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RESEARCH MEMORANDUM

THE ORIGIN AND DISTRIBUTION OF SUPERSONIC STORE INTERFERENCE FROM MEASUREMENT OF INDIVIDUAL FORCES ON SEVERAL WING-FUSELAGE-STORE CONFIGURATIONS

II. - SWEPT-WING HEAVY-BOMBER CONFIGURATION WITH LARGE STORE (NACELLE). LATERAL FORCES AND PITCHING MOMENTS; MACH NUMBER, 1.61

By Norman F. Smith and Harry W. Carlson

Langley Aeronautical Laboratory
Langley Field, Va.

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SUMMARY

A supersonic wind-tunnel investigation of the origin and distribution of store interference has been performed in the Langley 4- by 4-foot supersonic pressure tunnel at a Mach number of 1.6. Separate forces on a store, a fuselage, a swept wing, and a swept-wing—fuselage combination were measured. The store was separately sting-mounted on its own six-component internal balance and was traversed through a wide systematic range of spanwise, chordwise, and vertical positions. The configuration investigated simulated a heavy bomber airplane with a large store or nacelle having frontal area equivalent to a twin-engine nacelle.

Large changes in store and wing-fuselage forces and moments may occur with small spanwise or chordwise changes in store position. The effects of vertical position of the store are relatively small. The increases which occur with configuration angle of attack are somewhat larger for store side force than for store lift. Store side force is probably the important load from the standpoint of store-support design. The measured store moments are large at zero angle of attack but do not display the large increases with angle of attack which were measured for the other store forces.

The wing is shown to be the predominant factor in the production of all interference forces and moments on the store. The effect of the fuselage is very small in the case of store lift and pitching moment, but it is of significant magnitude in the case of store side force and yawing

moment, particularly for the inboard store locations. The total interference lift on the complete configuration is due principally to the interference lift felt by the wing. The values measured for some store positions are large and important from the standpoint of rolling moments produced in asymmetrical store carriage or asymmetrical store drops.

INTRODUCTION

Reference 1 describes in detail an experimental investigation in the Langley 4- by 4-foot supersonic pressure tunnel aimed at supplying data on stores interference which is general in nature and which provides an improved understanding of the sources of interference. The investigation consists of measurement of individual forces and moments (six components) on various sting-mounted stores in the vicinity of several fuselage, wing, and wing-fuselage combinations for which individual forces and moments (four components) were also simultaneously measured. Reference 1 presents the first part of the results of this program, the lift and drag at a Mach number of 1.6 on a store, a fuselage, a swept wing and a swept-wing—fuselage combination.

The present report supplements reference 1 and presents the side force, yawing moment, and pitching moment on the same store and the pitching moment and rolling moment on the same fuselage, wing, and wing-fuselage combination at a Mach number of 1.6. The wing-fuselage configuration simulates a swept-wing heavy bomber, whereas the store represents a large external store or a twin-engine nacelle (with no provision for internal flow). Some additional analysis of the lift data presented in reference 1 is included. As in the case of reference 1, the data herein are presented with a somewhat limited "illustrative" analysis in order to expedite publication.

SYMBOLS

C_L lift coefficient of fuselage, wing, or wing-fuselage combination as noted by subscripts, $\frac{\text{Lift}}{qS}$

C_m pitching-moment coefficient of fuselage, wing, or wing-fuselage combination as noted by subscripts (measured about $\bar{c}/4$), $\frac{\text{Pitching moment}}{qS\bar{c}}$

$C_{l_{wf}}$ wing-root bending moment for wing-fuselage combination (positive up), $\frac{\text{Bending moment}}{qS\frac{b}{2}}$

C_{L_s} lift coefficient of store, $\frac{\text{Lift}}{qF}$

C_{m_s} pitching-moment coefficient of store (positive when nose is up), $\frac{\text{Pitching moment}}{qFl}$

C_{Y_s} side-force coefficient of store (positive to the right), $\frac{\text{Side force}}{qF}$

C_{n_s} yawing-moment coefficient of store (positive to the right), $\frac{\text{Yawing moment}}{qFl}$

C_{L_t} total lift coefficient of complete configuration (wing-fuselage plus store) based on wing area, $C_L + C_{L_s}\frac{F}{S}$

$C_{L_{s_\alpha}}$ slope of variation of store lift coefficient with wing-fuselage angle of attack

$C_{Y_{s_\alpha}}$ slope of variation of store side-force coefficient with wing-fuselage angle of attack

$C_{n_{s_\alpha}}$ slope of variation of store yawing-moment coefficient with wing-fuselage angle of attack

S total area of wing semispan, 0.5 sq ft

F maximum frontal area of store, 0.0123 sq ft

S/F ratio of wing area to maximum frontal area of store, 40.6

$\bar{c}$ mean aerodynamic chord of wing, 6.58 in.

q dynamic pressure, lb/sq ft

b/2 wing semispan, 12 in.

l store length, 12 in.

x chordwise position of store midpoint, measured from nose of fuselage, in. (see fig. 1)

y spanwise position of store center line, measured from fuselage center line, in.

z vertical position of store center line, measured from wing chord plane, positive downward, in.

α angle of attack

β cotangent of Mach angle, $\sqrt{M^2 - 1}$

Subscripts:

f fuselage

w wing

wf wing-fuselage combination

s store

t total, for complete configuration (wing-fuselage plus store)

APPARATUS AND TESTS

The models and the general arrangement of the test setup are shown in figures 1 and 2. Reference 1 describes in detail the models, equipment, tests, and methods, and contains remarks on support interference. No airplane tail surfaces or store-support pylons were used in this investigation. All tests were run with boundary-layer transition fixed as described in reference 1. The angle of attack of the wing-fuselage combination was varied from 0° to 4°, with the store remaining at $\alpha = 0$ throughout.

The tests were performed in the Langley 4- by 4-foot supersonic pressure tunnel at Mach numbers of 1.6 and 2.0, corresponding to Reynolds numbers per foot of 4.20×10^6 and 3.62×10^6, respectively. This report presents the lateral forces and pitching moments at $M = 1.6$ and additional analysis of the lift data presented in reference 1.

The repeatability or relative accuracies of the data in this report are estimated from an inspection of repeat test points and static deflection calibrations to be as follows:

Store position:	
x, in.	±0.025
y, in.	±0.05
z, in.	±0.05
Store:	
C_{Y_s}	±0.010
C_{n_s}	±0.005

C_{m_s} . . . . ±0.005
C_{L_s} . . . . ±0.010

Wing-fuselage:
C_m . . . . ±0.002
C_L . . . . ±0.005
C_l . . . . ±0.002

RESULTS AND DISCUSSION

Basic Data

Isolated store and wing-fuselage data.- The lift and pitching-moment coefficients for the isolated store at angles of attack up to 10° are shown in figure 3. Data are shown for pitch tests in both the plane of the balance normal-force beam and in the plane of the balance side-force beam. The data thus obtained are shown to agree within the stated accuracy of the tests, except possibly at the highest angle of attack. The pitching-moment data are computed both about the nose of the store and about the midpoint of the store because interference data presented in subsequent figures are referenced to both points.

Figure 4 shows the lift and pitching-moment coefficients for the isolated fuselage, wing, and wing-fuselage combination for angles of attack up to 4°.

Chordwise plots of force coefficients.- The basic data for the store in the presence of the fuselage, wing, and wing-fuselage are presented in figures 5 to 13. The basic data for the fuselage, wing, and wing-fuselage in the presence of the store are presented in figures 14 to 17. The data are presented in the form of plots of coefficients against a chordwise-position parameter which is a function of the position of the midpoint of the store. To allow relatively large coefficient scales to be used, a horizontal offset is employed. The Mach line offset used, discussed in detail in reference 1, permits the curves of chordwise variation of coefficients to be faired as a "family," thereby obtaining a more accurate fairing between test points than would otherwise be possible. Offset vertical scales are also used so that data for the 11 spanwise positions can be shown on a single page. On the right and left margins the zero line for each curve is identified by the symbol corresponding to that spanwise position. On each figure is shown a sketch of the configuration involved. The spanwise and chordwise store positions at which measurements were obtained are indicated by the appropriate symbol on the grid drawn to scale below the sketch.

The store pitching-moment data and the store yawing-moment data are presented with reference to the store nose in the basic-data figures. Using the plotted moment data and the lift or side force, as appropriate, the moment about any desired point with reference to either the store or the airplane can be calculated. Some analysis figures presented later in the report show moments which have been computed with reference to the store midpoint.

The basic data for the fuselage, wing, and wing-fuselage combination are shown with dashed lines forward of longitudinal store position $x = 18$ inches because of the presence of interference between the store-support sting and the fuselage or wing. This interference is discussed in detail in reference 1.

Contour Plots

To aid in examination and analysis of the data, contour plots (figs. 18 to 32) have been made for each coefficient, covering two vertical heights and two angles of attack (three plots in all). The store midpoint is the reference point (the point at which the force coefficient is plotted) for all contour plots. Similar plots or maps for other conditions can be prepared from the remainder of the basic-data plots (figs. 5 to 17).

Store lift.- Contour plots of store lift in the presence of the wing and wing-fuselage are presented in figures 20 and 24. The basic lift data for both store and wing-fuselage are given in reference 1. Contour plots or lift, which were not included in reference 1, are presented in this paper as a part of a further analysis of lift.

As was pointed out briefly in reference 1, a negative pressure region has been shown to exist beneath the wing at $\alpha = 0^{\circ}$. The pressure gradient produced on the store results in a positive interference lift of relatively large magnitude when located in the vicinity of the wing. Ahead of and behind the wing, where the effective pressure is positive, the store lift is reduced and in some positions it becomes negative. Increasing the displacement between store and wing does not appreciably change the magnitudes of the interference lifts, but shifts the contour lines rearward somewhat. It will be noted from a comparison of figures 20 and 24 that the fuselage does not enter into the production of store lift to an important extent.

At $\alpha = 4^{\circ}$ (fig. 20(c)) the store lift for most store positions in the vicinity of the wing has decreased as compared with the value at $\alpha = 0^{\circ}$ because of the increase (in the positive direction) of pressure which occurs beneath the wing. For the wing-tip position, however, the store lift has increased considerably. This positive interference lift on the store has been encountered previously for wing-tip stores at subsonic speeds (ref. 2, for example) and is due to the presence of the store in the wing-tip vortex.

Store pitching moment.- Contour plots of store pitching moment are presented in figures 21 and 25. Pitching-moment coefficients in these figures are calculated about the nose of the store. The values shown are therefore largely the consequence of lift on the store, and the pitching moments tend to follow the trends outlined previously for lift.

Store side force.- Store side-force coefficients for the store in the presence of the fuselage, wing, and wing-fuselage are presented in contour form in figures 18, 22, and 26. The variation of store side force with store position in the presence of the wing or wing-fuselage is large, as is the increase of side force with wing angle of attack (fig. 26). Further discussion of this component will be found in a later section entitled "Effect of wing-fuselage angle of attack." Reference 3 also contains additional analysis of these data.

Store yawing moment.- Contour plots of store yawing-moment coefficient are shown in figures 19, 23, and 27. Inasmuch as the store yawing moments have been computed about the store nose, the yawing moments shown are principally the result of side force. The preceding discussion on side force therefore tends to apply also to yawing moment.

Wing and wing-fuselage lift.- Contour plots of wing and wing-fuselage lift are presented in figures 28 and 30. These figures show that in certain positions the store produces lifts that are equivalent to the lift produced by a wing angle of attack of about 1°. (See fig. 4.) The region of store midpoint locations for maximum positive lift interference is the inboard region of the wing trailing edge. For store positions toward the leading edge of the wing or toward the tip, the lift interference becomes small. For some store positions ahead of the wing, negative lift interference is obtained.

Wing and wing-fuselage pitching moment.- Figures 29 and 31 show that the lift interferences described in the previous section are reflected in the wing and wing-fuselage pitching moments. The inboard store positions near the wing trailing edge produced negative pitching moments as a result of positive lift interference behind the moment center of the wing ($\bar{c}/4$). The positive pitching moments measured for forward store positions are similarly explained.

It should be noted that the measured effects of the store on the airplane configuration include only those on the wing and fuselage, since no tail was present. The effects of a tail, particularly for inboard store positions, would likely be important.

Wing-root bending moment.- Contour plots of the wing-root bending moment of the wing-fuselage combination are shown in figure 32.

Although the contour plots of the wing-root bending-moment coefficient are quite different in appearance from those of the lift coefficient, an analysis of two corresponding plots (figs. 30(a) and 32(a), for example) shows that the two are compatible.

It will be noted that a change in vertical displacement of the store from 1.15 inches to 2.09 inches (figs. 32(a) and (b)) produces a major change in the bending-moment contours. Reference to the lift contours for corresponding store positions in figures 30(a) and (b) shows that the increased vertical displacement of the store has moved the positive lift-interference contours forward and toward the tip, and that these changes explain the wing-root bending moments which suddenly appear at the wing-tip location in figure 32(b). The peak value of wing-root bending-moment coefficient shown on this figure corresponds to that produced by a wing angle of attack of about 1°.

ANALYSIS

The data which have been presented are directly useful in connection with configurations which very closely match the configuration tested. Application of these results to configurations appreciably different, however, rapidly becomes difficult and dubious as configuration differences increase, unless a basic understanding of the contribution of each component to the measured interference is available along with an understanding of the effects of the many variables such as angle of attack and Mach number. An analysis of these data, based upon these needs, has consequently been made. The analysis is not exhaustive, but rather is intended to be illustrative and suggestive of the ways in which the data can be used.

Contribution of Components to Interference

Store lift and pitching moment.- The contribution of each component to the measured interference can be readily seen in the results of the configuration-breakdown tests. Figure 33 shows the lift of the store in the presence of the fuselage, wing, and wing-fuselage plotted against store chordwise position x for four spanwise stations. (The basic lift data are presented in reference 1.) The close agreement between the curves for store lift in the presence of the wing and wing-fuselage shows that the lift interference produced on the store is dependent, for all practical purposes, only upon the wing. The reason for the interference lift on the store in the presence of the fuselage for $x = 27$ inches is unknown. It is considered possible that the data for this store position are in error.

The pitching-moment data (fig. 34) similarly show that store pitching moment is primarily dependent upon the wing.

Store side force and yawing moment.- The side-force and yawing-moment data (figs. 35 and 36), on the other hand, show that the fuselage makes a significant contribution to these forces, especially at the more inboard store locations. The relative importance of the contribution of the fuselage diminishes as the angle of attack of the wing increases because of the development of the spanwise flow which produces store side force.

Lift and pitching moment for wing, fuselage, and complete model.- The variations in lift of the fuselage, wing, and wing-fuselage with chordwise position of the store are shown in figure 37. The fuselage gains very little lift as a result of store interference. The wing, however, develops an appreciable interference lift, either positive or negative, depending upon the store position. The curve for the wing-fuselage combination is of the same shape but does not closely match the wing-alone curve, especially at the inboard stations, even though the fuselage alone showed very little lift interference. The difference between the curves is probably the result of wing-fuselage interference.

Figure 38 shows the lift for the store and the wing-fuselage combination and the sum of these two, which is the total lift of the complete model. The lift coefficient of the store (reduced to wing area) is very small in comparison with the lift produced on the wing-fuselage combination by the store. The total interference lift coefficient is large for some store positions, reaching a maximum of more than 0.04. This value corresponds to the lift coefficient produced by a wing angle of attack of about 1°. For airplanes using removable stores in regions of large lift interference, large rolling moments could be encountered if unsymmetrical carriage or unsymmetrical drops were attempted.

The variations of the pitching-moment coefficient for the fuselage, wing, and wing-fuselage are shown in figure 39. As in the case of the lift, the effect of the store on the fuselage alone is small, and the difference between the curves for the wing alone and the wing-fuselage is believed to be due to mutual interference of the wing and fuselage. It will be noted that to obtain the total interference pitching moment for the complete configuration it is necessary to add to the values shown in figure 39 the pitching moment of the store and the moment of the lift of the store at each particular position considered.

Effect of Store Vertical Displacement and Wing-Fuselage Angle of Attack

Effect of store vertical displacement z at $\alpha = 0^{\circ}$.- The effects of vertical displacement between store and wing on store forces and moments in the presence of the wing-fuselage combination are shown in figures 40 to 43. The effect upon store lift (fig. 40, taken from ref. 1) is shown to be appreciable, particularly at the inboard store locations where the peak of the lift-variation curve is lowered and reduced in width by moving the store (vertically) away from the wing. It will be remembered from figure 38, however, that the values of lift interference shown for the store are very small compared with those measured for the airplane.

The effects of store vertical displacement on store pitching moment shown in figure 41 (calculated in this case about the store midpoint) are similar in degree and character to those described for lift.

Store side force and yawing moment (also calculated about the store midpoint) are shown in figures 42 and 43 to be affected to only a small degree by store vertical displacement at $\alpha = 0^{\circ}$, particularly for the outboard store locations.

The effects of vertical displacement of the store on wing-fuselage lift and pitching moment and on total lift are shown in figures 44, 45, and 46 to be similar to the effects on the store lift and pitching moment except that the lift peak is somewhat broadened rather than narrowed by increasing displacement.

Thus, within the range of store positions investigated herein, the effects of vertical displacement of the store on all forces and moments with the exception of drag are measurable but relatively small. Reference 1 shows that the effects upon drag are large.

Effect of wing-fuselage angle of attack.- The effects of angle of attack of the wing-fuselage combination on store lift are shown in figure 47 (taken from ref. 1) and figure 48. As pointed out in reference 1, the effect of angle of attack is to increase the intensity of the positive-pressure region between the bow shock and the wing leading edge and to decrease the intensity of (make more positive) the negative-pressure region beneath the wing. The increased gradients in the forward positive-pressure region increase the magnitude of the negative store lift produced in this region, while the decreased pressure gradients in the rearward negative-pressure region decrease the positive store lift produced as the wing angle of attack is increased. Figure 48, which is a contour map of $C_{L_{S_\alpha}}$ for angles of attack up to 4°, shows that wing lift changes the store interference lift in a negative direction over a range of store positions considerably larger than the wing plan form, with the exception of store positions in the region of the wing tip. Here the tip vortex increases the store lift as the wing lift increases.

It should be noted that the store was at $\alpha = 0^{\circ}$ for all tests. The values of store lift presented therefore represent only interference values, and the store lift due to store angle of attack must also be considered in applying these data to conditions wherein the store angle of attack is a finite value.

The magnitude of the changes in store pitching moment produced by wing angle of attack is shown in figure 49 to be small.

Figures 50 and 51 show that angle of attack is a powerful influence on store side force, and that the store position relative to the wing is also of very great importance. The influence of angle of attack is felt principally in the region of the wing and is primarily due to the progressive increase in the strength of spanwise flow. The largest values of $C_{Y_{S_\alpha}}$ are consequently found at the tip, and large changes also occur in moving the store from the leading edge to the trailing edge of the wing near the midspan.

These data were obtained by increasing the wing-fuselage angle of attack up to 4° as mentioned earlier. The fact that the store remained at $\alpha = 0^{\circ}$ affects the store lift, but not to any appreciable extent the store side force. The effects of the change in vertical displacement between wing and store which occurs when the wing-fuselage angle of attack is changed are, as has been shown previously in the discussion of figure 42, small and unimportant compared with the effects now being considered.

The $C_{Y_{S_\alpha}}$ contour map (fig. 51) was prepared from data limited to 4° angle of attack. For many conditions, considerably larger angles of attack are of interest and may, as suggested by the data shown here, be a design or limiting condition for store or pylon loads.

Figure 7 of reference 3 compares data taken from figure 51 with data for a similar configuration tested in the Langley 9- by 12-inch blowdown tunnel up to $\alpha = 12^{\circ}$. The comparison shows good agreement between the results of the two investigations and shows that data from the present tests can be judiciously extrapolated to higher angles of attack, using the data from the 9- by 12-inch blowdown tunnel data as a guide.

Figures 52 and 53 show that the effect of angle of attack on store yawing moment is small. Further, $C_{n_{S_\alpha}}$ does not vary greatly with store position. The reasons for these phenomena are not understood at this time.

Figures 54 and 55 show the effect of angle of attack on the lift and pitching moment, respectively, of the wing-fuselage combination in the presence of the store, while figure 56 shows the effect of angle of attack on the total lift of the complete (wing-fuselage plus store) configuration. Although the lift or pitching moment produced by angle of attack displaces the curves on each figure, it will be noted that the curves remain quite similar in shape and in magnitude of changes. The effects of the store on the wing-fuselage lift and pitching moment are thus shown to be principally dependent upon the store position and relatively unaffected by angle of attack.

Effect of Store Configuration

The side force and normal force on the large store are compared with the forces on a small geometrically similar store and on the large store with fins in figures 5 and 11 of reference 3. The forces on both the large finned store and the small store exhibit much higher peak values than do the forces on the large unfinned store. Consequently, it is apparent that use of force coefficients as measured for the large (unfinned) store might be very unconservative for stores of appreciably different configurations.

Remarks on the Store-Pylon Problem

The data presented in this report are concerned only with the loads on the store – neither the forces on nor the effect of a store pylon are included. Some remarks on the store-support problem from the standpoint of drag are included in reference 1. Further discussion on the effects of pylons, including some data, is presented in reference 3. The conclusions reached in this reference on the basis of scattered data are that the store loads (particularly side force) may be greatly affected by the presence of a pylon, with pylon plan form and pylon loading (side force) having considerable influence on the amount of interference. Further work is needed on the effects of pylons.

CONCLUSIONS

The results of a supersonic wind-tunnel investigaion at a Mach number of 1.61 in which separate forces were measured on a store, a fuselage, a swept wing, and a swept-wing—fuselage combination for a very wide range of store positions provide the following conclusions with regard to lateral forces and pitching moment:

1. Large changes in store and wing-fuselage forces and moments may occur with small spanwise or chordwise changes in store position. The effects of vertical position of the store are relatively small.

2. The increases which occur with configuration angle of attack are somewhat larger for store side force than for store lift. Side force is probably the important load from the standpoint of store-support design.

3. The measured store moments are large at zero angle of attack but do not display the large increases with angle of attack which were measured for the other store forces.

4. The wing is shown to be the predominant factor in the production of all interference forces and moments on the store. The effect of the fuselage is very small in the case of store lift and pitching moment, but it is of significant magnitude in the case of store side force and yawing moment, particularly for the inboard store locations.

5. The total interference lift on the complete configuration is due principally to the interference lift felt by the wing. The values measured for some store positions are large and important from the standpoint of rolling moments produced in asymmetrical store carriage or asymmetrical store drops.

6. The interference effects of the store on the wing and wing-fuselage combination are roughly the same at all angles of attack and appear to depend primarily upon store position.

Langley Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., May 9, 1955.

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2. Alford, William J., Jr., and Silvers, H. Norman: Investigation at High Subsonic Speeds of Finned and Unfinned Bodies Mounted at Various Locations From the Wings of Unswept- and Swept-Wing—Fuselage Models Including Measurements of Body Loads. NACA RM L54B18, 1954.

3. Smith, Norman F., and Carlson, Harry W.: Some Effects of Configuration Variables on Store Loads at Supersonic Speeds. NACA RM L55E05, 1955.

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TABLE I.- PERTINENT MODEL DIMENSIONS

Store:	
Maximum diameter, in.	1.5
Maximum frontal area, sq ft	0.0123
Base diameter, in.	0.96
Base area, sq ft	0.005
Overall length, in.	12
Nose fineness ratio	3
Afterbody fineness ratio	1.82
Overall fineness ratio	8
Fuselage:	
Maximum diameter, in.	2.75
Maximum frontal area (semicircle), sq ft	0.0206
Base diameter, in.	1.372
Base area (semicircle), sq ft	0.0051
Overall length, in.	35.75
Nose fineness ratio	4.75
Afterbody fineness ratio	3
Overall fineness ratio	13
Swept wing:	
Semispan, in.	12
Mean aerodynamic chord, in.	6.580
Area (semispan), sq ft	0.500
Sweep (c/4), deg	45
Aspect ratio	4
Taper ratio	0.3
Center-line chord, in.	9.23
Section	NACA 65A006

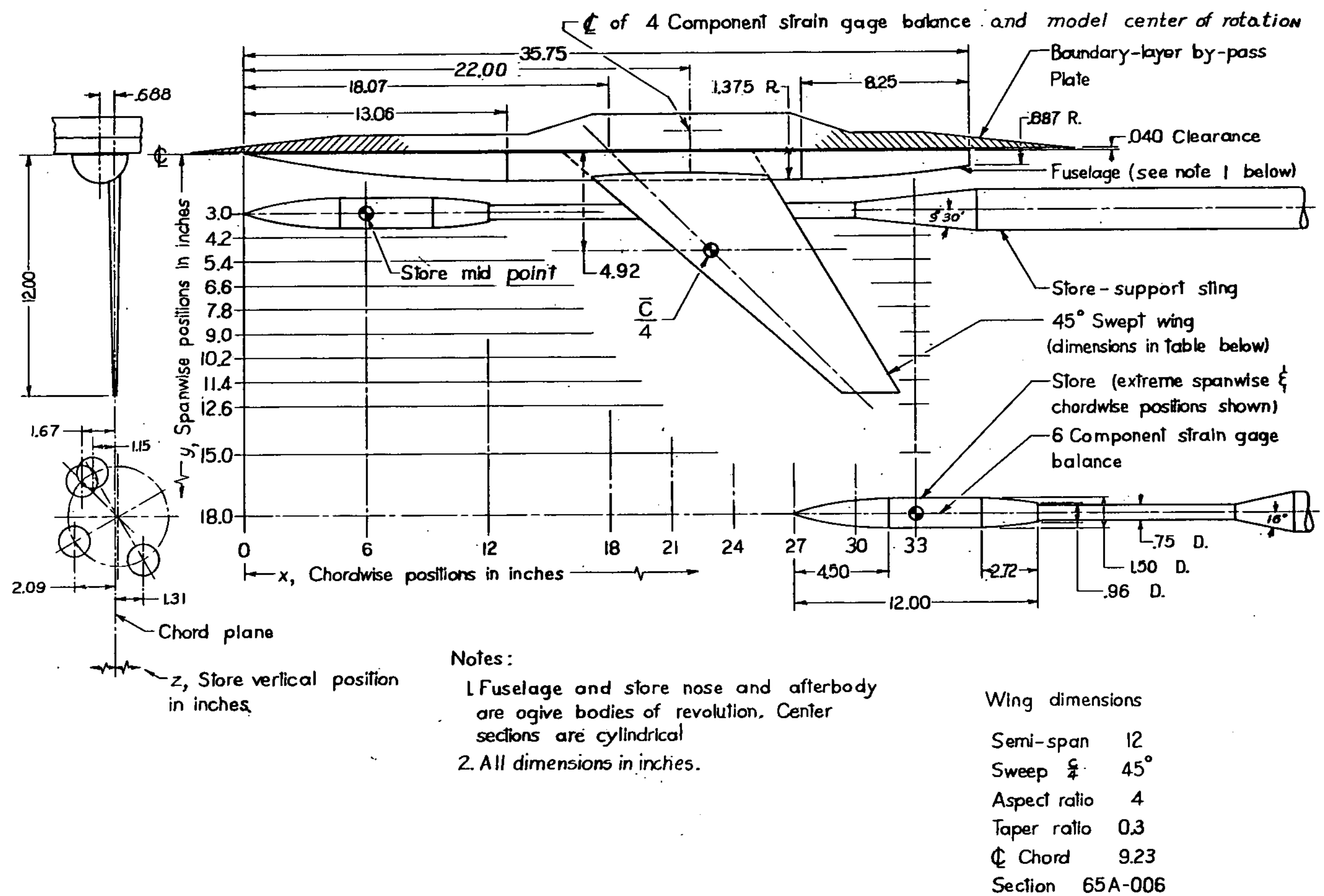

Figure 1.- Layout of models showing dimensions of components and ranges of store positions investigated.

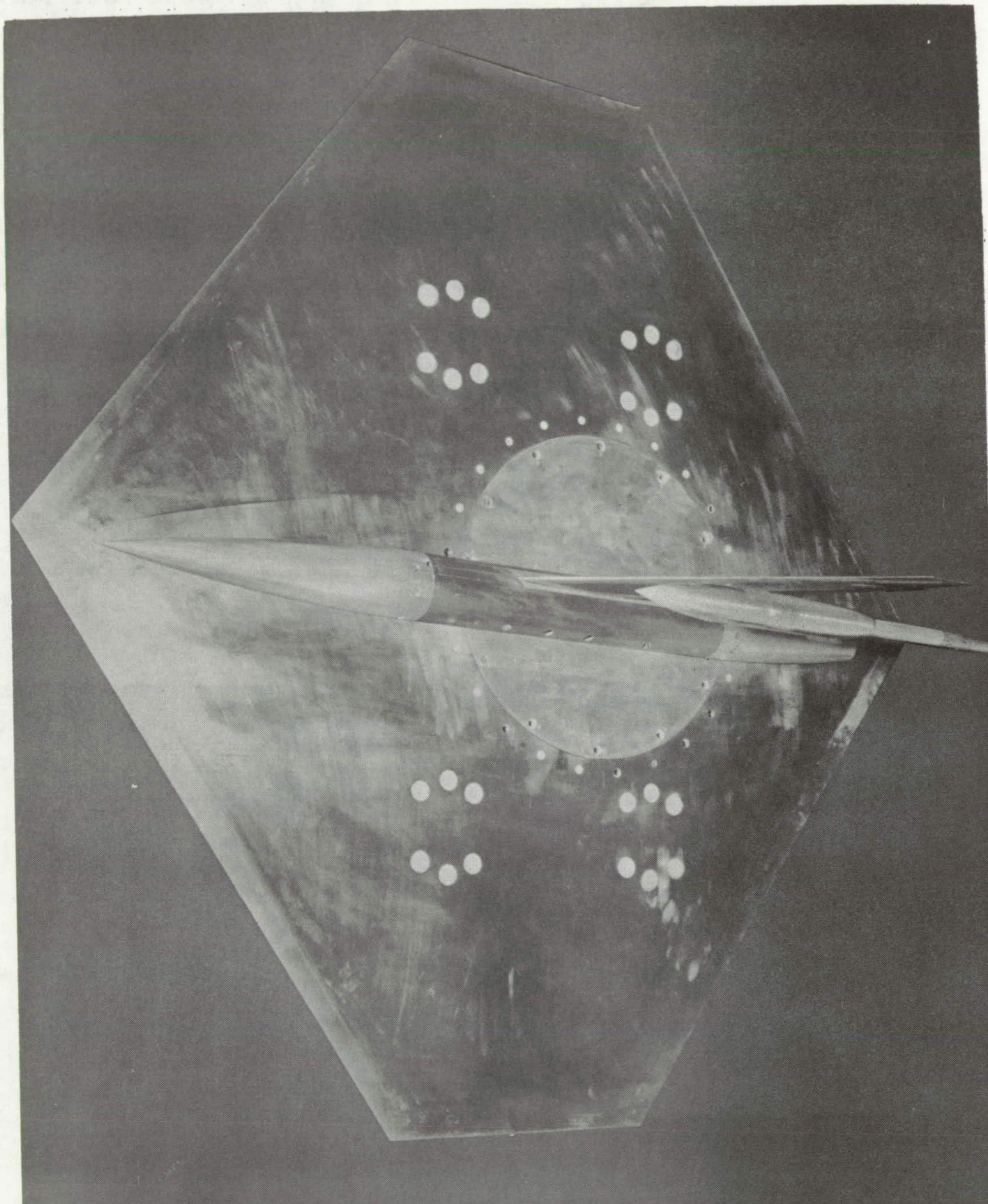

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Figure 2.- Photograph of models and mounting plate. Boundary-layer transition strips not shown.

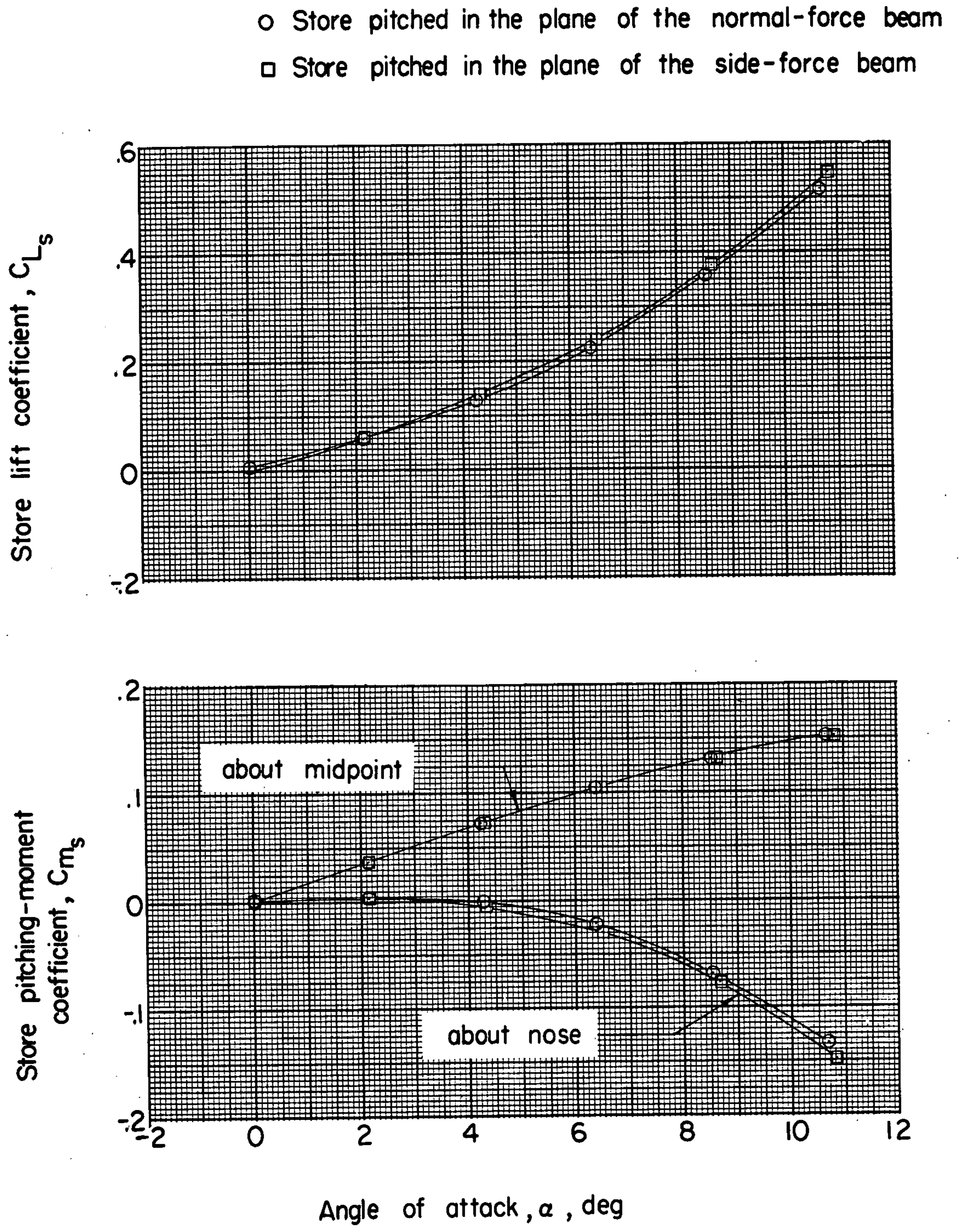


Figure 3.- Lift and pitching-moment characteristics of the isolated store.

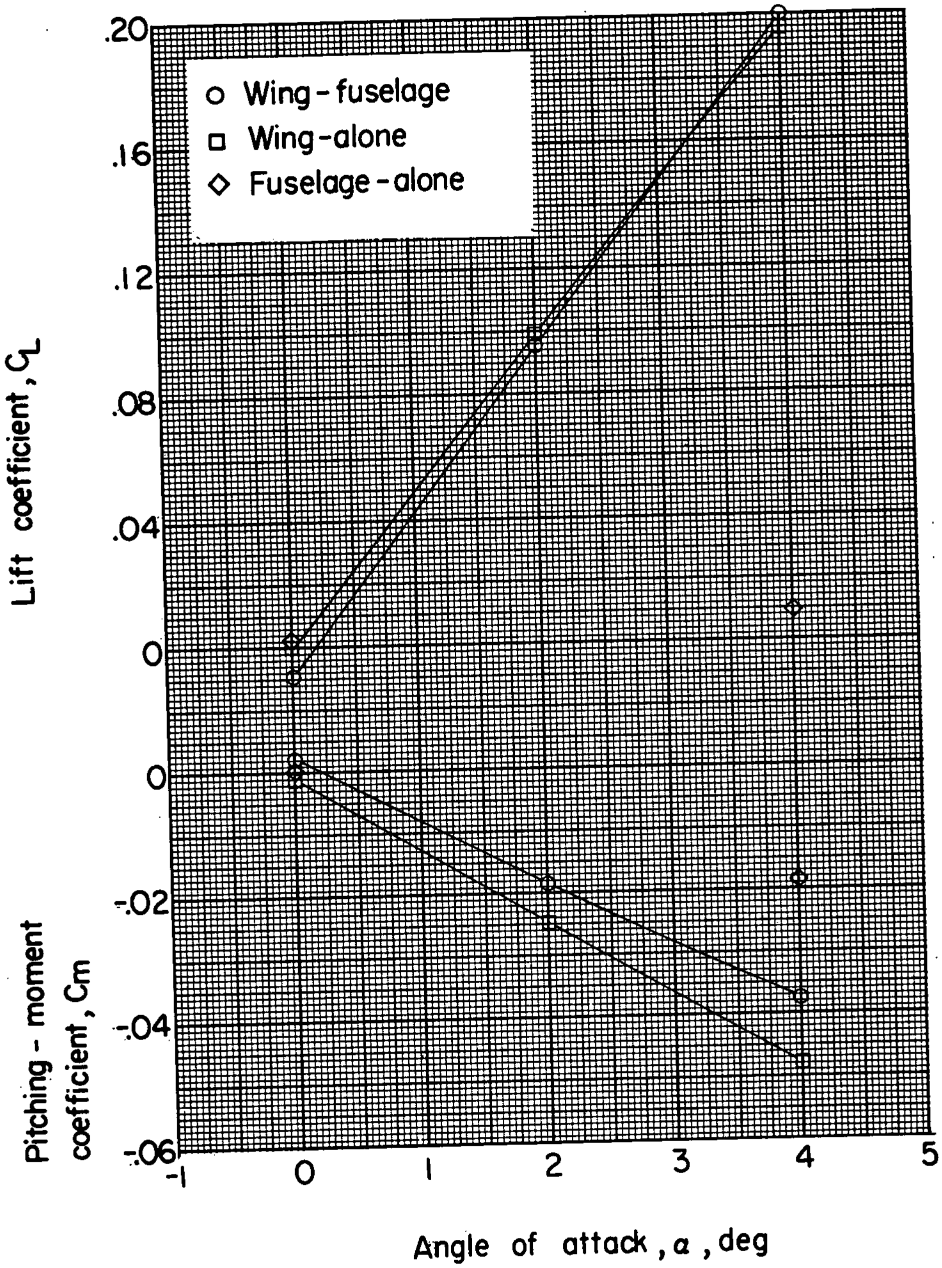


Figure 4.- Lift and pitching-moment characteristics of the isolated wing, fuselage, and wing-fuselage combination. M = 1.61.

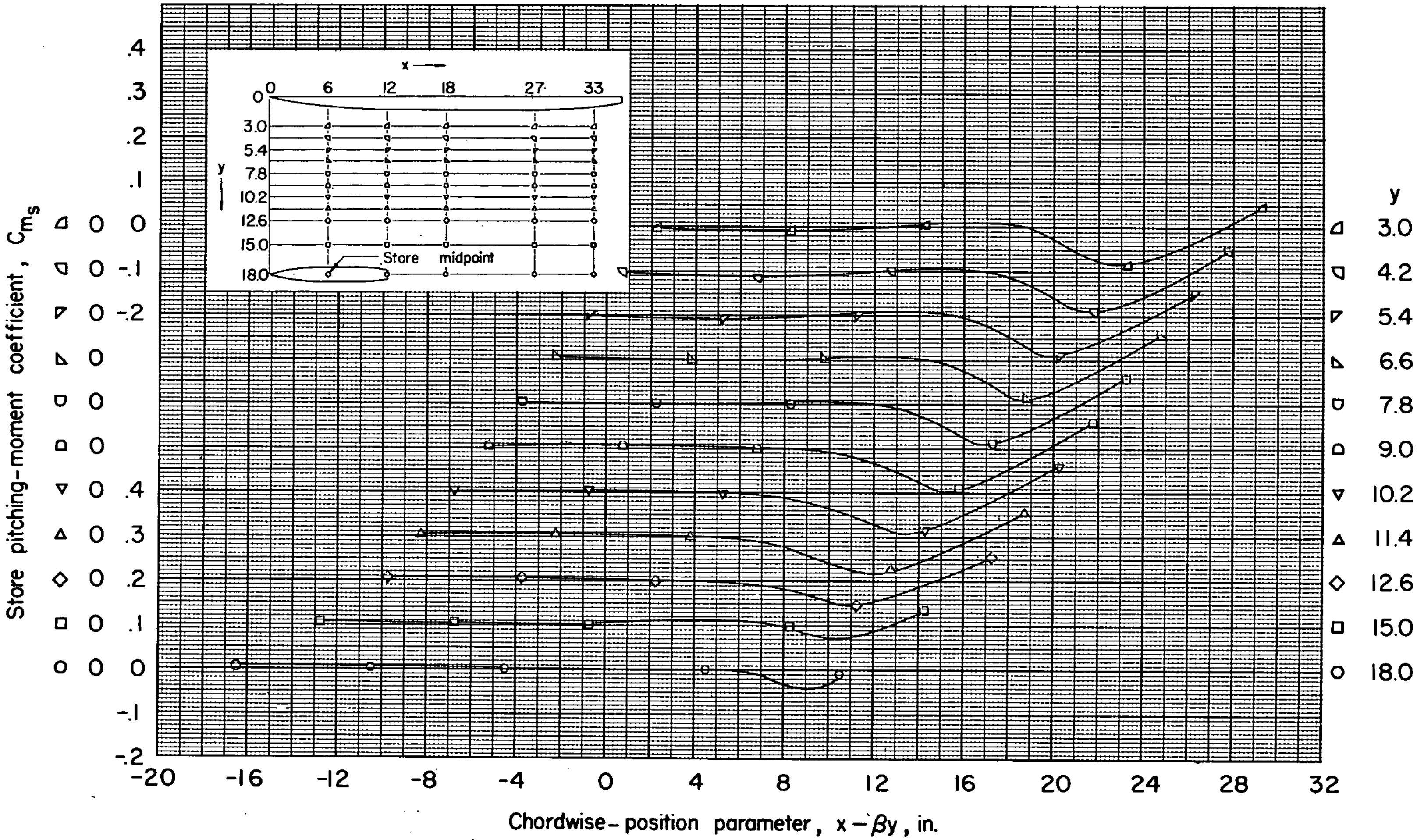
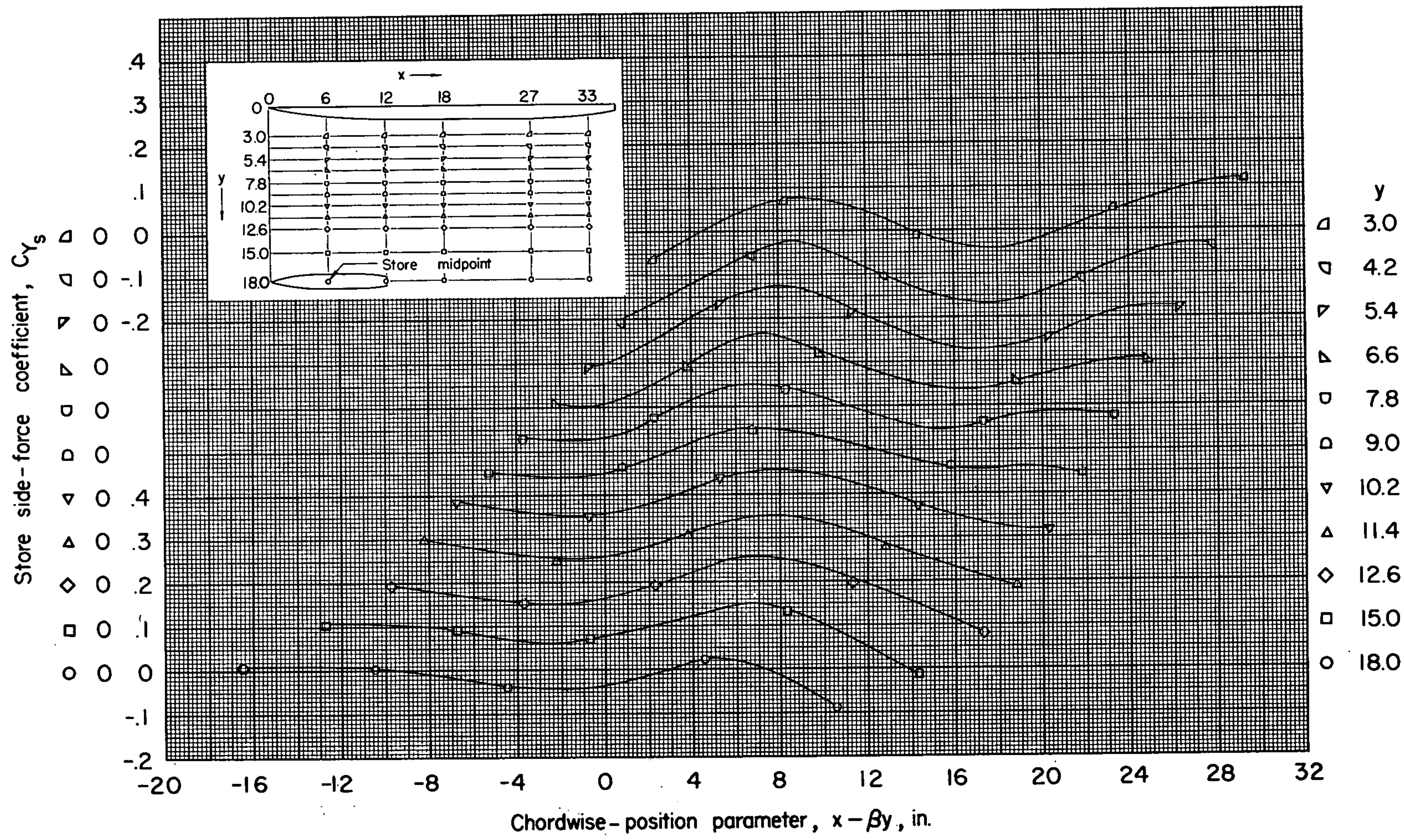
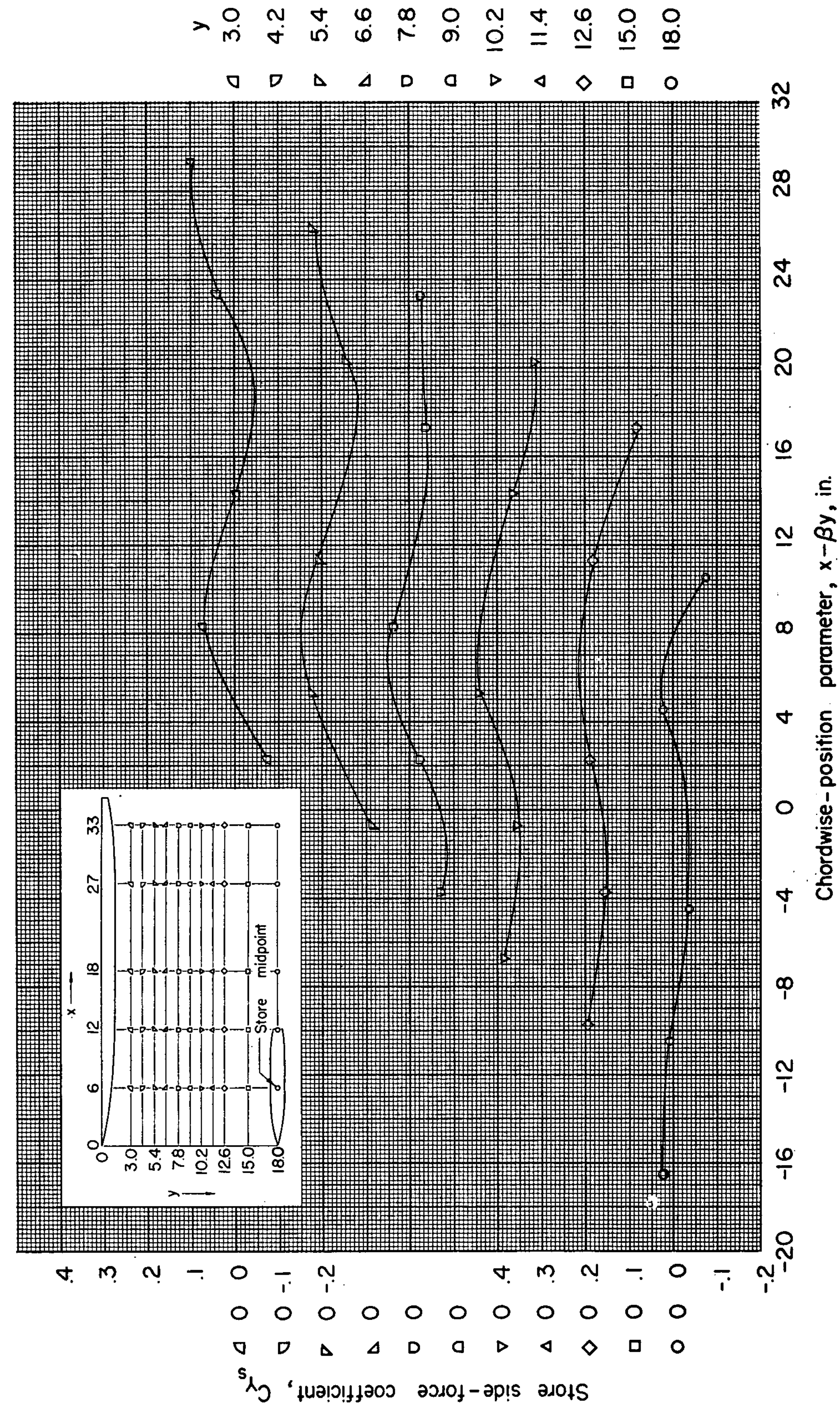


Figure 5.- Pitching moment of store in presence of fuselage (center of moments is store nose). $z = 1.15$ inches; $\alpha = 0^{\circ}$.



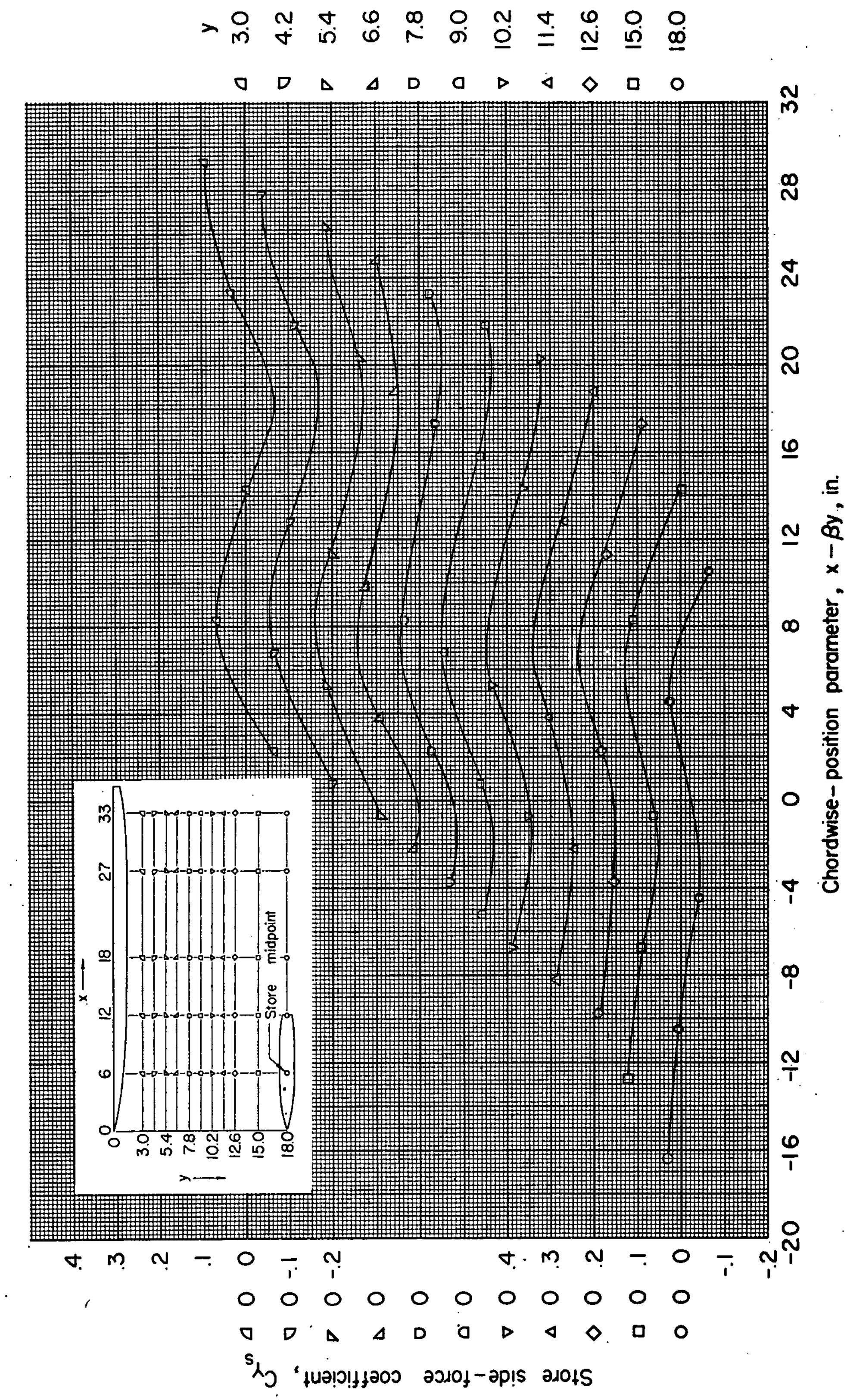
(a) z = 1.15 inches; α = 0°.

Figure 6.- Side force of store in presence of fuselage. M = 1.61.



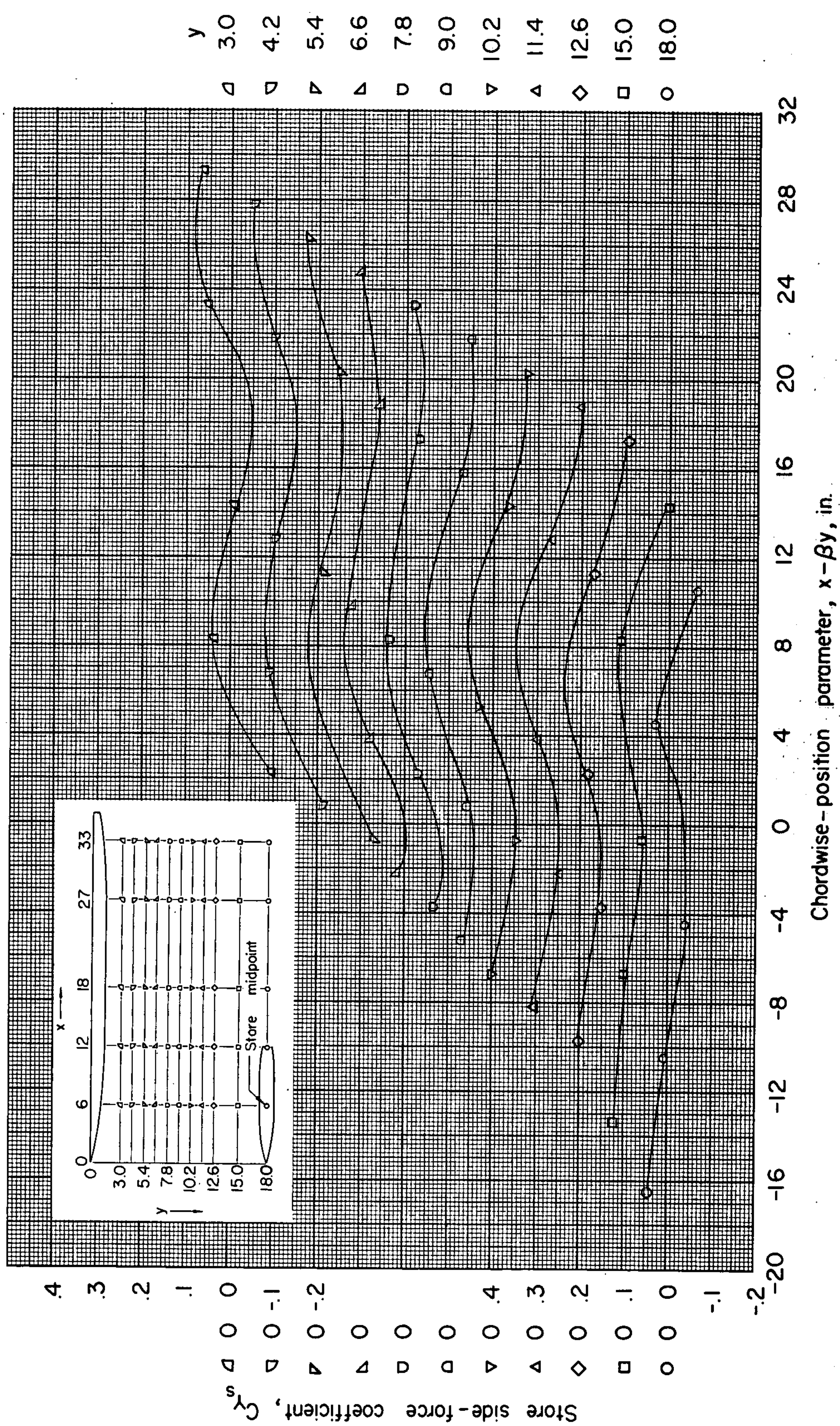
(b) $z = 1.67$ inches; $\alpha = 0^{\circ}$.

Figure 6.- Continued.



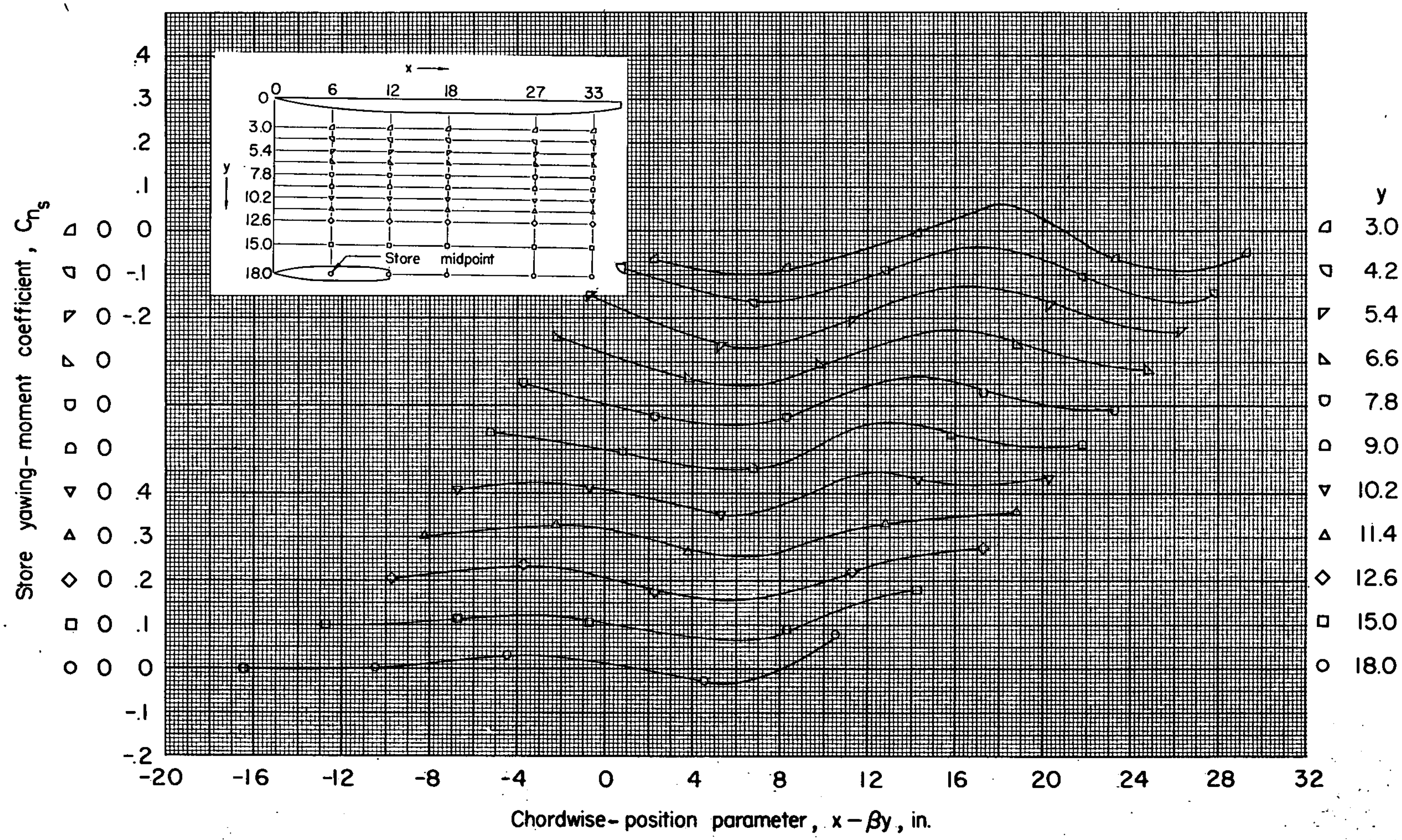
(c) z = 2.09 inches; α = 0°.

Figure 6.- Continued.



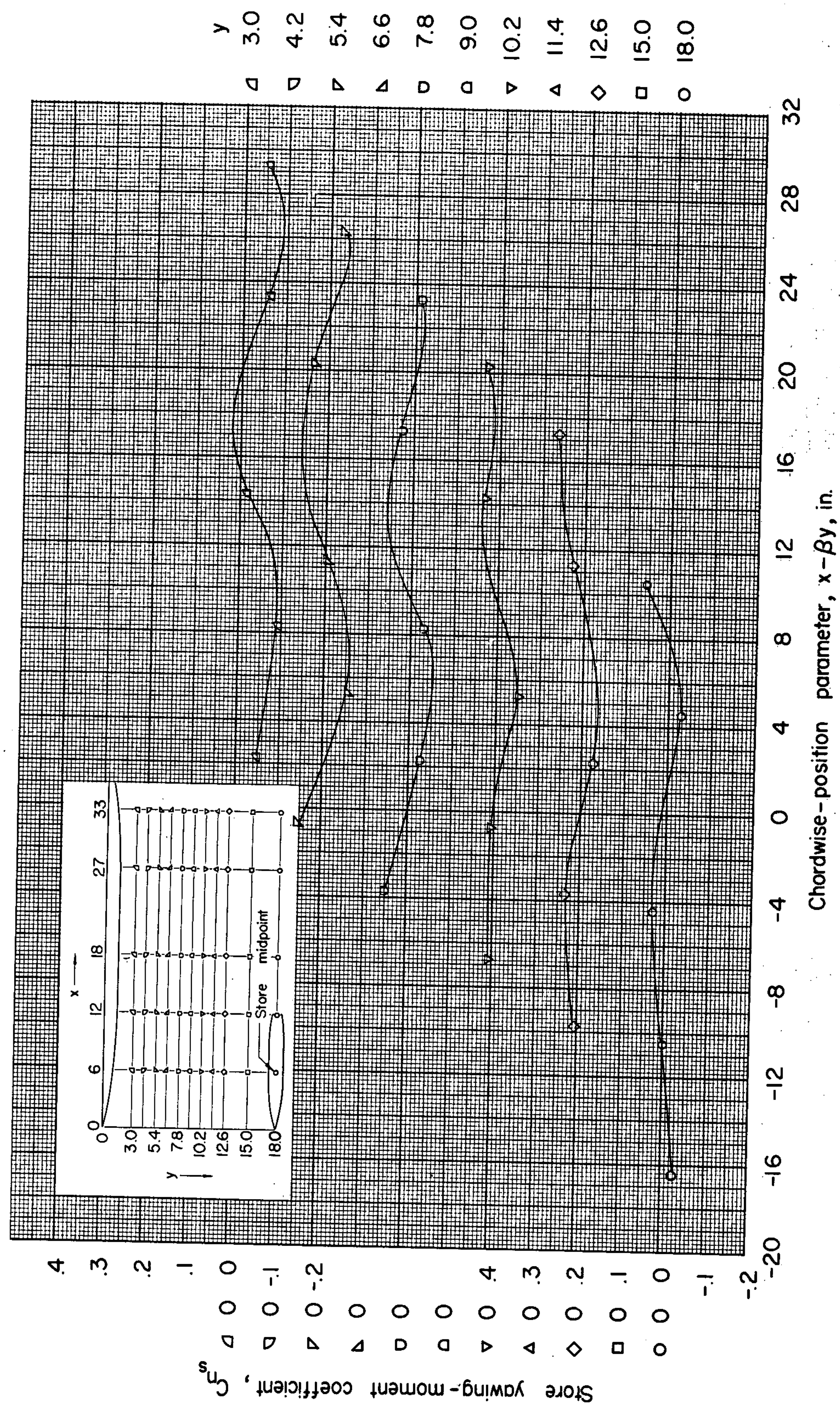
(d) $z = 2.09$ inches; $\alpha = 4^{\circ}$.

Figure 6.- Concluded.



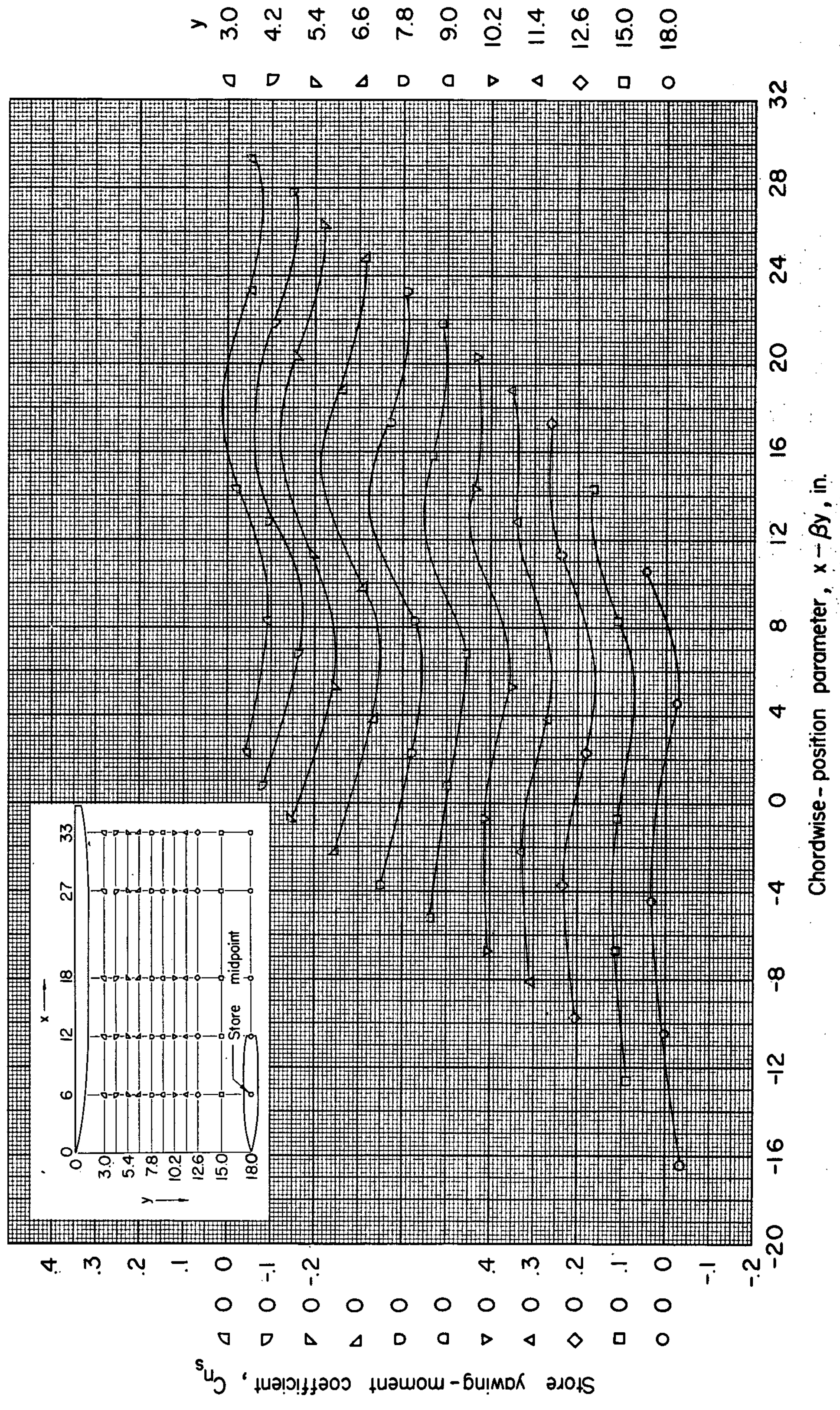
(a) $z = 1.15$ inches; $\alpha = 0^{\circ}$.

Figure 7.- Yawing moment of store in presence of fuselage (center of moments is store nose). $M = 1.61$.



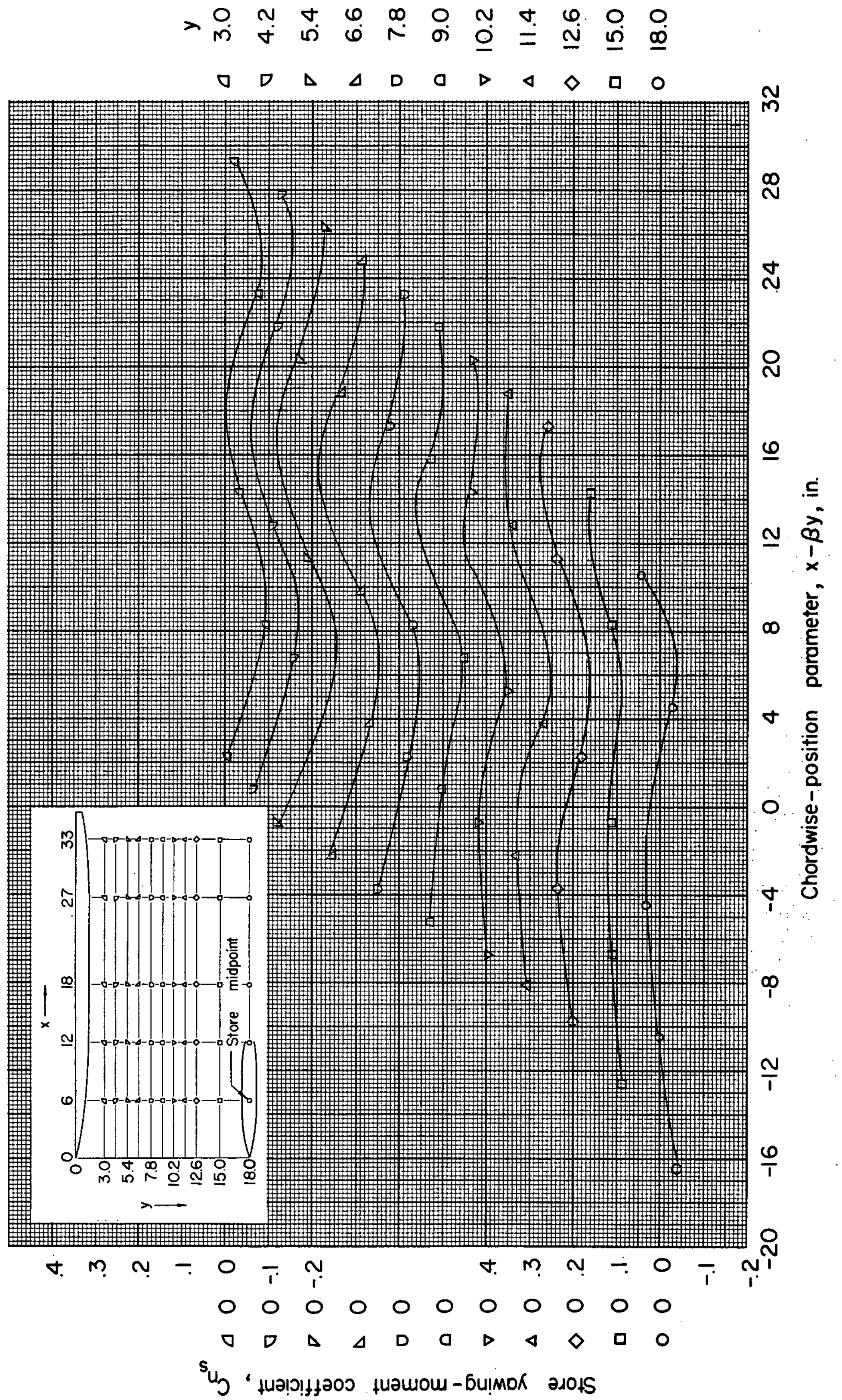
(b) $z = 1.67$ inches; $\alpha = 0^{\circ}$.

Figure 7.- Continued.



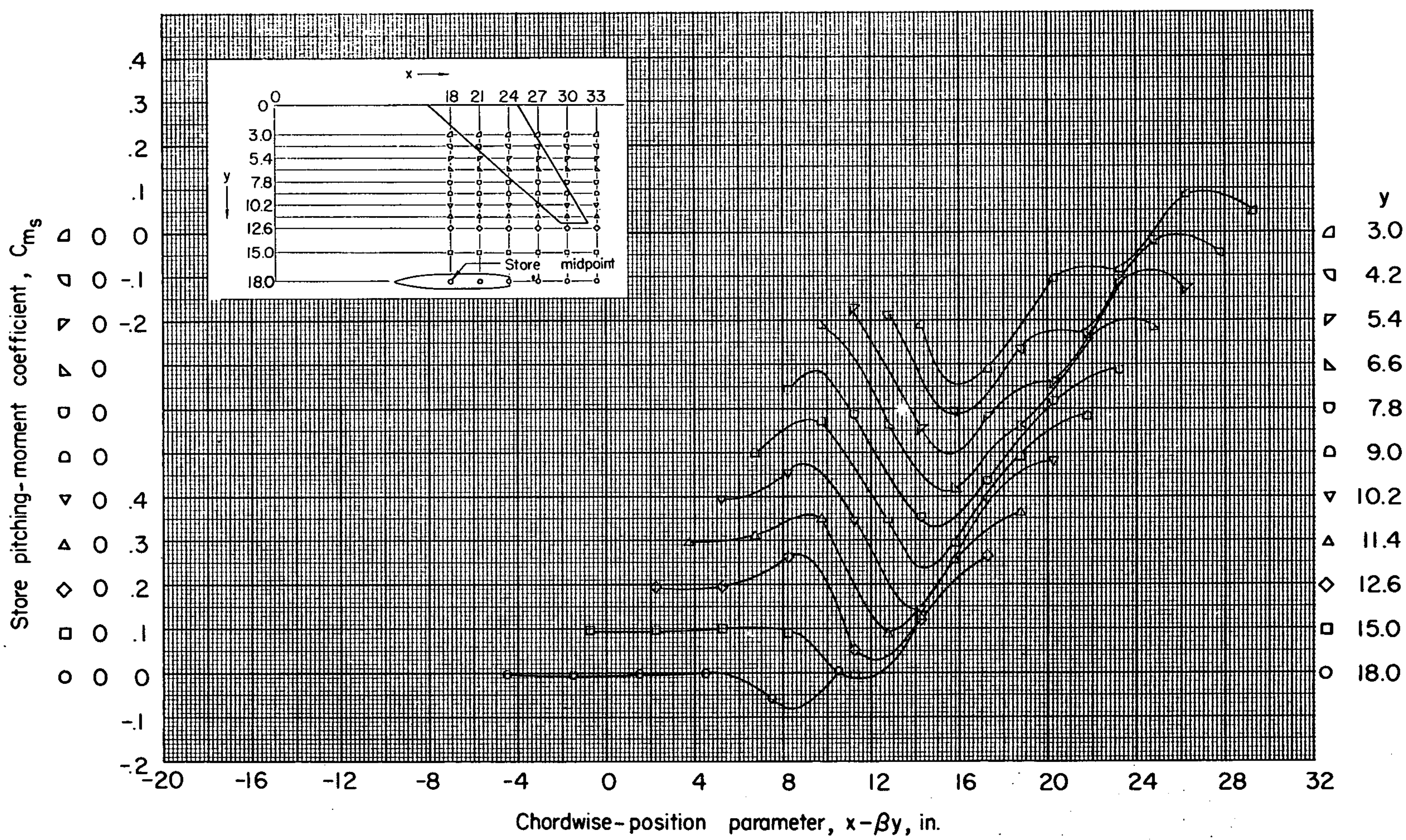
(c) z = 2.09 inches; α = 0°.

Figure 7.- Continued.



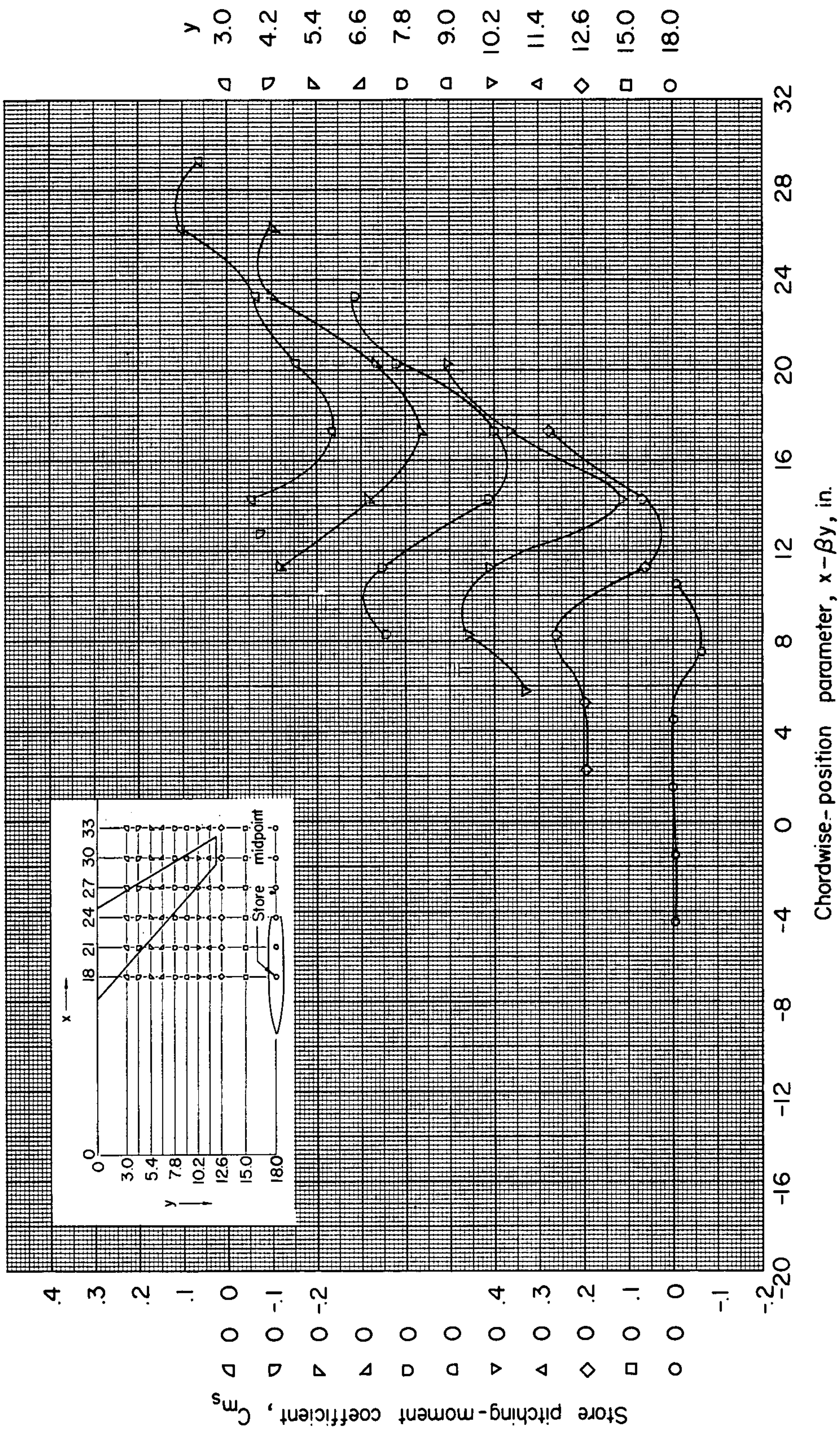
(d) z = 2.09 inches; α = 4°.

Figure 7.- Concluded.



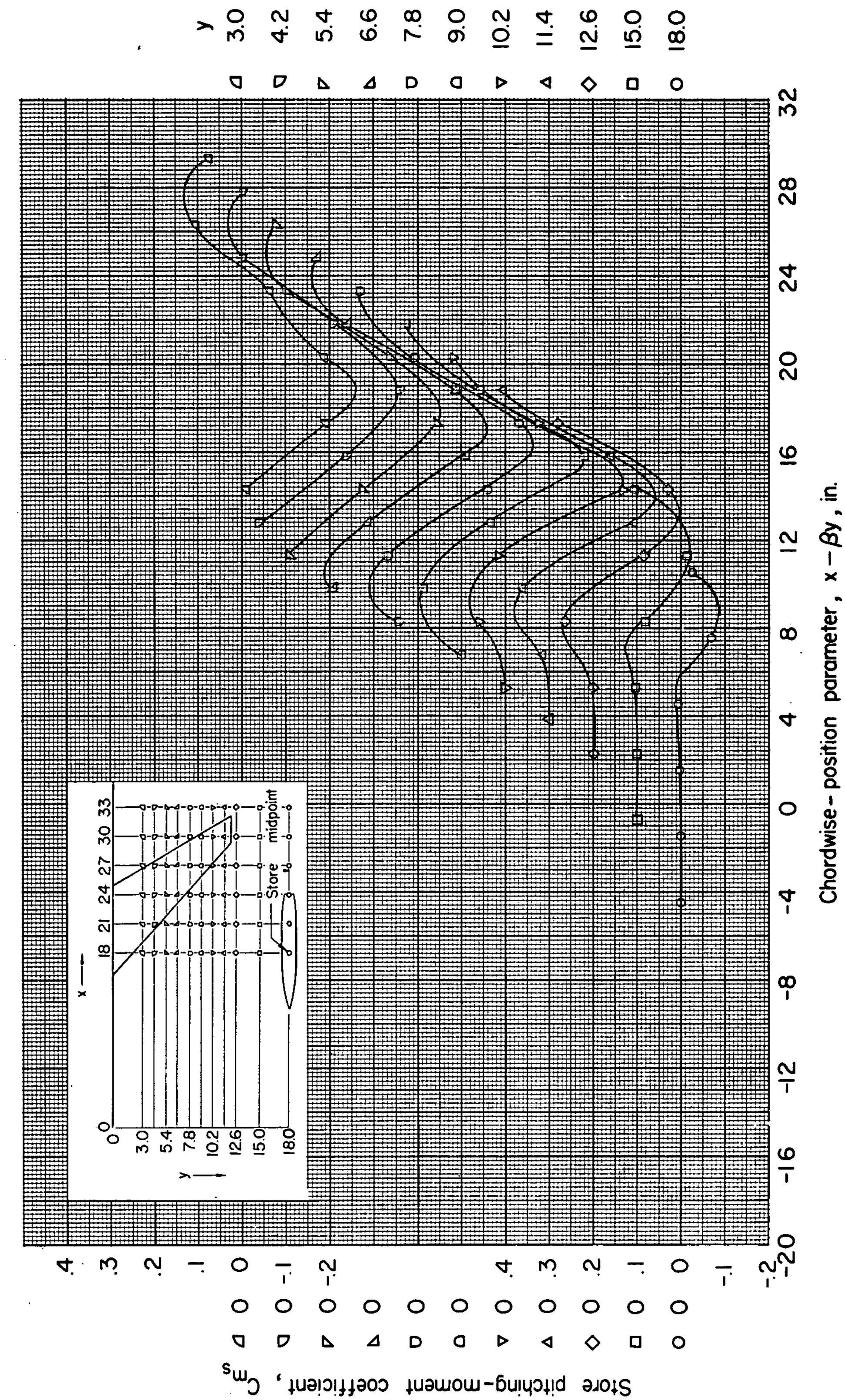
(a) z = 1.15 inches; α = 0°.

Figure 8.- Pitching moment of store in presence of wing (center of moments is store nose). M = 1.61.



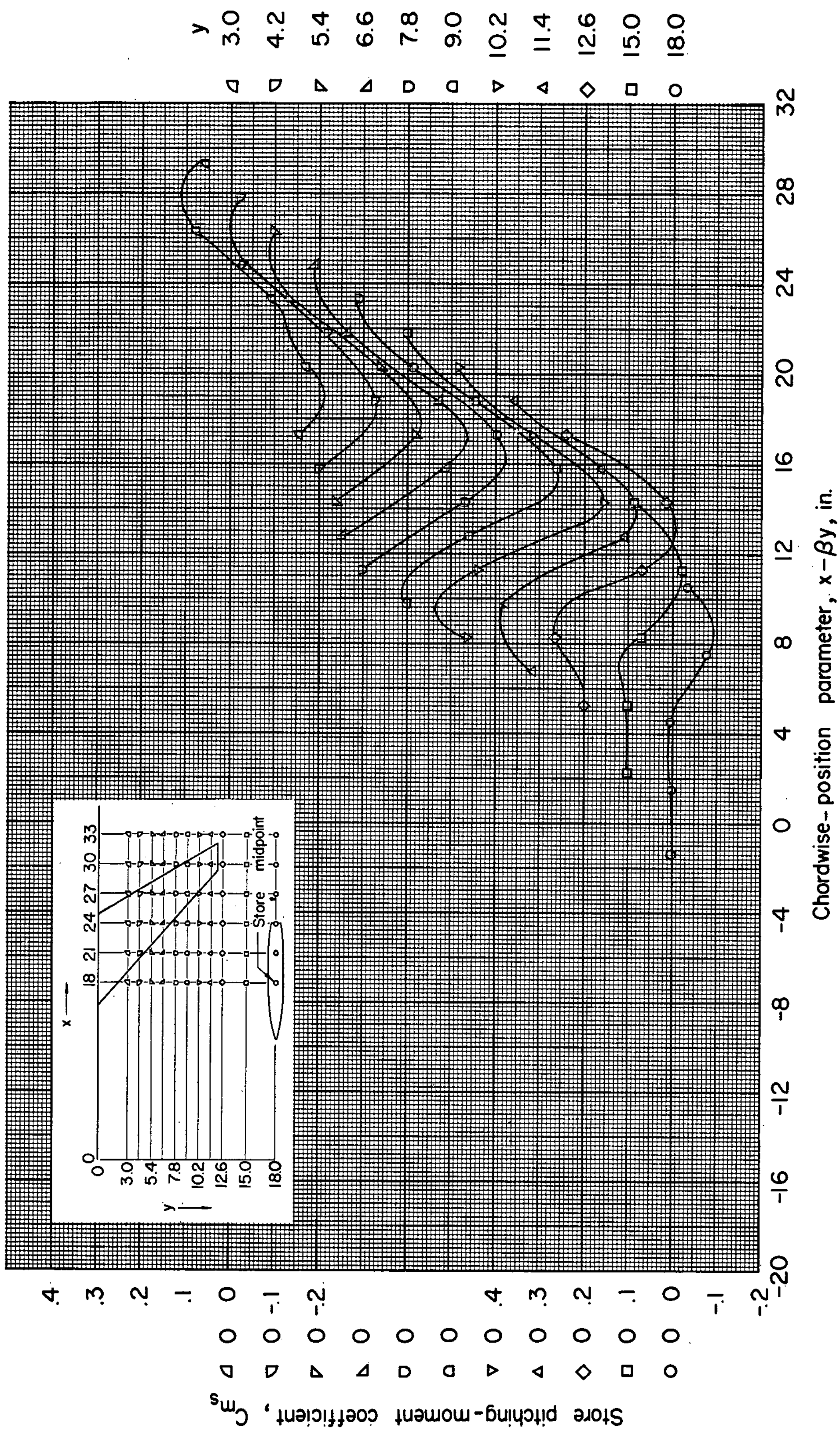
(b) z = 1.67 inches; α = 0°.

Figure 8.- Continued.



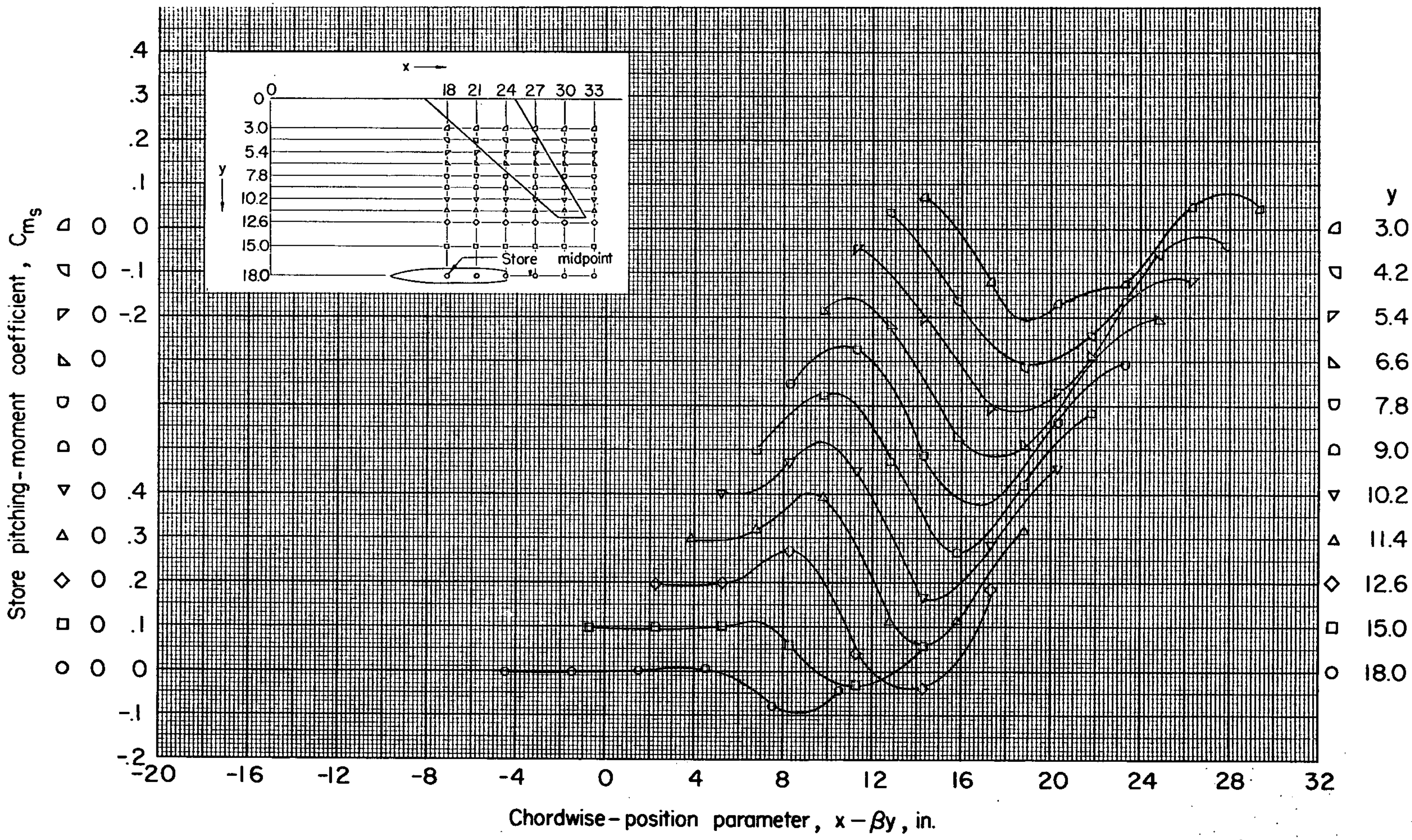
(c) z = 2.09 inches; α = 0°.

Figure 8.- Continued.



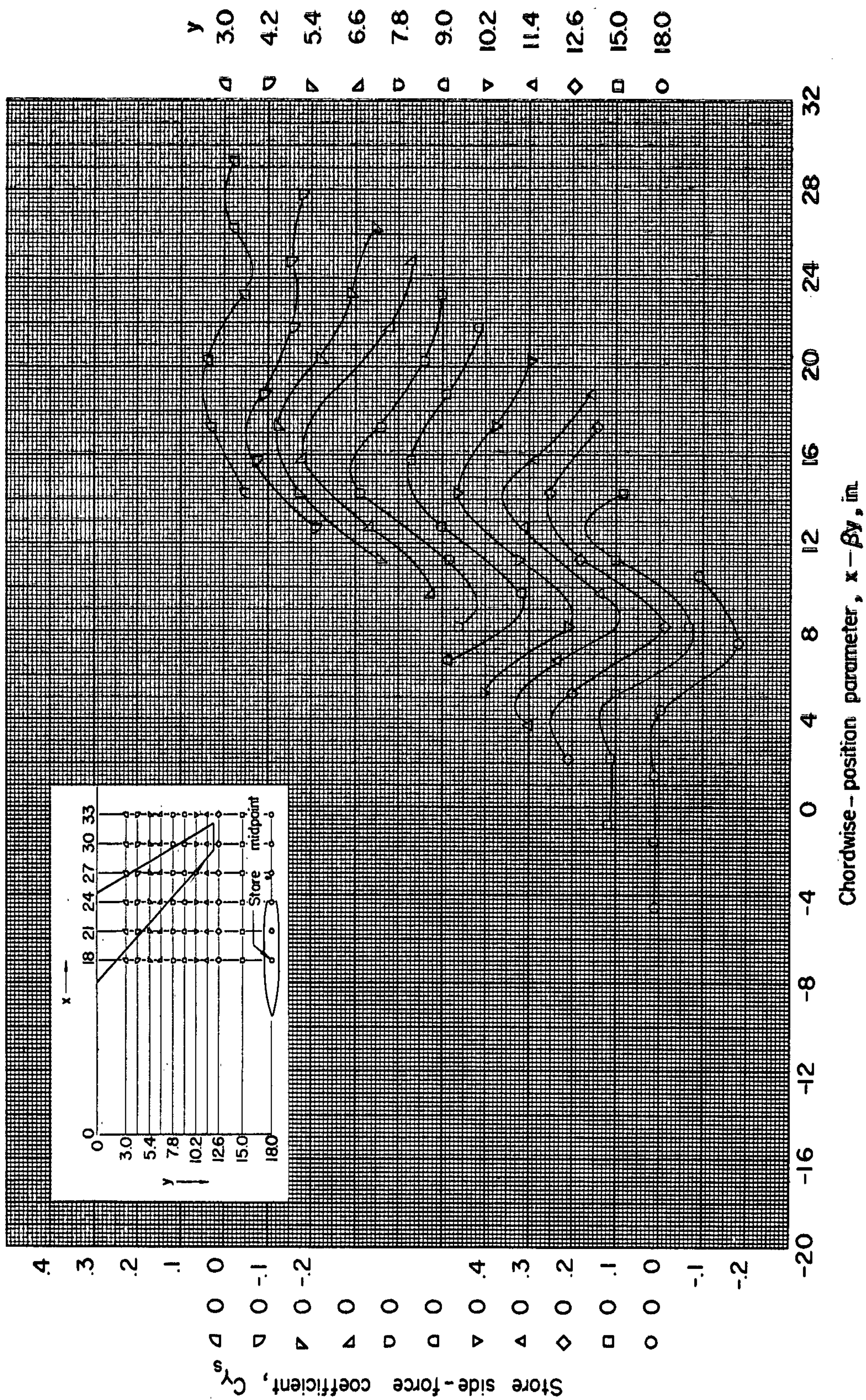
(d) z = 2.09 inches; α = 2°.

Figure 8.- Continued.



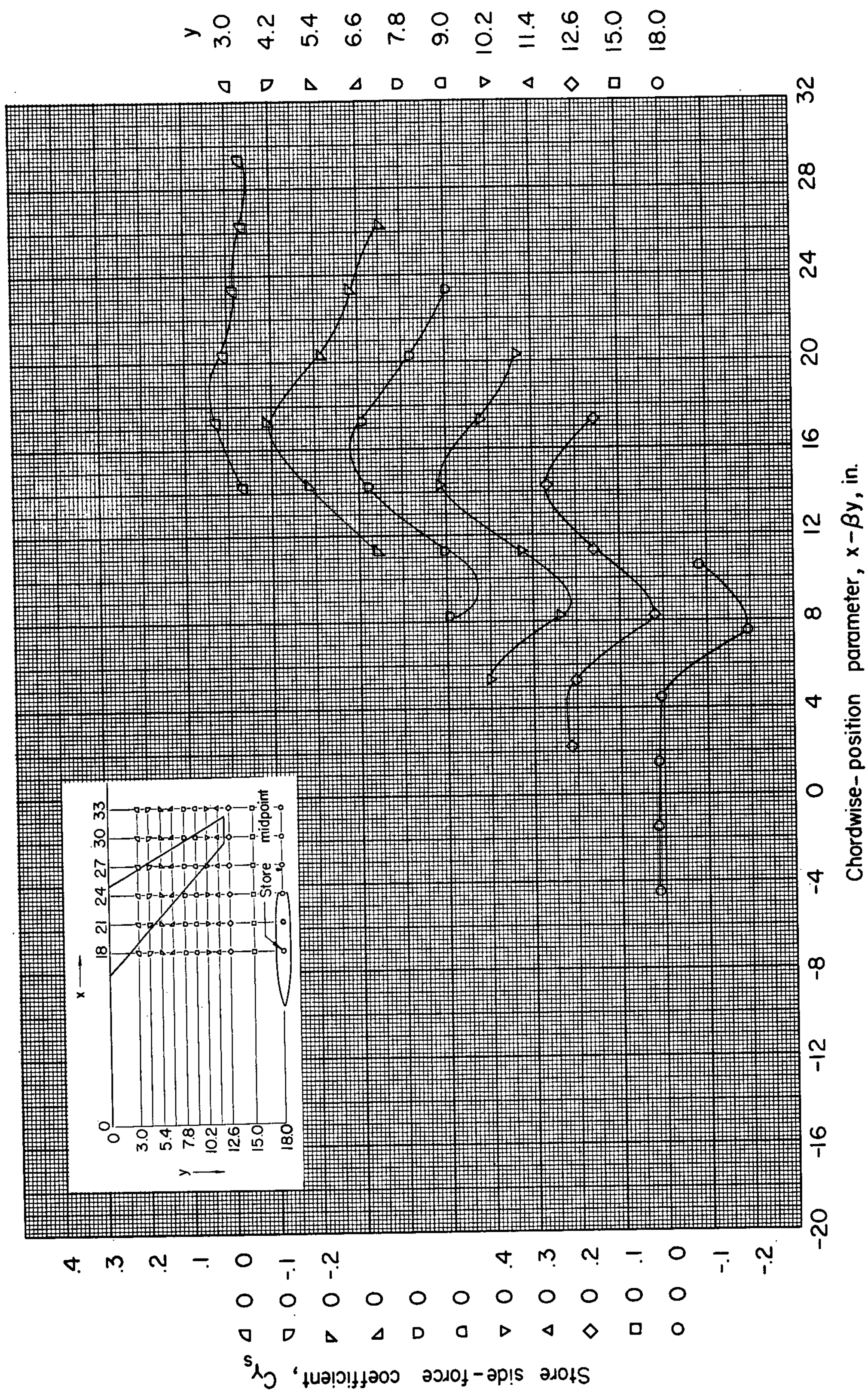
(e) $z = 2.09$ inches; $\alpha = 4^{\circ}$.

Figure 8.- Concluded.



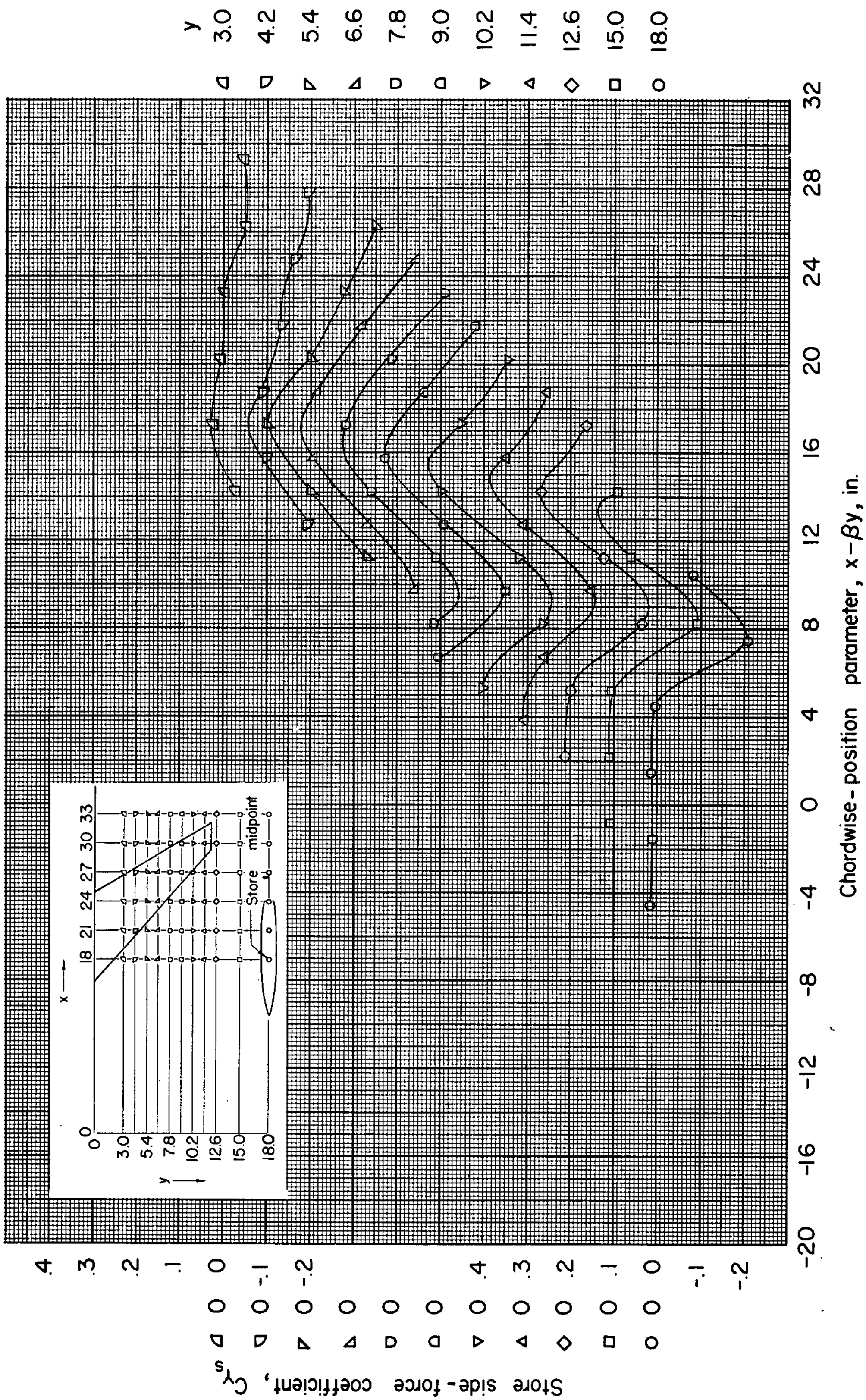
(a) z = 1.15 inches; α = 0°.

Figure 9.- Side force of store in presence of wing. M = 1.61.



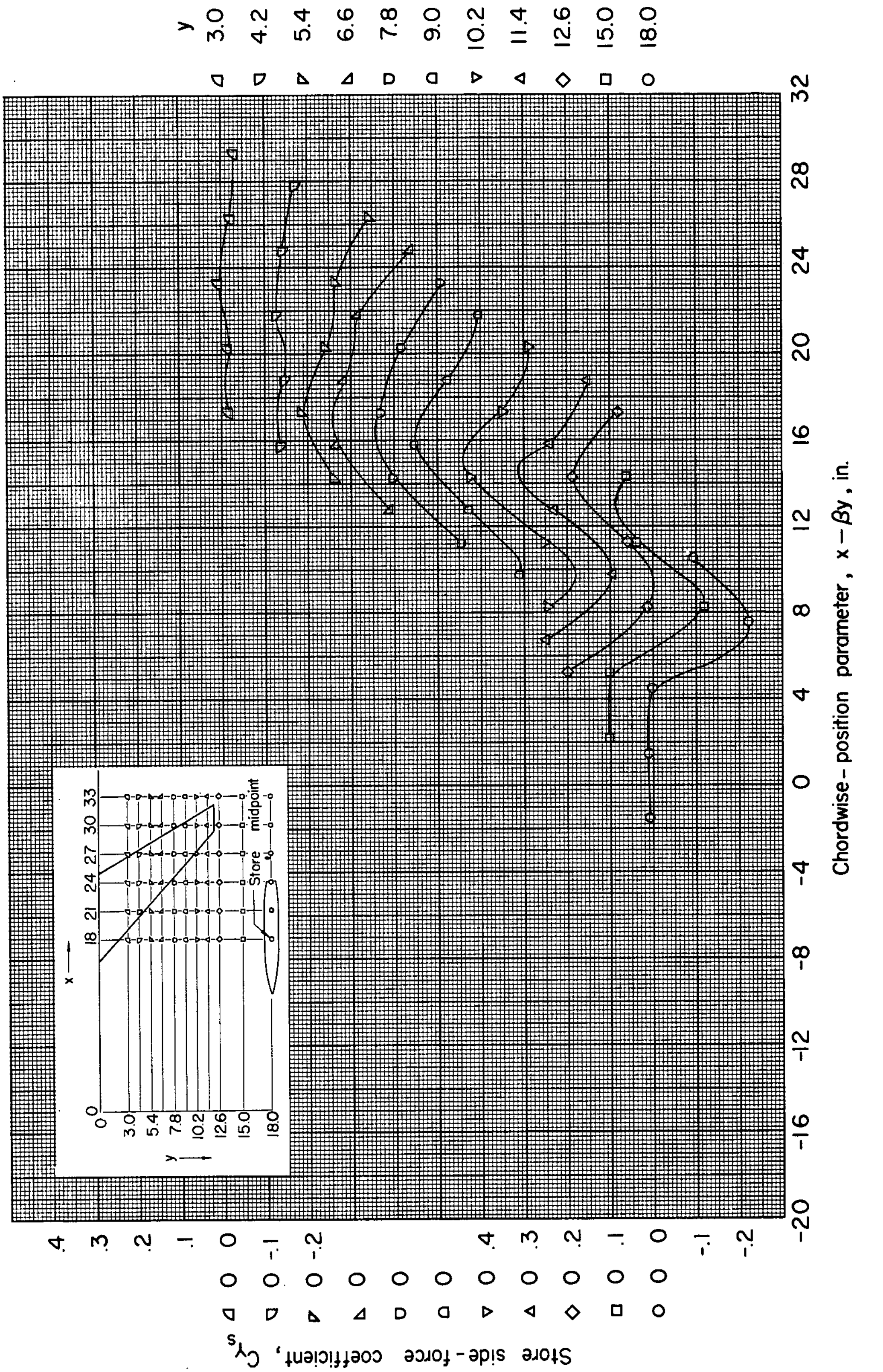
(b) z = 1.67 inches; α = 0°.

Figure 9.- Continued.



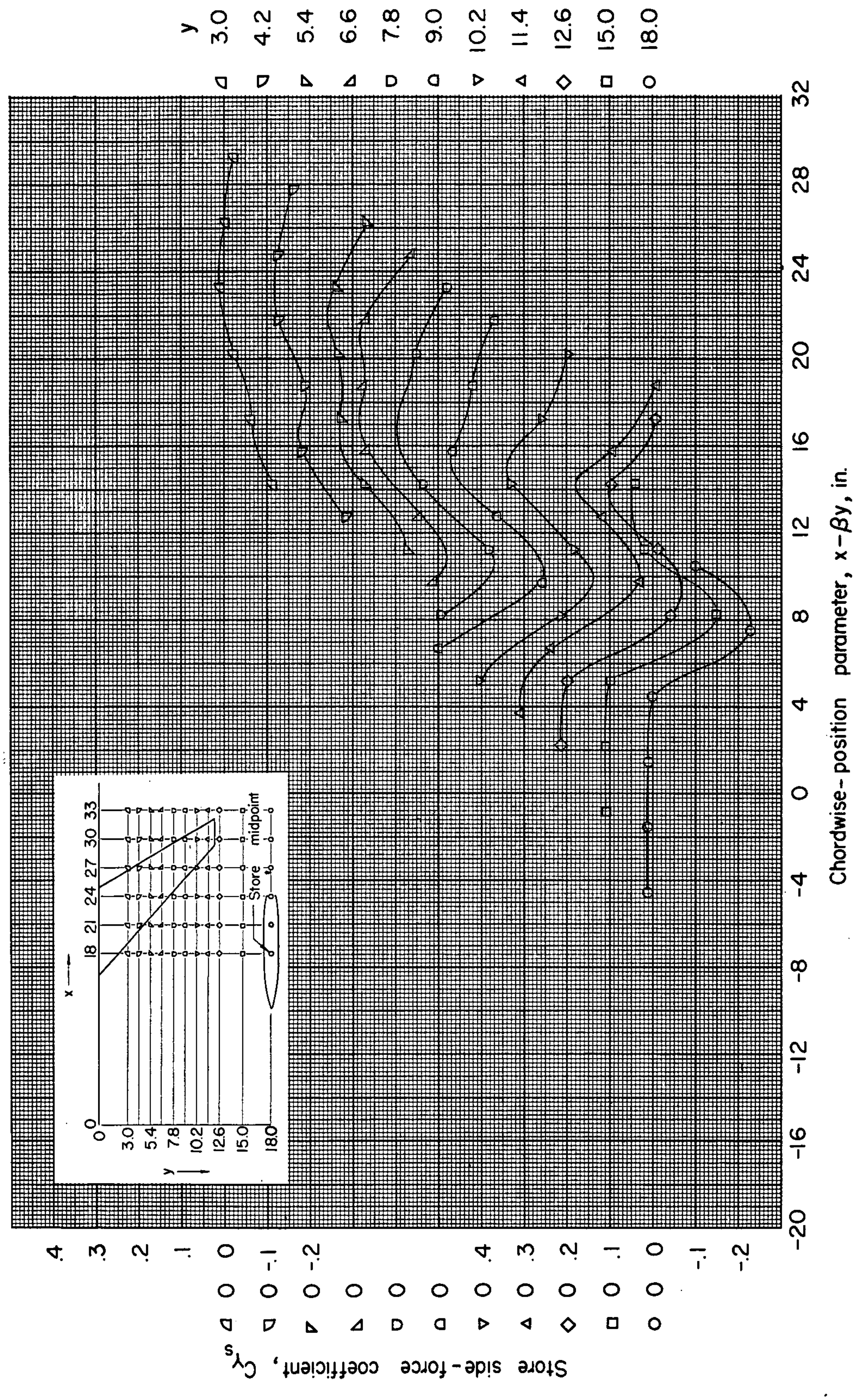
(c) $z = 2.09$ inches; $\alpha = 0^\circ$.

Figure 9.- Continued.



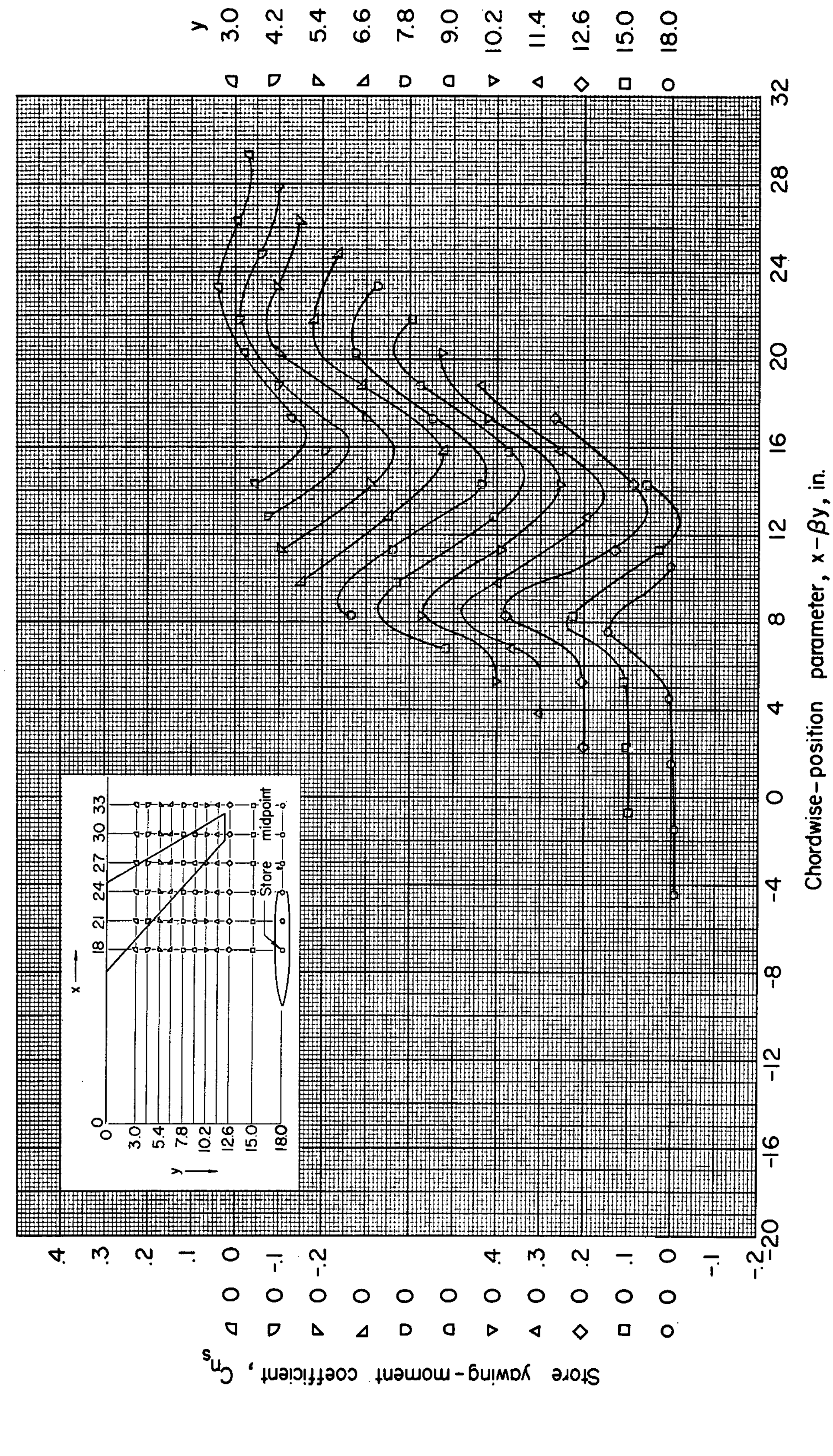
(d) z = 2.09 inches; α = 2°.

Figure 9.- Continued.



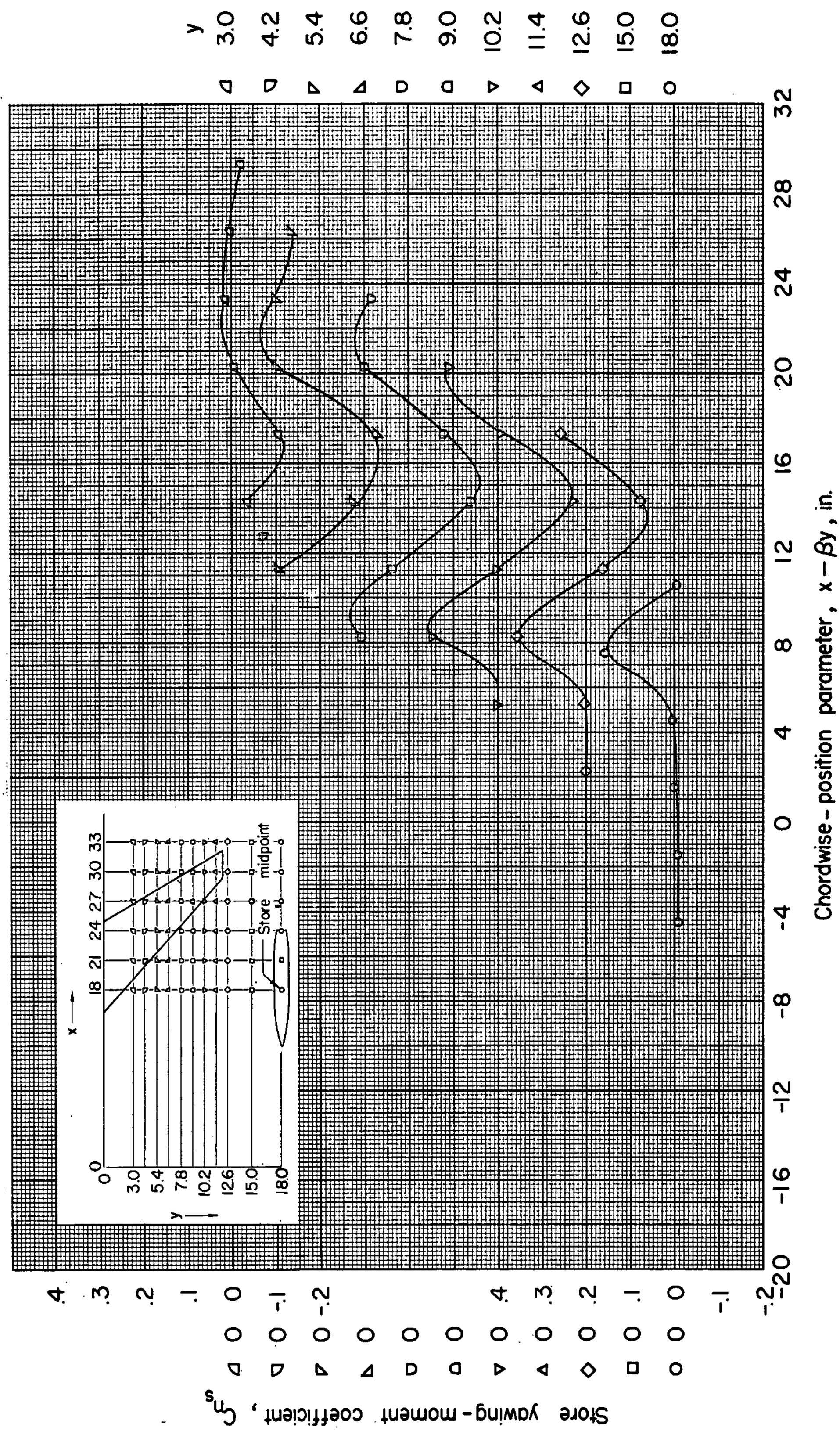
(e) z = 2.09 inches; α = 4°.

Figure 9.- Concluded.



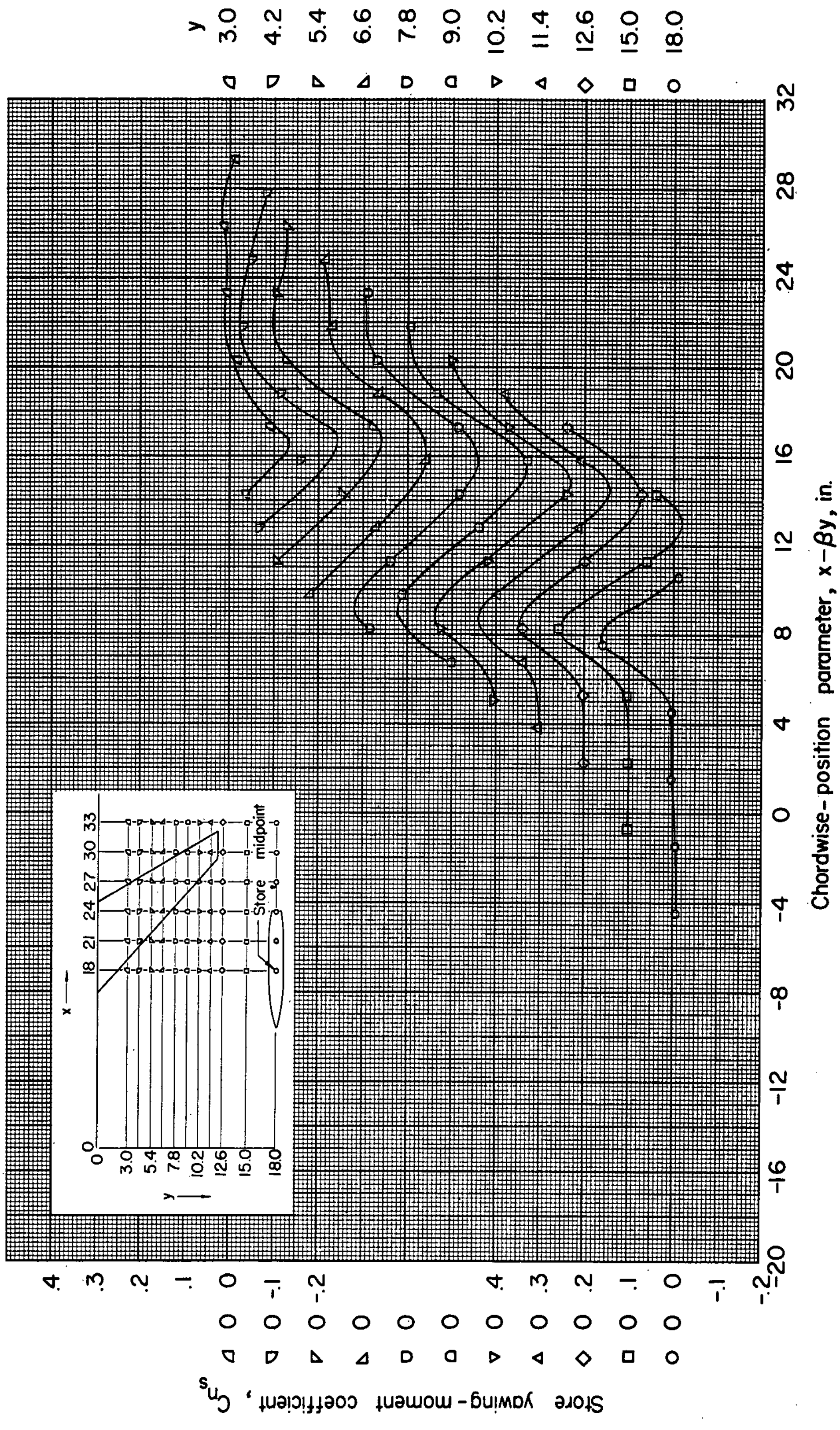
(a) z = 1.15 inches; α = 0°.

Figure 10.- Yawing moment of store in presence of wing (center of moments is store nose). M = 1.61.



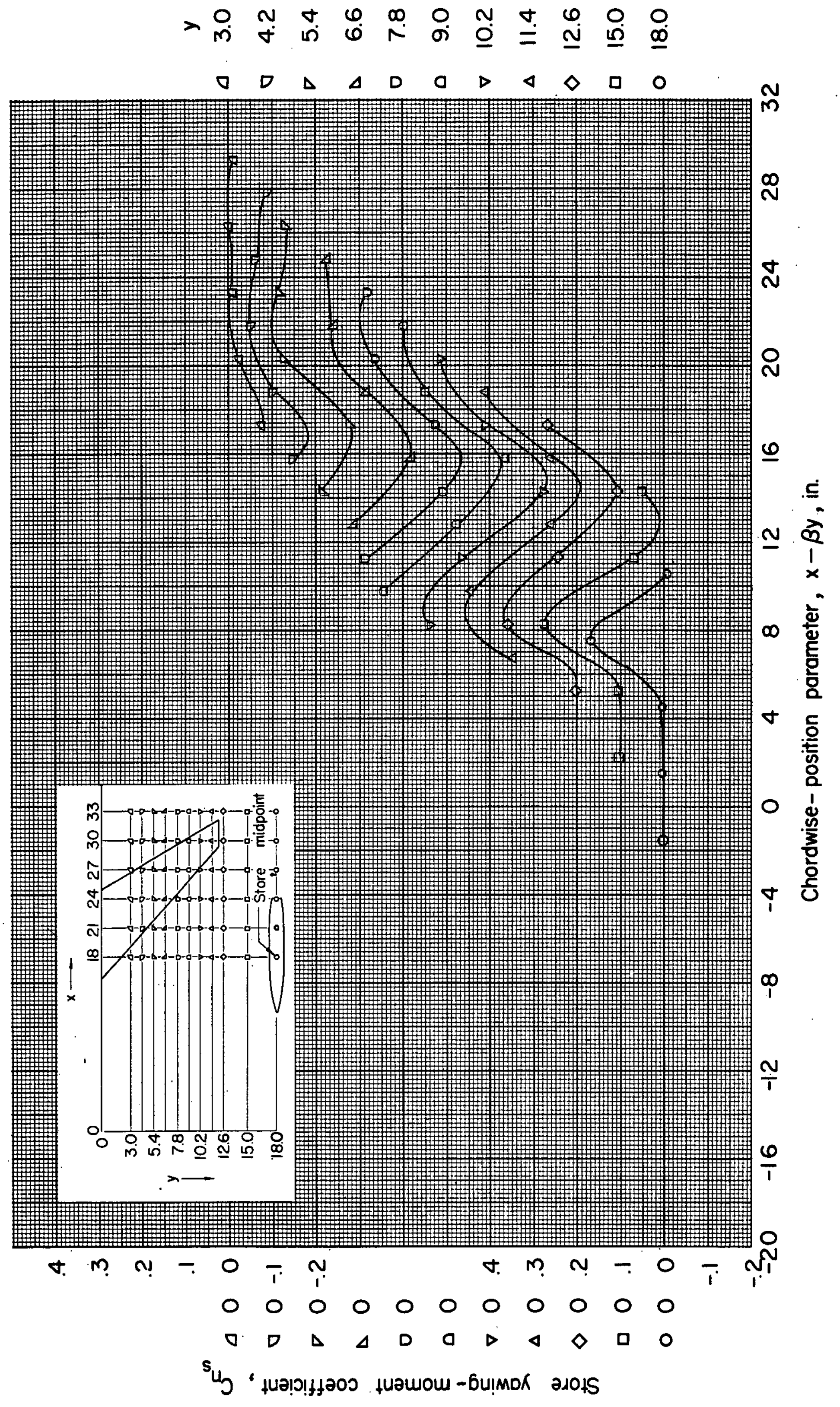
(b) z = 1.67 inches; α = 0°.

Figure 10.- Continued.



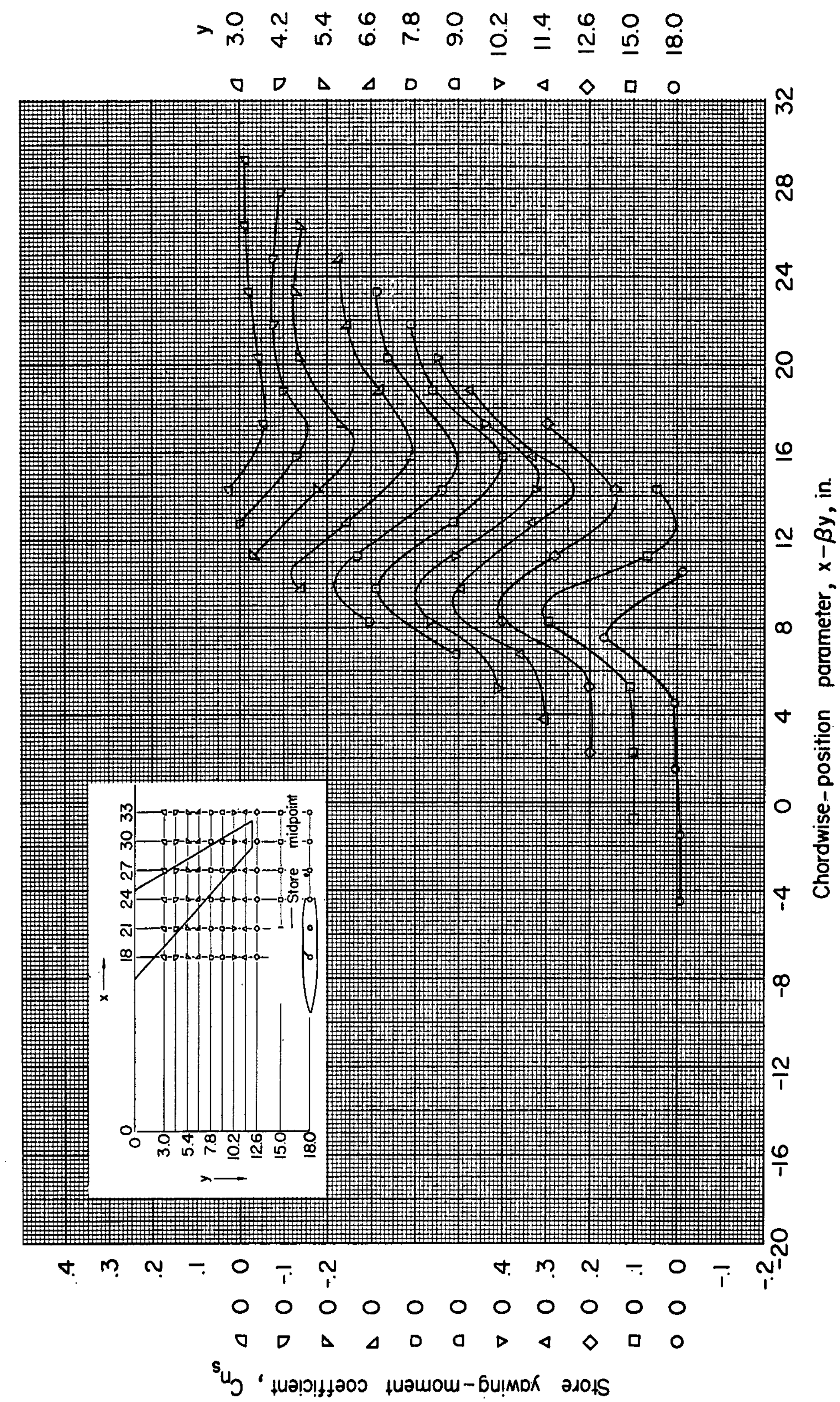
(c) z = 2.09 inches; α = 0°.

Figure 10.- Continued.



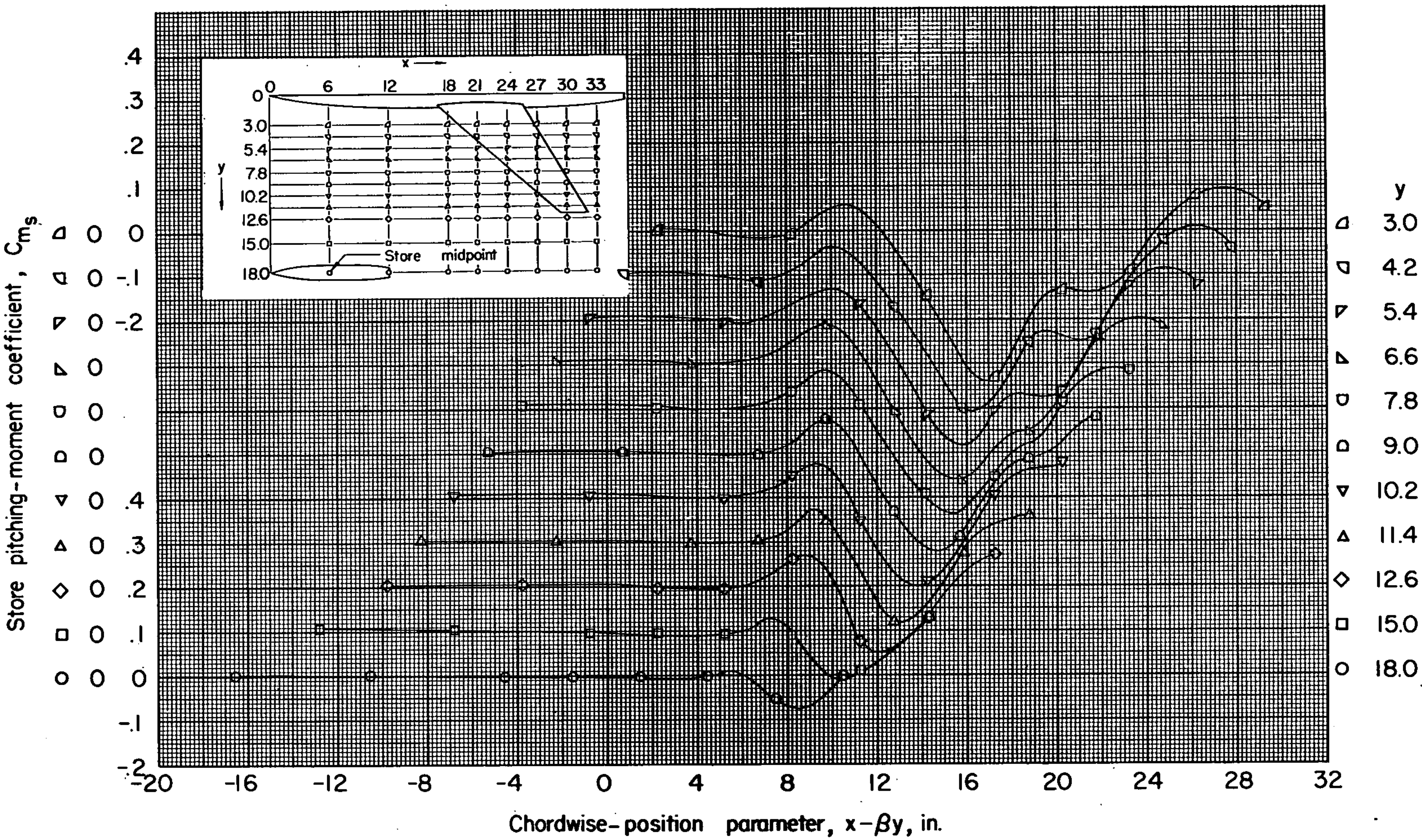
(d) z = 2.09 inches; α = 2°.

Figure 10.- Continued.



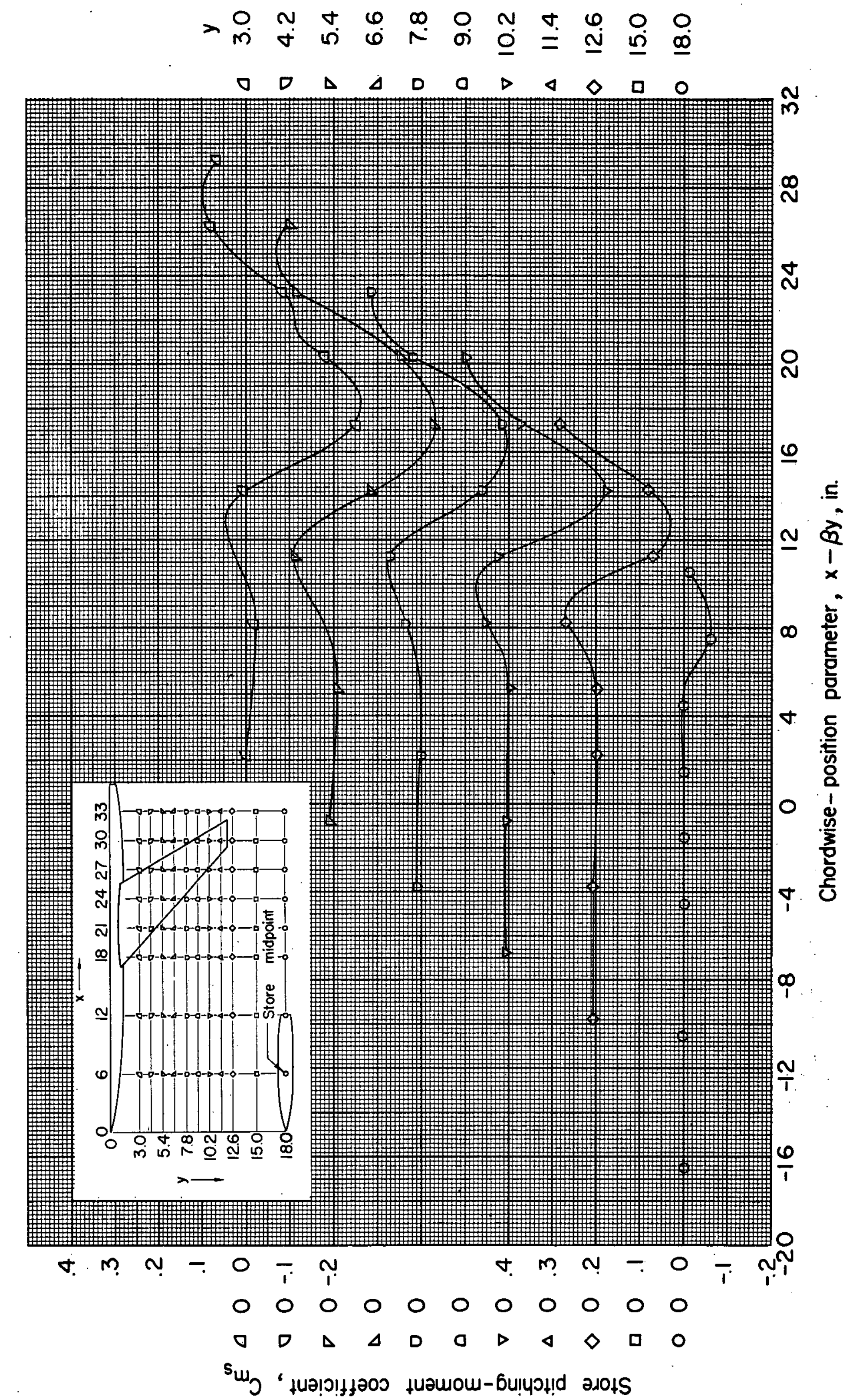
(e) z = 2.09 inches; α = 4°.

Figure 10.- Concluded.



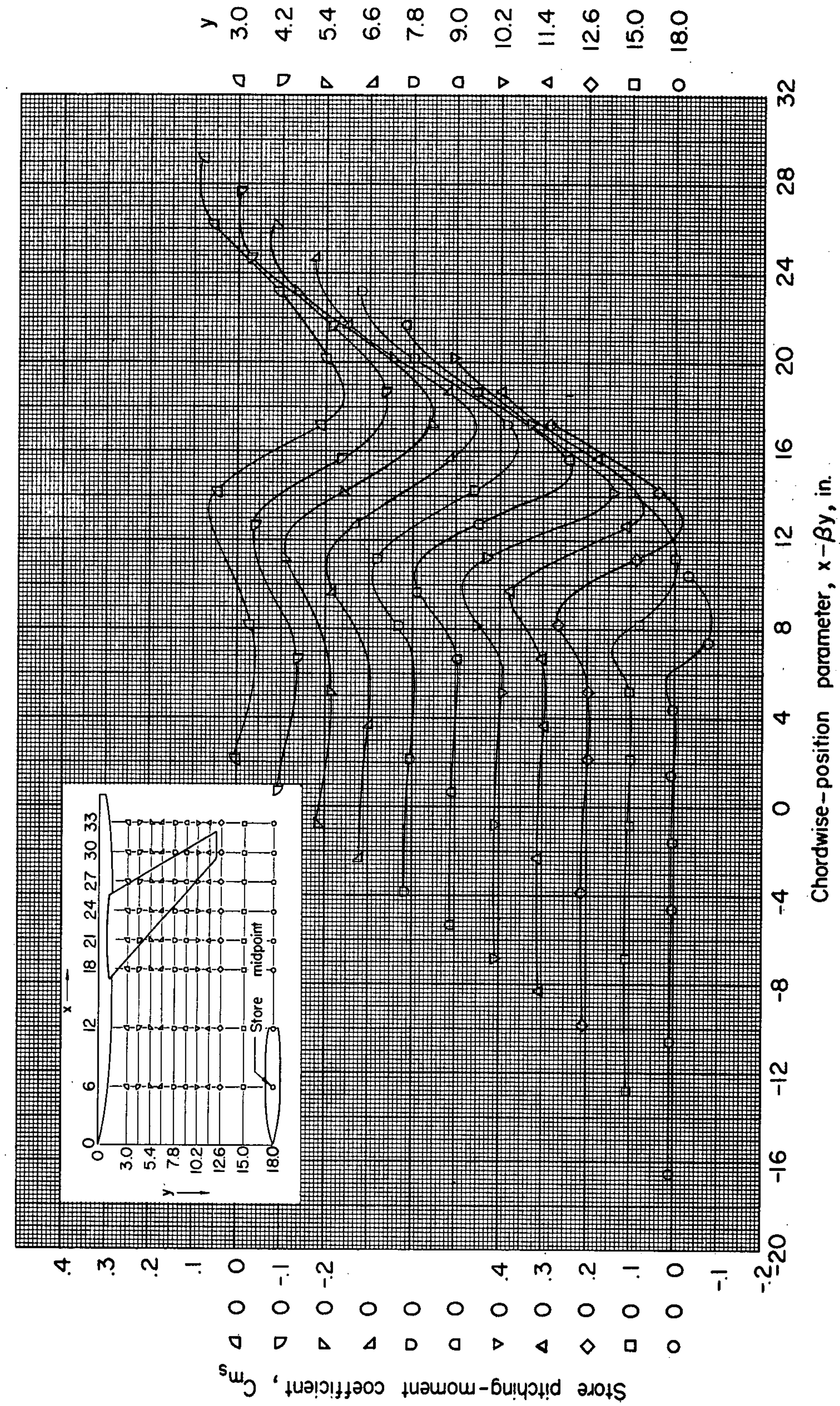
(a) z = 1.15 inches; α = 0°.

Figure 11 - Pitching moment of store in presence of wing-fuselage combi-



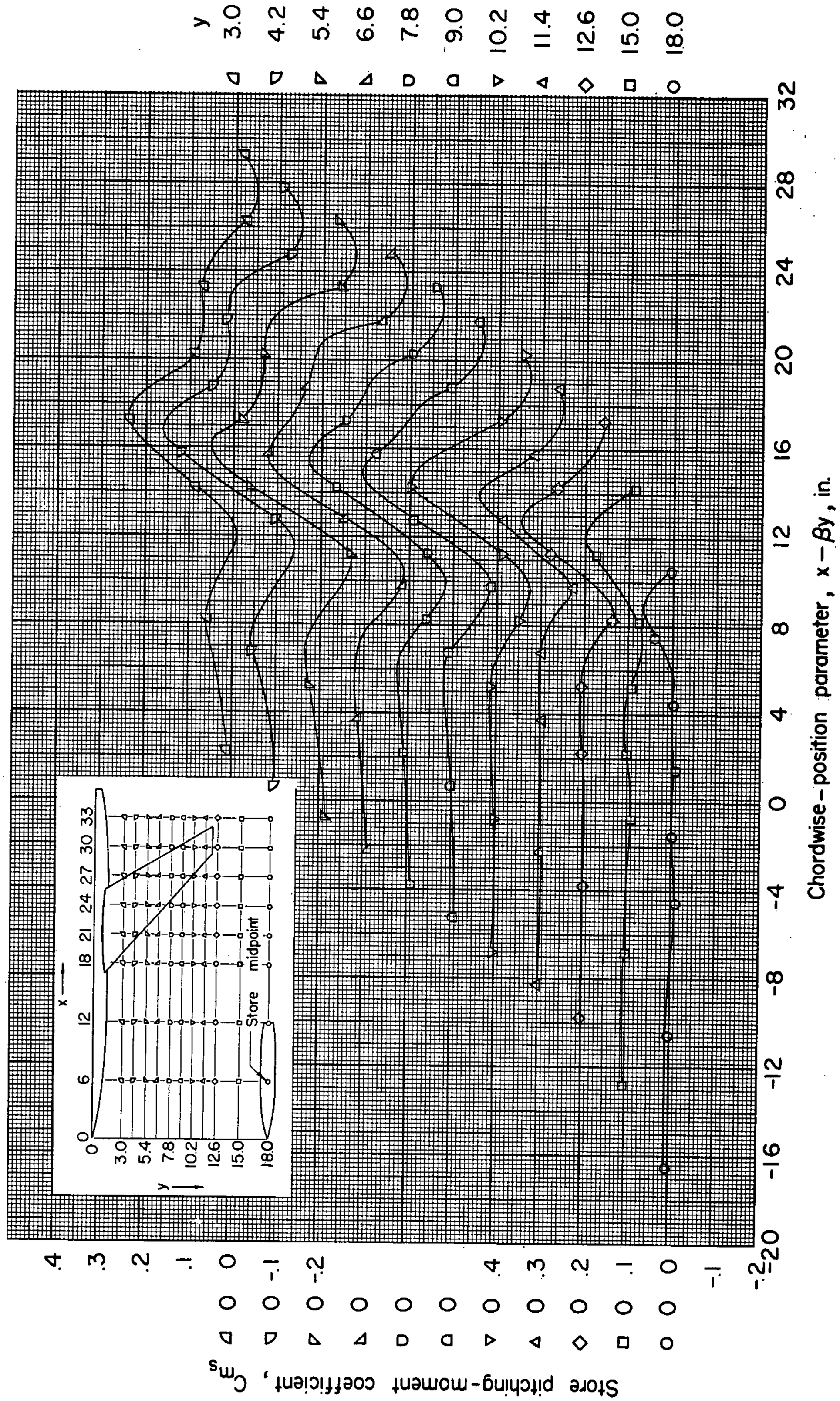
(b) z = 1.67 inches; α = 0°.

Figure 11.- Continued.



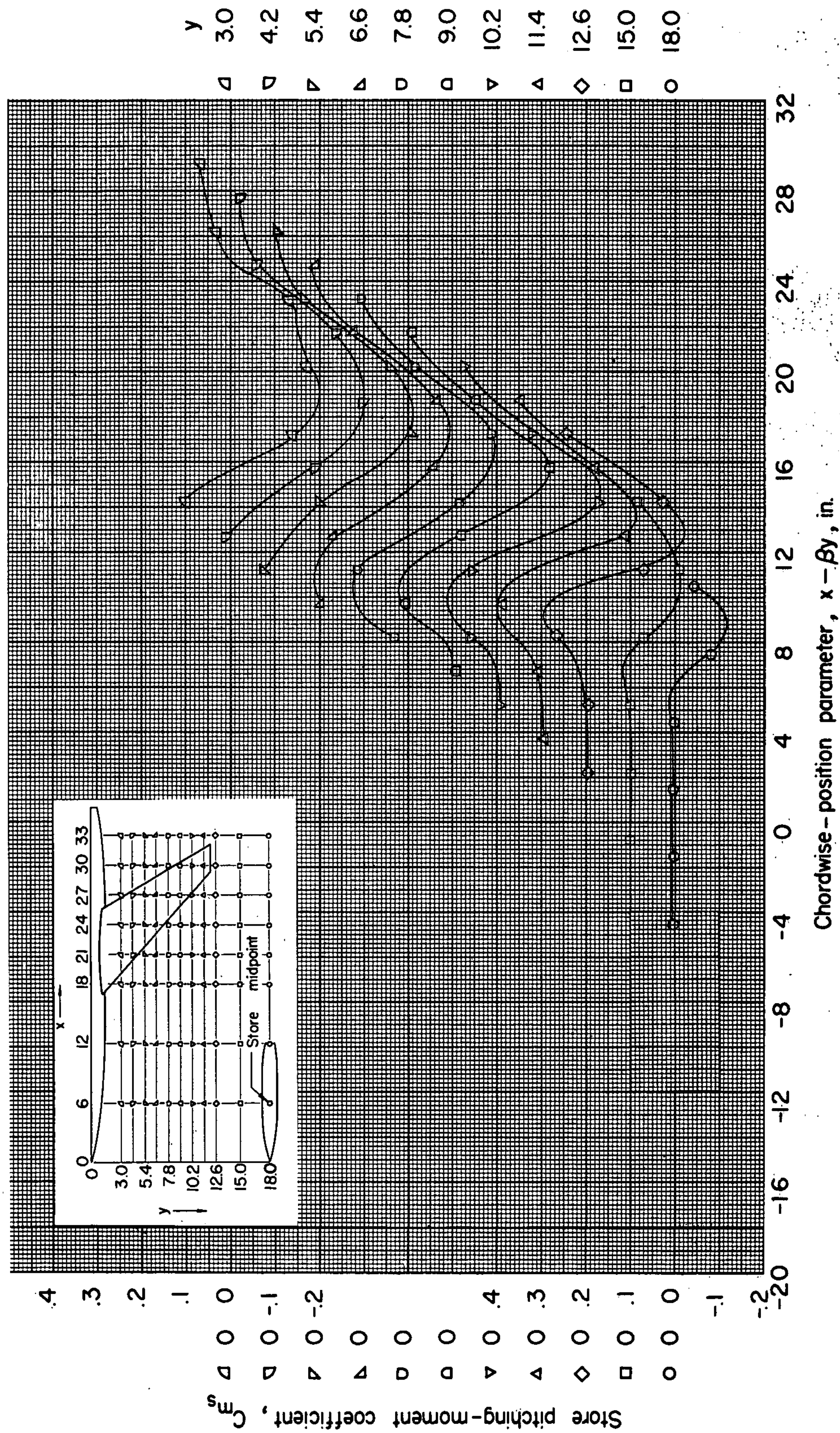
(c) z = 2.09 inches; α = 0°.

Figure 11.- Continued.



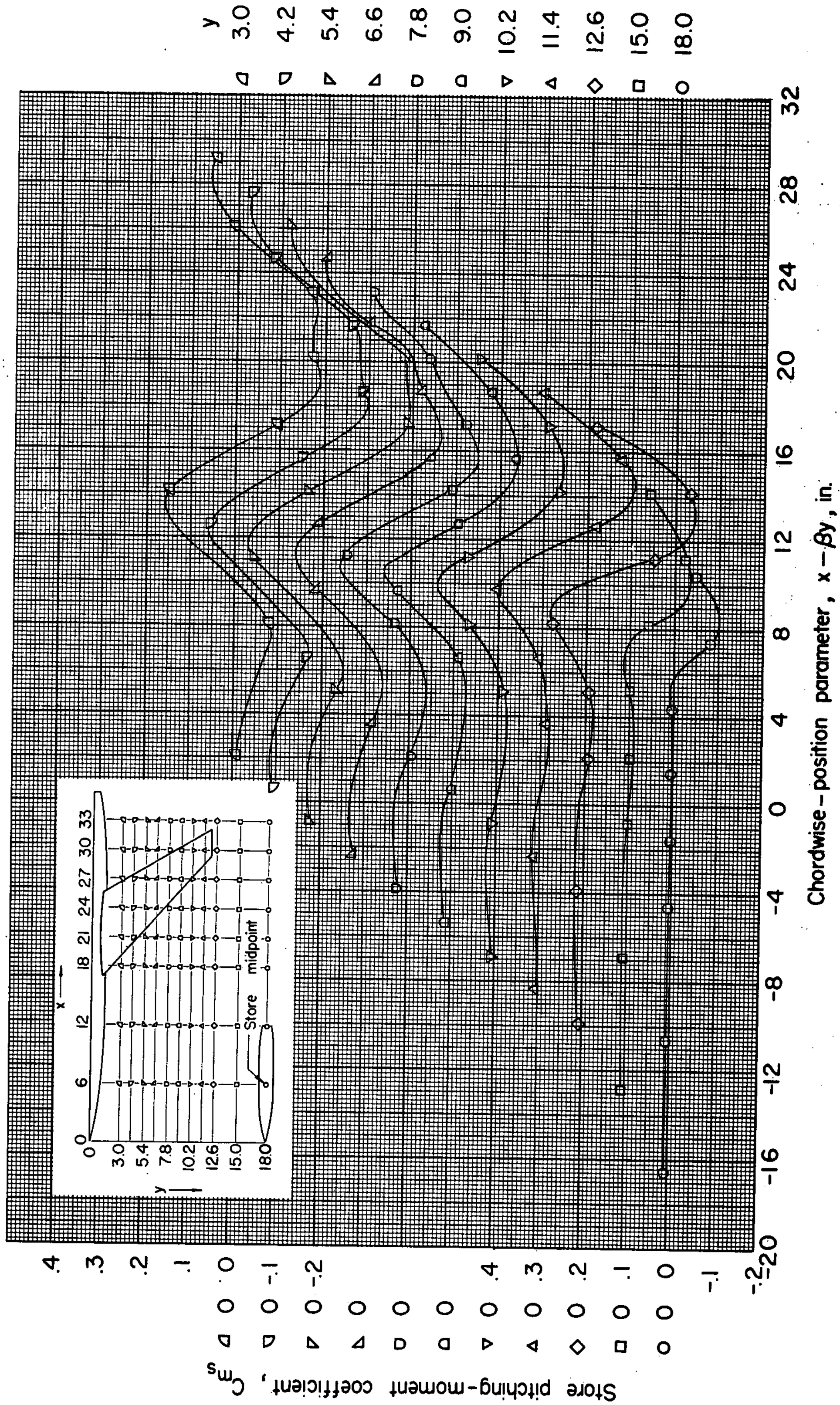
(d) $z = -1.31$ inches; $\alpha = 0^{\circ}$.

Figure 11.- Continued.



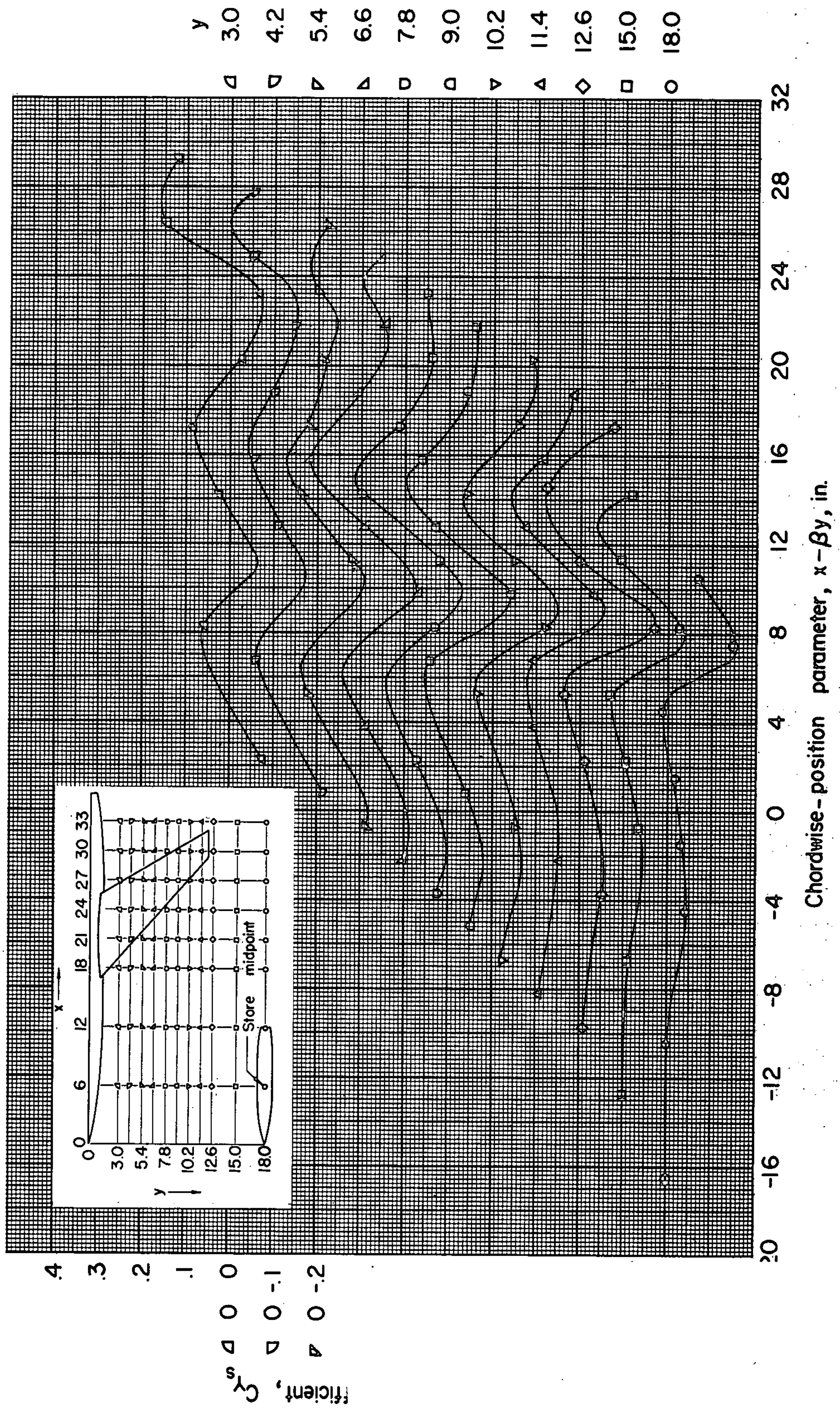
(e) z = 2.09 inches; α = 2°.

Figure 11.- Continued.



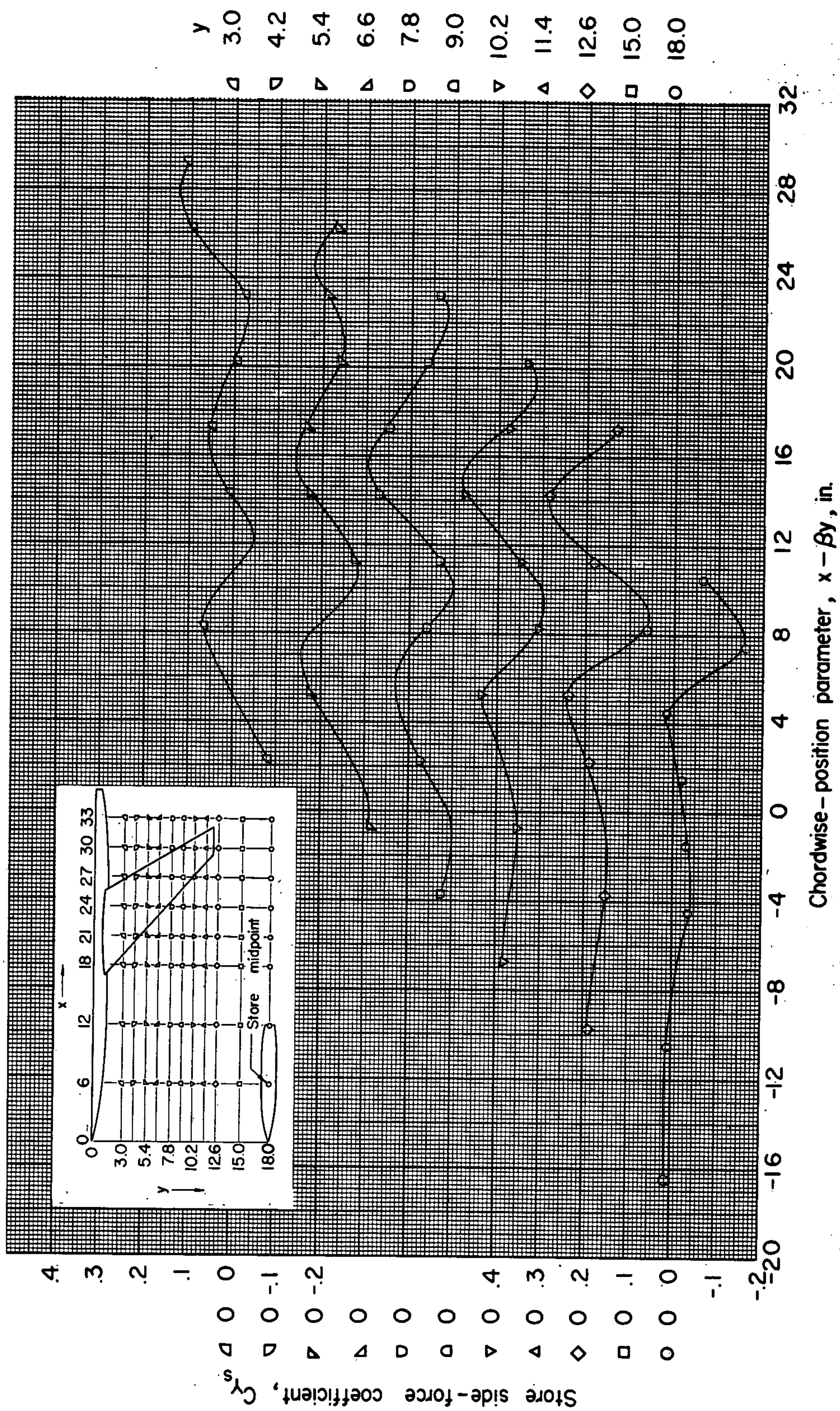
(f) z = 2.09 inches; α = 4°.

Figure 11.- Concluded.



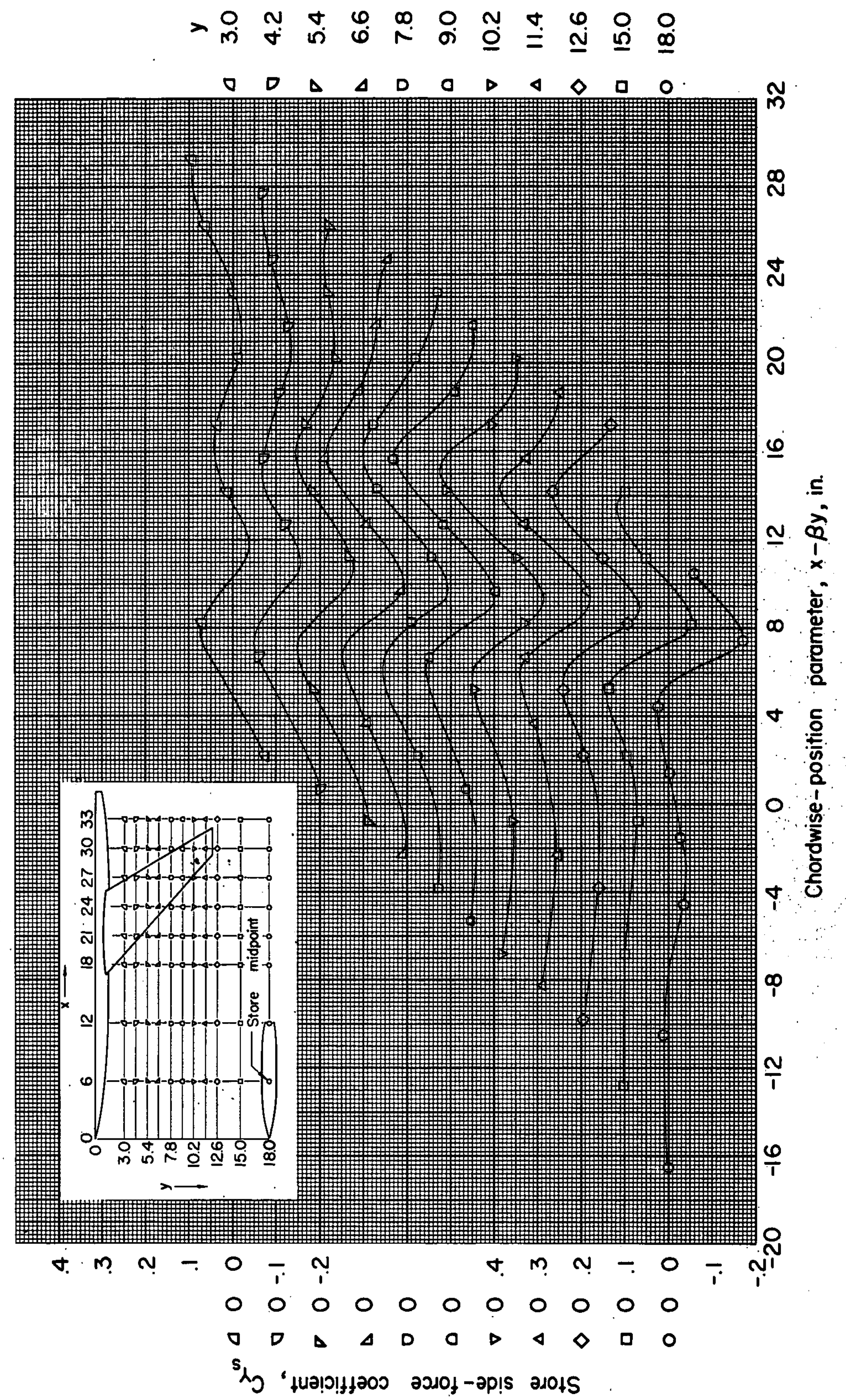
(a) z = 1.15 inches; α = 0°.

Figure 12.- Side force of store in presence of wing-fuselage combination. M = 1.61.



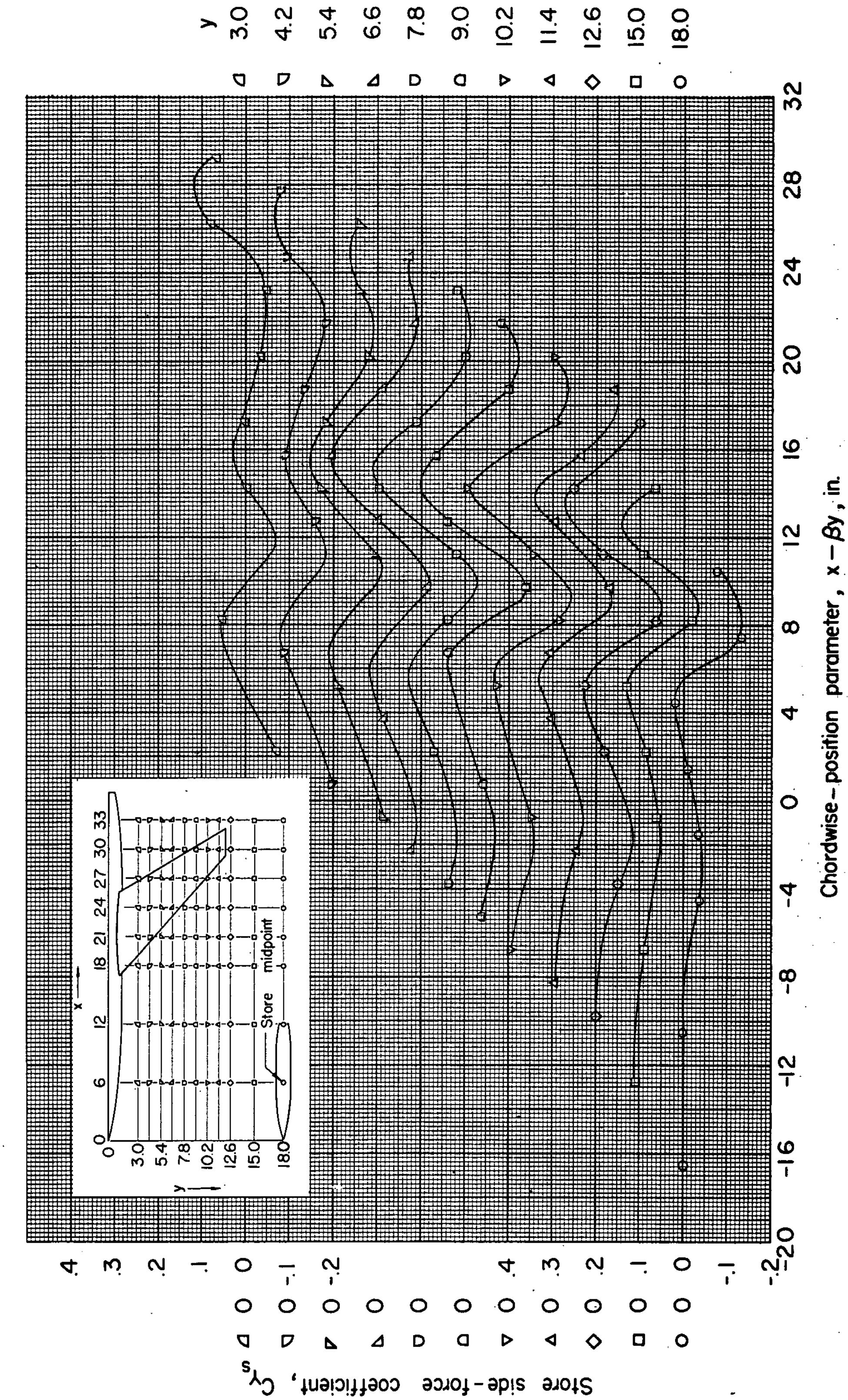
(b) z = 1.67 inches; α = 0°.

Figure 12.- Continued.



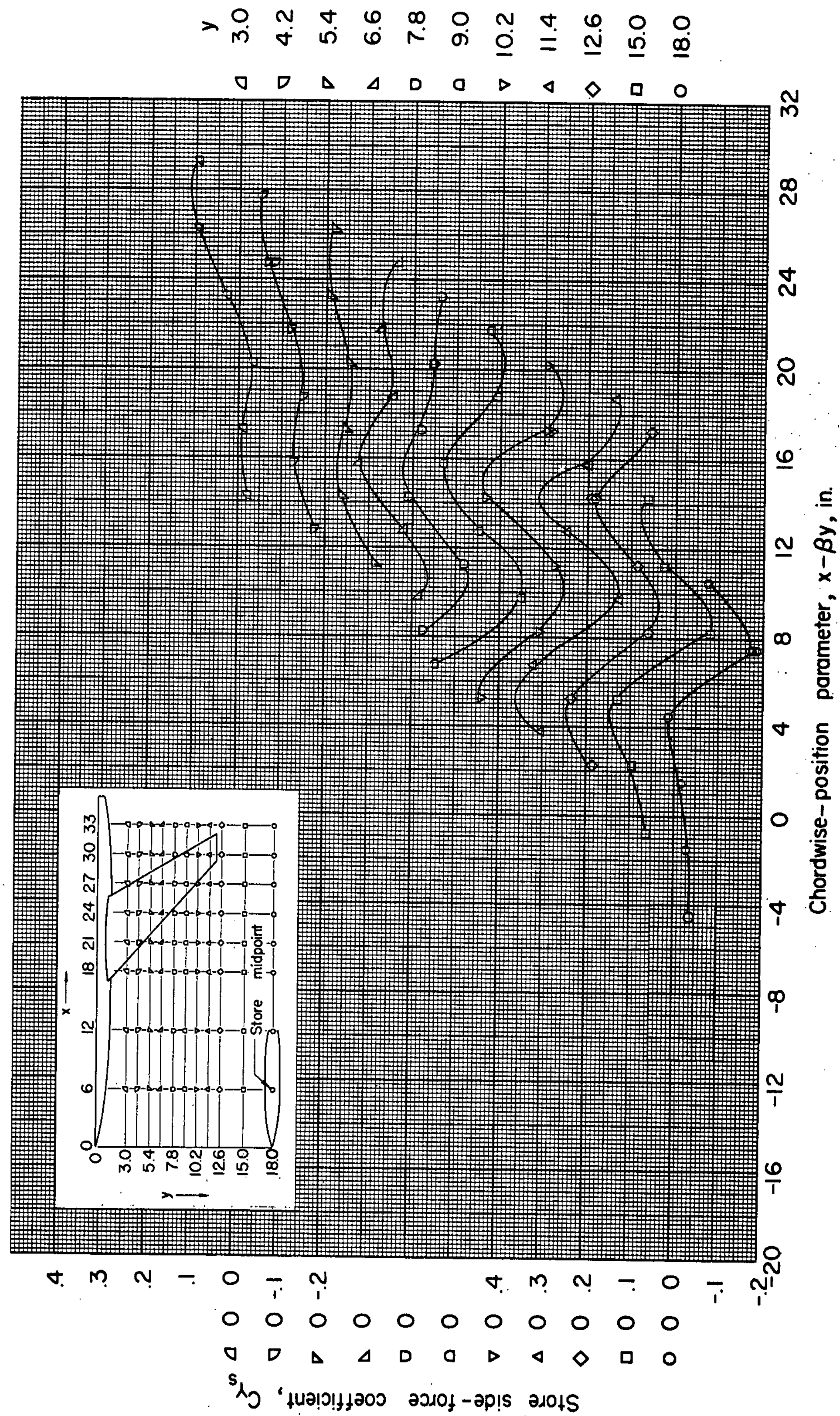
(c) $z = 2.09$ inches; $\alpha = 0^{\circ}$.

Figure 12.- Continued.



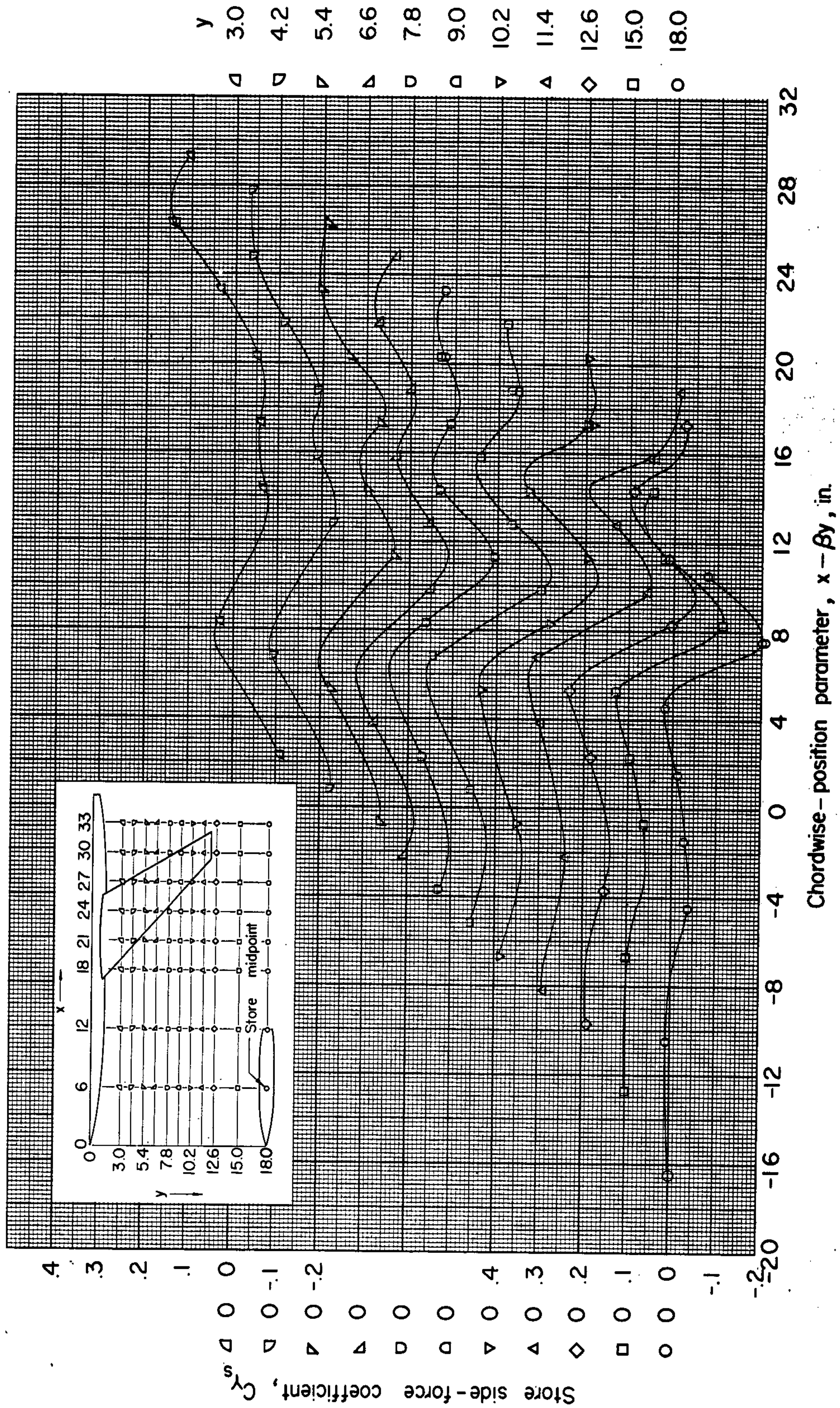
(d) $z = -1.31$ inches; $\alpha = 0^{\circ}$.

Figure 12.- Continued.



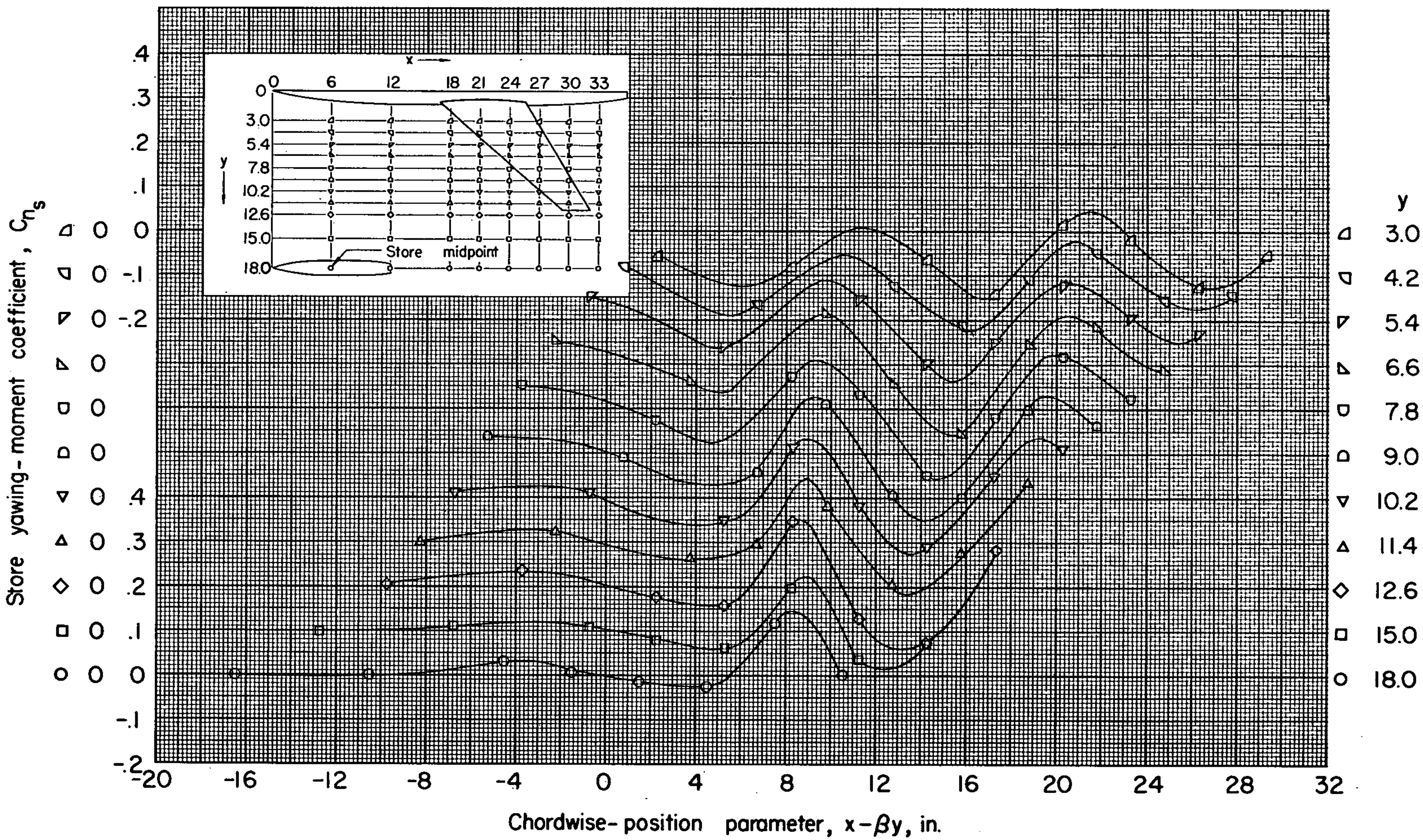
(e) $z = 2.09$ inches; $\alpha = 2^{o}$.

Figure 12.- Continued.



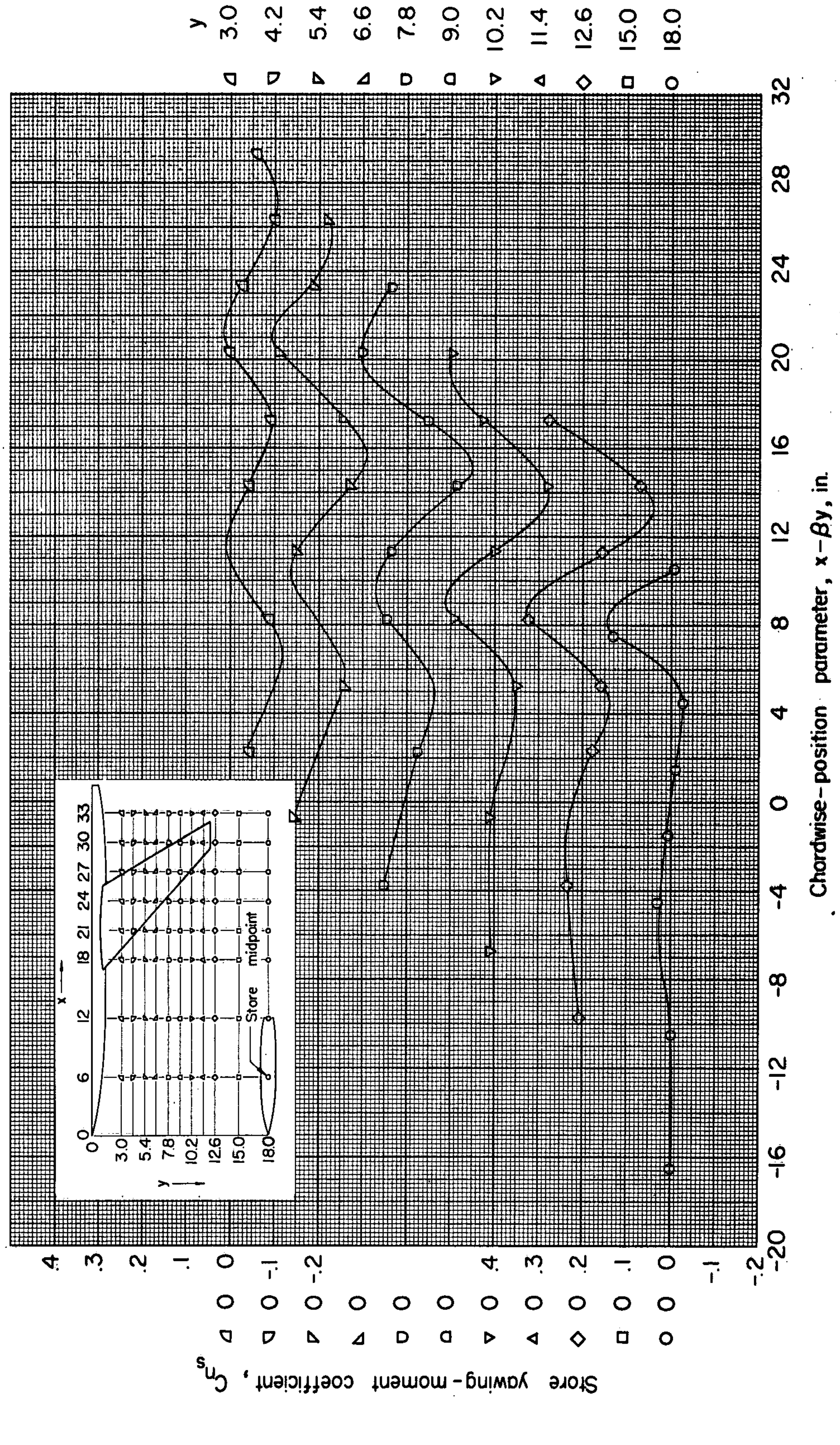
(f) z = 2.09 inches; α = 4°.

Figure 12.- Concluded.



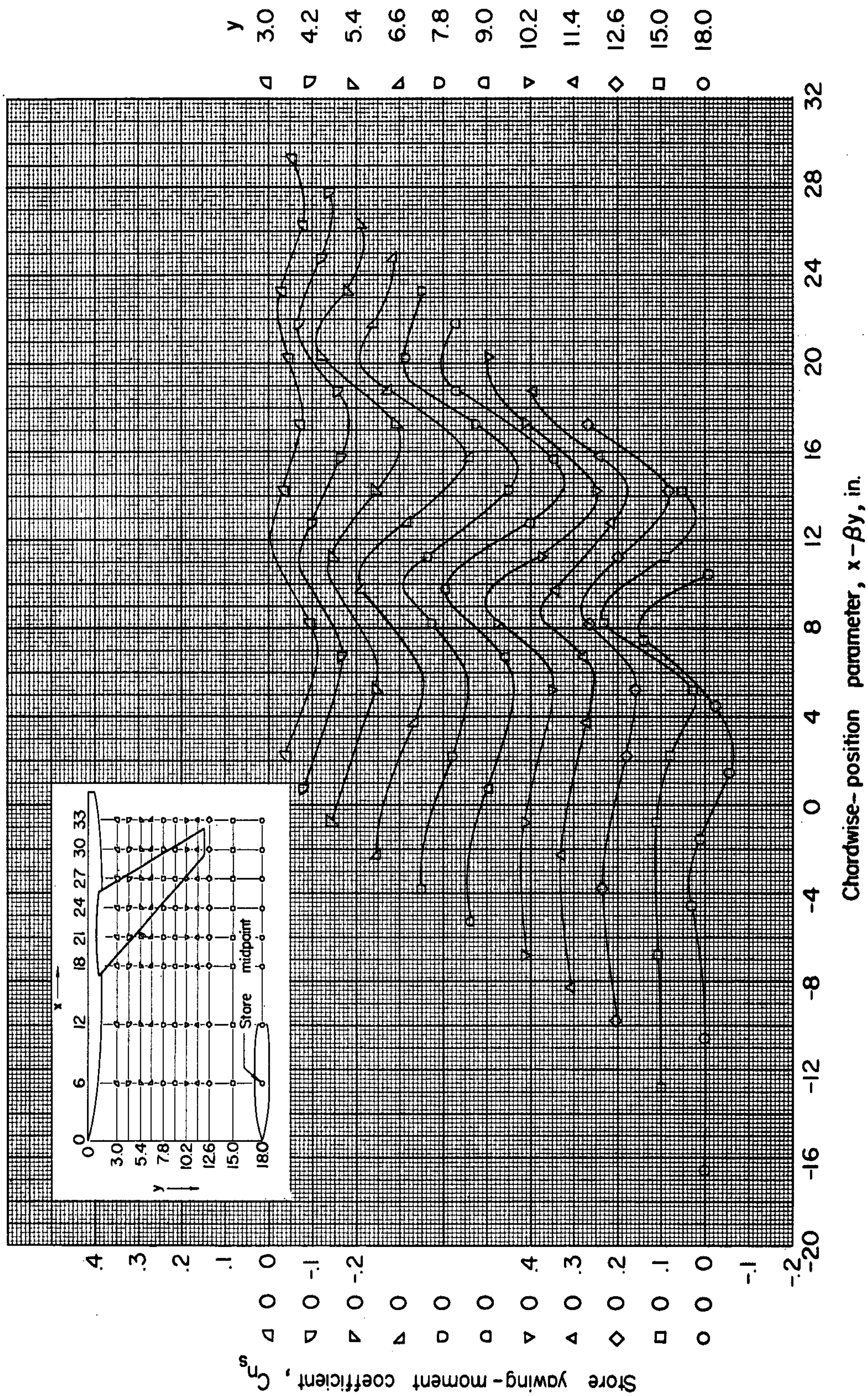
(a) z = 1.15 inches; α = 0°.

Figure 13.- Yawing moment of store in presence of wing-fuselage combination (center of moments is store nose). M = 1.61.



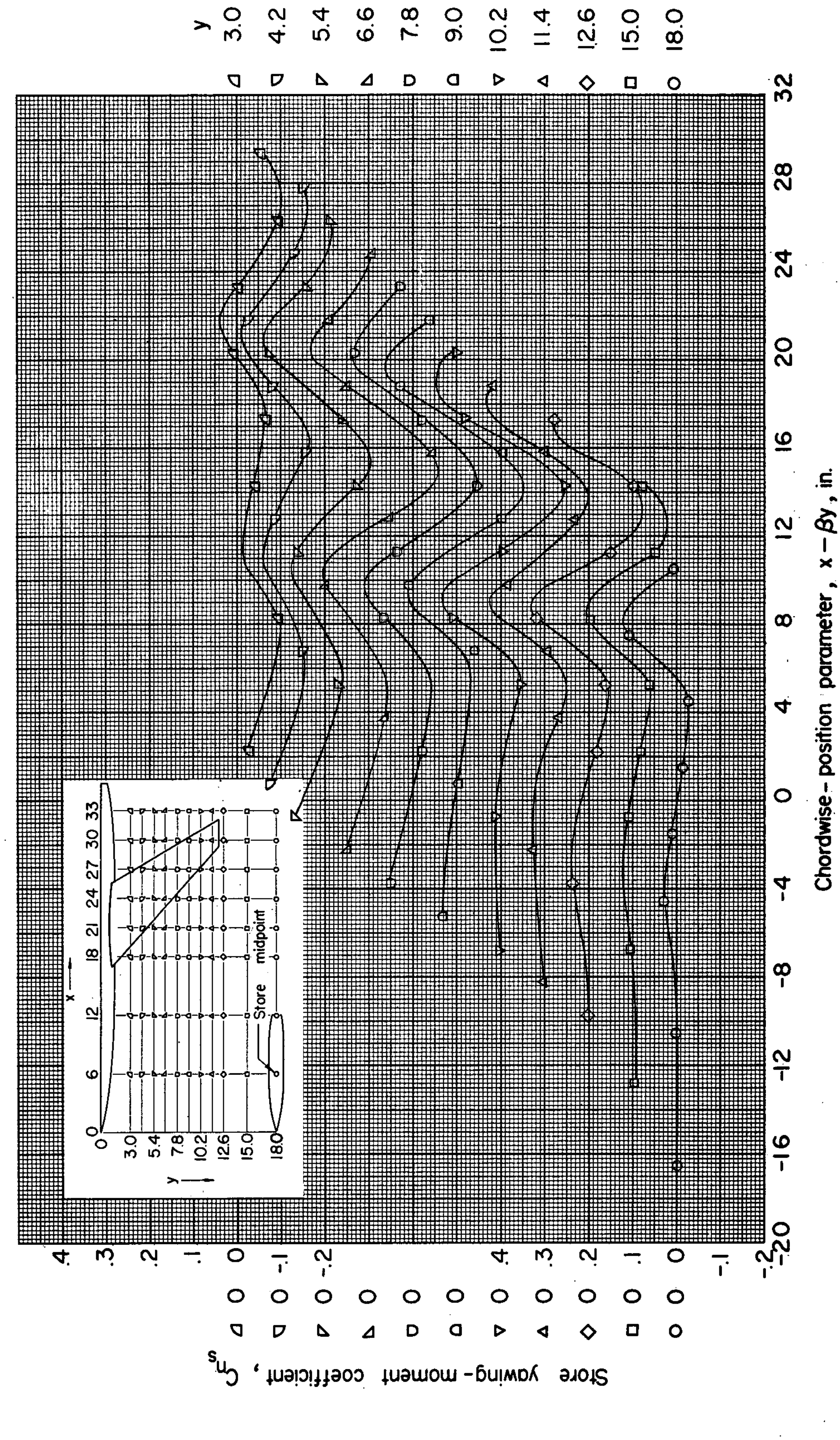
(b) $z = 1.67$ inches; $\alpha = 0^{\circ}$.

Figure 13.- Continued.



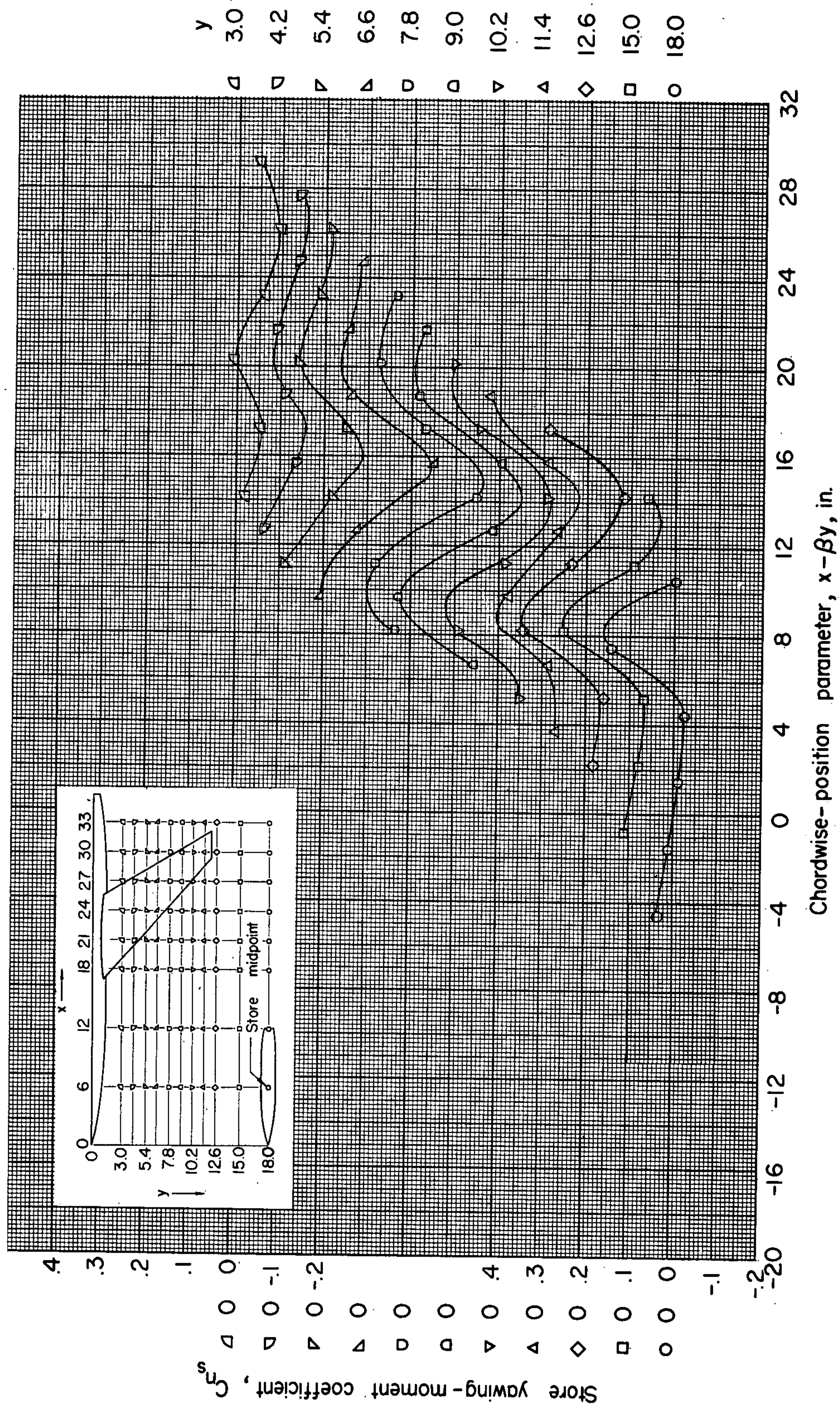
(c) z = 2.09 inches; α = 0°.

Figure 13.- Continued.



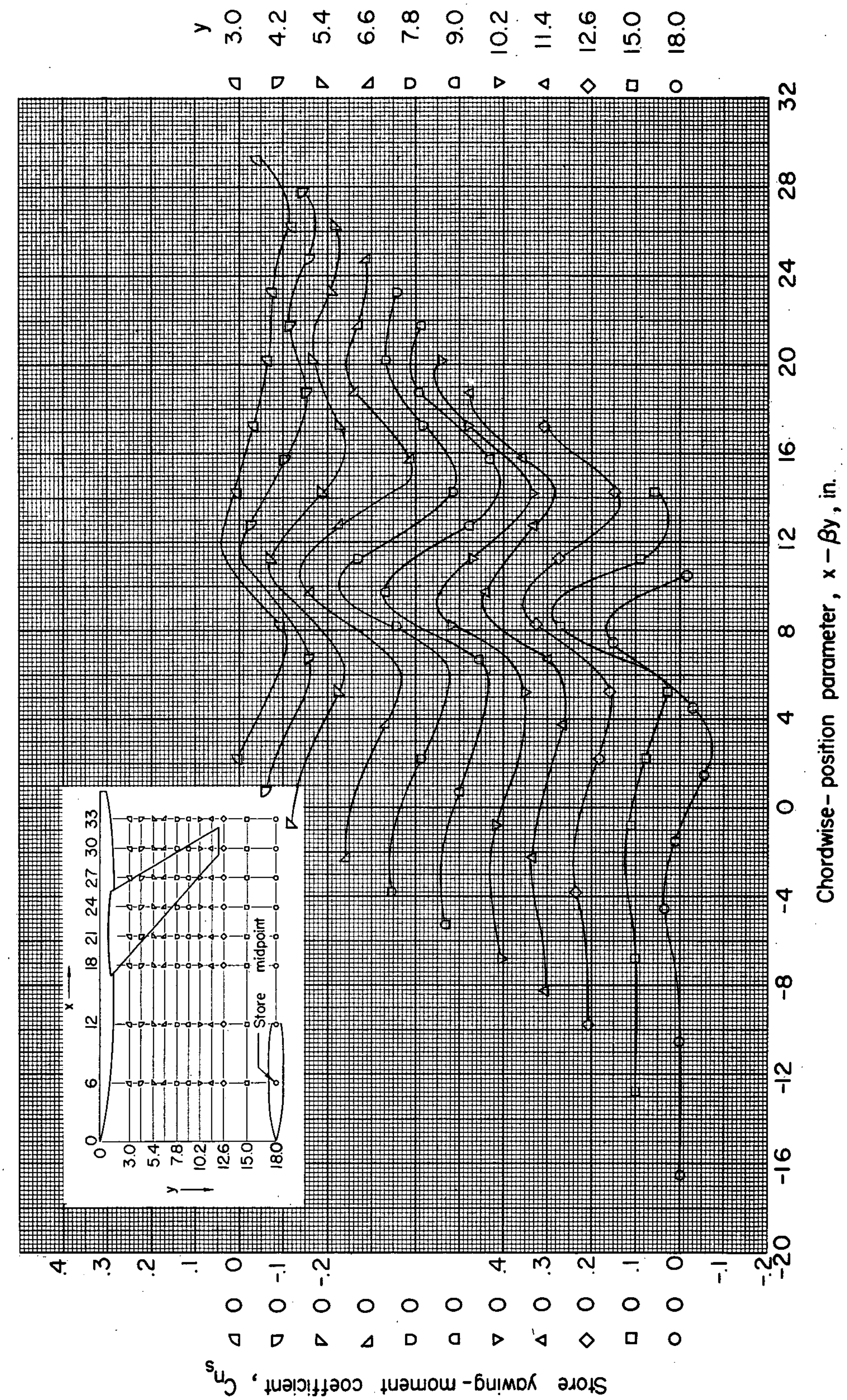
(d) $z = -1.31$ inches; $\alpha = 0^{\circ}$.

Figure 13.- Continued.



(e) z = 2.09 inches; α = 2°.

Figure 13.- Continued.



(f) $z = 2.09$ inches; $\alpha = 4^{o}$.

Figure 13.- Concluded.

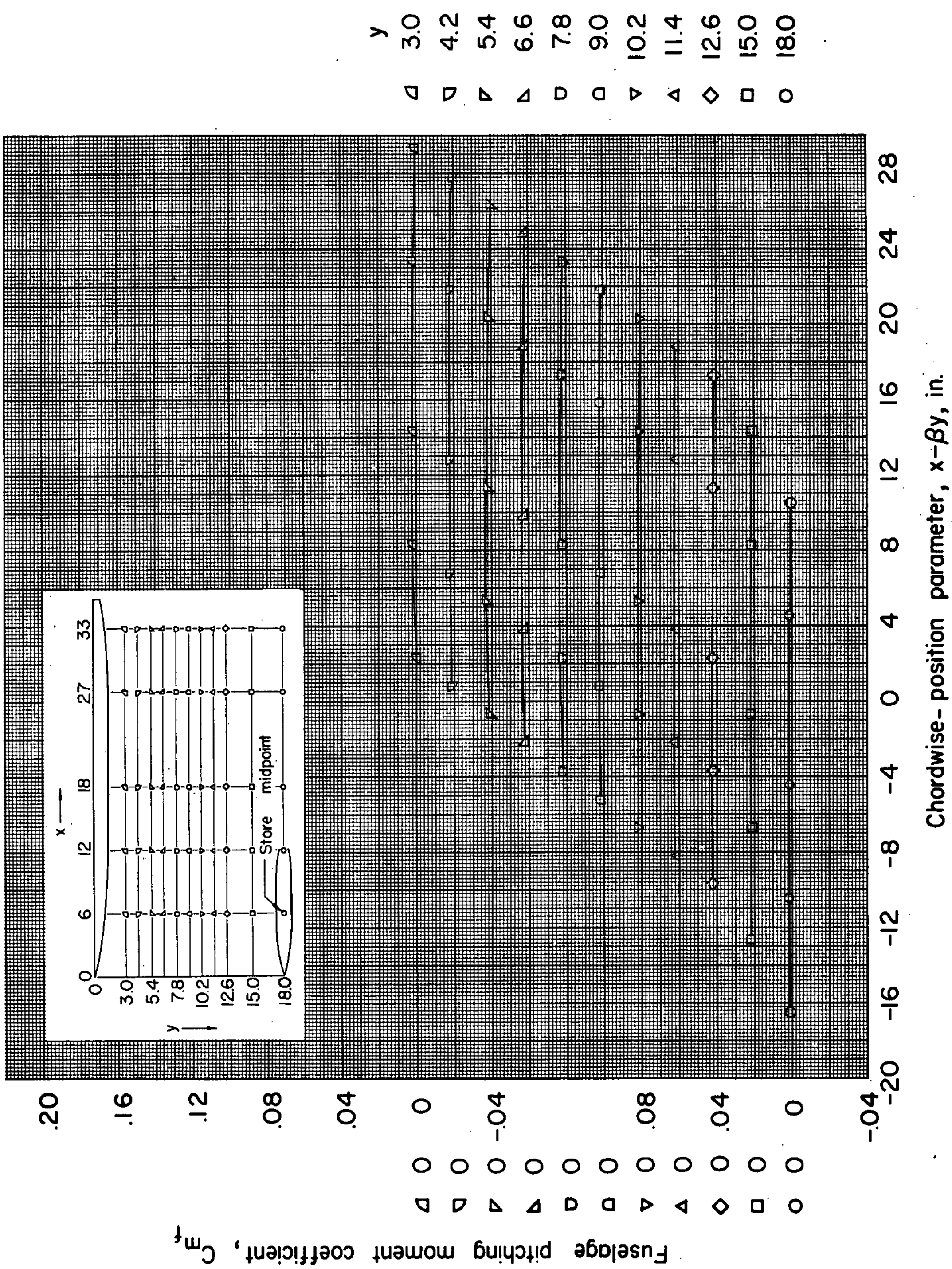
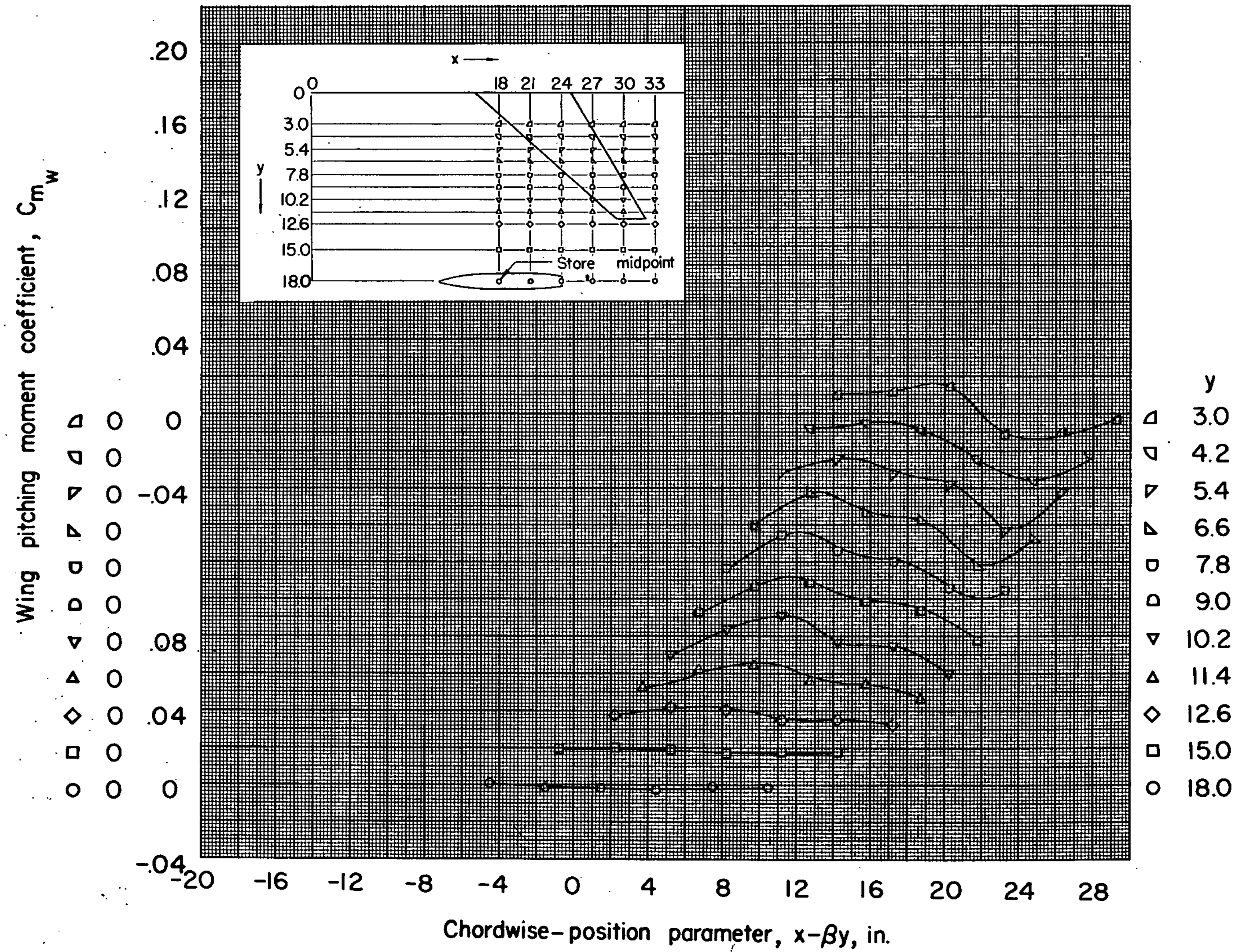
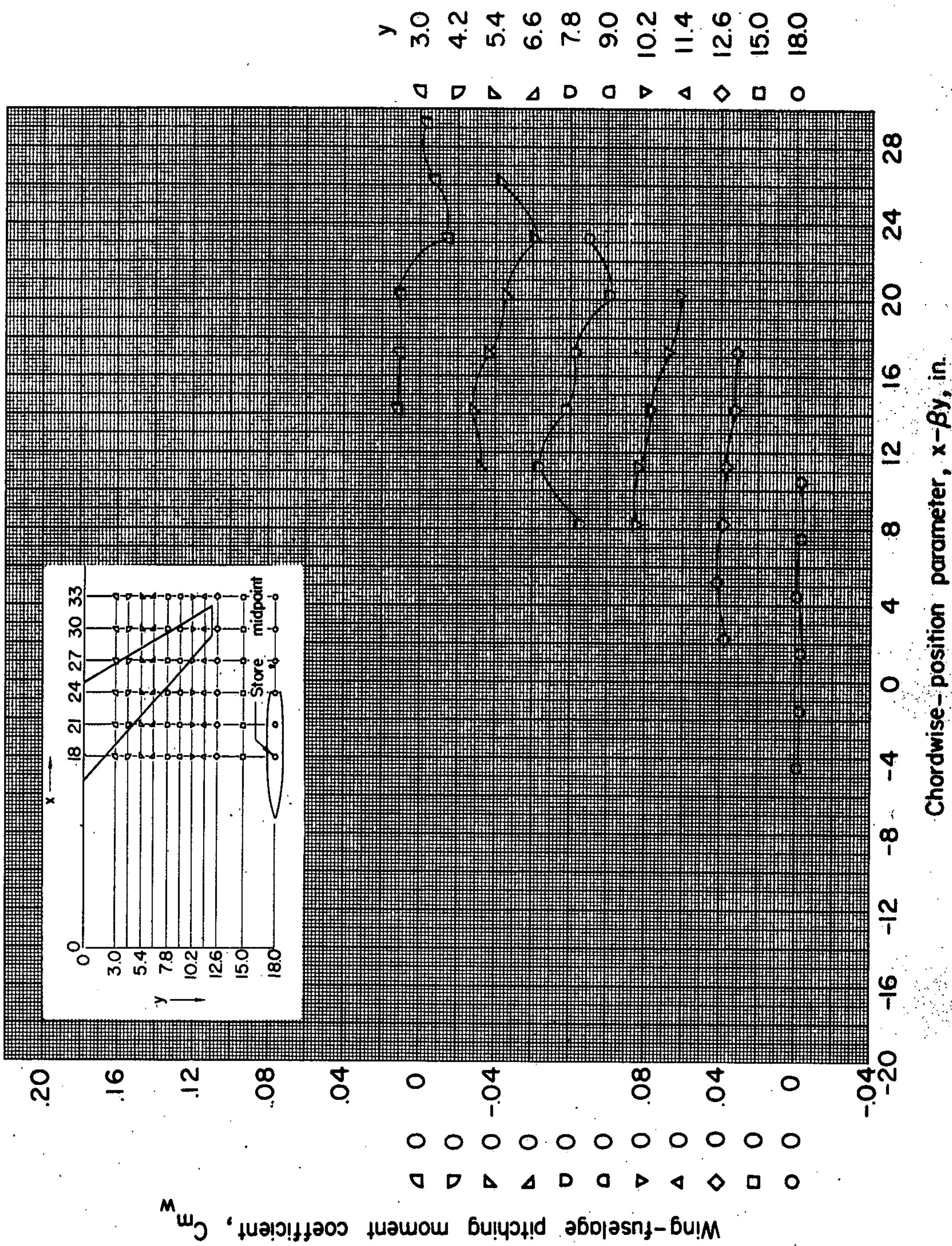


Figure 14.- Pitching moment of fuselage in presence of store. z = 1.15 inches; α = 0°; M = 1.61.



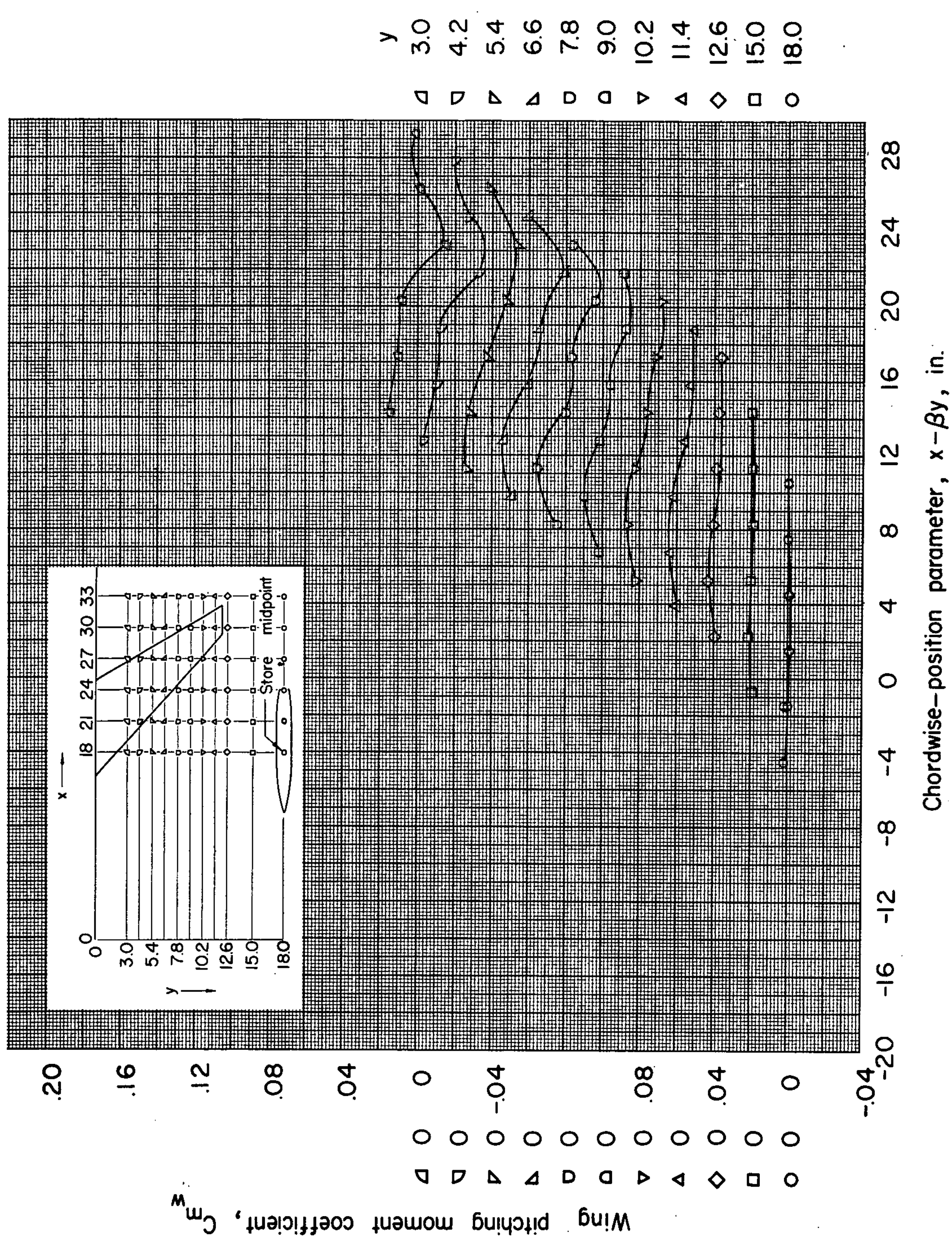
(a) z = 1.15 inches; α = 0°.

Figure 15.- Pitching moment of wing in presence of store. M = 1.61.



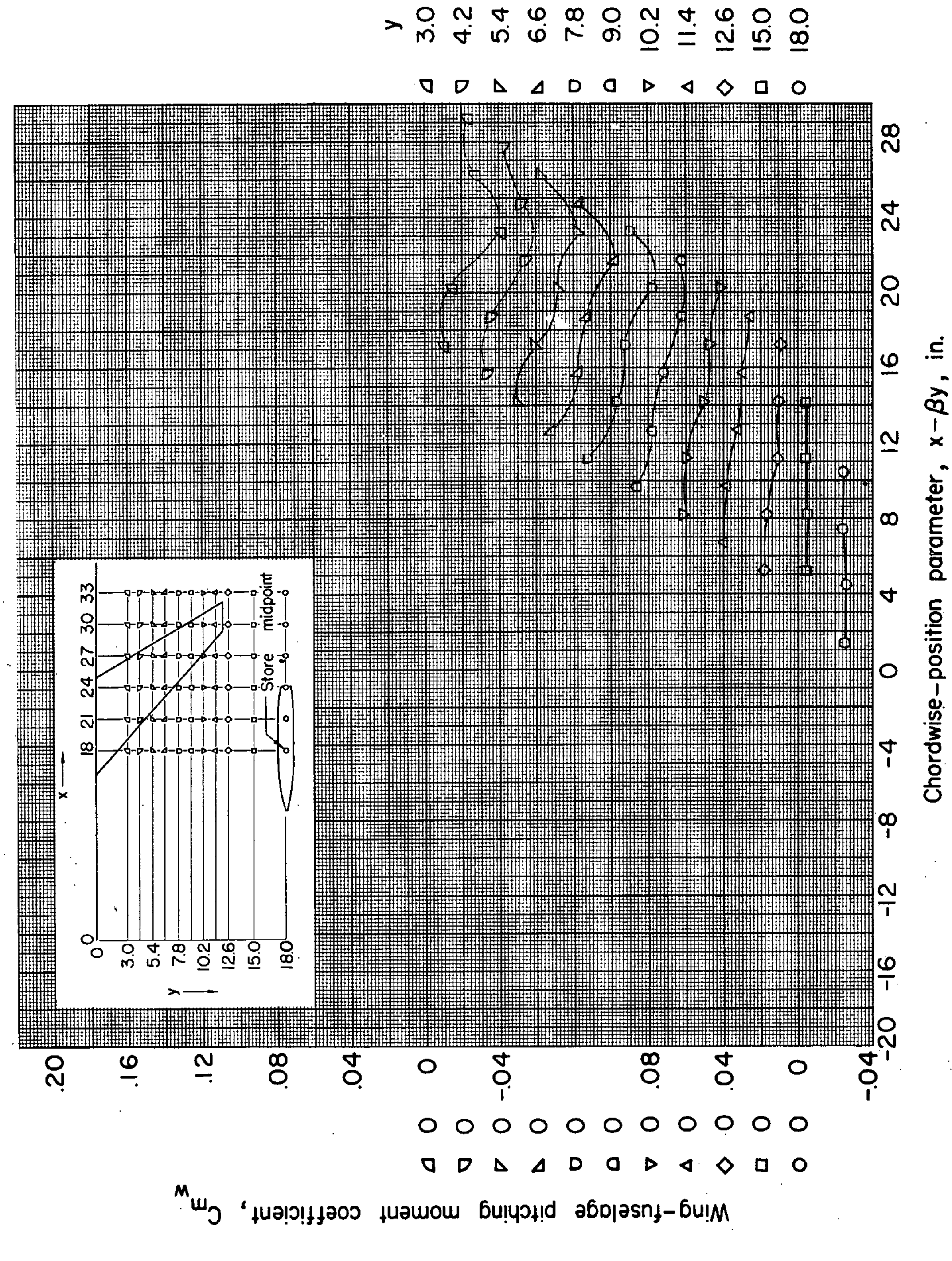
(b) z = 1.67 inches; α = 0°.

Figure 15.- Continued.



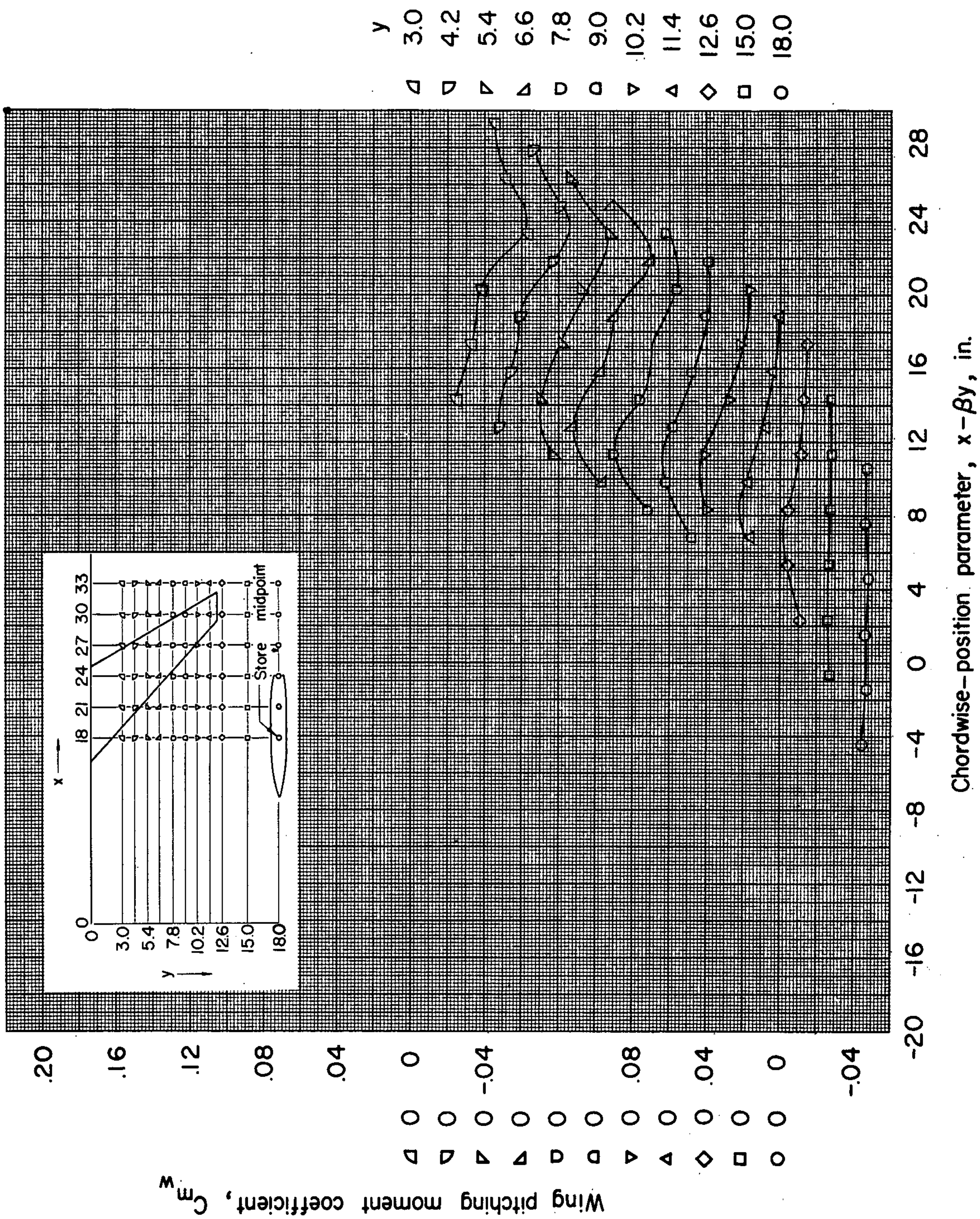
(c) $z = 2.09$ inches; $\alpha = 0^{\circ}$.

Figure 15.- Continued.



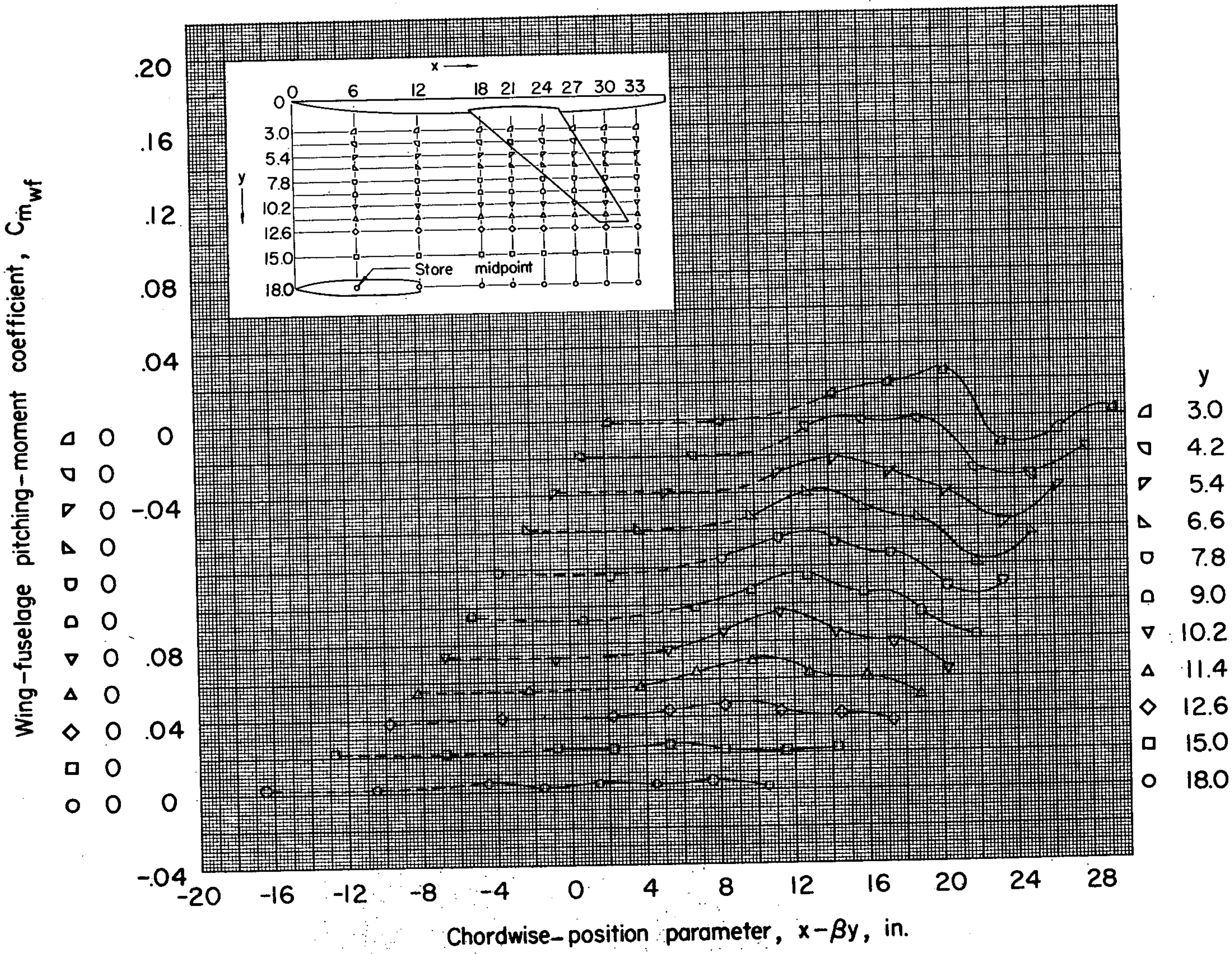
(d) z = 2.09 inches; α = 2°.

Figure 15.- Continued.



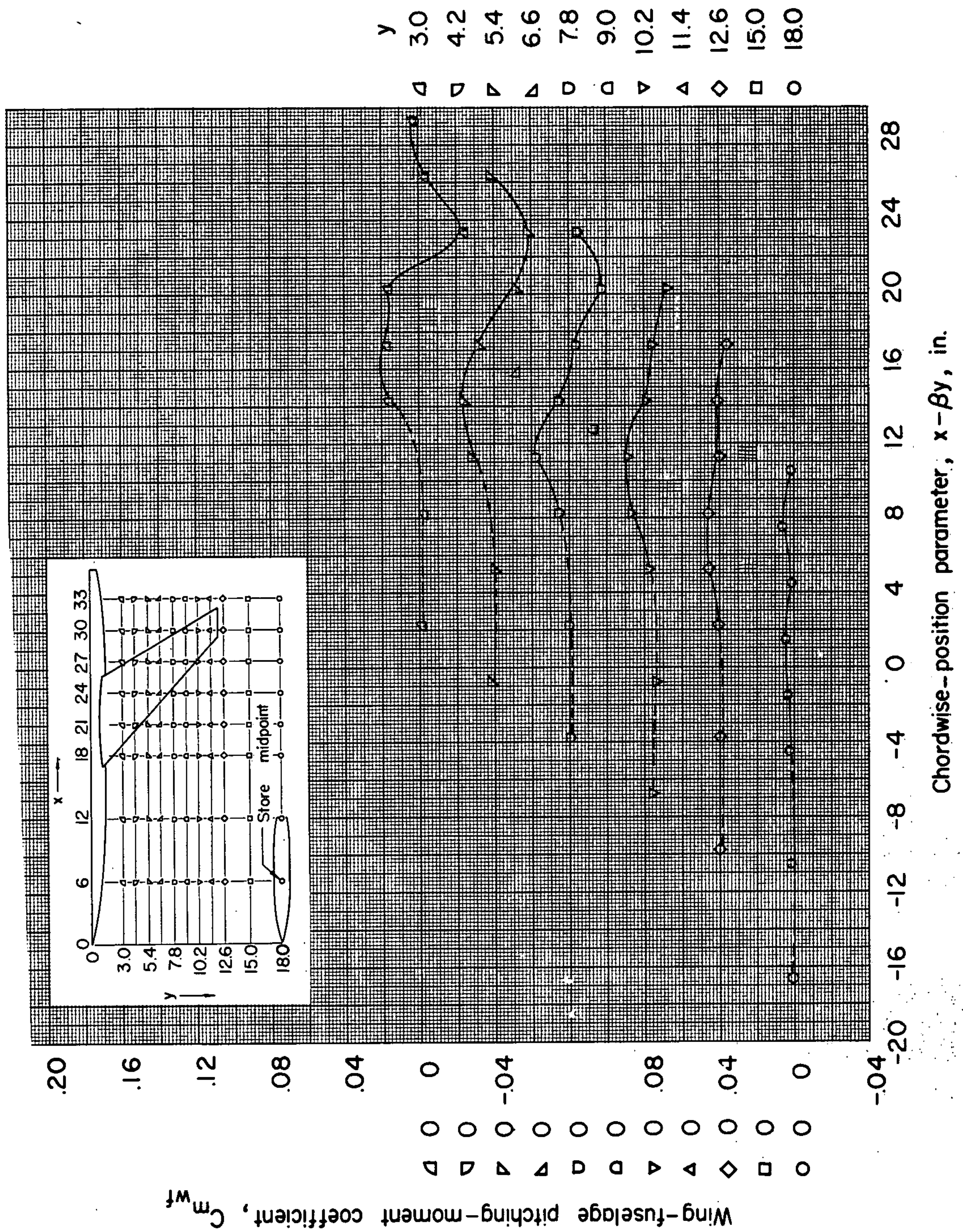
(e) $z = 2.09$ inches; $\alpha = 4^\circ$.

Figure 15.- Concluded.



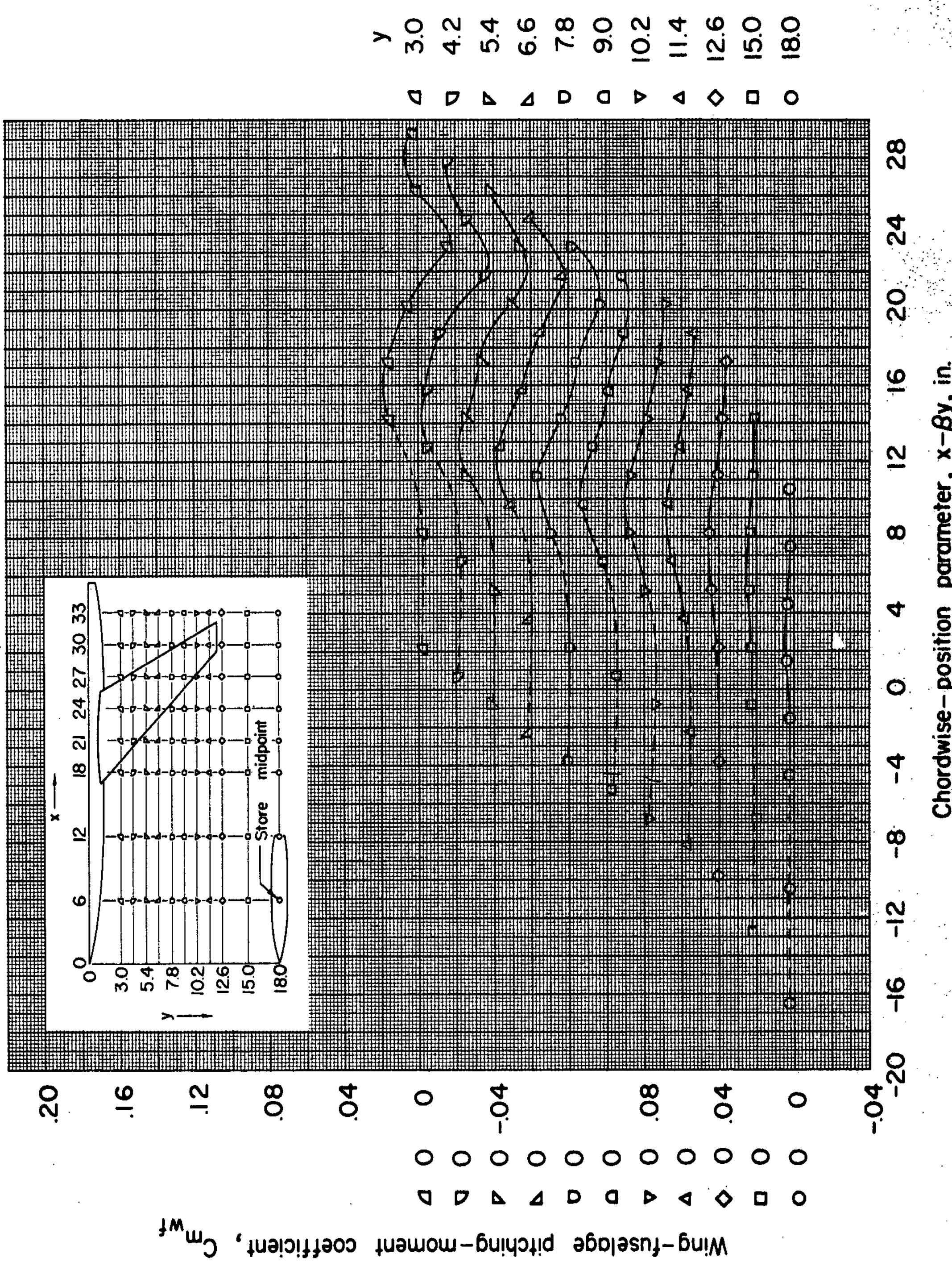
(a) $z = 1.15$ inches; $\alpha = 0^{\circ}$.

Figure 16.- Pitching moment of wing-fuselage combination in presence of store. M = 1.61. Dashed lines indicate presence of interference of store sting.



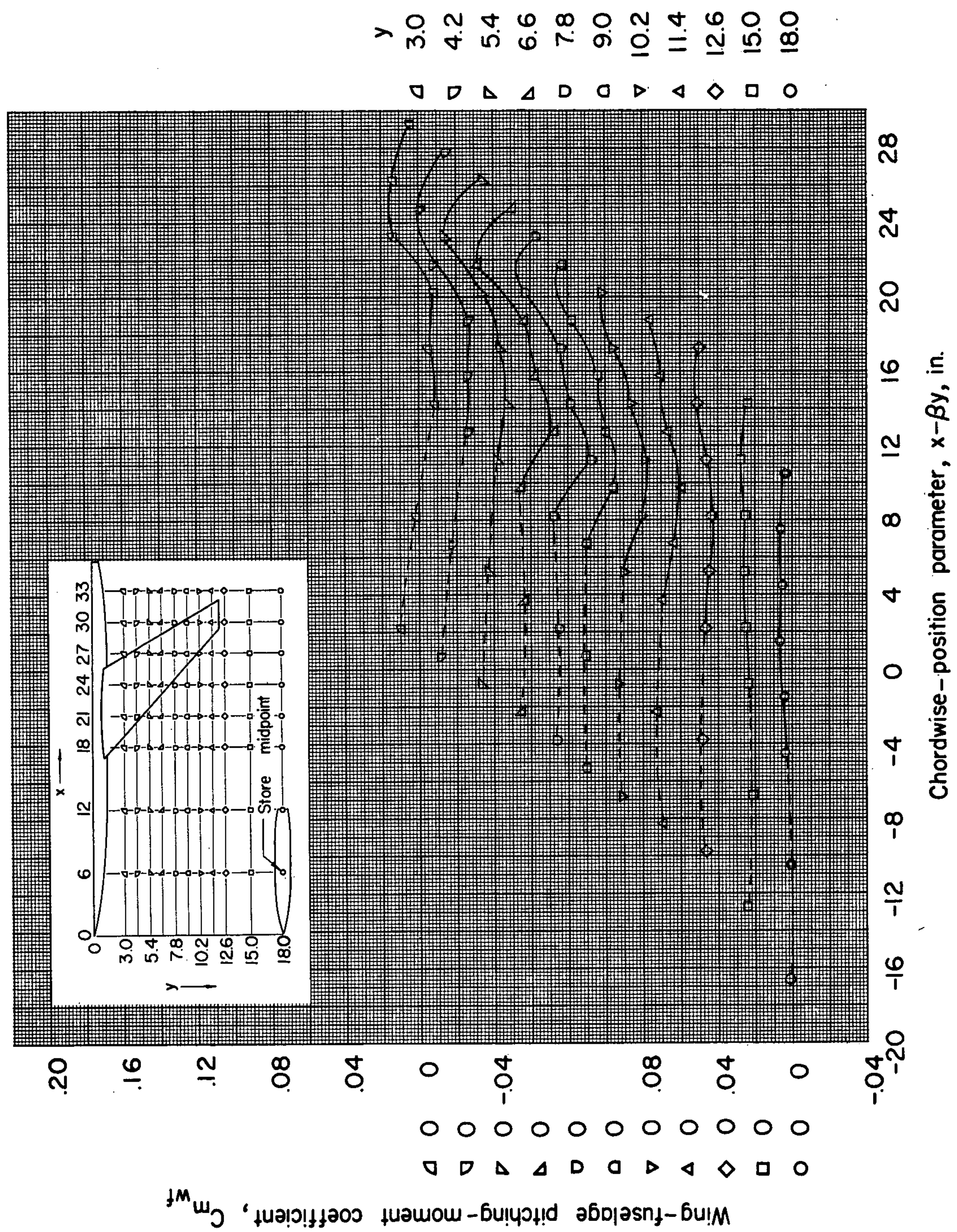
(b) z = 1.67 inches; α = 0°.

Figure 16.- Continued.



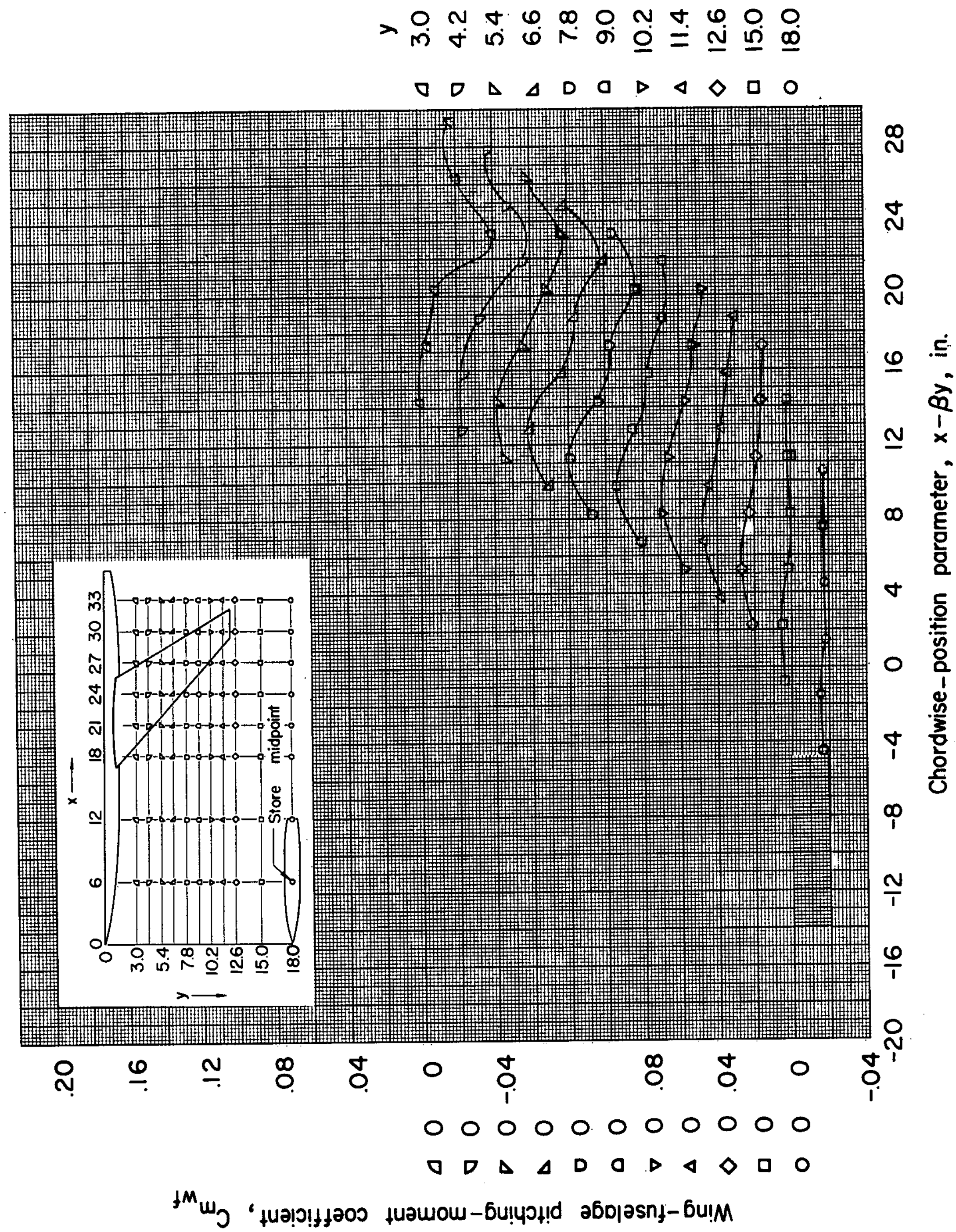
(c) z = 2.09 inches; α = 0°.

Figure 16.- Continued.



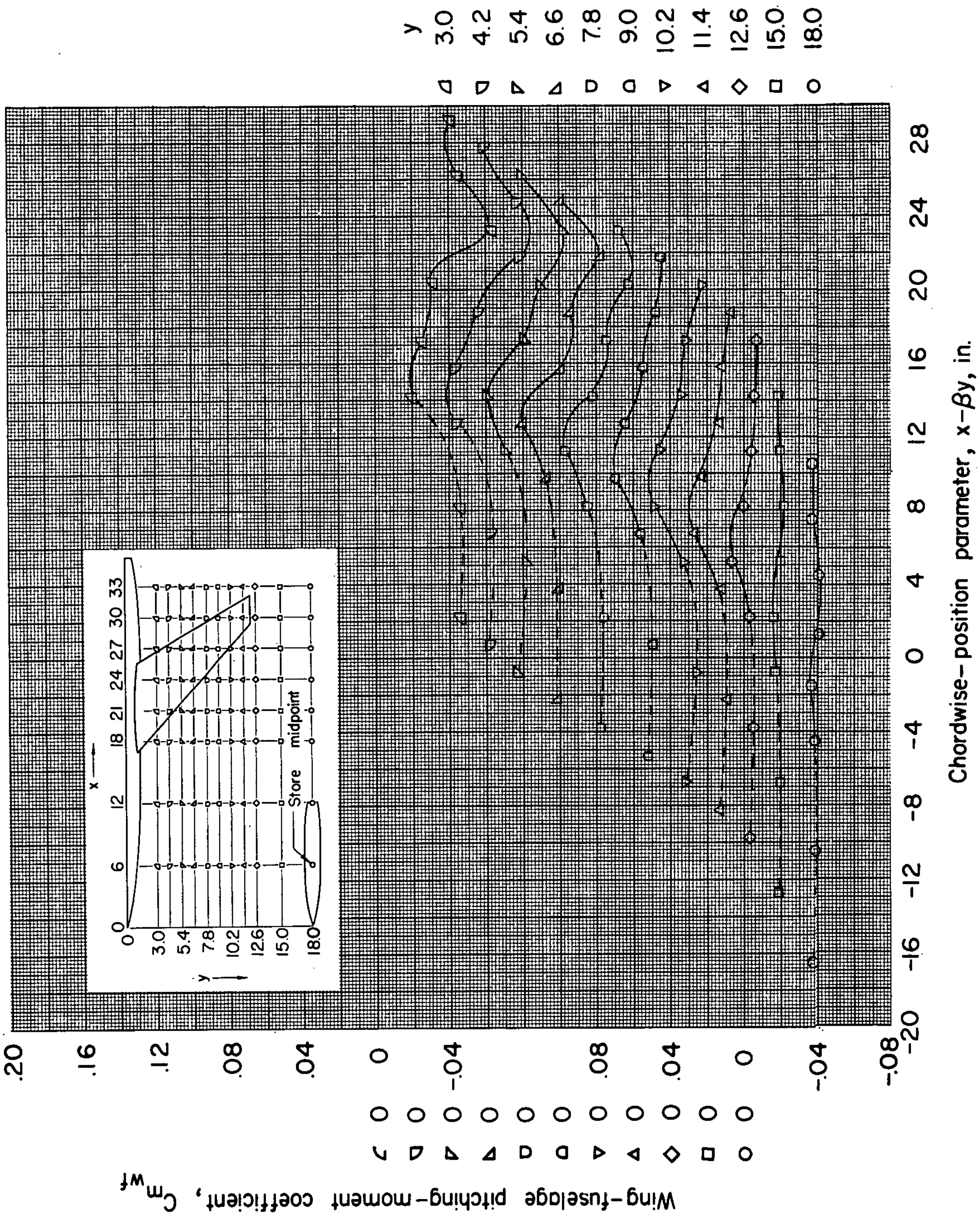
(d) $z = -1.31$ inches; $\alpha = 0^{\circ}$.

Figure 16.- Continued.



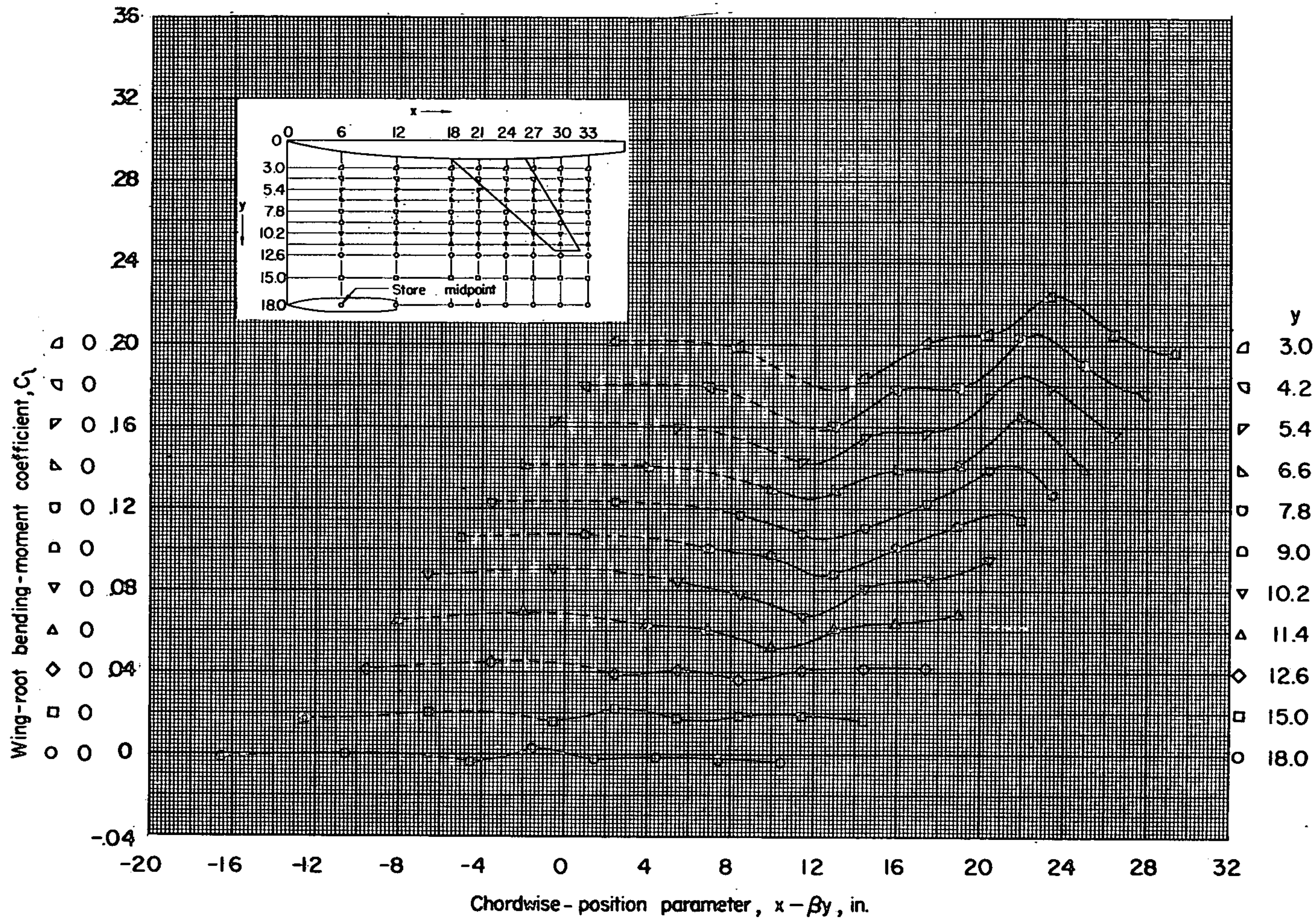
(e) $z = 2.09$ inches; $\alpha = 2^{\circ}$.

Figure 16.- Continued.



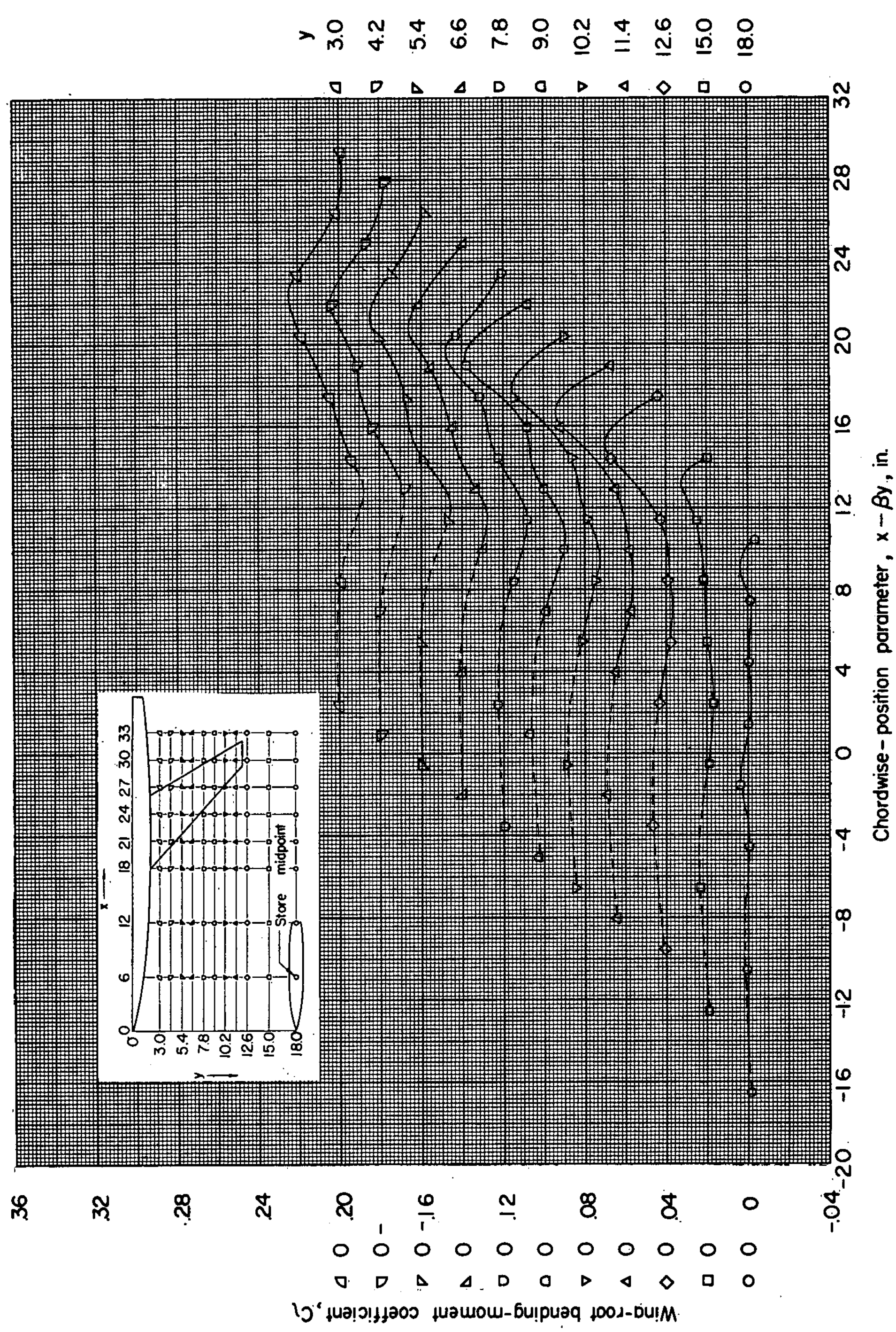
(f) $z = 2.09$ inches; $\alpha = 4^{\circ}$.

Figure 16.- Concluded.



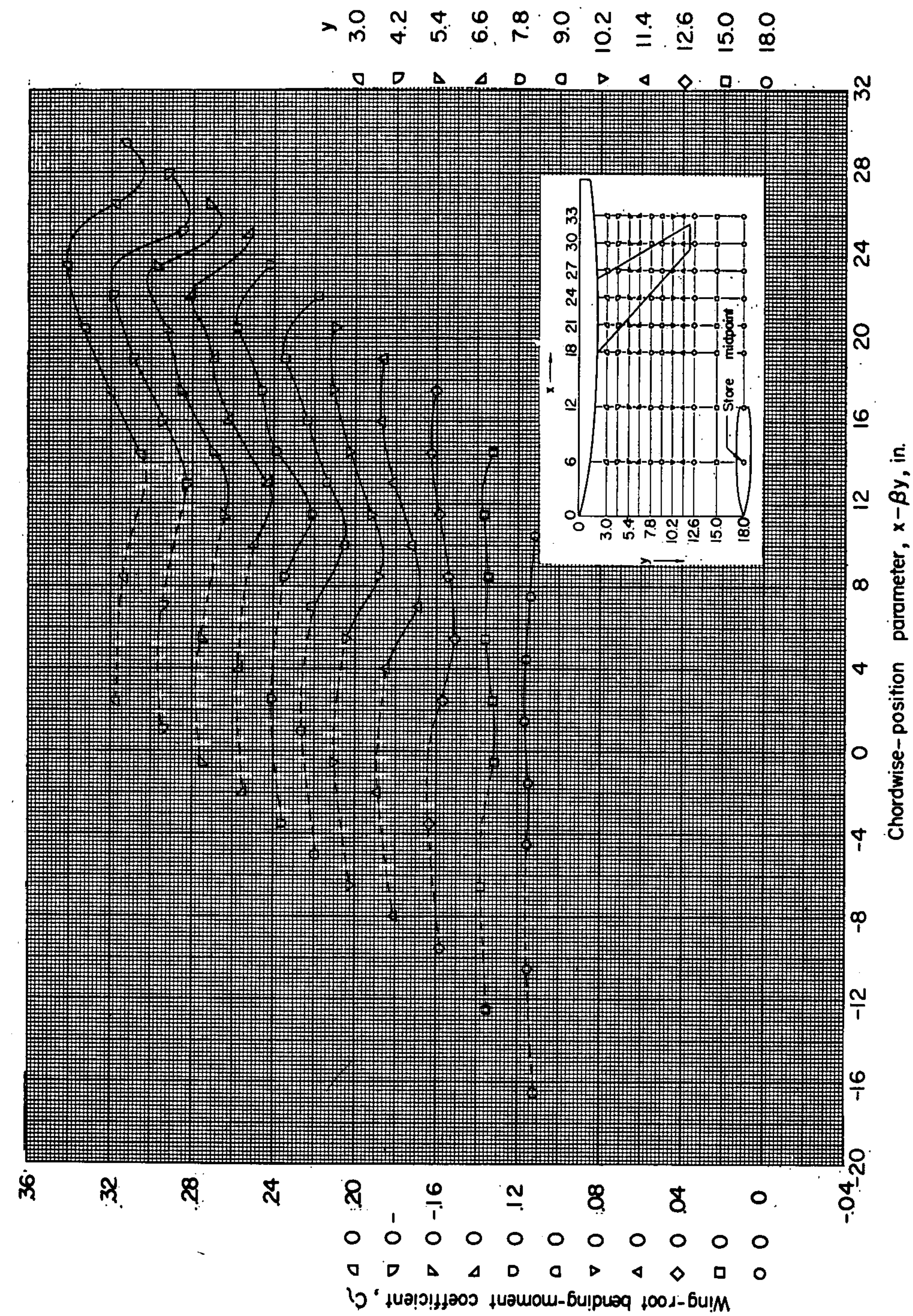
(a) z = 1.15 inches; α = 0°.

Figure 17.- Wing-root bending moment for wing-fuselage combination in presence of store. M = 1.61. Dashed lines indicate presence of interference of store sting.



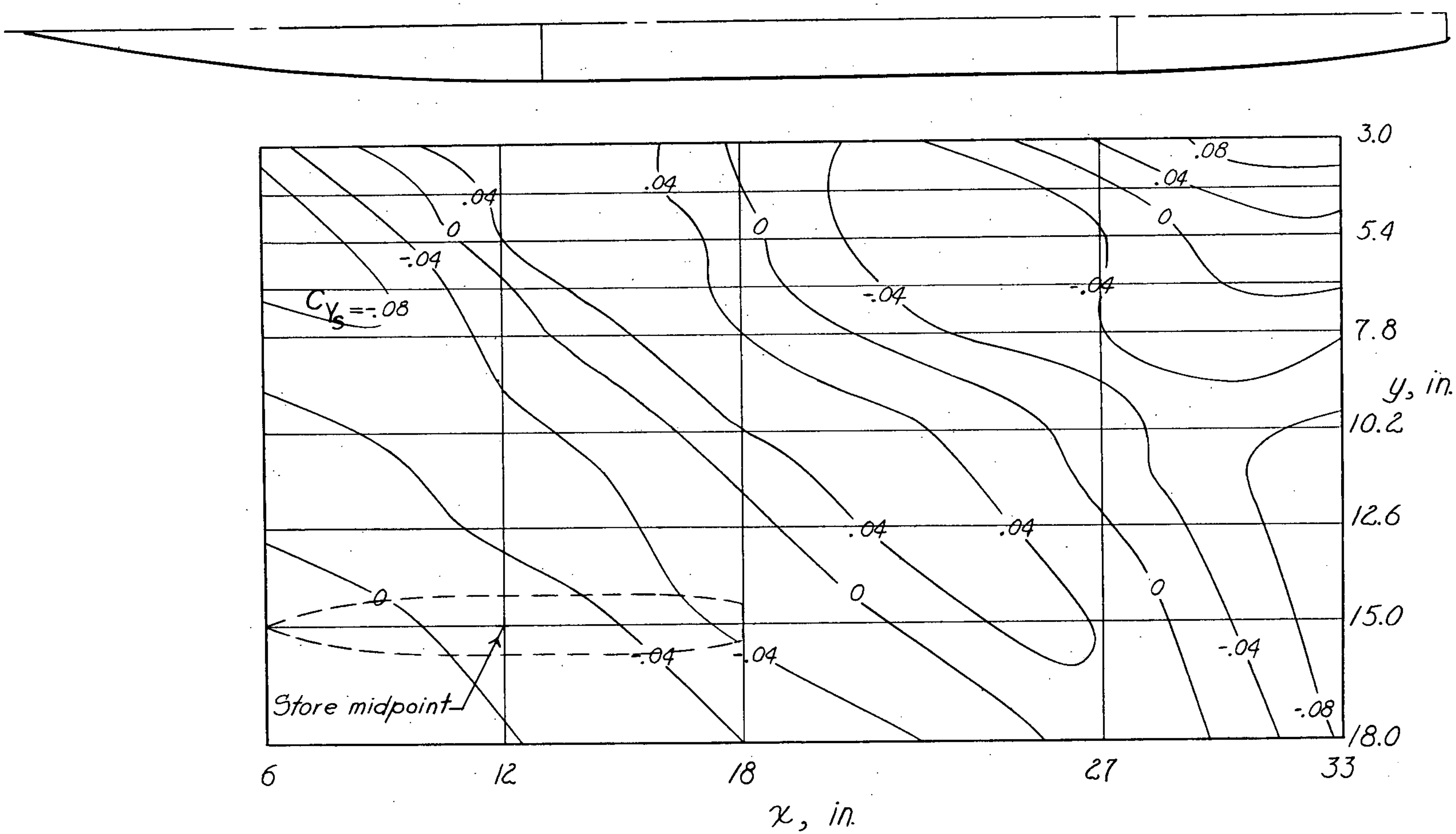
(b) $z = 2.09$ inches; $\alpha = 0^{\circ}$.

Figure 17.- Continued.



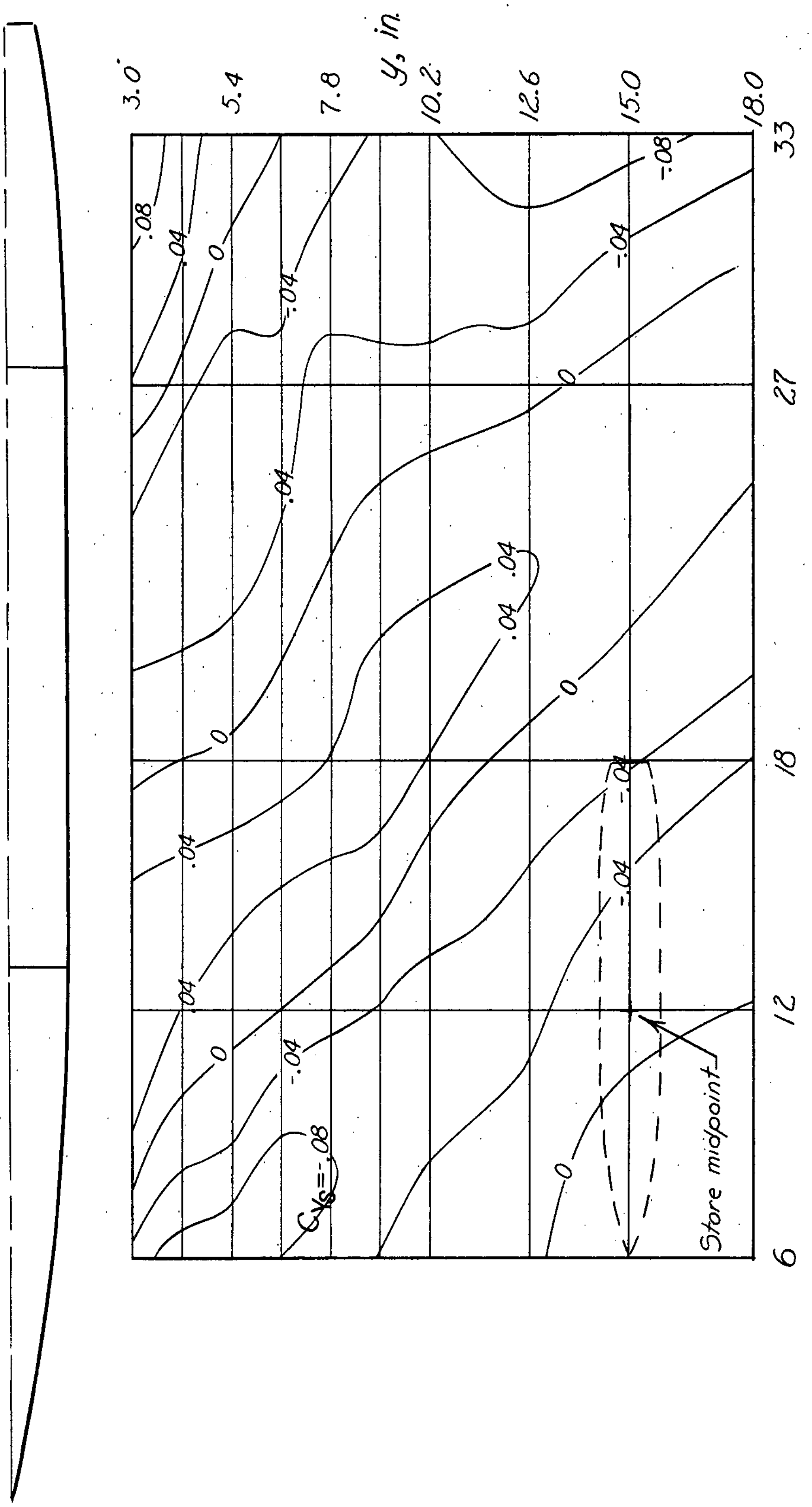
(c) $z = 2.09$ inches; $\alpha = 4^{\circ}$.

Figure 17.- Concluded.



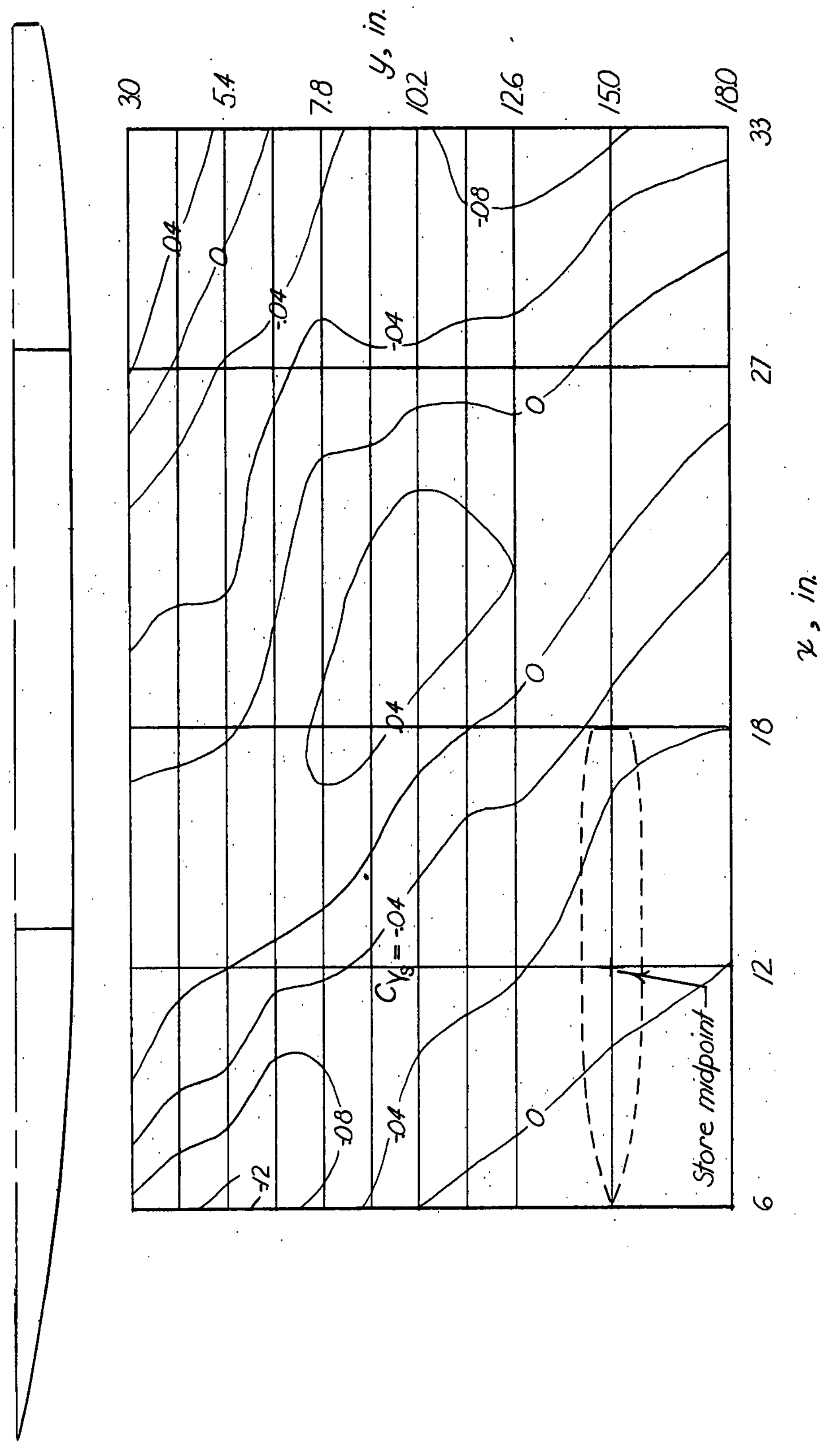
(a) z = 1.15 inches; α = 0°.

Figure 18.- Contour plot of side force of store in presence of fuselage.



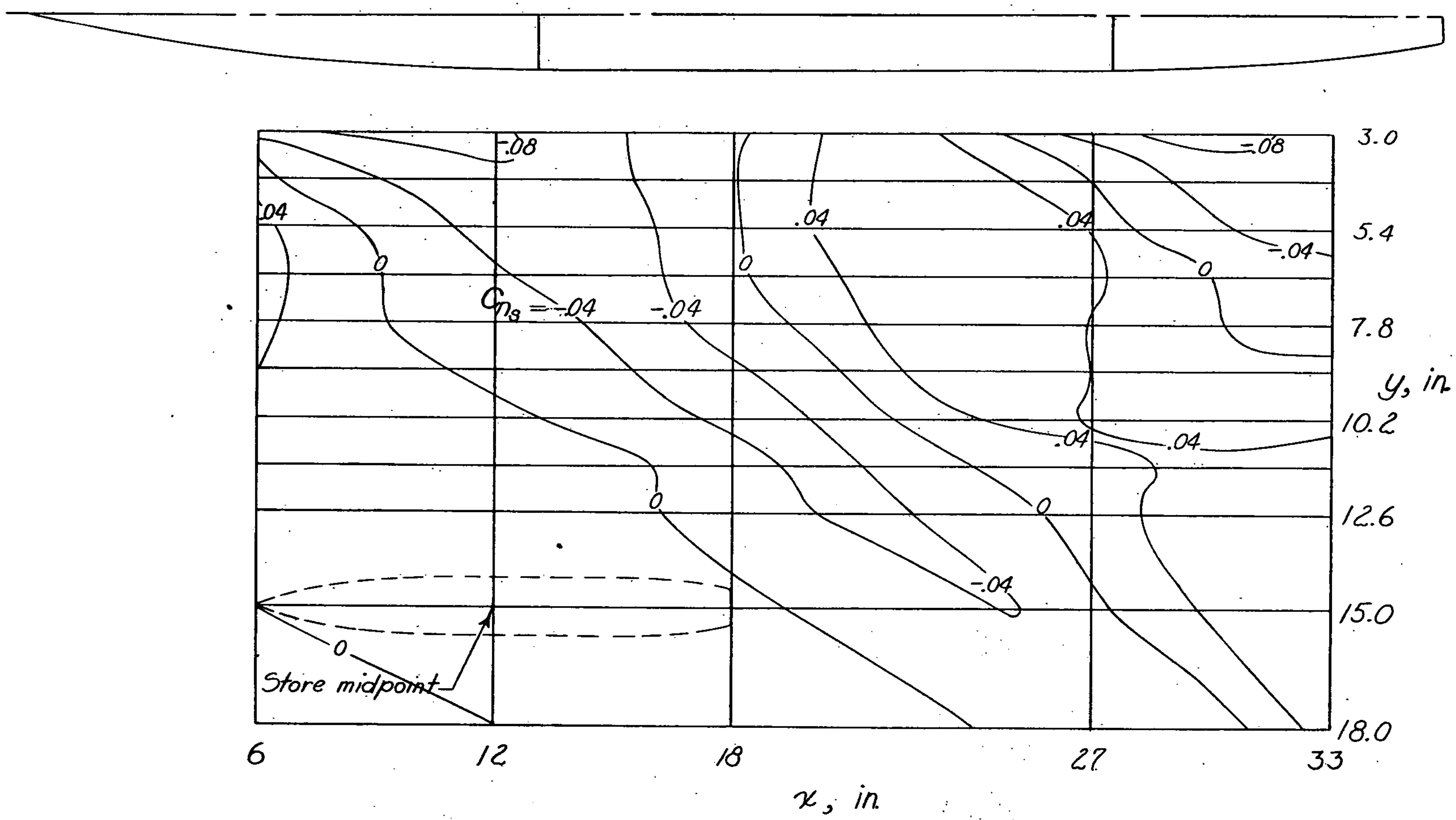
(b) z = 2.09 inches; α = 0°.

Figure 18.- Continued.



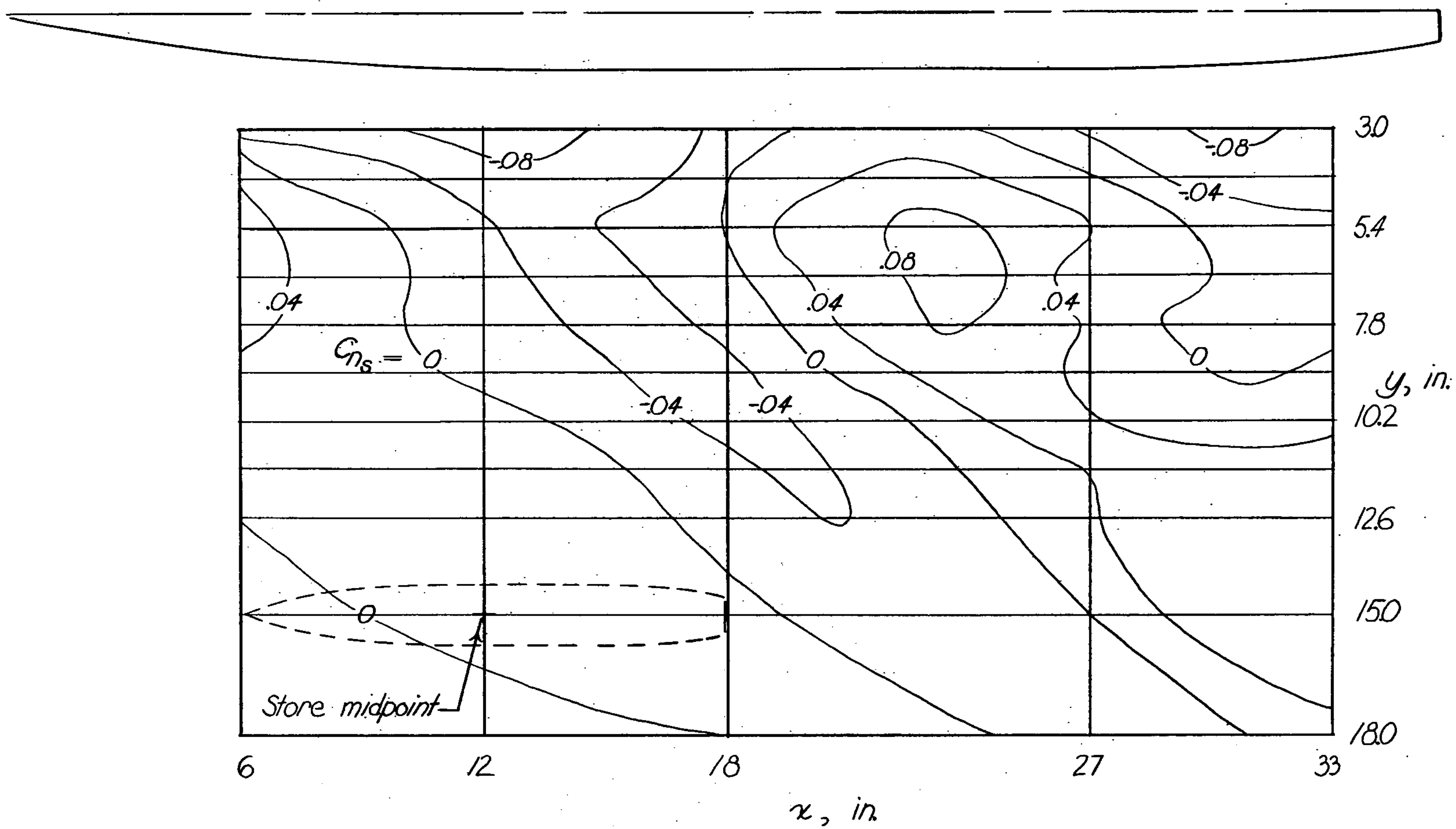
(c) z = 2.09 inches; α = 4°.

Figure 18.- Concluded.



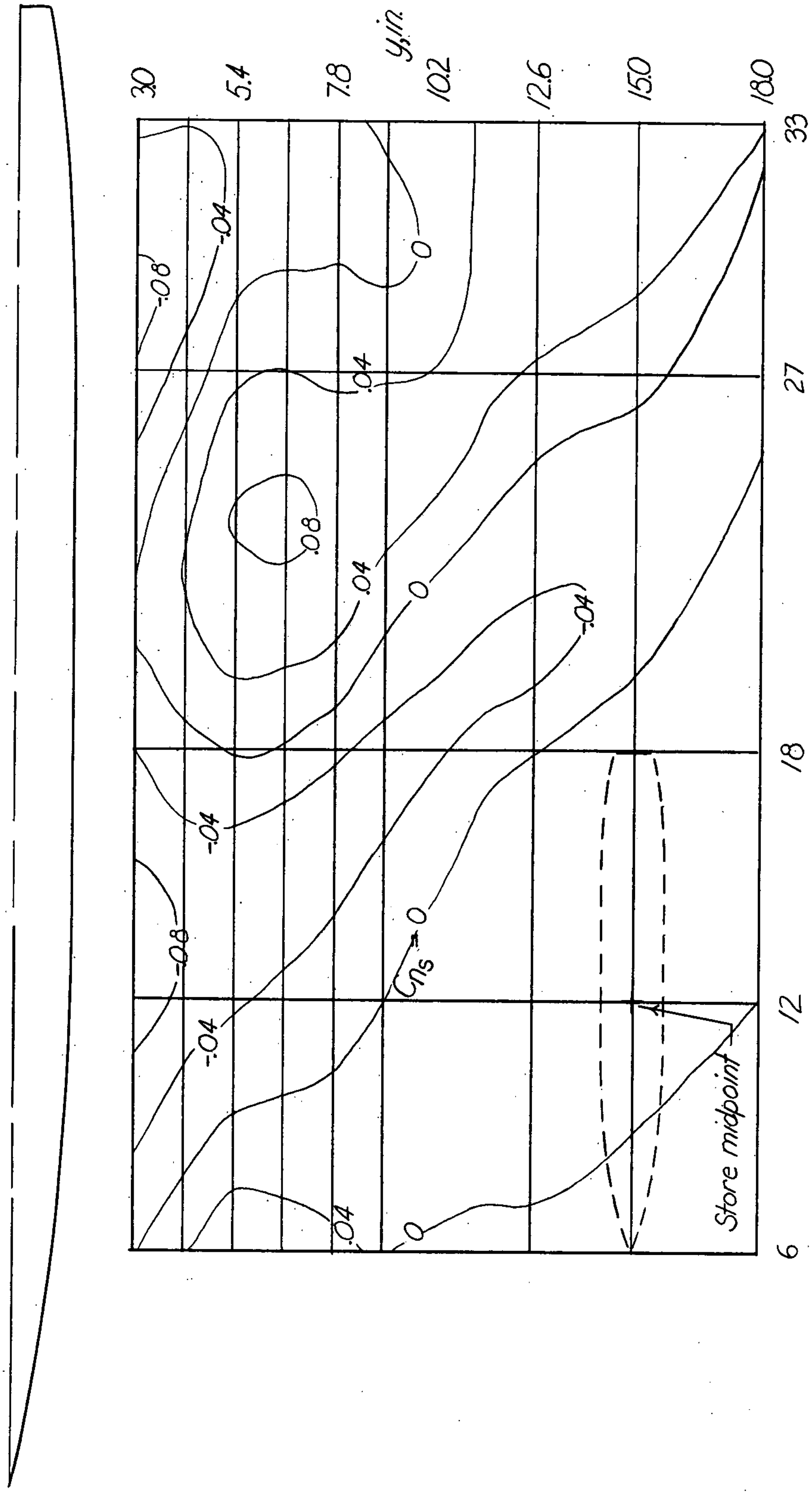
(a) z = 1.15 inches; α = 0°.

Figure 19.- Contour plot of yawing moment of store in presence of fuselage (center of moments is store nose).



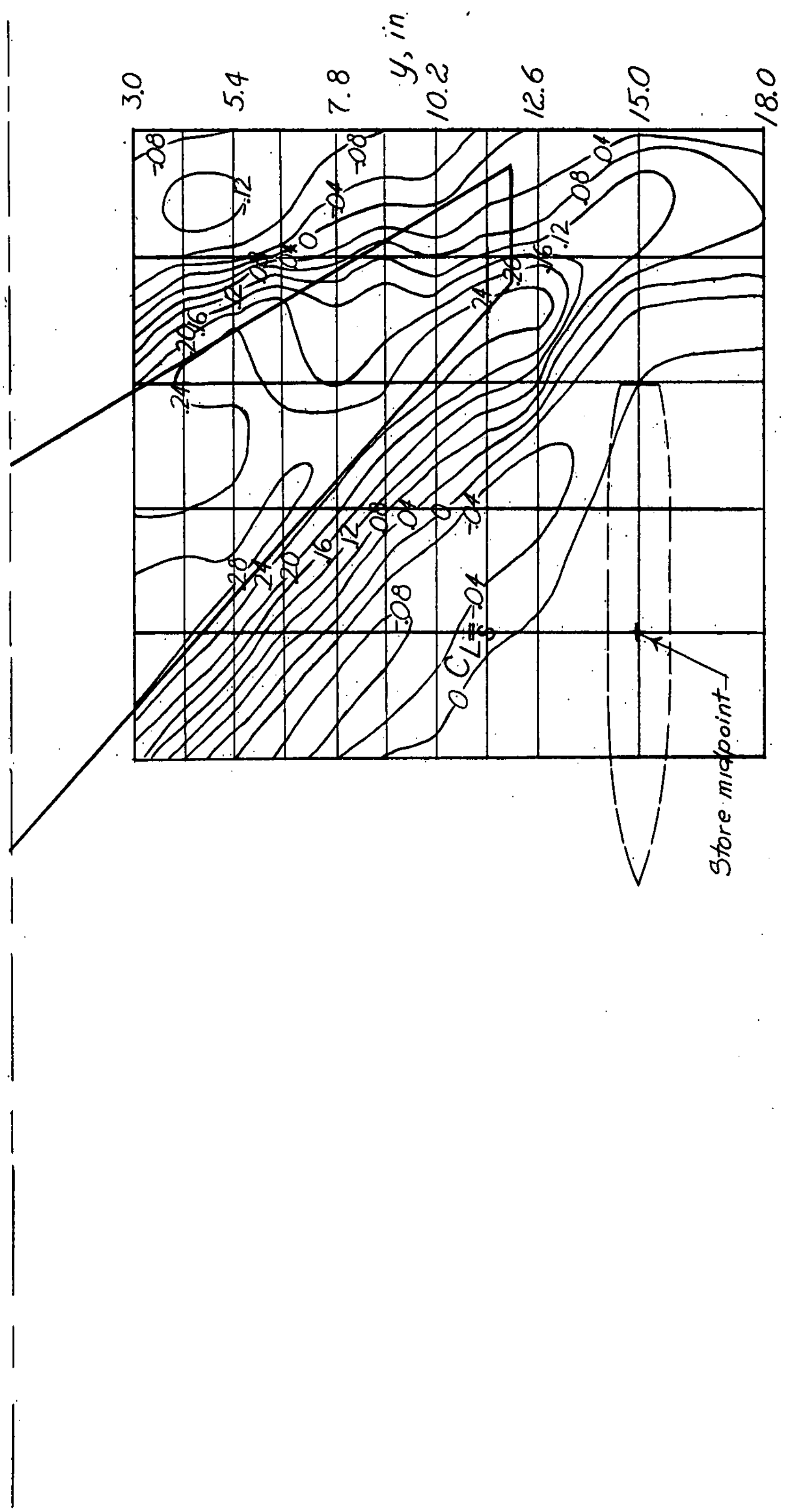
(b) z = 2.09 inches; α = 0°.

Figure 19.- Continued.



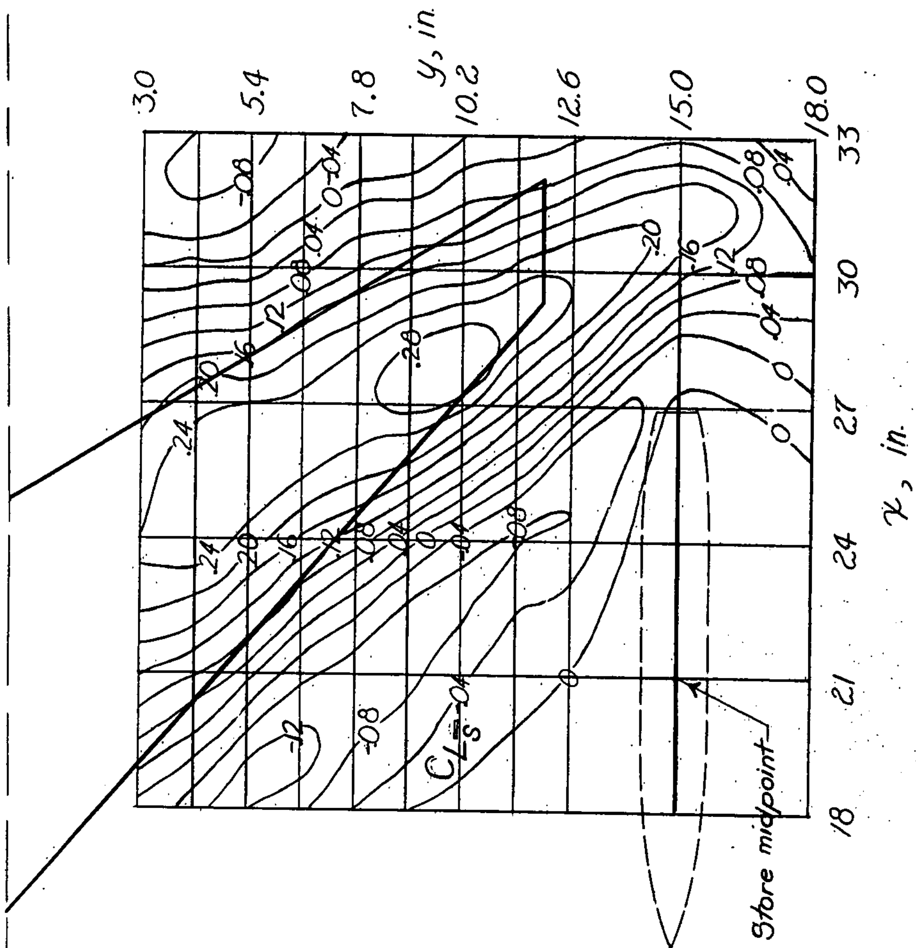
(c) z = 2.09 inches; α = 4°.

Figure 19.- Concluded.



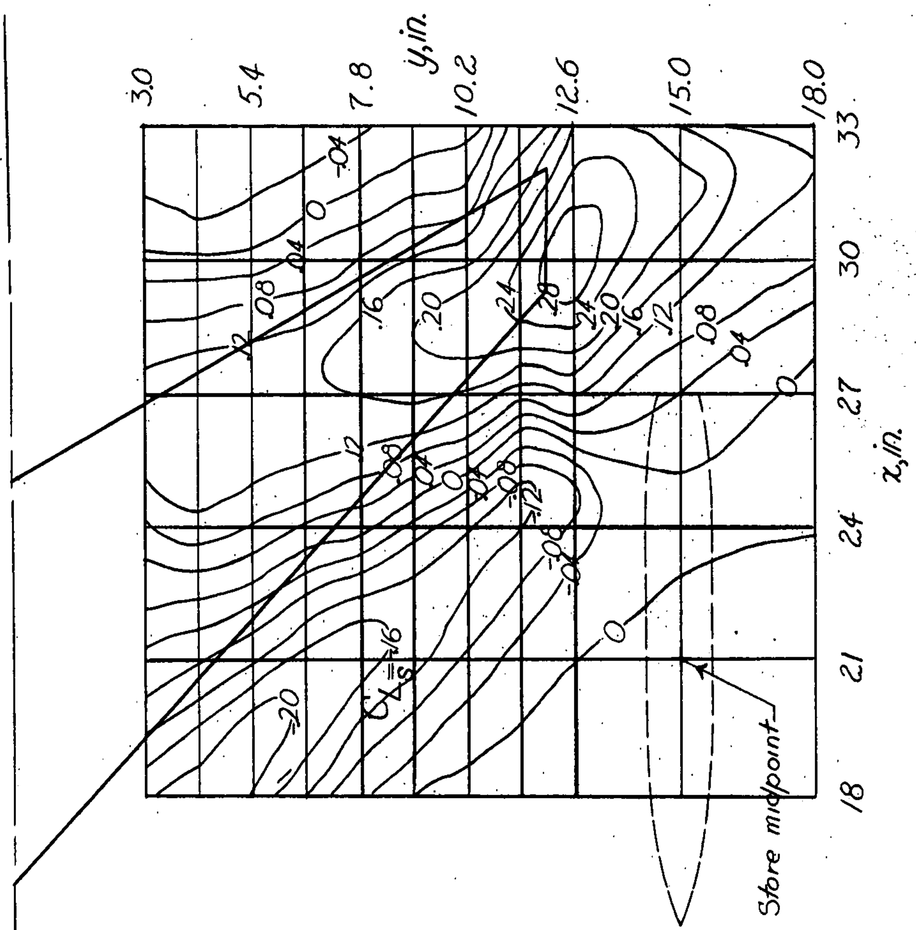
(a) z = 1.15 inches; α = 0°.

Figure 20.- Contour plot of lift of the store in presence of wing.



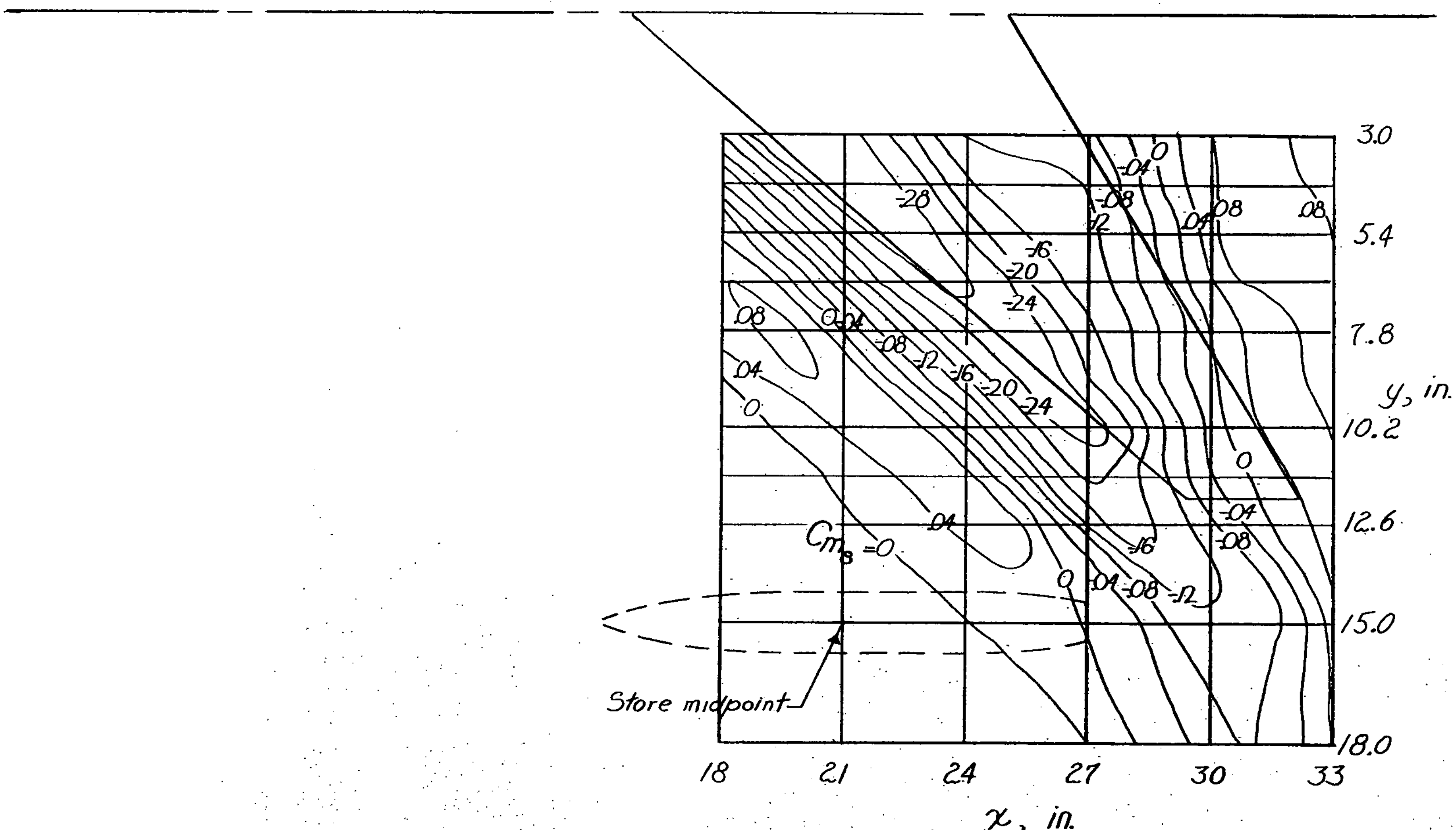
(b) z = 2.09 inches; α = 0°.

Figure 20.- Continued.



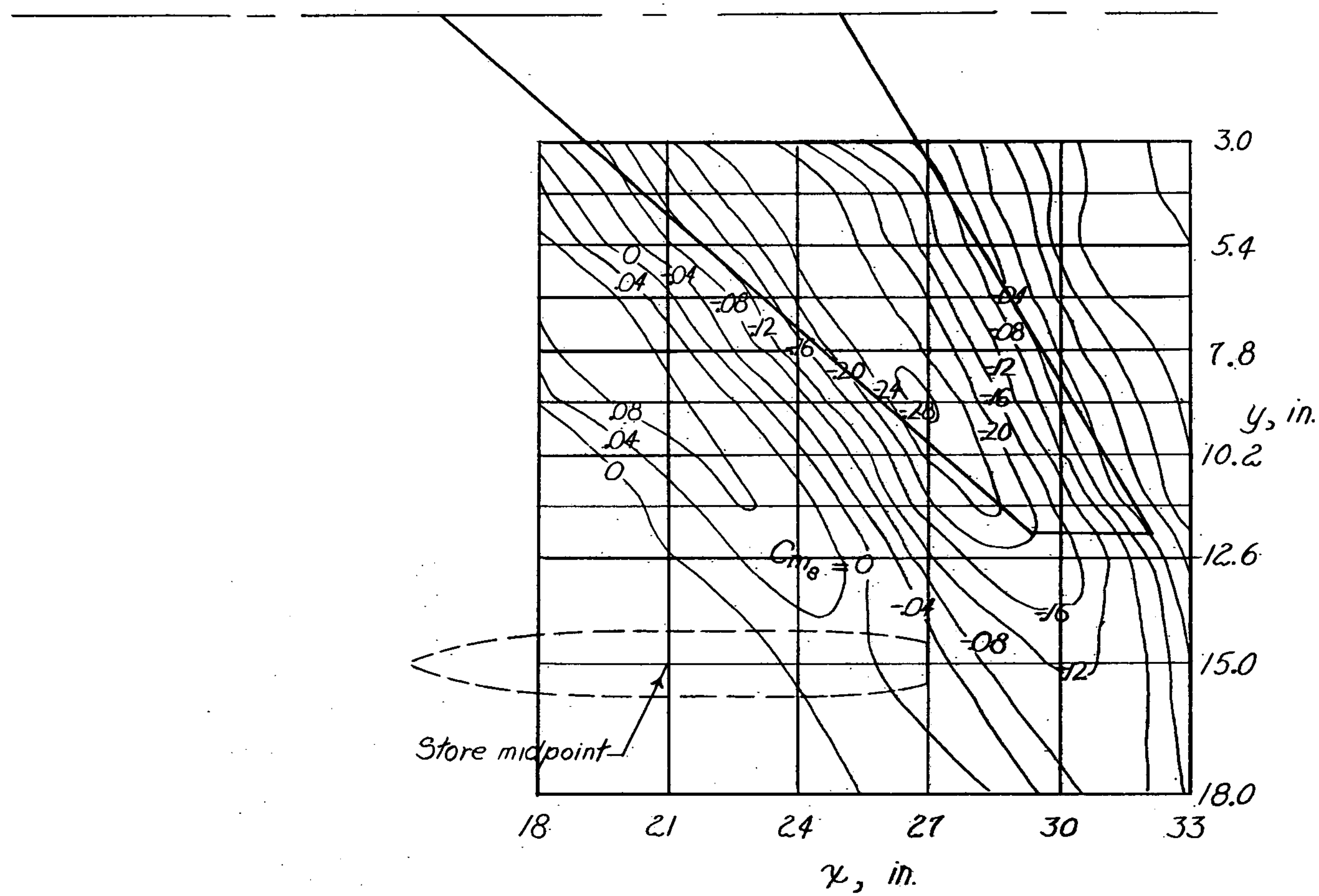
(c) z = 2.09 inches; α = 4°.

Figure 20.- Concluded.



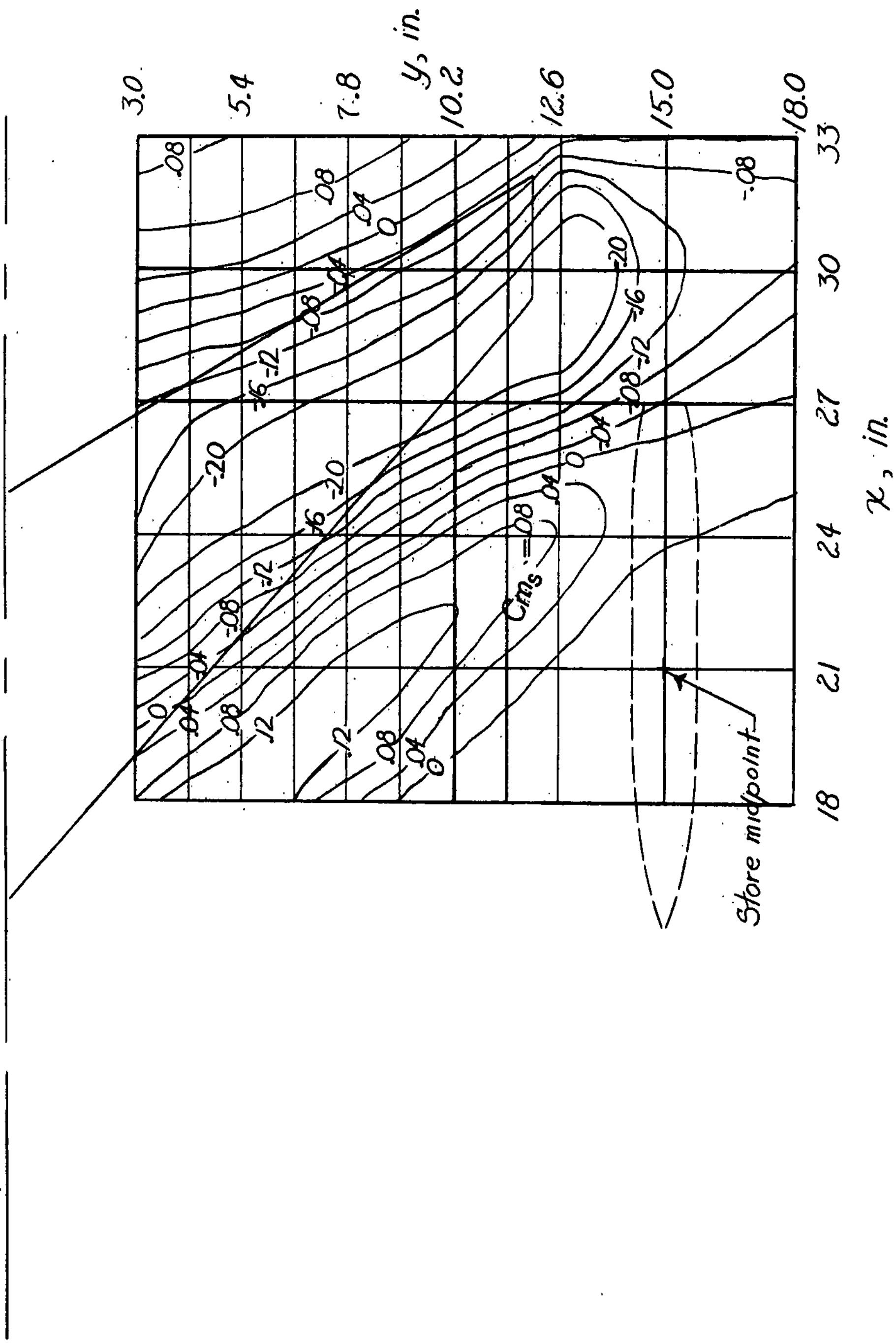
(a) z = 1.15 inches; α = 0°.

Figure 21.- Contour plot of pitching moment of store in presence of wing (center of moments is store nose).



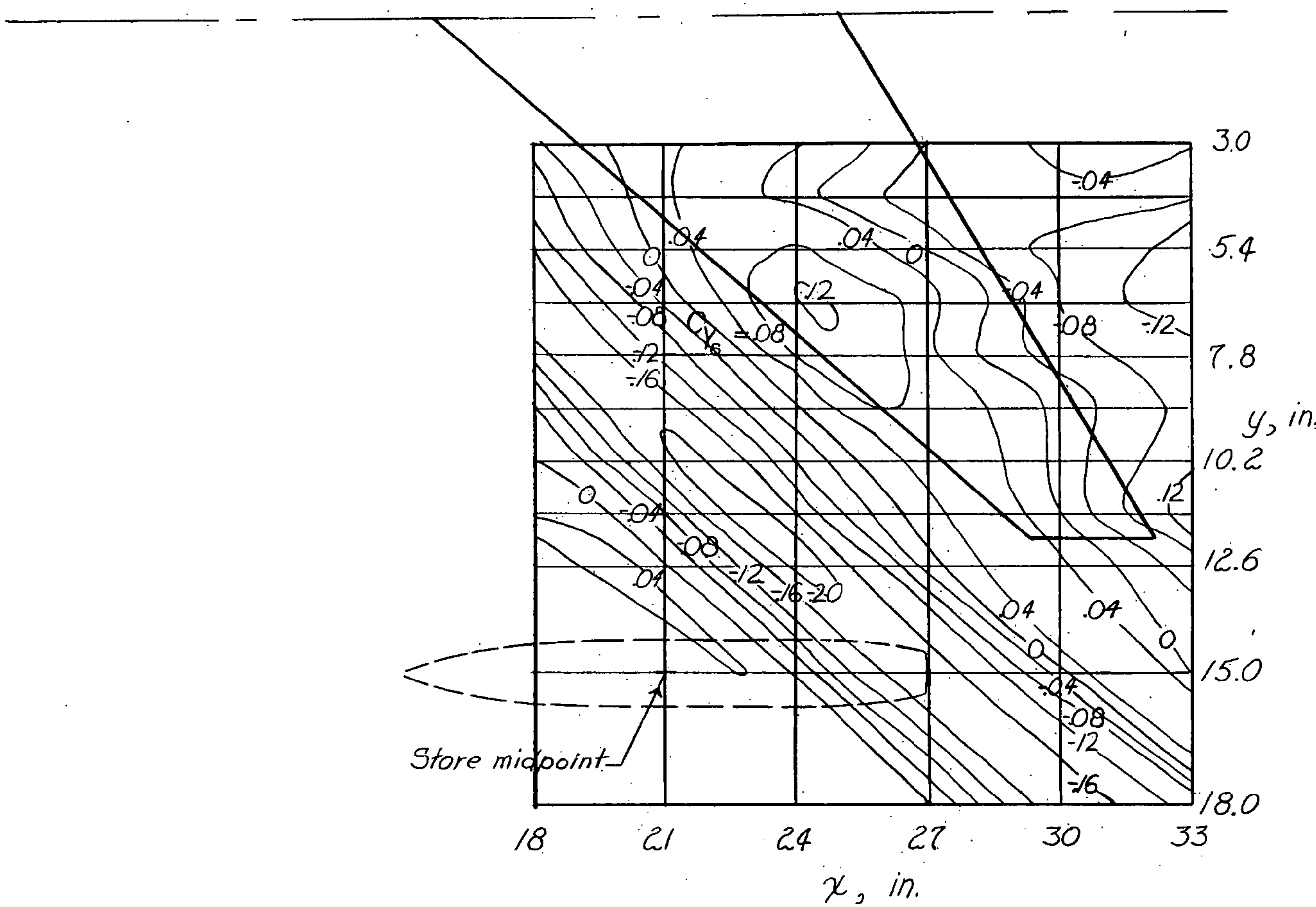
(b) z = 2.09 inches; α = 0°.

Figure 21.- Continued.



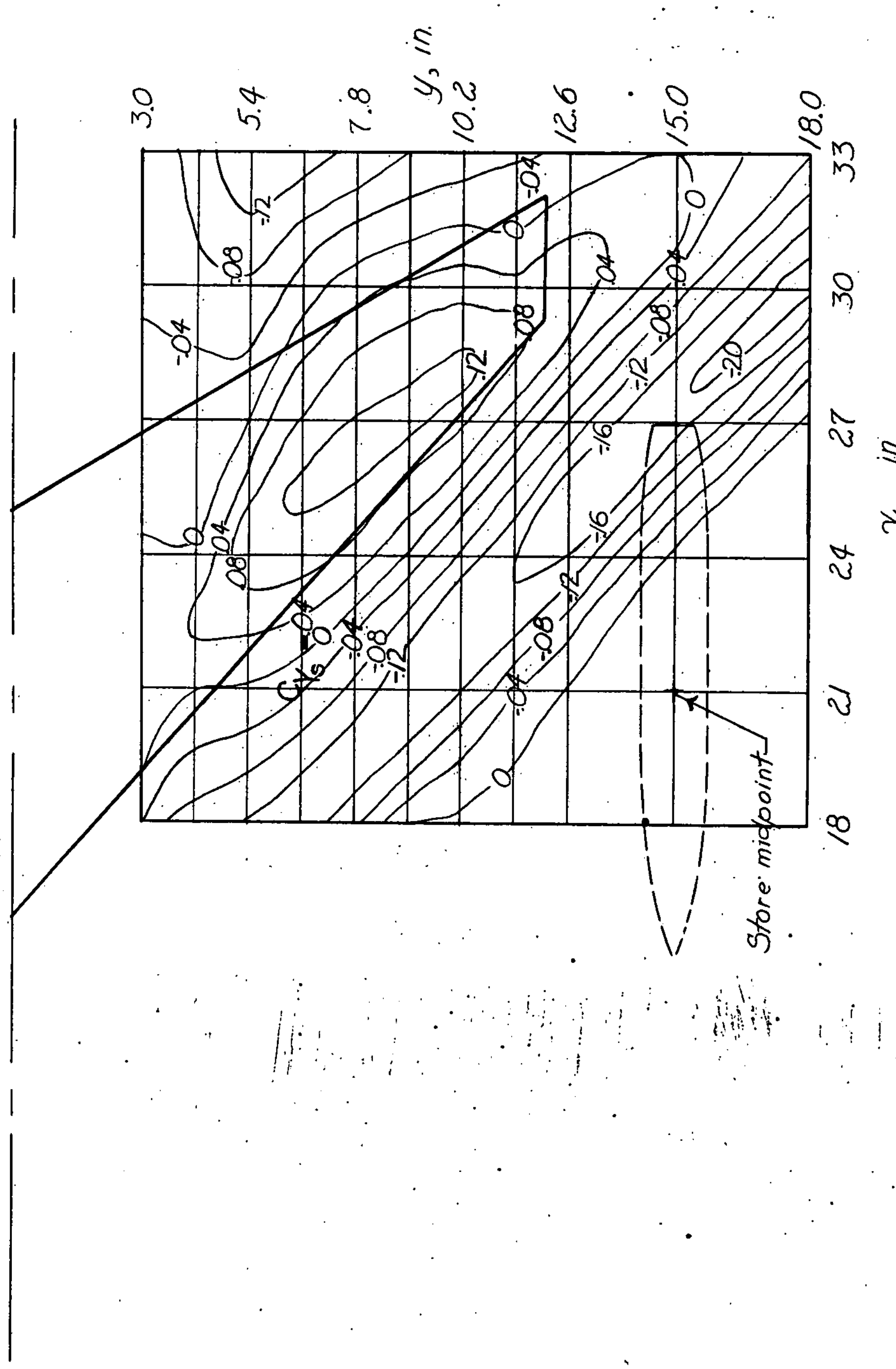
(c) z = 2.09 inches; $\alpha = 4^{\circ}$.

Figure 21.- Concluded.



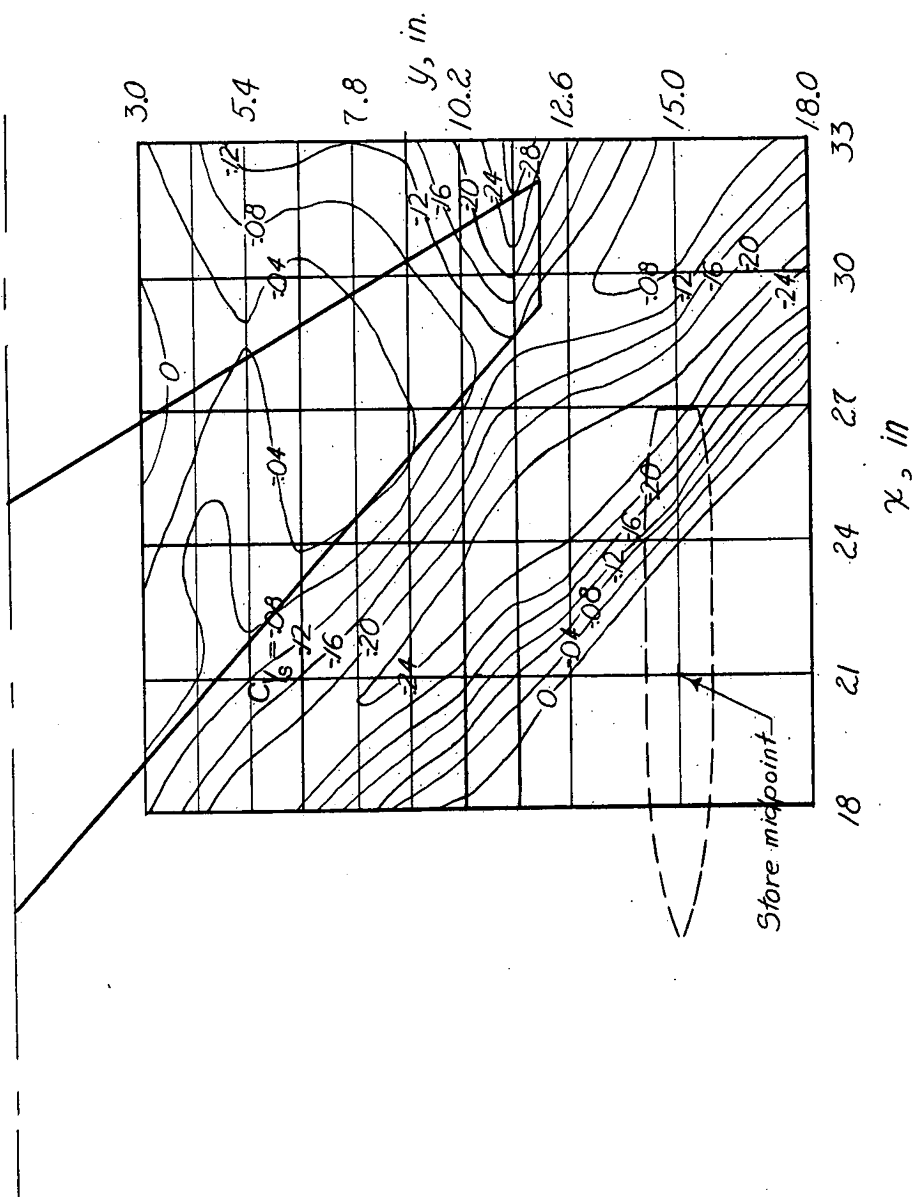
(a) $z = 1.15$ inches; $\alpha = 0^{\circ}$.

Figure 22.- Contour plot of side force of store in presence of wing.



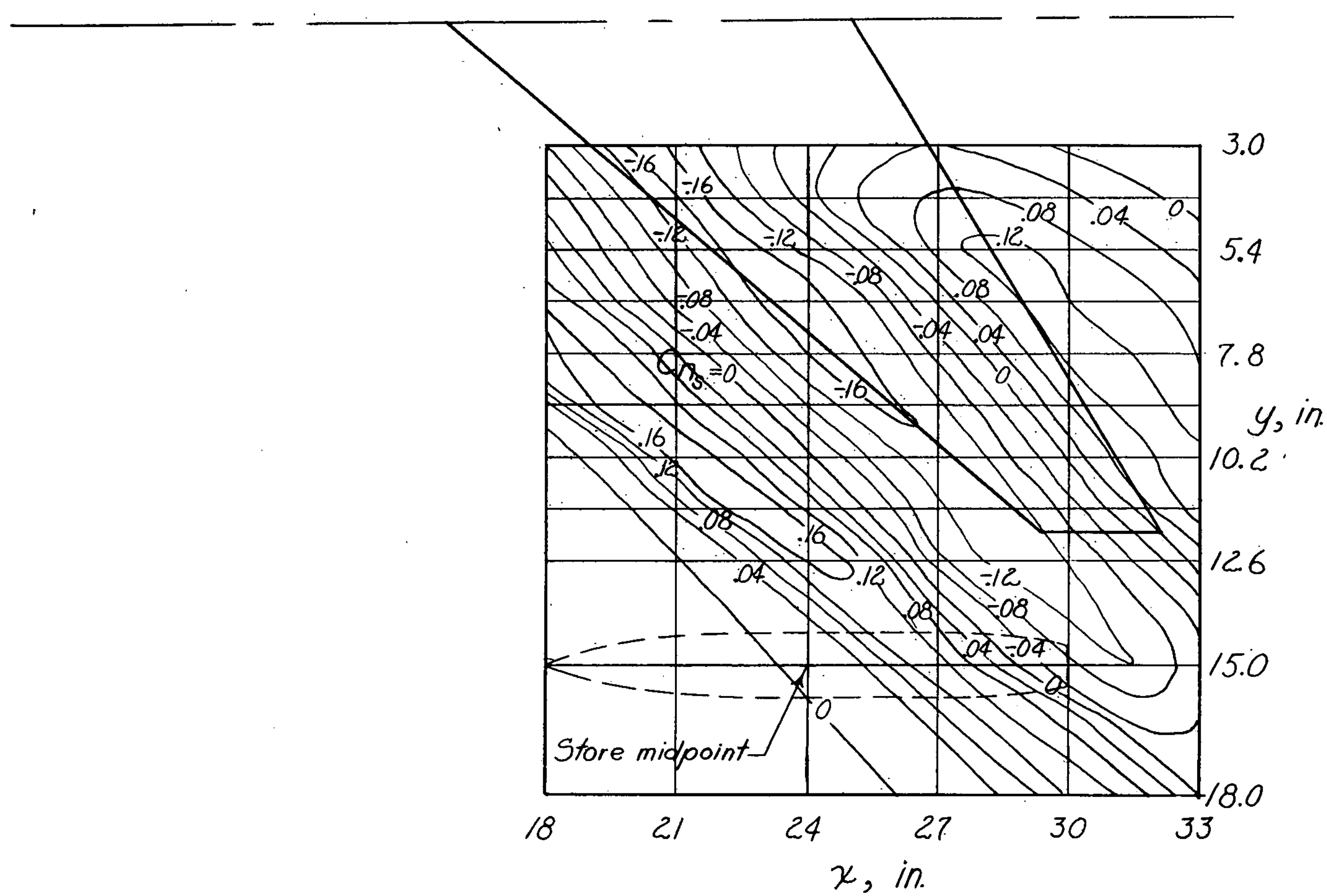
(b) z = 2.09 inches; α = 0°.

Figure 22.- Continued.



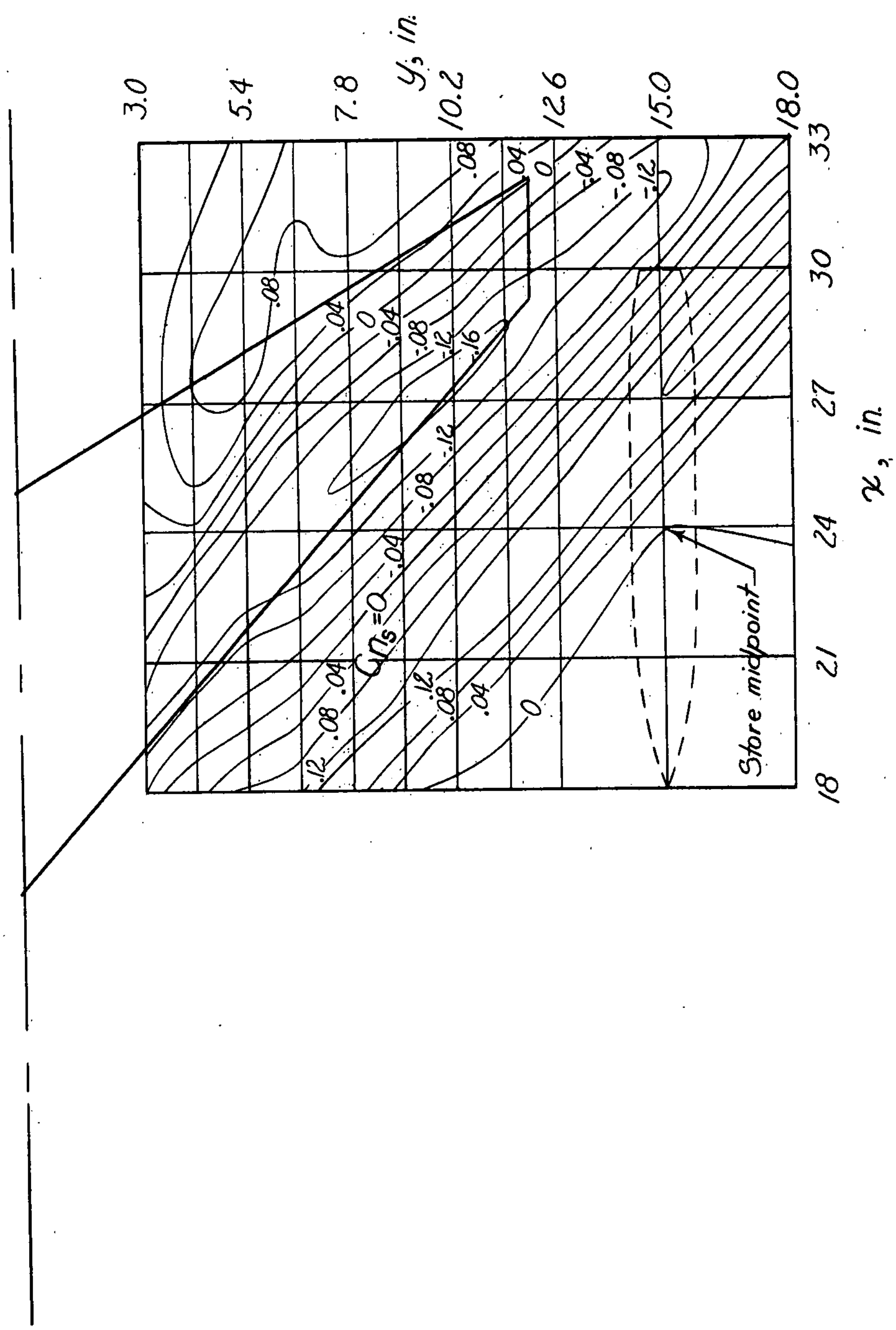
(c) z = 2.09 inches; α = 4°.

Figure 22.- Concluded.



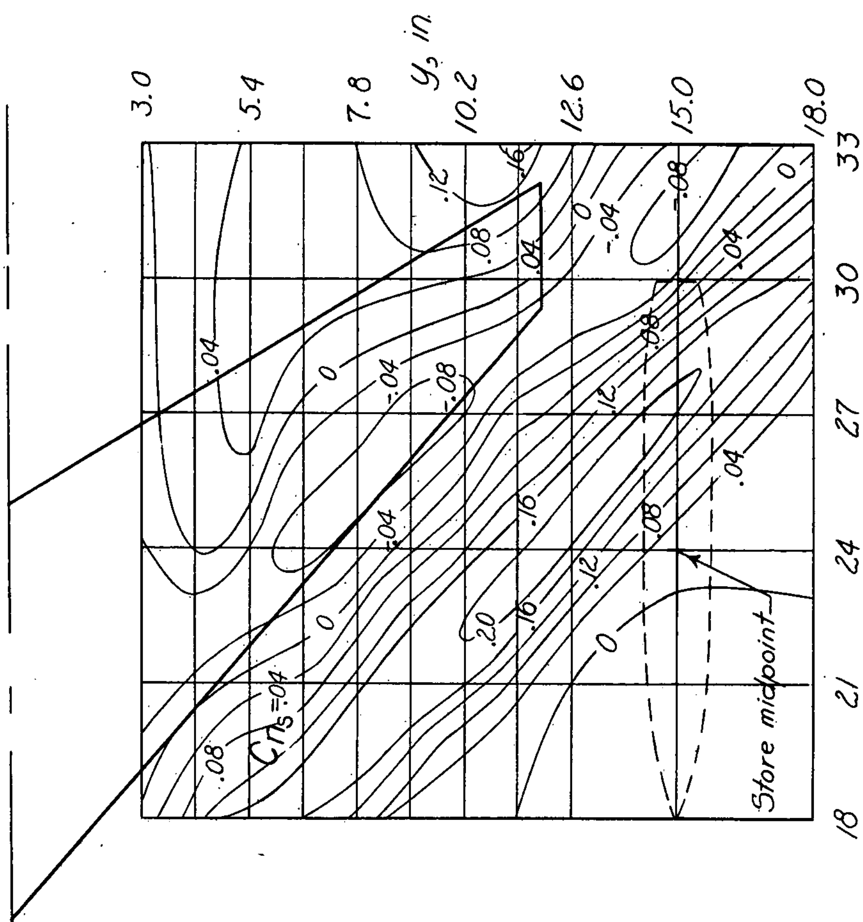
(a) z = 1.15 inches; α = 0°.

Figure 23.- Contour plot of yawing moment of store in presence of wing (center of moments is store nose).



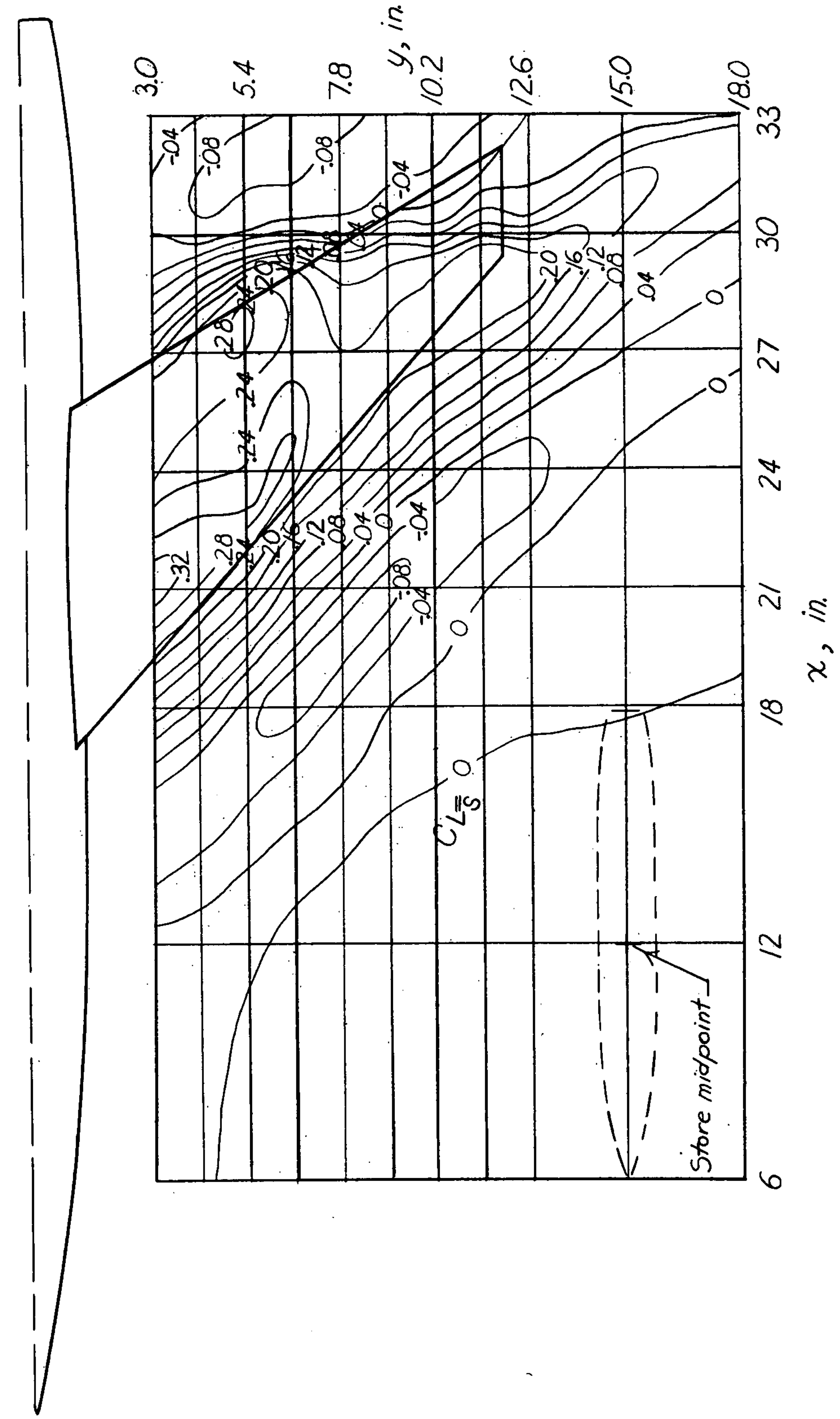
(b) z = 2.09 inches; α = 0°.

Figure 23.- Continued.



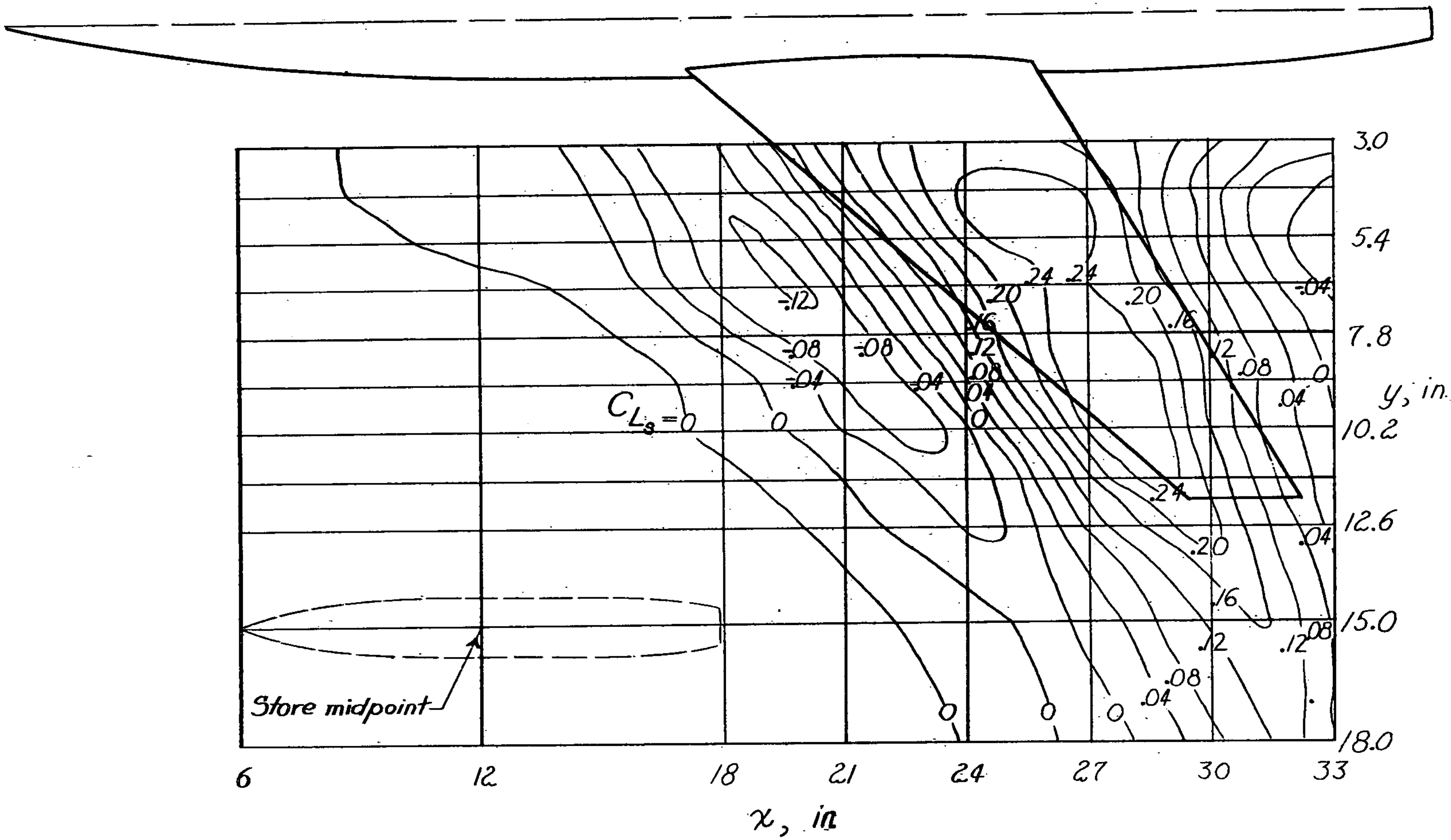
(c) z = 2.09 inches; α = 4°.

Figure 23.- Concluded.



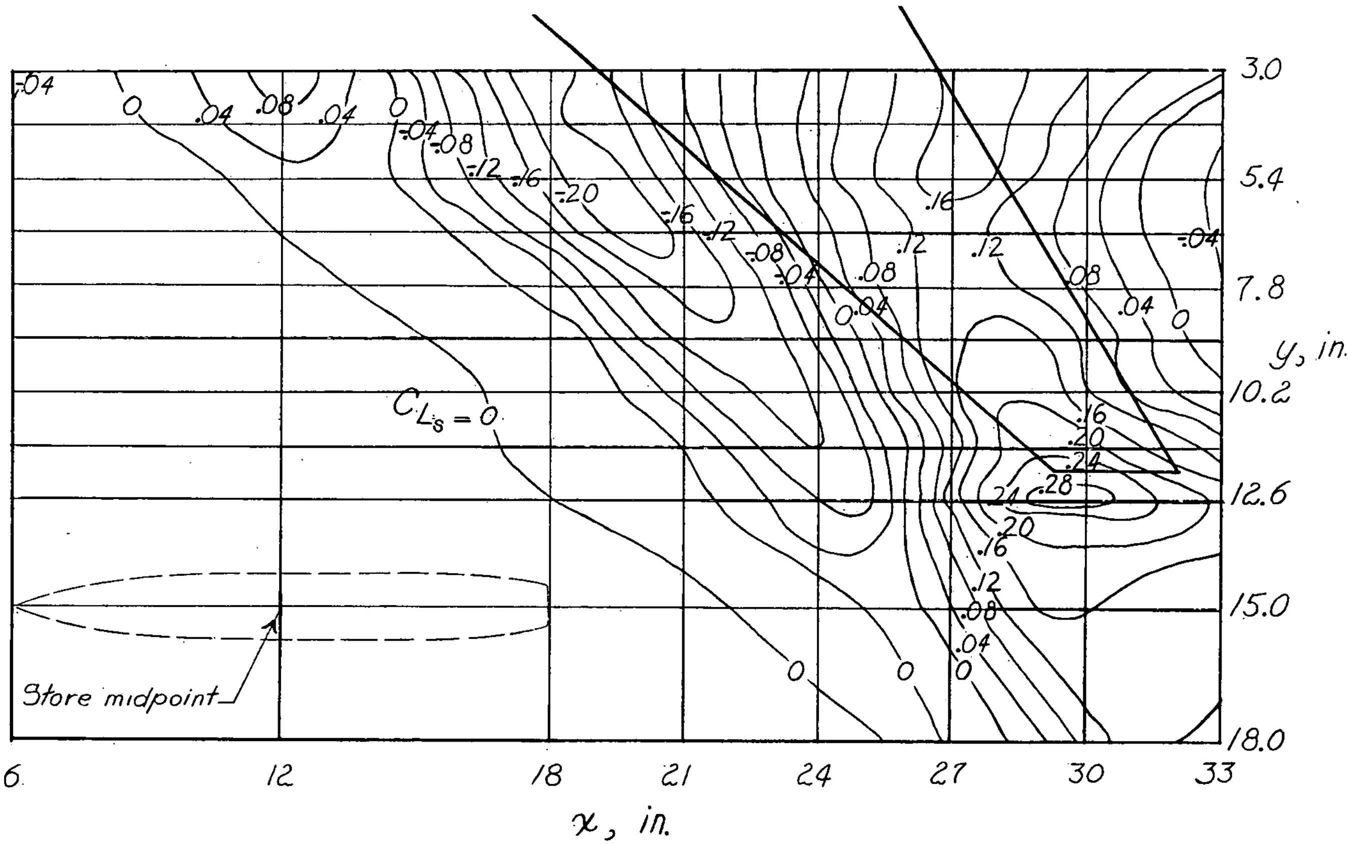
(a) z = 1.15 inches; α = 0°.

Figure 24.- Contour plot of the lift of store in presence of wing-fuselage combination.



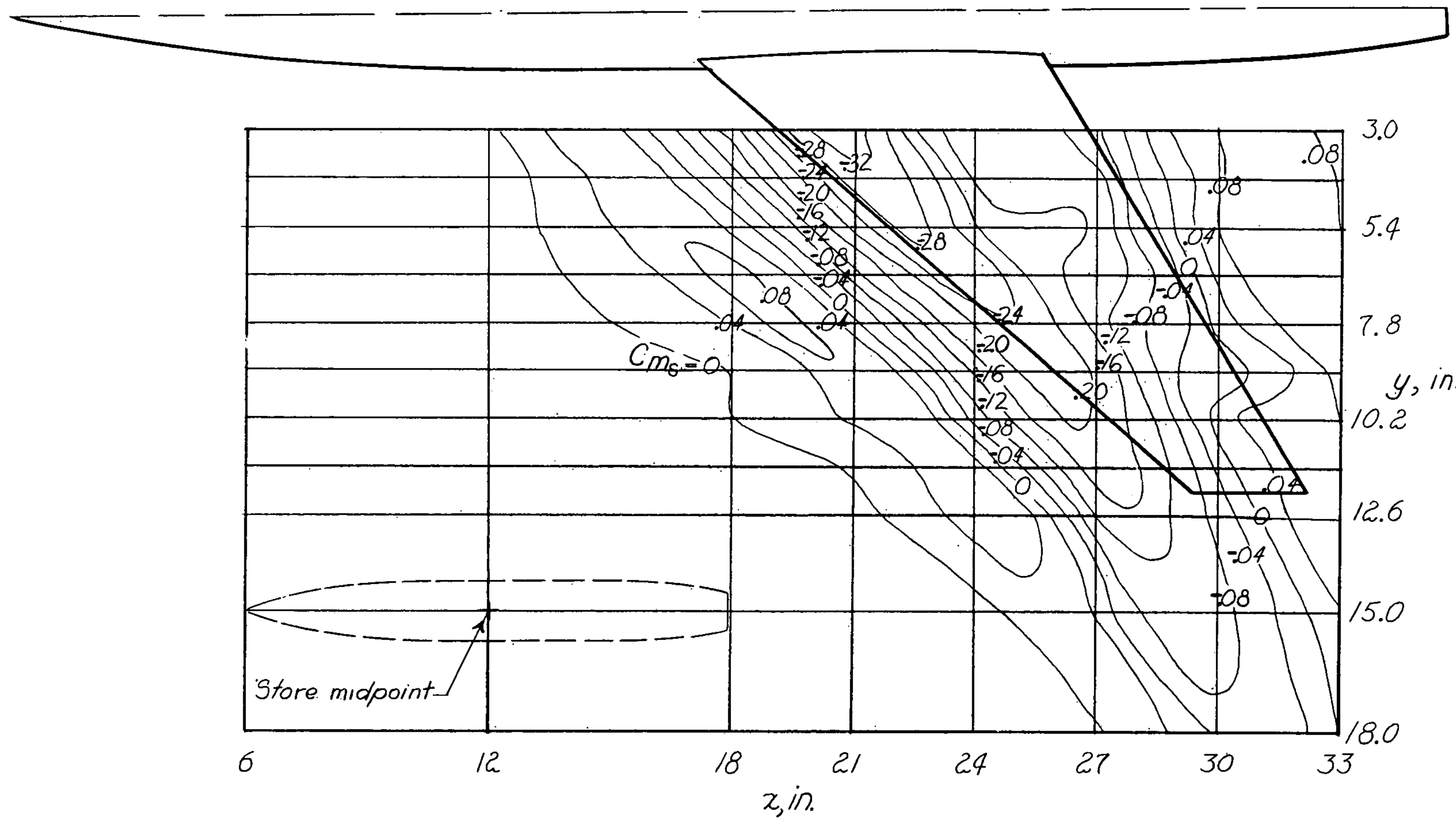
(b) z = 2.09 inches; α = 0°.

Figure 24.- Continued.



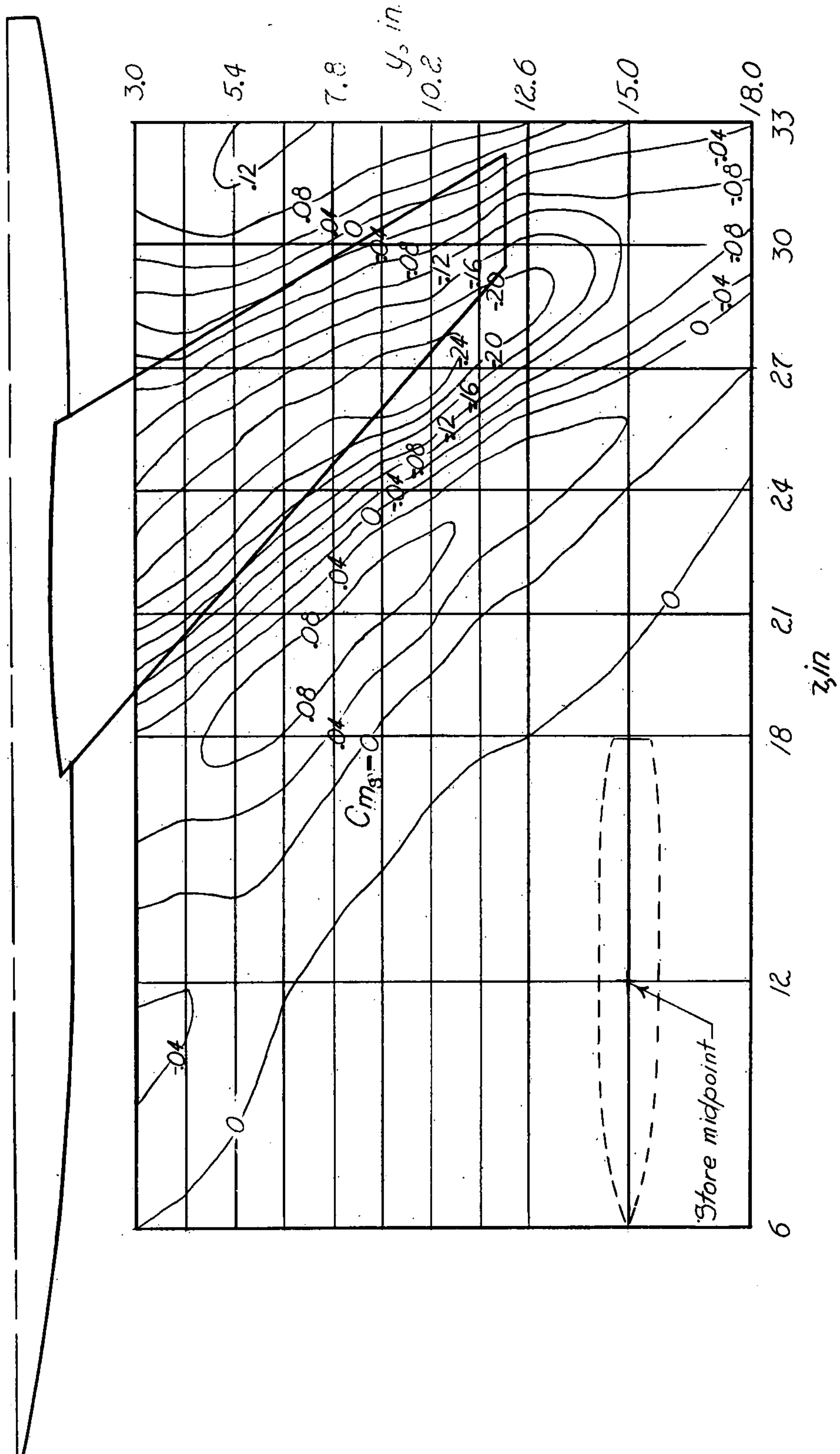
(c) z = 2.09 inches; $\alpha = 4^{\circ}$.

Figure 24.- Concluded.



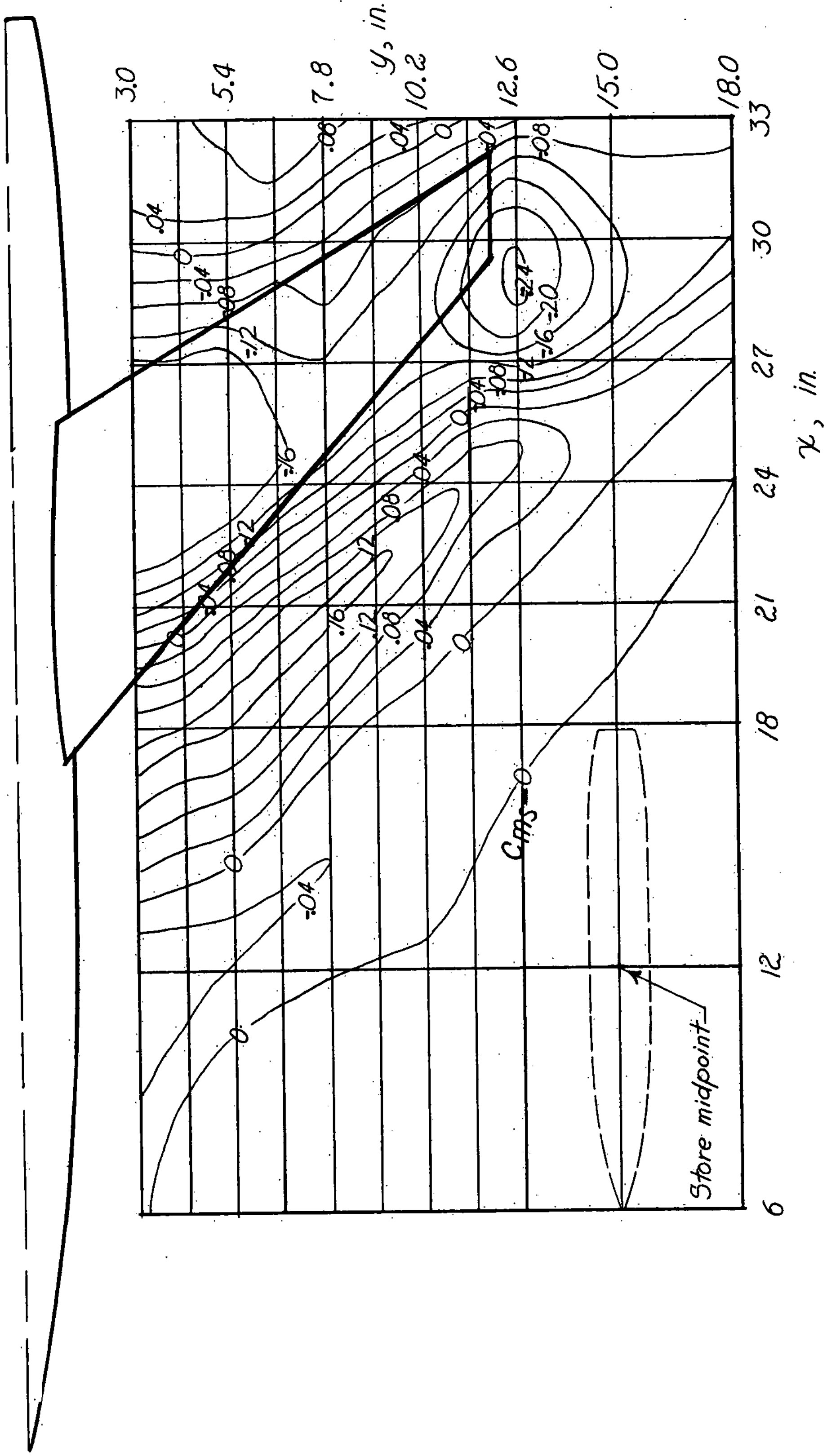
(a) z = 1.15 inches; α = 0°.

Figure 25.- Contour plot of pitching moment of store in presence of wing-fuselage combination (center of moments is store nose).



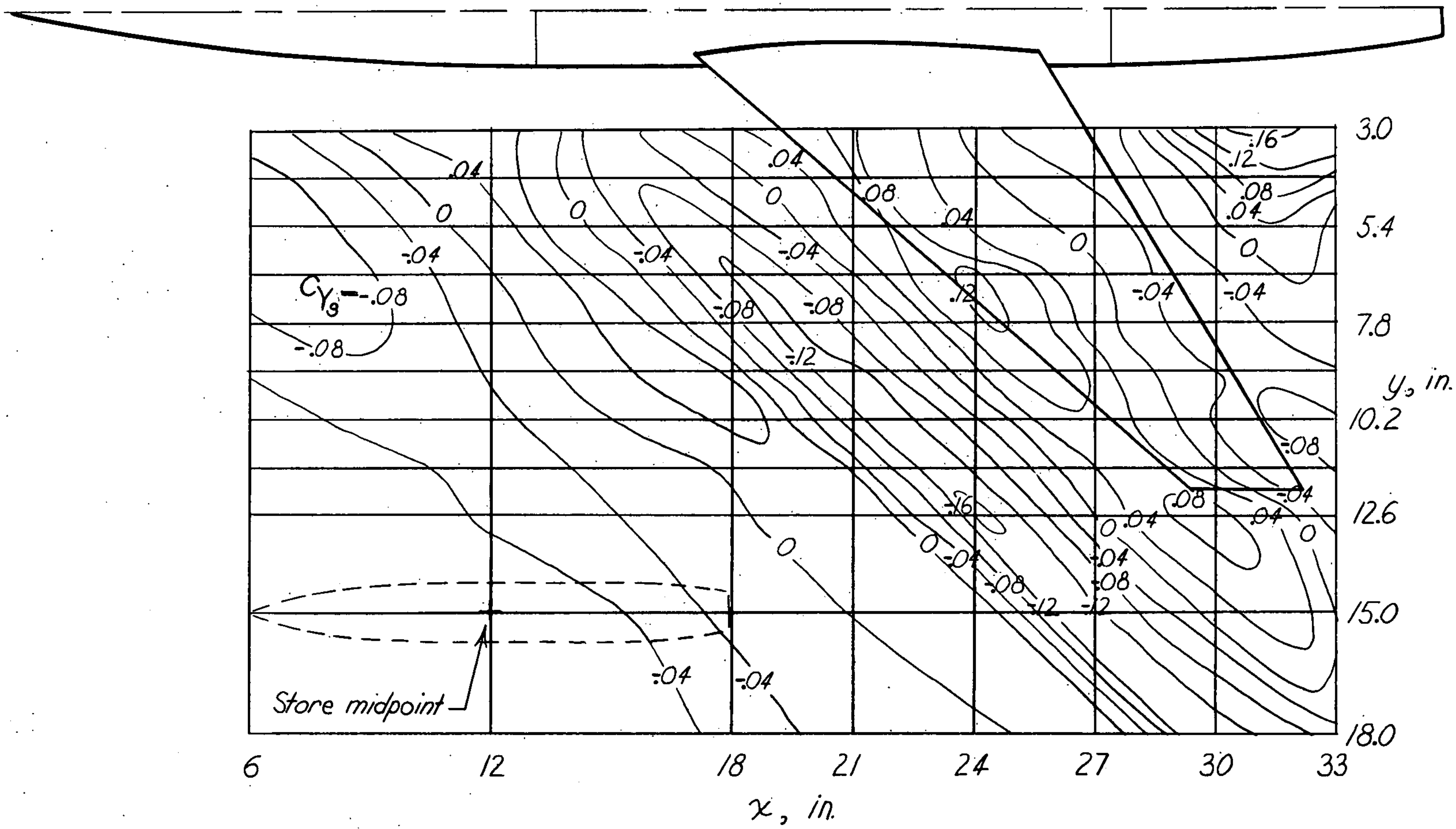
(b) z = 2.09 inches; α = 0°.

Figure 25.- Continued.



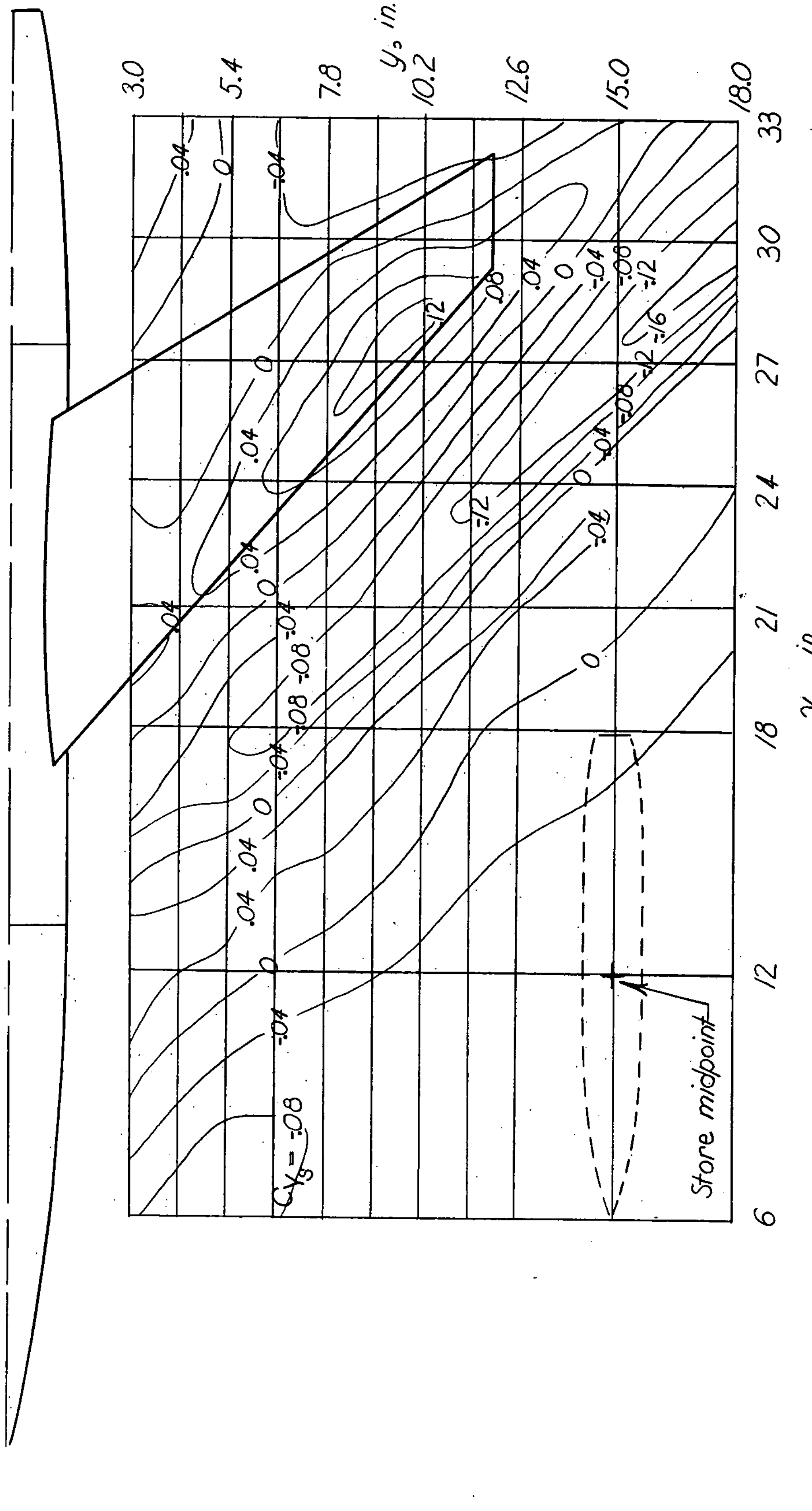
(c) z = 2.09 inches; α = 4°.

Figure 25.- Concluded.



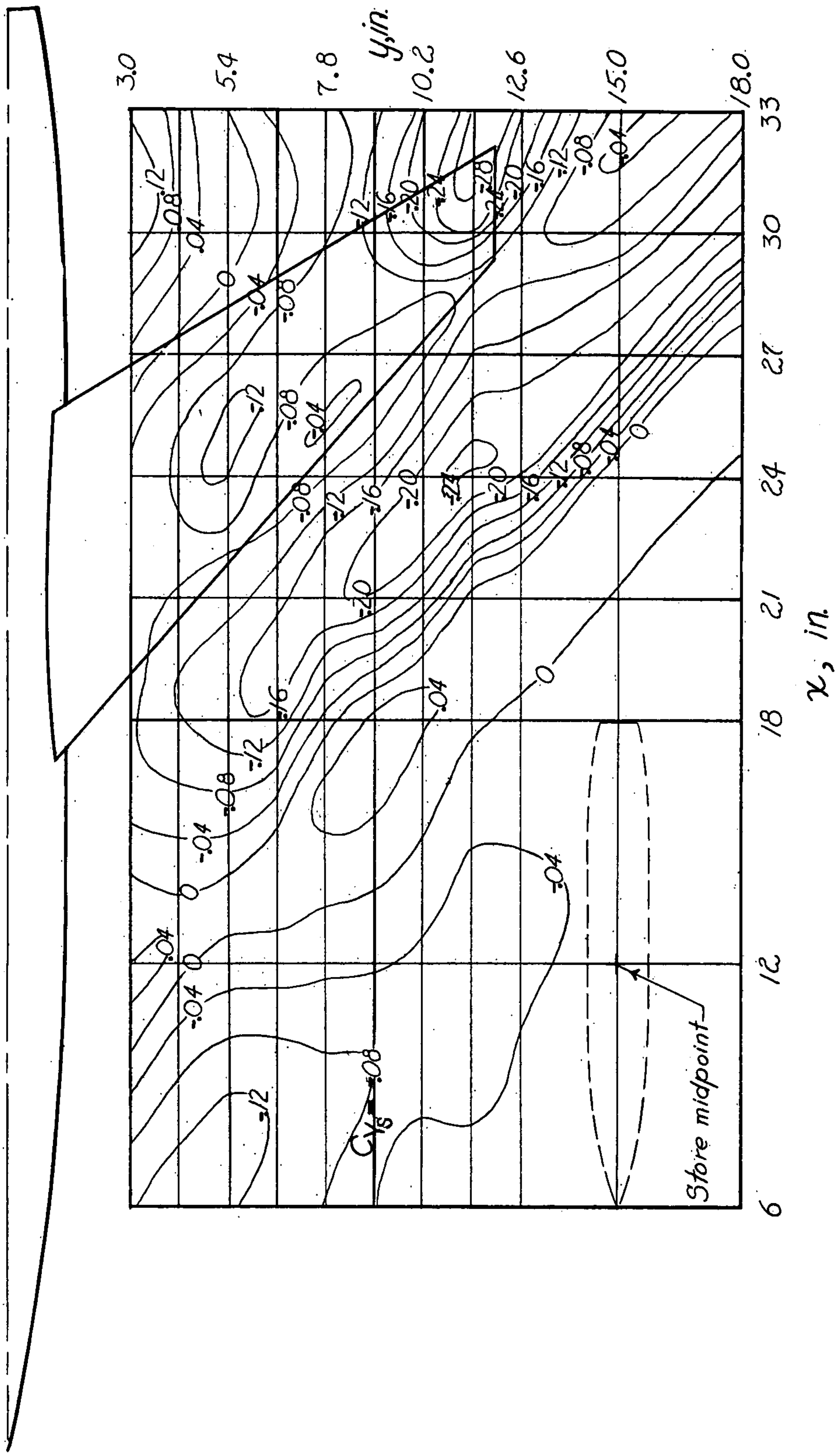
(a) z = 1.15 inches; α = 0°.

Figure 26.- Contour plot of side force of store in presence of wing-fuselage combination.



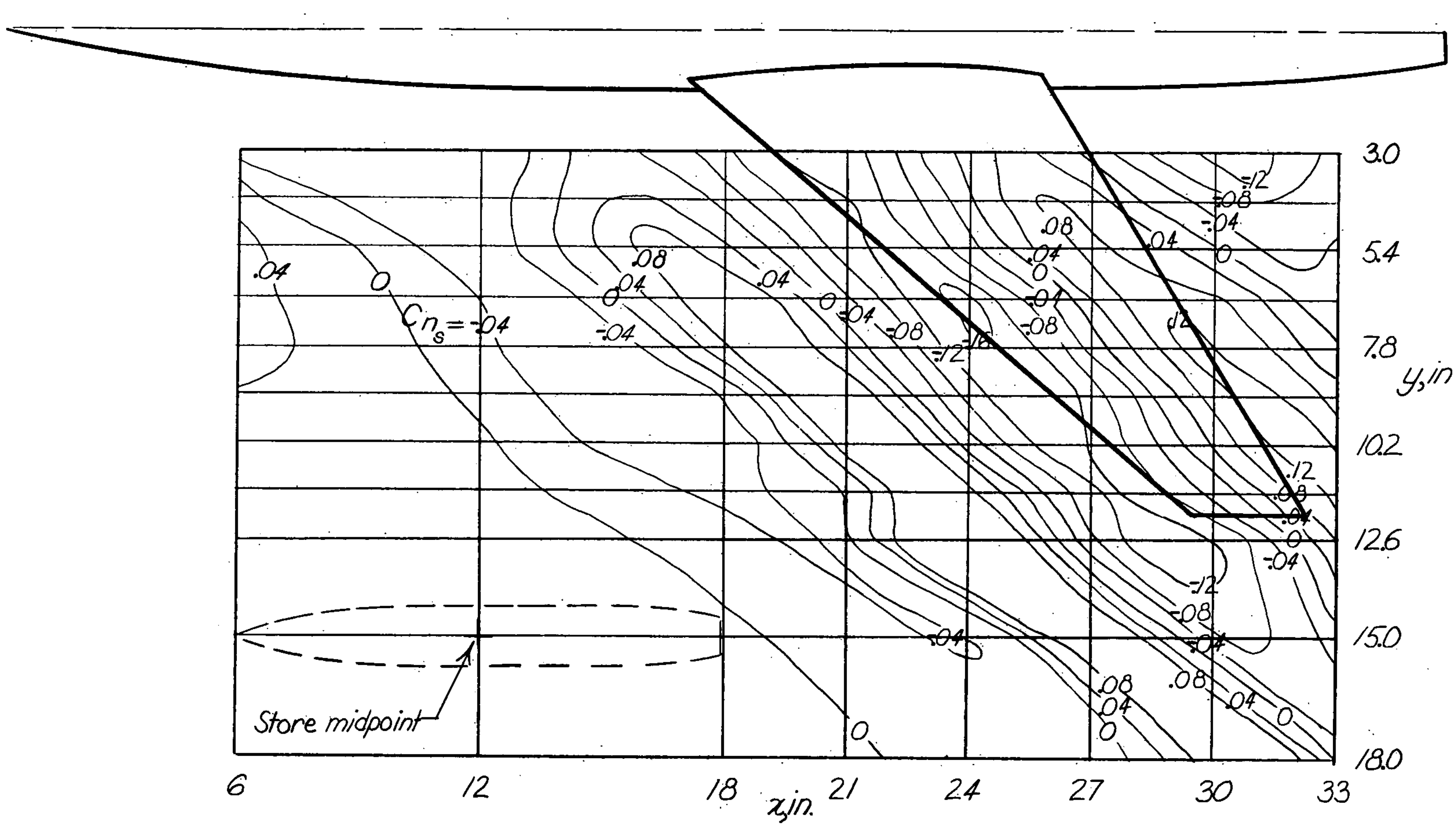
(b) z = 2.09 inches; α = 0°.

Figure 26.- Continued.



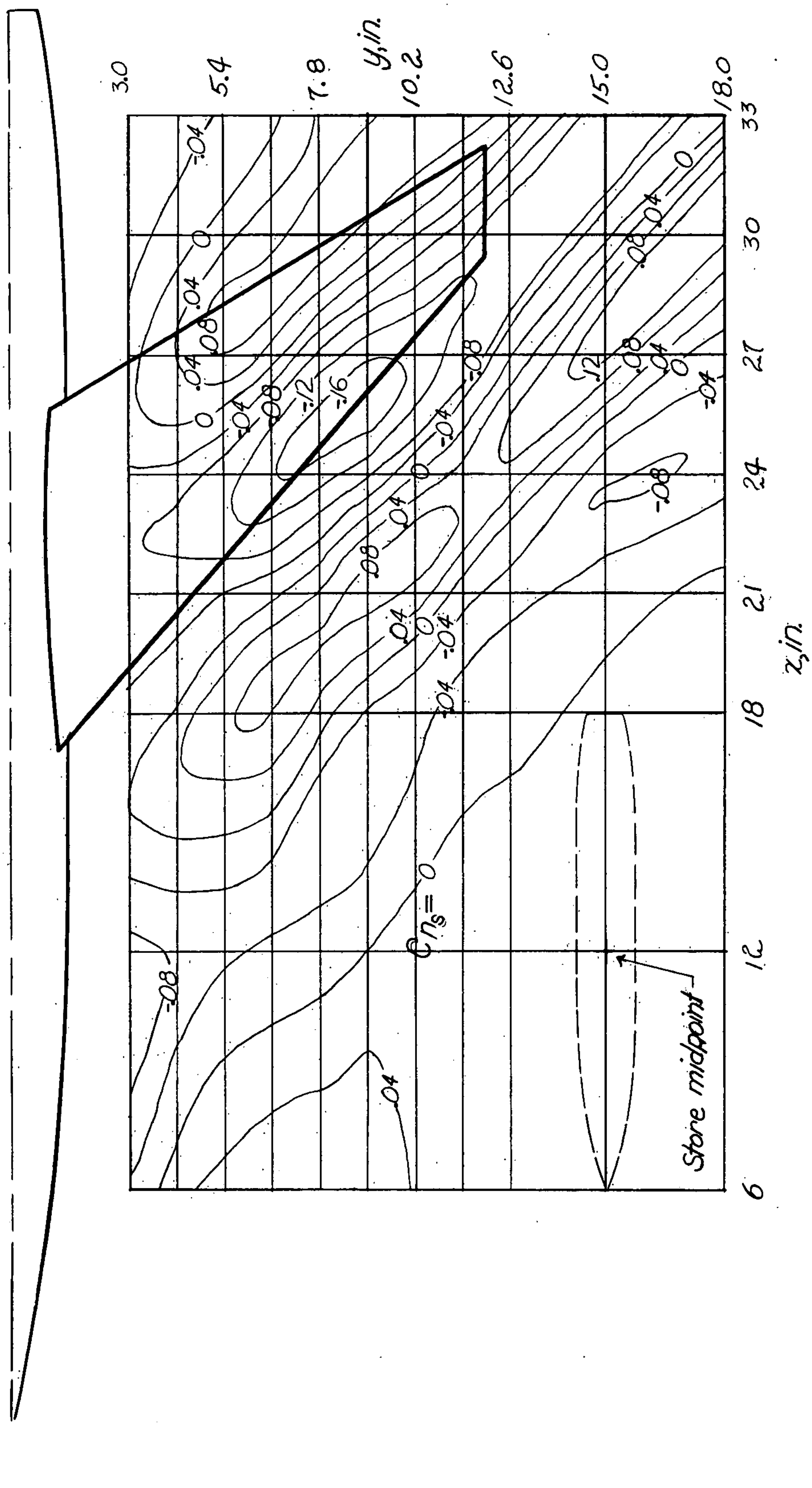
(c) z = 2.09 inches; α = 4°.

Figure 26.- Concluded.



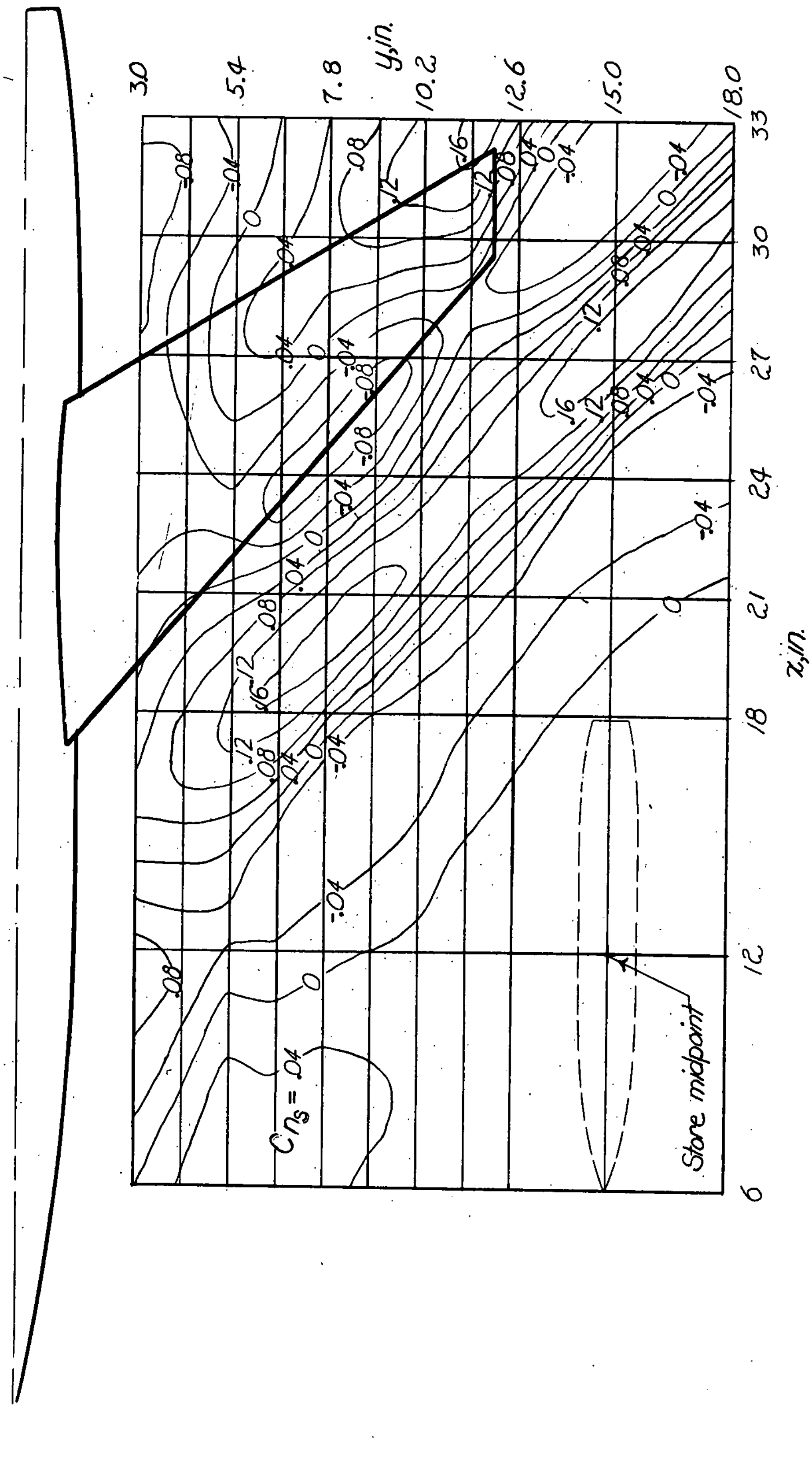
(a) $z = 1.15$ inches; $\alpha = 0^{\circ}$.

Figure 27.- Contour plot of yawing moment of store in presence of wing-fuselage combination (center of moments is store nose).



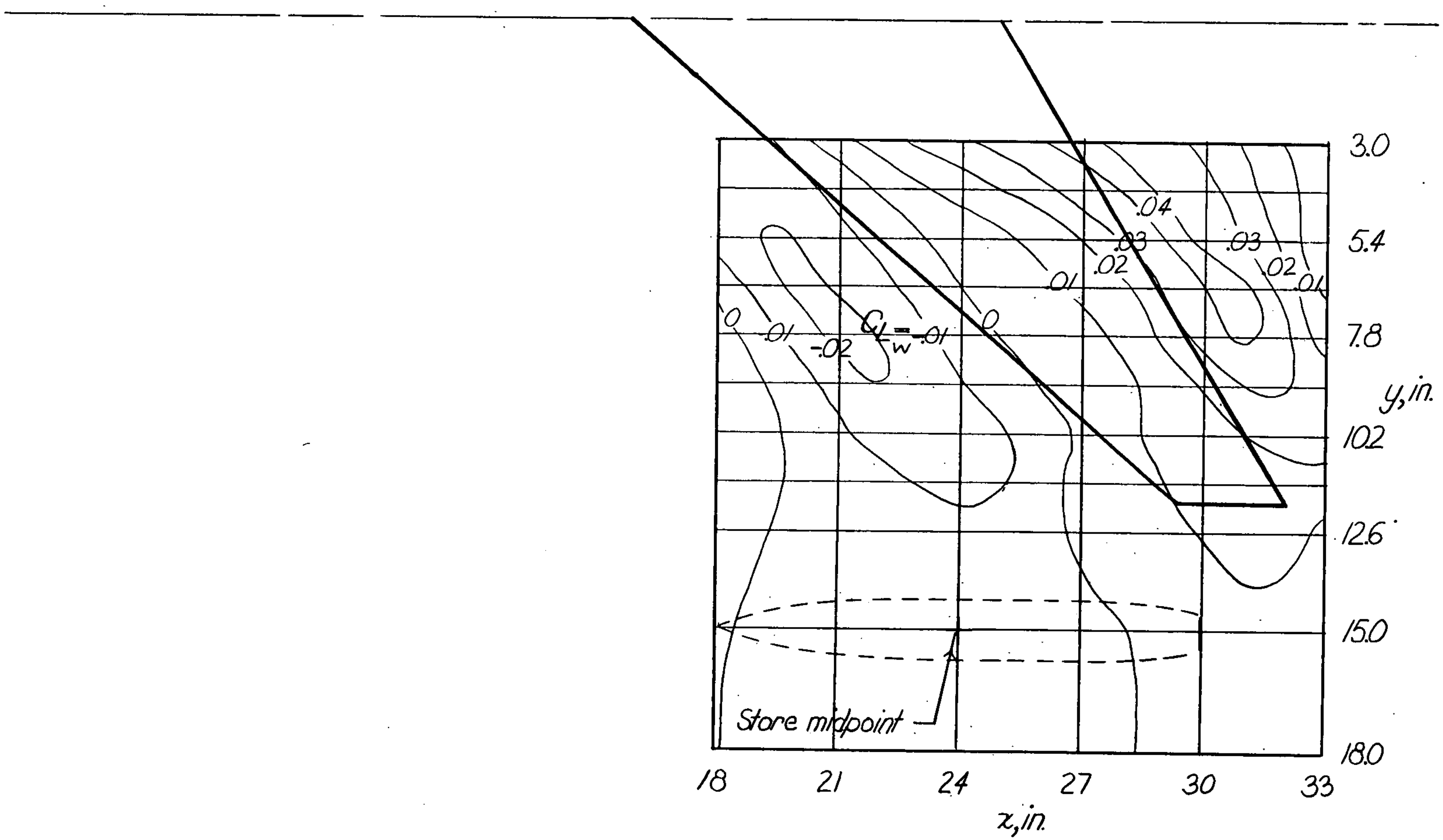
(b) z = 2.09 inches; α = 0°.

Figure 27.- Continued.



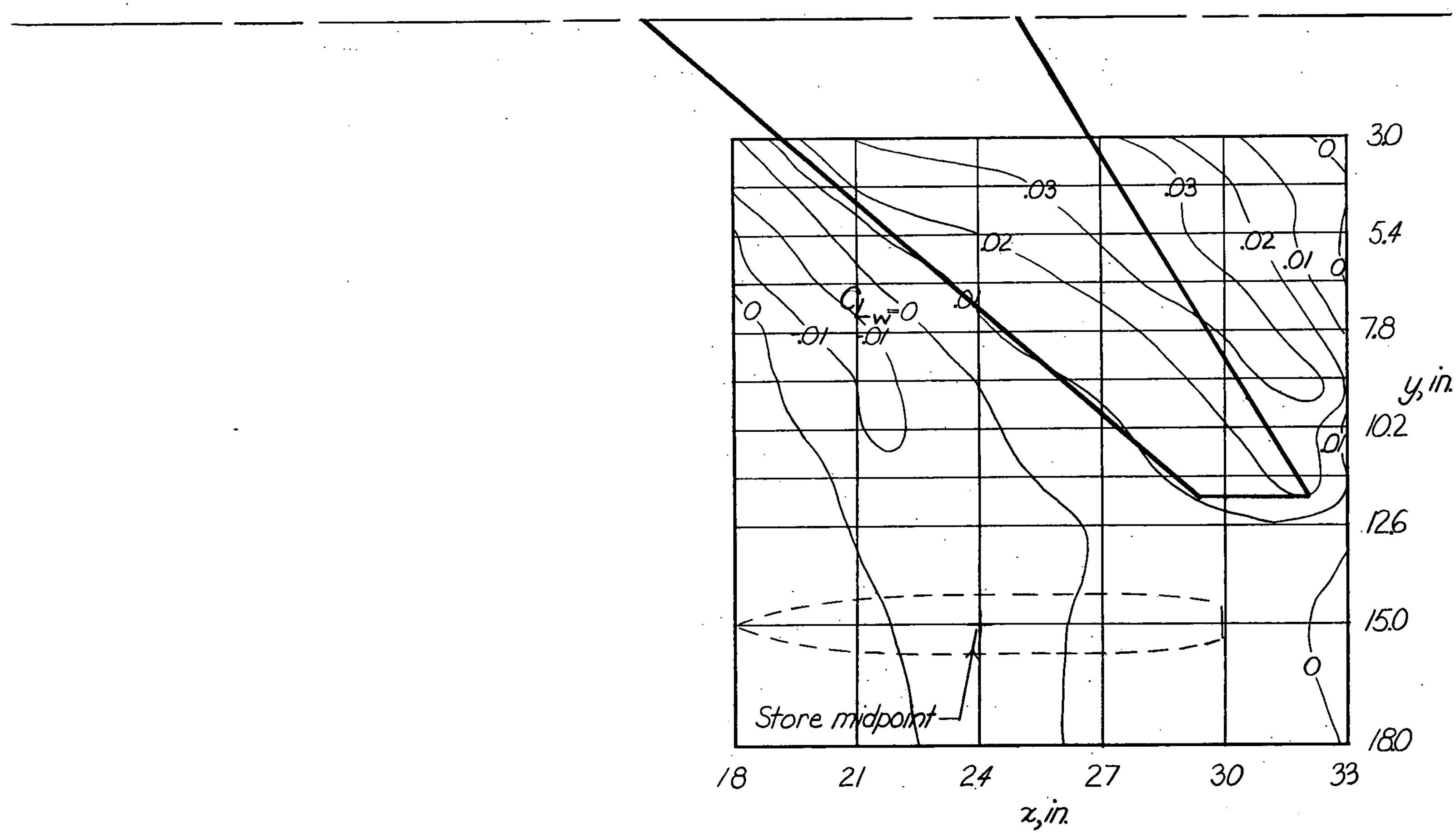
(c) $z = 2.09$ inches; $\alpha = 4^{\circ}$.

Figure 27.- Concluded.



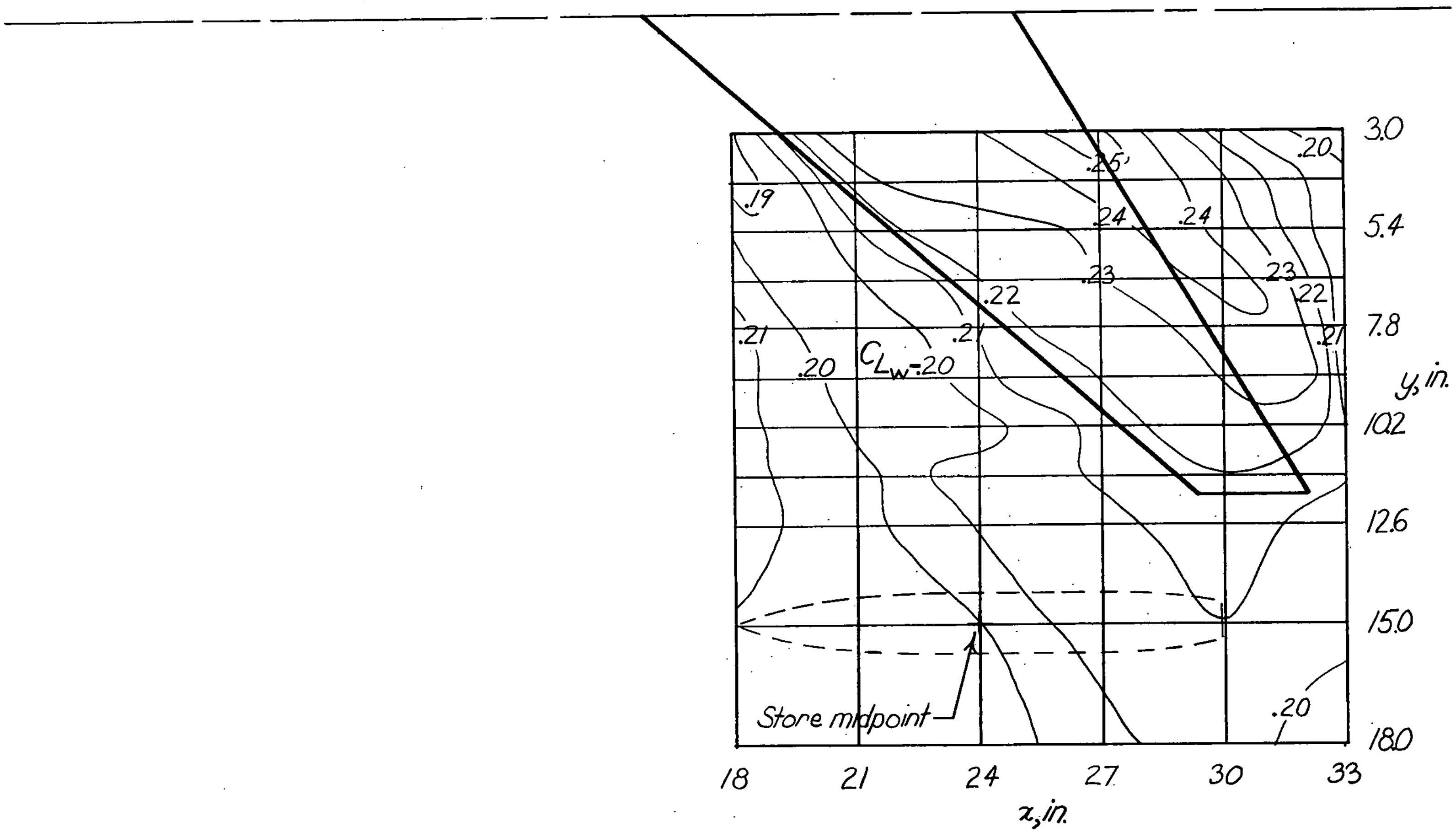
(a) z = 1.15 inches; α = 0°. For isolated wing, C_{L_W} = 0.

Figure 28.- Contour plot of lift of wing in presence of store.



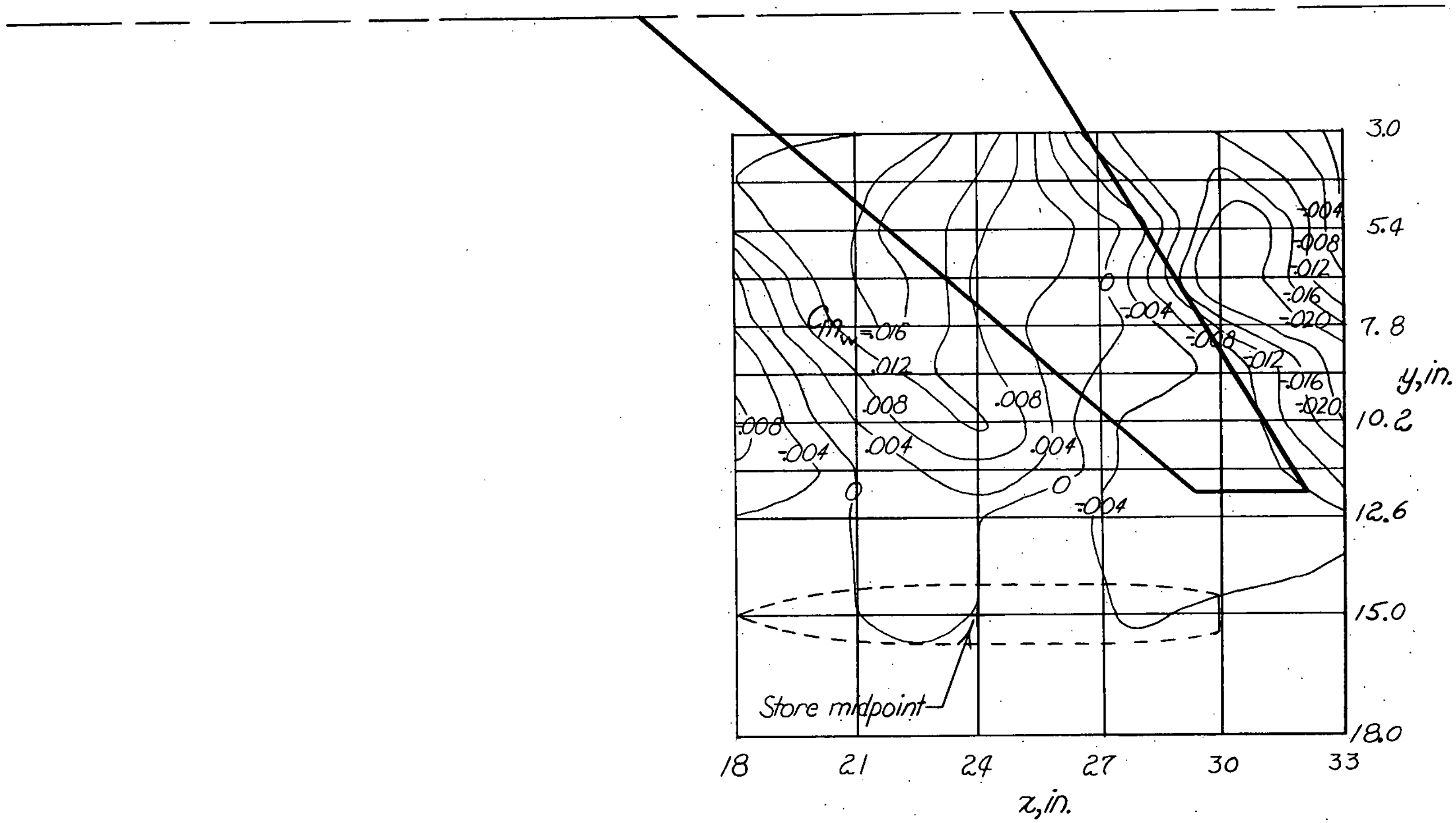
(b) z = 2.09 inches; $\alpha = 0^{\circ}$. For isolated wing, $C_{L_W} = 0$.

Figure 28.- Continued.



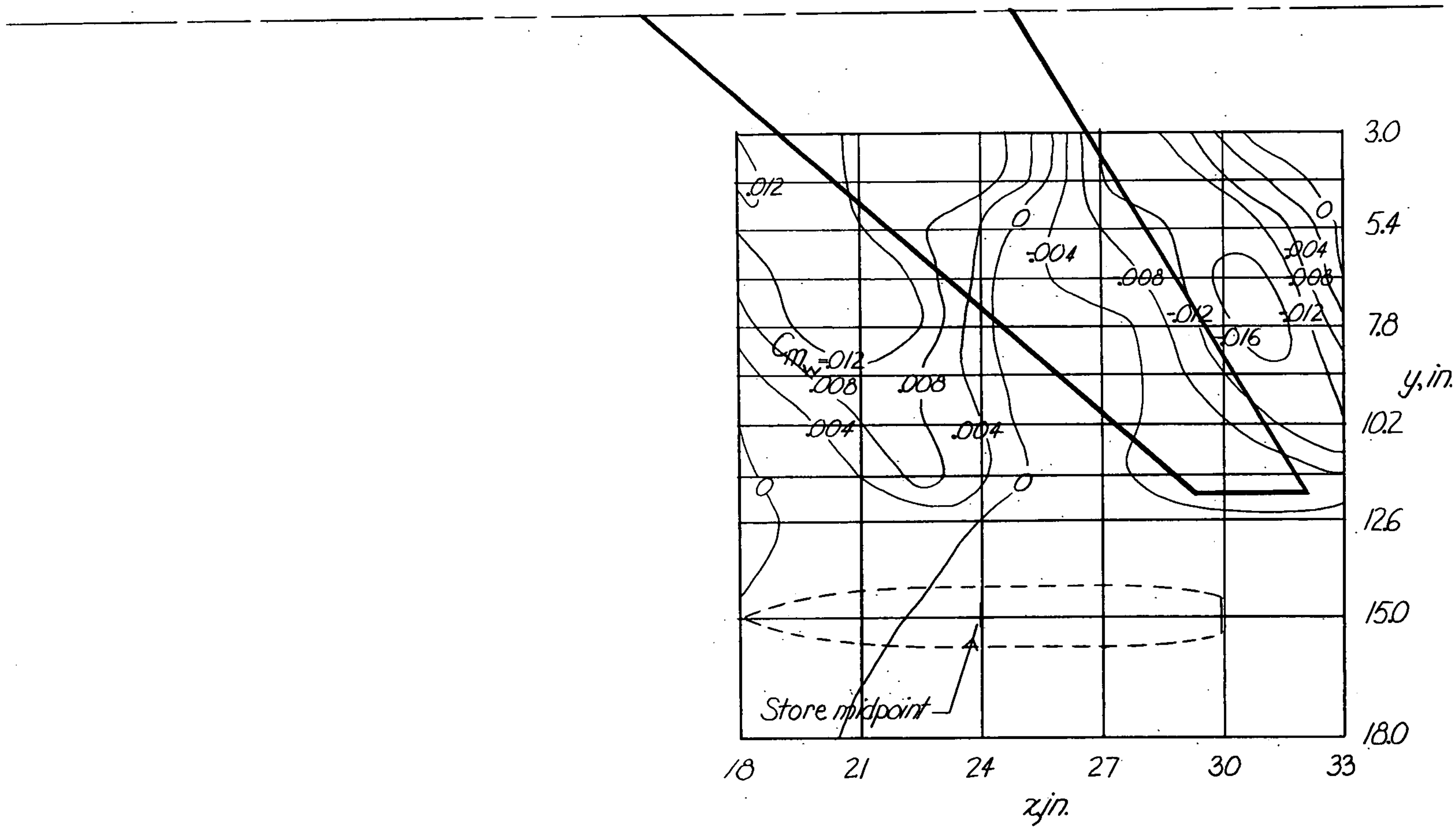
(c) z = 2.09 inches; α = 4°. For isolated wing, C_{L_W} = 0.196.

Figure 28.- Concluded.



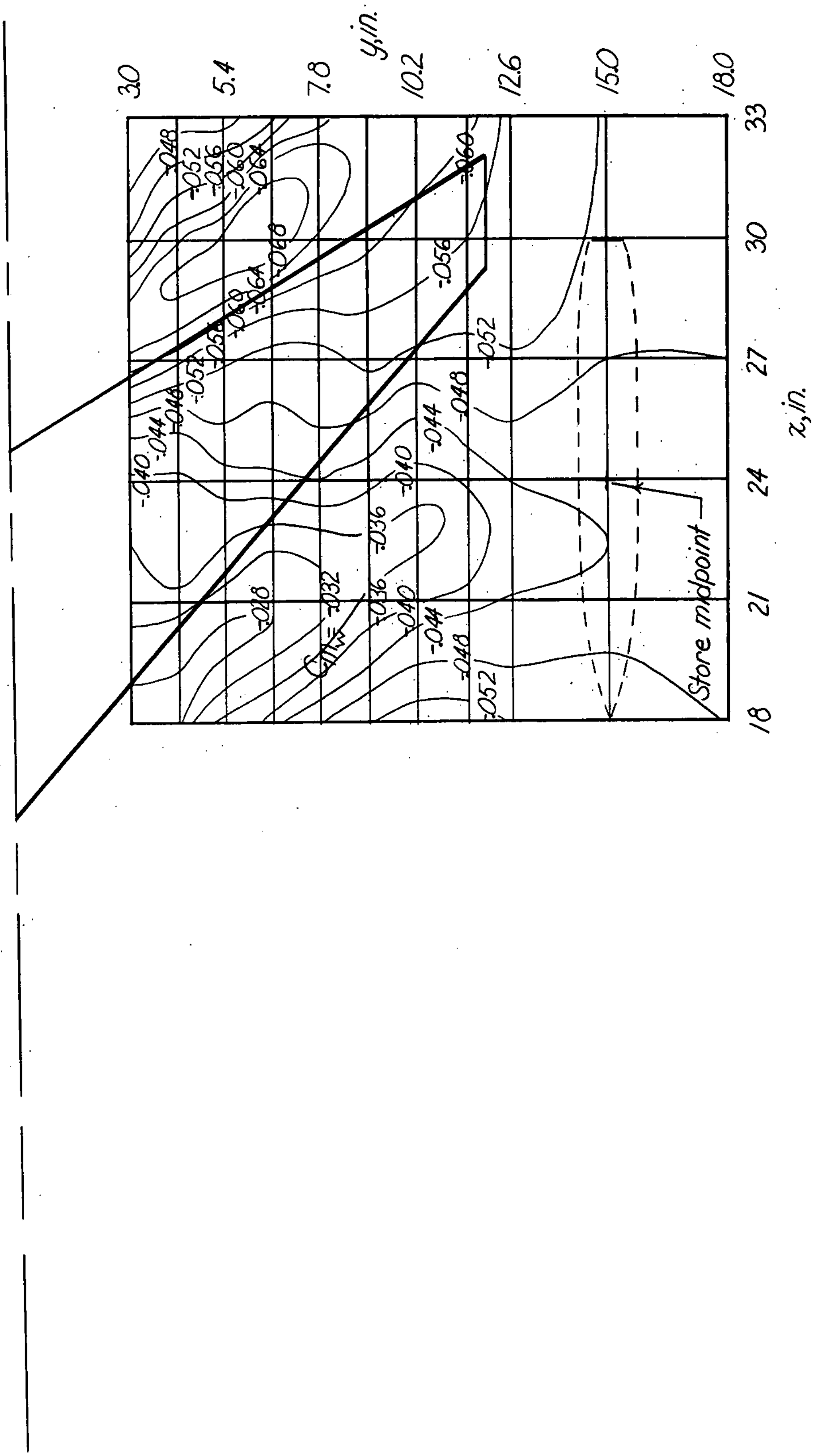
(a) z = 1.15 inches; α = 0°. For isolated wing, C_{m_W} = -0.001.

Figure 29.- Contour plot of pitching moment of wing in presence of store.



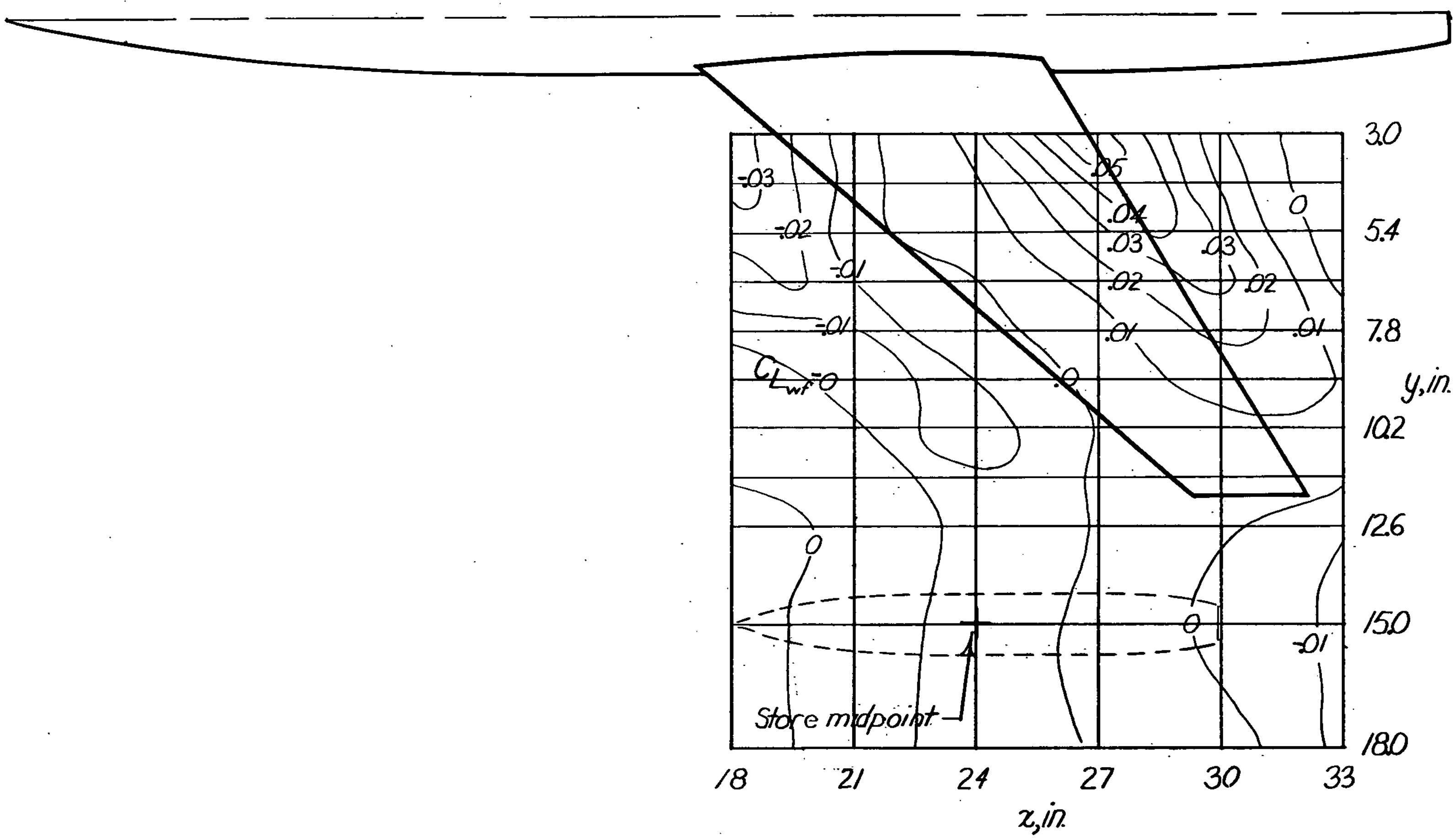
(b) z = 2.09 inches; $\alpha = 0^{\circ}$. For isolated wing, $C_{m_W} = -0.001$.

Figure 29.- Continued.



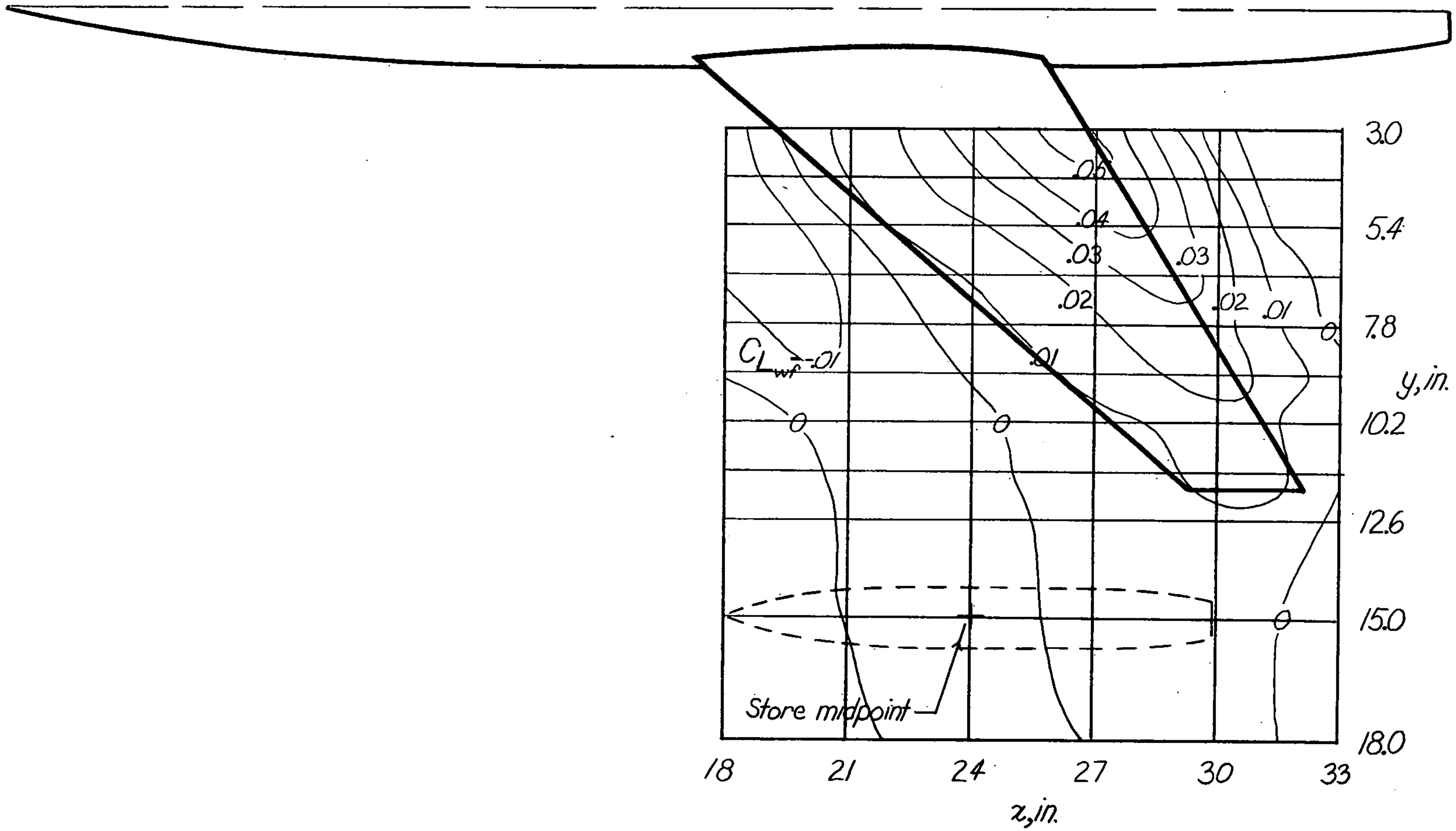
(c) z = 2.09 inches; α = 4°. For isolated wing, C_{m_W} = -0.048.

Figure 29.- Concluded.



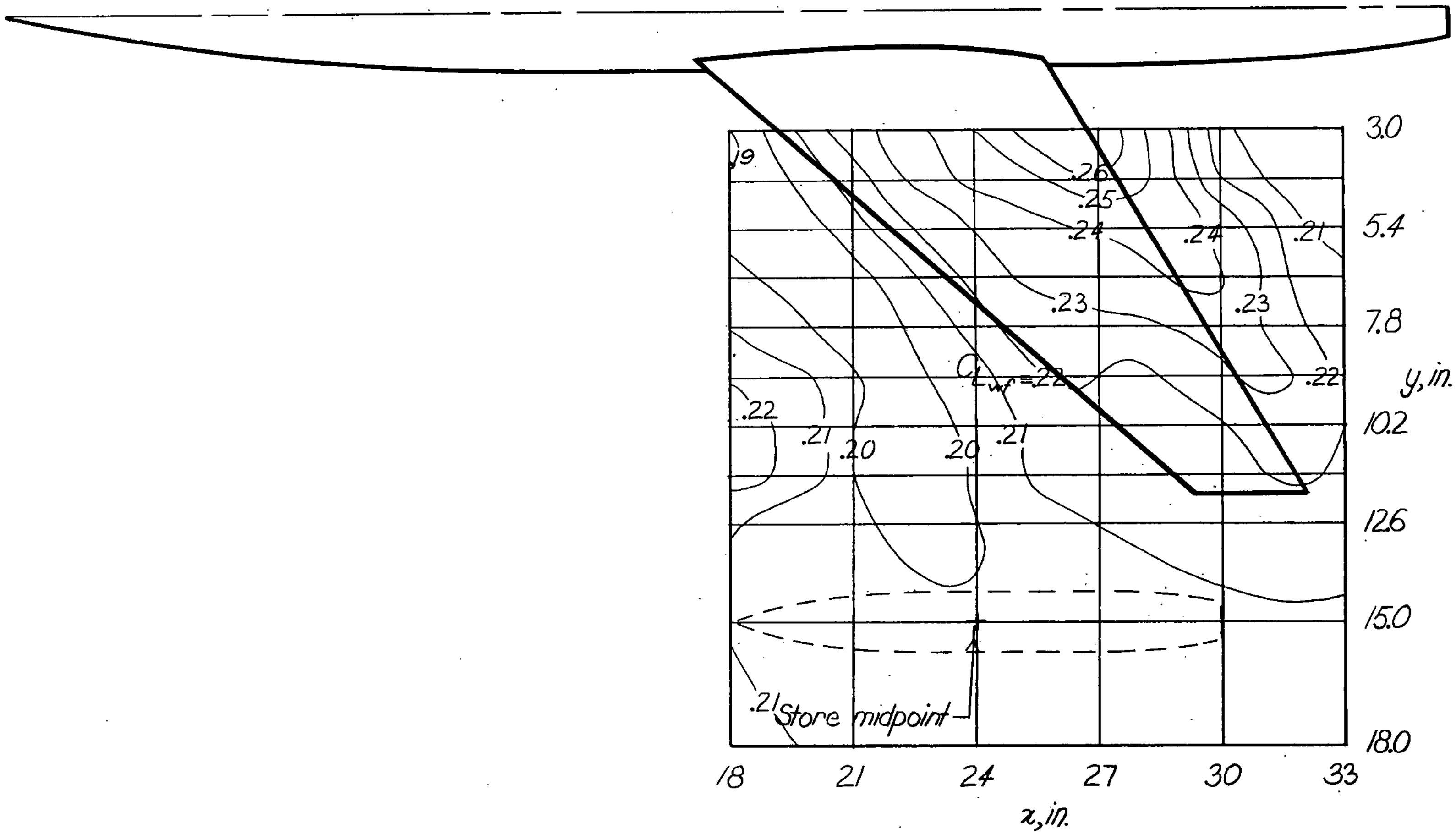
(a) z = 1.15 inches; α = 0°. For isolated wing-fuselage, $C_{L_{wf}}$ = -0.009.

Figure 30.- Contour plot of lift of wing-fuselage combination in presence of store.



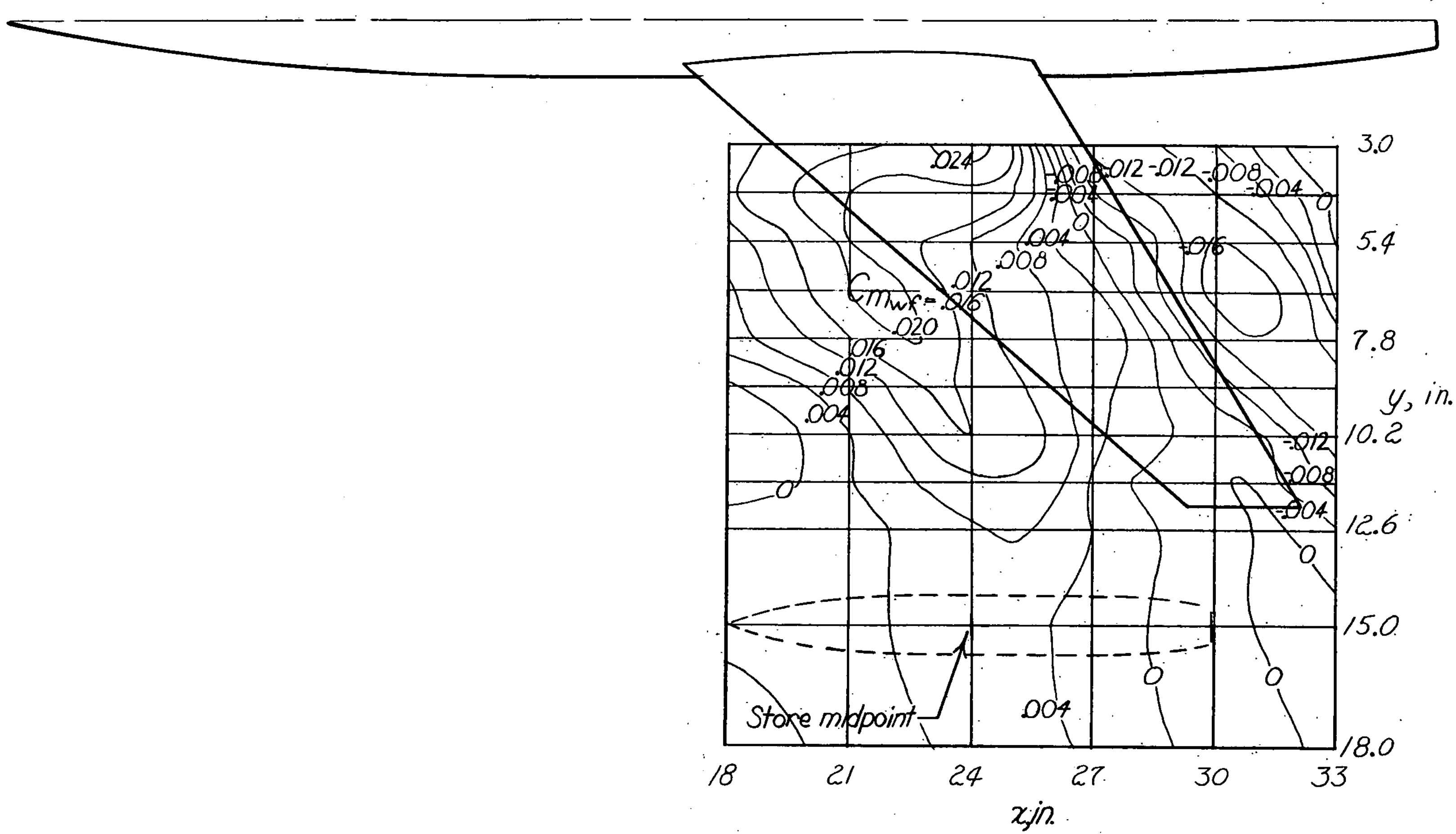
(b) z = 2.09 inches; α = 0°. For isolated wing-fuselage, $C_{L_{wf}}$ = -0.009.

Figure 30.- Continued.



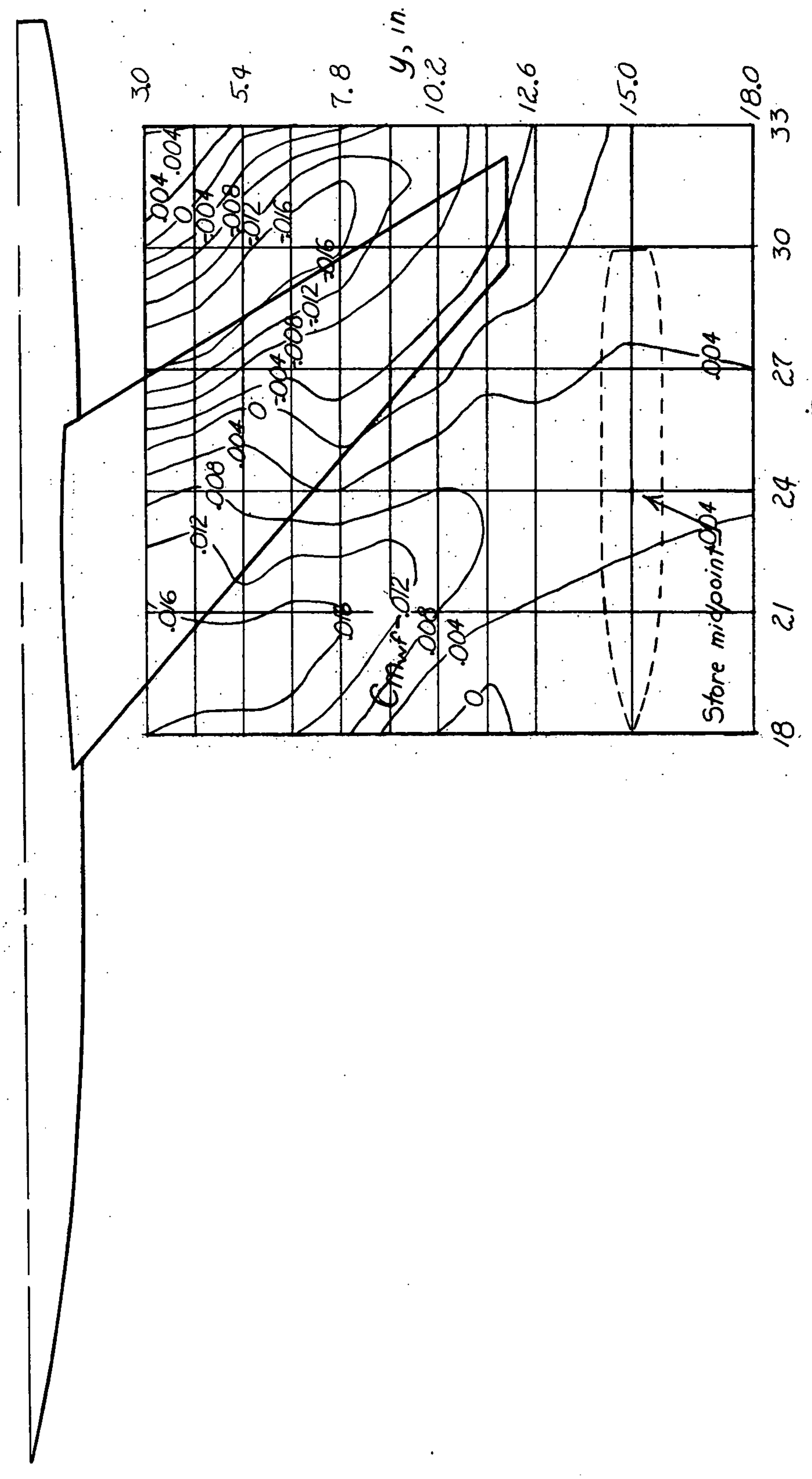
(c) z = 2.09 inches; α = 4°. For isolated wing-fuselage, $C_{L_{wf}}$ = 0.20.

Figure 30.- Concluded.



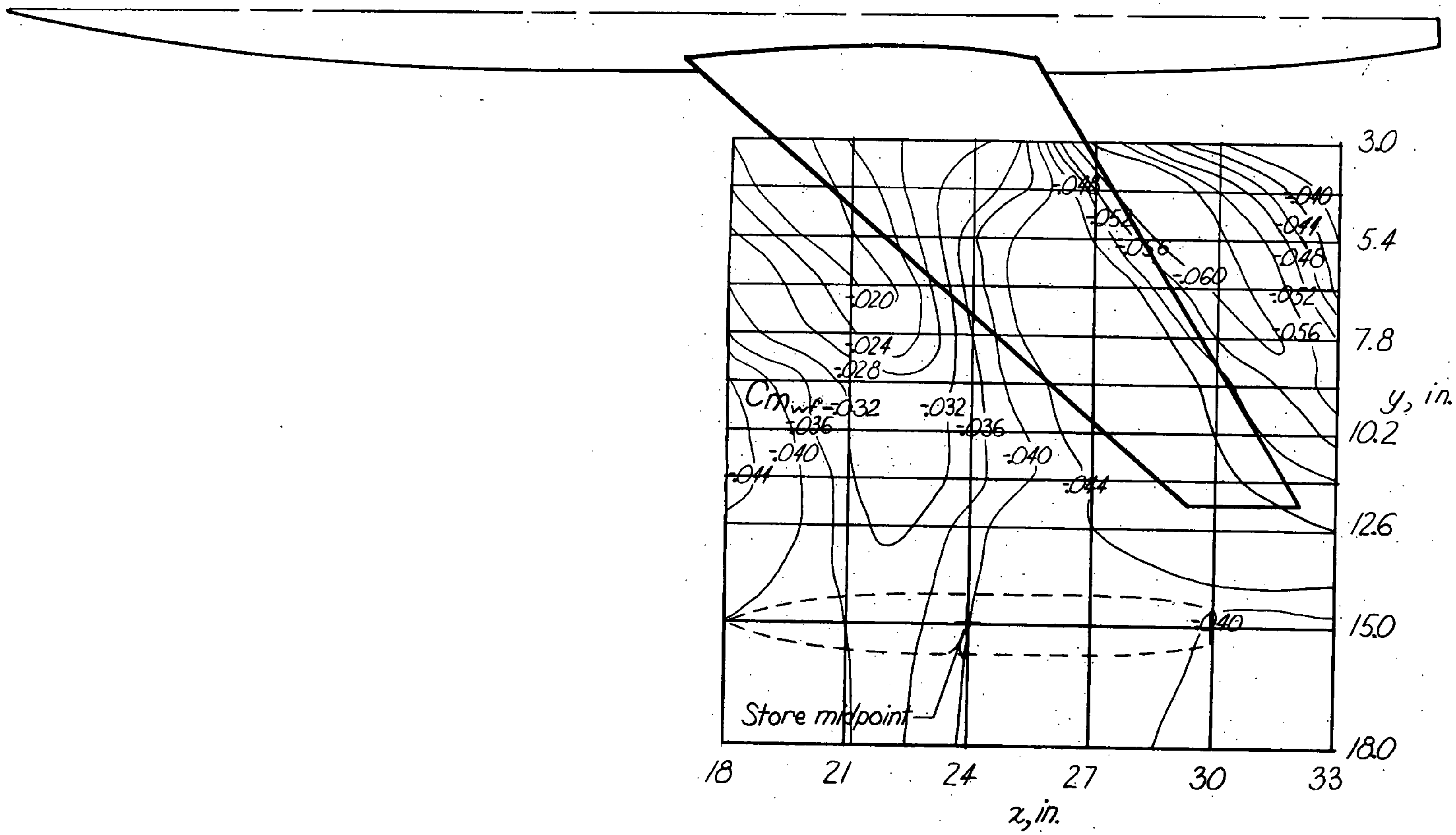
(a) z = 1.15 inches; $\alpha = 0^{\circ}$. For isolated wing-fuselage, $C_{m_{wf}} = 0.002$.

Figure 31.- Contour plot of pitching moment of wing-fuselage combination in presence of store.



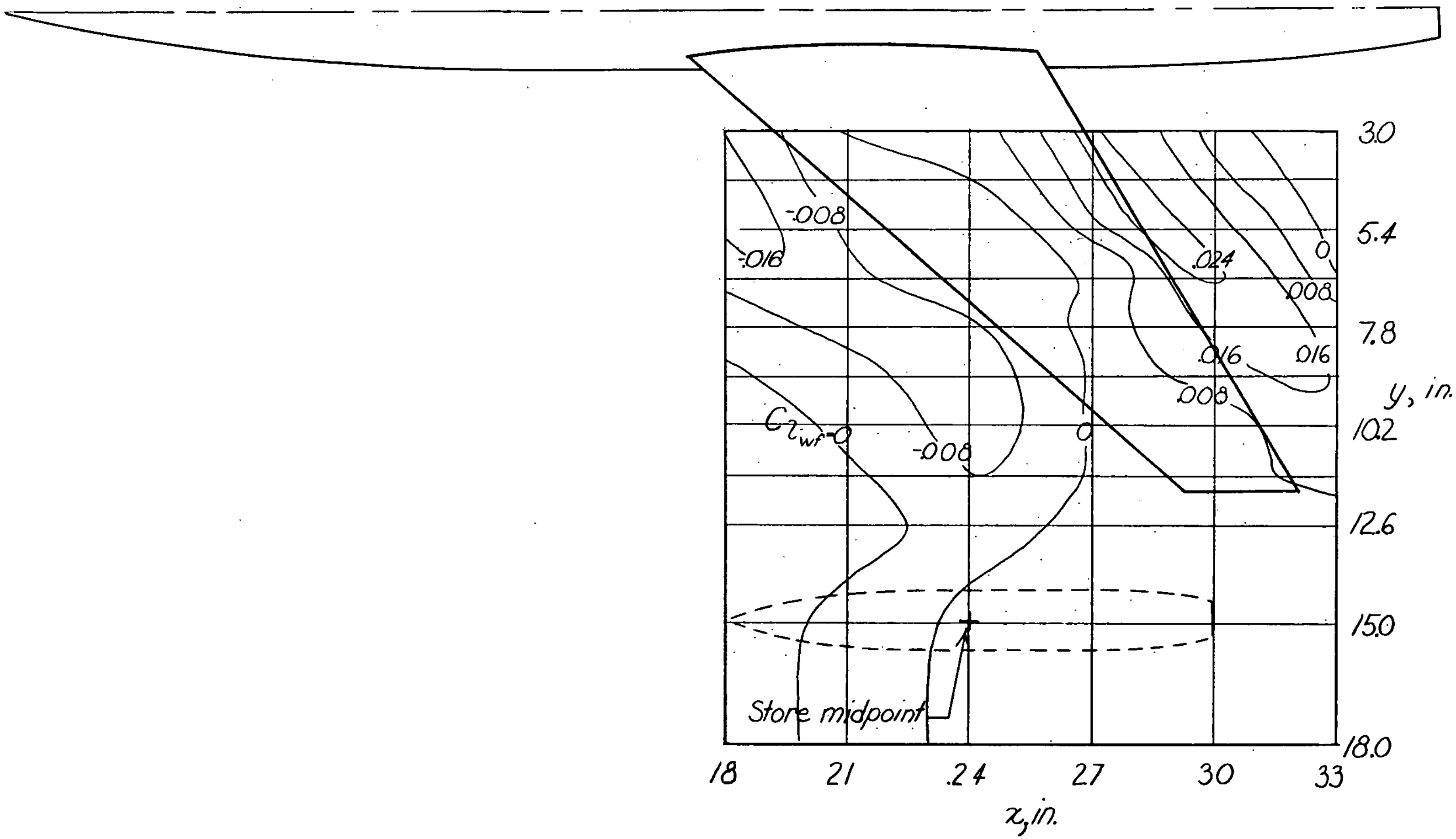
(b) z = 2.09 inches; α = 0°. For isolated wing-fuselage, $C_{m_{wf}} = 0.002$.

Figure 31.- Continued.



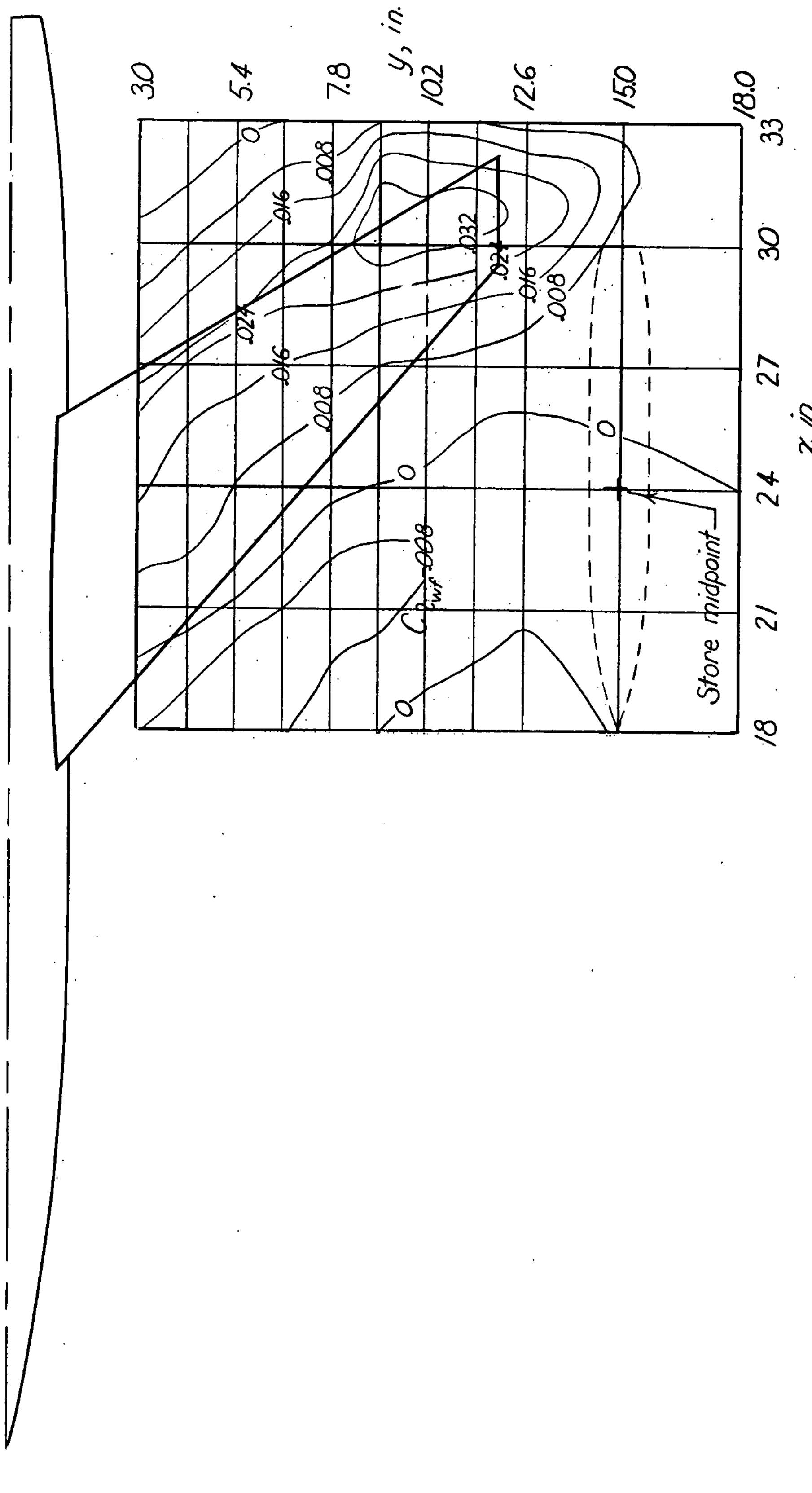
(c) z = 2.09 inches; α = 4°. For isolated wing-fuselage, $C_{m_{wf}}$ = -0.0375.

Figure 31.- Concluded.



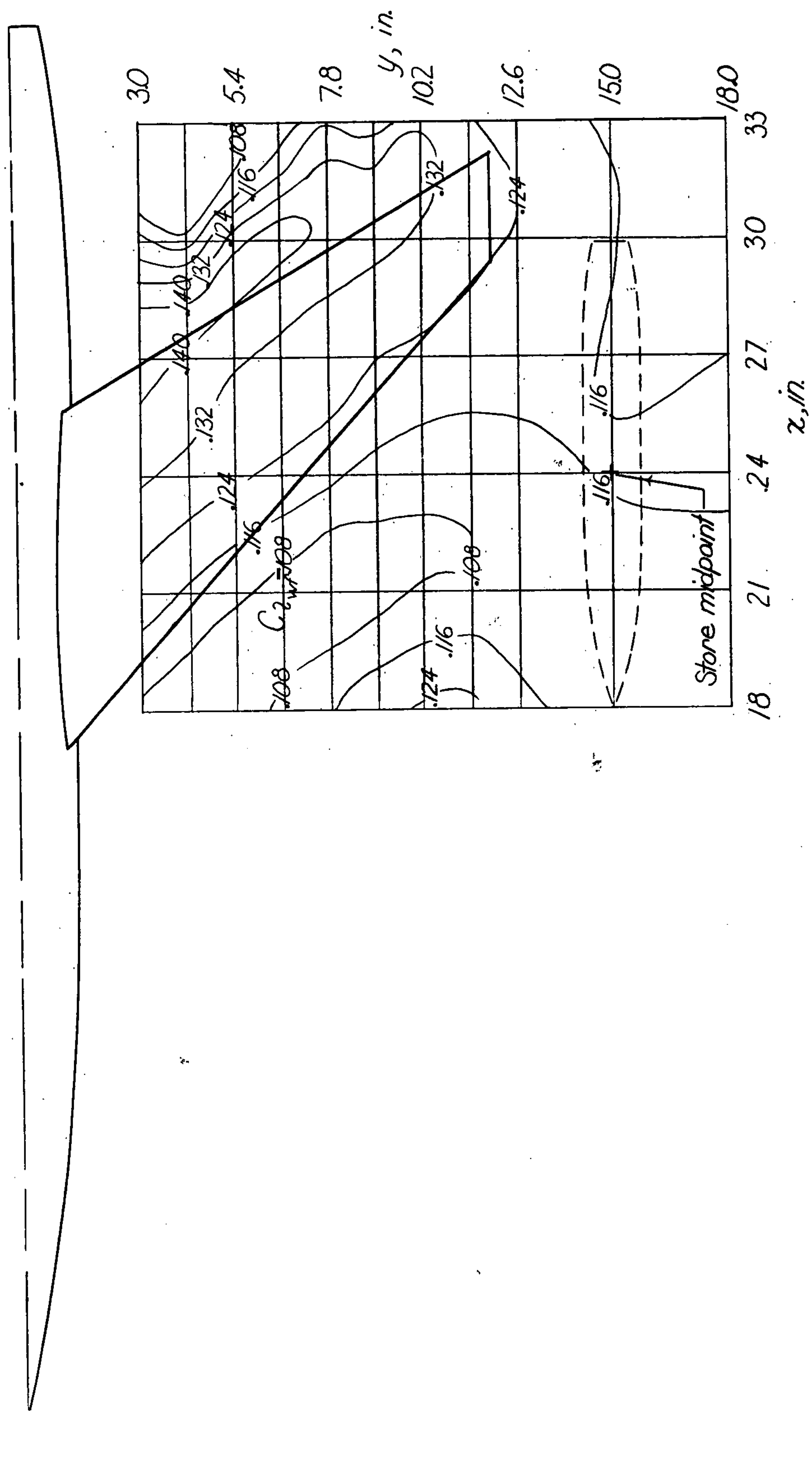
(a) z = 1.15 inches; $\alpha = 0^{\circ}$.

Figure 32.- Contour plot of wing-root bending moment of wing-fuselage combination in presence of store.



(b) z = 2.09 inches; α = 0°.

Figure 32.- Continued.



(c) z = 2.09 inches; α = 4°.

Figure 32.- Concluded.

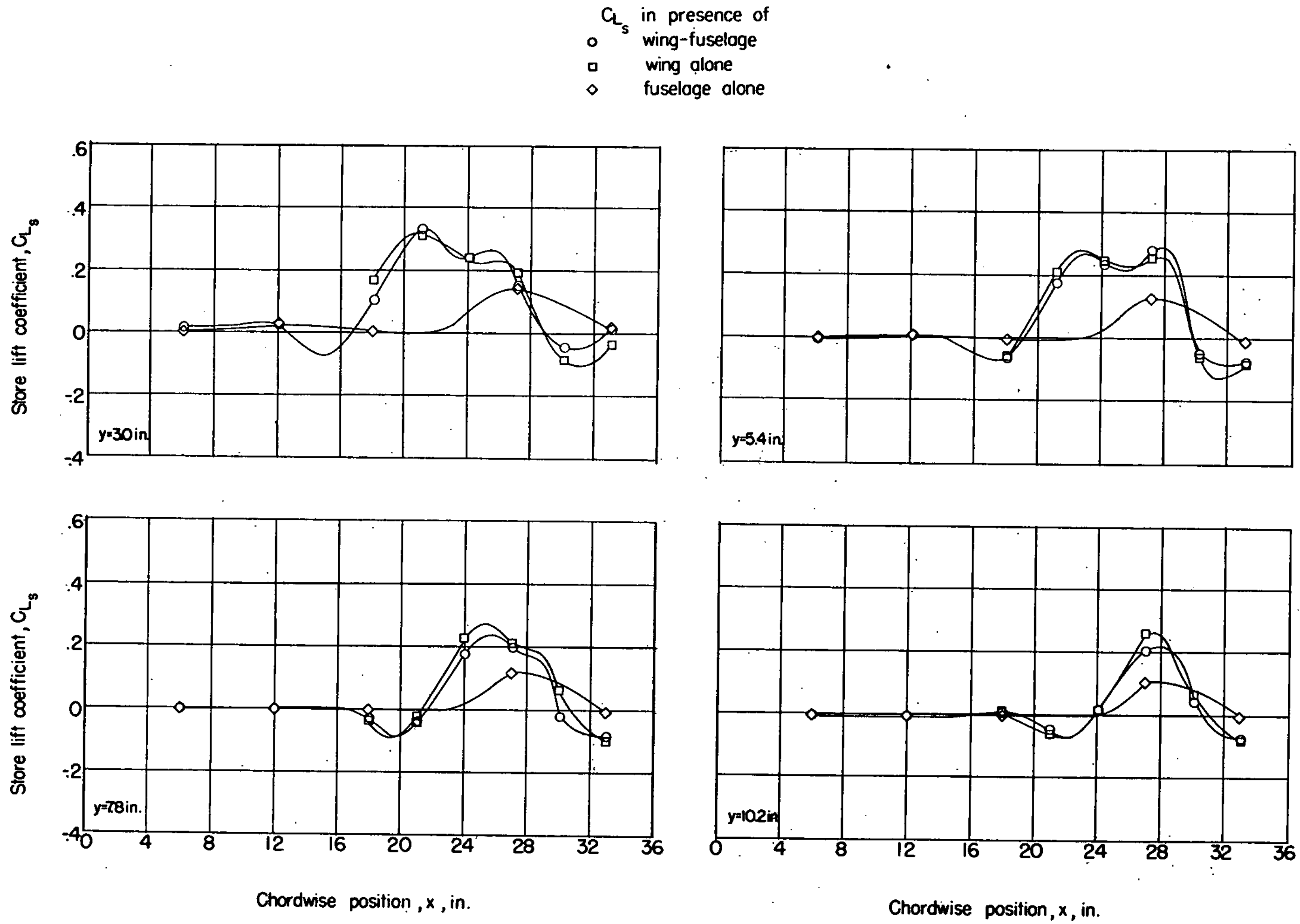


Figure 33.- Comparison of store lift in the presence of the wing alone, fuselage alone, and wing-fuselage combination. $z = 1.15$ inches; $\alpha = 0^{\circ}$.

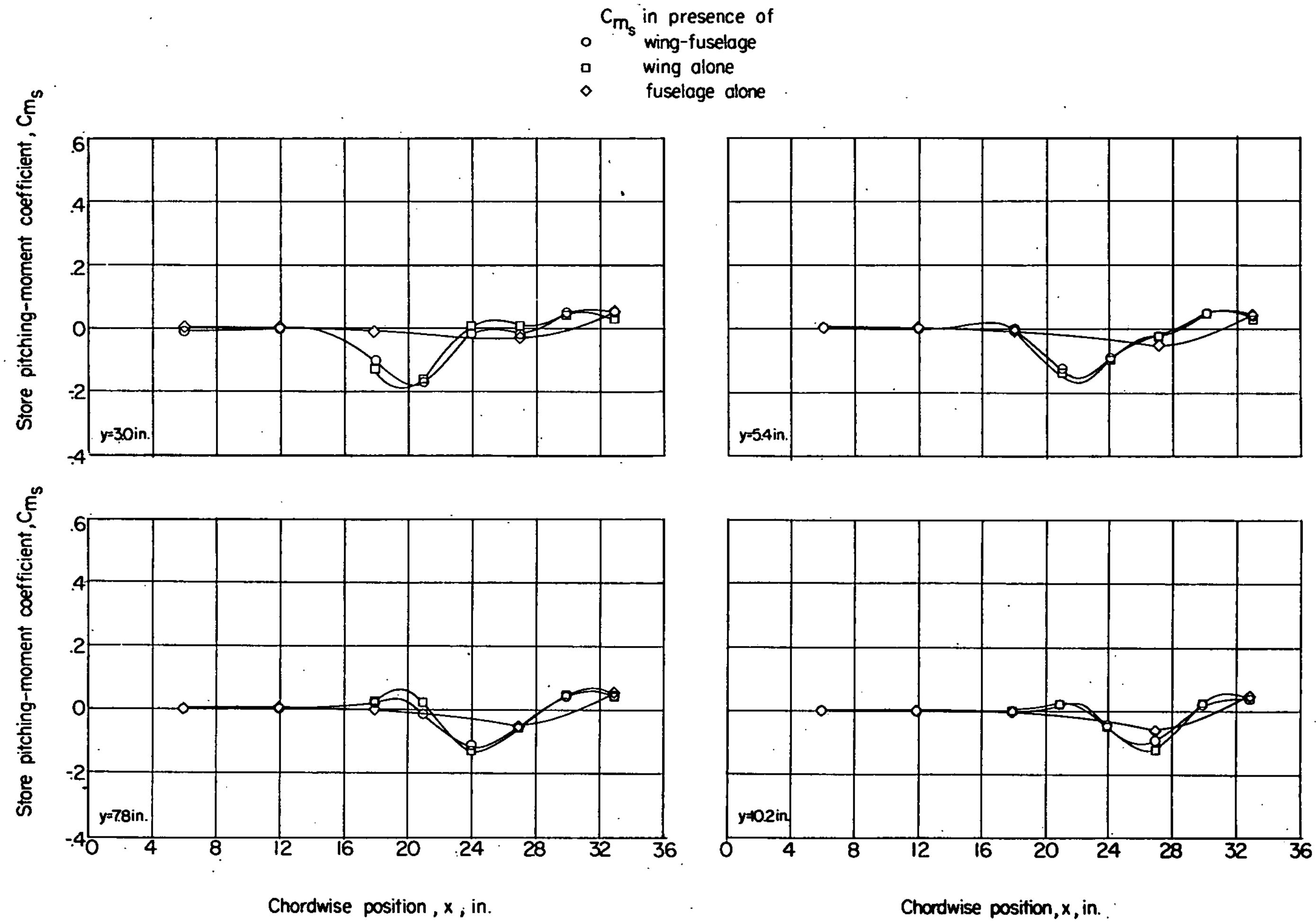


Figure 34.- Comparison of store pitching moment in the presence of the fuselage alone, wing alone, and wing-fuselage combination. Values recalculated about the store midpoint. $z = 1.15$ inches; $\alpha = 0^{\circ}$.

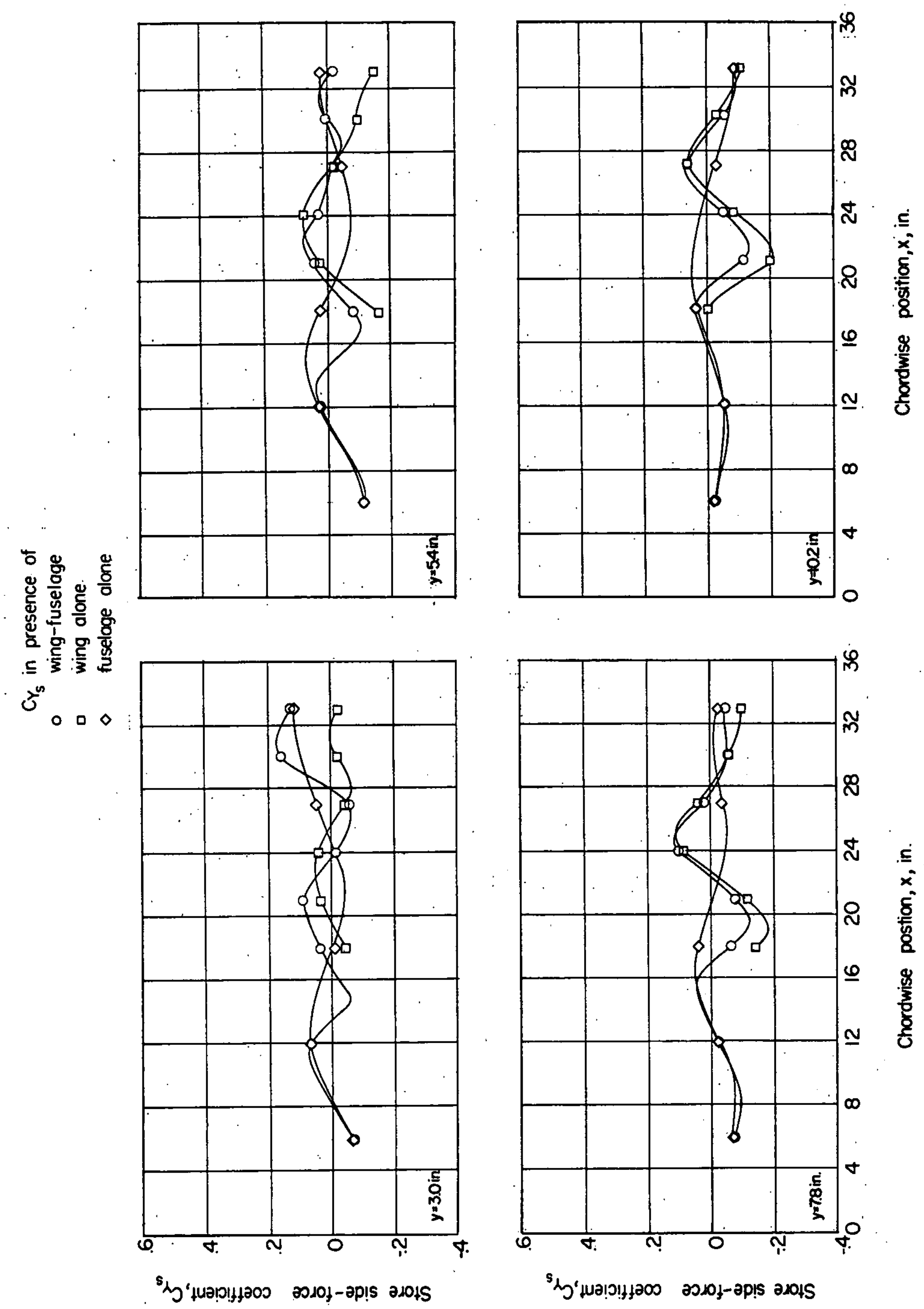


Figure 35.- Comparison of store side force in the presence of the wing alone, fuselage alone, and wing-fuselage combination. z = 1.15 inches; $\alpha = 0^{\circ}$.

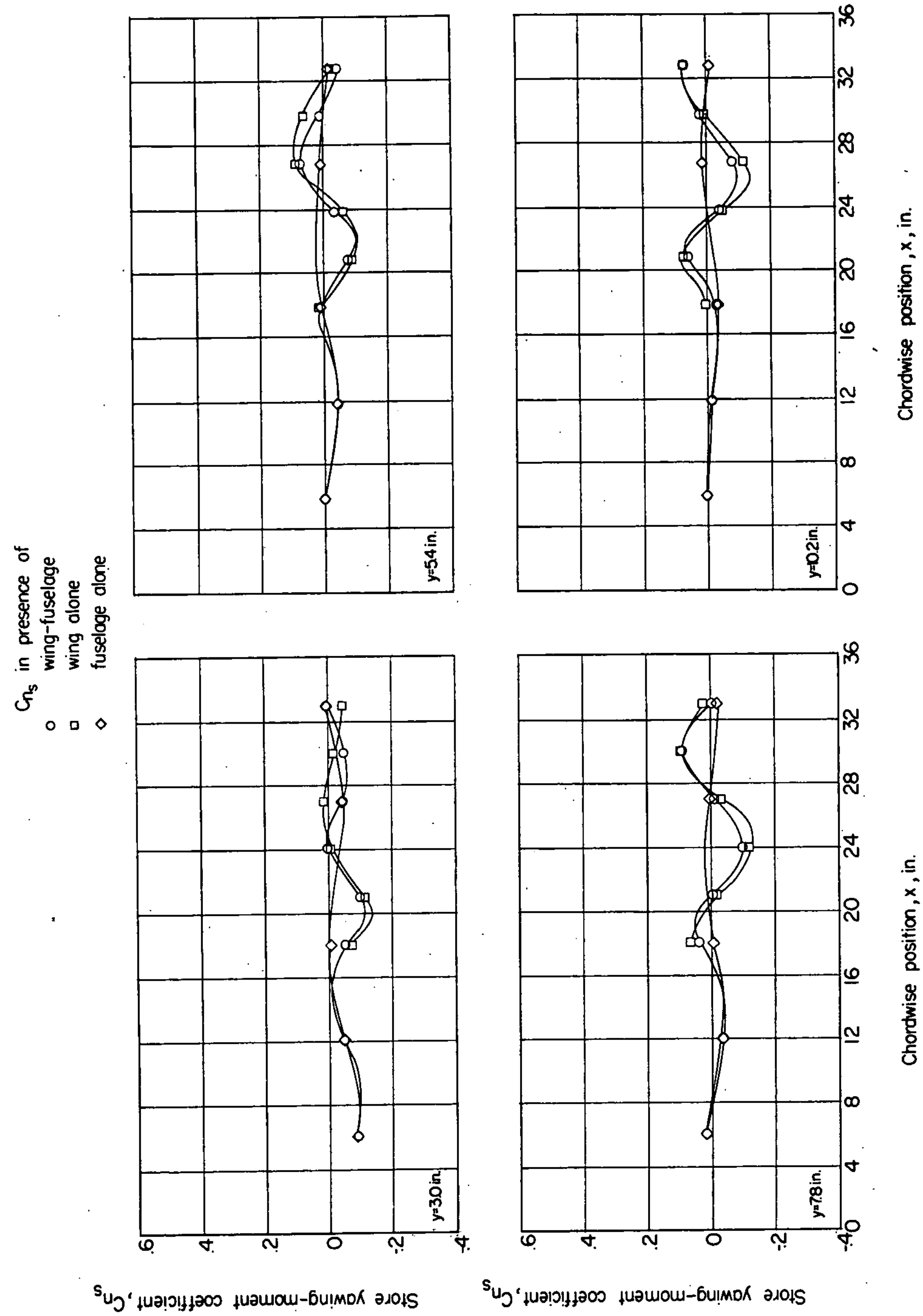


Figure 36.- Comparison of store yawing moment in the presence of the fuselage alone, wing alone, and wing-fuselage combination. Values recalculated about midpoint of store. z = 1.15 inches; $\alpha = 0^{\circ}$.

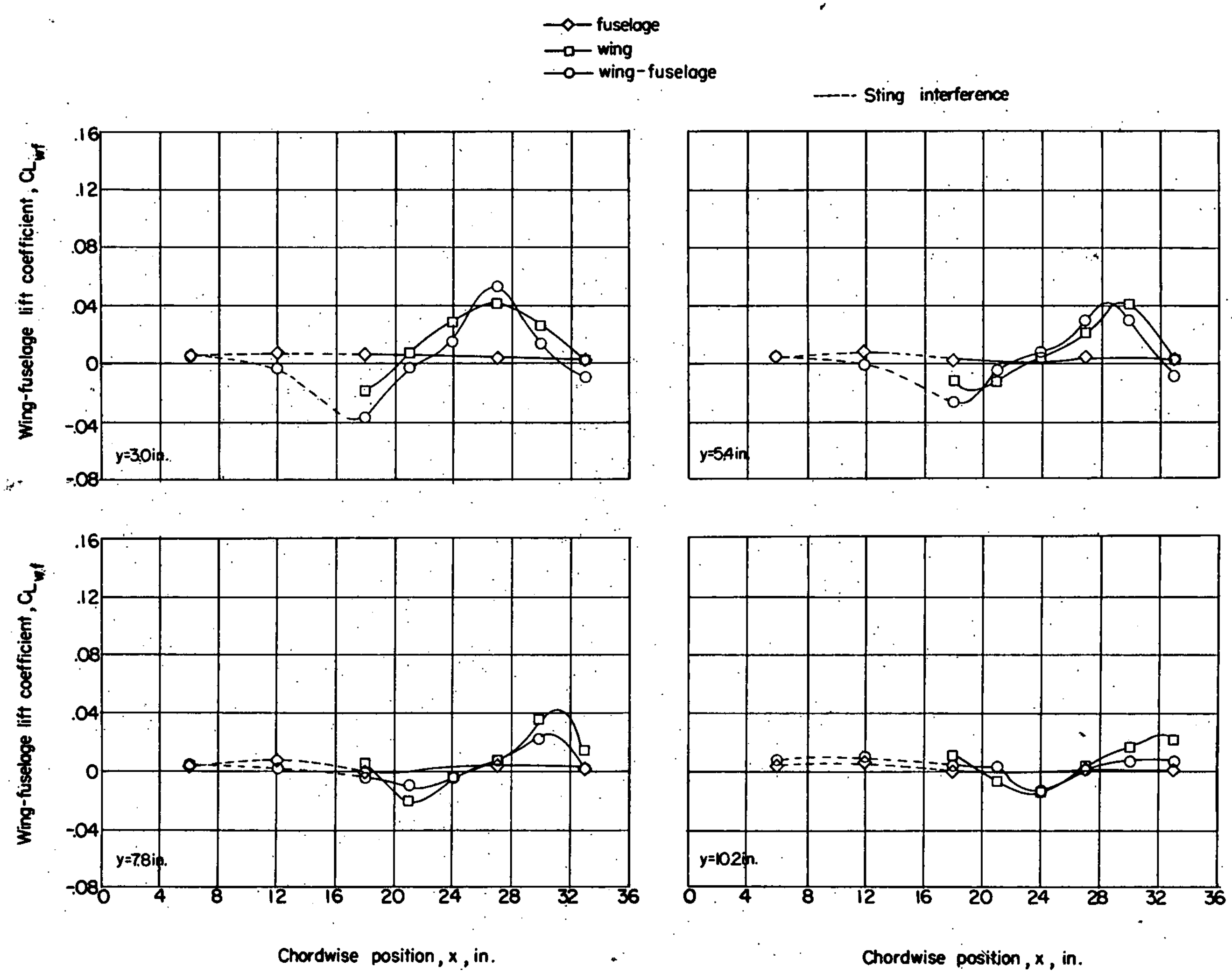


Figure 37.- Comparison of lift of the fuselage alone, wing alone, and wing-fuselage combination in the presence of the store. z = 1.15 inches; $\alpha = 0^{\circ}$.

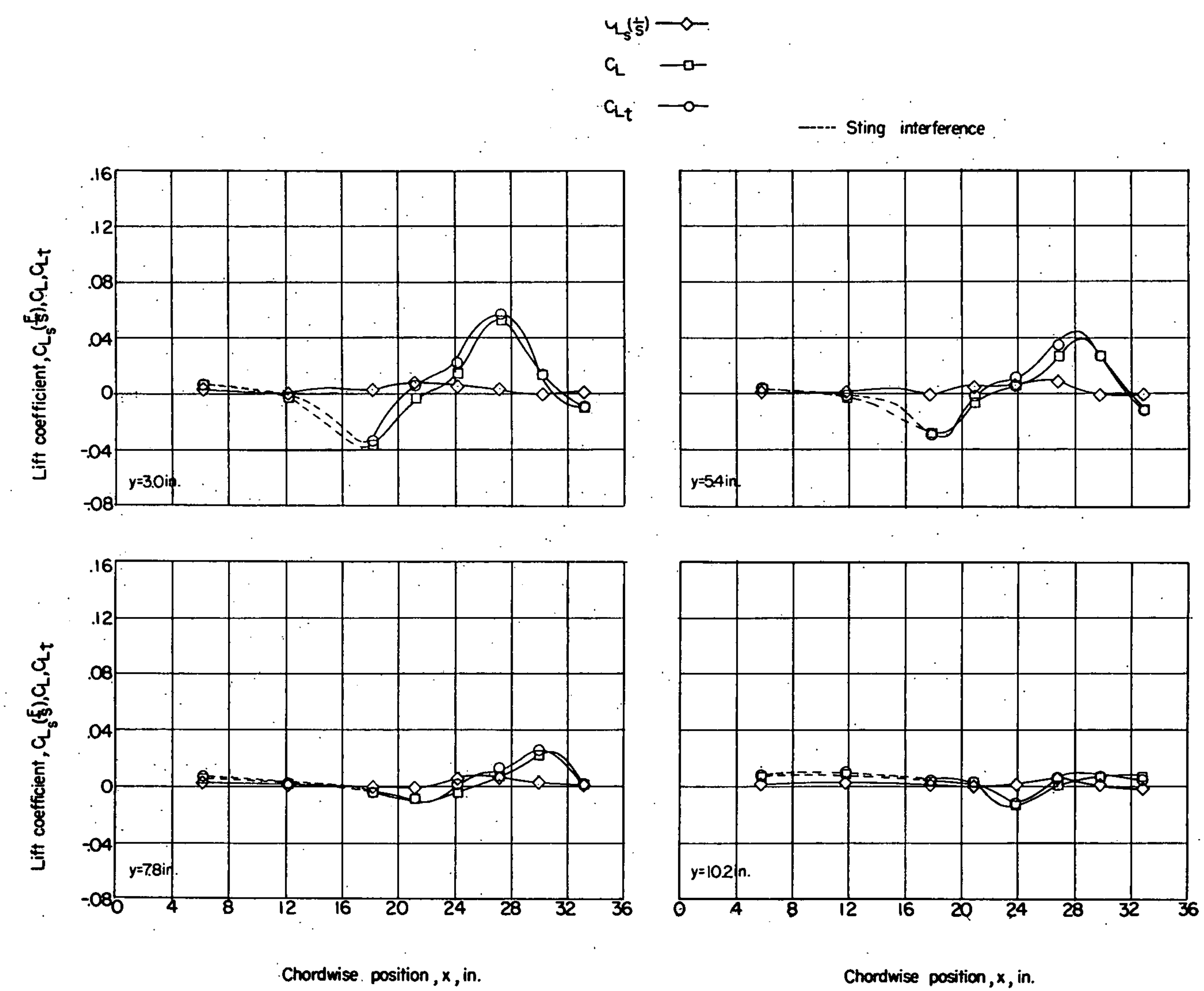


Figure 38.- Relative contributions of store lift and wing-fuselage lift to total lift of configuration. Coefficients based on wing area. z = 1.15 inches; $\alpha = 0^{\circ}$.

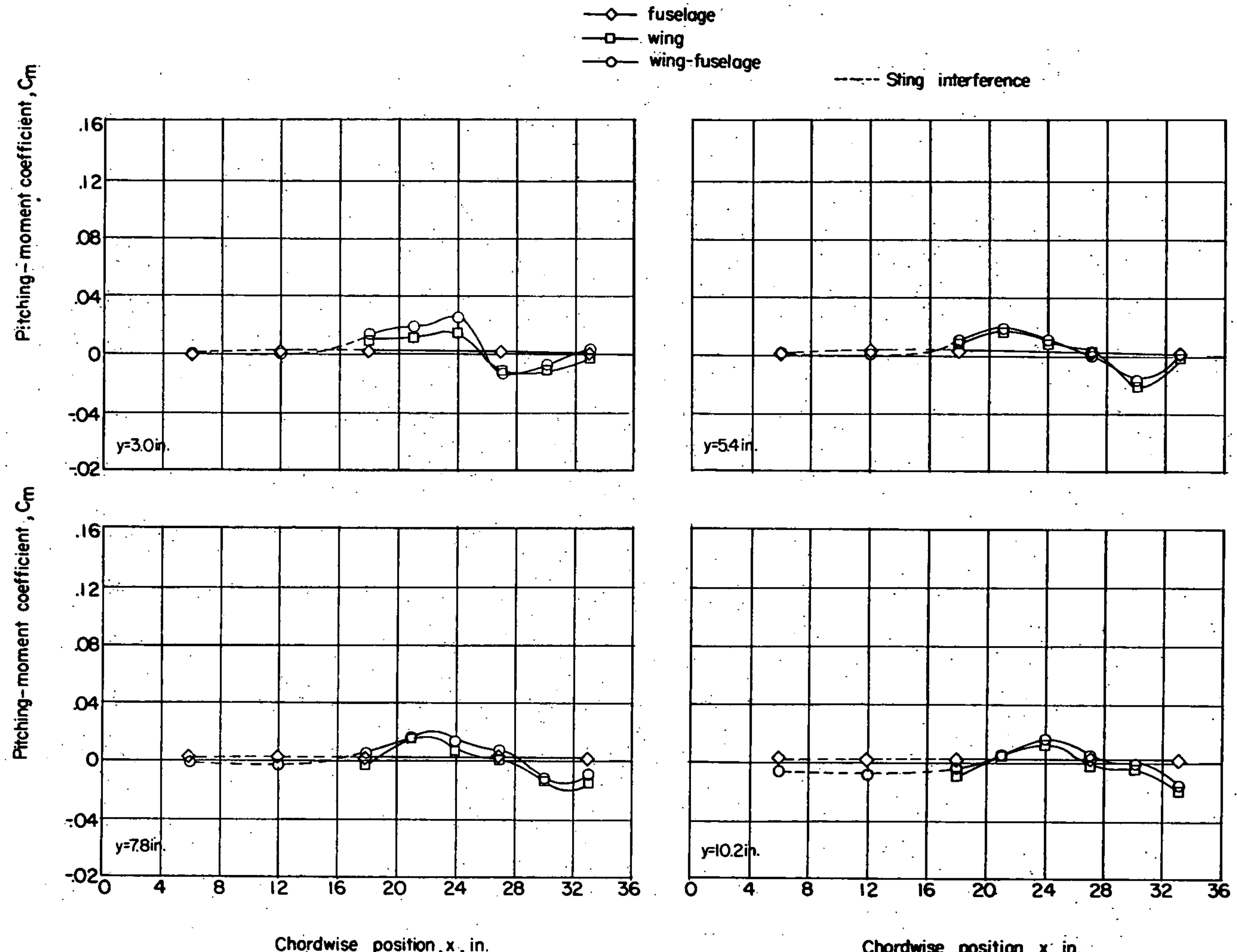


Figure 39.- Comparison of pitching moment of the wing alone, fuselage alone, and wing-fuselage combination in the presence of the store. $z = 1.15$ inches; $\alpha = 0^{\circ}$.

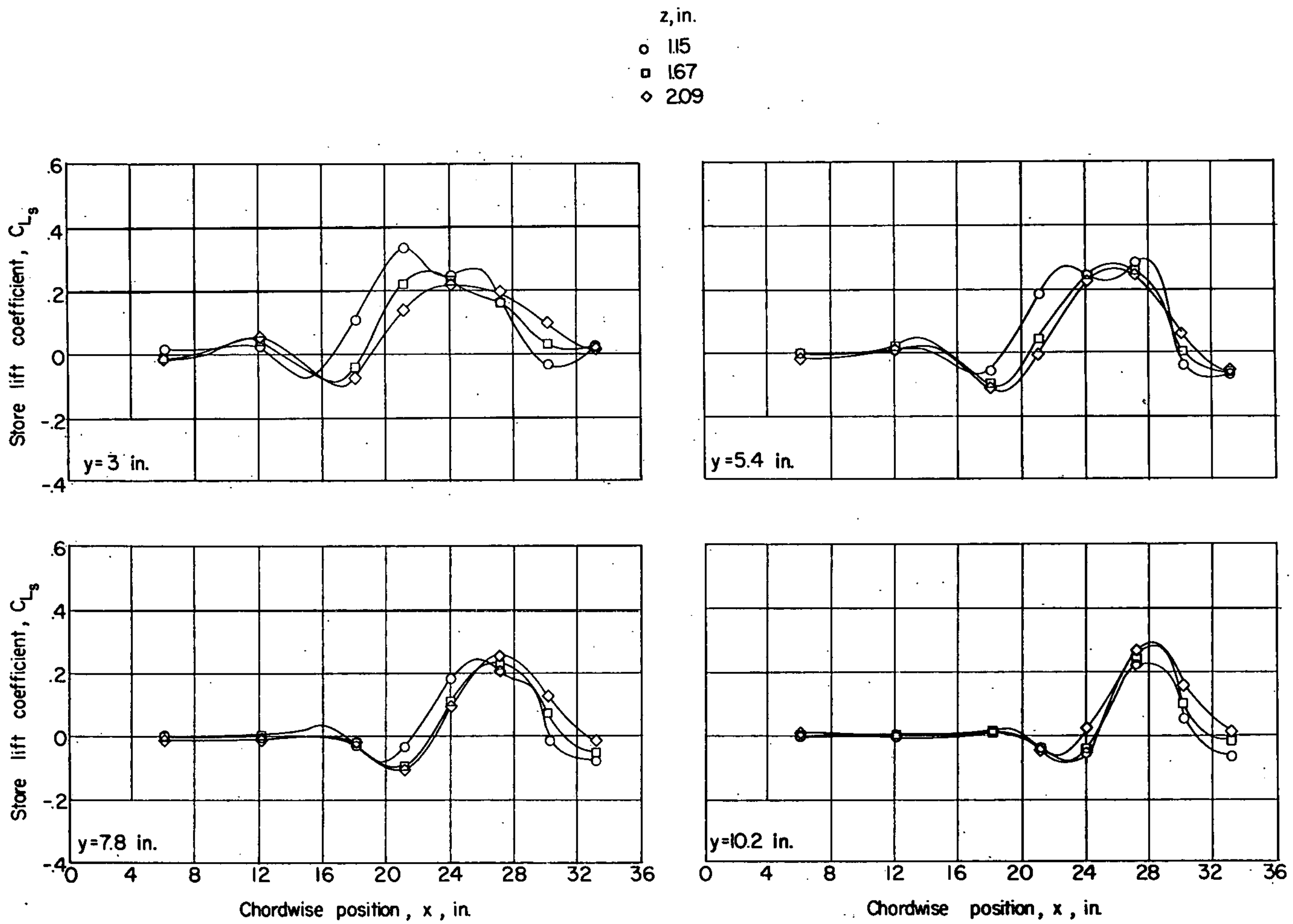


Figure 40.- Effect of store vertical position z on store lift in presence of wing-fuselage combination. $\alpha = 0^{\circ}$.

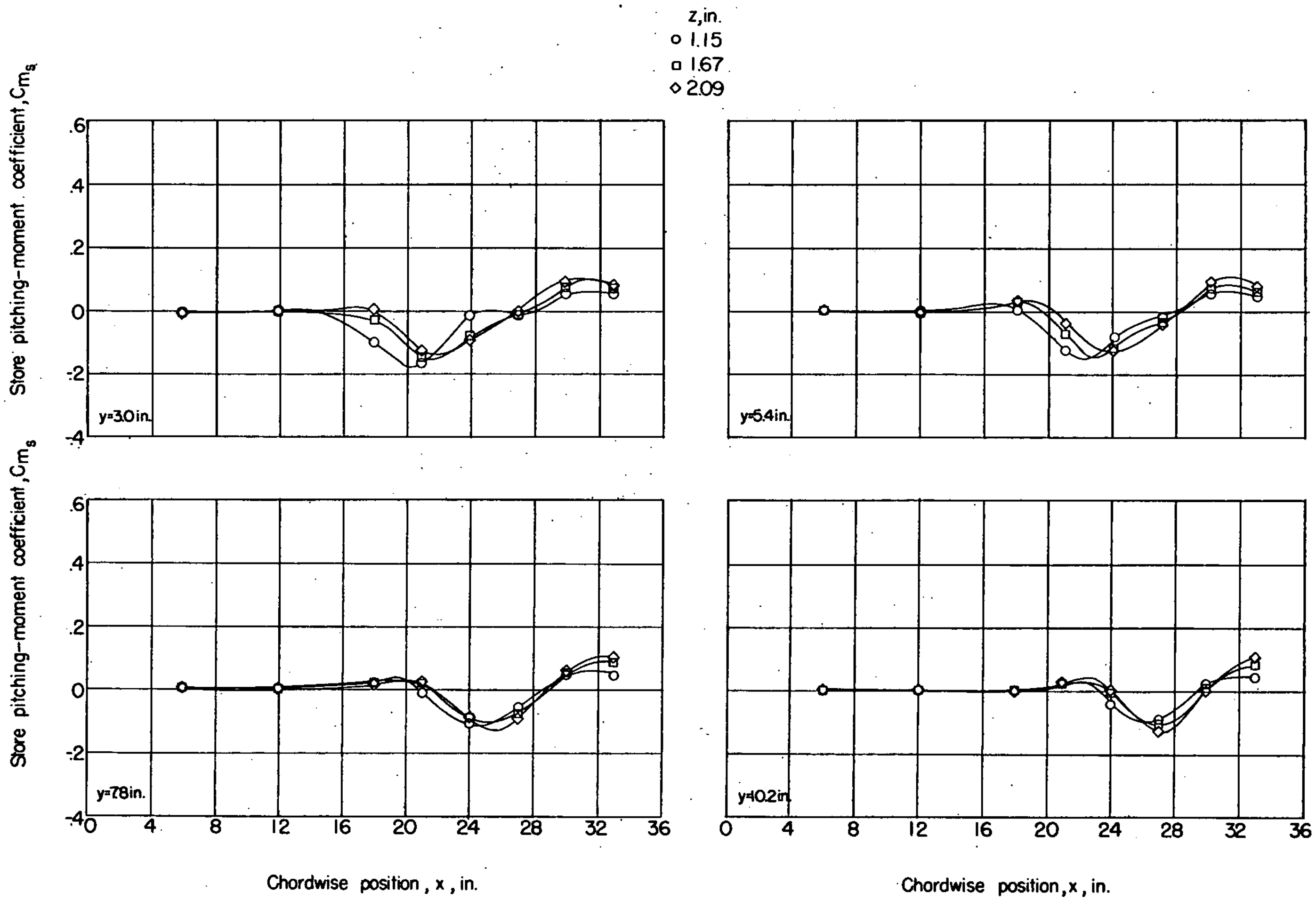


Figure 41.- Effect of store vertical position z on store pitching moment in presence of wing-fuselage combination. Values recalculated about store midpoint. $\alpha = 0^{\circ}$.

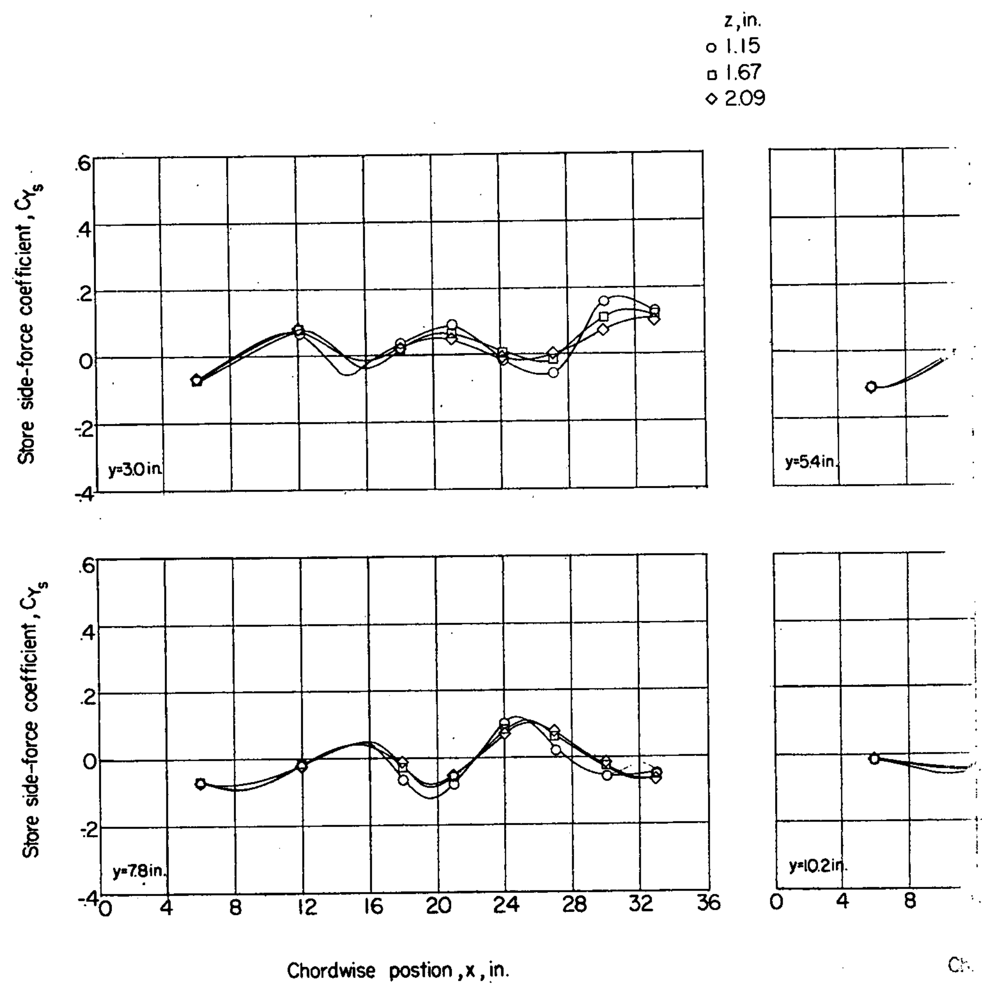


Figure 42.- Effect of store vertical position z
presence of wing-fuselage combination.

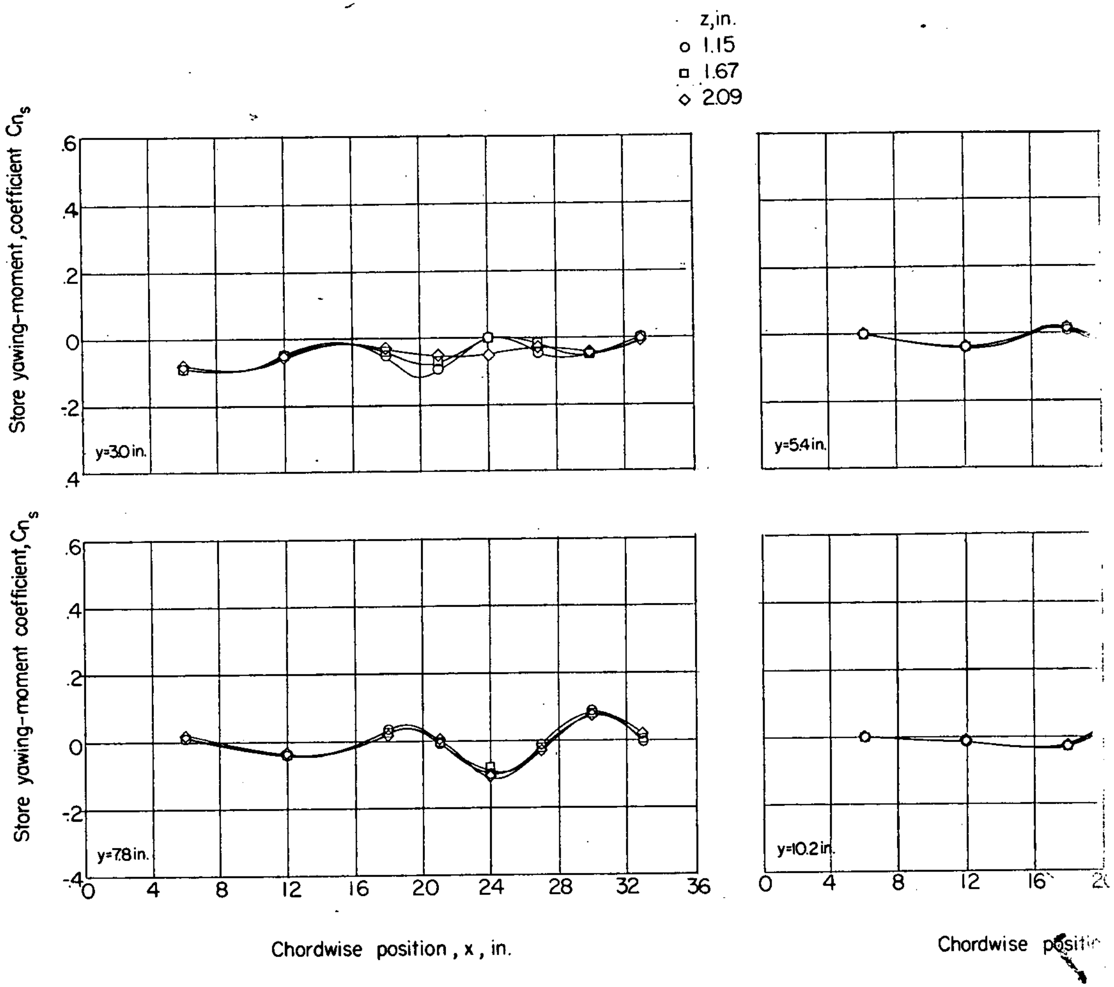


Figure 43.- Effect of store vertical position z on store ; in presence of wing-fuselage combination. Values recalc store midpoint. $\alpha = 0^{\circ}$.

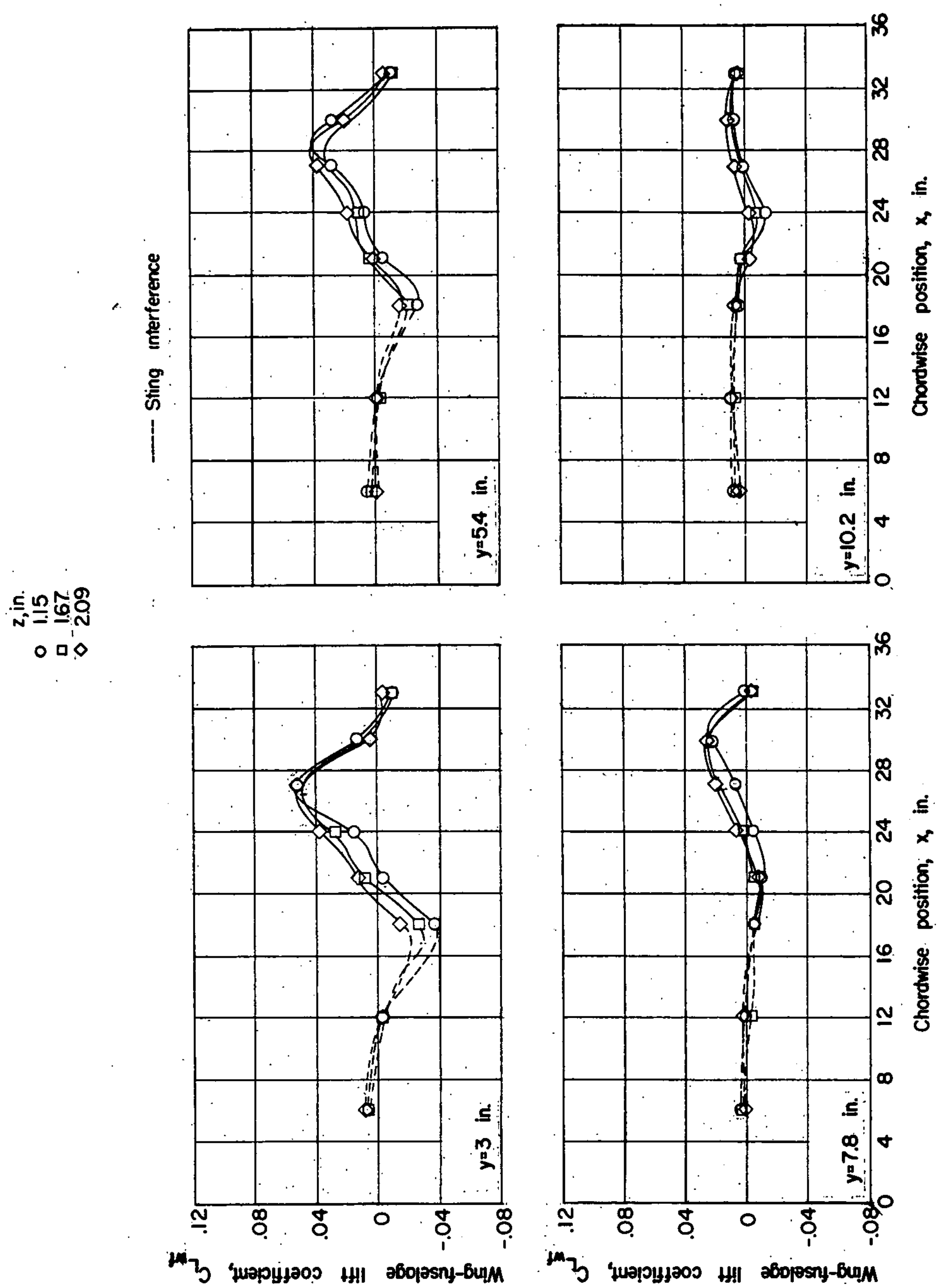


Figure 44.- Effect of store vertical position z on wing-fuselage lift. $\alpha = 0^{\circ}$.

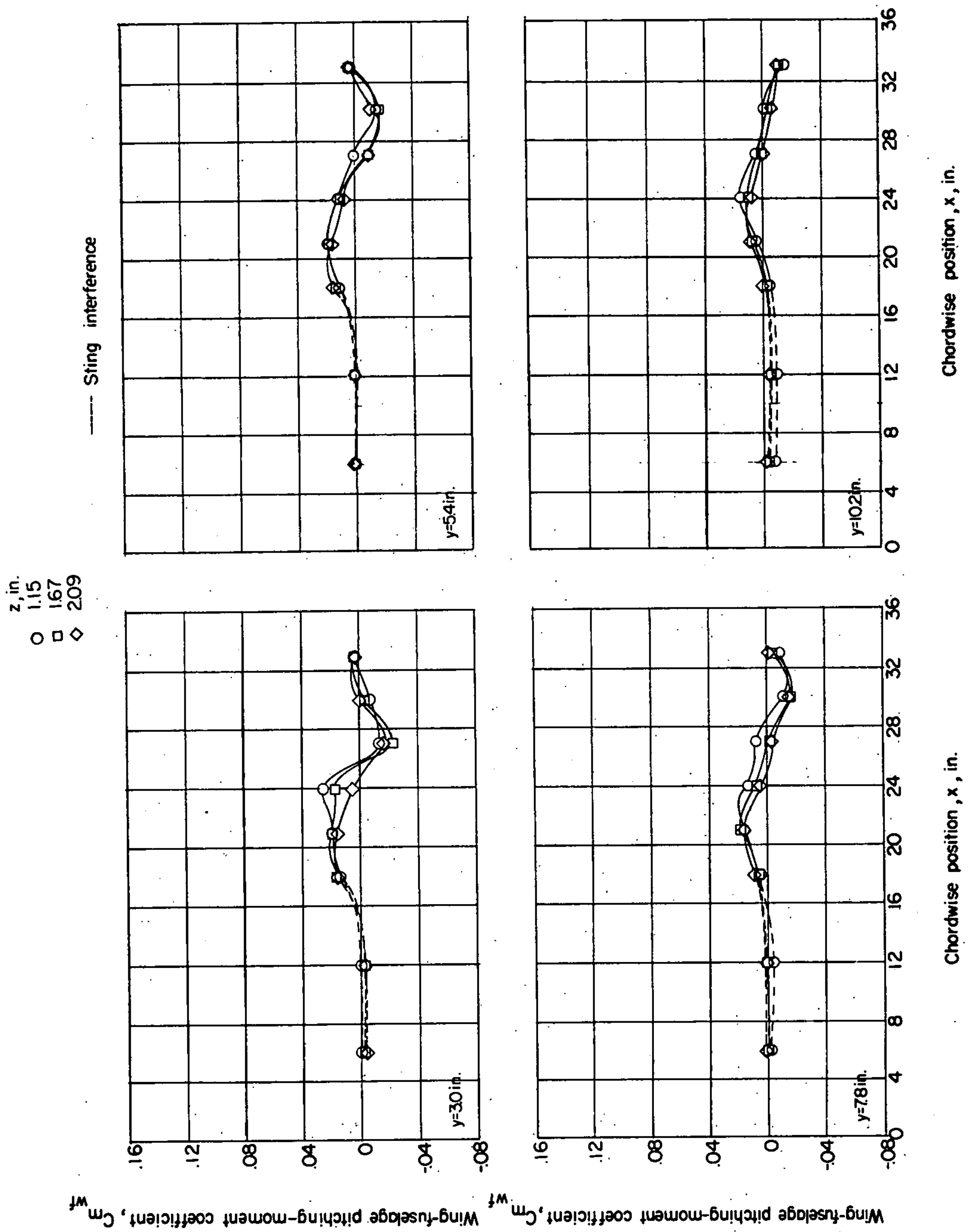


Figure 45.- Effect of store vertical position z on wing-fuselage pitching moment. $\alpha = 0^{\circ}$.

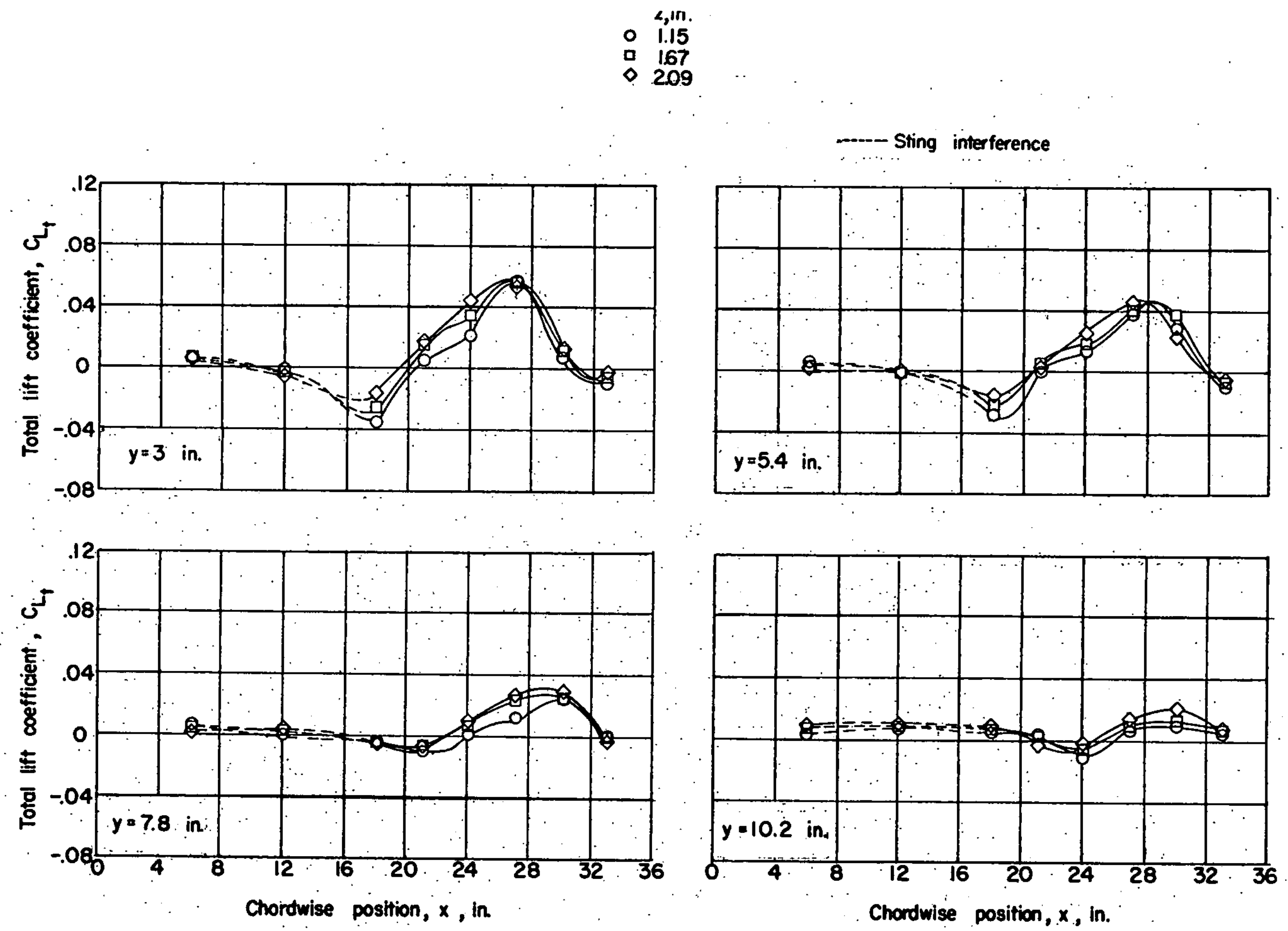


Figure 46.- Effect of store vertical position z on total (wing-fuselage plus store) lift. $\alpha = 0^{\circ}$.

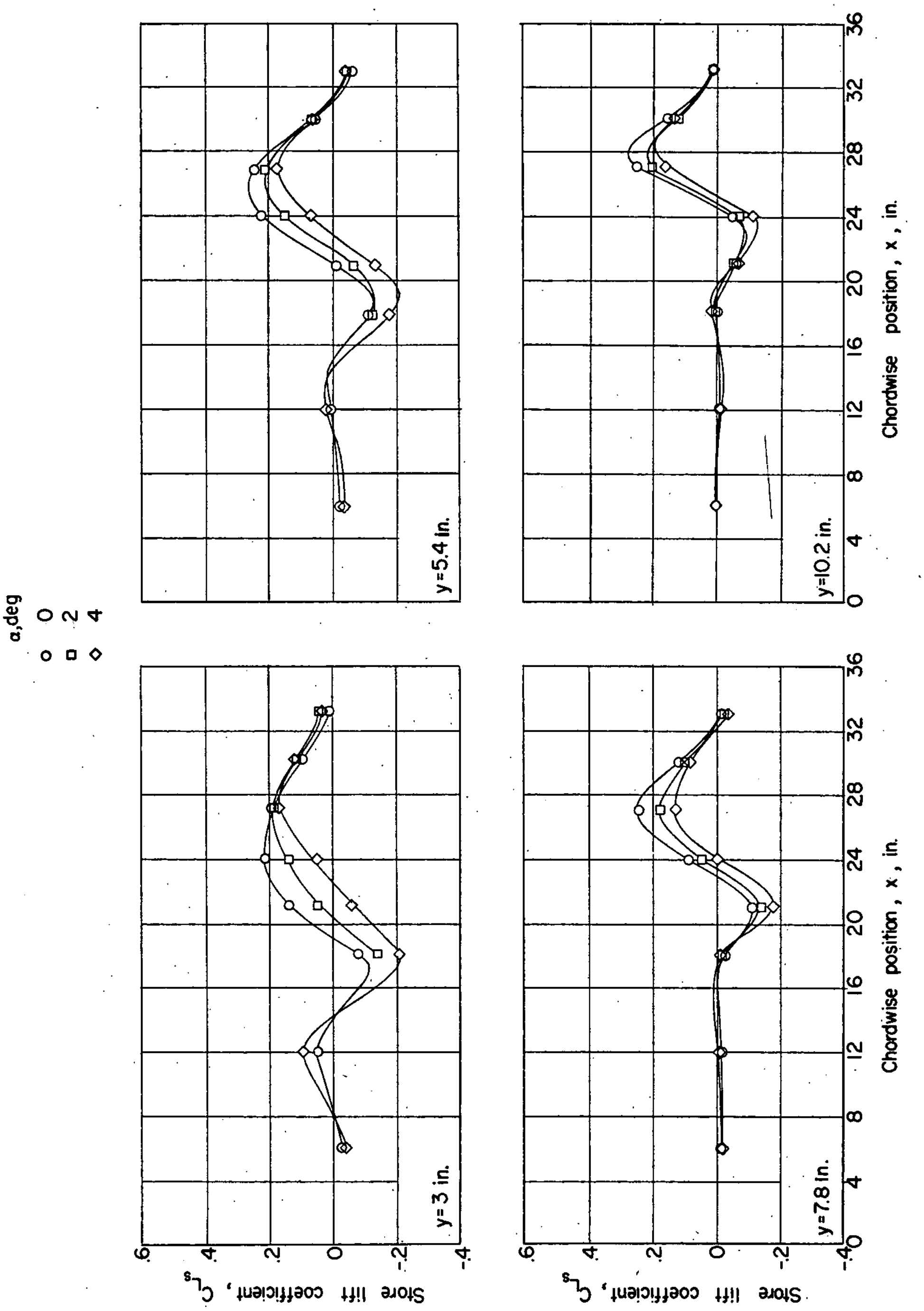


Figure 47.- Effect of angle of attack of wing-fuselage combination on store lift. z = 2.09 inches.

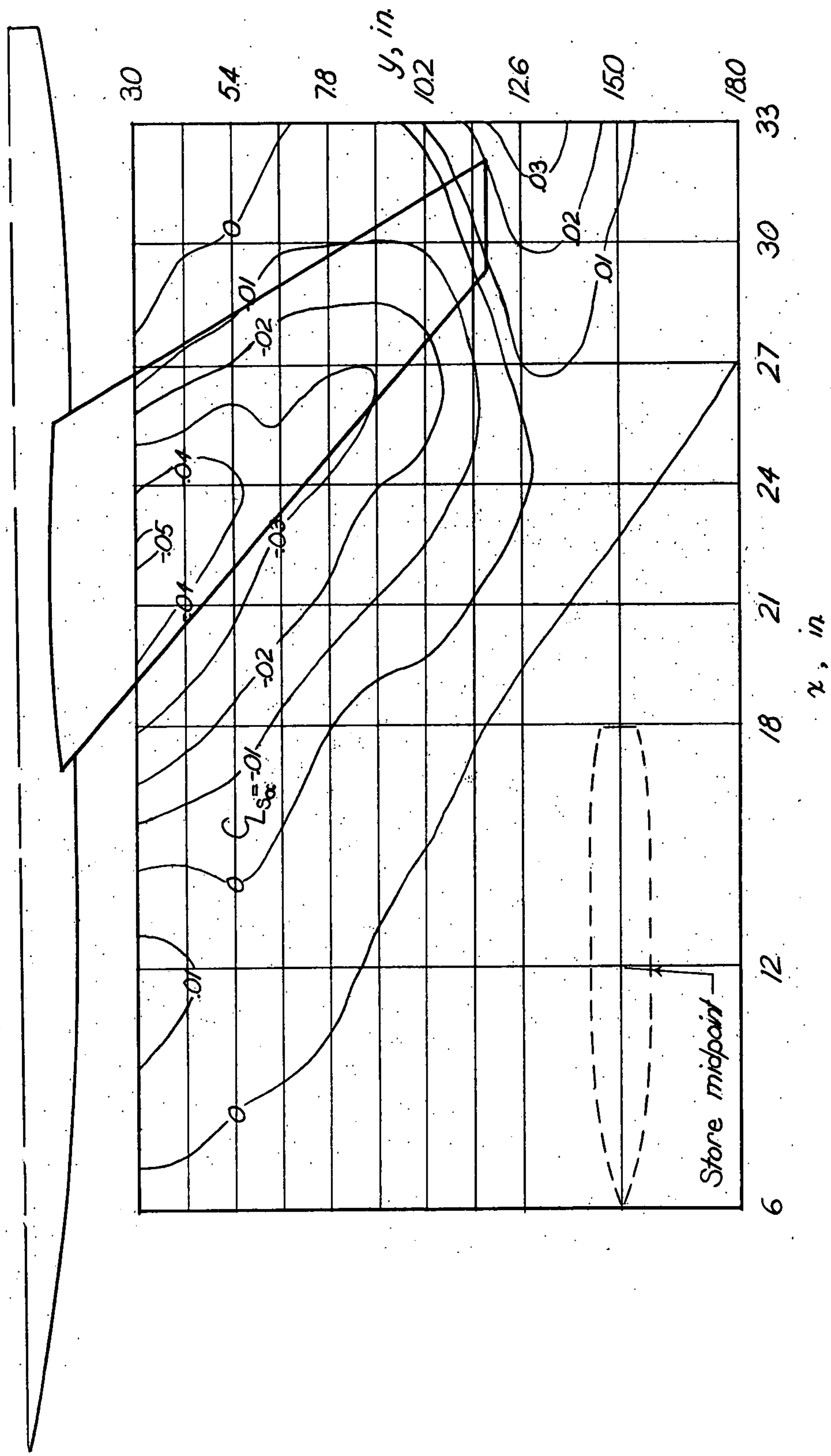


Figure 48.- Contour plot of slope of store lift coefficient $C_{L_{S_\alpha}}$ with angle of attack of wing-fuselage combination. z = 2.09 inches; $\alpha = 0^{\circ}$ to 4°.

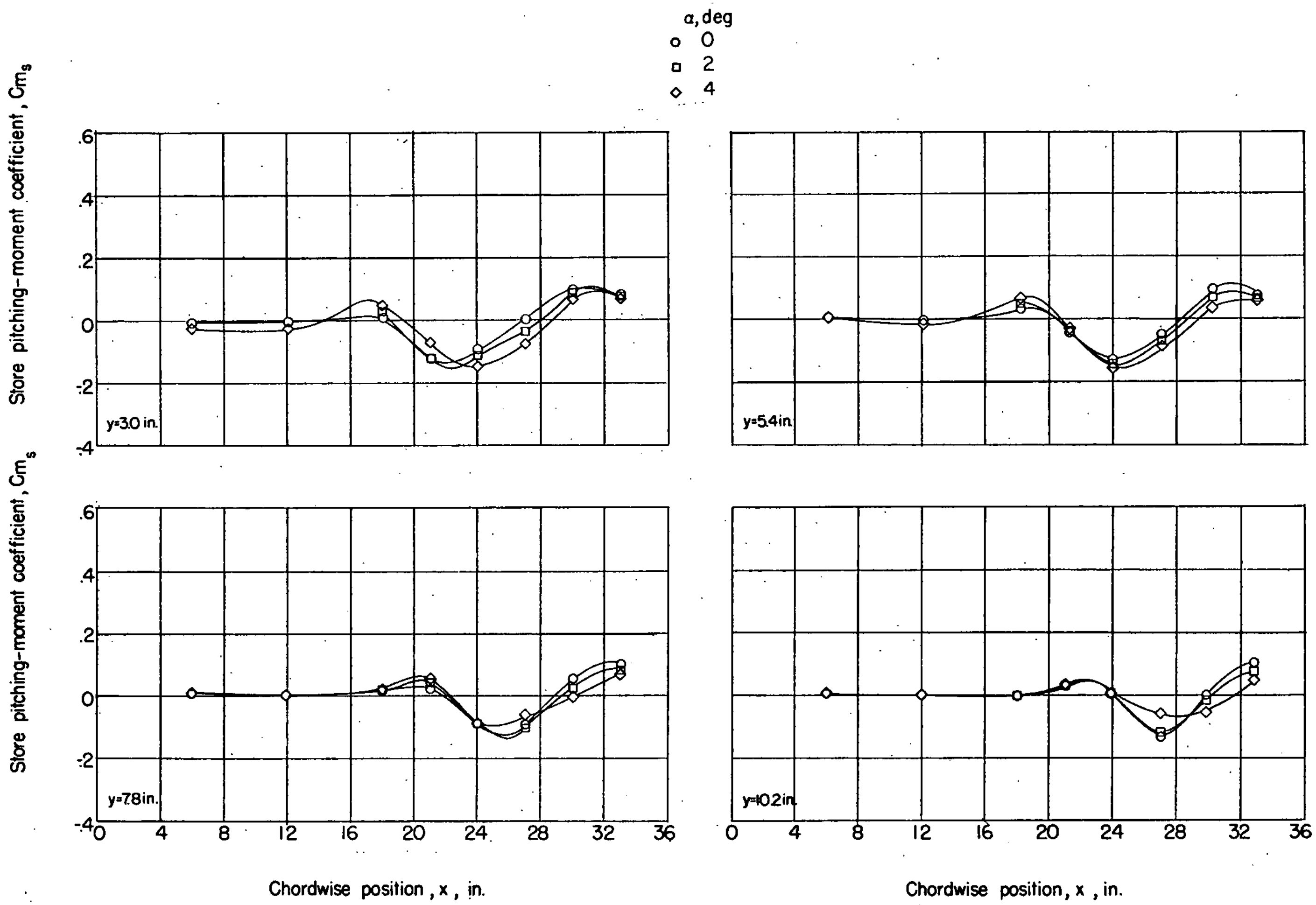


Figure 49.- Effect of angle of attack of wing-fuselage combination on store pitching moment. Values recalculated about store midpoint. z = 2.09 inches.

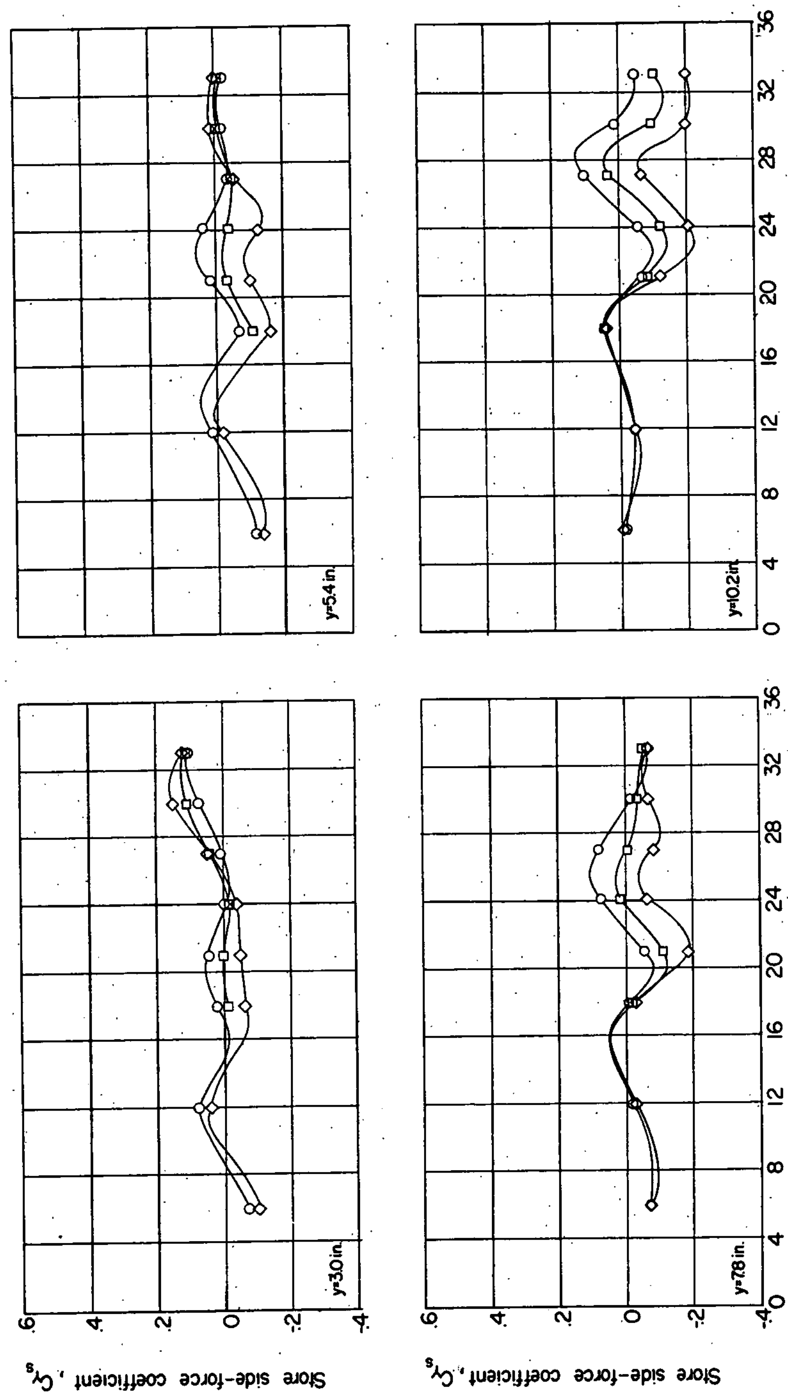


Figure 50.- Effect of angle of attack of wing-fuselage combination on store side force. z = 2.09 inches.

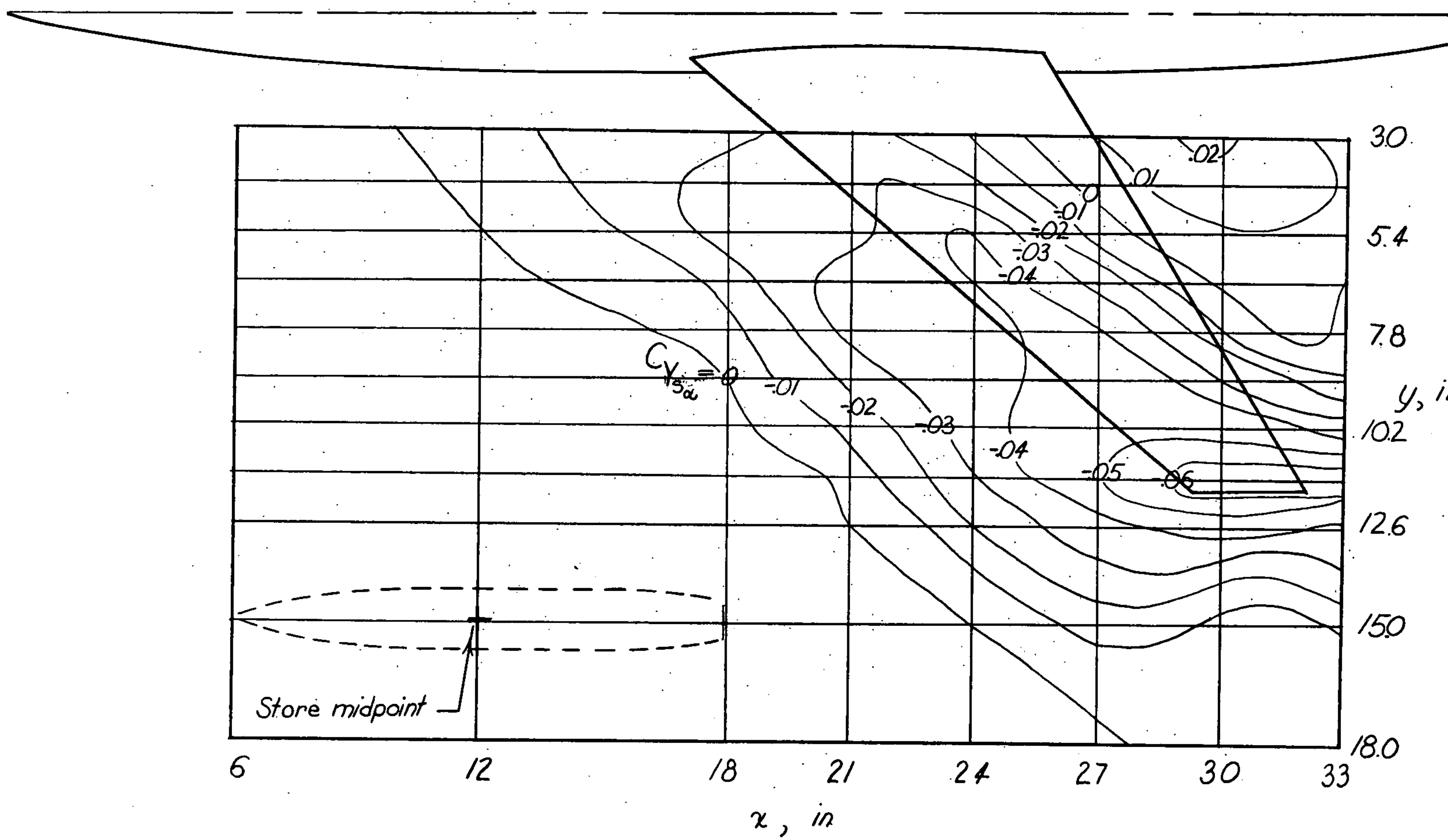


Figure 51.- Contour plot of slope of store side-force coefficient $C_{Y_{s_\alpha}}$ with angle of attack of the wing-fuselage combination. z = 2.09 inches; $\alpha = 0^{\circ}$ to 4°.

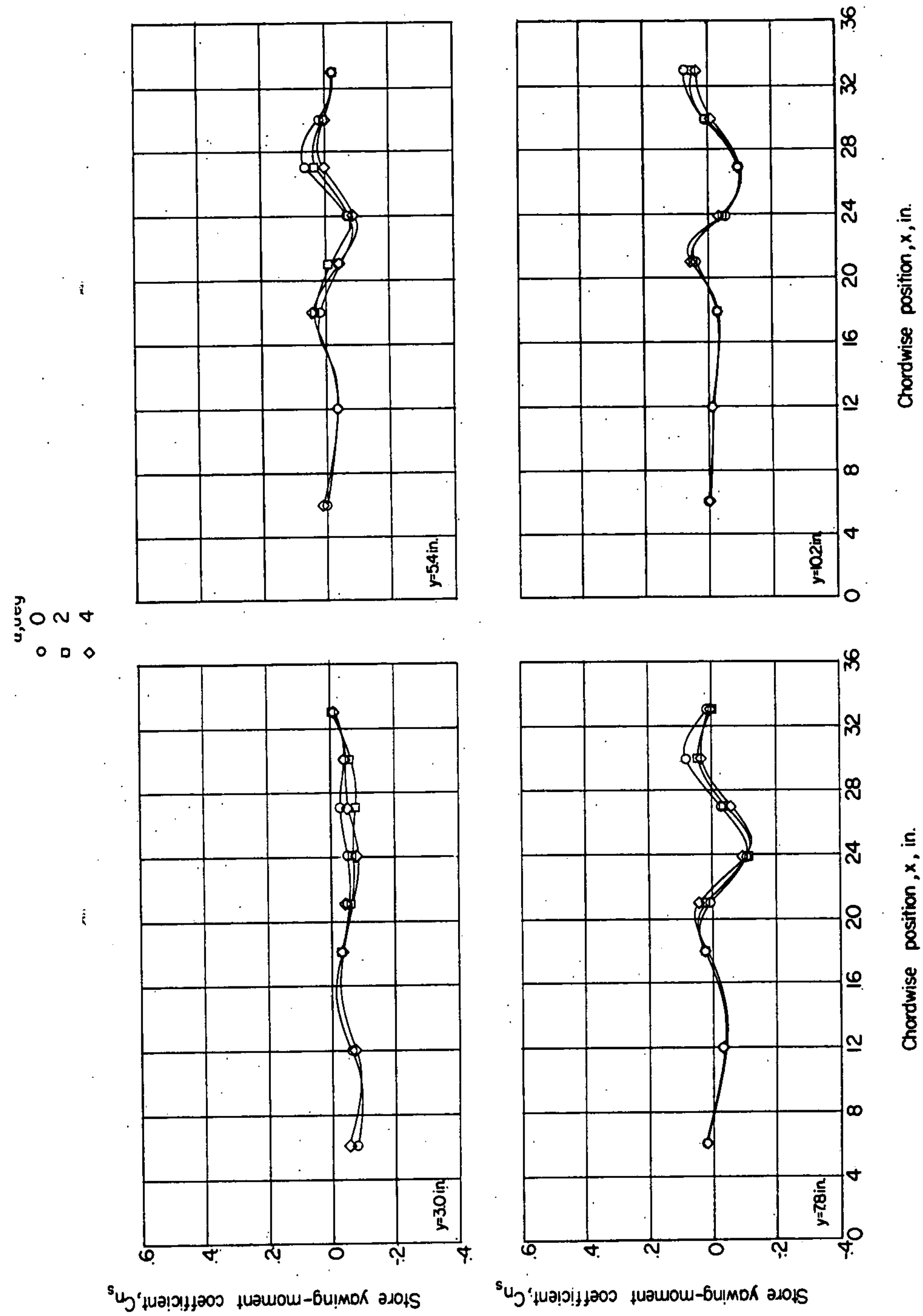


Figure 52.- Effect of angle of attack of wing-fuselage combination on store yawing moment. Values recalculated about midpoint of store. z = 2.09 inches.

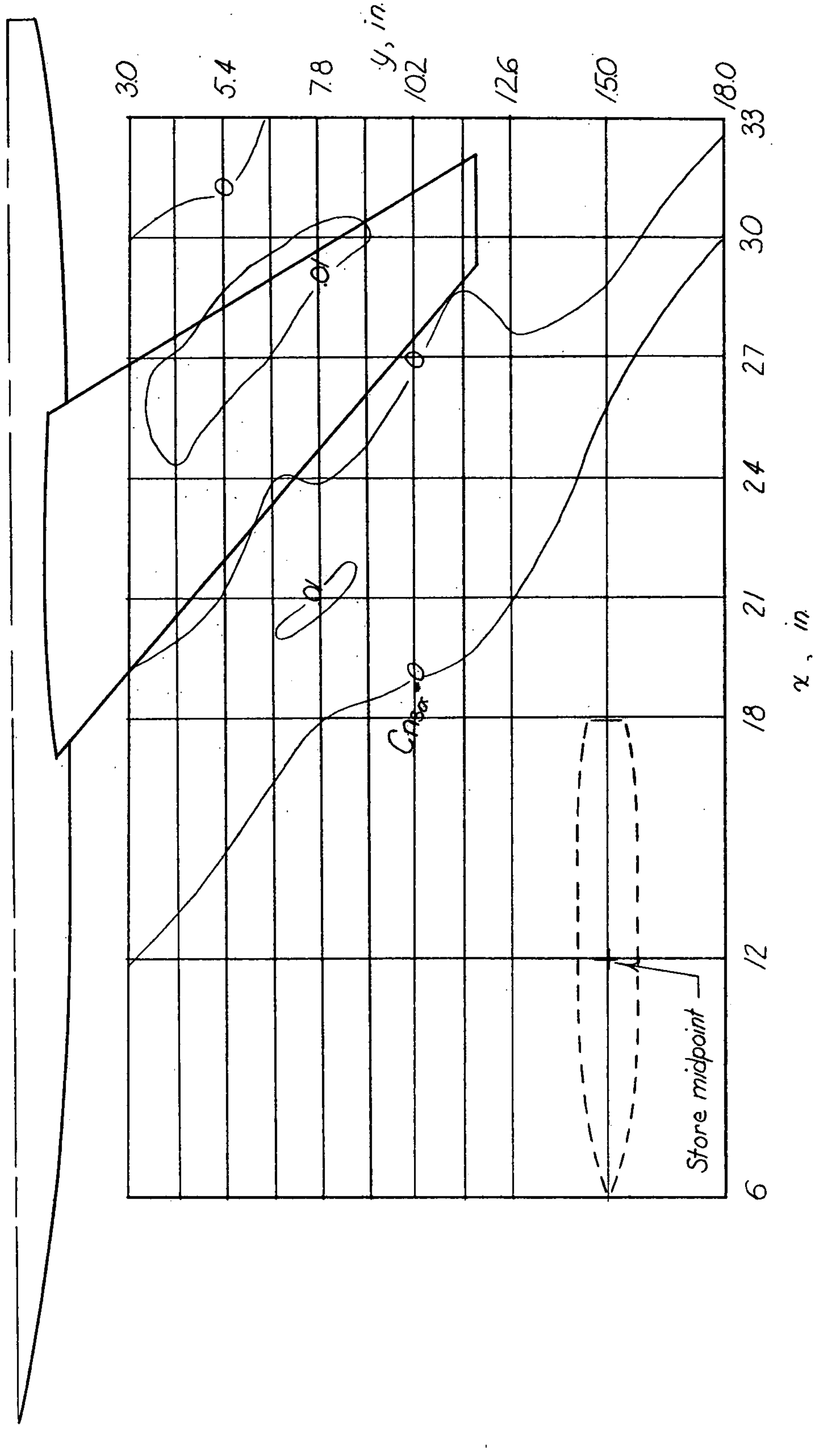


Figure 53.- Contour plot of slope of store yawing-moment coefficient $C_{n_{S\alpha}}$ with angle of attack of wing-fuselage combination. $z = 2.09$ inches; $\alpha = 0^{\circ}$ to 4° (center of moments is store midpoint).

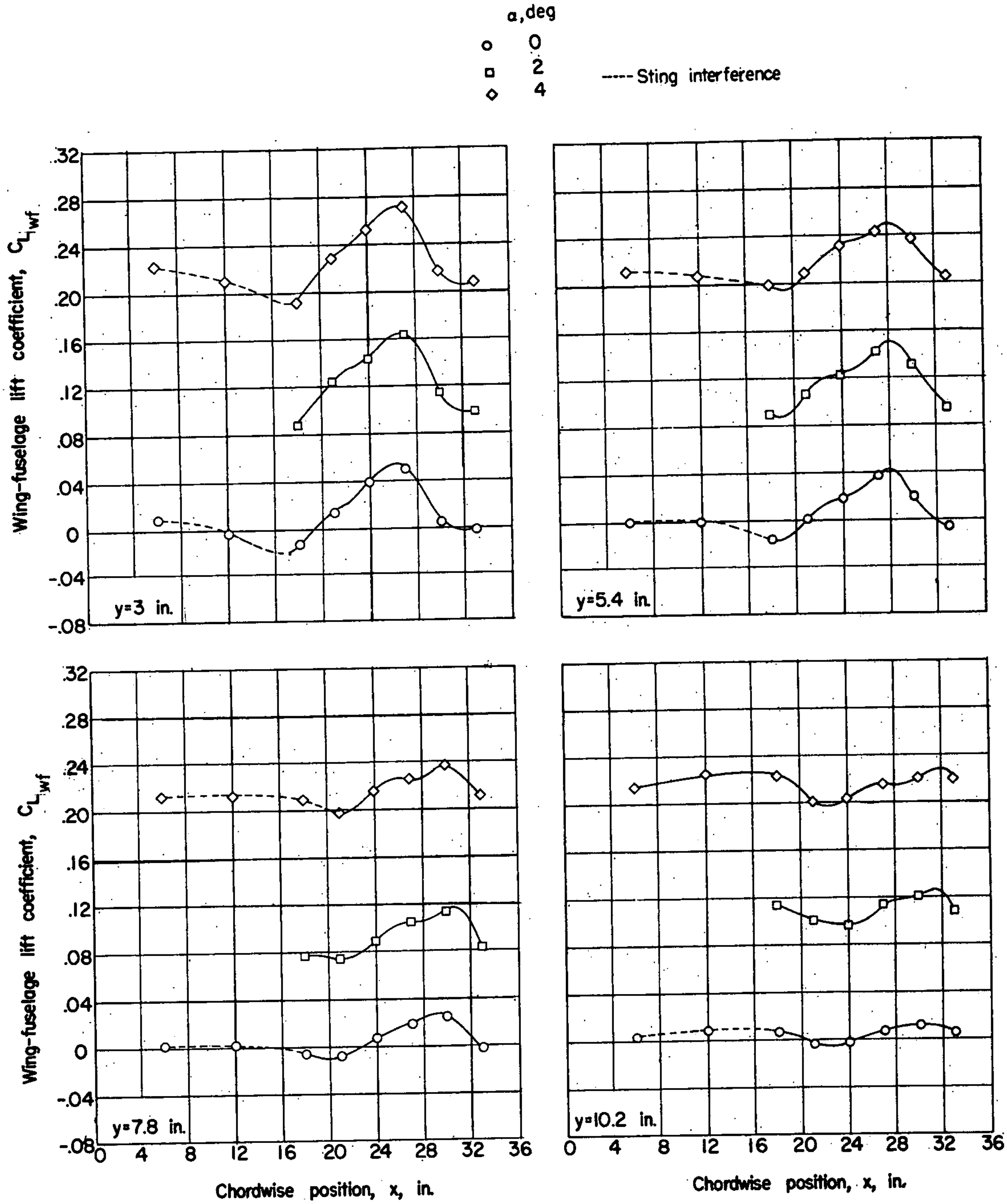


Figure 54.- Effect of angle of attack of wing-fuselage combination on wing-fuselage lift. z = 2.09 inches.

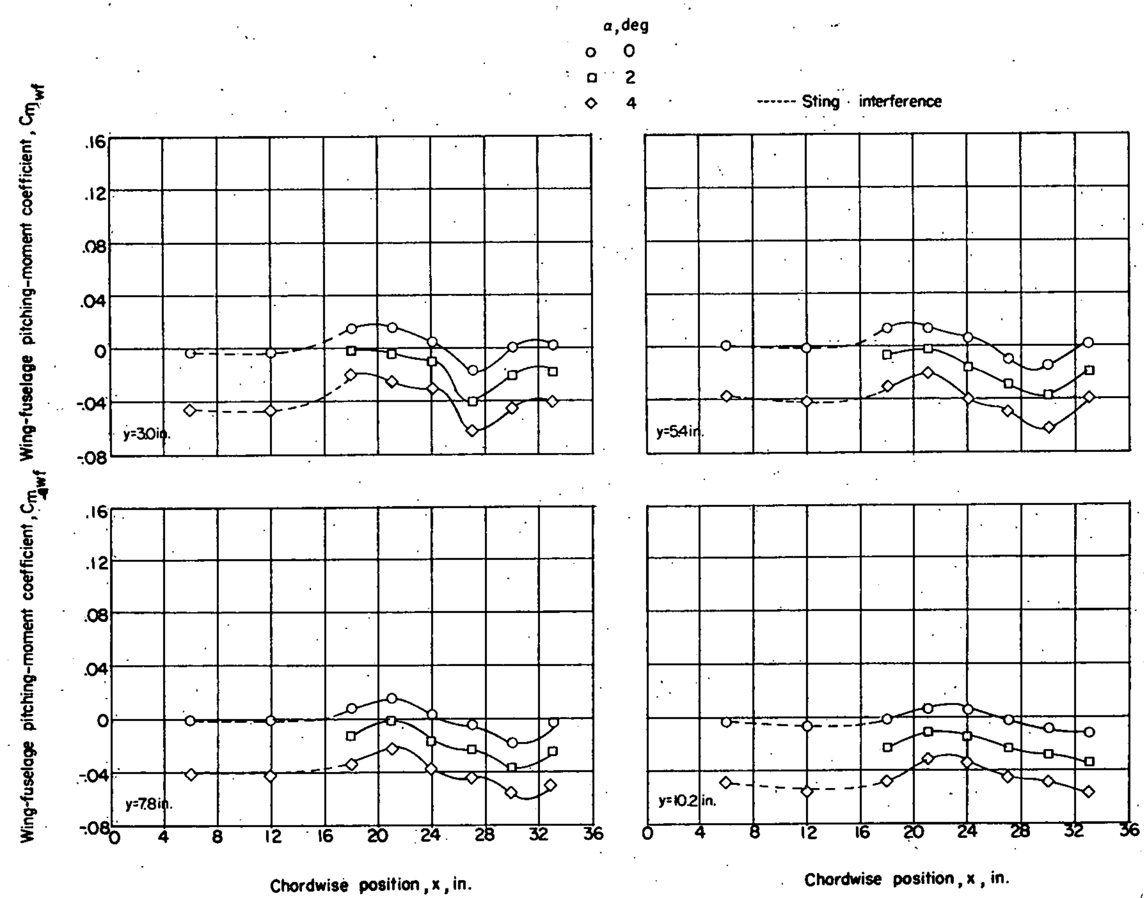


Figure 55.- Effect of angle of attack of wing-fuselage combination on wing-fuselage pitching moment. z = 2.09 inches.

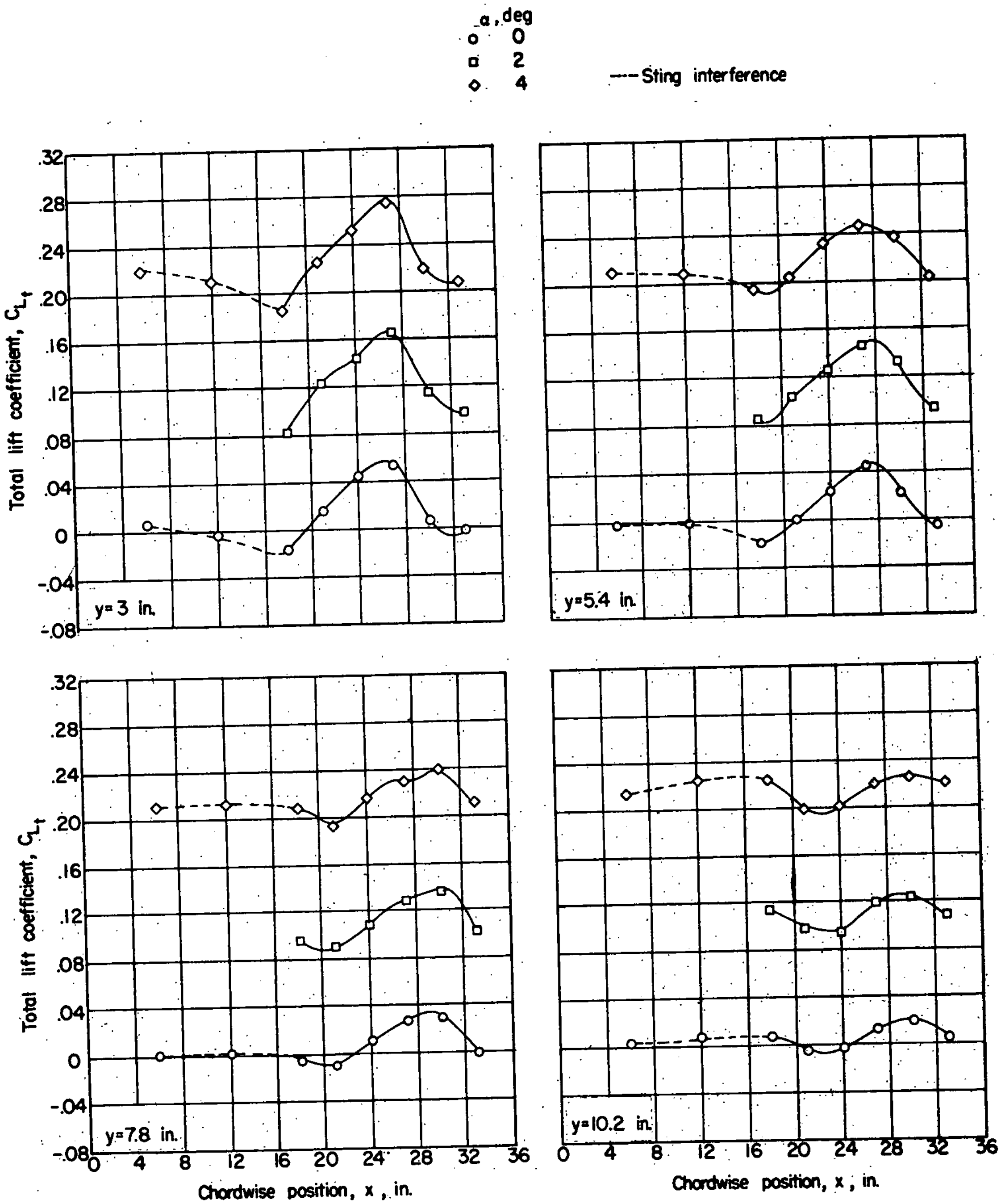


Figure 56.- Effect of angle of attack of wing-fuselage combination on total (wing-fuselage plus store) lift. z = 2.09 inches.