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# Model Representation in the PANCOR Wall Interference Assessment Code

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THE PANCOR WALL INTERFERENCE ASSESSMENT CODE  
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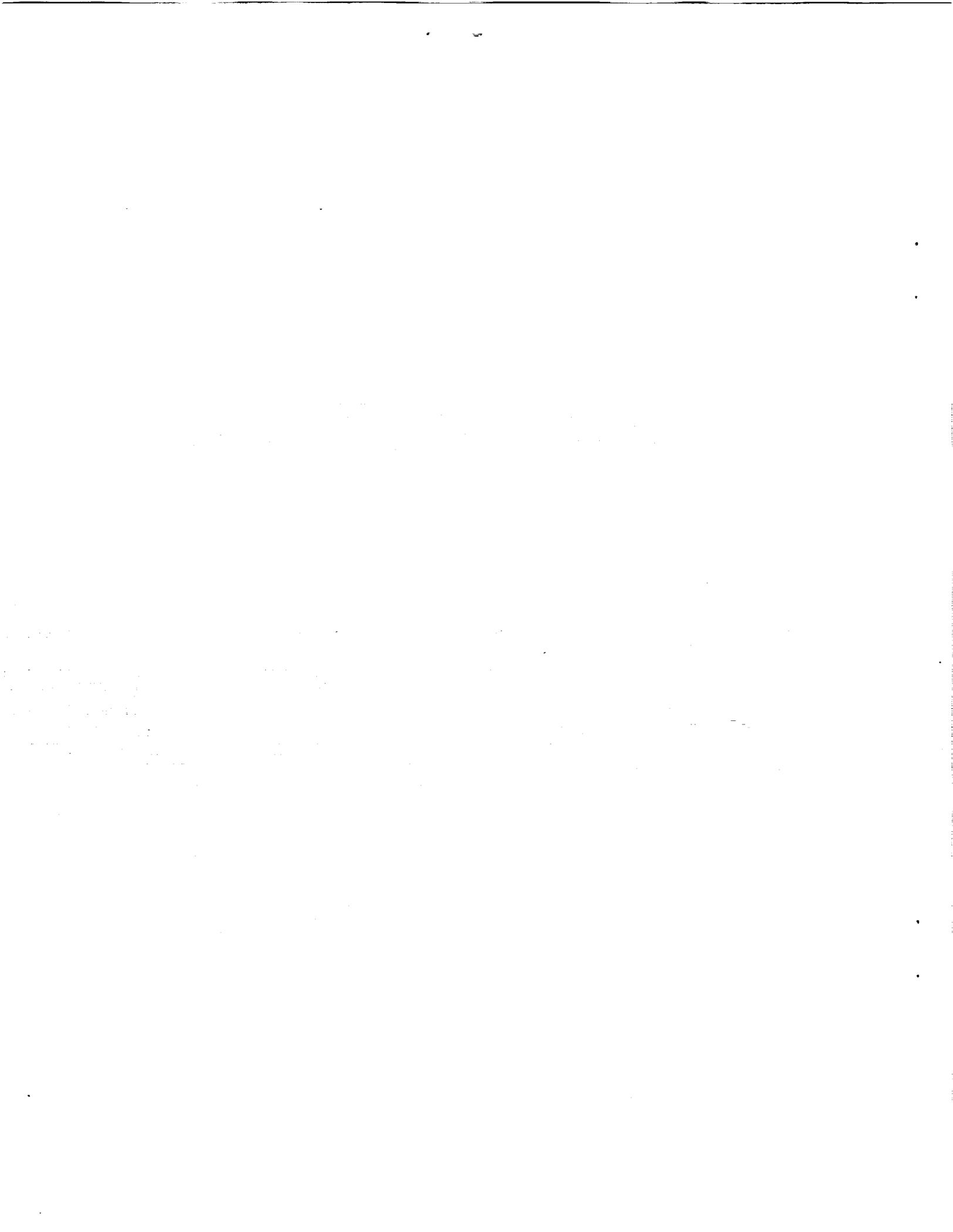
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## Summary

An investigation into the aircraft model description requirements of a wall interference assessment and correction code known as PANCOR has been conducted. The first part of the study was directed towards defining the accuracy necessary in specifying various elements of the model description. It was found that the specified lift coefficient is the most important model parameter in the wind tunnel simulation. An accurate specification of the model volume was also found to be important. The second part of this work consisted of developing a partially automated technique for generating the wing lift distributions that are required as input to PANCOR. An existing three-dimensional transonic small disturbance code was modified to provide the necessary information. A group of auxiliary computer programs and procedures was developed to help generate the required input for PANCOR.

## Introduction

The PANCOR computer code was developed to perform wall interference assessment calculations for model configurations tested in transonic wind tunnels with slotted-wall test sections [1,2]. The code makes use of high order panel methodology with the capability to allow simulation of certain test section flow effects such as those due to finite length discrete slots. PANCOR has been used to help examine wall interference effects in the National Transonic Facility (NTF) at NASA-Langley Research Center [3]. The code requires a description of the model being tested, including the model support sting, and a definition of the test section geometry as input. In addition to the configuration geometry, experimentally measured wall pressures are used in satisfying the wall boundary conditions. The present work concentrates on the model description used in PANCOR. First, a study is performed to determine the accuracy requirements of the model description itself. Then a procedure is developed to help generate the wing description input for use in PANCOR.

## Symbols

$\bar{c}$	average wing chord length, ft
$C_D$	drag coefficient
$C_L$	lift coefficient
$C_m$	pitching moment coefficient
$C_p$	pressure coefficient
$M$	Mach number
$X$	streamwise direction
$Y$	spanwise direction
$Z$	vertical direction
$\alpha$	angle of attack, deg
$\Delta$	interference increment

## Sensitivity of the PANCOR Computer Program to Model Representation

### Approach

The test section and model are simulated in PANCOR by means of potential flow singularity distributions. The model representation incorporates terms to account for blockage (source/sink terms), lift (vorticity terms), and fuselage crossflow (doublet terms) [1,2]. In addition, the code has the capability to adjust the various singularity strengths in the model description in order to

match experimentally measured values of the model lift, drag, and pitching moment coefficients. The solution boundary conditions require that experimentally measured pressures on the top and bottom walls be matched in the presence of the perturbation resulting from the model description plus the unknown perturbations from the wall slot flow. The purpose of this part of the investigation is to study the effect of altering various model description parameters on the computed wall interference solution. Note that the corresponding wall pressures are not changed in any way for these studies. Thus this exercise may be viewed as an attempt to determine the accuracy requirements of the model representation in PANCOR independent of the effects of the experimentally measured wall pressures.

The sensitivity study was carried out by modifying individual elements of the model description and then obtaining PANCOR solutions. Each of the alterations was chosen to cause a substantial misrepresentation of a key element of either the model geometry or the flow situation. The effects of the alterations are then seen by comparing each of the perturbed PANCOR solutions to a baseline solution which was obtained using the normal model description. The resulting comparisons give an indication of the accuracy requirements of each component of the model description. The study consists of the following set of modifications to the model description parameters:

1. Reduce fuselage volume to zero
2. Reduce wing volume to zero
3. Reduce fuselage and wing volume to zero
4. Reduce wing and tail lift to zero
5. Reduce drag to zero
6. Change pitching moment to shift lift center
7. Reduce model dimensions to approximate a point disturbance

These particular alterations were chosen in order to determine the sensitivity of the solution to the fundamental elements of the model representation. The wall interference levels are presented in terms of two parameters:  $\Delta M$ , an incremental Mach number which represents a blockage effect, and  $\Delta\alpha$ , an increment in angle of attack which represents a flow angularity error. These parameters give an indication of the change in the flowfield induced by the presence of the test section walls as compared with the equivalent free-air condition. They are calculated as the total flow perturbation in the test section solution minus the perturbation due to the model itself. The results are presented in terms of local  $\Delta M$  and  $\Delta\alpha$  distributions along flowfield survey lines, with survey lines in several different test section locations being used to present the  $\Delta M$  and  $\Delta\alpha$  comparisons. In addition, calculated pressure coefficient values on the test section sidewall are compared with experimentally measured values in order to determine how well the PANCOR solution agrees with experiment. Note that the calculated sidewall  $C_p$  values are a function of the total flow solution. Thus the calculated pressure coefficients are directly affected by changes in the model representation while the interference parameters are only indirectly affected through resulting changes in the panel solution singularities (since the actual model perturbation is subtracted out.)

#### **Analysis of Model Description Elements**

The test section simulated in the current work is that of the NTF (fig. 1). The baseline case used for comparison was calculated using data taken on the Pathfinder I model in the NTF [4]. Pathfinder I is a representation of a generic commercial transport aircraft (fig. 2). The flow conditions selected for this study were a Mach number of 0.7 and an angle of attack of 2.73

degrees, with resulting lift and drag coefficients of 0.5315 and 0.0362 respectively. Measured wall pressure data from the appropriate NTF data point was used in all of the PANCOR solutions obtained for this part of the study. The baseline (best) PANCOR solution corresponding to this point resulted in the solution labeled "BASIC" in the following figures. The solutions resulting from modifications to the basic model representation are labeled "COMP" (for "comparison"). In each case, except as noted, the experimental values of  $C_L$ ,  $C_D$ , and  $C_m$  are matched by the PANCOR solution.

In each of the following figures the test section extends in the  $X$  direction from station 0 at the upstream end to station 30 at the downstream end, spanwise from 0 at the centerline (symmetry plane) to 4.1 at the sidewall ( $Y$  direction), and vertically from  $Z=-4.1$  at the floor to  $Z=4.1$  at the ceiling (fig. 1). These stations give the dimensions of the NTF test section in units of feet. The longitudinal location of the Pathfinder I model is between  $X$  stations 10 and 15, and the wing extends to a spanwise location of 2.21. PANCOR allows the user to define lines of survey points in the flowfield. At the flow survey points total flow properties such as velocity and  $C_p$  are given, as well as the interference velocity components and the interference parameters  $\Delta M$  and  $\Delta\alpha$ . In this investigation several standard locations are used for the flow surveys (fig. 1). One survey line is located along the model centerline in the longitudinal direction. A second line is positioned in the wing plane half way between the centerline and wall. This line is referred to as the test section mid-halfwidth location. A third survey line runs longitudinally along the test section sidewall in a location half way between the floor and ceiling. This line corresponds to a row of pressure orifices in the NTF sidewall, allowing comparisons to be made between the experimentally-measured wall pressure coefficients and those calculated by PANCOR. In addition to these standard survey locations, some specialized locations are used to further examine some of the cases considered. These locations will be discussed as appropriate.

In order to analyze the results it is necessary to establish the approximate minimum change in the interference parameters that should be considered as significant. Experimental measurement accuracies are used to establish general guidelines. Mach number variations on the order of 0.001 and flow angularities of around  $0.1^\circ$  are routinely measurable in the NTF. If variations in the calculated interference parameters within an order of magnitude of these values are judged to have possible significance, then variations smaller than roughly 0.0001 in  $\Delta M$  and  $0.01^\circ$  in  $\Delta\alpha$  may be considered negligible. Representative samples of the results are shown in the following figures.

Case 1 consists of setting the fuselage volume equal to zero. This change is made by setting all of the individual body segment volumes equal to zero (the QBV values in the PANCOR input file; see ref. [2]). Along the model centerline, eliminating the body volume results in a maximum 0.0003 decrease in  $\Delta M$  (fig. 3) and extremely little change in  $\Delta\alpha$  (approximately  $0.002^\circ$ ). By the reasoning outlined above, this change in  $\Delta\alpha$  is insignificant. The sharp increase in  $\Delta M$  aft of  $X=15$  for both the baseline and comparison cases in figure 3 is due to the presence of the model support sting. Along the mid-halfwidth survey line there are negligible changes in both  $\Delta M$  and  $\Delta\alpha$ . Figure 4 shows the distribution of the sidewall  $C_p$ , with the experimentally-measured values shown for reference. Since the model is located approximately between stations 10 and 15, the small bump between stations 10 and 15 in the curve for the baseline case may be interpreted as the primary model influence on the sidewall pressure signature. As shown in figure 4, reducing the fuselage volume to zero results in about a 0.004 increase in the calculated sidewall pressure coefficient at the center of the model location ( $X=13$ ), while immediately upstream and downstream of the model location a slight decrease in the sidewall  $C_p$  results. Thus, eliminating the fuselage volume has the effect of smoothing the bump in the sidewall  $C_p$

curve through the model region, implying that the model-induced sidewall pressure signature is a function of the model volume to some extent.

The second case consists of setting the wing volume equal to zero. The modification is made by assigning values of zero to the wing thickness multipole series coefficients (QS0, QS1, QS2, and QS3 of reference [2]). Note that the experimental drag coefficient can not be matched in this case since the match is normally accomplished by varying the wing trailing edge thickness. Here the trailing edge thickness must be zero since the wing thickness is zero. This alteration results in negligible changes in  $\Delta M$  and  $\Delta\alpha$  at both the model centerline and tunnel mid-halfwidth survey locations. There is approximately a 0.002 increase in the sidewall  $C_p$  at the center of the model location, followed by a slight decrease just downstream of the model (fig. 5). This behavior is qualitatively similar to that observed when the fuselage volume is eliminated, but the magnitude of the change is less with only the wing volume removed. This behavior is reasonable since the fuselage volume is larger than the wing volume.

In the third case both the wing and body volumes are eliminated. The changes are made by combining the modifications made in cases 1 and 2. The solution is almost identical to that of case 1, in which the fuselage volume alone is removed. This behavior indicates that eliminating the wing volume in addition to the fuselage volume results in no additional changes in the solution. Since eliminating the wing volume alone does have a small effect on the sidewall  $C_p$ , it appears that the PANCOR solution is somewhat dependent on the total model volume, although changes in model volume past a certain extent (i.e., on the order of the fuselage volume for this configuration) result in no further variation in the solution. In order to gain further insight into the effects of model volume representation, solution characteristics along additional survey lines were investigated. The spanwise variation of  $\Delta M$  along a line in the wing plane is shown in figure 6. Eliminating the model volume results in a 0.0002 positive shift in  $\Delta M$  at the centerline and a 0.0005 negative shift at the tunnel wall. Note that the wing tip is just inboard of the location where the curves cross in figure 6. The curve for the zero-volume case is flatter than that of the baseline case. This behavior is similar to the smoothing of the sidewall  $C_p$  curve that results from elimination of the fuselage volume, as discussed above in connection with case 1. Little variation is seen in  $\Delta\alpha$  along a similar spanwise survey line (fig. 7).

The model lift is set equal to zero in case 4 by forcing the solution to match an experimental  $C_L$  of zero. There are large changes in  $\Delta\alpha$  evident along the mid-halfwidth survey line, as shown in figure 8. There is an increase in  $\Delta\alpha$  which ranges from 0.04 to 0.16 through the model region, with the increase growing to 0.20 downstream of the model. Large differences continue to be seen through the model support region in figure 8. Setting the lift equal to zero results in a 0.0002 more negative shift in  $\Delta M$  along the model centerline. This change in  $\Delta M$  is small but is of the same order as the change induced by eliminating the fuselage volume. Setting the lift to zero results in essentially no change in the sidewall pressure coefficient.

Case 5 involves setting the drag coefficient equal to zero. This action results in no apparent change in the calculated flowfield. As an example, figure 9 shows the model centerline  $\Delta M$  distributions, with the two curves being virtually identical. Note that the insensitivity to drag coefficient matching seen here implies that the features observed in cases 2 and 3 (in which the experimental  $C_D$  could not be matched) are due to model volume effects only.

In case 6 the center of lift is shifted to the rear by a distance equal to one average chord length,  $z$ . This movement is accomplished by changing the value of the pitching moment coefficient which is matched by PANCOR. In the matching procedure the total lift is proportioned between the wing and horizontal stabilizer such that matches to both  $C_L$  and  $C_m$  are obtained. Selecting a more negative value for  $C_m$  results in a rearward shift of the center of lift since the lift is

redistributed. A slight displacement in the  $\Delta\alpha$  curve along the model centerline is evident in figure 10. Shifting the lift center aft by  $\bar{z}$  results in a forward shift of the  $\Delta\alpha$  curve by approximately  $\bar{z}$ . Expressed in terms of  $\Delta\alpha$ , this change corresponds to a decrease in the magnitude of  $\Delta\alpha$  of almost  $0.01^\circ$  through the model region. The small amount of change seen here approaches the limits of what may be considered significant, as discussed above. Shifting the lift center results in no significant changes in either  $\Delta M$  or the sidewall  $C_p$  distribution.

The final case represents an attempt to approximate the disturbance due to the model with an equivalent point disturbance. In other words, the magnitudes of the flow disturbances induced by the model are retained while the physical model dimensions are reduced. For this approximation all model lengths are diminished by a factor of 100 while the lift and thickness coefficients are scaled up to yield the same overall singularity strengths as in the baseline case. A consequence of this scaling of lengths and singularity strengths is an increase in the apparent model cross-sectional area, resulting in a larger wake and more drag. Thus to retain consistency the experimental  $C_D$  is also scaled up to provide a proper match. Along the model centerline the point disturbance model induces a small negative shift (0.0002) in  $\Delta M$  (fig. 11) and a  $0.01^\circ$  negative shift in  $\Delta\alpha$ . Along the test section mid-halfwidth survey line, the scaled model results in essentially no change in the  $\Delta M$  distribution and approximately a  $-0.01^\circ$  shift in  $\Delta\alpha$  (fig. 12). The small changes seen in  $\Delta\alpha$  at each of these survey locations are almost negligible. On the test section sidewall, the point disturbance model results in a 0.004 maximum variation in  $C_p$  at the model location (fig. 13). It appears that the point model results in a model pressure signature that has a greater magnitude than that of the baseline case, but which occurs over a shorter region (in the  $X$ -direction). This type of discretizing behavior is expected when simulating a point disturbance. It is interesting to compare figure 13 with figure 4, which shows the effect of eliminating the fuselage volume on the sidewall  $C_p$  distribution. Eliminating the fuselage volume smooths the model-induced pressure signature while the point model appears to accentuate the disturbance. However, in each figure the total area under the baseline and comparison curves seems to remain approximately the same - i.e., any increases in  $C_p$  in the model region seem to be compensated for by decreases in  $C_p$  upstream and/or downstream of the model.

## Wing Representation For Use In PANCOR

### Approach

The second purpose of this study was to develop a procedure for generating a suitable wing description for use in PANCOR. To simulate an aircraft wing the code requires wing thickness and lift information as input data. Lift distributions for two different values of wing lift are required as input so that interpolation can be performed in PANCOR's match to experimental lift coefficient. Ideally the two lift coefficients provided would bracket the lift coefficient which PANCOR is to match. At transonic speeds, and in high-lift situations, the aircraft flowfield can not be accurately described in a linear fashion. This nonlinear behavior implies that interpolation may be improper. If the interpolation is over a small range, however, the technique can yield good results. Thus to provide accurate wing lift information at typical NTF flow conditions, an aerodynamic analysis which treats the nonlinear transonic flowfield is required. It must be determined how closely the experimental  $C_L$  needs to be bracketed by the analytical lift values. As the nonlinearity of the flowfield increases,  $C_L$  values much closer to the experimental  $C_L$  may have to be used.

In the present work, a transonic aerodynamic analysis code was modified to provide the necessary wing geometric and lift data in a form suitable for incorporation into PANCOR. The

aerodynamic code chosen is known as WBPPW (Wing-Body code with Pod, Pylon and Winglet analysis capabilities; refs. [5] and [6]). This code solves an extended three-dimensional transonic small disturbance equation using a finite difference calculation and includes a boundary layer calculation for the treatment of wing viscous effects. Auxiliary programs and procedures are developed to manipulate the wing data output by WBPPW, perform the necessary lift and thickness calculations, and create files suitable for incorporation into PANCOR input files.

### Procedure

The model description used in PANCOR is discussed in appendix C of reference [2]. The first four terms of two multipole singularity series are used to approximate the wing lift and thickness perturbations in the far field. The coefficients in the thickness and lift series expansions are evaluated as chordwise integrations of various moments of the chord thickness and lift distributions. The wing description must extend to the aircraft symmetry plane (model centerline), which allows for the treatment of wing/fuselage carryover lift. For each wing station PANCOR requires the spanwise position, midchord location, and local chord length in addition to the series coefficients.

The WBPPW code automatically generates the grids used in its finite difference calculation. In normal use there are eighteen spanwise wing stations with each station having 100 uniformly-spaced grid points along the chord. Some of the wing stations lie inside the fuselage and are not included in the calculation. Fuselage carryover lift is modeled as a linear variation from the value at the wing/body junction to a value at the symmetry plane which is determined from the fuselage lift. The geometric wingtip is located between two grid planes, so no calculations are actually performed there (the spanwise lift distribution is assumed to go to zero at the tip). In the current method the wing description generated for use in PANCOR uses the span locations defined by WBPPW (the spanwise grid planes) along with an additional station at the geometric wingtip. The WBPPW code was modified to calculate the local vorticity and thickness gradient at each chordwise point for each wing station, with an additional thickness calculation performed at the geometric wingtip. The local vorticity is defined as the jump in the streamwise velocity across the wing plane at each chord location. The local thickness gradient is equivalent to the difference in the upper and lower surface slopes.

The computer program named PPWPCOR was developed to use the wing information from the WBPPW code to calculate the series coefficients required by PANCOR and create a file containing the wing description in the PANCOR input format. A few details concerning PPWPCOR should be noted. The thickness gradient at each wing station is proportional to the difference in upper and lower surface slopes. In the WBPPW code 100 uniformly-spaced points are used along the chord at each spanwise station, which results in a crude representation of the surface slope in high curvature regions such as the leading edge. As a consequence a chordwise integration of this thickness gradient can result in a slight thickness error which is most noticeable as an improper trailing edge thickness. In PPWPCOR an adjustment is made to the thickness gradient at the leading edge of each wing section so that the trailing edge thickness is brought to zero. This action forces the PANCOR QS0 coefficient (equivalent to the trailing edge thickness, reference [2]) to have a value of zero but should result in more accurate values for the higher order multipole coefficients. This procedure imposes no restriction on the wing representation since the QS0 terms are adjusted in the PANCOR drag coefficient matching procedure to simulate a wake [2]. The second comment concerns the wing/body intersection and fuselage carryover lift. In order to account for the fuselage carryover lift, values of the lift multipole coefficients for the symmetry-plane wing station are obtained by multiplying the coefficients of the wing

root station (wing/body junction) by a WBPPW-determined scaling factor. At the wing root there are two wing stations defined for PANCOR at an identical spanwise location. The two stations have the same values for the lift multipole coefficients, but the first station is defined to have zero thickness while the second has its thickness given by the normally calculated multipole coefficients. The thickness coefficients for the symmetry-plane wing station also have values of zero. Since the wing stations which lie inside the fuselage are defined to have no thickness, and thus no volume, the model volume within the wing/body junction region must all be accounted for in the specification of the fuselage volume.

A set of files and procedures was developed to enable a user to execute the WBPPW code and then generate PANCOR wing descriptions using the PPWPCOR program. Details on obtaining the necessary files are given in the appendix. The appendix also contains descriptions of the files and instructions on the use of the procedures. To illustrate the results of these procedures, an example of the output file produced by PPWPCOR is given in table 1. A brief discussion of the contents of this file is in order. The number of PANCOR wing stations which PPWPCOR generates depends on the aircraft geometry. Specifically, the number depends on the number of WBPPW wing stations which lie outside the fuselage. At most there will be 20 wing stations defined for PANCOR. Examination of the file listing in table 1 shows that it contains 36 lines; half of these give geometric data and half give lift information. Thus, there are 18 PANCOR wing stations in this example and the PANCOR variable NWS must be assigned the value 18 in the PANCOR input file [2]. The first 18 lines of the file contain wing geometry data starting at the centerline and proceeding to the tip, with each line corresponding to one wing station and consisting of seven entries. The seven entries, with the PANCOR variable names given in parentheses, are the spanwise location of the wing station (YWG), the axial location of the midchord point (XCW), the section chord length (CW), and the four thickness multipole coefficient values (QS0, QS1, QS2, and QS3). Note that all the QS0 values in the file have a value of zero, meaning that the trailing edge thickness is zero as discussed above. Also note that the first two lines have values of zero for all the thickness coefficients and thus have no thickness. These are the entries for wing stations which lie inside the fuselage. The second group of 18 lines contains the two sets of wing lift multipole coefficients, again proceeding from the centerline to the tip. Each line has data for one wing station and contains eight values in two groups of four. The first group corresponds to the multipole coefficients for the first lift coefficient (QG01, QG11, QG21, QG31) and the second group to the second  $C_L$  (QG02, QG12, QG22, and QG32). Note that the entries on the last line, which corresponds to the wing tip, all have values of zero. This fact indicates that the spanwise lift distribution goes to zero at the wing tip.

Finally, note that it is also possible to use PPWPCOR to generate a horizontal stabilizer description for use in PANCOR. As noted in reference [2], the representation used for a horizontal stabilizer in PANCOR is the same as that for a wing. However, lift multipole coefficients for only one value of lift are required. To generate the PANCOR stabilizer description the WBPPW code would first have to be run with the stabilizer geometry input instead of the wing geometry. The code only needs to be run once since lift information for only a single  $C_L$  is needed. The value of the parameter ROOTLE (see appendix) which corresponds to the horizontal stabilizer geometry must be put in PPWPCOR. The user would then execute the PPWPCOR program as discussed in the appendix. Since a single wing data file is sufficient, the same file name should be entered twice when the user is prompted for the names of the wing data files. This action will result in a PPWPCOR output file that has two groups of lift multipole coefficients which are identical. The user need only delete the second of these groups to make the file suitable for inclusion in a PANCOR input file.

## Concluding Remarks

It is seen that rather gross changes in the PANCOR model representation induce relatively small changes in the interference solution when the measured wall pressures are unaltered. Of the parameters investigated, the lift coefficient has the largest effect on the interference solution. The experimental lift coefficient should be accurately matched in order to yield a realistic  $\Delta\alpha$  distribution throughout the test section. The  $\Delta M$  distribution is also slightly influenced by the lift coefficient specification. Precise matching of the model volume does not appear to be critical, although a gross change in the volume has a small effect on  $\Delta M$  near the model. None of the other parameters examined have a significant influence on  $\Delta\alpha$  or  $\Delta M$ . The flow solution itself shows some dependence on accurate representation of the model volume, as evidenced by the volume-induced variation seen in the sidewall pressure distribution. The model pressure signature on the wall is not affected by changes in the specified model lift or pitching moment coefficients and seems to be a function of model volume only. The fact that the point disturbance model representation gives reasonably good results seems to be a verification of the problem formulation—i.e., the interference solution is calculated on the walls and the model is essentially treated as a far field disturbance. It should be noted that this particular aircraft model, the Pathfinder I, is sized to have minimal wall interference effects. Hence a larger model may have more stringent PANCOR model representation accuracy requirements. Finally, a partially automated technique for generating the wing representation required in the PANCOR model description is developed. The spanwise lift distribution is determined using a transonic small disturbance method for aircraft configurations. As a result, consistent and accurate lift information can be easily included in the wall interference simulation.

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## Appendix – Generation of PANCOR Wing Description

This appendix details the steps to be followed in generating a PANCOR wing description using the WBPPW aerodynamic analysis code. The WBPPW code has been modified so that wing section slope, vorticity, and position data are written to a file which is saved for postprocessing. A separate program, known as PPWPCOR, is subsequently used to generate a file consisting of a wing description in PANCOR input format. This wing description file may be directly incorporated within a PANCOR input file. The codes have been implemented on the NASA-Langley Cray-2S computer known as Voyager, although with minor modification the programs may be

executed on any suitable computer (i.e., with sufficient memory and storage capabilities) with a UNIX operating system. The files necessary for performing these procedures are located on the Mass Storage Subsystem, which is part of Langley's Supercomputing Network System (SNS). From any of the SNS machines the files may be obtained by typing

*masget -r @alsaadi/PPWPANCOR*

Typing this command creates a series of subdirectories and files under the user's current directory. The main subdirectory, named "PPWPANCOR," contains two other subdirectories named "Comp" and "Run". The "Comp" directory contains the source code for WBPPW and the files necessary for compiling the code. The "Run" directory contains files necessary to run WBPPW (including a sample input file named ppwinpt) and to generate PANCOR wing description files.

The WBPPW code must first be compiled. The source code is maintained using the UNIX "makefile" utility. The file in the "Comp" subdirectory named PPW.source consists of all the routines which compose the WBPPW code. From within the "Comp" subdirectory, the code is separated into individual FORTRAN files by typing

*fsplit PPW.source*

The code is then compiled by typing

*Compilef*

The compilation is performed as a background process and when it is complete the executable file, named PPWW, is created in the "Comp" subdirectory.

The WBPPW code is executed from within the "Run" subdirectory. Recall that two WBPPW runs with different lift coefficients are needed to generate a PANCOR input file. The ability to create and save multiple WBPPW output wing description files is provided through the use of a filename specification file. The first line of this file contains the name of a WBPPW input file and the second line gives the name of the file that will have the wing lift and thickness information written to it. The file named RunFN is an example of such a specification file. Inspection of RunFN shows that WBPPW will be run using ppwinpt as the input file and upon completion wing description data will be written to a file named ppwpc1. Reference [6] contains a user's guide for the actual WBPPW code, including descriptions of the input file requirements and format. Once the wing information for two suitable lift coefficients has been obtained, the PANCOR wing description is generated by executing a procedure named GenPC. The user will be prompted for the names of two wing information files that have been generated by WBPPW (i.e., ppwpc1 and ppwpc2) and for the name of the file to be created that will contain the wing description in PANCOR format. GenPC then invokes the PPWPCOR program to perform the appropriate calculations and generate the wing description file. An example of a wing description file is given as table 1.

There are three configuration-dependent parameters in PPWPCOR that the user must adjust. The integer variable NSTA is defined as the number of wing stations used by WBPPW plus one (to account for the wingtip). NSTA will normally have a value of 19. The variable XSCALE is a length scale factor by which the model geometry used in WBPPW must be multiplied to yield units of feet on the actual wind tunnel model. As an illustration, assume that the geometry ordinates of a transport aircraft are given for use in WBPPW with units of inches on the full-scale aircraft. If a three-percent scale model is tested in the wind tunnel, then XSCALE would have

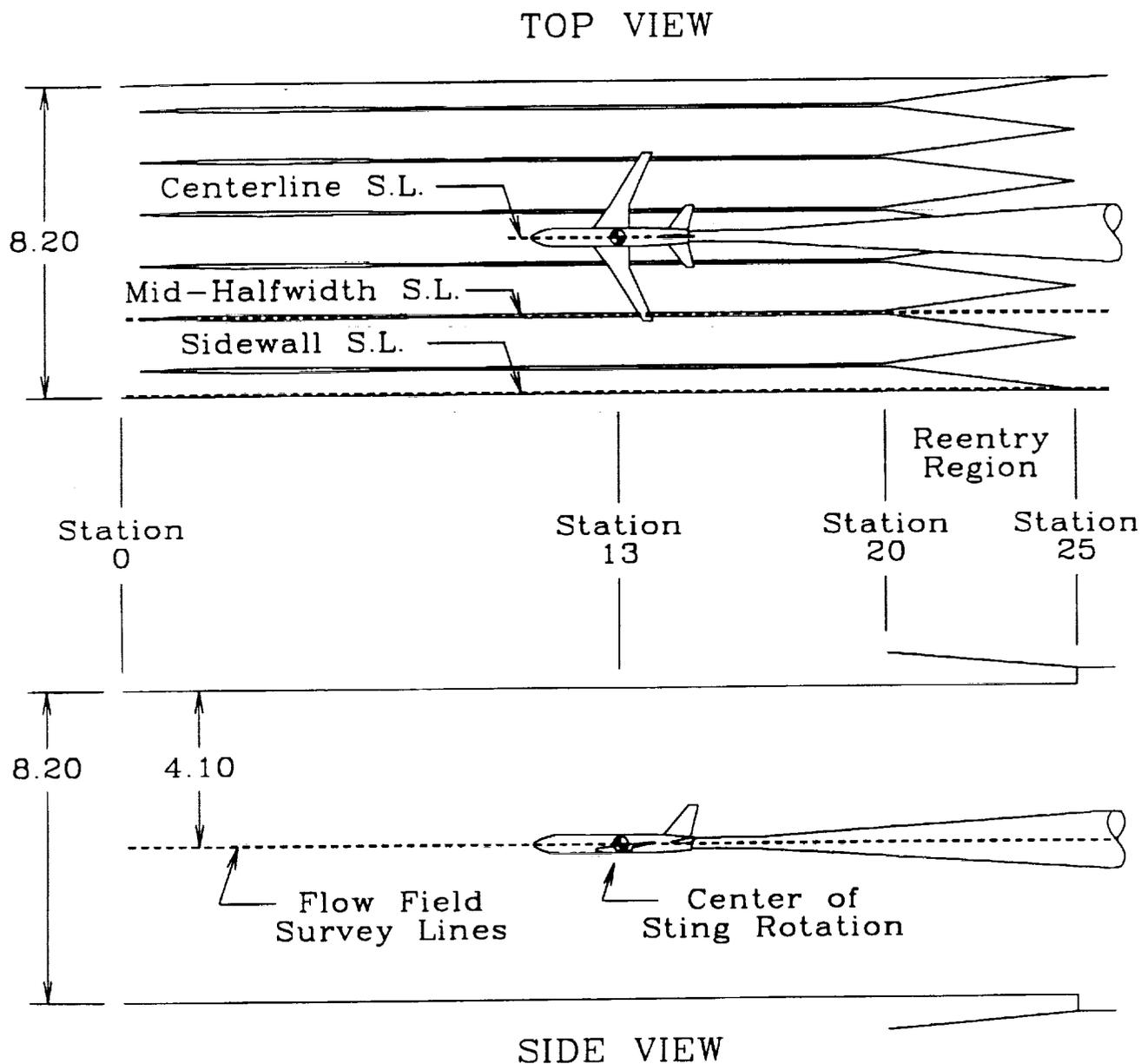
a value of  $(0.03) \times (1/12)$ , resulting in ordinates in units of feet on the wind tunnel model. The variable ROOTLE gives the longitudinal location of the wing leading edge in the model symmetry plane. ROOTLE must also have units of feet in the PANCOR model coordinate system.

The steps required to generate a PANCOR wing description file are summarized below.

1. Obtain the files.
  - a. Log on to Voyager and change to the directory that is to contain the set of files.
  - b. Type *masget -r @alsaadi/PPWPANCOR* to copy the files from the SNS Mass Storage Subsystem.
2. Compile the WBPPW code.
  - a. Type *cd PPWPANCOR/Comp* to change to the "Comp" subdirectory.
  - b. Type *fsplit PPW.source* to split the source code into subprogram units for the "makefile" utility.
  - c. Type *Compilef* to initiate the compilation as a background process.  
Note: the file named Maker which is created contains compiler and loader statistics. It may be monitored to check the progress of the compilation.
3. Ensure that model description information is correct.
  - a. Move to the PPWPANCOR/Run subdirectory.
  - b. Edit *ppwpcor.f* to include the proper values of the parameters NSTA, XSCALE, and ROOTLE for the model geometry of interest.
4. After compilation is complete, execute WBPPW at least two times to obtain lift information at the desired lift coefficients.
  - a. Ensure that current working directory is PPWPANCOR/Run.
  - b. Edit WBPPW input file to adjust solution parameters. (The file named *ppwinpt* is a sample input file which uses the Pathfinder I geometry.)
  - c. Edit *RunFN* so that it contains the proper WBPPW input file name and an output wing data file name.
  - d. Type *Runf* to run the job as a background process.  
Note: the file named *tsout* which is created contains solution information.
5. Generate PANCOR wing description file.  
Type *GenPC* and enter the requested file names for two wing data files (as named in item 4.c above) and the name of the PANCOR wing description file that is to be created. This PANCOR wing description file can be incorporated into a PANCOR input file.

**Table 1.** This table contains a sample listing of the output file generated by program PPWPCOR. The file contains the data necessary for representation of an aircraft wing in PANCOR. The output file may be directly incorporated within a PANCOR input file since the data is in the format required by PANCOR (ref. [2]).

.000000	2.212983	1.146458	.000000	.000000	.000000	.000000	
.323243	2.344007	.954420	.000000	.000000	.000000	.000000	
.323243	2.344007	.954420	.000000	-.081981	.015842	-.013937	
.432630	2.387218	.892002	.000000	-.066760	.011414	-.009723	
.543465	2.430725	.829158	.000000	-.053302	.007907	-.006558	
.656168	2.475395	.766088	.000000	-.041263	.005124	-.004201	
.771190	2.525139	.709795	.000000	-.032858	.003570	-.002805	
.889048	2.579582	.659005	.000000	-.026592	.002529	-.001916	
1.010320	2.641532	.618515	.000000	-.023097	.002004	-.001462	
1.135678	2.705569	.576660	.000000	-.019740	.001542	-.001082	
1.265910	2.772593	.534138	.000000	-.016965	.001177	-.000796	
1.401965	2.843000	.490503	.000000	-.014622	.000886	-.000579	
1.544995	2.917035	.444623	.000000	-.012354	.000636	-.000403	
1.696438	2.995518	.396238	.000000	-.010161	.000429	-.000264	
1.858123	3.082077	.350055	.000000	-.008106	.000296	-.000164	
2.032438	3.176697	.302845	.000000	-.006168	.000192	-.000093	
2.222608	3.280447	.252295	.000000	-.004387	.000111	-.000046	
2.324975	3.336264	.225080	.000000	-.003562	.000079	-.000030	
.069126	.002330	.005998	-.000609	.171728	-.008639	.013307	-.002311
.096063	.003238	.008335	-.000846	.234425	-.011793	.018166	-.003155
.096063	.003238	.008335	-.000846	.234425	-.011793	.018166	-.003155
.096526	.003003	.007053	-.000728	.233367	-.013756	.015990	-.002934
.096180	.003449	.005452	-.000389	.231603	-.013001	.013293	-.002221
.094299	.003824	.003944	-.000130	.228299	-.011334	.010687	-.001558
.093615	.004365	.002978	.000039	.225344	-.009542	.008790	-.001099
.092476	.004455	.002263	.000131	.220723	-.008357	.007187	-.000796
.090694	.004219	.001863	.000151	.214716	-.007679	.006056	-.000621
.088436	.003992	.001583	.000149	.207574	-.006787	.005046	-.000471
.084344	.003407	.001303	.000115	.198119	-.006061	.004127	-.000358
.078826	.002687	.001036	.000078	.187285	-.005355	.003302	-.000269
.073056	.002148	.000829	.000058	.174325	-.004794	.002537	-.000194
.065160	.001587	.000610	.000035	.159287	-.004185	.001888	-.000128
.055648	.001212	.000382	.000021	.148104	-.002778	.001360	-.000074
.039609	.000484	.000159	.000011	.127023	-.002663	.000871	-.000049
.022868	.000015	.000049	.000005	.094701	-.002467	.000428	-.000029
.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000



**Figure 1.** Sketch of the NTF test section with the Pathfinder I model installed. Also shown are the locations of the three flow field survey lines routinely used in the PANCOR analysis. All dimensions in feet.

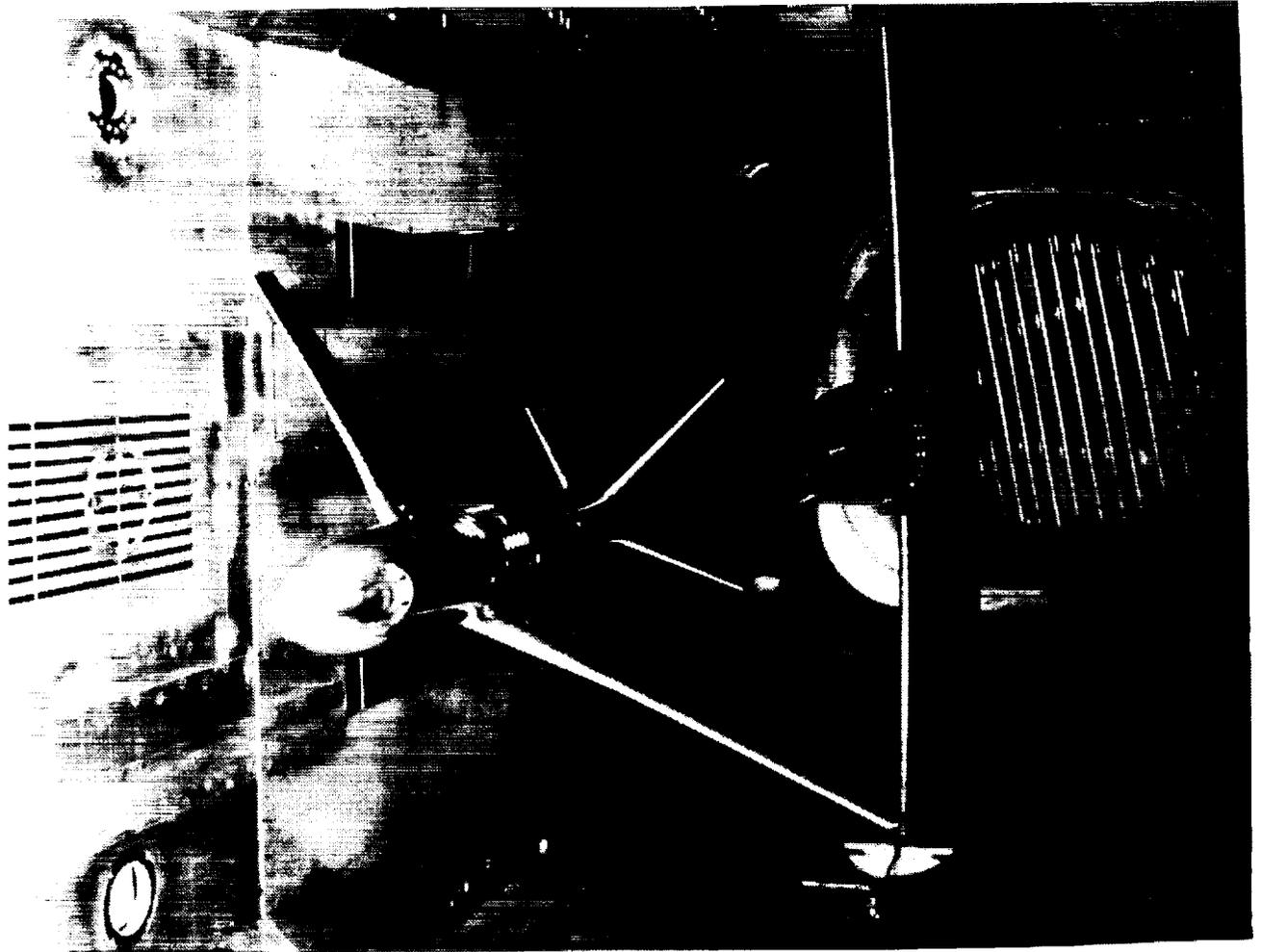


Figure 2. Photograph of Pathfinder I in the NTF test section.

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OF POOR QUALITY

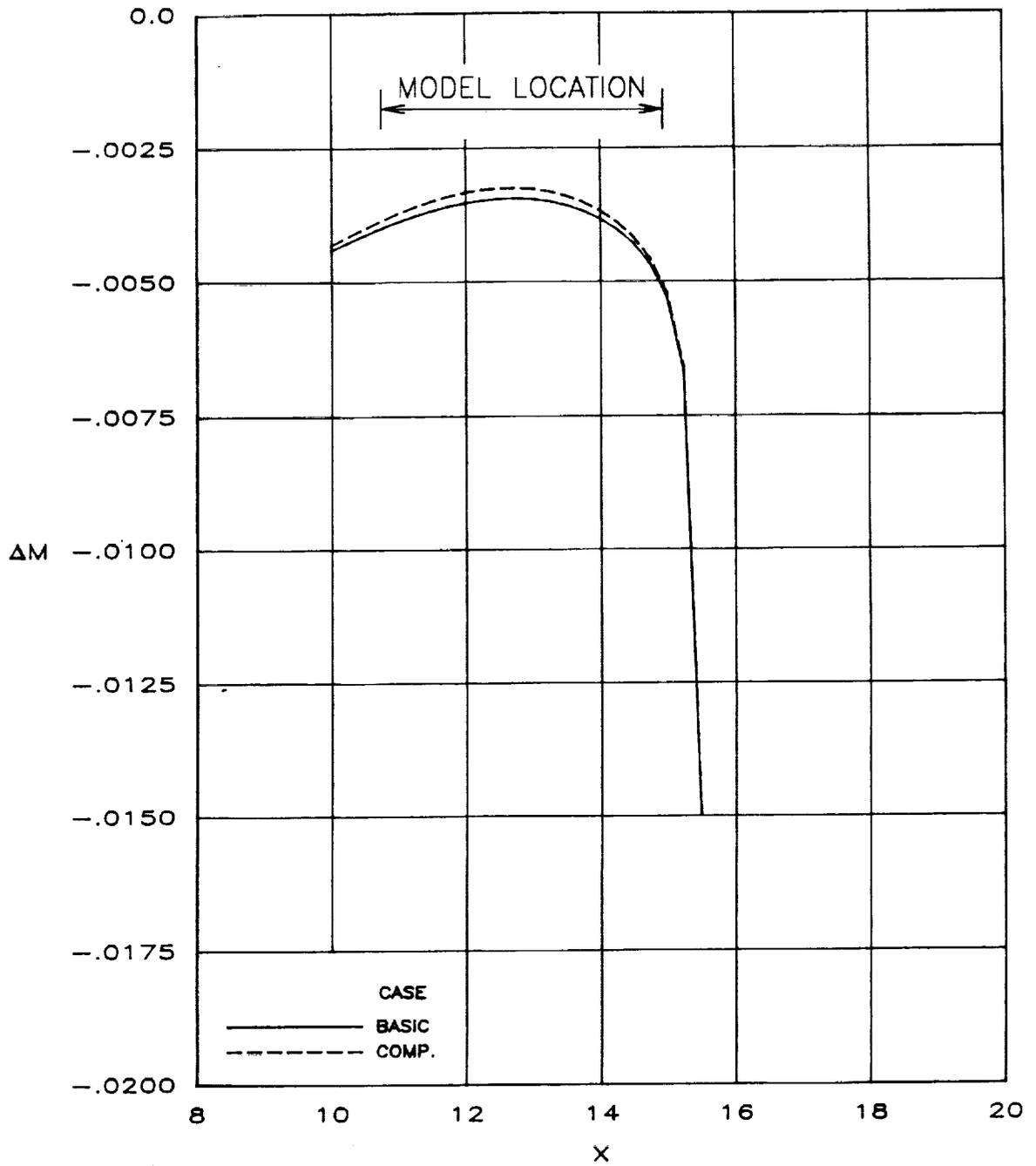


Figure 3. Effect of eliminating fuselage volume on model centerline  $\Delta M$  distribution at  $M_\infty = 0.7$  and  $C_L = 0.5315$ .

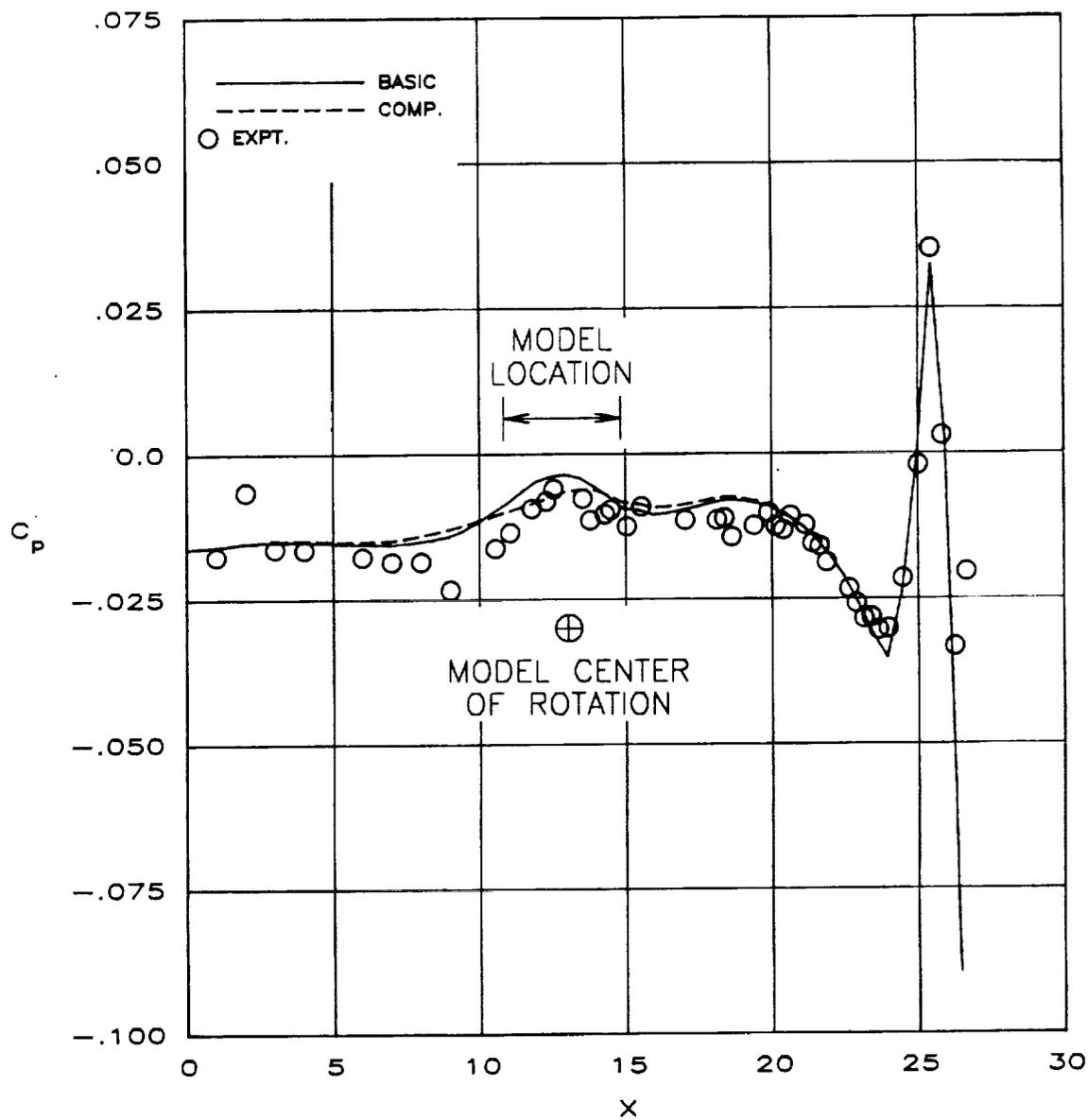


Figure 4. Effect of eliminating fuselage volume on test section sidewall pressure distribution at  $M_\infty = 0.7$  and  $C_L = 0.5315$ .

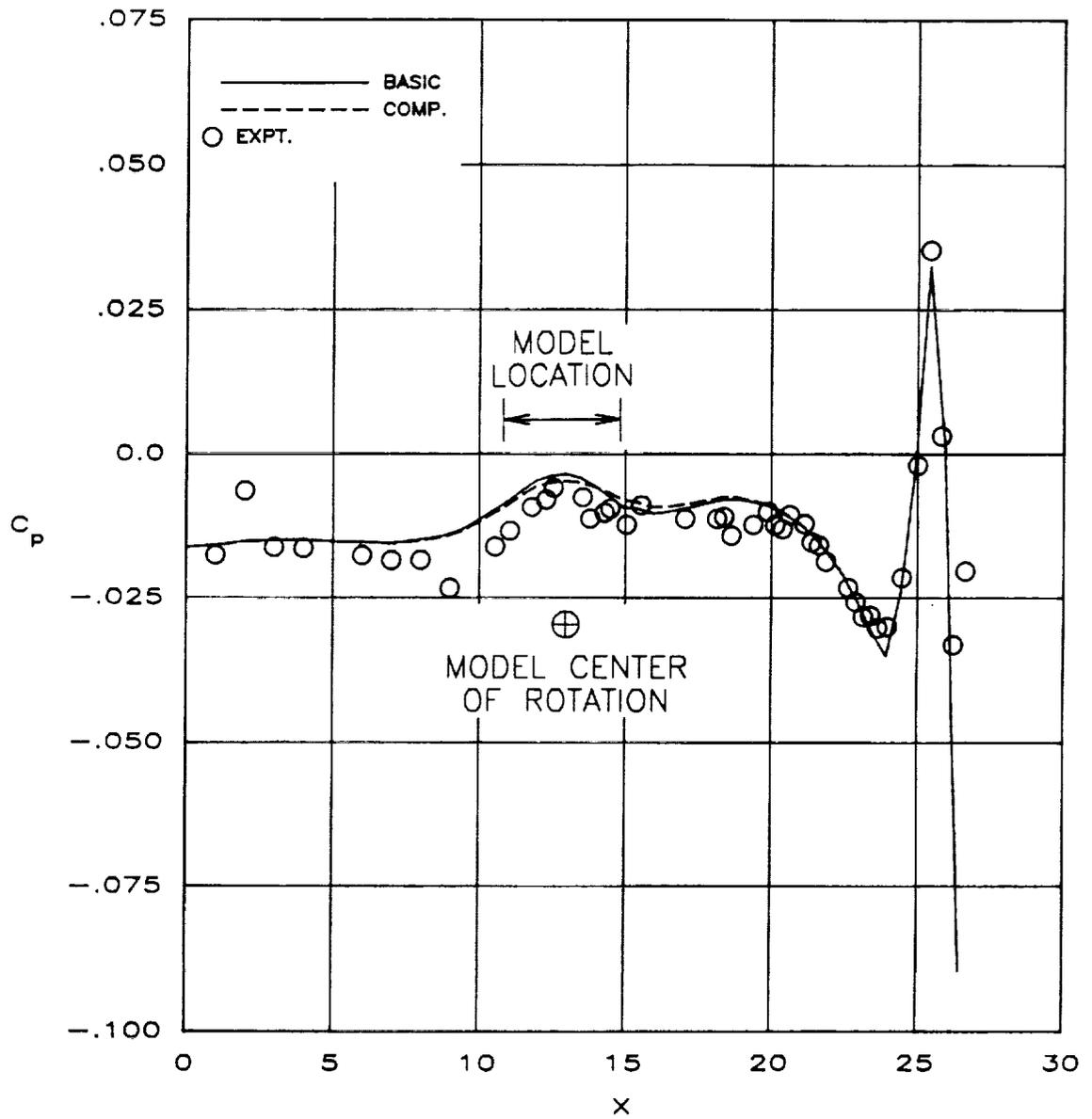


Figure 5. Effect of eliminating wing volume on test section sidewall pressure distribution at  $M_\infty = 0.7$  and  $C_L = 0.5315$ .

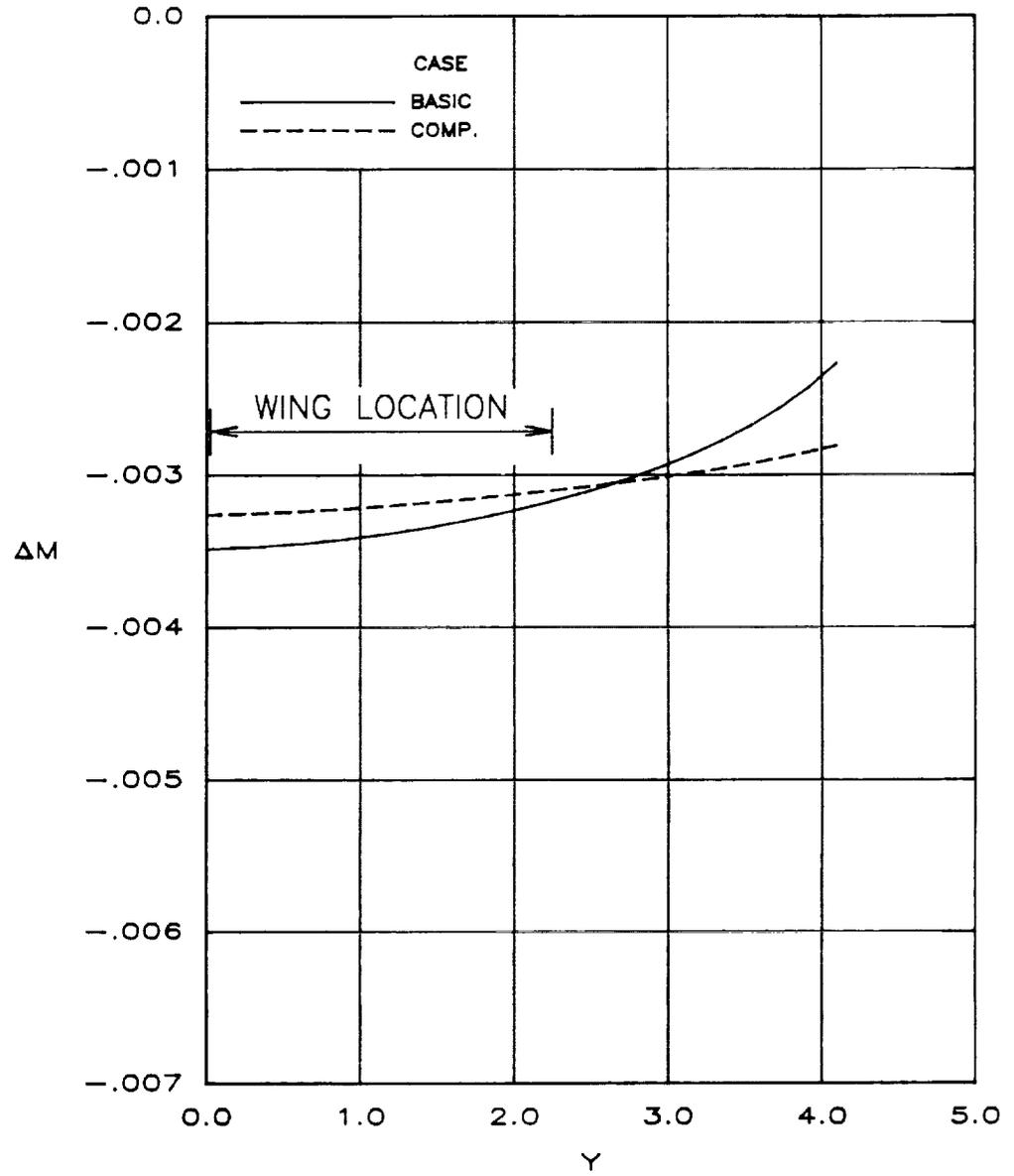


Figure 6. Effect of eliminating model volume on spanwise  $\Delta M$  distribution in wing plane at  $M_\infty = 0.7$  and  $C_L = 0.5315$ .

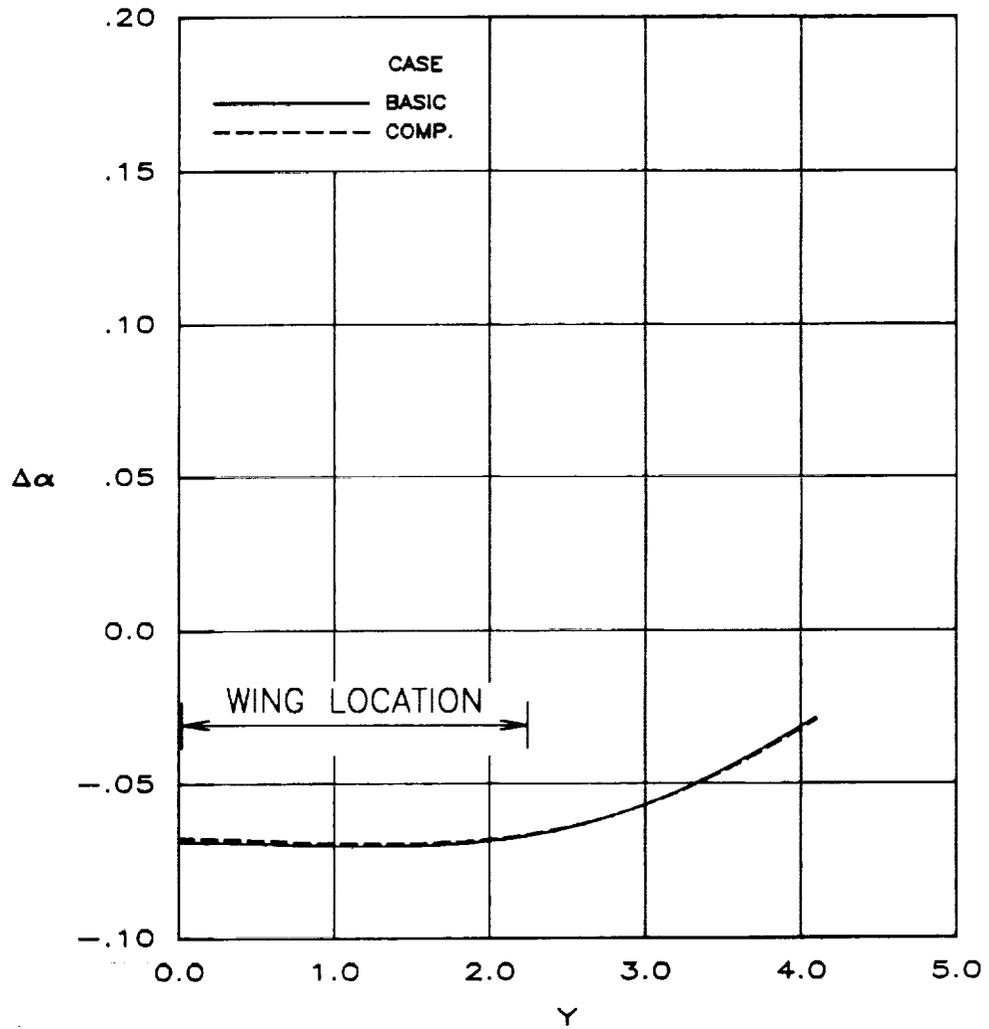


Figure 7. Effect of eliminating model volume on spanwise  $\Delta\alpha$  distribution in wing plane at  $M_\infty = 0.7$  and  $C_L = 0.5315$ .

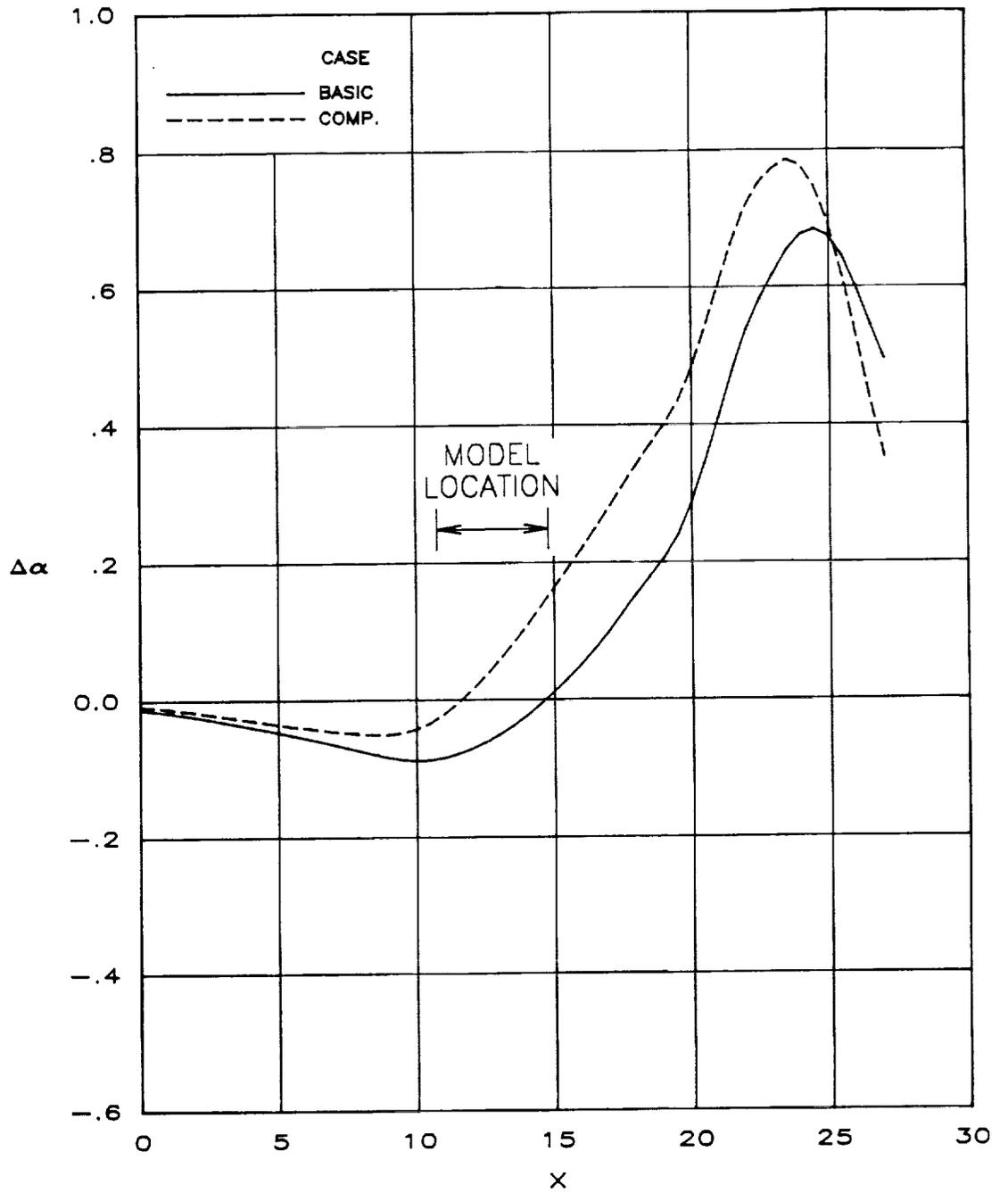


Figure 8. Effect of setting model lift equal to zero on tunnel mid-halfwidth  $\Delta\alpha$  distribution at  $M_\infty = 0.7$ . Baseline  $C_L = 0.5315$ .

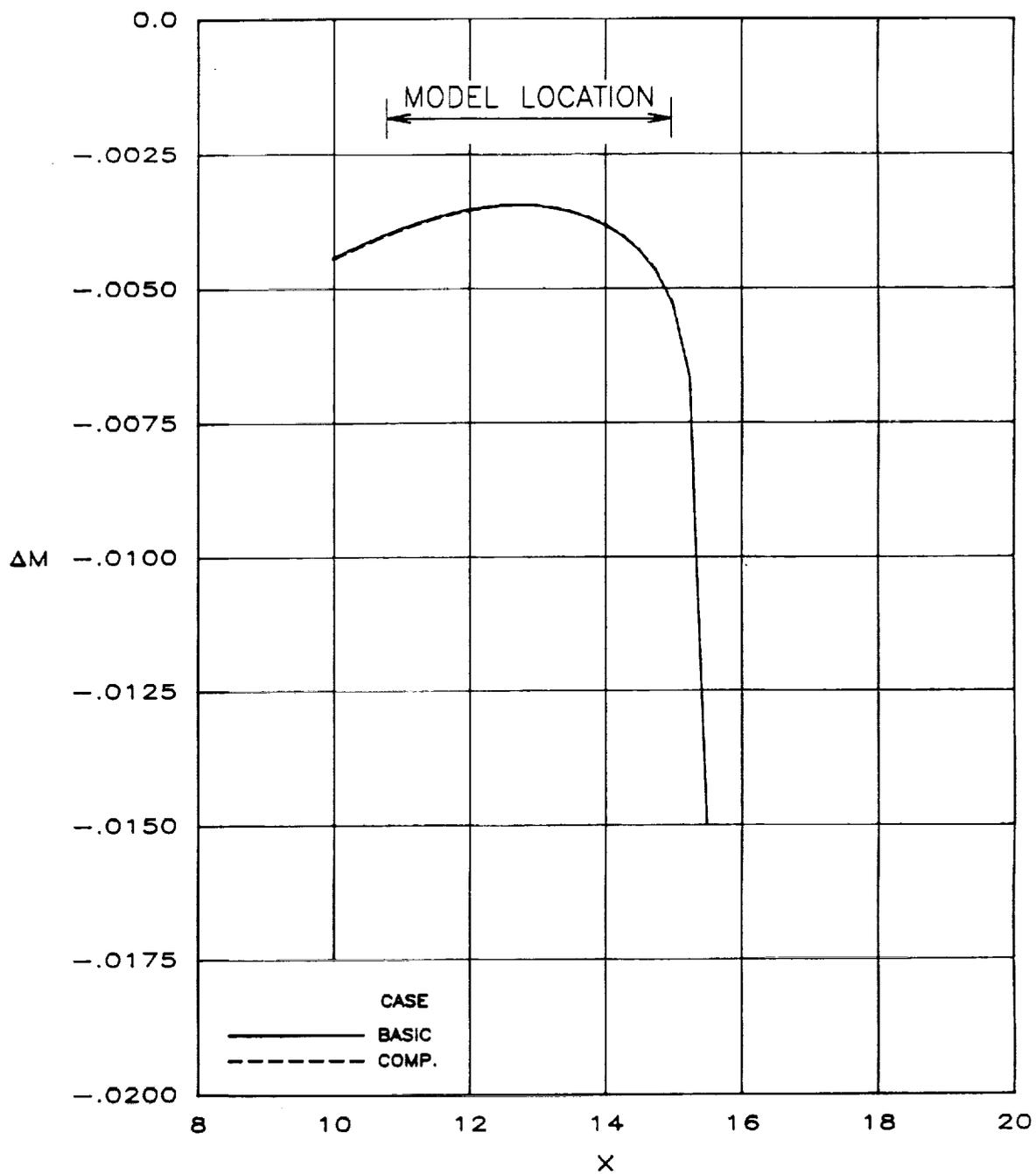


Figure 9. Effect of setting drag equal to zero on model centerline  $\Delta M$  distribution at  $M_\infty = 0.7$  and  $C_L = 0.5315$ .

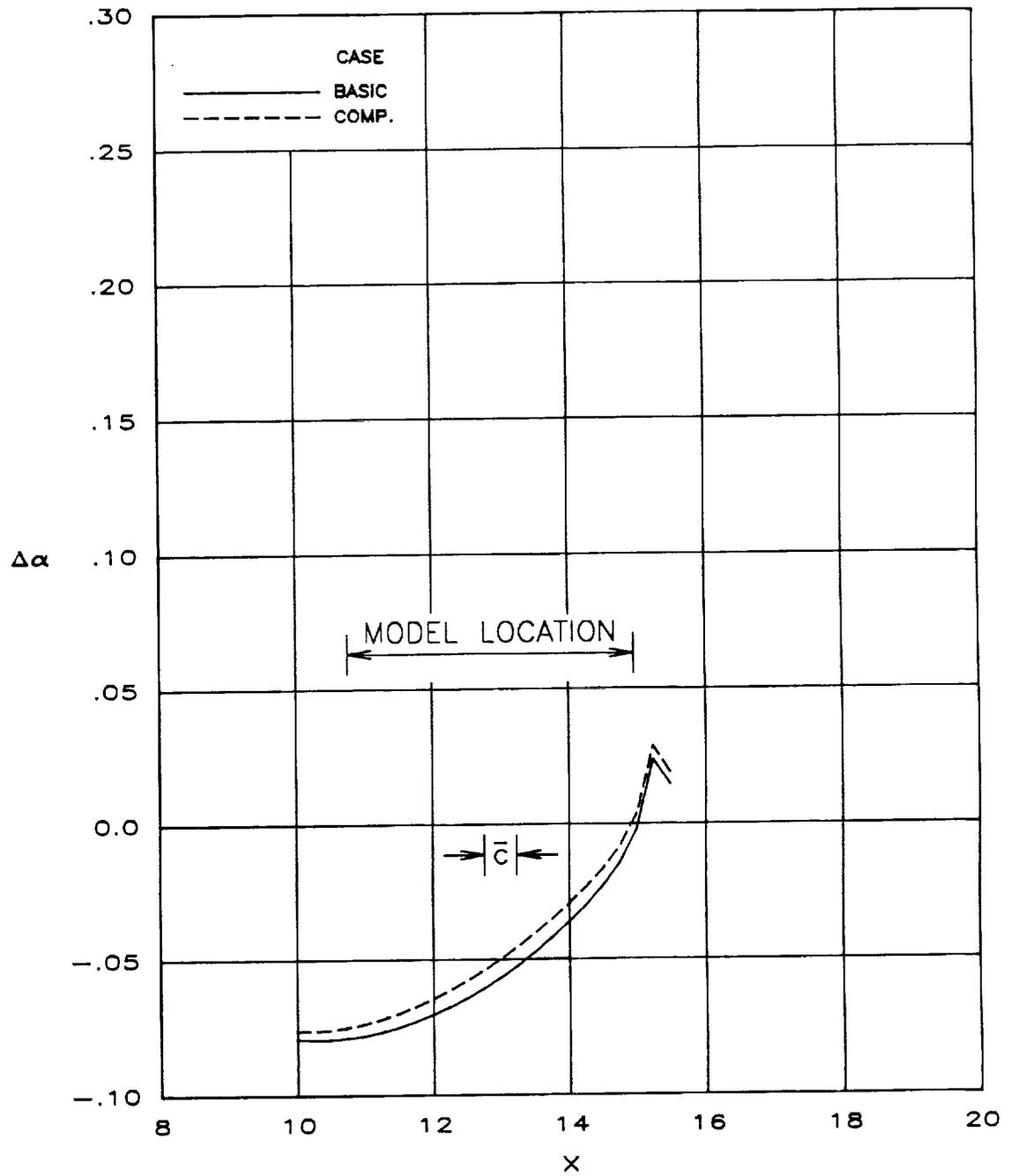


Figure 10. Effect of shifting lift center rearward by  $\bar{c}$  on model centerline  $\Delta\alpha$  distribution at  $M_\infty = 0.7$  and  $C_L = 0.5315$ .

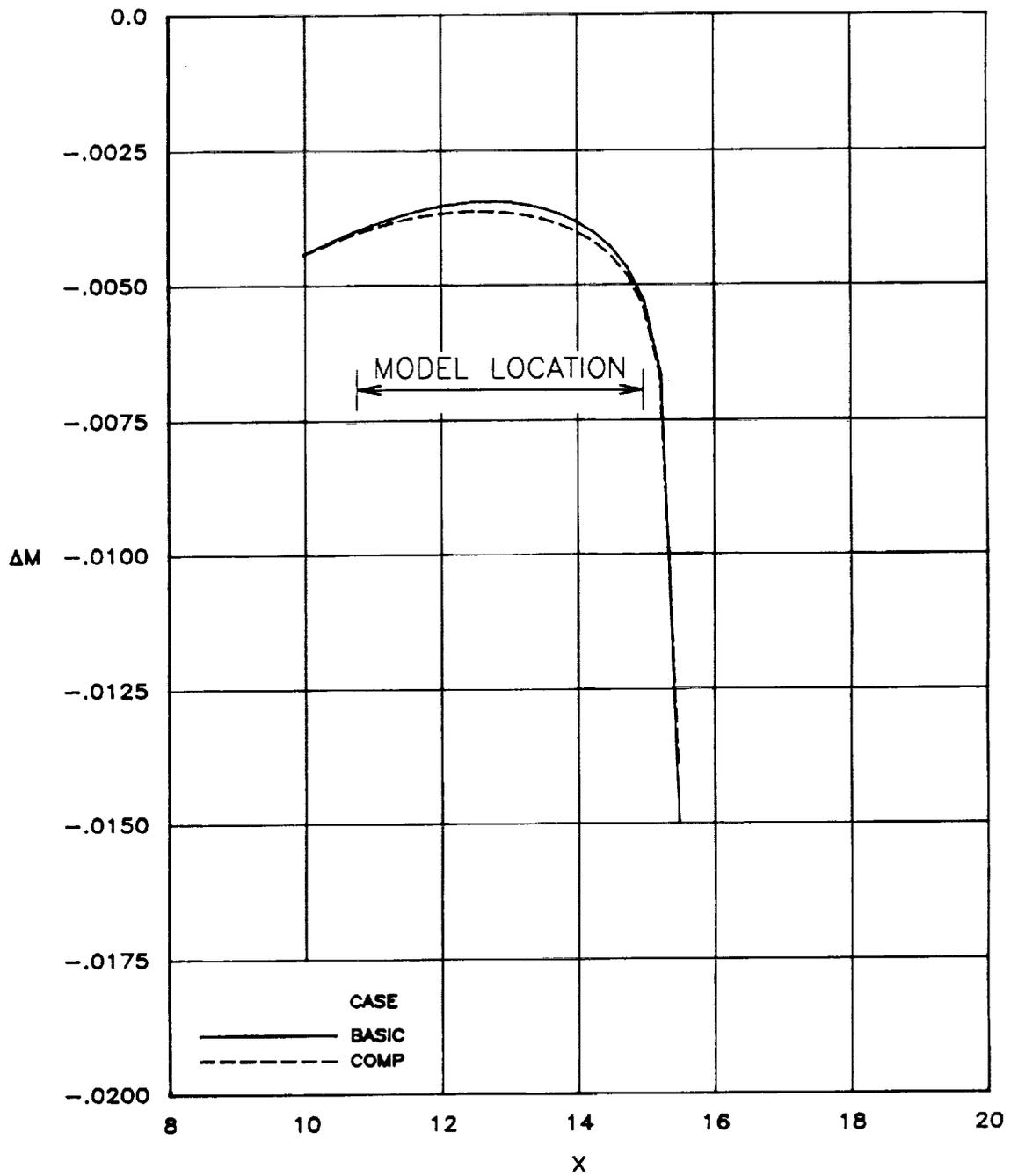


Figure 11. Effect of point-disturbance model representation on model centerline  $\Delta M$  distribution at  $M_\infty = 0.7$  and  $C_L = 0.5315$ .

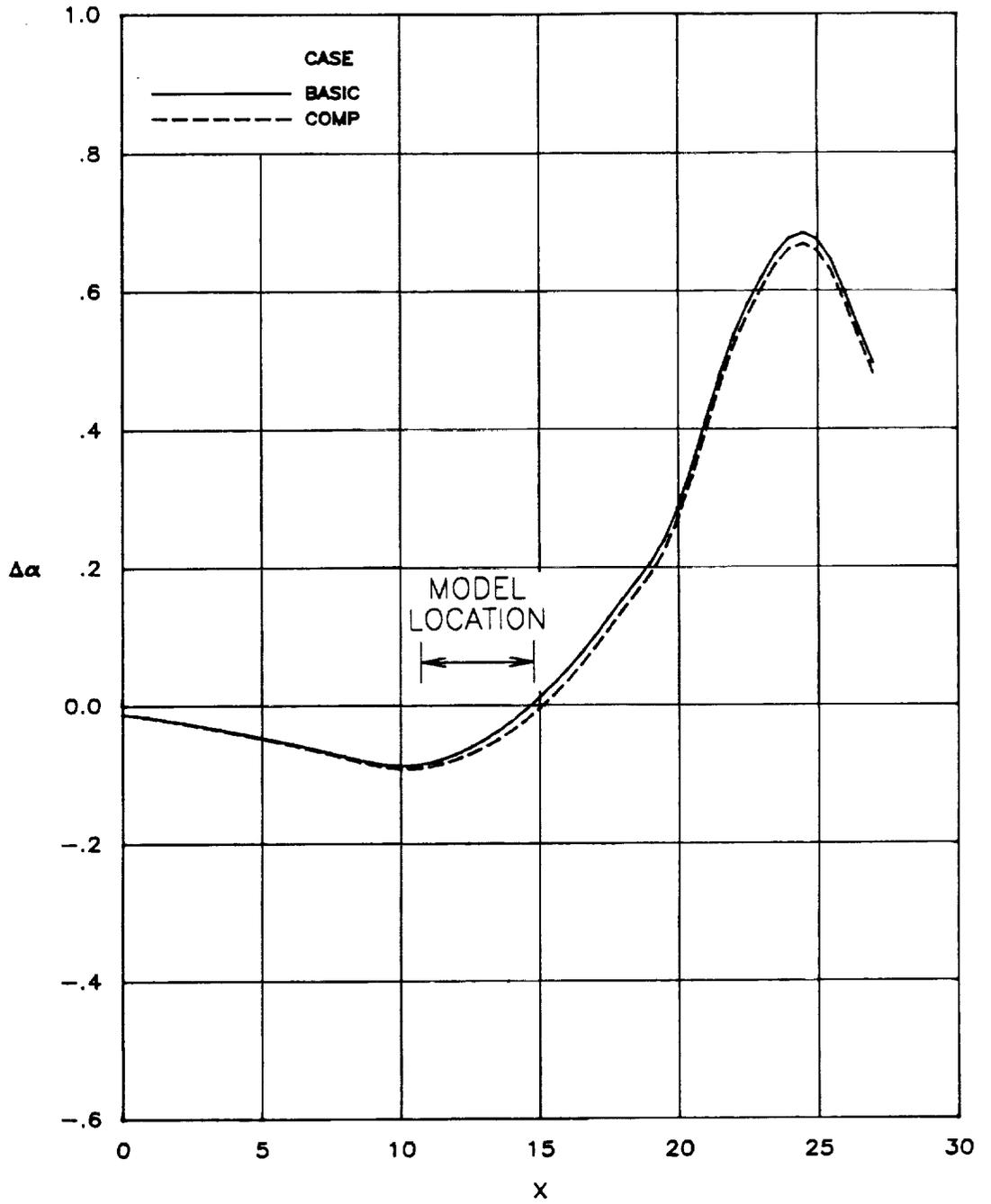


Figure 12. Effect of point-disturbance model representation on test section mid-halfwidth  $\Delta\alpha$  distribution at  $M_\infty = 0.7$  and  $C_L = 0.5315$ .

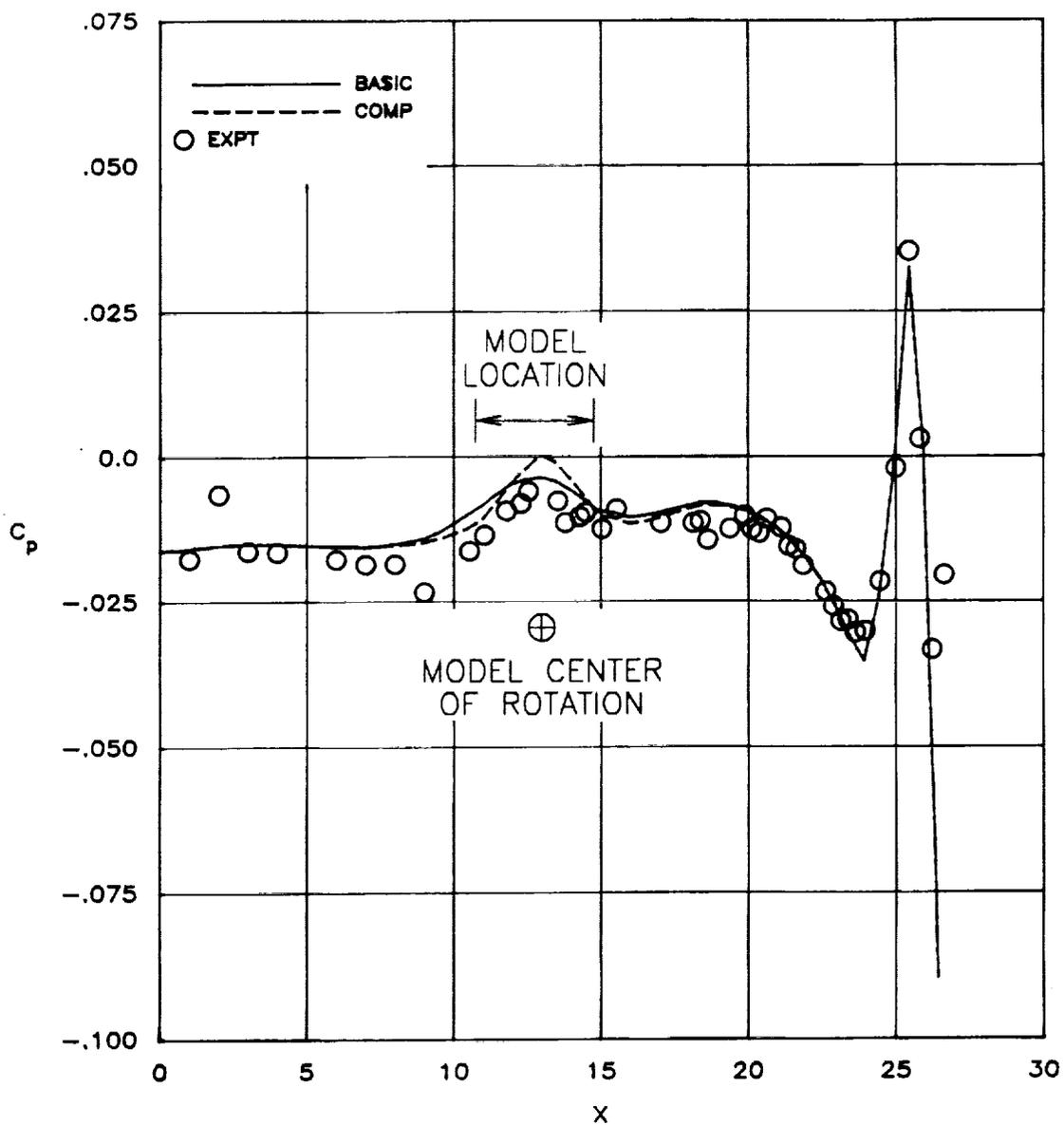


Figure 13. Effect of point-disturbance model representation on test section sidewall pressure distribution at  $M_\infty = 0.7$  and  $C_L = 0.5315$ .



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