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METHOD FOR PREDICTING THE JET-INDUCED AERODYNAMICS FOR V/STOL C--ETC(U)
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**METHOD FOR PREDICTING THE JET-INDUCED
AERODYNAMICS OF V/STOL CONFIGURATIONS IN TRANSITION**

Marvin M. Walters and Robert E. Palmer
Aircraft and Crew Systems Technology Directorate
NAVAL AIR DEVELOPMENT CENTER
Warminster, Pennsylvania 18974

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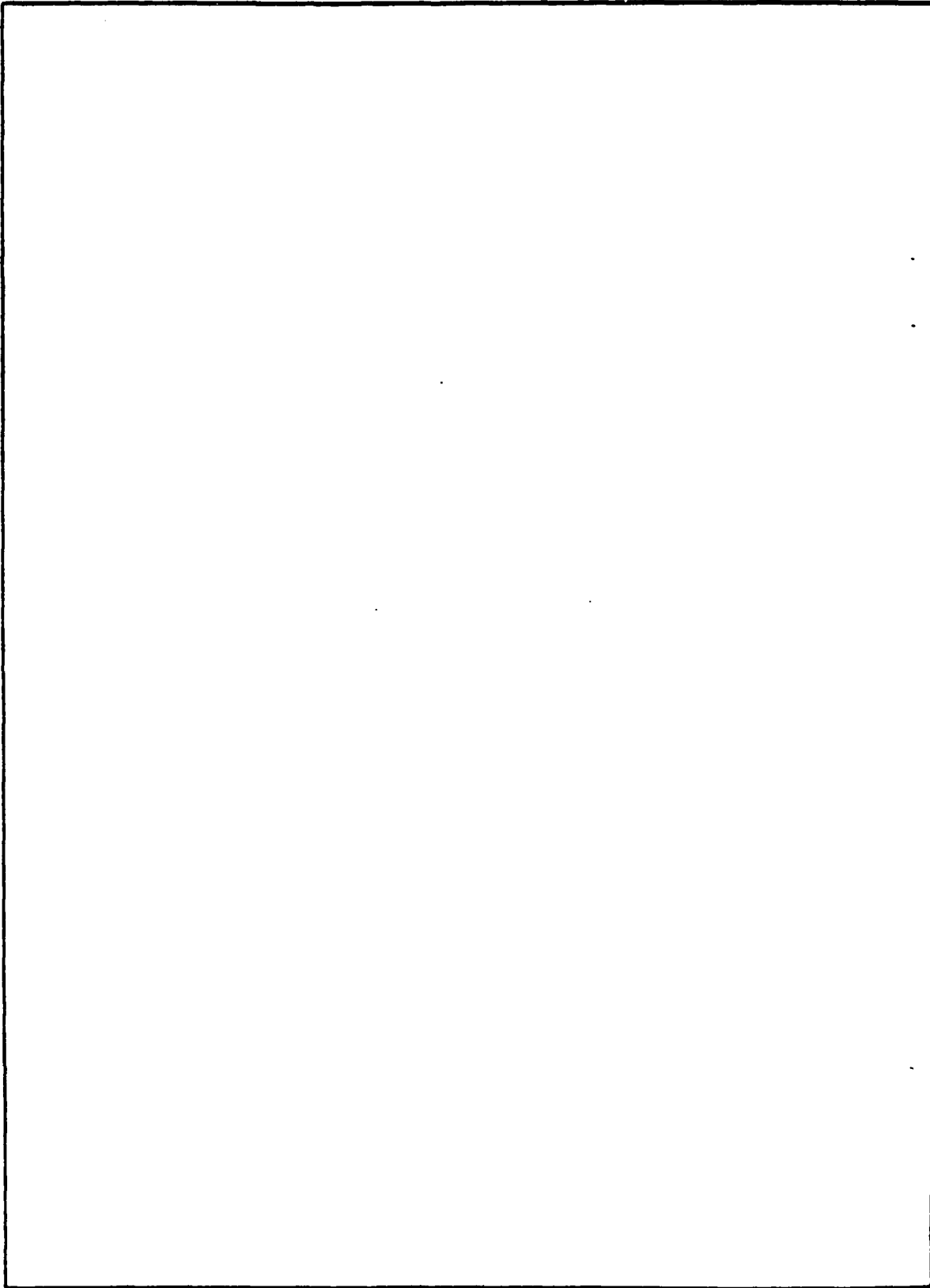
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SUMMARY

A method for predicting the propulsion-induced aerodynamics of a VSTOL aircraft in the transition flight regime has been developed. This method represents the formulation of wind tunnel test data consisting of pressure coefficients at numerous locations on a flat plate due to a circular jet exhausting normally into crossflows of freestream to jet velocity ratios from 0.1 to 0.3. As a result, the method is applicable to low-wing, circular jet subsonic V/STOL configurations with normally exhausting jets.

This report documents the development of the formulation along with validation results for various V/STOL configurations indicating its applicability as well as limitations. The computer code used in the validation of the method is also presented along with the required input and configuration modelling procedures.

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LIST OF SYMBOLS

AR	Aspect Ratio
C_p	Pressure coefficient
C_{pMAX}	Maximum pressure coefficient for a particular velocity ratio
C_{pNORM}	Pressure coefficient normalized by C_{pMAX}
D_e	Equivalent diameter - diameter whose circular area equals the total exit area of all jets in the configuration
D_j	Jet diameter
L	Lift; total length of configuration
M	Pitching moment
p	Pressure
q	Dynamic pressure
S	Planform area
S_j	Jet exit area
V_e	Equivalent velocity ratio - $\frac{V_\infty}{V_j}$
V_j	Jet Velocity
X	Longitudinal distance along aircraft centerline
Y	Lateral distance from aircraft centerline

Subscript

∞ Freestream

Mathematical Symbol

$\Delta()$ Incremental quantity

INTRODUCTION

The V/STOL transition flight regime covers the velocity range from low speed hover to the sustained velocity required for fully wingborne flight. Jet exhaust effects have a major influence on aerodynamic characteristics in this regime resulting in large forces and moments being induced on the aircraft. These jet effects involve the interaction of the jet and free stream flow and are primarily the result of four viscous flow phenomena: jet blockage, wake separation, entrainment, and vortex generation. Due to complex viscous interaction of these four phenomena, the individual effect of each component has not been separated, making analytical/numerical prediction most difficult.

Current prediction techniques applicable to the transition flight regime consist of potential flow analysis computer programs with empirically derived adjustments or corrections to account for the viscous interactions which characterize transition aerodynamics. These techniques are extremely time consuming with respect to modelling the aircraft configuration with panels required by the potential flow analysis, and also with respect to the computer time required to run the program. Unfortunately, this time expended does not necessarily result in an associated increase in accuracy. As a result, these techniques are primarily applicable to detailed design type of analysis, being too expensive for use as a preliminary design tool.

The methodology presented here represents the development of a prediction technique which is designed for use as a preliminary design tool. The induced lift and pitching moment are calculated requiring only the configuration geometry and jet location. Since most of the available experimental data applicable to the transition flight regime resulted from specific aircraft configurations, it was decided to use the more fundamental data obtained from tests of jets issuing from flat plates. This data formed the basis of the prediction technique which could then be applied or adapted to most aircraft configurations.

Prior to the formal publication of this report, this method was used as the basis for a more complete prediction technique for V/STOL transition aerodynamics with no restrictions concerning aircraft configuration. Coefficients are applied to the basic lift loss value calculated by the method contained herein to account for various configuration effects including wing aspect ratio, longitudinal position of the jet, wing height, lateral spacing of multiple jets, nozzle configuration, and jet deflection angle. A complete discussion of the development of the more complete technique is contained in reference (6).

METHOD DEVELOPMENT

The preliminary design stage of a V/STOL aircraft involves the assessment of various conceptual designs to determine which concept most satisfies the design requirements to justify further development. As part of this assessment, the propulsion induced aerodynamic effects must be predicted to ensure the selection of that design which, when weighed against the other design requirements, minimizes the negative effects and maximizes the positive effects.

In developing a method to predict the propulsion induced effects in such a design environment, the design information required by the method must be limited to that which would be known at that stage. Accordingly, the present method was developed under the guidelines of requiring only general configuration geometry, jet location, and free stream-to-jet velocity ratio for the desired flight conditions. The approach then taken to develop this generalized, preliminary design stage type of empirical formulation to predict the transition aerodynamics was to:

- a. Obtain available pressure coefficient data measured on a large flat plate due to a jet exhausting perpendicular to the free stream.
- b. Derive an expression for the pressure coefficient data as a function of velocity ratio, V_e , and longitudinal and lateral distances from the jet, X/D and Y/D respectively.
- c. Use the finalized expression as a basis to integrate over the configuration planform area of interest relative to nozzle location to obtain the jet induced aerodynamics in transition flight.
- d. Validate the resulting method initially using simplified flat plate or low wing configurations followed by more realistic complex designs.
- e. Modify or adjust the expression, based on results of step (d) to account for configuration variables such as jet nozzle location relative to wing and fuselage, planform-to-jet area ratio, jet deflection, and fuselage contour.

The pressure coefficient data used to develop the empirical formulation was obtained from flat plate data generated by Fearn, reference (1). This data was obtained for free stream-to-jet velocity ratios ranging from 0.1 to 0.45 using a four-inch diameter jet exhausting normally from a flat plate 24 jet diameters wide by 27 diameters long. The pressure coefficient was defined as

$$C_p = \frac{p - p_\infty}{q_\infty}$$

where p is the difference between the pressure measured at the test condition and the pressure measured with the power off, and p_∞ is the static pressure of the free stream fluid. Thus, the data represents the induced effects produced by the jet. As plotted in figures (1) to (4) the data approximates an exponential trend with X/D which tends to flatten out as Y/D is increased, with a non-linear peak value variation with V_e . In developing an expression to fit this data, each of these variations must be accounted for plus the variation of the X/D location of the peak values for a particular V_e , as emphasized in Figure (4).

The equations representing the induced pressure coefficient data were developed in essentially two parts. The first part, $C_{P_{MAX}}$, equation (1), calculates the peak pressure coefficient as a function of Y/D_e and V_e . The second part, $C_{P_{NORM}}$, equation (2), represents the remaining normalized data points (normalized by the peak C_p value, $C_{P_{MAX}}$, for each V_e). The two equations are then simply multiplied according to equation (3) to obtain the desired induced pressure coefficient.

$$C_{P_{MAX}} = \frac{-4.25}{(4V_e - 1)^2 (Y/D_e + .5) (3.25 V_e + 1.4)} \quad (1)$$

$$C_{P_{NORM}} = \frac{1}{[K_1 (X/D_e - F)]^{K_2}} - \frac{(3.67 Y/D_e + 5) V_e^4}{e^{(X/D_e + .4 Y/D_e + 2.5)^2}} \quad (2)$$

$$F = (2.48 Y/D_e - 1.6) V_e - .1 Y/D_e - .07$$

and for $(X/D_e - F) \leq 0$

$$K_1 = \frac{1}{(-2.28 V_e + 1.36) Y/D_e}$$

$$K_2 = \frac{16 V_e}{Y/D_e} + 1.55 \ln (Y/D_e) - 1$$

whereas for $(X/D_e - F) \geq 0$

$$K_1 = \frac{1}{1.1 Y/D_e}$$

$$K_2 = -.13 (Y/D_e - 3.5)^2 + 1.8$$

$$C_P = C_{P_{MAX}} C_{P_{NORM}} \quad (3)$$

In equation (1), the constant -4.25 establishes the maximum value which C_{pMAX} attains. The term $e^{(4V_e-1)^2}$ accounts for the exponential variation of C_{pMAX} values as shown in Figure (2), with the term

$$(Y/D_e + .5)(3.25 V_e + 1.4)$$

providing the variation in C_{pMAX} values with Y/D_e and V_e which tends to flatten the C_p curves as Y/D_e increases, as seen in Figures (1) to (4).

The first part of the C_{pNORM} equation

$$\frac{1}{e^{[K_1 (X/D_e - F)]^{K_2}}}$$

establishes the basic exponential shape of the curve, being a version of the general equation $\frac{1}{e^{(ax)^b}}$. Replacing the x term by $(X/D_e - F)$ accounts for the

X/D_e shift in the C_{pMAX} values with varying V_e and Y/D_e as indicated in Figures

(1) to (4). The term K_1 represents the coefficient of x required to curve fit the data and provides a corrective effect to insure the exponent remains positive. The overall exponential shape of the curve is made symmetrical about the ordinate axis by the factor K_2 which again varies with V_e and Y/D_e . The second term of the C_{pNORM} equation

$$\frac{(3.67 Y/D_e + 5) V_e^4}{e^{(X/D_e + .4 Y/D_e + 2.5)^2}}$$

modifies the original shape of the curve at high negative X/D_e values to account for the positive pressure coefficient in front of the jet.

With the equation developed in this form, the calculation of induced pressure coefficients is relatively simple. However, calculating the induced forces for an entire configuration is more amenable to use of the computer. As a result, the formulation was computerized with a configuration modelling technique and an integration procedure included as part of the code. The modelling technique and integration procedure are discussed in Appendix A. A listing of the computer program, a discussion of the required input, and a sample output are then presented in Appendix B.

METHOD VALIDATION

Since the data used for formulation represents pressures on a flat plate due to normally exhausting jets, the method mainly applies to low wing configurations with a normally exhausting jet. The jet should be centrally located in the fuselage or wing undersurface, away from wing or fuselage edges which would result in additional circulation effects not contained in the data. Additionally, nozzle pressure ratios during the test indicate the method to be applicable to subsonic configurations. Therefore, the method was validated against configurations commensurate with its capability plus additional configurations to indicate possibilities for extending its capability.

The first correlation of the method was done with data from reference (2) for a rectangular wing. Figure (5) shows fairly good agreement for both lift and resulting pitching moment, especially since the data contains some circulation effects causing the apparent over-prediction of induced lift loss while the method does not contain circulation effects.

Figure (6a) shows the correlation of data, also from reference (2), for an elongated body with a jet located 40% from the leading edge. Excellent results are shown for jet induced lift while the pitching moment exhibits fair correlation. Additional comparisons with the same elongated body but with the jet located 60% from the leading edge are shown in Figure (6b). Very good agreement again is shown between the test data and predicted results.

For a delta wing configuration with a small jet, also from reference (2), excellent agreement with test data is shown in Figure (7a) for a velocity ratio range of 0.1 to 0.3. This velocity range is representative of the lower and middle transition region and thus a good correlation in this range is considered to be of primary importance. The corresponding pitching moment plot, however, indicates gross disagreement. This is due to questionable data since the aberrant points on the plot represent a large hump in the data which substantially deviates from the trend.

Results of replacing the small jet with a larger jet in the same delta wing configuration are shown in Figure (7b). For this configuration, the predicted results for jet induced lift are slightly greater than actual test data, but again this difference is small. Excellent agreement for pitching moments is shown between the predicted results and test data for the velocity range 0.1 to 0.3.

Further validation was conducted with a delta wing design from reference (3). Figure (8a) shows the comparison to be fair for the configuration with a jet to planform area ratio of 0.006, whereas increasing the ratio to 0.024 produced quite good results as indicated in Figure (8b).

To determine the possibilities of extending the method application to multiple jet configurations, data from reference (4) for a four jet arrangement of the same configuration as above was used for comparison. The method was applied in the same manner as before for each jet, however a thrust weighted summation was used to obtain the total induced force as given by

$$\frac{\Delta L}{T} = \left(\frac{\Delta L}{T} \right)_1 \frac{T_1}{T_{\text{total}}} + \left(\frac{\Delta L}{T} \right)_{i+1} \frac{T_{i+1}}{T_{\text{total}}} + \dots + \left(\frac{\Delta L}{T} \right)_n \frac{T_n}{T_{\text{total}}}$$

where $(\Delta L/T)_i$ and T_i are the induced lift and thrust associated with an individual jet, and T_{total} is the total thrust of the configuration. Figure (8c) contains a planform view of the configuration along with results of the comparison, indicating excellent agreement up to velocity ratio of 0.15, where the prediction begins to diverge into only fair agreement at $Ve = 0.25$.

A final validation of the method was done using data from reference (5) for a high wing configuration. This represents an additional extension of the method's applicability beyond the low wing type of configuration. As shown in Figure (9), the comparison is quite good for the single jet configuration indicating wing height to be a secondary effect in this design. However, Figures (10a) and (10b) indicate an important limitation of this method being the inability to account for additional circulation created by a jet located near the trailing edge of a wing. The additional lift and subsequent reduction in induced lift loss associated with such a jet/wing arrangement is clearly illustrated in the figure.

CONCLUSIONS AND RECOMMENDATIONS

The method developed herein to predict the propulsion induced lift of a V/STOL aircraft in the transition flight regime has been shown to be quite effective. When applied to those configurations which do not exceed the limitations imposed by its development, the method's predictions are well within the accuracy required of a preliminary design phase analysis technique.

However, these limitations require that further development of the method be directed towards extending its capability to include other configuration variables. These variables include nozzle location relative to the wing, jet deflection angle, and sideslip conditions. Additionally, nozzle pressure ratio effects must also be included to allow prediction of supersonic V/STOL configurations which are typically characterized by one or more high nozzle pressure ratio exhaust jets.

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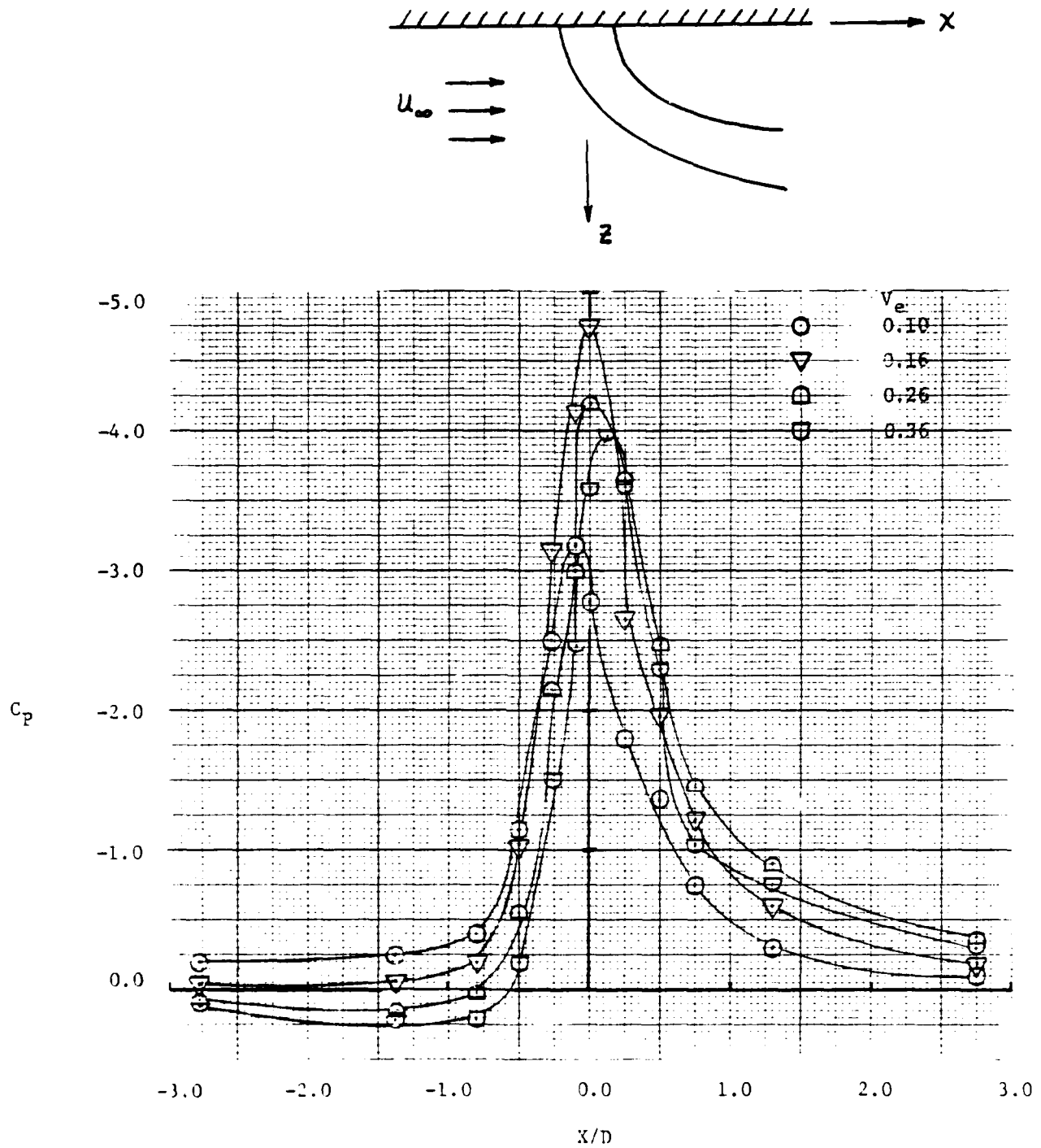


FIGURE 1. Pressure Coefficient Distribution
for $V_e = .1 \sim .36$, $Y/D = 0.5$

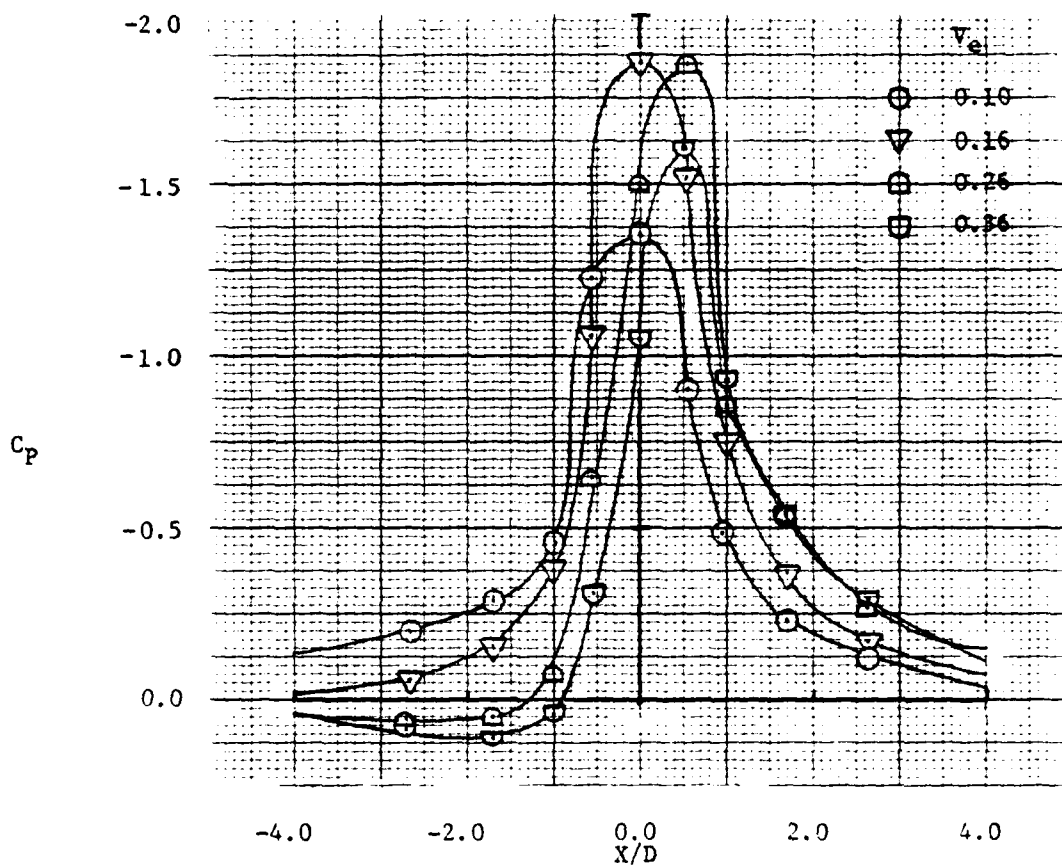


FIGURE 2. Pressure Coefficient Distribution for $V_e = .1 - .36$, $Y/D = 1.0$

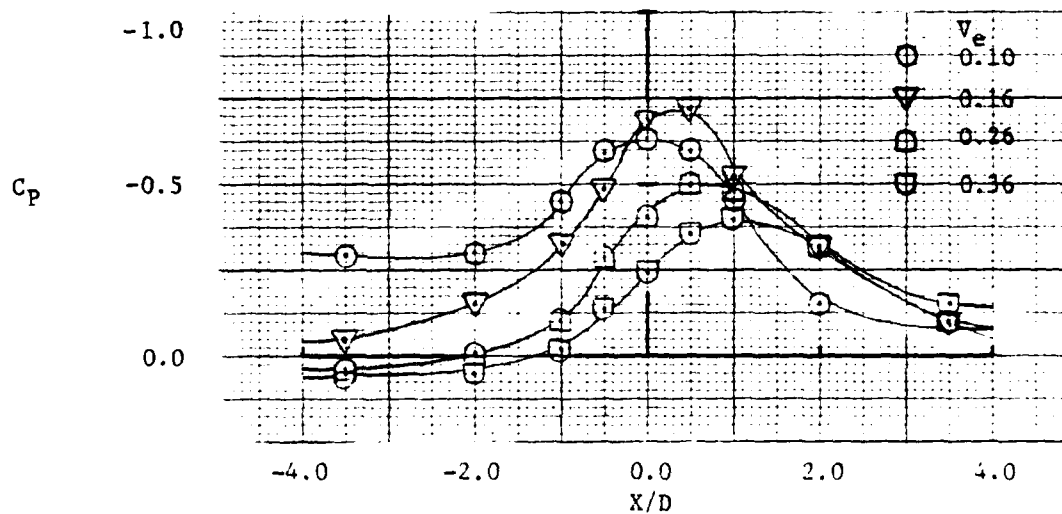


FIGURE 3. Pressure Coefficient Distribution for $V_e = .1 - .36$, $Y/D = 2.0$

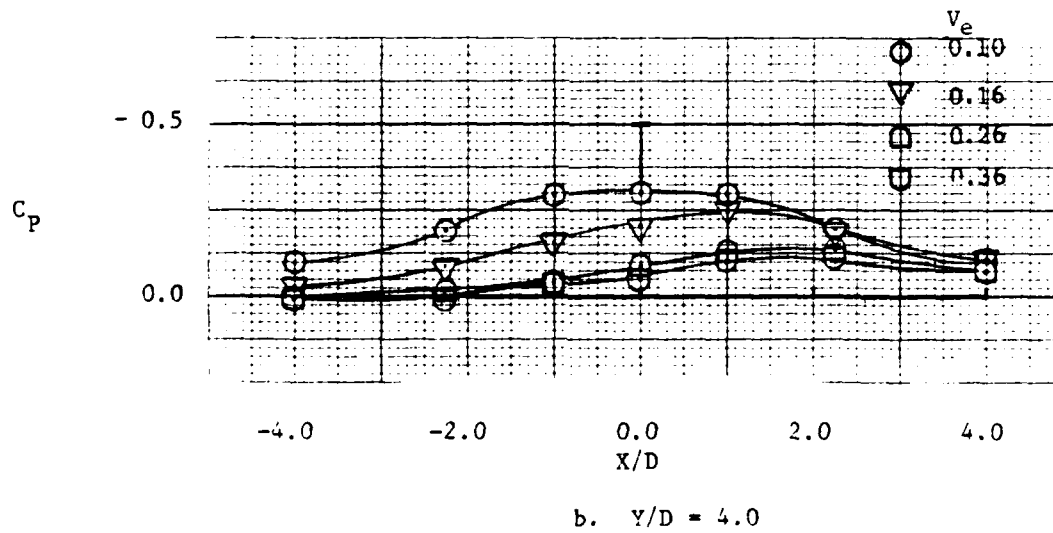
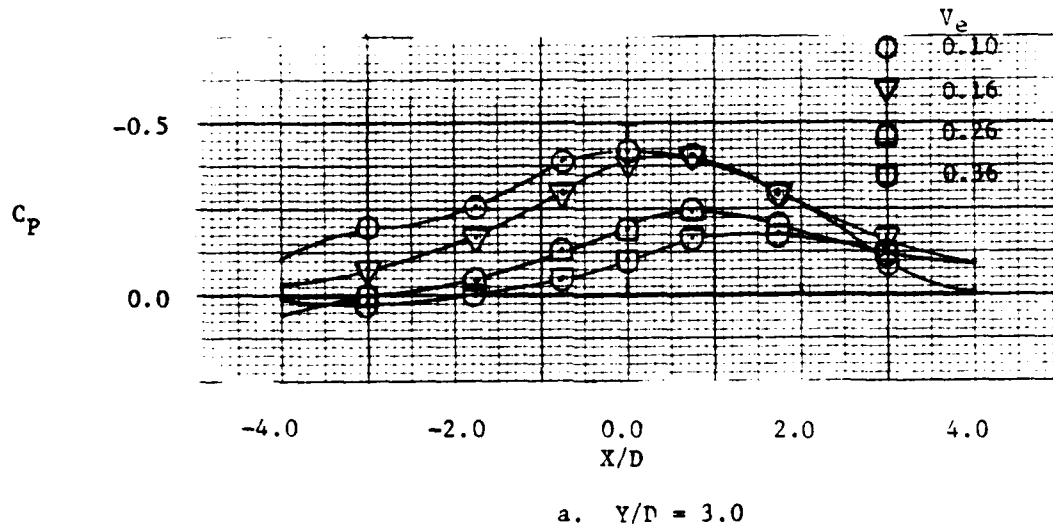


FIGURE 4. Pressure Coefficient Distribution
for $V_e = .1 - .36$, (a) $Y/D = 3.0$, (b) $Y/D = 4.0$

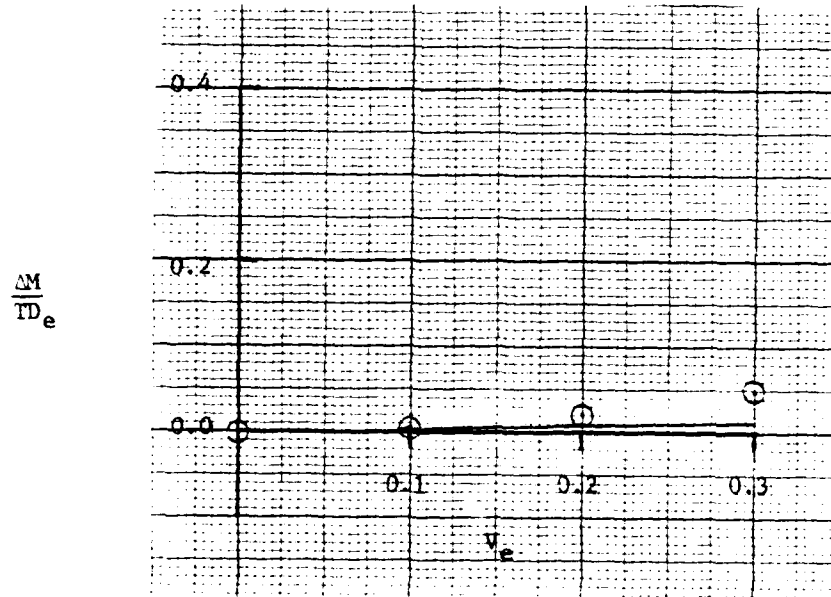
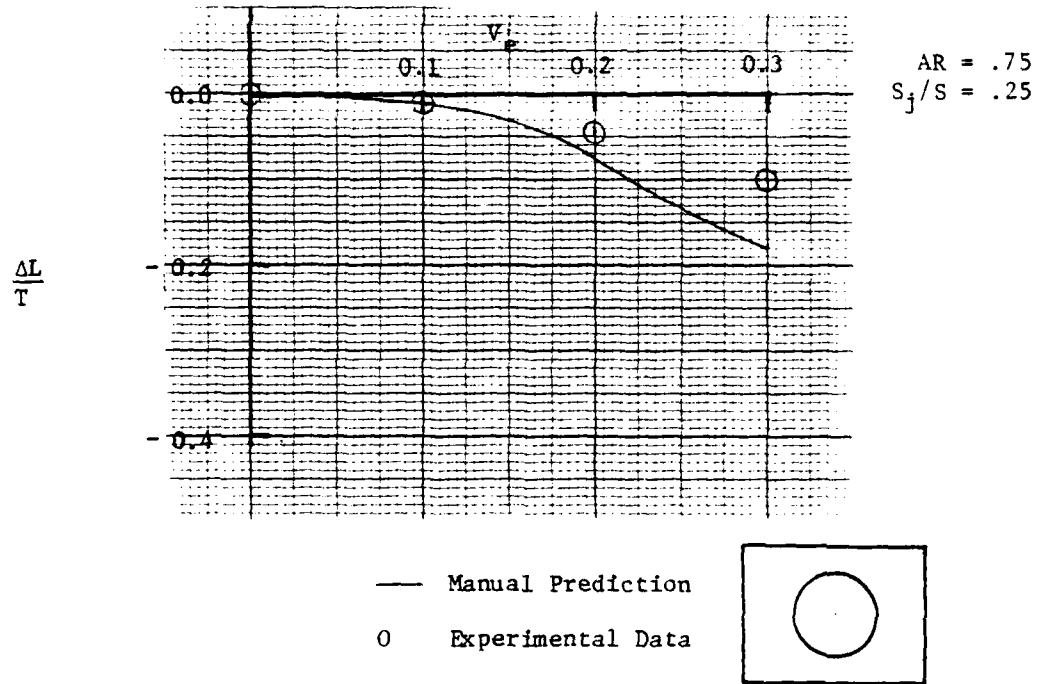
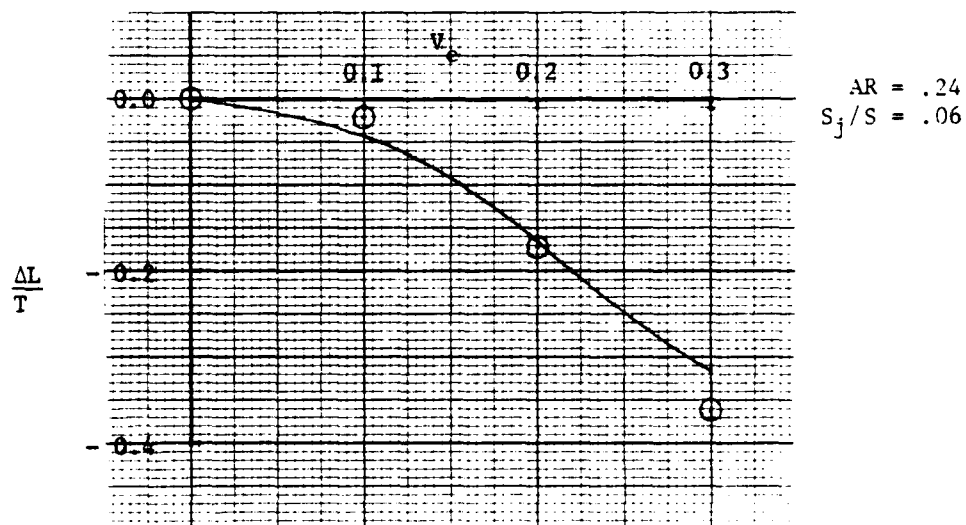
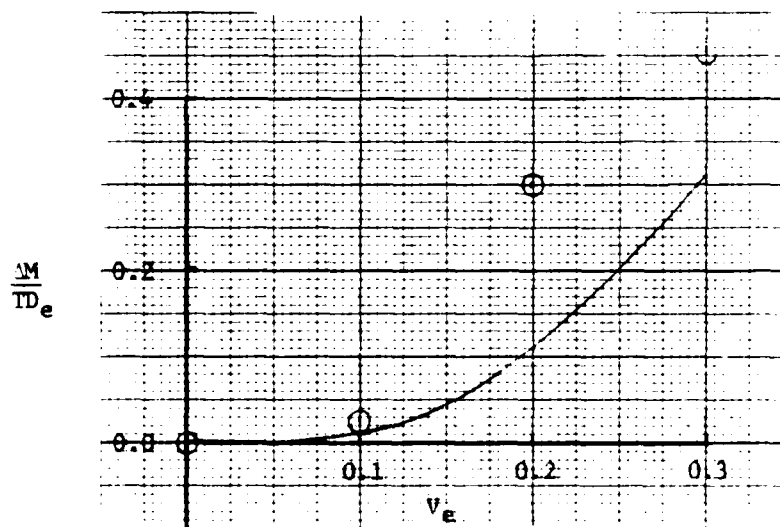


FIGURE 5. Comparison of Predicted Results with Test Data of a Rectangular Wing

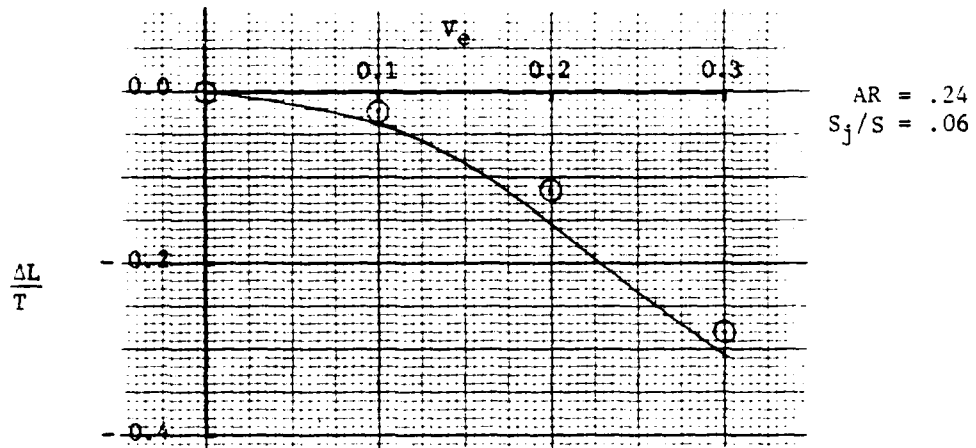


— Manual Prediction
○ Experimental Data

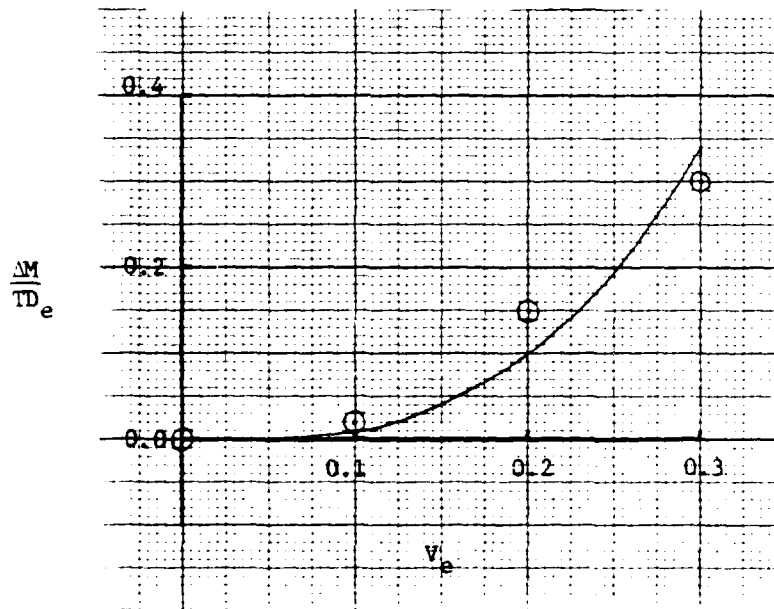


a. X/L = 0.40

FIGURE 6. Comparison of Predicted Results with Test Data of an Elongated Body

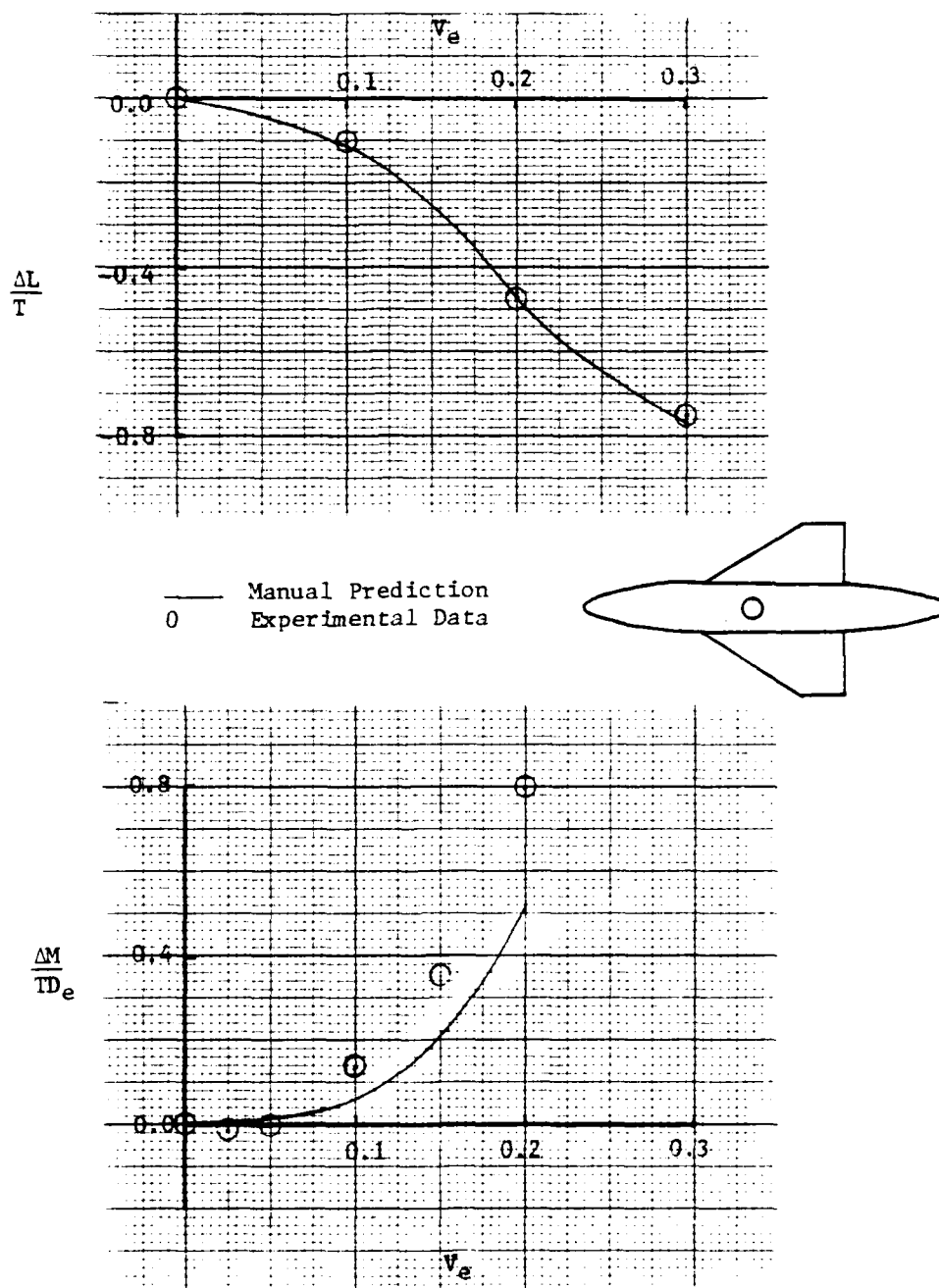


— Manual Prediction
○ Experimental Data



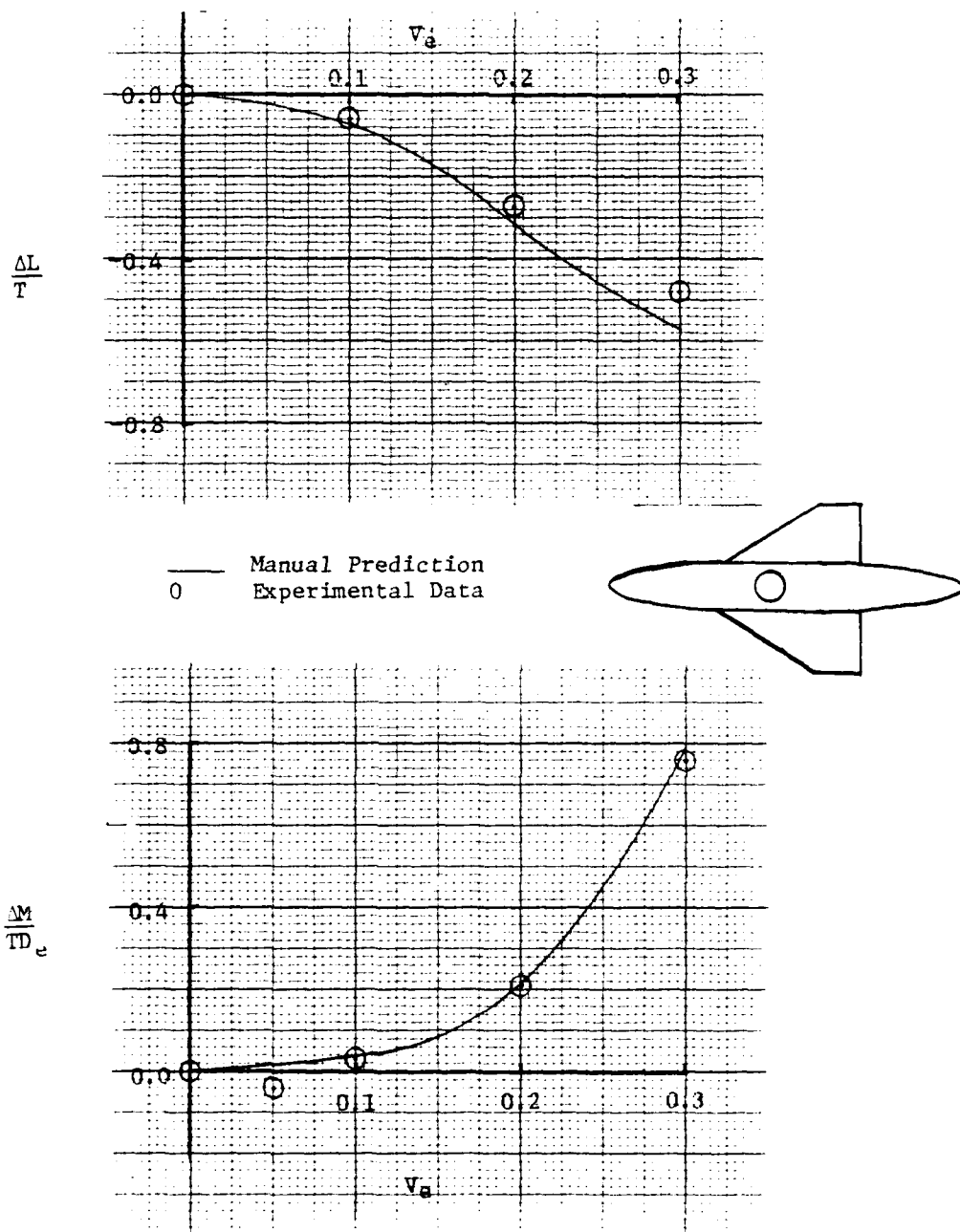
b. X/L = 0.60

FIGURE 6. Continued



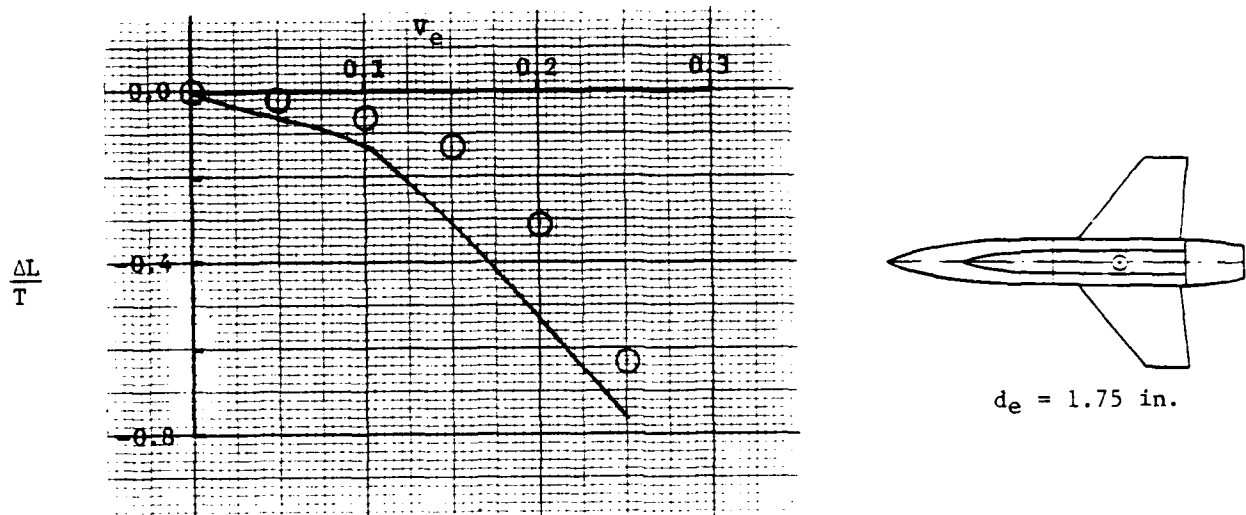
a. $S_j/S = 0.013$

FIGURE 7. Comparison of Predicted and Experimental Data of a Clipped Delta Wing Configuration

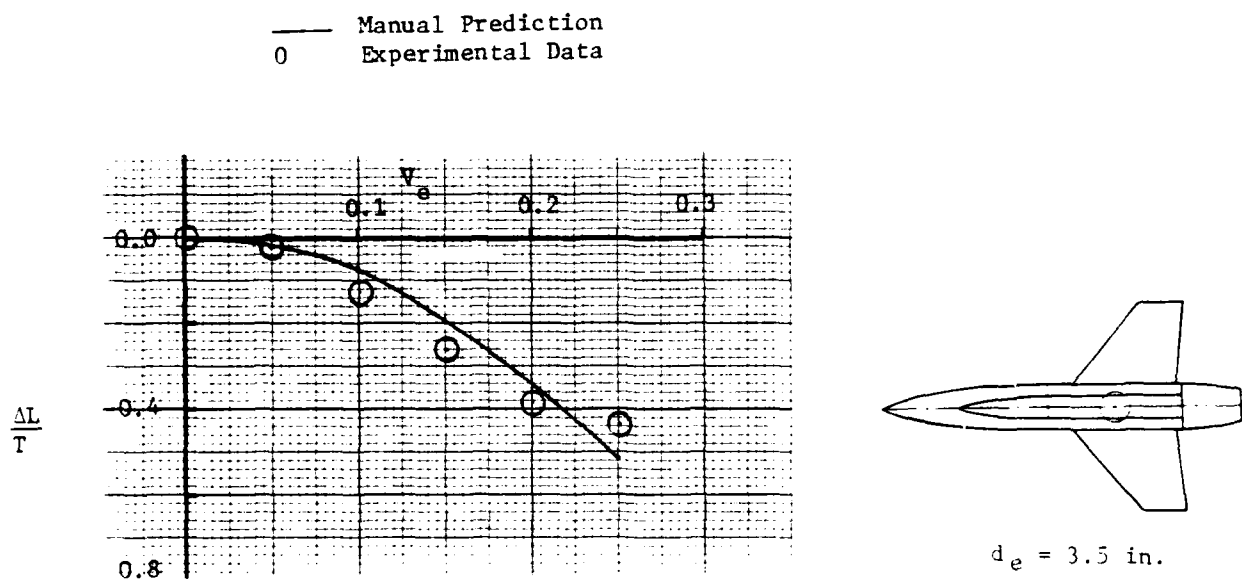


b. $S_j/S = 0.026$

FIGURE 7. Continued

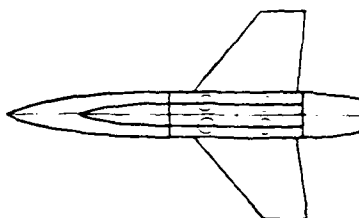


a. Single Jet Configuration, $S_j/S = 0.006$



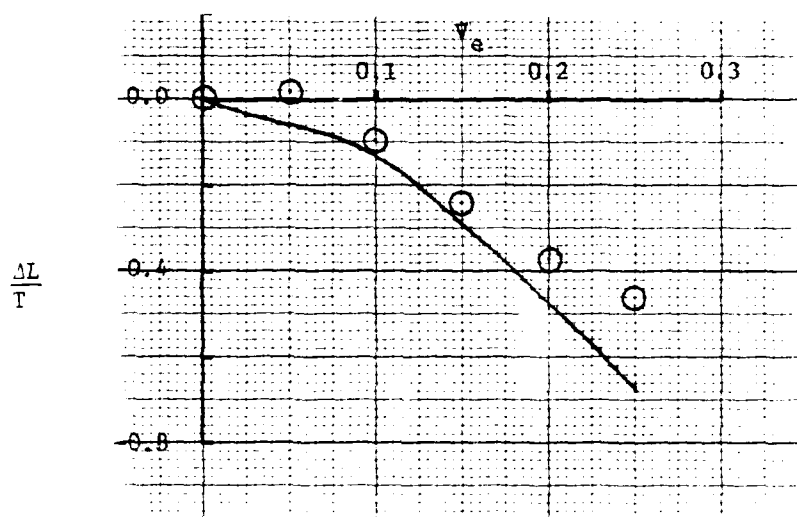
b. Single Jet Configuration, $S_j/S = 0.024$

FIGURE 3. Comparison of Predicted and Experimental Data of Clipped Delta Wing Configuration



$$d_j = 1.75$$

$$d_e = 3.5$$



c. Four Jet Configuration, $S_j/S = 0.024$

FIGURE 8. (Continued)

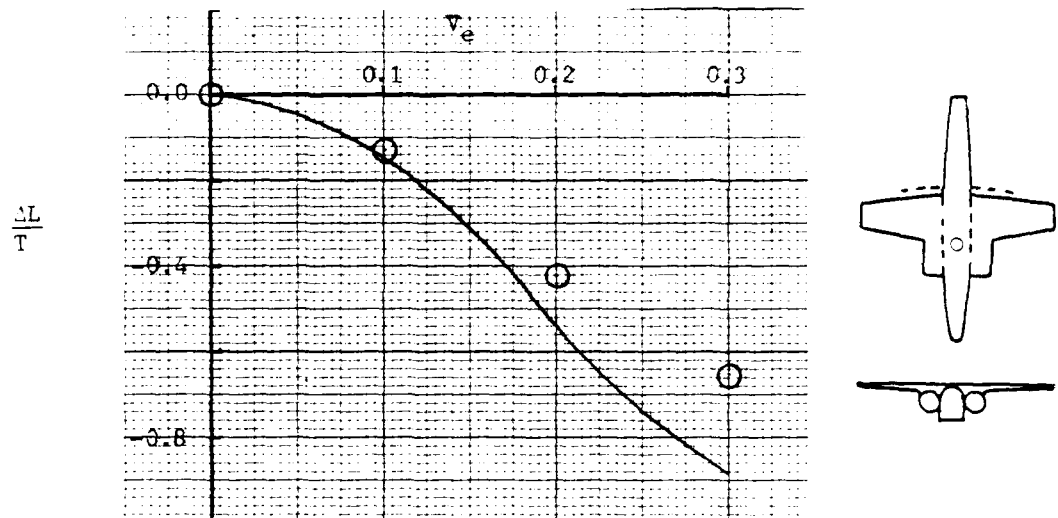
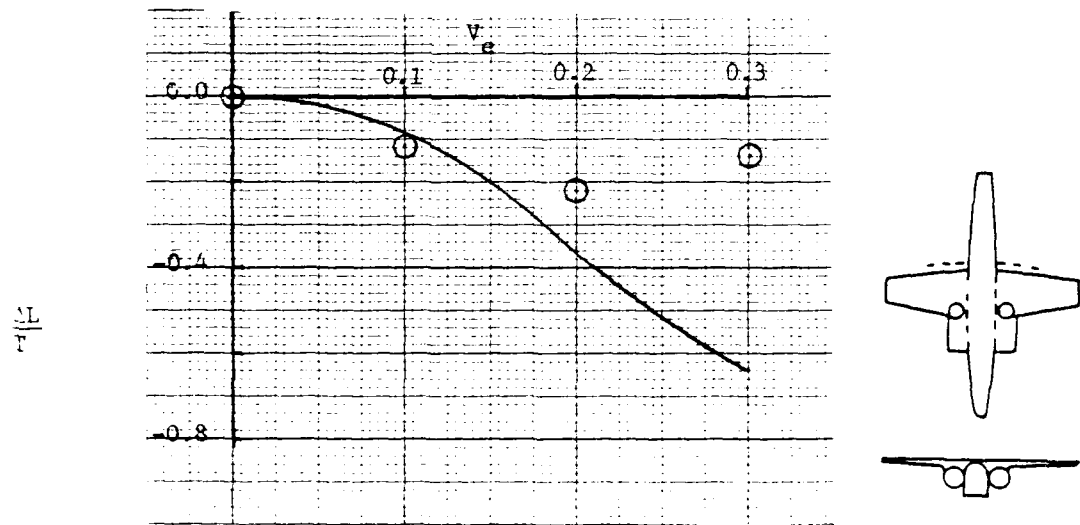
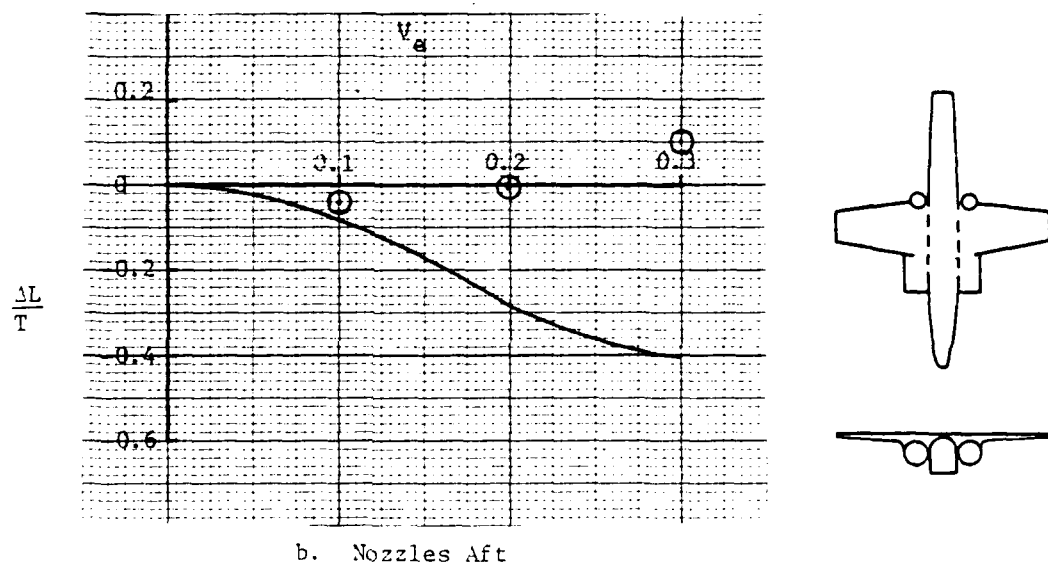


FIGURE 9. Comparison of Predicted and Experimental Data of a Single Jet High Wing Configuration



a. Nozzles Forward

FIGURE 10. Comparison of Predicted and Experimental Data of a Two-Jet, High Wing Configuration



b. Nozzles Aft

FIGURE 10. Continued

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APPENDIX A

MODELLING AND CALCULATIONS PROCEDURES

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Modelling the Configuration

A simple panelling method using rectangular segments to approximate the geometry of the planform is used to input the desired configuration. As shown in Figure (A-1), the length of these rectangular segments is restricted only by the size of the configuration, with the width being dictated by the accuracy with which the curved and angled aircraft components are to be modelled. To further refine the calculation of the induced pressures within each rectangular segment, an integration interval is used and required as input by the computer program which defines the longitudinal and lateral grid of rectangular elements. The mid-point of these elements defines the point at which actual pressure coefficient calculations are made.

The only caution to be heeded when panelling the configuration is that sufficiently small elements are defined in the area around the jet to enable accurate calculation of the rapidly changing induced pressures associated with this area. Conversely, modelling of the planform at distances beyond five jet diameters from the jet is not critical since induced pressures are negligible beyond this distance.

Once the configuration is panelled, the computer program is structured to calculate the induced pressures for any number of different velocity ratios. This can be done by simply inputting the number of cases to be run and the associated values of velocity ratio; a more detailed discussion of which is given in the computer program section.

Integration Procedure

The integration procedure used to exercise and validate the developed method consists of the incremental form of the equation

$$\frac{\Delta L}{T} = \frac{2}{\pi} \frac{q_{\infty}}{q_j} \iint C_p d(X/D) d(Y/D)$$

The procedure used involves the following steps:

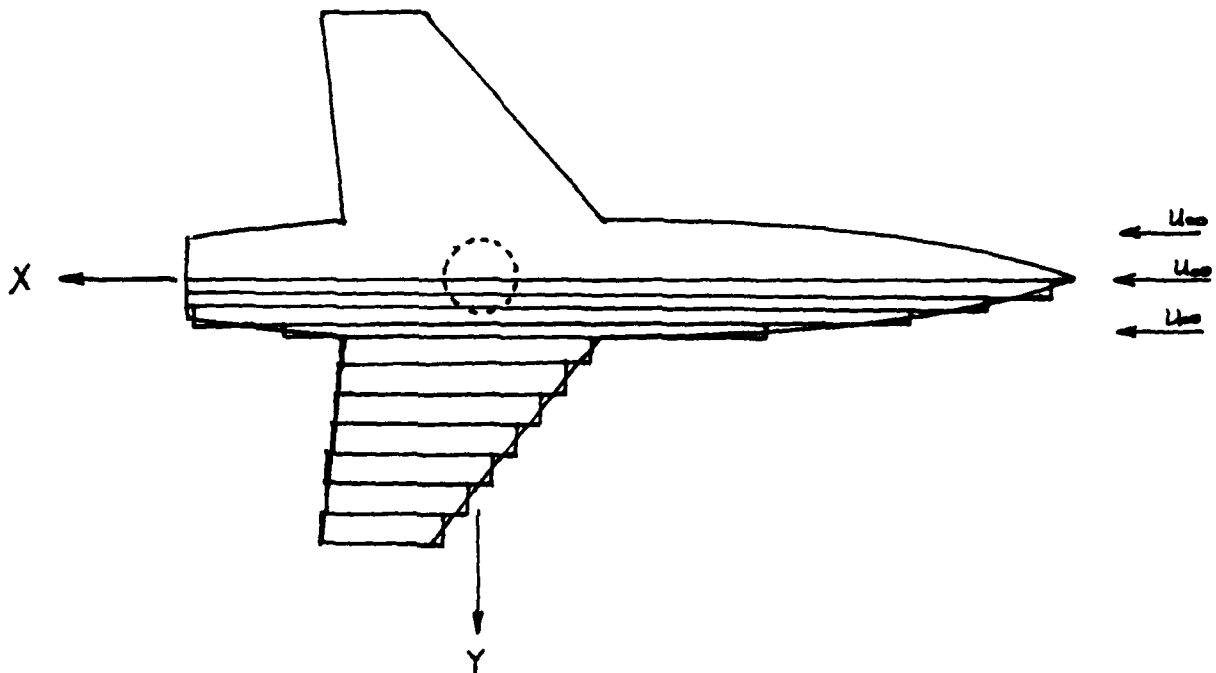
(1) Pressure coefficients calculated at various longitudinal stations for a constant span station are plotted, with the area under the curve calculated assuming the pressure coefficient to be constant across the various longitudinal intervals.

(2) Step 1 is repeated for each span station at which pressure coefficients are calculated.

(3) The resulting forces per station are then plotted against their particular span station to again calculate the area under the curve which results in the total induced force. This procedure is followed for each rectangular segment. The resultant pressure coefficient and induced lift of each segment is then summed for all segments to obtain the induced lift for the total planform.

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The accuracy of this procedure is dependent upon the integration interval chosen. This is especially true in close proximity to the jet exit when the surface pressure variations are quite large for only small changes in location.



NOTES:

1. Rectangular segments are smaller near the location of the jet than those farther away. Some consideration must be given in determining the integration intervals.
2. Rectangular segment lengths are sized for accuracy in modelling the plan-form contour.
3. For applicable configurations, only half of configuration panelled, with results multiplied by two for symmetry.
4. Jet center is considered to be the origin with the central most panel(s) offset from the origin to avoid a zero value for Y/D .
5. All lengths are non-dimensionalized by the jet diameter. Accordingly, all input data for any configuration should be similarly non-dimensionalized.

FIGURE A-1. Schematic of Configuration Panelling Procedure

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APPENDIX B

COMPUTER PROGRAM

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Computer Program

An interactive computer program was developed to facilitate the calculation of the jet induced pressure coefficient over any configuration planform. The program contains equations (1) to (4) with which to calculate the pressure coefficients for any given point, the methodology with which to panel the configuration planform, and the integration routine to calculate the induced lift from the pressure distribution. Programing these equations has also enabled calculation of the pitching moment resulting from the planform pressure distribution according to equation (A-1)

$$\frac{\Delta M}{TD_j} = \sum_{i=1}^n \left(\frac{\Delta L}{T} \right)_i \frac{X_i}{D_j} \quad (A-1)$$

where

$$\left(\frac{\Delta L}{T} \right)_i = \text{induced lift of a particular panel}$$

$$\frac{X_i}{D_j} = \text{the X location of the panel center of pressure}$$

$$n = \text{number of panels used to simulate the planform}$$

The planform center of pressure is then calculated according to equation (A-2)

$$\frac{\bar{X}}{D_j} = \frac{\frac{\Delta M}{TD_j}}{\frac{\Delta L}{T}} \quad (A-2)$$

As output, the program provides the pressure coefficient, induced lift, pitching moment, and center of pressure for each panel used to model the planform and for the entire planform. A listing of the program along with a sample input and resulting output is contained at the end of this appendix.

Computer Program Input

The input required by the computer program consists of data required to panel the configuration planform, the jet location, and the equivalent velocity ratio. This input is tabulated below.

COMPUTER INPUT

ITTL	Case Title (Up to 80 Characters)
NCOMP	Number of rectangular segments
NVE	Number of velocity ratios
VE	Velocity ratio
DELXY	Integration interval into which rectangular segments are divided (interval for both x and y directions; different values can be input for the various segments)
XOD1	Minimum x-coordinate of rectangular segment
XOD2	Maximum x-coordinate of rectangular segment
YOD1	Minimum Y-coordinate of rectangular segment
YOD2	Maximum Y-coordinate of rectangular segment

XOD1, XOD2, YOD1, YOD2 must be repeated for each rectangular segment.

SAMPLE INPUT

```

-PROBA
1 INPUT TITLE
2 ELONGATED BODY X/C-40
3 INPUT NUMBER OF COMPONENTS
4 2
5 INPUT NUMBER OF VELOCITY RATIOS AND VALUES
6 0.04, 0.10, 0.15, 0.20, 0.25, 0.30
7 INTEGRATION INTERVALS EQUAL? YES=1, NO=0
8 1
9 INPUT INTEGRATION INTERVAL
10 .1
11 INPUT X1, X2, Y1, Y2 FOR EACH PANEL
12 2.00, 4.40, .10, .70
13 2.85, 4.15, .70, .00
14 COMP X1 X2 Y1 Y2
15 1 -2.0000 4.4000 .1000 .7000
16 2 -2.8500 4.1500 .7000 .0000
17 IS INPUT CORRECT? YES=1, NO=0
18 1
19 STOP
20 .304 CP SECONDS EXECUTION TIME

```

SAMPLE OUTPUT

```

ELONGATED BODY X/C-40
COMP X1 X2 Y1 Y2
1 -2.0000 4.4000 .1000 .7000
2 -2.8500 4.1500 .7000 .0000

COMP 1
-----
X1= -2.00 X2= 4.40
Y1= .10 Y2= .70
DELX= .10 NY= 7
RESULTS MAY BE INVALID FOR UE LESS THAN 0.1
UE= .0500 CPT= -2.2571 DLOT= -.0026
UE= .1000 CPT= -1.5984 DLOT= -.0108
UE= .1500 CPT= -1.0678 DLOT= -.0282
UE= .2000 CPT= -2.1781 DLOT= -.0555
UE= .2500 CPT= -2.2167 DLOT= -.0882
UE= .3000 CPT= -2.0242 DLOT= -.1180

COMP 2
-----
X1= -2.85 X2= 4.15
Y1= .70 Y2= .00
DELX= .10 NY= 3
RESULTS MAY BE INVALID FOR UE LESS THAN 0.1
UE= .0500 CPT= -.5436 DLOT= -.0009
UE= .1000 CPT= -.6827 DLOT= -.0043
UE= .1500 CPT= -.7296 DLOT= -.0105
UE= .2000 CPT= -.7453 DLOT= -.0190
UE= .2500 CPT= -.7020 DLOT= -.0280
UE= .3000 CPT= -.6036 DLOT= -.0346

TOTALS- SUM OF COMPONENTS
-----
UE .0500 TCPT -2.8000 TDLOT -.0045 TROLL -.0022 XBAR -1.4637 YBAR -.4918
.1000 -2.3512 -.0152 .0082 .4927 .5408
.1500 -2.8372 -.0306 .0274 .7102 .5271
.2000 -2.8234 -.0744 .0602 .8082 .5161
.2500 -2.0196 -.1162 .0586 .9186 .5040
.3000 -2.6279 -.1506 .0743 1.1121 .4934

```

COMPUTER PROGRAM LISTING

```

1  PROGRAM MOMENTA(INPUT,OUTPUT,TAPES)
5  DIMENSION VOB(1001),VE(10),CA(1001),XD(1001)
    DIMENSION IUD(20),CIN(1001),DELXY(20),ITTL(8)
    DIMENSION XOB1(20),XOB2(20),YOB1(20),YOB2(20)
    DIMENSION SLOTT(200),SPITCH(200),SROLL(200),SCPT(200)
    REAL K1,K2
    JJ=1
10  TCPT=0.
    TDLOT=0.
    TPITCH=0.
    TROLL=0.
    PRINT 555
15  555 FORMAT(1H ,SINPUT TITLES)
    READ 103,(ITTL(I),I=1,8)
    WRITE(6,103)(ITTL(I),I=1,8)
    103 FORMAT(8A10)
    WRITE(6,104)
    104 FORMAT(1H ,S)
    500 FORMAT(1H ,SINPUT NUMBER OF COMPONENTS)
    READ 8,NCOMP
    PRINT 505
20  505 FORMAT(1H ,SINPUT NUMBER OF VELOCITY RATIOS AND VALUES)
    READ 8,NVE,(VE(I),I=1,NVE)
    PRINT 509
25  509 FORMAT(1H ,SINTEGRATION INTERVALS EQUAL? YES=1,NO=0)
    READ 8,ITEST
    IF(ITEST.NE.1) GO TO 511
    PRINT 508
30  508 FORMAT(1H ,SINPUT INTEGRATION INTERVALS)
    READ 8,DXY
    DO 111 I=1,NCOMP
        DELXY(I)=DXY
    111 CONTINUE
    GO TO 512
35  511 PRINT 510
    510 FORMAT(1H ,SINPUT INTEGRATION INTERVAL (DELXY) FOR EACH COMPONENT
        (S))
    READ 8,(DELXY(I),I=1,NCOMP)
    512 WRITE(6,850)
    850 FORMAT(1H ,3X,SCOMPS,5X,2X1S,5X,2X2S,5X,2X3S,5X,2X4S)
40  C8533 MATRIX OF COMPONENT DATA 8533
45  PRINT 520
    520 FORMAT(1H ,SINPUT X1,X2,V1,V2 FOR EACH PANELS)
    DO 89 I=1,NCOMP
        READ 8,XOB1(I),XOB2(I),YOB1(I),YOB2(I)
    89 CONTINUE
    205 PRINT 777
    777 FORMAT(1H ,2 COMPS,4X,2X1S,5X,2X2S,5X,2X3S,5X,2X4S)
    DO 5 I=1,NCOMP
        PRINT 855,I,XOB1(I),XOB2(I),YOB1(I),YOB2(I)
55  855 FORMAT(1H ,5X,12,X,4F10.4)
    5 CONTINUE
    5 PRINT 808

```

```

908 FORMAT(1H ,3IS INPUT CORRECT? YES=1,N0=08)
      READ 3,IIMP
      IF(IIMP.EQ.1) GO TO 999
      PRINT 200
200  FORMAT(1H ,SINPUT NO. OF INCORRECT LINES AND VALUES)
      READ 5,MNU,(IUV(I),I=1,MNU)
      DO 2 I=1,MNU
        PRINT 778,IU(I)
778  FORMAT(1H ,SINPUT LINE #,I2)
      READ 5,XOB1(IUV(I)),XOBE2(IUV(I)),YOB1(IUV(I)),YOB2(IUV(I))
      2 CONTINUE
      GO TO 205
205  DO 81 I=1,NCOMP
      WRITE(6,851),XOB1(I),XOBE1(I),YOB1(I),YOB2(I)
851  FORMAT(1H ,4X,I2,4F10.4)
      81 CONTINUE
      WRITE(6,307)
307  FORMAT(1H ,8 X)
      DO 95 IC=1,NCOMP
      WRITE(6,839)
839  FORMAT(1H ,8 X)
      WRITE(6,849)IC
849  FORMAT(1H ,2COMP #,I2)
      WRITE(6,880)
880  FORMAT(1H ,8-----8/)
      C*****CALCULATE YOB(I) AND NY LE 1001 *****
      NY=((YOB2(IC)-YOB1(IC))/DELXY(IC))*1.5
      C*****INDIVIDUAL COMPONENT DATA *****
      WRITE(6,700)XOB1(IC),XOBE1(IC)
700  FORMAT(1H ,8X1=8,F6.2,4X,8X2=8,F6.2)
      WRITE(6,710)YOB1(IC),YOB2(IC)
710  FORMAT(1H ,8V1=8,F6.2,4X,8V2=8,F6.2)
      WRITE(6,720)DELXY(IC),NY
720  FORMAT(1H ,8DELXY=8,F4.2,8X,8NY=8,I2/)
      K=1
      DO 60 I=1,NY
        YOB1(I)=YOB1(IC)+DELXY(IC)*(K-1)
        K=K+1
60  CONTINUE
      DO 30 I=1,NUE
        IF(U(I).EQ.0,UVE(I)).00001
          IVE(I).GE.0.1) GO TO 73
      WRITE(6,125)
125  FORMAT(1H ,RESULTS MAY BE INVALID FOR UE LESS THAN 0.18)
      73 CONTINUE
      NBAR=0.
      YEAR=0.
      DO 70 I=1,NY
        CPIX(I)=0.
70  CONTINUE
      DO 30 I=1,NY

```

```

115      C8888 CALCULATE CP US. XOD 8888
      XBARJ=0.
      K=0
100 K=K+1
      XOD=XOD1(IC)*DELXY(IC)*K-1)
      F=(2.48*YOD(1)-1.6)*XUE(J)-1.5*YOD(1)-.07
      IF(XOD-F).LT.0. GO TO 120
      K1=1./(1.5*YOD(1))
      K2=-.13*(YOD(1)-3.5)*K2+1.8
      GO TO 120
120 K1=1./(1-2.28*XUE(J)+1.36)*YOD(1))
      K2=(16.8*XUE(J)/YOD(1))+1.558*LOG(YOD(1))-1.
130 A=EXP((4.3*XUE(J)-1.3)*K2)
      B=(YOD(1)+.5)*K2*(3.25*XUE(J)+1.4)
      CPMAX=-4.25/(A*B)
      C=1/(K1*(XOD-F)+K2)
      IF(C.GT.10.)*C=10.
      D=(XOD+.4*YOD(1)+2.5)*K2
      IF(D.GT.10.)*D=10.
      XOD(K)=XOD
      CP(K)=(1./EXP(C))-((3.67*YOD(1)+5.3*XUE(J)*K2)/EXP(D))*CPMAX
135      C8888 CALCULATE AREA UNDER CP US. XOD CURVE 8888
      TEST=(XOD)*K2*(YOD(1))*K2
      IF(TEST.LE..85)GO TO 40
      IF(K.EQ.1) GO TO 40
      CPI=(CP(K)+CP(K-1))*SDELXY(IC)
      XIJ=XOD-.5*SDELXY(IC)
      XBARJ=XBARJ+CPI*XIJ
      CPIX(I)=CPIX(I)+CPI
      XBARJDI=XBARJ/CPIX(I)
40 IF(XOD.GT.(XOD2(IC)-.5*SDELXY(IC))*XOD=XOD2(IC)
      GO TO 100
145
150      C8888 IF INDIVIDUAL COMPONENT DATA IS DESIRED
      C8888 REPLACE GO TO 90 WITH GO TO 50 AND
      C8888 ELIMINATE C ON COMMENT CARDS
      C 50 IF(I.NE.1) GO TO 750
      C WRITE(6,900)
      C 900 FORMAT(1H,3X,SKS,4X,31Z,7X,YODS,8X,SCPS)
      C 750 WRITE(6,901)K1,YOD(1),CPIX(1),XBARJDI(1)
      C 901 FORMAT(1H,21Z,3F10.4)
      90 IF(I.NE.NY) GO TO 30
160      C8888 CALCULATE AREA UNDER CP US. YOD CURVE 8888
      MH=NY-1
      DO 10 M=1,MH
      CPIV=(CPIX(M+1)+CPIX(M))*SDELXY(IC)
      XI=(XBARJDI(M)+XBARJDI(M+1))*S.5
      VI=YOD(M)+.5*SDELXY(IC)
      XBAR=XBAR+CPIV*XI
      YBAR=YBAR+CPIV*VI
      CPT=CPT+CPIV
170

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```

175      XBARD(IC)=XBAR/CPT
      YBAR(IC)=YBAR/CPT
180      DLOT=12.5UE(J)*23CPT/3.14159
      WRITE(6,810)UE(J),CPT,DLOT
      FORMAT(1H,4X,5UE-2,F10.4,4X,2CPT-2,F10.4,4X,2DLOT-2,F10.4)
      CPT(JJ)=CPT
      DLOT(JJ)=DLOT
      SPITCH(JJ)=1.5DLOTXBARD(IC)
      STROLL(JJ)=1.5DLOTYBAR(IC)
      JJ=JJ+1
      GO TO 20
200      CONTINUE
205      CONTINUE
210      CONTINUE
      CZZZ CALCULATE TOTALS- SUM OF COMPONENTS 8888
      WRITE(6,847)
      FORMAT(1H,/)
      WRITE(6,848)
      FORMAT(1H,STOTALS- SUM OF COMPONENTS)
      WRITE(6,885)
      FORMAT(1H,8-----8/)
      WRITE(6,300)
      FORMAT(1H,4X,5UE-2,7X,2CPTS,5X,2DLOTS,4X,2PTCHS,5X,2STROLLS,5X,
      12XBARS,5X,2YBARS)
      J=0
      KK=0
      LL=0
      MM=0
      NN=0
      400 LL=LL+1
      410 MM=MM+1
      NN=NN+5
      TDLOT=TDLOT+DLOT(LL+NN)
      TCPT=TCPT+CPT(LL+NN)
      TPITCH=TPITCH+SPITCH(LL+NN)
      KTROLL=KTROLL+STROLL(LL+NN)
      KK=KK+1
      IF (MM.NE.NCOMP) GO TO 410
      J=J+1
      TABAR=1.2TPITCH/TDLOT
      TYBAR=1.2STROLL/TDLOT
      450 WRITE(6,450)UE(J),CPT,TDLOT,TPITCH,TROLL,TXBAR,TYBAR
      FORMAT(7F10.4)
      IF (LL.EQ.NUE) GO TO 420
      TCPT=0.
      TDLOT=0.
      TPITCH=0.
      KTROLL=0.
      KK=0
      MM=0
      GO TO 400
      480 CONTINUE
      STOP
      END

```

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