\,(0.2 + M^{-2})^{0.5} \times 10^{-3}$

Reynolds number: the nominal value of $Re \times 10^{-6}$ for any Mach number can be interpolated from the following table:

M	p_t (bar)		
	0.46	0.6	0.9
0.60	-	-	6.6
0.80	-	5.2	7.8
0.90	4.2	5.5	-
0.95	4.3	5.6	-
1.00	4.4	5.7	-
1.10	-	5.8	-

Table 7.2

DETAILS OF EXPERIMENTAL CASES FOR WHICH DATA ARE INCLUDED

CT Case	M	α_m (deg)	$\alpha_0 \equiv \theta_0$ (deg) nominal	f (Hz)	k nominal	p_t (bar)	Re $\times 10^{-6}$	Steady M_L HST Test No.	Steady M_L HST Table	Oscillatory pressures HST Test No.	Oscillatory pressures HST Table	Oscillatory pressures S2 Test No.	Oscillatory pressures S2 Table
-	0.80	0	0.5	5	0.038	0.90	7.8	2010	7.7	2185	7.14	-	-
1	0.80	0	0.5	40	0.31	0.90	7.8	2010	7.7	2010	7.15	80	7.28
-	0.80	4.0	0.5	5	0.038	0.90	7.8	2014	7.8	2190	7.16	-	-
2*	0.80	4.0	0.5	40	0.31	0.90	7.8	2014	7.8	2014	7.17	-	-
3	0.90	0	0.5	5	0.035	0.60	5.5	2029	7.9	2124	7.18	-	-
4	0.90	0	0.5	40	0.28	0.60	5.5	2029	7.9	2029	7.19	76	7.29
-	0.90	4.0	0.5	5	0.035	0.60	5.5	2035	7.10	2136	7.20	-	-
5*	0.90	4.0	0.5	40	0.28	0.60	5.5	2035	7.10	2035	7.21	-	-
-	0.95	0	0.5	5	0.034	0.60	5.6	2046	7.11	2114	7.22	-	-
6*	0.95	0	0.5	40	0.27	0.60	5.6	2046	7.11	2046	7.23	69	7.30
7	0.95	4.75	0.5	5	0.034	0.46	4.3	2083	7.12	2100	7.24	-	-
8	0.95	4.75	0.5	40	0.27	0.46	4.3	2083	7.12	2083	7.25	-	-
-	1.10	0.55	0.5	5	0.030	0.60	5.8	2045	7.13	2113	7.26	-	-
9	1.10	0.55	0.5	40	0.24	0.60	5.8	2045	7.13	2045	7.27	-	-

* Denotes CT priority case.

Table 7.3

POSITIONS OF PRESSURE HOLES

Section	0	1	2	3	4	5	6
y/s	0.133	0.389	0.524	0.612	0.712	0.786	0.895
Pressures	Steady	Steady	Unsteady	Steady	Unsteady	Steady	Steady
			E. Extrados (upper surface)				
X =	0.0125	0.025	0.012	0.05	0.012	0.075	0.10
	0.025	0.05	0.025	0.10	0.025	0.15	0.15
	0.05	0.10	0.05	0.15	0.05	0.22	0.22
	0.10	0.15	0.10	0.22	0.10	0.30	0.30
	0.22	0.22	0.20	0.30	0.20	0.40	0.40
	0.30	0.30	0.28	0.40	0.28	0.50	0.50
	0.40	0.40	0.35	0.50	0.35	0.62	0.62
	0.62	0.50	0.40	0.62	0.40	0.75	0.75
	0.75	0.62	0.45	0.75	0.45	0.88	
	0.90	0.75	0.50	0.90	0.50		
		0.90	0.55		0.55		
			0.60		0.60		
			0.65		0.65		
			0.70		0.70		
			0.80		0.80		
			0.87		0.87		
			I. Intrados (lower surface)				
X =	0.0125	0.025	0.05	0.05	0.05	0.075	0.10
	0.025	0.05	0.10	0.10	0.10	0.15	0.15
	0.05	0.10	0.20	0.15	0.20	0.22	0.22
	0.10	0.15	0.28	0.22	0.28	0.30	0.30
	0.22	0.22	0.40	0.30	0.40	0.40	0.40
	0.30	0.30	0.50	0.40	0.50	0.50	0.50
	0.40	0.40	0.60	0.50	0.60	0.62	0.62
	0.62	0.50	0.70	0.62	0.70	0.75	0.75
	0.75	0.62		0.75		0.85	
	0.90	0.75		0.87			
		0.88					

Table 7.4

POSITION OF ACCELEROMETERS IN RELATION TO $x_\alpha(y)$ THE CHORDWISE POSITION OF THE DESIGN AXIS OF OSCILLATION

y/s	Forward position (A)		Rearward position (B)	
	Accel. No.	$x_\alpha - x_A$ (mm)	Accel. No.	$x_B - x_\alpha$ (mm)
0.169	1	260	2	180
0.655	3	110	4	90
0.931	5	55	6	48

Table 7.5

DISPLACEMENTS DEDUCED FROM ACCELEROMETERS. DISPLACEMENTS Z' AND Z", MEASURED IN mm, ARE RESPECTIVELY IN-PHASE AND IN-QUADRATURE COMPONENTS PHASE REFERENCED TO DATUM ANGULAR DISPLACEMENT θ

Note: These are taken from Ref 7.1 but a change of sign has been applied throughout

Test No.	η = 0.169				η = 0.655				η = 0.931			
	Accel. No.1 (A)		Accel. No.2 (B)		Accel. No.3 (A)		Accel. No.4 (B)		Accel. No.5 (A)		Accel. No.6 (B)	
	Z'_A	Z''_A	Z'_B	Z''_B	Z'_A	Z''_B	Z'_A	Z''_B	Z'_A	Z''_B	Z'_A	Z''_B
2010	2.322	0.086	-1.602	-0.038	1.148	0.072	-0.672	0.027	0.753	0.089	-0.211	0.084
2014	2.305	0.125	-1.570	-0.080	1.184	0.083	-0.598	-0.009	0.847	0.077	-	0.056
2029	2.314	0.104	-1.614	-0.058	1.116	0.073	-0.708	0.009	0.709	0.086	-0.271	0.056
2035	2.271	0.150	-1.567	-0.100	1.138	0.089	-0.639	-0.023	0.769	0.080	-0.153	0.053
2046	2.297	0.079	-1.590	-0.051	1.130	0.052	-0.661	0.009	0.743	0.061	-0.209	0.044
2083	2.282	0.113	-1.584	-0.092	1.124	0.040	-0.653	-0.047	0.756	0.019	-0.203	-0.033
2045	2.323	0.046	-1.590	-0.049	1.173	0.009	-0.621	-0.029	0.802	0.000	-0.143	-0.016

Table 7.6

LOCAL DISPLACEMENTS IN PITCH $(\theta, \varepsilon_\theta)_\eta$ AND NORMAL TRANSLATION OF DESIGN AXIS $(Z, \varepsilon_z)_\eta$ PHASE REFERENCED TO DATUM $\theta = \theta_0 \sin \omega t$. COMPLEX QUANTITIES θ_η AND Z_η ARE DERIVED FROM TABLES 7.4 AND 7.5 ON THE BASIS THAT CHORDWISE SECTIONS DO NOT DEFORM, THUS

$$\theta_\eta = (Z_A - Z_B)/(x_B - x_A) , \qquad Z_\eta = \left[Z_A(x_B - x_A) + Z_B(x_\alpha - x_A)\right] \Big/ (x_B - x_A)$$

CT Case	M	α_m	Test No.	θ_0	η = 0.169				η = 0.655				η = 0.931			
					θ (deg)	ε_θ (deg)	Z (mm)	ε_z (deg)	θ (deg)	ε_θ (deg)	Z (mm)	ε_z (deg)	θ (deg)	ε_θ (deg)	Z (mm)	ε_z (deg)
1	0.80	0	2010	0.50	0.51	2	0.01	76	0.52	1	0.15	18	0.54	0	0.25	20
2	0.80	4.0	2014	0.50	0.50	3	0.01	14	0.51	2	0.21	9	-	-	-	-
4	0.90	0	2029	0.50	0.51	2	0.01	-49	0.52	2	0.12	19	0.55	2	0.20	21
5	0.90	4.0	2035	0.50	0.50	4	0.00	-	0.51	4	0.16	10	0.51	2	0.28	13
6	0.95	0	2046	0.50	0.51	2	0.00	-	0.51	1	0.15	11	0.53	1	0.24	12
8	0.95	4.75	2083	0.48	0.50	3	0.01	-106	0.51	3	0.15	-3	0.54	3	0.24	-2
9	1.10	0.55	2045	0.50	0.51	1	0.01	-43	0.51	1	0.19	-4	0.53	1	0.30	-2

Table 7.7

NORA TEST 2010 MACH=.802

X	SECTION 0 MLOC EXTR	SECTION 0 MLOC INTR	SECTION 1 MLOC EXTR	SECTION 1 MLOC INTR	SECTION 3 MLOC EXTR	SECTION 3 MLOC INTR	SECTION 5 MLOC EXTR	SECTION 5 MLOC INTR	SECTION 6 MLOC EXTR	SECTION 6 MLOC INTR
.012	.883	.814								
.025	.759	.817	.834	.838						
.050	.763	.815	.816	.861	.802	.854				
.075							.816	.845		
.100	.782	.826	.818	.844	.825	.852			.818	.855
.150			.814	.849	.829	.852	.825	.854	.820	.848
.220	.808	.828	.841	.840	.867	.850	.839	.847	.840	.853
.300	.827	.843	.850	.855	.846	.859	.844	.854	.847	.868
.400	.838	.852	.867	.863	.869	.870	.852	.862	.857	.856
.500			.862	.872	.871	.862	.858	.864	.851	.854
.620	.841	.841	.861	.865	.860	.860	.841	.850	.831	.836
.750	.795	.807	.827	.835	.822	.828	.816	.822	.805	.813
.900	.804	.804	.781	.799	.774	.794	.772	.790		

Table 7.8

NORA TEST 2014 MACH=.802

X	SECTION 0 MLOC EXTR	SECTION 0 MLOC INTR	SECTION 1 MLOC EXTR	SECTION 1 MLOC INTR	SECTION 3 MLOC EXTR	SECTION 3 MLOC INTR	SECTION MLOC EXTR	SECTION MLOC INTR	SECTION 6 MLOC EXTR	SECTION 6 MLOC INTR
.012	1.126	.697								
.025	.911	.726	1.087	.707						
.050	.834	.739	1.101	.726	1.102	.730				
.075							1.153	.735		
.100	.843	.768	.943	.767	1.113	.761			1.146	.751
.150			.860	.781	1.009	.774	.994	.770	1.119	.768
.220	.861	.782	.896	.783	.898	.785	.932	.781	1.012	.791
.300	.879	.801	.902	.803	.882	.803	.905	.799	.879	.824
.400	.889	.812	.911	.818	.908	.824	.888	.821	.847	.833
.500			.897	.833	.897	.827	.876	.838	.842	.846
.620	.856	.821	.883	.836	.874	.835	.852	.838	.829	.837
.750	.802	.800	.838	.820	.829	.818	.824	.820	.811	.818
.900	.805	.805	.785	.793	.778	.792	.785	.791		

Table 7.9

NORA TEST 2029 MACH=.903

X	SECTION 0 MLOC EXTR	SECTION 0 MLOC INTR	SECTION 1 MLOC EXTR	SECTION 1 MLOC INTR	SECTION 3 MLOC EXTR	SECTION 3 MLOC INTR	SECTION 5 MLOC EXTR	SECTION 5 MLOC INTR	SECTION 6 MLOC EXTR	SECTION 6 MLOC INTR
.012	.995	.903								
.025	.886	.910	1.013	.937						
.050	.853	.916	.918	.969	.916	.966				
.075							.928	.958		
.100	.879	.928	.924	.953	.940	.967			.936	.978
.150			.920	.960	.944	.974	.947	.985	.941	.978
.220	.909	.931	.957	.952	1.001	.972	.965	.973	.970	.986
.300	.936	.954	.968	.976	.973	.987	.974	.984	.978	1.015
.400	.948	.964	1.000	.991	1.011	1.010	.984	1.000	.994	.994
.500			1.002	1.016	1.015	.997	.994	1.004	.974	.978
.620	.966	.965	.997	1.004	.993	.994	.960	.970	.943	.949
.750	.899	.913	.944	.952	.932	.940	.920	.926	.903	.912
.900	.907	.907	.877	.899	.866	.890	.861	.883		

Table 7.10

NORA TEST 2035 MACH=.902

X	SECTION 0 MLOC EXTR	SECTION 0 MLOC INTR	SECTION 1 MLOC EXTR	SECTION 1 MLOC INTR	SECTION 3 MLOC EXTR	SECTION 3 MLOC INTR	SECTION 5 MLOC EXTR	SECTION 5 MLOC INTR	SECTION 6 MLOC EXTR	SECTION 6 MLOC INTR
.012	1.204	.779								
.025	1.163	.812	1.212	.795						
.050	.912	.834	1.238	.824	1.272	.826				
.075							1.361	.832		
.100	.936	.861	1.113	.865	1.299	.861			1.390	.856
.150			.978	.881	1.186	.878	1.180	.876	1.356	.872
.220	.967	.876	1.023	.883	1.041	.890	1.106	.886	1.263	.900
.300	1.000	.903	1.041	.909	1.035	.913	1.075	.910	1.049	.949
.400	1.015	.917	1.068	.929	1.073	.941	1.026	.940	.950	.967
.500			1.057	.955	1.050	.946	.999	.969	.949	.981
.620	.983	.937	1.024	.959	.994	.963	.964	.963	.938	.959
.750	.904	.906	.949	.935	.932	.933	.926	.930	.909	.923
.900	.906	.906	.878	.895	.869	.891	.877	.887		

Table 7.11

NORA TEST 2046 MACH=.954

X	SECTION 0 MLOC EXTR	SECTION 0 MLOC INTR	SECTION 1 MLOC EXTR	SECTION 1 MLOC INTR	SECTION 3 MLOC EXTR	SECTION 3 MLOC INTR	SECTION 5 MLOC EXTR	SECTION 5 MLOC INTR	SECTION 6 MLOC EXTR	SECTION 6 MLOC INTR
.012	1.048	.945								
.025	.952	.953	1.071	.981						
.050	.892	.960	.966	1.017	.967	1.015				
.075							.978	1.011		
.100	.921	.975	.975	1.006	.992	1.014			1.005	1.049
.150			.968	1.013	.995	1.038	1.013	1.063	1.005	1.060
.220	.954	.976	1.012	1.000	1.074	1.042	1.040	1.046	1.043	1.057
.300	.988	1.008	1.024	1.027	1.033	1.041	1.055	1.073	1.077	1.111
.400	1.000	1.012	1.062	1.061	1.088	1.101	1.078	1.088	1.115	1.143
.500			1.074	1.086	1.129	1.107	1.126	1.138	1.160	1.176
.620	1.065	1.062	1.123	1.128	1.121	1.135	1.021	1.066	.959	.959
.750	.953	.968	1.007	1.015	.977	.984	.951	.953	.935	.942
.900	.958	.958	.919	.942	.901	.924	.895	.915		

Table 7.12

NORA TEST 2083 MACH=.951

X	SECTION 0 MLOC EXTR	SECTION 0 MLOC INTR	SECTION 1 MLOC EXTR	SECTION 1 MLOC INTR	SECTION 3 MLOC EXTR	SECTION 3 MLOC INTR	SECTION 5 MLOC EXTR	SECTION 5 MLOC INTR	SECTION 6 MLOC EXTR	SECTION 6 MLOC INTR
.012	1.276	.794								
.025	1.297	.832	1.285	.813						
.050	1.005	.859	1.314	.856	1.362	.853				
.075							1.457	.862		
.100	.987	.888	1.280	.894	1.403	.892			1.507	.890
.150			1.113	.911	1.360	.912	1.355	.914	1.493	.912
.220	1.023	.906	1.073	.917	1.203	.926	1.265	.927	1.449	.940
.300	1.077	.938	1.105	.946	1.103	.955	1.232	.953	1.341	.998
.400	1.074	.955	1.127	.971	1.158	.991	1.217	.989	1.172	1.045
.500			1.145	1.011	1.201	.998	1.200	1.041	1.051	1.107
.620	1.122	.996	1.188	1.022	1.212	1.033	1.041	1.069	1.022	1.096
.750	.962	.963	1.060	.999	.958	1.011	.975	.986	.971	.975
.900	.955	.955	.910	.950	.901	.938	.922	.931		

Table 7.13

NORA TEST 2045 MACH=1.102

X	SECTION 0 MLOC EXTR	SECTION 0 MLOC INTR	SECTION 1 MLOC EXTR	SECTION 1 MLOC INTR	SECTION 3 MLOC EXTR	SECTION 3 MLOC INTR	SECTION 5 MLOC EXTR	SECTION 5 MLOC INTR	SECTION 6 MLOC EXTR	SECTION 6 MLOC INTR
.012	1.236	1.040								
.025	1.212	1.057	1.240	1.062						
.050	1.007	1.082	1.080	1.082	1.076	1.100				
.075							1.083	1.109		
.100	1.034	1.099	1.084	1.082	1.120	1.115			1.133	1.129
.150			1.080	1.123	1.132	1.129	1.124	1.141	1.124	1.147
.220	1.064	1.066	1.137	1.107	1.167	1.145	1.158	1.125	1.142	1.112
.300	1.120	1.120	1.157	1.134	1.140	1.144	1.167	1.150	1.170	1.155
.400	1.122	1.142	1.168	1.145	1.190	1.173	1.178	1.148	1.206	1.206
.500			1.172	1.176	1.234	1.191	1.235	1.204	1.252	1.266
.620	1.248	1.242	1.242	1.229	1.260	1.232	1.268	1.280	1.305	1.315
.750	1.214	1.236	1.257	1.236	1.279	1.260	1.326	1.327	1.296	1.315
.900	1.108	1.108	1.224	1.251	1.248	1.316	1.297	1.338		

Table 7.14

NORA TEST 2185 MACH=0.80 FREQUENCY= 5.HZ PRESSURE=0.90 BAR CP'/R=CP"/I=3.40

SECTION 2E X	SECTION 2E R	SECTION 2E I	SECTION 4E X	SECTION 4E R	SECTION 4E I
.012	3.792	0.227	.012	4.077	0.375
.025	-0.702	-0.016	.025	0.916	0.063
.050	1.213	0.082	.050	1.870	0.129
.100	0.902	0.078	.100	1.045	0.090
.200	0.664	0.063	.200	0.751	0.075
.280	0.572	0.068	.280	0.615	0.076
.350	0.501	0.067	.350	0.529	0.071
.400	0.428	0.059	.400	0.404	0.059
.450	0.379	0.070	.450	0.363	0.054
.500	0.335	0.066	.500	0.203	0.137
.550	0.289	0.055	.551	0.242	0.043
.600	0.238	0.047	.601	0.191	0.043
.650	0.173	0.039	.651	0.098	0.035
.700	0.130	0.039	.701	0.079	0.031
.800	0.047	0.024	.801	0.016	0.012
.870	0.008	0.020	.871	-0.008	0.012

SECTION 2I X	SECTION 2I R	SECTION 2I I	SECTION 4I X	SECTION 4I R	SECTION 4I I
.050	-1.124	-0.086	.049	-1.803	-0.130
.100	-1.026	-0.088	.100	-1.171	-0.100
.200	-0.749	-0.080	.199	-0.795	-0.084
.280	-0.647	-0.074	.280	-0.591	-0.067
.399	-0.531	-0.077	.400	-0.473	-0.069
.500	-0.388	-0.066	.501	-0.316	-0.062
.600	-0.243	-0.057	.600	-0.181	-0.042
.700	-0.130	-0.039	.701	-0.087	-0.035

Table 7.15

NORA TEST 2010 MACH=0.80 FREQUENCY= 40.HZ PRESSURE=0.90 BAR CP'/R=CP"/I=3.40

SECTION 2E			SECTION 4E		
X	R	I	X	R	I
.012	3.378	-0.935	.012	4.815	-1.196
.025	-0.515	0.381	.025	0.819	-0.099
.050	1.132	-0.197	.050	1.701	-0.282
.100	0.815	-0.049	.100	0.978	-0.001
.200	0.632	0.035	.200	0.732	0.057
.280	0.553	0.108	.280	0.588	0.100
.350	0.478	0.156	.350	0.492	0.120
.400	0.425	0.183	.400	0.397	0.204
.450	0.353	0.208	.450	0.353	0.181
.500	0.331	0.246	.500	0.274	0.204
.550	0.289	0.219	.551	0.247	0.198
.600	0.228	0.240	.601	0.178	0.194
.650	0.163	0.211	.651	0.092	0.204
.700	0.121	0.234	.701	0.064	0.184
.800	0.057	0.215	.801	0.014	0.144
.870	0.007	0.184	.871	-0.014	0.128

SECTION 2I			SECTION 4I		
X	R	I	X	R	I
.050	-1.099	0.204	.049	-1.741	0.373
.100	-0.953	0.155	.100	-1.152	0.130
.200	-0.705	0.028	.199	-0.784	0.021
.280	-0.617	-0.035	.280	-0.607	-0.079
.399	-0.515	-0.113	.400	-0.485	-0.119
.500	-0.379	-0.161	.501	-0.304	-0.190
.600	-0.243	-0.206	.600	-0.185	-0.174
.700	-0.131	-0.197	.701	-0.072	-0.162

Table 7.16

NORA TEST 2190 MACH=0.80 FREQUENCY= 5.HZ PRESSURE=0.90 BAR CP'/R=CP"/I=3.39

SECTION 2E			SECTION 4E		
X	R	I	X	R	I
.012	1.138	0.113	.012	0.826	0.124
.025	1.005	0.114	.025	1.067	0.133
.050	0.992	0.110	.050	1.422	0.144
.100	3.805	0.235	.100	1.603	0.152
.200	1.878	0.075	.200	3.206	0.169
.280	0.004	0.040	.280	3.233	0.199
.350	0.095	0.055	.350	2.016	0.153
.400	0.161	0.051	.400	0.916	0.076
.450	0.200	0.066	.450	0.417	0.069
.500	0.212	0.068	.500	0.037	0.060
.550	0.164	0.056	.551	-0.153	0.048
.600	0.125	0.040	.601	-0.254	0.040
.650	0.076	0.032	.651	-0.127	0.032
.700	0.060	0.032	.701	-0.159	0.032
.800	0.048	0.016	.801	-0.092	0.028
.870	0.044	0.016	.871	-0.010	0.028

SECTION 2I			SECTION 4I		
X	R	I	X	R	I
.050	-0.931	-0.080	.049	-1.049	-0.076
.100	-0.767	-0.066	.100	-0.839	-0.064
.200	-0.590	-0.066	.199	-0.608	-0.064
.280	-0.538	-0.064	.280	-0.538	-0.058
.399	-0.438	-0.066	.400	-0.398	-0.056
.500	-0.361	-0.061	.501	-0.357	-0.053
.600	-0.287	-0.054	.600	-0.228	-0.046
.700	-0.185	-0.044	.701	-0.096	-0.032

Table 7.17

NORA TEST 2Ø14 MACH=Ø.8Ø FREQUENCY= 4Ø.HZ PRESSURE=Ø.9Ø BAR CP'/R=CP"/I=3.39

SECTION 2E			SECTION 4E			SECTION 2I			SECTION 4I		
X	R	I	X	R	I	X	R	I	X	R	I
.Ø12	1.ØØØ	Ø.ØØ7	.Ø12	Ø.921	Ø.274						
.Ø25	Ø.945	Ø.Ø78	.Ø25	1.39Ø	Ø.176						
.Ø5Ø	1.ØØ7	Ø.Ø91	.Ø5Ø	1.914	-Ø.Ø32	.Ø5Ø	-Ø.846	Ø.1Ø5	.Ø49	-1.ØØØ	Ø.1Ø9
.1ØØ	3.555	-1.Ø44	.1ØØ	1.986	-Ø.Ø66	.1ØØ	-Ø.7Ø6	Ø.Ø35	.1ØØ	-Ø.8Ø1	Ø.Ø35
.2ØØ	1.666	-Ø.629	.2ØØ	2.66Ø	-Ø.756	.2ØØ	-Ø.539	-Ø.Ø63	.199	-Ø.546	-Ø.Ø77
.28Ø	Ø.156	Ø.275	.28Ø	2.323	-Ø.911	.28Ø	-Ø.491	-Ø.119	.28Ø	-Ø.52Ø	-Ø.1Ø2
.35Ø	Ø.199	Ø.318	.35Ø	1.394	-Ø.47Ø						
.4ØØ	Ø.248	Ø.3Ø2	.4ØØ	Ø.715	-Ø.Ø77	.399	-Ø.4Ø1	-Ø.163	.4ØØ	-Ø.359	-Ø.17Ø
.45Ø	Ø.23Ø	Ø.284	.45Ø	Ø.317	Ø.132						
.5ØØ	Ø.252	Ø.288	.5ØØ	Ø.Ø72	Ø.28Ø	.5ØØ	-Ø.326	-Ø.2Ø7	.5Ø1	-Ø.326	-Ø.179
.55Ø	Ø.183	Ø.296	.551	-Ø.Ø64	Ø.374						
.6ØØ	Ø.135	Ø.3Ø2	.6Ø1	-Ø.138	Ø.387	.6ØØ	-Ø.267	-Ø.187	.6ØØ	-Ø.192	-Ø.177
.65Ø	Ø.Ø85	Ø.266	.651	-Ø.Ø71	Ø.294						
.7ØØ	Ø.Ø67	Ø.254	.7Ø1	-Ø.Ø96	Ø.311	.7ØØ	-Ø.156	-Ø.193	.7Ø1	-Ø.Ø78	-Ø.176
.8ØØ	Ø.Ø35	Ø.2ØØ	.8Ø1	-Ø.Ø53	Ø.229						
.87Ø	Ø.Ø18	Ø.155	.871	Ø.ØØØ	Ø.163						

Table 7.18

NORA TEST 2124 MACH=Ø.9Ø FREQUENCY= 5.HZ PRESSURE=Ø.6Ø BAR CP'/R=CP"/I=2.97

SECTION 2E			SECTION 4E			SECTION 2I			SECTION 4I		
X	R	I	X	R	I	X	R	I	X	R	I
.Ø12	3.939	Ø.2ØØ	.Ø12	5.7Ø4	Ø.3Ø3						
.Ø25	3.Ø88	Ø.2Ø7	.Ø25	3.956	Ø.227						
.Ø5Ø	1.236	Ø.Ø71	.Ø5Ø	1.971	Ø.1Ø7	.Ø5Ø	-1.667	-Ø.Ø94	.Ø49	-2.239	-Ø.117
.1ØØ	1.Ø52	Ø.Ø76	.1ØØ	1.293	Ø.Ø83	.1ØØ	-1.274	-Ø.Ø8Ø	.1ØØ	-1.471	-Ø.Ø97
.2ØØ	Ø.785	Ø.Ø65	.2ØØ	1.Ø3Ø	Ø.Ø84	.2ØØ	-Ø.972	-Ø.Ø74	.199	-1.Ø38	-Ø.Ø88
.28Ø	Ø.738	Ø.Ø72	.28Ø	Ø.831	Ø.Ø97	.28Ø	-Ø.849	-Ø.Ø79	.28Ø	-Ø.771	-Ø.Ø76
.35Ø	Ø.692	Ø.Ø89	.35Ø	Ø.815	Ø.1Ø8						
.4ØØ	Ø.658	Ø.Ø82	.4ØØ	Ø.659	Ø.1Ø1	.399	-Ø.794	-Ø.Ø88	.4ØØ	-Ø.653	-Ø.Ø91
.45Ø	Ø.583	Ø.Ø87	.45Ø	Ø.479	Ø.Ø7Ø						
.5ØØ	Ø.523	Ø.1Ø3	.5ØØ	Ø.231	Ø.176	.5ØØ	-Ø.55Ø	-Ø.Ø81	.5Ø1	-Ø.4Ø4	-Ø.Ø84
.55Ø	Ø.399	Ø.Ø77	.551	Ø.191	Ø.Ø59						
.6ØØ	Ø.258	Ø.Ø62	.6Ø1	Ø.Ø87	Ø.Ø53	.6ØØ	-Ø.298	-Ø.Ø62	.6ØØ	-Ø.114	-Ø.Ø35
.65Ø	Ø.132	Ø.Ø41	.651	-Ø.Ø21	Ø.Ø29						
.7ØØ	Ø.Ø54	Ø.Ø44	.7Ø1	-Ø.Ø33	Ø.Ø3Ø	.7ØØ	-Ø.Ø93	-Ø.Ø38	.7Ø1	-Ø.ØØ6	-Ø.Ø24
.8ØØ	-Ø.Ø63	Ø.Ø36	.8Ø1	-Ø.Ø51	Ø.Ø18						
.87Ø	-Ø.Ø18	Ø.Ø24	.871	-Ø.Ø6Ø	Ø.Ø12						

Table 7.19

NORA TEST 2029 MACH=0.90 FREQUENCY= 40.HZ PRESSURE=0.60 BAR CP'/R=CP"/I=2.97

SECTION 2E

X	R	I
.012	3.450	-1.096
.025	2.756	-0.651
.050	1.122	-0.280
.100	0.957	-0.169
.200	0.768	-0.037
.280	0.744	0.021
.350	0.739	0.095
.400	0.734	0.137
.450	0.648	0.219
.500	0.617	0.337
.550	0.459	0.333
.600	0.278	0.359
.650	0.149	0.332
.700	0.053	0.350
.800	-0.011	0.247
.870	-0.011	0.180

SECTION 4E

X	R	I
.012	4.802	-1.581
.025	3.527	-0.963
.050	1.924	-0.517
.100	1.202	-0.242
.200	1.045	-0.048
.280	0.839	0.064
.350	0.803	0.111
.400	0.745	0.306
.450	0.519	0.271
.500	0.353	0.333
.551	0.215	0.334
.601	0.087	0.302
.651	-0.049	0.258
.701	-0.022	0.249
.801	-0.054	0.164
.871	-0.044	0.119

SECTION 2I

X	R	I
.050	-1.417	0.448
.100	-1.119	0.275
.200	-0.866	0.137
.280	-0.808	0.021
.399	-0.811	-0.080
.500	-0.579	-0.300
.600	-0.268	-0.355
.700	-0.032	-0.306

SECTION 4I

X	R	I
.049	-1.979	0.569
.100	-1.394	0.254
.199	-0.967	0.095
.280	-0.829	-0.111
.400	-0.651	-0.223
.501	-0.382	-0.354
.600	-0.043	-0.291
.701	0.074	-0.211

Table 7.20

NORA TEST 2136 MACH=0.90 FREQUENCY= 5.HZ PRESSURE=0.60 BAR CP'/R=CP"/I=2.98

SECTION 2E

X	R	I
.012	1.557	0.095
.025	1.526	0.095
.050	1.315	0.095
.100	2.995	0.178
.200	4.092	0.155
.280	0.600	0.066
.350	0.302	0.053
.400	0.713	0.030
.450	0.374	0.064
.500	0.103	0.213
.550	0.130	0.089
.600	0.036	0.053
.650	-0.050	0.035
.700	0.000	0.042
.800	0.018	0.036
.870	0.024	0.030

SECTION 4E

X	R	I
.012	2.487	0.165
.025	1.632	0.119
.050	1.154	0.089
.100	0.755	0.071
.200	3.499	0.149
.280	4.223	0.265
.350	2.606	0.268
.400	1.331	0.172
.450	0.839	0.094
.500	0.151	0.124
.551	-0.109	0.042
.601	-0.262	0.047
.651	0.012	0.030
.701	-0.131	0.036
.801	-0.045	0.036
.871	0.036	0.024

SECTION 2I

X	R	I
.050	-1.026	-0.086
.100	-0.828	-0.080
.200	-0.690	-0.074
.280	-0.645	-0.080
.399	-0.575	-0.080
.500	-0.502	-0.075
.600	-0.409	-0.071
.700	-0.247	-0.062

SECTION 4I

X	R	I
.049	-1.201	-0.092
.100	-0.964	-0.083
.199	-0.714	-0.077
.280	-0.654	-0.065
.400	-0.530	-0.077
.501	-0.505	-0.078
.600	-0.284	-0.060
.701	-0.059	-0.041

Table 7.21

NORA TEST 2035 MACH=0.90 FREQUENCY= 40.HZ PRESSURE=0.60 BAR CP'/R=CP"/I=2.98

SECTION 2E

X	R	I
.012	1.305	-0.343
.025	1.302	-0.333
.050	1.195	-0.264
.100	2.416	-0.781
.200	3.204	-1.511
.280	0.605	-0.032
.350	0.267	0.127
.400	0.361	-0.169
.450	0.605	-0.417
.500	1.305	0.369
.550	1.122	1.164
.600	-0.075	0.696
.650	-0.128	0.444
.700	-0.064	0.360
.800	0.011	0.247
.870	0.021	0.191

SECTION 4E

X	R	I
.012	2.308	-0.611
.025	1.651	-0.339
.050	1.162	-0.232
.100	0.820	-0.127
.200	2.757	-1.177
.280	3.229	-1.600
.350	2.725	-0.781
.400	2.178	0.486
.450	1.058	0.740
.500	0.226	0.506
.551	-0.027	0.465
.601	-0.128	0.433
.651	0.021	0.253
.701	-0.032	0.318
.801	0.016	0.225
.871	0.086	0.149

SECTION 2I

X	R	I
.050	-0.938	0.105
.100	-0.847	0.021
.200	-0.725	-0.105
.280	-0.692	-0.164
.399	-0.639	-0.254
.500	-0.547	-0.338
.600	-0.390	-0.329
.700	-0.181	-0.333

SECTION 4I

X	R	I
.049	-1.143	0.095
.100	-0.973	0.021
.199	-0.747	-0.132
.280	-0.687	-0.137
.400	-0.575	-0.297
.501	-0.467	-0.290
.600	-0.224	-0.329
.701	0.000	-0.285

Table 7.22

NORA TEST 2114 MACH=0.95 FREQUENCY= 5.HZ PRESSURE=0.60 BAR CP'/R=CP"/I=2.82

SECTION 2E

X	R	I
.012	3.870	0.150
.025	3.532	0.168
.050	1.105	0.052
.100	1.079	0.058
.200	0.699	0.046
.280	0.507	0.041
.350	1.103	0.064
.400	0.740	0.035
.450	0.734	0.057
.500	0.778	0.070
.550	0.717	0.047
.600	0.594	0.058
.650	0.794	0.204
.700	-0.036	0.158
.800	-0.225	0.006
.870	-0.125	0.006

SECTION 4E

X	R	I
.012	5.078	0.201
.025	4.969	0.205
.050	1.450	0.058
.100	1.304	0.058
.200	0.980	0.047
.280	1.026	0.059
.350	1.046	0.076
.400	0.754	0.053
.450	0.765	0.057
.500	0.441	0.265
.551	0.677	0.075
.601	0.735	0.254
.651	-0.651	0.138
.701	-0.464	0.000
.801	-0.179	-0.015
.871	-0.100	0.000

SECTION 2I

X	R	I
.050	-1.533	-0.066
.100	-1.296	-0.058
.200	-0.706	-0.046
.280	-1.056	-0.046
.399	-0.658	-0.052
.500	-0.566	-0.053
.600	-0.666	-0.078
.700	-0.352	-0.150

SECTION 4I

X	R	I
.049	-2.516	-0.083
.100	-2.125	-0.075
.199	-0.835	-0.063
.280	-0.751	-0.052
.400	-1.034	-0.070
.501	-0.938	-0.082
.600	-0.504	-0.127
.701	0.464	-0.011

Table 7.23

NORA   TEST 2Ø46   MACH=Ø.95   FREQUENCY= 4Ø.HZ   PRESSURE=Ø.6Ø BAR   CP'/R=CP"/I=2.82

SECTION 2E

X	R	I
.Ø12	3.249	-1.Ø12
.Ø25	3.Ø37	-Ø.762
.Ø5Ø	Ø.915	-Ø.216
.1ØØ	Ø.9Ø5	-Ø.179
.2ØØ	Ø.617	-Ø.Ø27
.28Ø	Ø.467	Ø.Ø64
.35Ø	Ø.855	-Ø.138
.4ØØ	Ø.574	-Ø.Ø69
.45Ø	Ø.528	-Ø.Ø63
.5ØØ	Ø.572	-Ø.Ø79
.55Ø	Ø.561	-Ø.122
.6ØØ	Ø.521	-Ø.Ø63
.65Ø	1.597	-Ø.321
.7ØØ	1.287	Ø.719
.8ØØ	-Ø.223	Ø.644
.87Ø	-Ø.198	Ø.318

SECTION 4E

X	R	I
.Ø12	4.Ø48	-1.344
.Ø25	3.947	-1.164
.Ø5Ø	1.267	-Ø.343
.1ØØ	1.Ø54	-Ø.284
.2ØØ	Ø.744	-Ø.2Ø1
.28Ø	Ø.733	-Ø.2Ø4
.35Ø	Ø.748	-Ø.222
.4ØØ	Ø.627	-Ø.Ø95
.45Ø	Ø.636	-Ø.125
.5ØØ	Ø.626	-Ø.Ø32
.551	Ø.794	-Ø.153
.6Ø1	2.6Ø8	-Ø.317
.651	Ø.82Ø	1.98Ø
.7Ø1	-Ø.638	1.Ø37
.8Ø1	-Ø.43Ø	Ø.247
.871	-Ø.224	Ø.127

SECTION 2I

X	R	I
.Ø5Ø	-1.231	Ø.379
.1ØØ	-1.Ø26	Ø.296
.2ØØ	-Ø.538	Ø.Ø84
.28Ø	-Ø.777	Ø.226
.399	-Ø.526	Ø.Ø42
.5ØØ	-Ø.446	Ø.Ø32
.6ØØ	-Ø.652	Ø.212
.7ØØ	-1.615	-Ø.3Ø6

SECTION 4I

X	R	I
.Ø49	-1.965	Ø.748
.1ØØ	-1.672	Ø.667
.199	-Ø.697	Ø.137
.28Ø	-Ø.665	Ø.1Ø5
.4ØØ	-Ø.851	Ø.243
.5Ø1	-Ø.781	Ø.29Ø
.6ØØ	-1.ØØ5	Ø.Ø64
.7Ø1	Ø.287	-1.214

Table 7.24

NORA   TEST 21ØØ   MACH=Ø.95   FREQUENCY= 5.HZ   PRESSURE=Ø.46 BAR   CP'/R=CP"/I=2.83

SECTION 2E

X	R	I
.Ø12	1.597	Ø.Ø67
.Ø25	1.623	Ø.Ø67
.Ø5Ø	1.515	Ø.Ø6Ø
.1ØØ	2.224	Ø.113
.2ØØ	4.167	Ø.141
.28Ø	2.416	Ø.1Ø2
.35Ø	Ø.399	Ø.Ø67
.4ØØ	Ø.181	Ø.Ø67
.45Ø	Ø.253	Ø.Ø46
.5ØØ	Ø.362	Ø.Ø53
.55Ø	Ø.515	Ø.Ø47
.6ØØ	Ø.545	Ø.Ø4Ø
.65Ø	Ø.584	Ø.Ø47
.7ØØ	1.972	Ø.Ø87
.8ØØ	-Ø.Ø5Ø	Ø.Ø54
.87Ø	Ø.Ø13	Ø.Ø4Ø

SECTION 4E

X	R	I
.Ø12	1.795	Ø.Ø73
.Ø25	1.74Ø	Ø.Ø67
.Ø5Ø	1.824	Ø.Ø6Ø
.1ØØ	1.8Ø7	Ø.Ø94
.2ØØ	2.316	Ø.Ø81
.28Ø	3.222	Ø.17Ø
.35Ø	3.378	Ø.241
.4ØØ	2.448	Ø.117
.45Ø	1.55Ø	Ø.119
.5ØØ	Ø.58Ø	Ø.36Ø
.551	Ø.422	Ø.Ø74
.6Ø1	-Ø.391	Ø.Ø6Ø
.651	Ø.383	Ø.127
.7Ø1	Ø.222	Ø.Ø7Ø
.8Ø1	Ø.195	Ø.Ø61
.871	Ø.2Ø3	Ø.Ø47

SECTION 2I

X	R	I
.Ø5Ø	-Ø.855	-Ø.Ø81
.1ØØ	-Ø.835	-Ø.Ø89
.2ØØ	-Ø.693	-Ø.Ø85
.28Ø	-Ø.668	-Ø.Ø85
.399	-Ø.717	-Ø.1Ø3
.5ØØ	-Ø.6Ø2	-Ø.1Ø4
.6ØØ	-Ø.523	-Ø.Ø99
.7ØØ	-Ø.435	-Ø.Ø92

SECTION 4I

X	R	I
.Ø49	-1.1Ø5	-Ø.Ø87
.1ØØ	-Ø.974	-Ø.Ø74
.199	-Ø.757	-Ø.Ø83
.28Ø	-Ø.739	-Ø.Ø63
.4ØØ	-Ø.626	-Ø.111
.5Ø1	-Ø.6Ø7	-Ø.1Ø2
.6ØØ	-Ø.574	-Ø.1Ø1
.7Ø1	-Ø.195	-Ø.113

Table 7.25

NORA TEST 2083 MACH=0.95 FREQUENCY= 40.HZ PRESSURE=0.46 BAR CP'/R=CP"/I=2.83

SECTION 2E X	R	I	SECTION 4E X	R	I
.012	1.170	-0.385	.012	1.243	-0.556
.025	1.160	-0.374	.025	1.203	-0.518
.050	1.069	-0.358	.050	1.242	-0.516
.100	1.700	-0.565	.100	1.297	-0.479
.200	3.231	-1.503	.200	1.760	-0.849
.280	1.859	-0.902	.280	2.623	-1.237
.350	0.507	0.058	.350	2.986	-1.172
.400	0.331	0.100	.400	2.320	-0.845
.450	0.263	0.071	.450	1.609	-0.403
.500	0.313	0.029	.500	0.936	0.014
.550	0.424	-0.029	.551	0.516	-0.129
.600	0.442	-0.044	.601	-0.426	0.358
.650	0.426	-0.073	.651	0.605	-0.272
.700	1.487	-1.453	.701	0.447	0.101
.800	0.103	0.252	.801	0.317	0.117
.870	0.133	0.191	.871	0.319	0.072

SECTION 2I X	R	I	SECTION 4I X	R	I
.050	-1.002	0.136	.049	-1.126	0.171
.100	-0.910	0.086	.100	-0.974	0.158
.200	-0.787	0.000	.199	-0.852	0.036
.280	-0.778	-0.029	.280	-0.836	0.043
.399	-0.865	0.000	.400	-0.851	-0.144
.500	-0.937	-0.189	.501	-0.829	-0.189
.600	-0.725	-0.273	.600	-0.855	-0.245
.700	-0.735	-0.465	.701	-0.620	-0.074

Table 7.26

NORA TEST 2113 MACH=1.10 FREQUENCY= 5.HZ PRESSURE=0.60 BAR CP'/R=CP"/I=2.52

SECTION 2E X	R	I	SECTION 4E X	R	I
.012	2.475	0.100	.012	2.643	0.094
.025	3.309	0.189	.025	3.053	0.106
.050	3.042	0.124	.050	5.302	0.206
.100	0.792	0.053	.100	1.128	0.047
.200	0.935	0.053	.200	0.704	0.035
.280	0.822	0.042	.280	0.690	0.048
.350	0.531	0.050	.350	0.621	0.053
.400	0.516	0.038	.400	0.582	0.056
.450	0.517	0.052	.450	0.700	0.035
.500	0.597	0.065	.500	0.433	0.229
.550	0.663	0.047	.551	0.525	0.041
.600	0.661	0.047	.601	0.559	0.041
.650	0.654	0.047	.651	0.792	0.035
.700	0.595	0.053	.701	0.391	0.059
.800	0.672	0.054	.801	0.402	0.054
.870	0.573	0.083	.871	0.386	0.059

SECTION 2I X	R	I	SECTION 4I X	R	I
.050	-1.451	-0.071	.049	-1.713	-0.065
.100	-1.074	-0.053	.100	-1.071	-0.068
.200	-0.817	-0.050	.199	-0.989	-0.053
.280	-0.813	-0.050	.280	-0.819	-0.041
.399	-0.595	-0.038	.400	-0.830	-0.012
.500	-0.639	-0.024	.501	-0.660	-0.066
.600	-0.962	0.018	.600	-0.597	-0.077
.700	-0.579	-0.047	.701	-0.561	-0.074

Table 7.27

NORA TEST 2Ø45 MACH=1.1Ø FREQUENCY= 4Ø.HZ PRESSURE=Ø.6Ø BAR CP'/R=CP"/I=2.52

SECTION 2E

X	R	I
.Ø12	2.157	-Ø.6Ø6
.Ø25	3.Ø65	-Ø.55Ø
.Ø5Ø	1.626	-Ø.433
.1ØØ	Ø.659	-Ø.11Ø
.2ØØ	Ø.879	-Ø.127
.28Ø	Ø.722	-Ø.Ø81
.35Ø	Ø.524	Ø.Ø37
.4ØØ	Ø.511	Ø.Ø42
.45Ø	Ø.465	Ø.Ø42
.5ØØ	Ø.531	Ø.Ø21
.55Ø	Ø.56Ø	-Ø.Ø32
.6ØØ	Ø.546	-Ø.Ø11
.65Ø	Ø.542	Ø.Ø42
.7ØØ	Ø.495	Ø.Ø64
.8ØØ	Ø.6Ø5	Ø.Ø97
.87Ø	Ø.598	Ø.138

SECTION 4E

X	R	I
.Ø12	2.157	-Ø.58Ø
.Ø25	2.6ØØ	-Ø.7Ø9
.Ø5Ø	4.268	-1.283
.1ØØ	1.Ø3Ø	-Ø.221
.2ØØ	Ø.645	-Ø.Ø8Ø
.28Ø	Ø.616	-Ø.Ø16
.35Ø	Ø.492	Ø.Ø21
.4ØØ	Ø.532	Ø.Ø53
.45Ø	Ø.6Ø5	-Ø.Ø26
.5ØØ	Ø.5Ø9	Ø.Ø42
.551	Ø.486	Ø.Ø32
.6Ø1	Ø.455	Ø.Ø11
.651	Ø.637	-Ø.Ø84
.7Ø1	Ø.378	Ø.117
.8Ø1	Ø.414	Ø.15Ø
.871	Ø.395	Ø.149

SECTION 2I

X	R	I
.Ø5Ø	-1.165	Ø.295
.1ØØ	-Ø.898	Ø.18Ø
.2ØØ	-Ø.653	Ø.Ø63
.28Ø	-Ø.68Ø	Ø.Ø16
.399	-Ø.479	-Ø.Ø21
.5ØØ	-Ø.489	Ø.Ø32
.6ØØ	-Ø.572	Ø.1Ø6
.7ØØ	-Ø.521	-Ø.Ø21

SECTION 4I

X	R	I
.Ø49	-1.366	Ø.39Ø
.1ØØ	-Ø.988	Ø.138
.199	-Ø.818	Ø.1Ø6
.28Ø	-Ø.722	Ø.Ø53
.4ØØ	-Ø.591	Ø.Ø21
.5Ø1	-Ø.627	Ø.ØØØ
.6ØØ	-Ø.588	-Ø.Ø11
.7Ø1	-Ø.5ØØ	-Ø.Ø42

Table 7.28

NORA TEST 8Ø MACH=Ø.8Ø FREQUENCY= 4Ø.HZ PRESSURE=Ø.9Ø BAR Cp'/R=Cp"/I=3.4Ø

SECTION 2E

X	R	I
.Ø12	3.783	-Ø.912
.Ø25	Ø.393	Ø.ØØ9
.Ø5Ø	1.396	-Ø.241
.1ØØ	Ø.926	-Ø.Ø53
.2ØØ	Ø.6Ø4	Ø.Ø58
.28Ø	Ø.576	Ø.123
.35Ø	Ø.5Ø6	Ø.174
.4ØØ	Ø.45Ø	Ø.2Ø3
.45Ø	Ø.413	Ø.225
.5ØØ	Ø.356	Ø.231
.55Ø	Ø.299	Ø.233
.6ØØ	Ø.238	Ø.257
.65Ø	Ø.178	Ø.255
.7ØØ	Ø.118	Ø.245
.8ØØ	Ø.Ø41	Ø.197
.87Ø	Ø.Ø11	Ø.154

SECTION 4E

X	R	I
.Ø12	5.171	-1.Ø79
.Ø25	1.228	-Ø.158
.Ø5Ø	1.821	-Ø.25Ø
.1ØØ	1.ØØ9	-Ø.Ø53
.2ØØ	Ø.873	Ø.Ø34
.28Ø	Ø.625	Ø.126
.35Ø	Ø.549	Ø.155
.4ØØ	Ø.447	Ø.18Ø
.45Ø	Ø.372	Ø.218
.5ØØ	Ø.2Ø9	Ø.2ØØ
.551	-Ø.236	-Ø.231
.6Ø1	Ø.178	Ø.214
.651	Ø.Ø92	Ø.225
.7Ø1	Ø.Ø69	Ø.197
.8Ø1	-Ø.Ø13	Ø.158
.871	-Ø.Ø24	Ø.111

SECTION 2I

X	R	I
.Ø5Ø	-Ø.673	-Ø.Ø1Ø
.1ØØ	-1.ØØ9	Ø.Ø8Ø
.2ØØ	-Ø.715	-Ø.Ø52
.28Ø	-Ø.631	-Ø.126
.399	-Ø.4ØØ	-Ø.195
.5ØØ	-Ø.376	-Ø.245
.6ØØ	-Ø.23Ø	-Ø.251
.7ØØ	-Ø.112	-Ø.235

SECTION 4I

X	R	I
.Ø49	-1.935	Ø.291
.1ØØ	-1.2Ø9	Ø.Ø82
.199	-Ø.811	-Ø.Ø59
.28Ø	-Ø.657	-Ø.1ØØ
.4ØØ	-Ø.468	-Ø.193
.5Ø1	-Ø.323	-Ø.227
.6ØØ	-Ø.161	-Ø.219
.7Ø1	-Ø.ØØ3	-Ø.ØØ6

Table 7.29

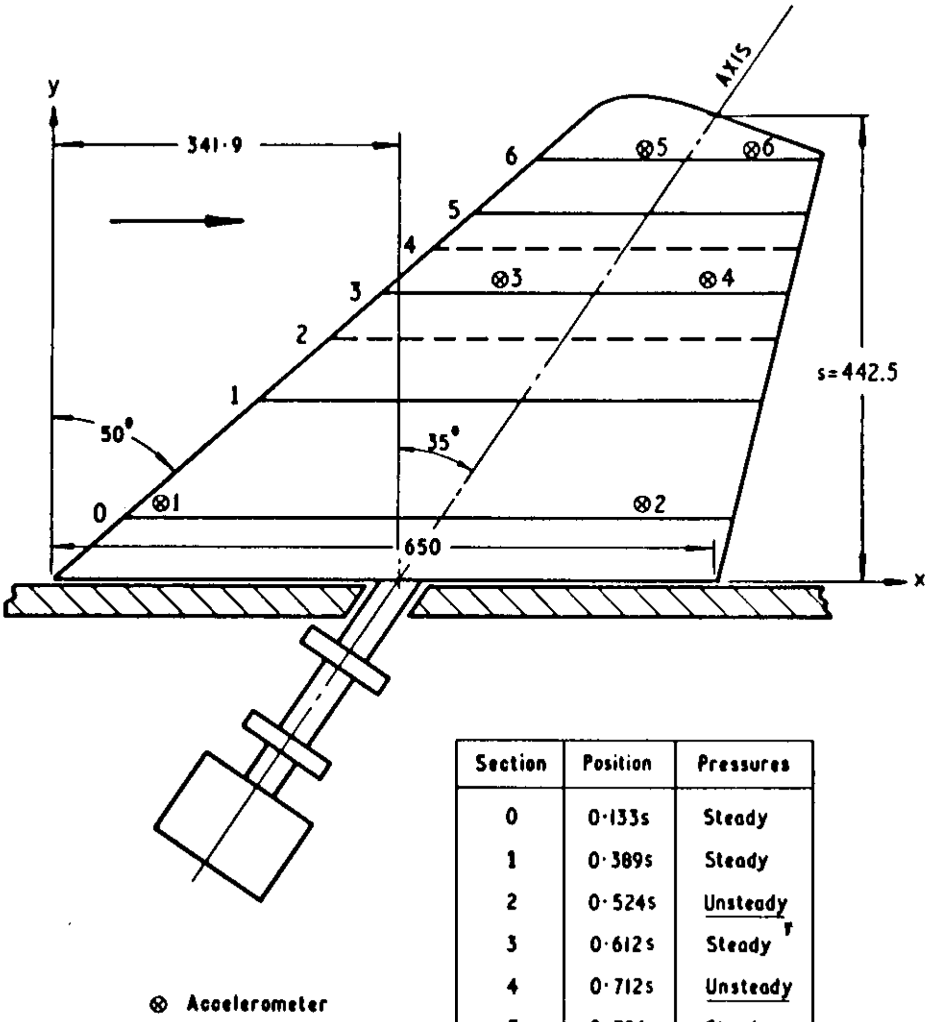
NORA TEST 76 MACH=0.90 FREQUENCY= 40.HZ PRESSURE=0.60 BAR Cp'/R=Cp"/I=2.98

SECTION 2E			SECTION 4E			SECTION 2I			SECTION 4I		
X	R	I	X	R	I	X	R	I	X	R	I
.012	3.751	-1.136	.012	5.313	-1.497						
.025	1.673	-0.342	.025	2.816	-0.573						
.050	1.206	-0.312	.050	2.182	-0.508	.050	-1.572	0.386	.049	-2.225	0.511
.100	1.112	-0.186	.100	1.319	-0.180	.100	-1.170	0.214	.100	-1.393	0.218
.200	0.852	-0.040	.200	1.141	-0.044	.200	-0.870	0.053	.199	-0.996	0.045
.280	0.800	0.057	.280	0.865	0.117	.280	-0.795	-0.045	.289	-0.877	-0.004
.350	0.752	0.120	.350	0.853	0.160						
.400	0.733	0.172	.400	0.760	0.285	.399	-0.001	-0.158	.400	-0.716	-0.255
.450	0.662	0.237	.450	0.570	0.316						
.500	0.584	0.320	.500	0.340	0.347	.500	-0.598	-0.314	.501	-0.449	-0.304
.550	0.468	0.339	.551	-0.252	-0.385						
.600	0.316	0.378	.601	0.133	0.330	.600	-0.310	-0.372	.600	-0.069	-0.322
.650	0.197	0.373	.651	-0.023	0.327						
.700	0.069	0.367	.701	-0.010	0.252	.700	-0.048	-0.337	.701	0.001	-0.006
.800	-0.017	0.250	.801	-0.081	0.178						
.870	-0.034	0.180	.871	-0.059	0.120						

Table 7.30

NORA TEST 69 MACH=0.95 FREQUENCY= 40.HZ PRESSURE=0.60 BAR Cp'/R=Cp"/I=2.83

SECTION 2E			SECTION 4E			SECTION 2I			SECTION 4I		
X	R	I	X	R	I	X	R	I	X	R	I
.012	3.630	-0.970	.012	4.891	-1.245						
.025	2.390	-0.463	.025	3.371	-0.636						
.050	0.957	-0.236	.050	1.746	-0.336	.050	-1.371	0.263	.049	-2.437	0.670
.100	1.121	-0.195	.100	1.241	-0.218	.100	-1.075	0.160	.100	-1.834	0.593
.200	0.762	-0.008	.200	1.086	-0.280	.200	-0.509	-0.068	.199	-2.579	0.907
.280	0.551	0.069	.280	0.963	-0.206	.280	-0.887	0.170	.280	-0.728	0.033
.350	1.067	-0.155	.350	0.771	-0.083						
.400	0.622	-0.088	.400	0.746	0.072	.399	-0.490	0.072	.400	-0.961	0.038
.450	0.567	-0.040	.450	0.839	0.084						
.500	0.561	-0.070	.500	0.956	-0.063	.500	-0.558	-0.263	.501	-0.762	-0.152
.550	0.813	0.053	.551	-1.792	0.866						
.600	0.838	0.219	.601	1.226	0.312	.600	-0.693	-0.246	.600	-1.495	1.555
.650	1.172	-0.028	.651	0.905	2.543						
.700	0.588	0.572	.701	-0.952	1.826	.700	-0.579	-0.327	.701	-0.001	-0.044
.800	-0.217	0.816	.801	-0.456	0.106						
.870	-0.268	0.357	.871	-0.247	0.084						



Section	Position	Pressures
0	0·133s	Steady
1	0·389s	Steady
2	0·524s	Unsteady
3	0·612s	Steady
4	0·712s	Unsteady
5	0·786s	Steady
6	0·895s	Steady

Fig 7.1 Model and rotary oscillator
(dimensions in mm)

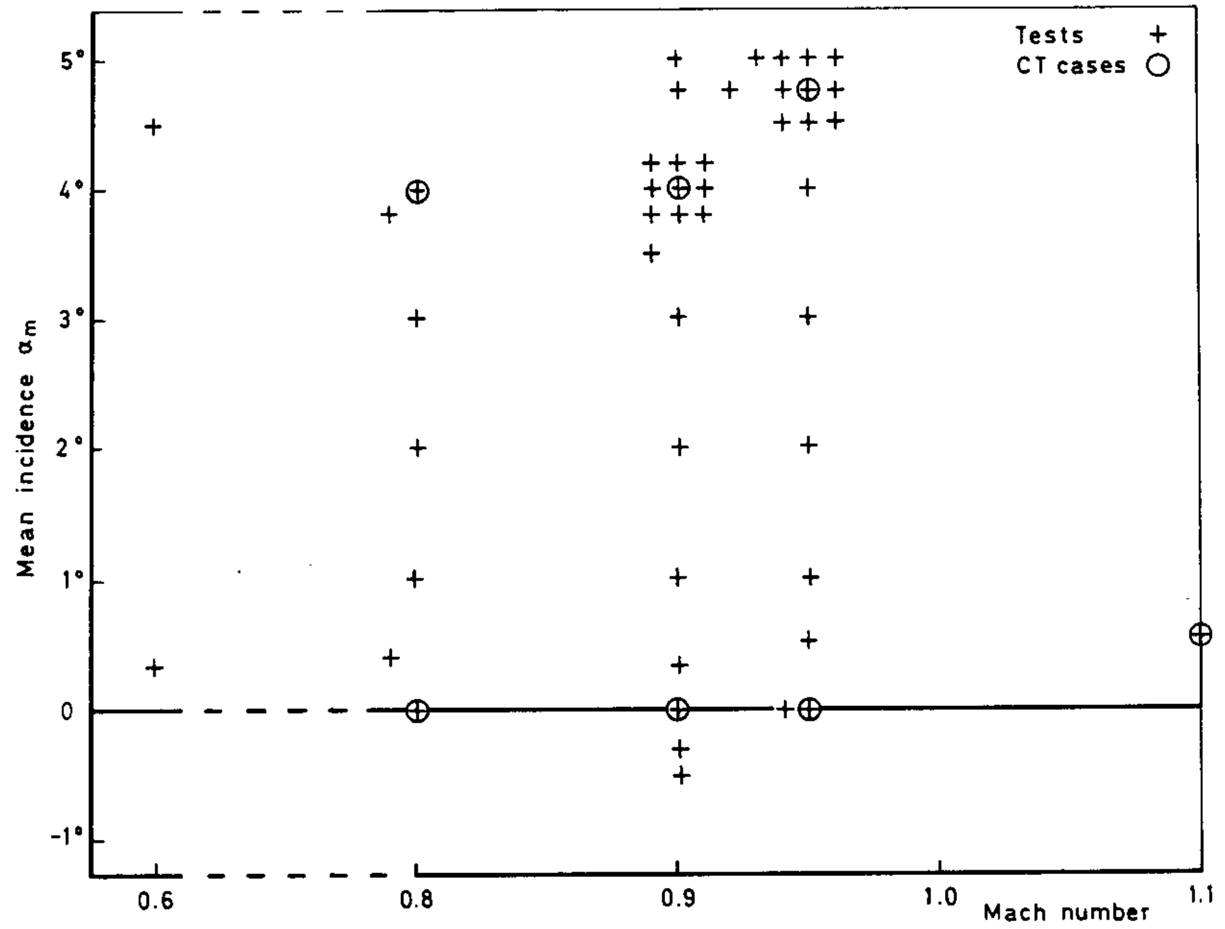


Fig 7.2 Test conditions and computational test cases

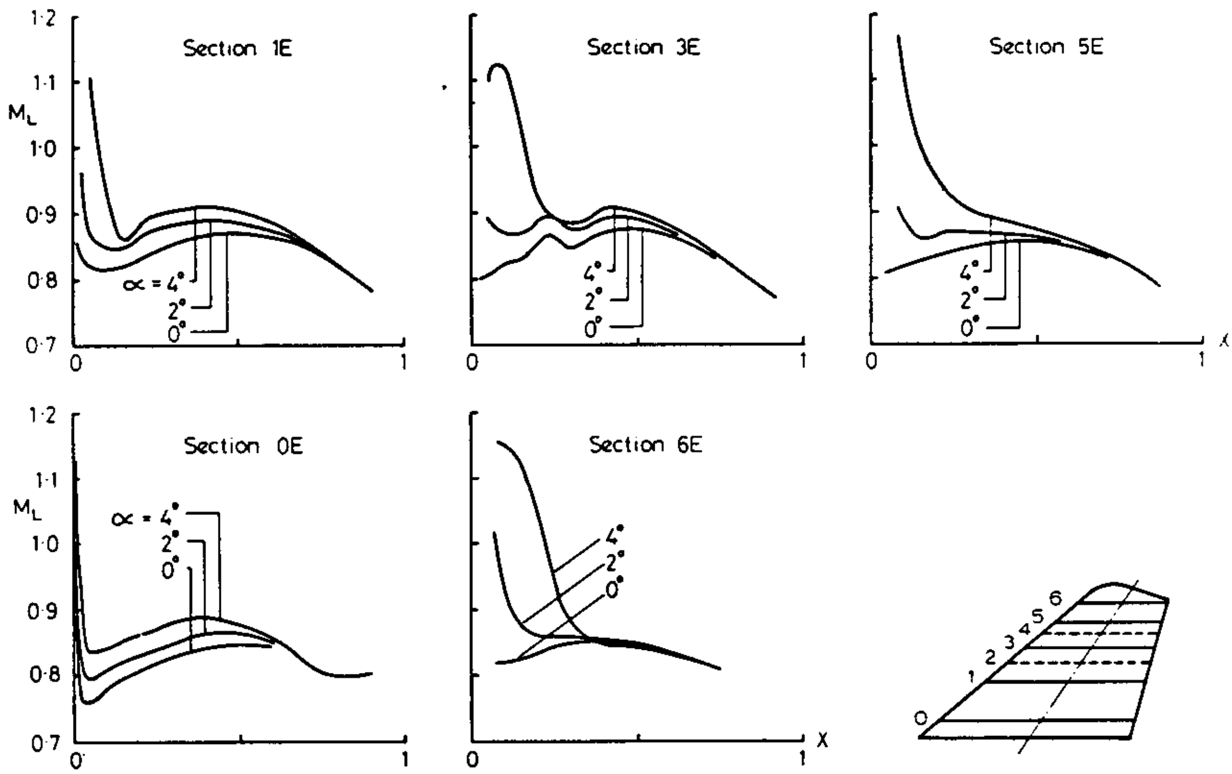


Fig 7.3 Local Mach numbers at upper surface, M = 0.80

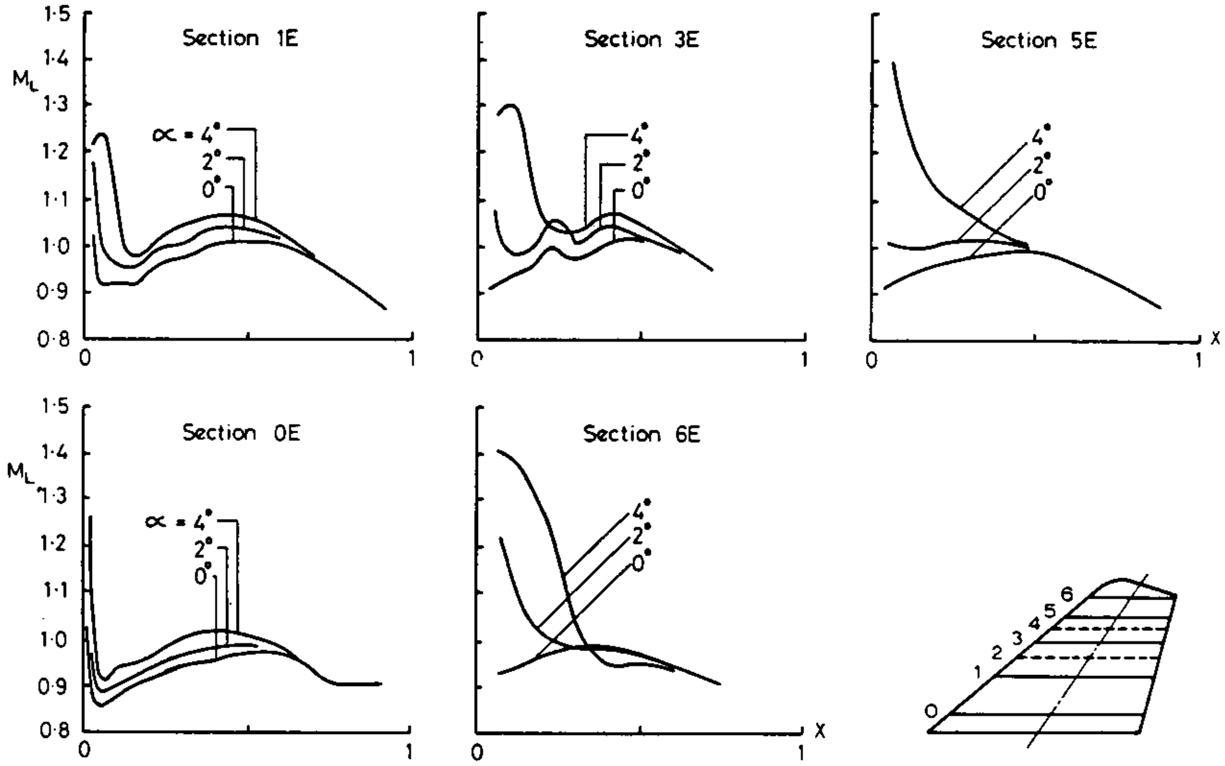


Fig 7.4 Local Mach numbers at upper surface, M = 0.90

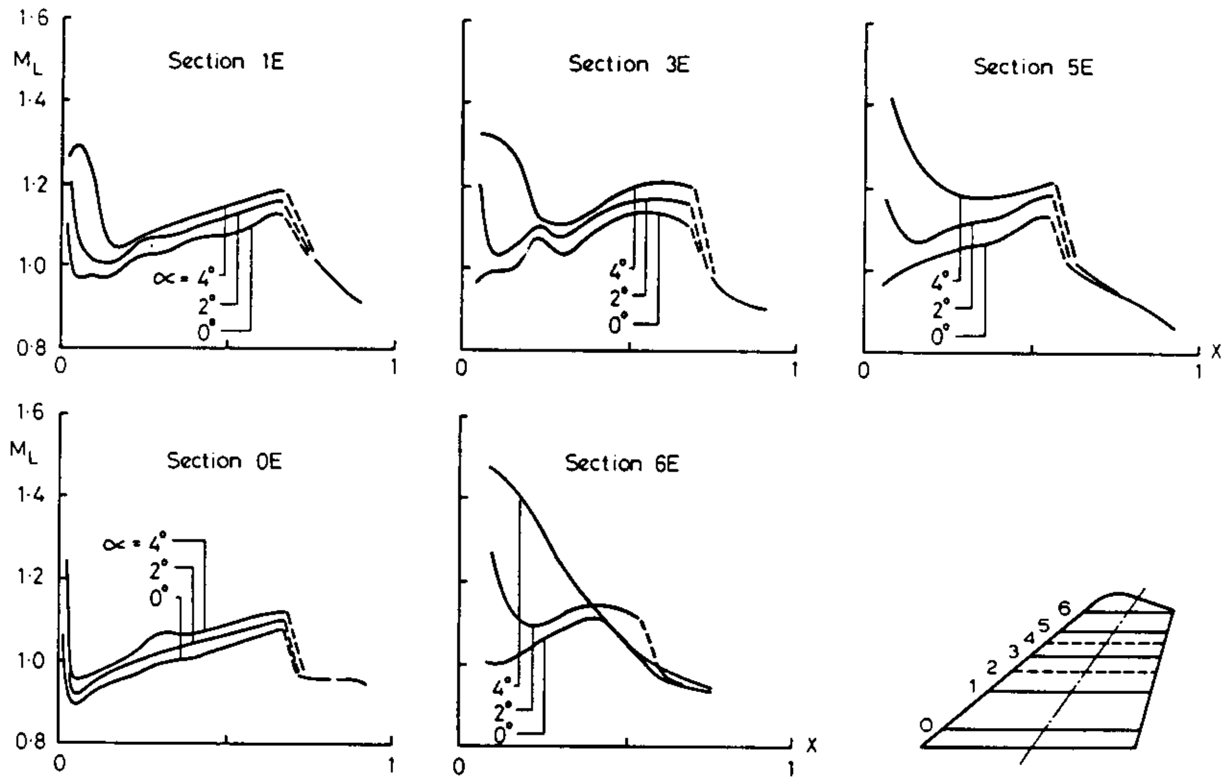


Fig 7.5 Local Mach numbers at upper surface, M = 0.95

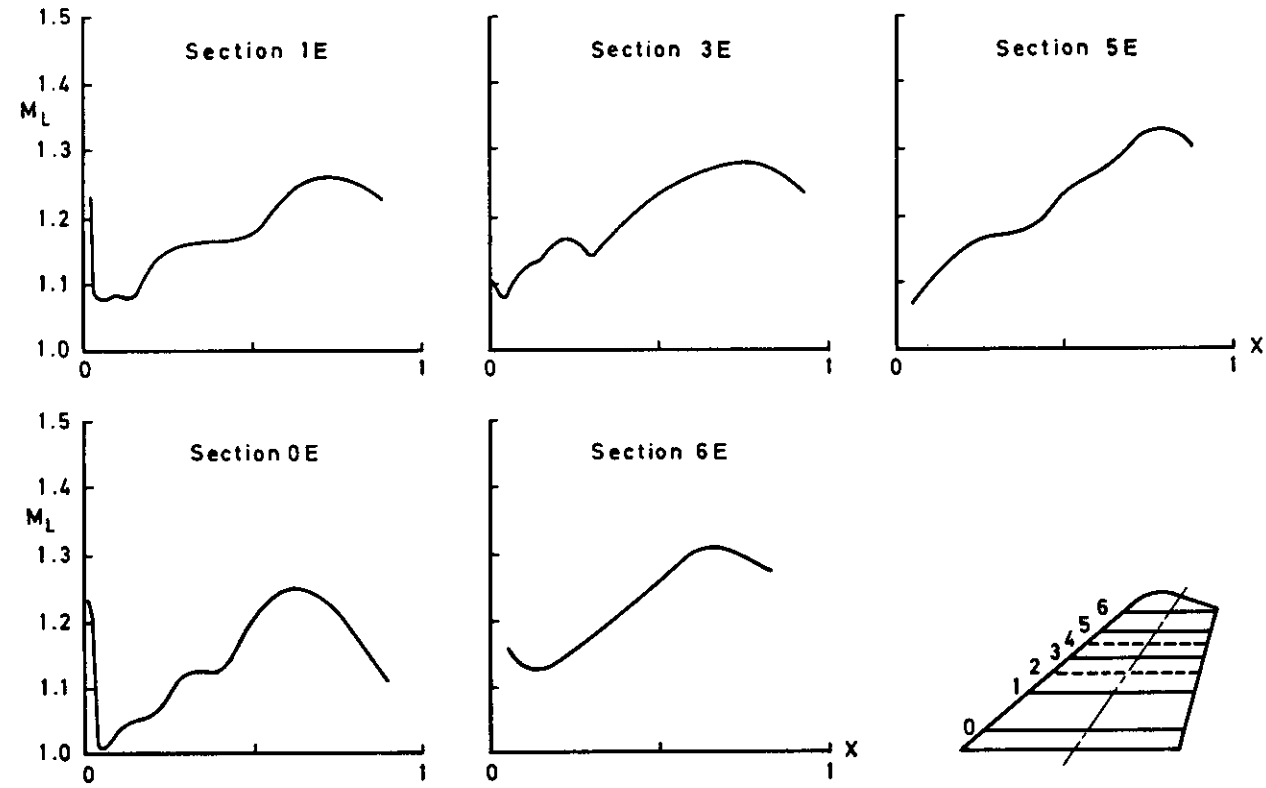


Fig 7.6 Local Mach numbers at upper surface, $M \simeq 1.10$, $\alpha \simeq 0$

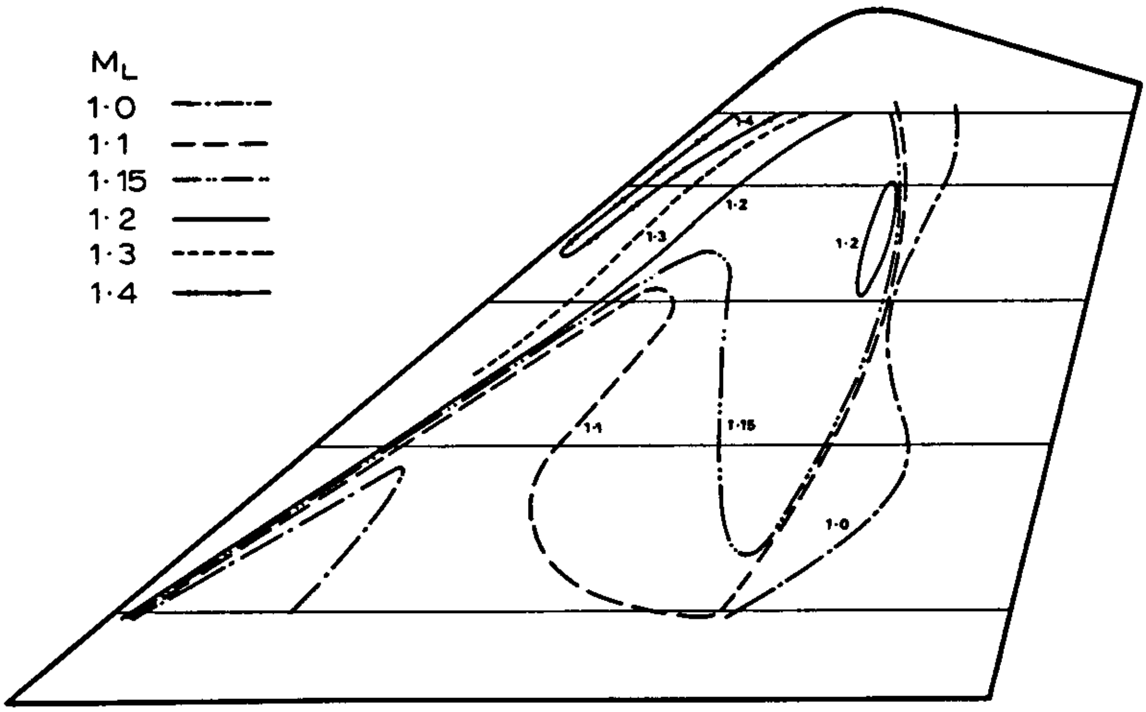


Fig 7.7 Isomachs, $M = 0.95$, $\alpha = 4^o$

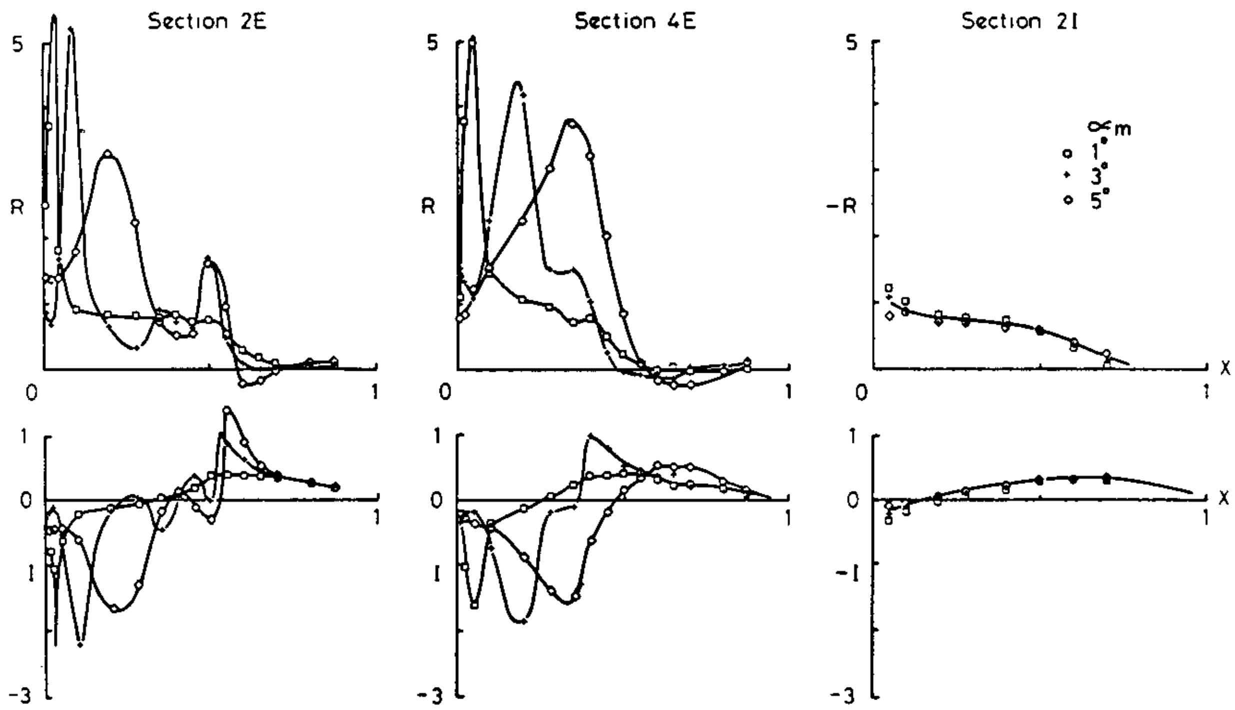


Fig 7.8 Oscillatory pressures. Influence of incidence, M = 0.90, f = 40 Hz

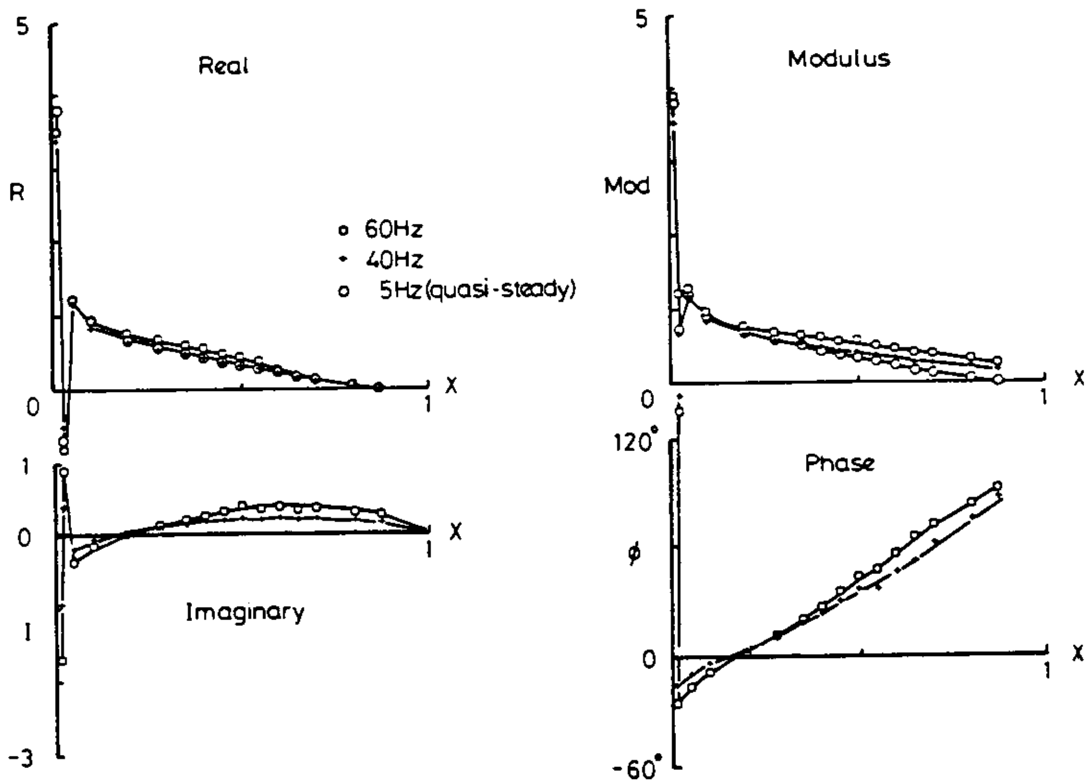


Fig 7.9 Oscillatory pressures, M = 0.80, α_m = 0. Influence of frequency, Section 2E

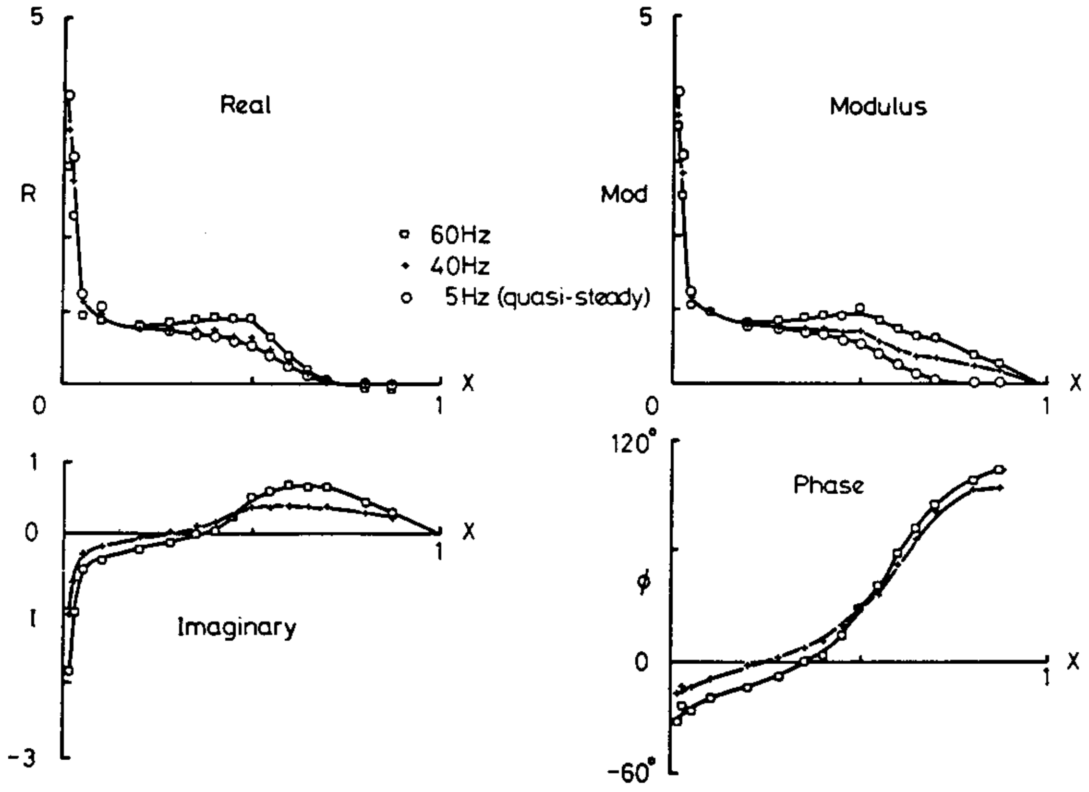


Fig 7.10 Oscillatory pressures, M = 0.90, α_m = 0. Influence of frequency, Section 2E

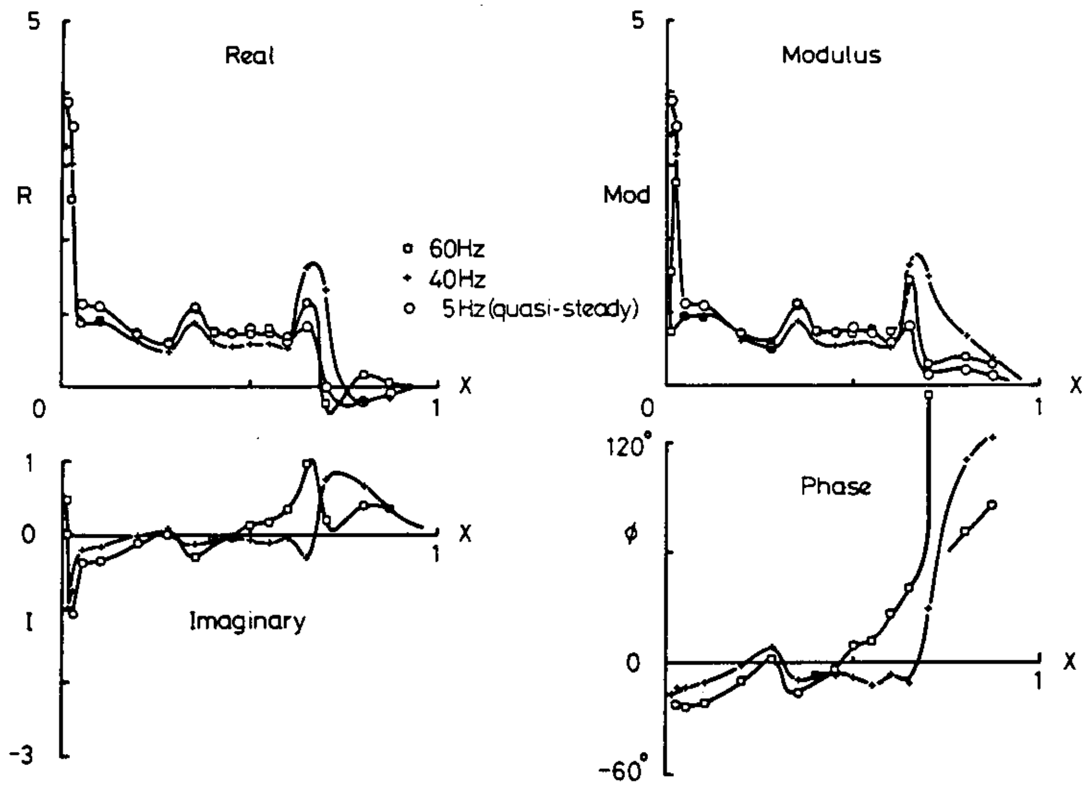


Fig 7.11 Oscillatory pressures, M = 0.95, α_m = 0. Influence of frequency, Section 2E

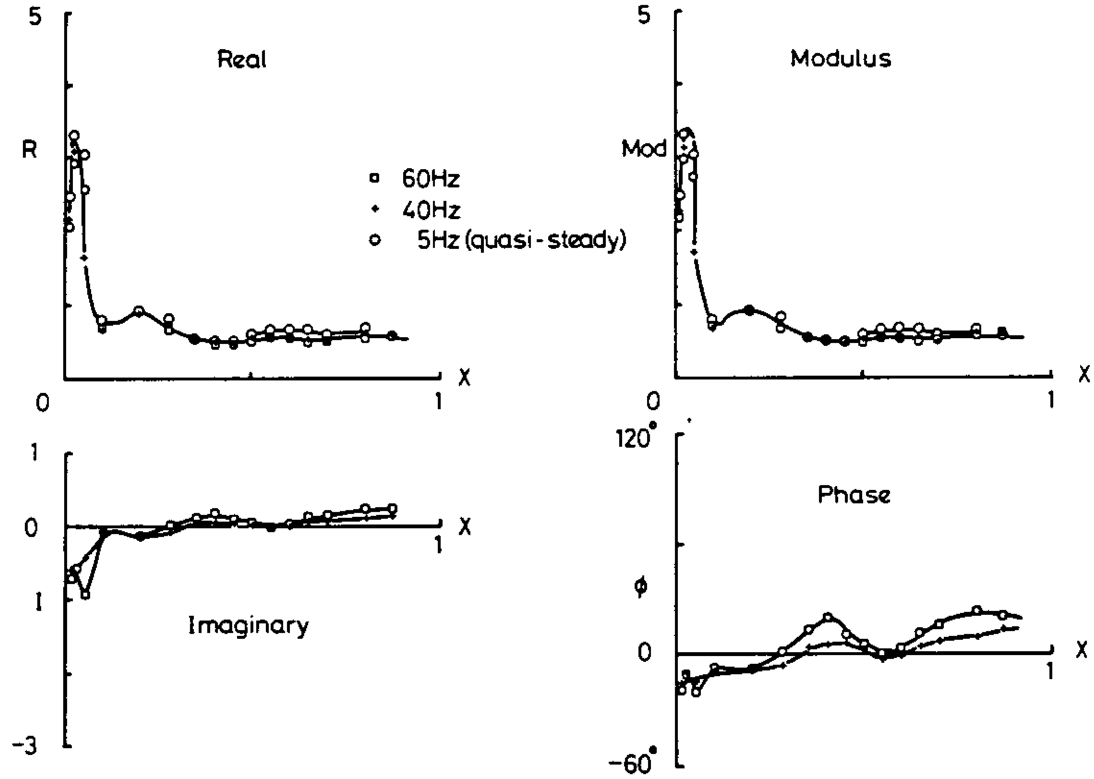


Fig 7.12 Oscillatory pressures, M = 1.10, $\alpha_m \simeq 0.55^0$. Influence of frequency, Section 2E

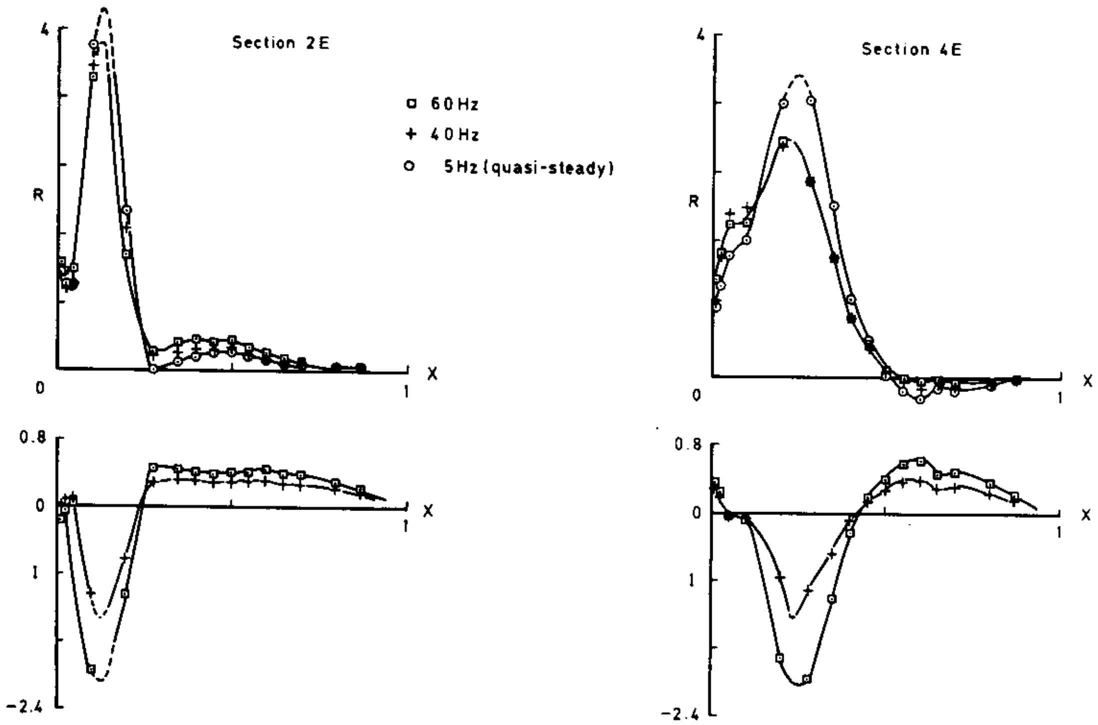


Fig 7.13 Oscillatory pressures, M = 0.80, $\alpha_m = 4.0^0$. Influence of frequency

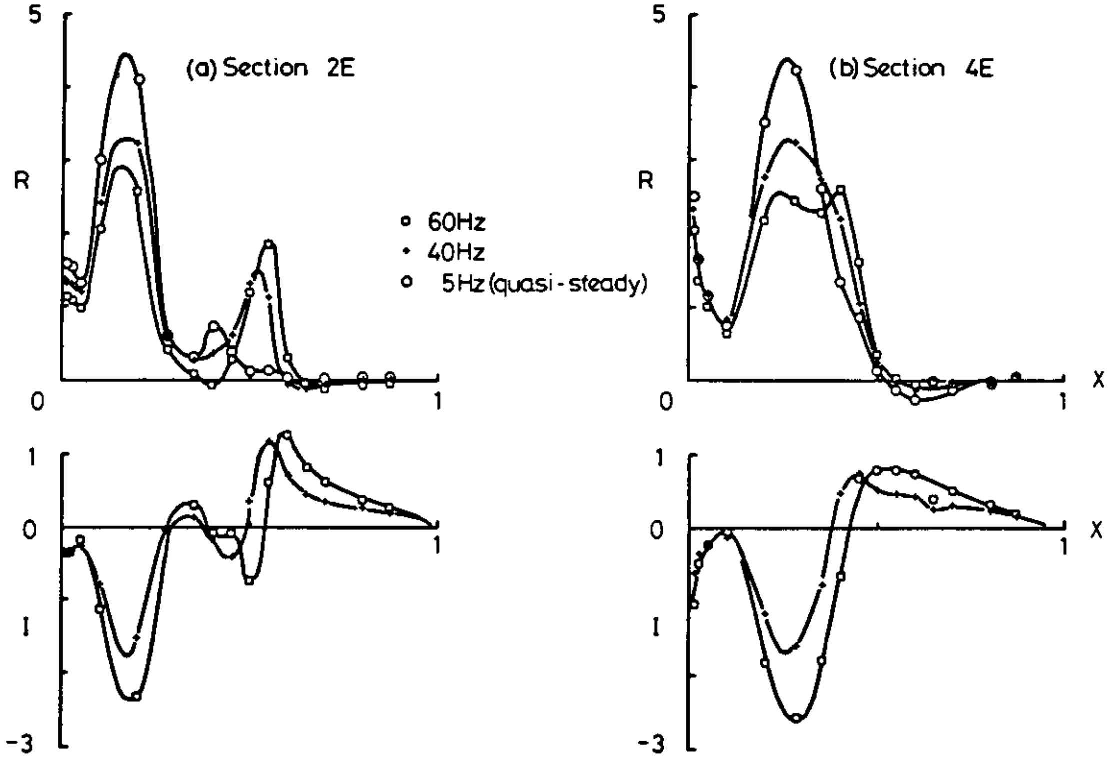


Fig 7.14 Oscillatory pressures, M = 0.90, $\alpha_m = 4^0$. Influence of frequency

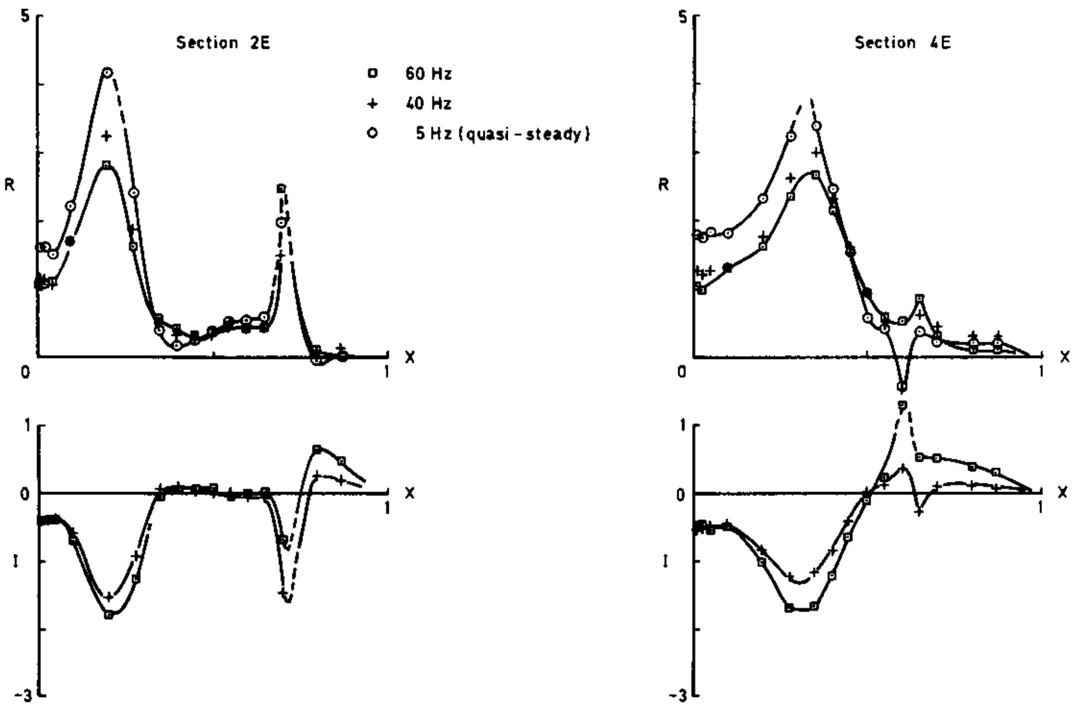


Fig 7.15 Oscillatory pressures, M = 0.95, $\alpha_m = 4.75^0$. Influence of frequency

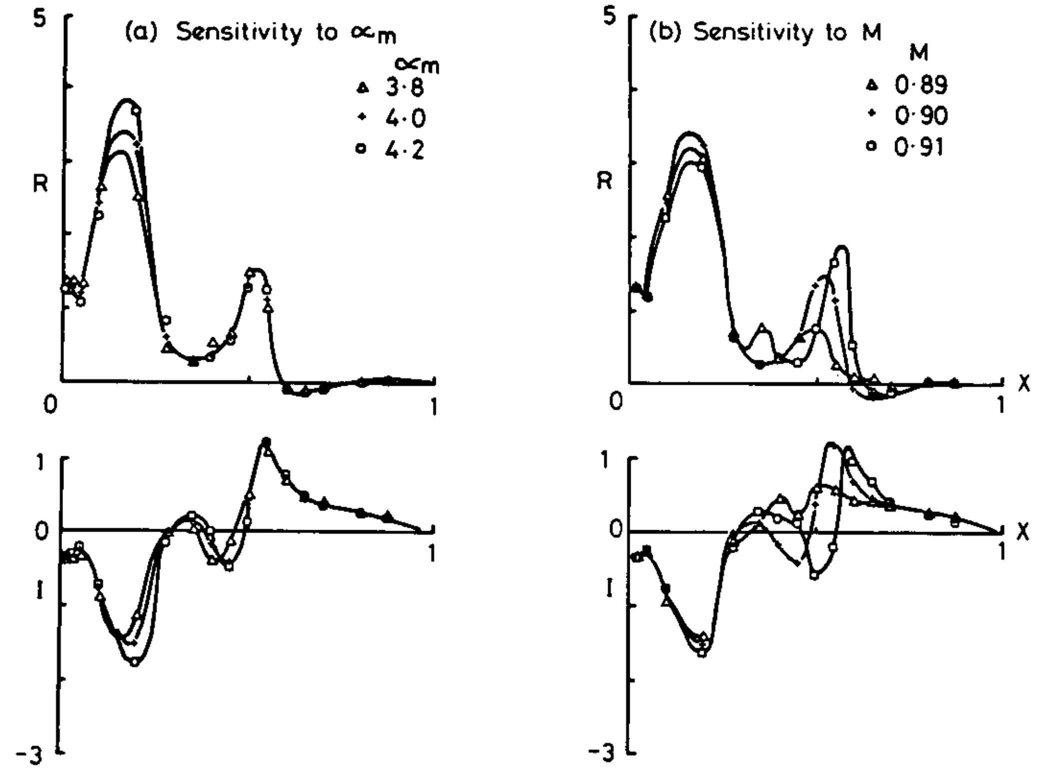


Fig 7.16 Oscillatory pressures. Sensitivity to small changes of incidence and Mach number. $M \simeq 0.90$, $\alpha_m \simeq 4^0$. Section 2E, f = 40 Hz

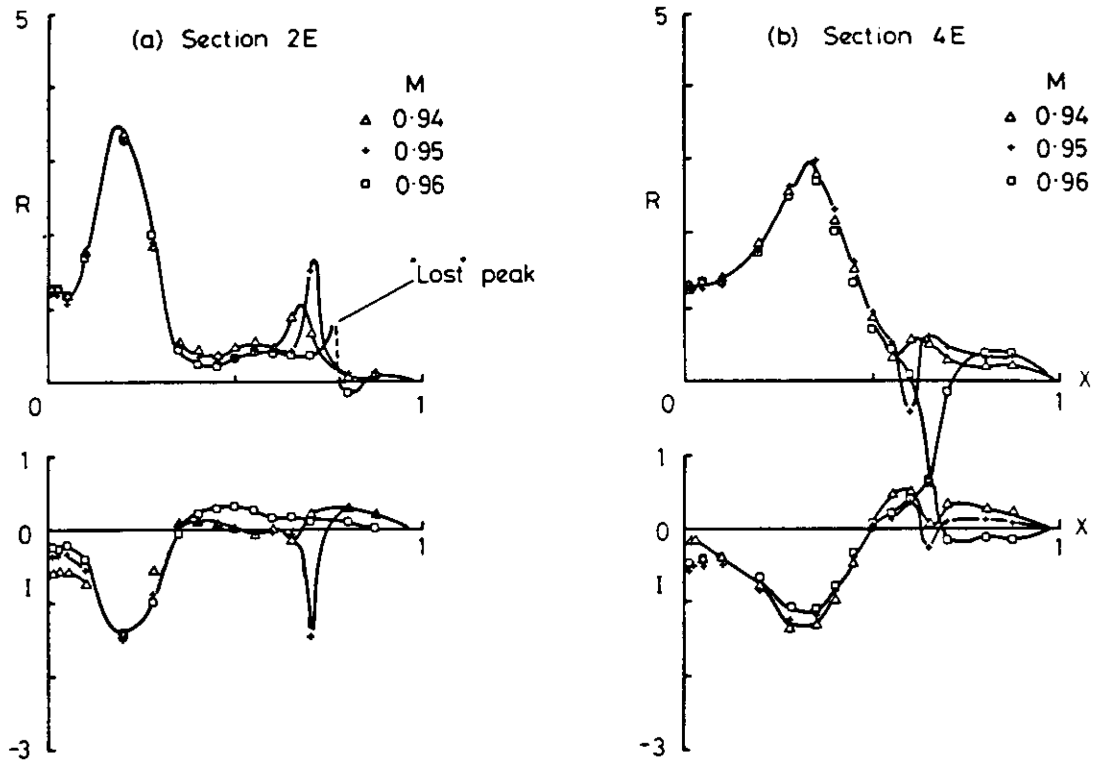


Fig 7.17 Oscillatory pressures. Sensitivity to small changes of Mach number. $M \simeq 0.95$, $\alpha_m = 4.75^0$, f = 40 Hz

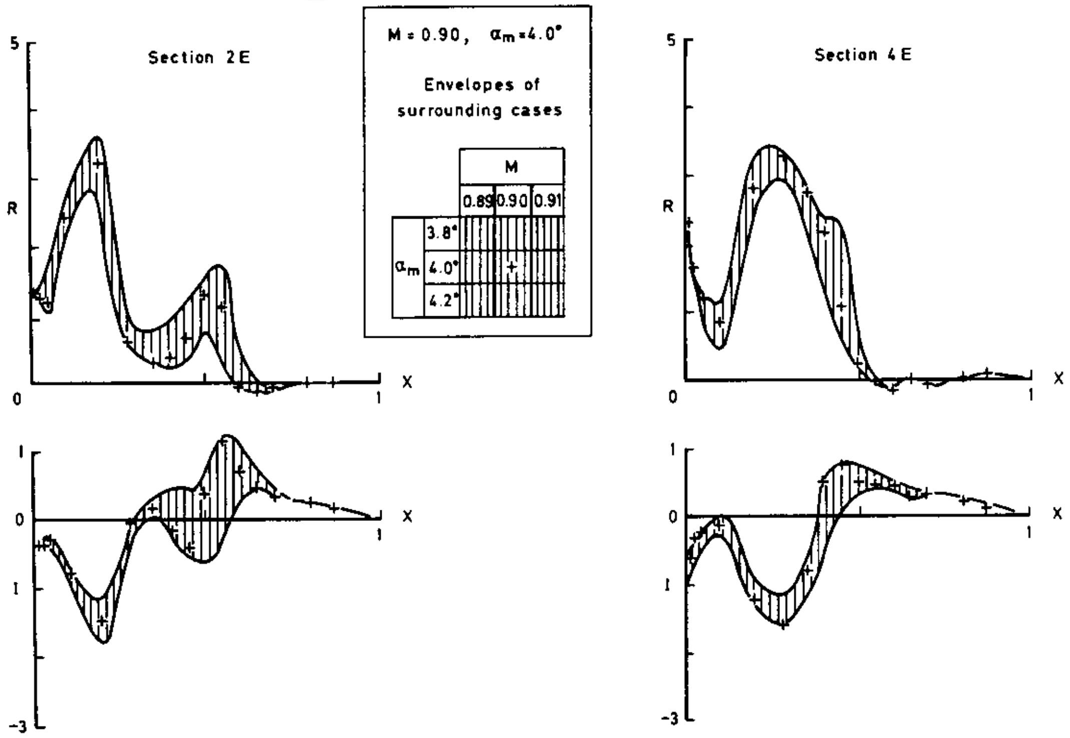


Fig 7.18 Oscillatory pressures for a matrix of cases centred on M = 0.90, α_m = 4.0^o, f = 40 Hz

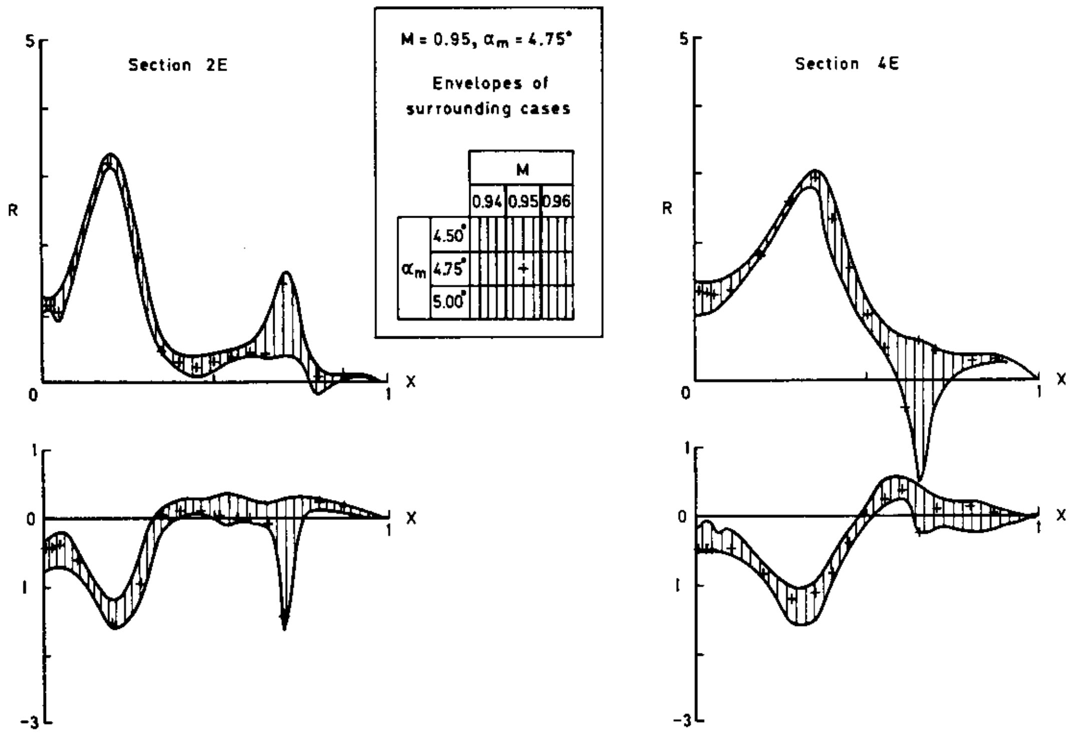


Fig 7.19 Oscillatory pressures for a matrix of cases centred on M = 0.95, α_m = 4.75^o, f = 40 Hz

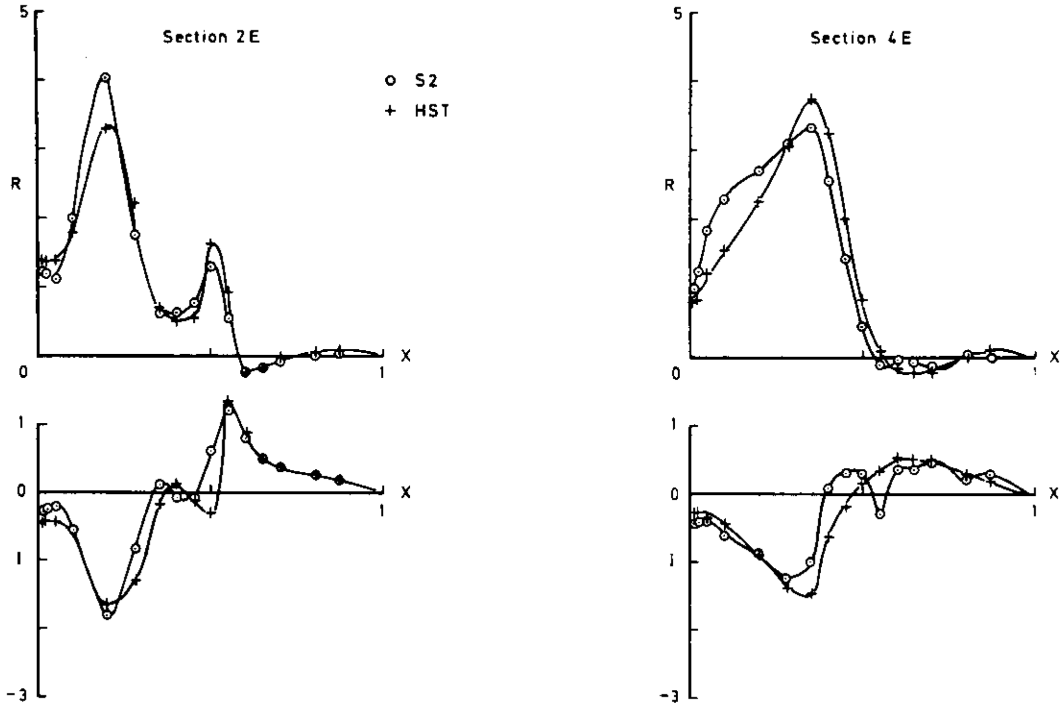


Fig 7.20 Oscillatory pressures. Comparison of data from S2 and HST.
$M = 0.90$, $\alpha_m = 5^0$, $f = 40$ Hz

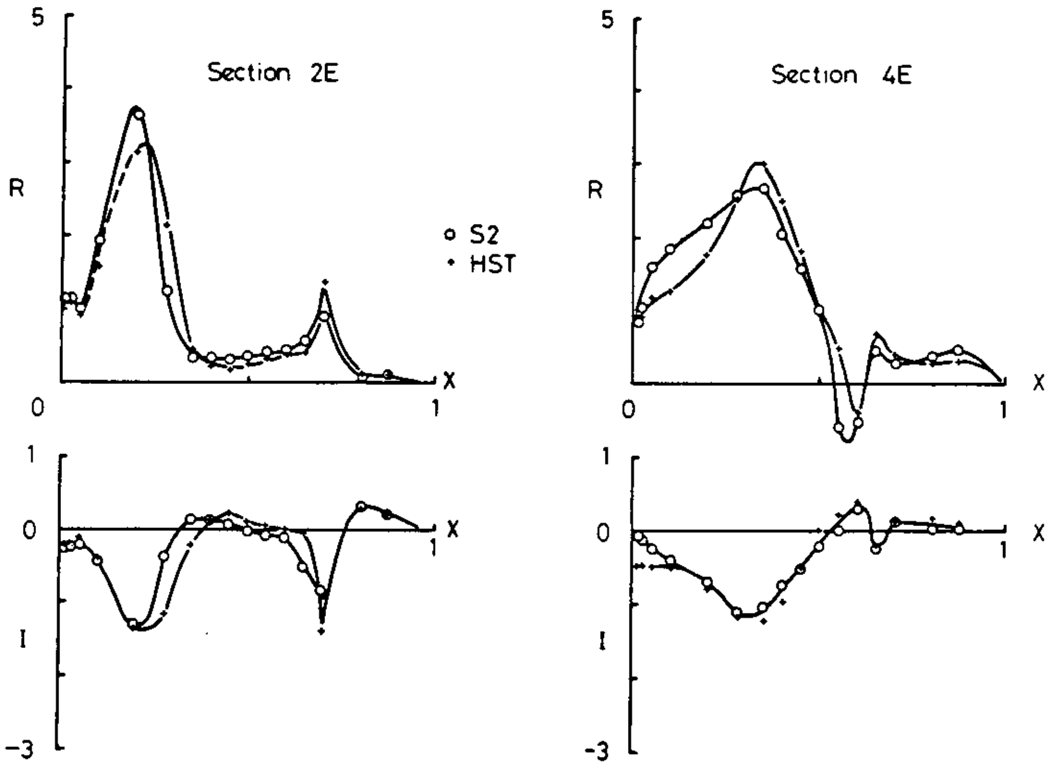


Fig 7.21 Oscillatory pressures. Comparison of data from S2 and HST.
$M = 0.95$, $\alpha_m = 5^0$, $f = 40$ Hz