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Final Report

WIND FORCES ON MOBILE HOMES

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WIND FORCES ON MOBILE HOMES

The use of the mobile home as permanent or semi-permanent housing has increased very greatly over the past several years. With this increase in the use and manufacture of these units has come a host of problems, many of which involve manufacturing and design standards. Others center around the relationship of these units to the socio-economic structure of which they must necessarily become a part, and involve planning, zoning, taxation, insurance, protection and the like.

During Hurricane Donna (September 10, 1960), a great many of these mobile homes were overturned and destroyed. Some were rolled or slid by the wind causing damage to both the moving mobile home and other property. Still others were torn asunder by the force of the gale. Needless to say, insurance losses were high. Since Hurricane Donna crossed Florida and other Southeastern states, the focus of attention was to this area. It must be recognized, however, that the problem of wind damage to these units is of importance in many other areas as well.

Public officials in a number of places have been urged to pass regulatory legislation for the purpose of protecting both the mobile home owner and the property of others. Insuring agencies have been seeking information which would allow them to establish a more accurate insurable limit, feeling that if a mobile home unit can be held upright and in place during a high wind, their losses may be reduced by approximately 70% or more. Mobile home park operators are interested in providing facilities which are attractive and safe. Mobile home dealers are concerned with the loss of their inventory in high winds and are interested in measures insuring safety to their units. The mobile home owner himself wants to protect his investment. In order to provide factual data that can be applied to the needs of all these interested parties, this research was undertaken at the University of Michigan.

The research program has been broken down into two major phases. First, an evaluation of the kinds of anchors available which would be suitable for anchoring a mobile home in position, and second, an evaluation of the forces which need to be resisted by the mobile home unit and its anchors. There is data available for a number of different anchor types and the holding power of each in various soils. This study has therefore attempted to organize this data and summarize it for this specific purpose.

The mobile home has a shape which is not commonly encountered in other structures. Further, it is only about one half as heavy as a conventional home, it is set on a rather narrow foundation, and the space between its floor and the ground is usually open. The mobile home is therefore unique in its response to high winds. Because of this uniqueness, very little information could be found which would allow a determination of the design forces to be applied and it was necessary to conduct wind tunnel tests on scale models.

ANCHORAGES

A popular soil anchor, and one which seems particularly suited to sandy beach areas, is the screw auger. (Figure 1). This consists of a circular helically deformed plate fastened to the bottom of a sturdy rod which is turned into the soil to the required depth. Although this device is limited to looser or softer soils, it is particularly these soils in which it is difficult to achieve a secure anchorage by other means. It does not require auxiliary equipment for installation and is relatively foolproof. A comparable anchor is the Arrowhead Anchor but this requires jacking equipment in order to set it.

Various manufacturers sell prefabricated anchors (Figure 2) which expand at the bottom of a pre-bored hole four or

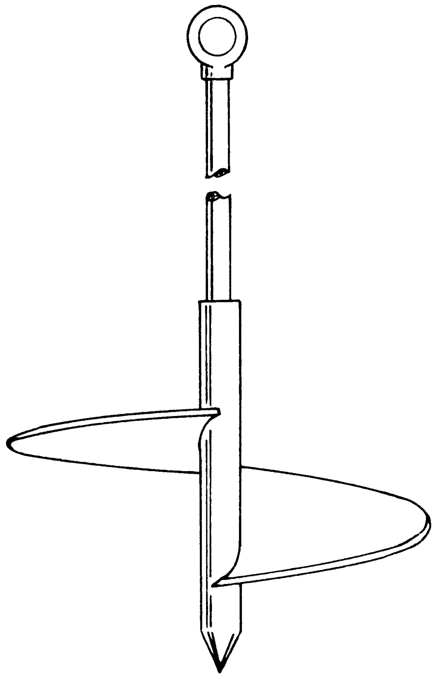


Figure 1.
Screw Auger

five feet deep. These require backfilling and tamping to complete their installation.

The most widely used and simplest, but not necessarily the best, anchor system is the so-called dead-man (Figure 3). Typically this may consist of a concrete block, either cast in place or positioned below the ground surface, to which is fastened the anchor rod or cable. There are, of course, many possible variations of this method, depending upon the inclinations of the builder and available materials. However, they are all essentially similar in that they require a pre-excavated hole into which are placed the structural elements of the anchor. They must be well backfilled and tamped. Minimum recommended sizes and depths for these anchors are given on pages 42, 43 and 44.

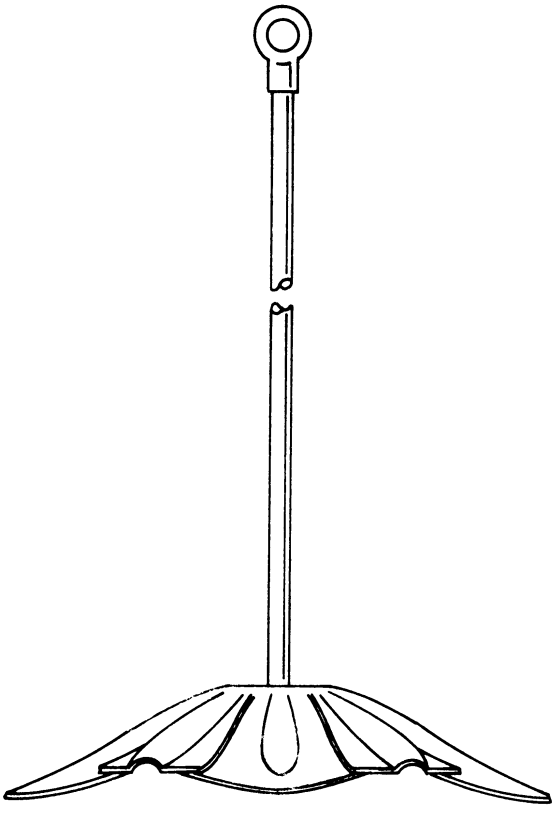


Figure 2.
Prefabricated
Expanding Anchor

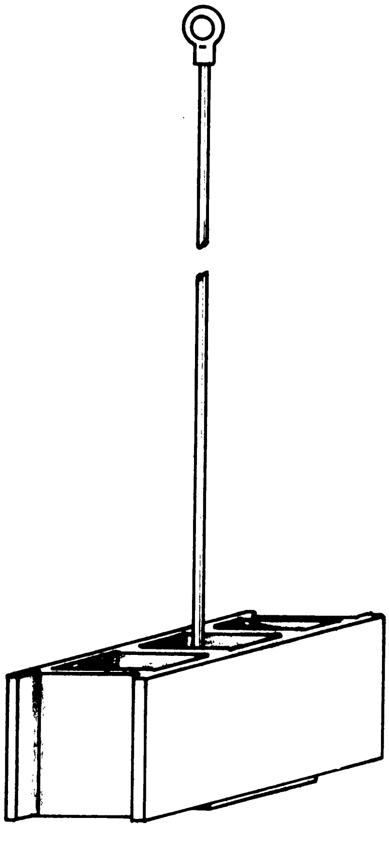


Figure 3.
Dead-Man
Anchor

DESIGN OF ANCHORAGE CAPACITY

The computations on pages 48 to 51 in the Appendix present examples of a method for evaluating the safe design capacity of both dead-man and screw auger systems. Some example computations are included and typical soil resistance values are given as a guide for various conditions. It should be pointed out that some judgment must be exercised in using these methods and particularly the soil conditions should be carefully studied to assure that the appropriate soil resistance values are employed. It should also be pointed out that moisture content of the soil plays an important part in choosing resistance values. Lower values should always be applied if, during the seasons, a particular soil can become saturated.

Page 48 presents a general procedure for evaluating dead-man anchorage capacity. Equations A and B indicate the anchorage as controlled by either side shear and surcharge, or by the weight of soil within the projected cone of influence. Suggested side shear values for use in Equation A are shown. Note that these values are available only where concrete is used. These resistances should not be used when considering disturbed soil, as in a backfilled precast block dead-man.

The example computation on page 49 is for a cast in place concrete plug, 1 foot in diameter, 2 feet deep, with 3 feet of surcharge acting. The indicated safe design capacity in loose sand would be about 1,500 pounds.

Pages 50 and 51 present an evaluation of a typical screw auger anchor. For the nominal 6 inch by 48 inch anchor, the safe indicated design capacity for a medium sand is 2,200 pounds pull. This is somewhat less than the 2,500 pounds recommented by the manufacturers, but is probably satisfactory.

THE WIND

At the same time as the studies on Anchor Types were proceeding, a complete review of the literature was undertaken to ascertain the magnitude of the winds which would be imposed on a mobile home anywhere in the continental United States, and also to ascertain the technical characteristics of the wind in the field and in the wind tunnel.

It was found that under severe atmospheric conditions some mobile homes were able to resist the wind forces, yet, reports were obtained showing units being overturned in winds lower than 65 miles per hour, in some instances as low as 30 miles per hour.

Brekke[1] includes a good discussion of the sources of high winds in his report. He characterizes tropical cyclones (hurricanes) as severe storms accompanied by strong, squally winds from 75 to 150 miles per hour.

H. C. S. Thom[2], Chief Climatologist of the U. S. Weather Bureau, has made extensive statistical studies of the fastest mile of wind for U. S. Weather Bureau stations throughout the country. One of his maps (see page 39 in Appendix) shows this velocity for a probable period of recurrence of 50 years. The southern portion of Florida and the Southeastern seaboard show the greatest velocities, in the order of 90 to 120 miles per hour.

On another map for a 100 year recurrence period, (Figure 5, page 7), the velocities in the same areas are of the order of 100 to 130 miles per hour. Thom's maps have a standardized height of 30 feet above the ground and have been adjusted for the location of the recording instruments, shielding of other structures, topography, and other local conditions.

While height plays an important part in establishing wind velocities, there is much disagreement as to velocities in regions below the 30 foot level. Most attempts to determine by theory the velocities near the ground result in wind speeds that are too low. The effect of vegetation, other structures, and topography is always an unknown factor which may account in part for the discrepancy. A conservative assumption is to use the 30 foot values from Thom's maps as basic even at the level of the mobile home.

For inland areas the usual one-seventh-power law may be taken to adjust local readings to the basic level of 30 feet. This may be expressed thus:

$$V_{30} = V_h \left(\frac{30}{h}\right)^{1/7}$$

where h is any height, V_h is the velocity at that height, and V_{30} is the velocity at the basic 30 foot level. This relationship is shown graphically in Figure 4.

Wind velocities may be reduced to pressures by making use of the basic velocity-pressure relationship for fluids, namely,

$$q = \rho\frac{V^2}{2}$$

where q is the dynamic pressure, V the velocity, and ρ the mass density of the fluid, in this case, air. The value of ρ varies with temperature and barometric pressure (altitude). Applying a value of $\rho = 0.00238$ slug/ft^3 at standard sea-level conditions of temperature and barometric pressure, one obtains

$$q = \frac{1}{2} \times 0.00238 \times \left(\frac{5280}{3600}\right)^2 V^2 = 0.002558\ V^2 \qquad (1)$$

V being expressed in miles per hour, and q in pounds per square foot.

If the force acting on an object is desired, as in this case, this dynamic pressure must be multiplied by a shape coefficient frequently called a drag coefficient and a characteristic area. These shape coefficients are dimensionless and are dependent upon the geometric shape of the object, its orientation to the wind, and air friction effects.

Using data available from some studies on building forms made at the State University of Iowa[3], the transverse drag coefficient for a flat roofed building having a length to width ratio of 4 is 1.33.

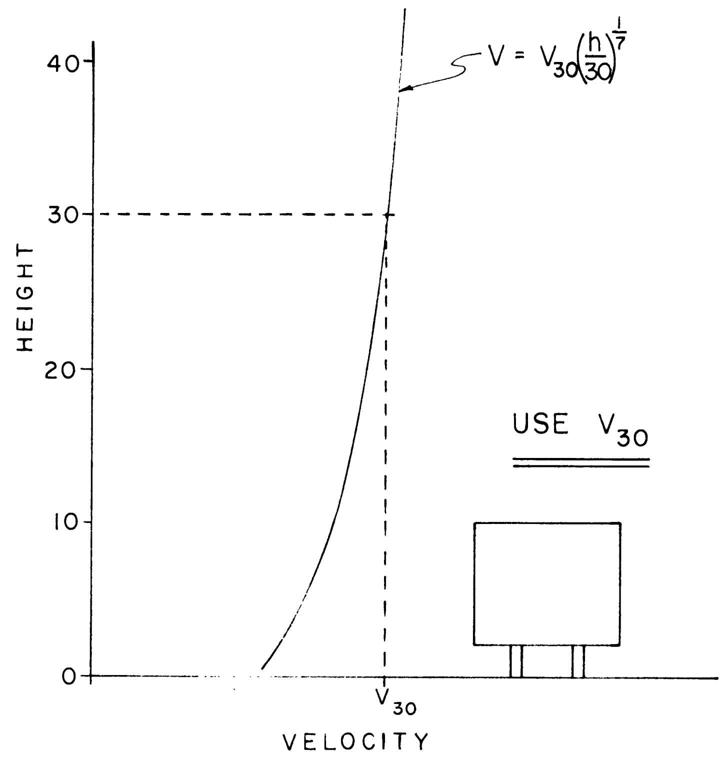


Figure 4.
Graphic Representation
Of One-Seventh-Power Law

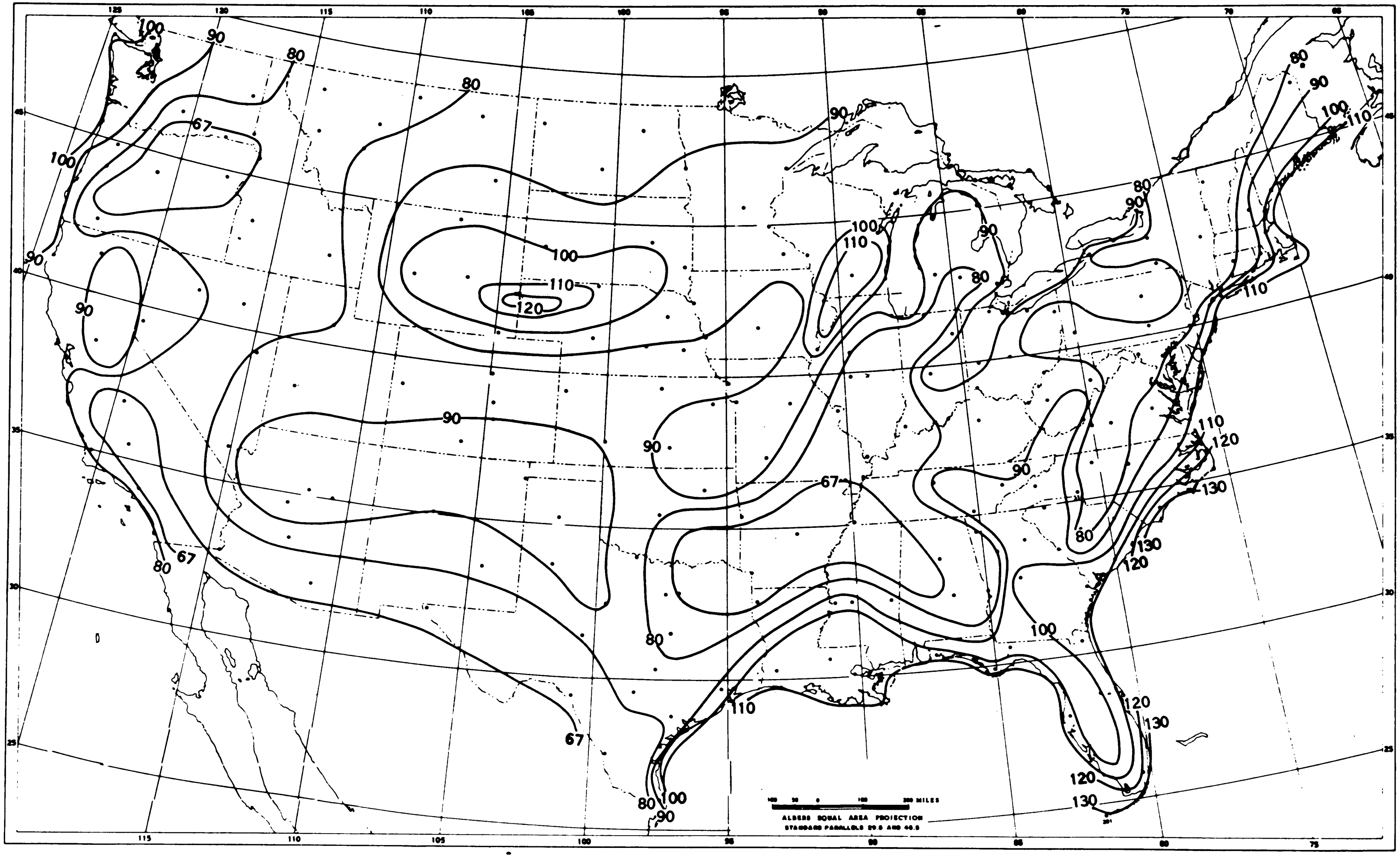


Figure 5.
Contours Showing Fastest Mile Of Wind,
In Miles Per Hour, 30 Feet Above The Ground,
100 Year Period Of Recurrence

Woodruff and Kozak[4] present data indicating that the drag coefficient for a plate with an aspect ratio of 6 (length to height) is about 1.3, and for a parallelopiped with a width to height ratio of 1 and an infinite length is 2.03. These results are based on tests with the objects in mid-stream unaffected by boundary conditions. Lower values were therefore anticipated in the tests and the results confirm this expectation.

Not only are the values of the forces acting on a mobile home significant, but so is the location of the various centers of pressure. The higher the center of pressure on the mobile home wall, the greater will be the anchorage requirement. The Iowa tests[3] show that for winds acting normal to the wall, the pressure centers are near the geometric center of the exposed face. However, when the wind is at an angle of about 60° from the normal, the center of windward pressure is 0.15 the height below the center and for the leeward pressure is 0.10 the height above the center. The effect of this shift in center of pressure was investigated and plays a major role in the results.

Another element of the wind which affects the mobile home is the variability of the wind itself. The data available from wind tunnel testing is all based on the use of steady wind velocities. In nature, this is not the case, hence some allowance must be made for gusts. Sherlock[5] shows that the gust factor may be taken as 1.3 and that is independent of height. Gentry[6] confirms that the factor is from 1.3 to 1.4 even during hurricane winds.

In summary, the total force acting on a mobile home normal to one of its surfaces, is the product of the dynamic pressure, the area of the surface, a shape factor, and a gust factor.

MOBILE HOME DETAILS

While the forces caused by the wind are the major consideration in anchoring a mobile home against strong winds, there are some aspects of the mobile home itself which contribute to the problem. Most of these concern the weight of the unit and its foundation.

Weights naturally vary with the manufacturer, model, and the user. A fifty foot ten wide as delivered will have weights ranging from 10,000 pounds to 12,500 pounds depending on model and maker. An average value of 11,100 pounds was found from weights given by eleven manufacturers. The users contribution can be very substantial by the time he adds dishes, cooking equipment, clothing, bedding, TV sets, and other specialized equipment. It is estimated that this can easily reach another 1,000 to 1,500 pounds. The total weight of the unit in place will run from 10,000 to 14,000 pounds for a fifty foot ten wide.

Many of the modern mobile homes have side aisles and fixed equipment along the left wall. This produces a decided shift in the center of gravity of the coach. One typical fifty foot ten wide was weighed and the center of gravity was found to be 1.485 feet to the left of center and 1.269 feet above the bottom of the frame. The addition of the users equipment in this coach would tend to shift the center of gravity upwards slightly and further to the left.

In setting a mobile home, the usual practice is to block it under the main longitudinal members of the frame. The spacing of these members therefore becomes important since the greater the spacing the greater will be the effectiveness of the blocking in resisting the overturning action of the wind. The distance center to center of the main longitudinal members varies from 55 inches to 75 inches depending upon the manufacturer, with some builders using a perimeter frame. The most critical spacing has been used in this study, namely 55 inches.

THE TESTING PROGRAM

Since shape factors are dependent upon the configuration and position of the object in the wind, a wind tunnel testing program was established using models of mobile homes to determine these values in some detail.

Initially, four basic models were made to a 1/16 scale. Each model was a simple rectangular shape fitted with 200 piezometer holes from which pressures acting on the model surface could be determined by the use of manometers. Sides, tops and bottoms were constructed representing 25 foot, 40 foot, 50 foot and 60 foot lengths of the prototype unit. The ends were made interchangeable so that throughout the testing, the same ends were used.

The 25 foot model was chosen since it is representative of the lower limit of trailers used as mobile homes. The 40 foot model was built since many older mobile homes are approximately this length. The 60 foot model was thought to represent the upper practical limit of mobile homes and the 50 foot model represents the most common length in use. Because of this popularity in size, the 50 foot model was chosen as the reference model.

Each of the four basic models was tested for nine wind angles (Figure 6) and six wind speeds. In addition, the 50 foot model was tested with the space beneath the coach enclosed with skirting, a practice among many mobile home owners; with the tongue down, a frequent practice among mobile home dealers; and with other coaches in fourteen different attitudes of shielding.

There are many variations in the design of mobile homes with respect to their tops, ends, and bottoms. Also the recent development of expando units and the widespread use of the cabana and awning increases the number of these variations almost without limit. Five additional models were tested with the nine wind angles and six wind speeds in an attempt to evaluate some of these variables.

The 50 foot model, fitted with a bottom representing a coach with the under carriage covered, was the first of these five. (Figure 7). It was assumed that this configuration would produce the least resistance to the passage of the wind beneath the coach and would help in stabilizing the units, an assumption which proved correct (see page 25).

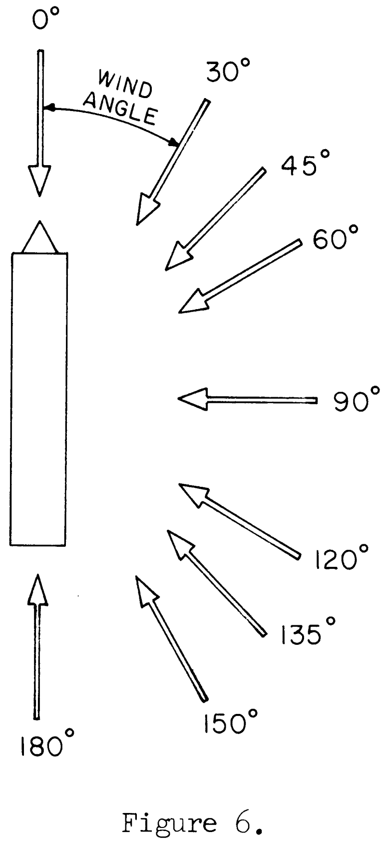


Figure 6.
Wind Angles Tested

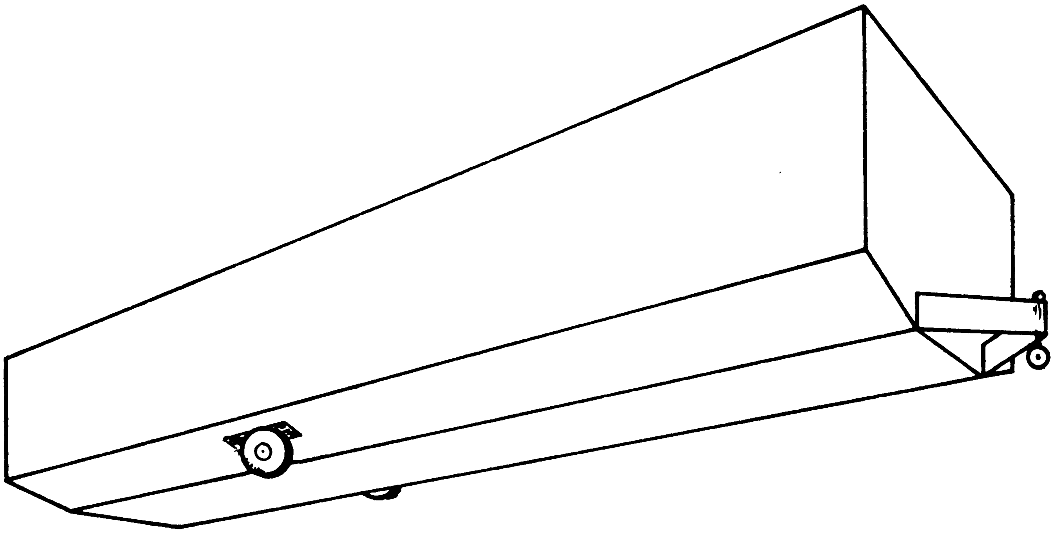


Figure 7.
Sketch Of 50 Foot Model With Bottom Covered

The second of these five tests was made on the 50 foot model with a clerestory top (Figure 8) in order to obtain some idea as to the effect of some of the common top modifications. The third test was made with an expando unit attached to the right side (Figure 9). The fourth test evaluated the effects of a large awning (Figure 10) along the right side and the fifth test was made with a cabana along part of the right side (Figure 11).

It was not possible to use manometers to measure the forces on the model in these last five tests. The support for the model was therefore instrumented with electric strain gages which could be calibrated by the application of known forces to the model. The position of the various centers of pressure remained an unknown so it became necessary to repeat the tests for the four basic models and to adjust the results to agree with the manometer tests in the analysis of the data.

The entire program produced 422 manometer tests and 485 strain gage tests which can be considered valid and from which the results presented here are drawn.

Additional photographs of equipment and models may be found on pages 52 to 54 in the Appendix.

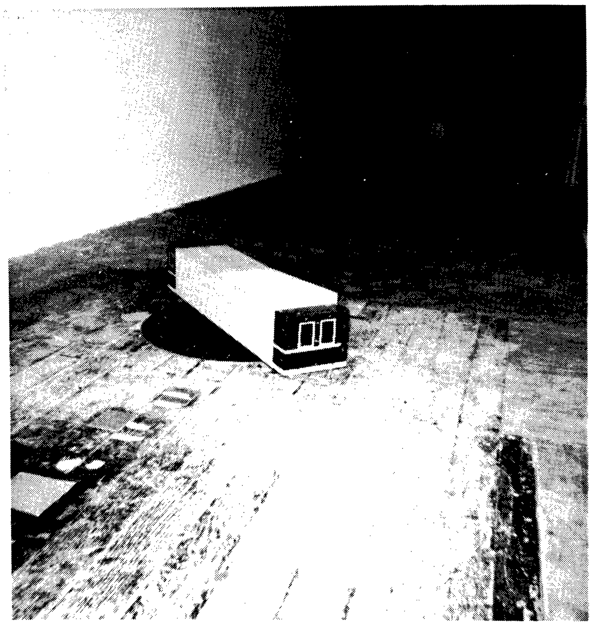


Figure 8.
50 Foot Model With Clerestory Top

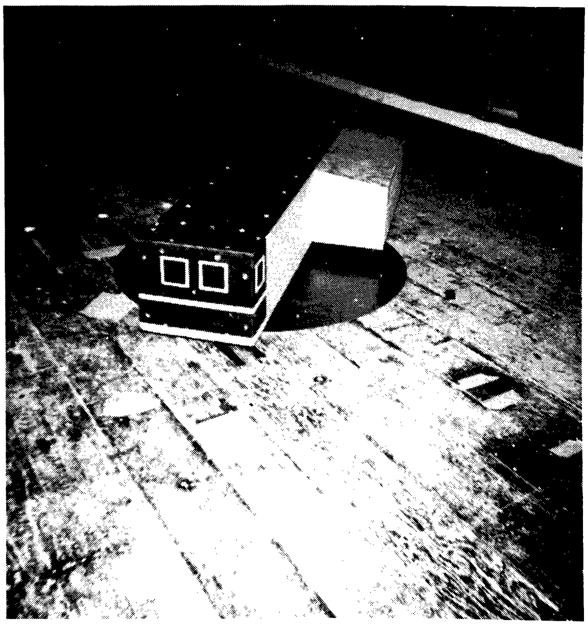


Figure 9.
50 Foot Model With Expando Unit Attached

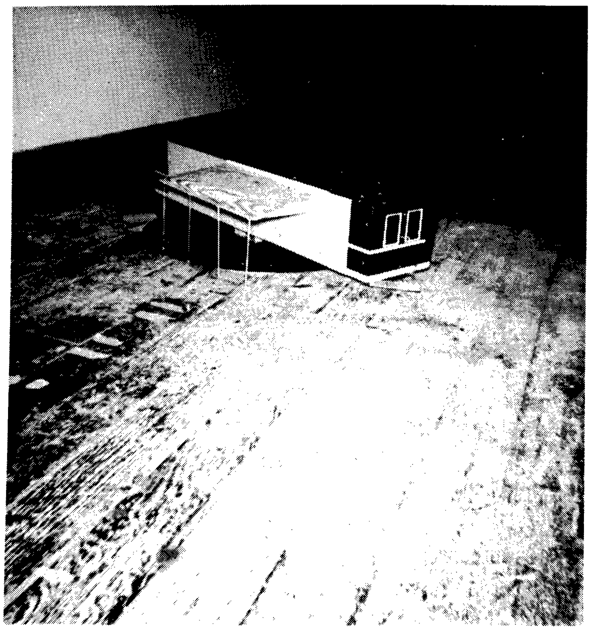


Figure 10.
50 Foot Model With Awning Attached

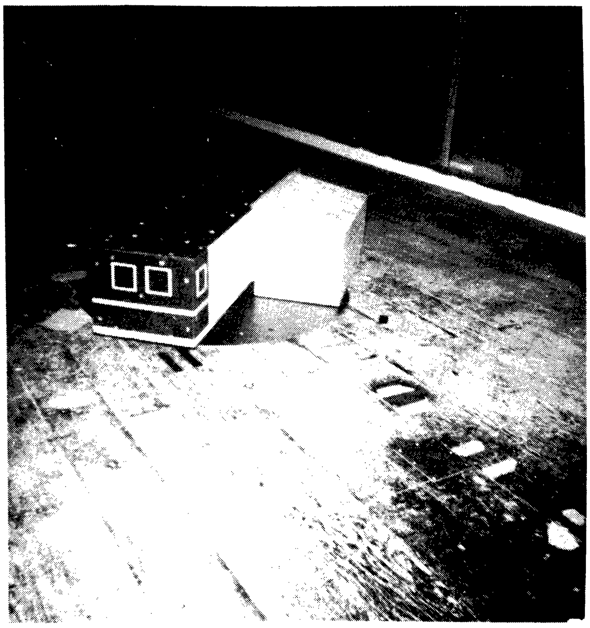


Figure 11.
50 Foot Model With Cabana

MANOMETER TESTING PROCEDURE

In testing the models by using manometers, each model was assembled in the wind tunnel test section, the bottom being installed first, followed by the sides and ends and then the top. The bottom was mounted on top of a fabricated square aluminum column extending through the floor of the tunnel. In order that this support would have as small a resistance as possible to the passage of the wind and would represent the field condition of the mobile home, its position was chosen at the location of the wheel assembly on the prototype. Arrangements were incorporated in this attachment for leveling the model and for raising and lowering it as desired. The model was not allowed to move during testing.

Each model was constructed of white pine to a 1/16 scale. Small capillary tubing, 0.05 inches inside diameter, was chosen for the piezometer fittings. Care was taken to set the end of each tube flush with the model surface and perpendicular to the surface, each tube projecting into the inner space of the model. Small plastic tubing was then attached to the projecting end of each capillary tube, passed down the center of the column and out a port near the column top. Adapters connected each plastic tube with a larger rubber tube which in turn was attached to the top of a glass manometer tube. Fifty of these tubes formed one manometer board which could be adjusted to any desired slope and which could have the fluid level controlled by means of a larger reservoir.

Every tube was marked and checked to see that there was no obstruction which would interfere with the transmission of pressure from the opening on the model surface to the top of the fluid column. When all the 200 tubes had been checked, the model was closed. Joints were made with wood screws and each had a gasket made of friction tape to insure that there would be no air leakage through the model.

Two standard ASHVE pitot-static tubes were used in conjunction with the model. One tube was connected to the tops of the reservoirs for the manometer boards in order to establish a pressure reference for the manometers. The other was used to measure the velocity of the wind in the tunnel test section. Water was used as the fluid in all manometers.

Because of limitations in the tunnel equipment, no attempt was made to hold to any set wind velocities, rather the wind velocity was held within a range of values and readings were made after the manometers had reached a stable position. Six approximate speeds were used throughout the testing. These were approximately 25, 35, 45, 60, 70, and 80 miles per hour.

With these speeds it was possible to obtain consistent values from which the analysis could proceed.

As the wind passed over the model under test, the fluid in each manometer tube rose to a position representative of the pressure it was sensing on the model surface. The four manometer boards were positioned so that a 35 mm camera could photograph the entire bank of 200 manometers. In this way a simultaneous record was made of the pressures over the entire surface of the model. The reading and analysis of the data was performed later.

STRAIN GAGE TESTING PROCEDURE

Models to be tested by the strain gage procedure were mounted on the same aluminum column used in the manometer tests. The same method of assembly and attachment was used except that the tubes were disconnected from the piezometer fittings so that a false drag effect would not be produced during the testing.

The column was free to deflect as the wind forces acting on the model were developed, the magnitude of this deflection being in the order of 1.0 to 1.5 inches at maximum wind speeds and at certain wind angles. The angle of rotation of the model caused by this deflection never exceeded 1°30' since the column length was about 69 inches. In conducting the tests, the column base could be rotated with leveling screws and adjustments could be made by means of blocking under the attaching screws inside the model. It was therefore possible to have the model in a level position while readings were being made and still accommodate the large deflection which was felt necessary to insure adequate strain gage readings.

The opening in the floor of the wind tunnel test section was closed with a two foot diameter number 14 gage steel plate with a 4 1/8 inch square hole in its center through which the column passed. This closure would thus slide freely on the column and adjust itself to any column deflection without loading the column.

Since the static pressure inside the wind tunnel was lower than that outside, considerable leakage took place around this closure. A number of plans for affecting a suitable air seal were tried without success. It was decided, therefore, to enclose the entire column with an airtight box and to bore a series of six holes one inch in diameter in the tunnel floor downstream of the model but connecting the inside of the box with the tunnel. The static pressure field in both the box and the tunnel test section was therefore maintained at the same level.

The four inch square column was constructed of 1/2 inch aluminum plate fastened with machine screws. This form of cross section was interrupted at selected points along the column length. Thin, one inch wide aluminum strips with SR 4 electric strain gages mounted on each side were used to bridge the gaps in the column. As the column was deflected by the wind, these gages reacted to the strains produced.

At one gap near the top of the column a lift capsule was installed. This consisted of two one inch wide, 1/4 inch thick by one foot long bars fastened together at the ends with spacers holding the bars apart a distance of 1/2 inch. The bars had strain gages mounted near each end which reacted to the strains produced by the opening or closing of these bars when loads were applied at their centers.

The base of the column was fitted with angles which were bolted securely to a base plate thus providing an end fixed against rotation. The base plate was in turn bolted to a mounting attached to the concrete floor of the working space. Bolt holes for the base plates were spaced at 15° angles so that the entire column with the model mounted on top could be rotated to any one of the desired angles.

As the wind passed over the model, there were vibrations set up by the shedding of vortices at the model's sharp edges. These vibrations were in turn transmitted to the column and the strain gages making it impossible to read the indicators. A number of means for dampening these oscillations was tried in the hope that some convenient way could be found which would allow readings to be made and at the same time would not affect the readings themselves. Four light bars were hinged to the column near its top and also hinged on the other end to a small plate which had a one inch square aluminum pad fastened to its under side. These pads rested on a plywood platform surrounding the column. When they were loaded with one or two ounces of weight, they dampened the oscillations sufficiently so that readings could be obtained. By lifting the pads free of the platform, zero readings could be reproduced throughout the testing.

The strain gages on the thin strips and the lift capsule were connected so as to create eight transducer circuits each of which was capable of producing readings proportionate to a force or a moment of force. Results could then be determined for the lift force, the drag force transverse to the model, the drag force longitudinal to the model, the torque, the overturning moment transverse to the model, and the pitching moment longitudinal to the model.

The eight transducer circuits terminated at a switch box which in turn was connected to a Baldwin SR 4 Strain Gage Analyzer with a null indicator.

At the beginning of each test the dampening pads were lifted and zero readings were taken on each circuit. The wind tunnel was started and brought up to speed. When the flow regime had established itself, readings were again taken on each circuit and the wind tunnel was allowed to return to static conditions. Zero readings were then repeated. If any large discrepancy appeared between these readings and the initial readings, the test was discarded and subsequently rerun.

Wind speeds were held to the same approximate ranges as in the manometer tests. The same pitot tube was used to measure these speeds.

ANALYSIS OF MANOMETER DATA

The analysis of the pressure data photographed during the manometer test runs began with the mounting of the 35 mm negatives in 2 x 2 slide holders. Each slide was then projected on a screen and the readings of the tubes were punched directly into standard IBM cards. A program for an IBM 709 Digital Computer was prepared which would process these cards and print out the lift and drag forces and the moments of these forces acting on the model. In addition, the centers of pressure were obtained. This integration process saved many man hours since it accomplished in 12 seconds the same amount of work it took a man using a desk calculator 8 hours to complete.

Using the results obtained from the computer program, plots were made for the lift or drag force versus the velocity pressure or velocity pitot tube reading. Sample plots, shown in Figures 12, 13, and 14, are for the 50 foot model with a wind angle of 45°.

As previously stated, the force acting on the model can be expressed as the product of the shape factor, the dynamic pressure, and the area exposed to the wind. Thus,

$$F = C_s q \, A \qquad (2)$$

The shape coefficient, C_s, then becomes

$$C_s = \frac{F}{qA} \qquad (3)$$

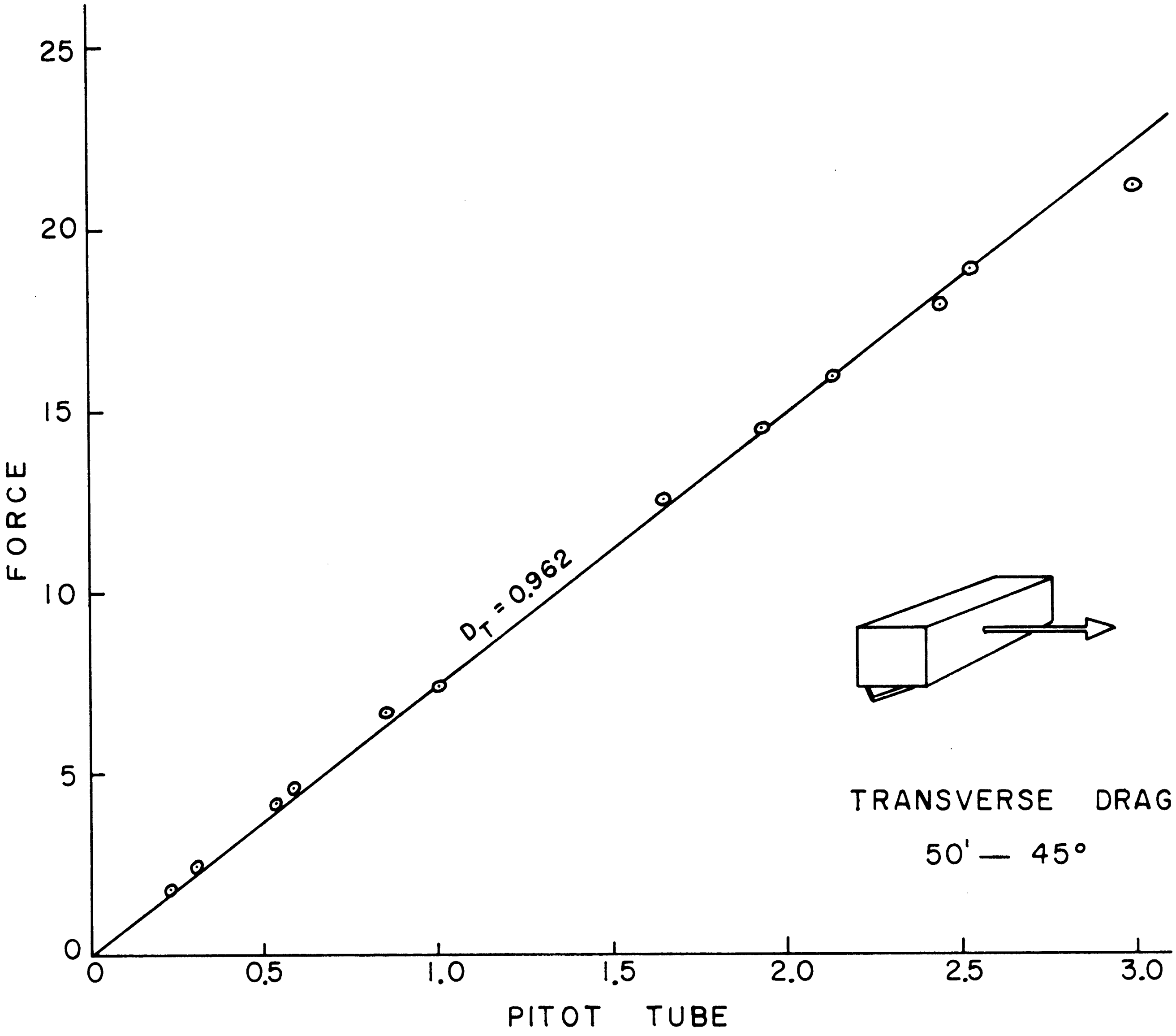


Figure 12.
Transverse Drag Force Versus Pitot Tube Reading
For 50 Foot Model, Wind At 45°

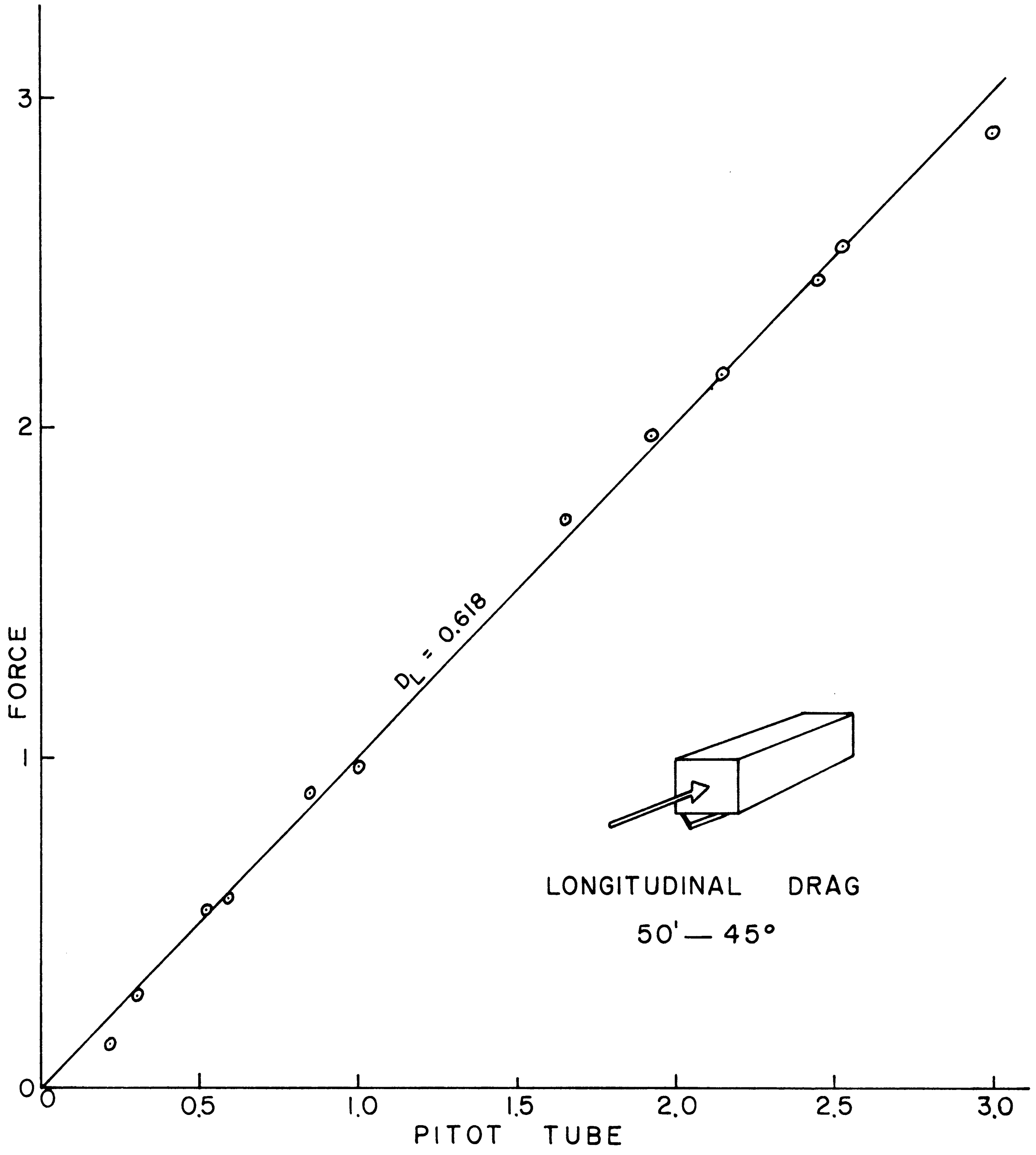


Figure 13.
Longitudinal Drag Force Versus Pitot Tube Reading
For 50 Foot Model, Wind at 45°

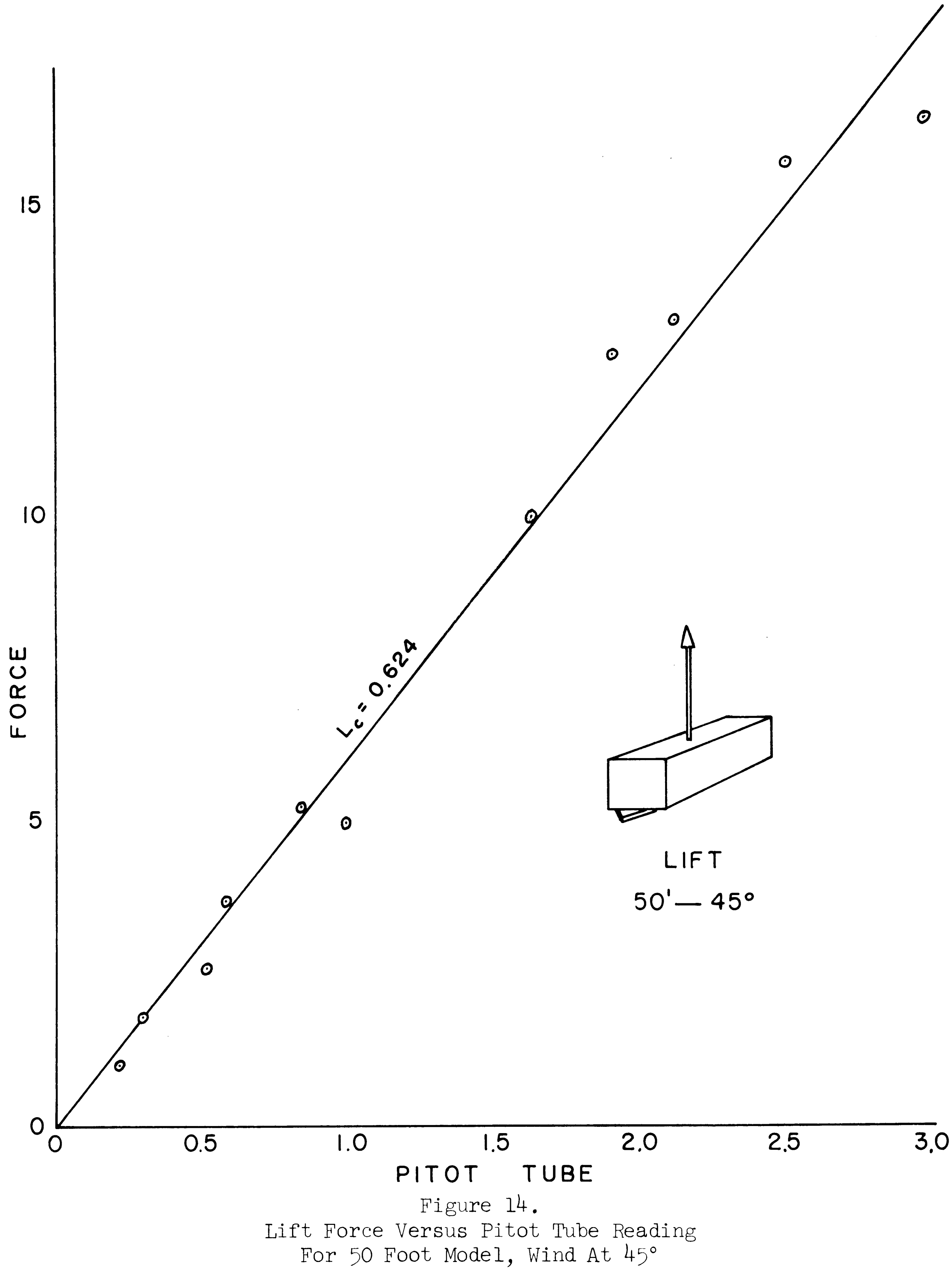


Figure 14.
Lift Force Versus Pitot Tube Reading
For 50 Foot Model, Wind At 45°

where F is the measured force, A the area of exposure and q is the dynamic pressure which is given by the pitot tube manometer in inches of water. Calling this value, H, the value of q in pounds per square inch can be expressed as

$$q = H \times \frac{62.4}{1728} = 0.036111\ H$$

Substituting this in Equation (3) the shape coefficient becomes

$$C_S = \frac{F}{0.036111\ H\ A} \tag{4}$$

In the analysis the shape coefficient C_S becomes the transverse drag coefficient, D_T, when the transverse drag force is used. Similarly, it becomes the longitudinal drag coefficient when the longitudinal drag force is used and the lift coefficient when the lift force is used.

Transverse drag coefficients, D_T, were computed using the slope of the line, F/H, from the plotted results. In order that these coefficients could be compared for all wind angles the area of the side of the model was used throughout. The value for the sample in Figure 12 is therefore

$$D_T = \frac{14.8}{0.036111 \times 2 \times 213} = 0.962$$

By a similar computation the longitudinal drag coefficient for the sample in Figure 13 was found to be 0.618 based on the end area and for the lift coefficient for the sample in Figure 14 to be 0.624 based on the area of the top. The variation in lift and drag coefficients for various wind angles is shown for each model tested by means of the curves on pages 55 to 82 in the Appendix.

Curves were also plotted for the moments of the lift and drag forces acting on each model face.

Since the major area of interest was the anchorage requirement needed for the prototype, all the curves were extrapolated by computation to a pitot tube reading of 10 inches of water or a wind velocity of about 145 miles per hour. These values were then used to compute the force needed per foot of length of the coach to insure stability. A sample of this Wind Velocity-Anchorage Requirement curve is shown in Figure 15. In making this computation a weight of 12,000 pounds was used for the 50 foot mobile home. Proportionate weights were used for the other lengths.

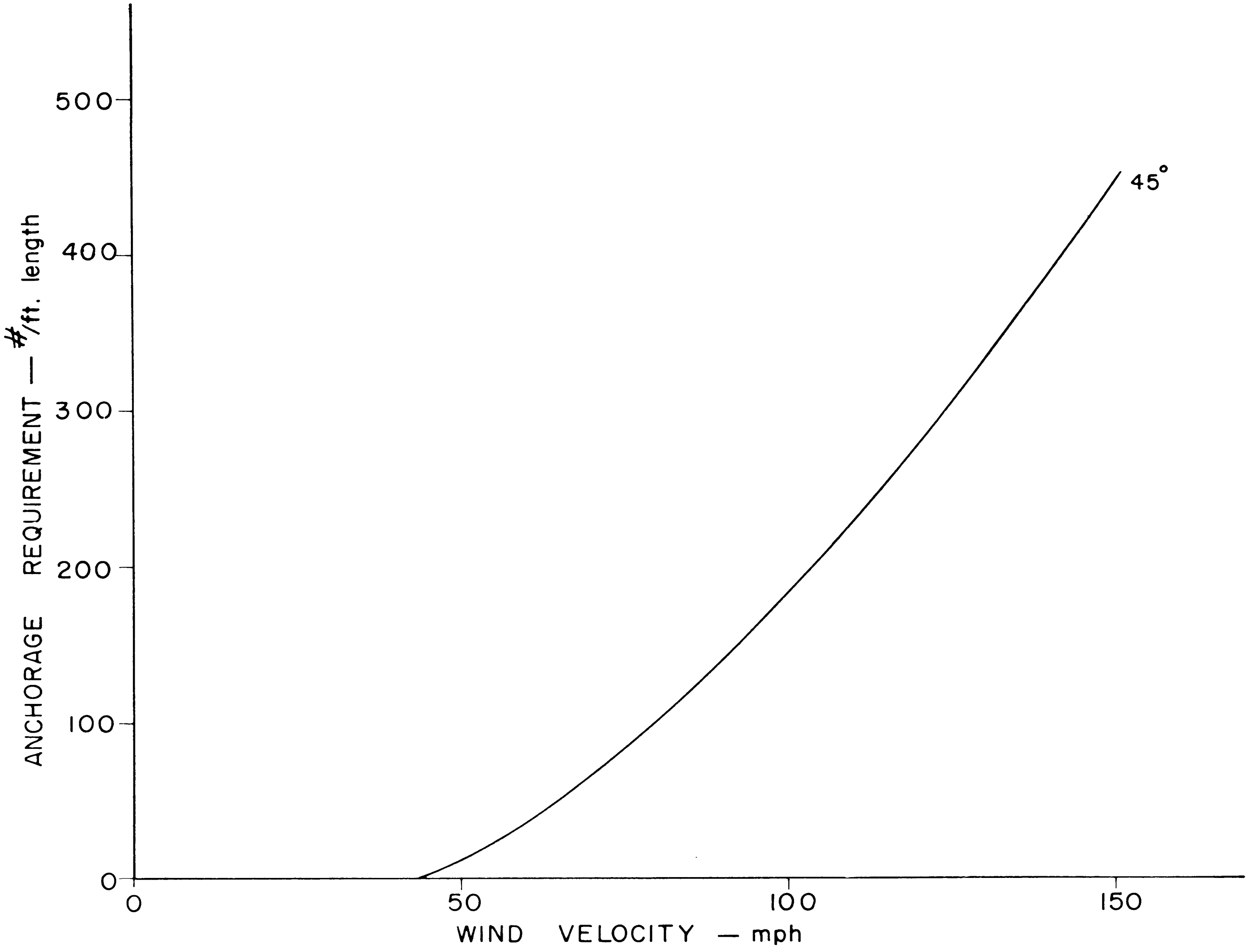


Figure 15.
Wind Velocity-Anchorage Requirement Curve,
50 Foot Model With Wind Angle Equal To 45°

Wind Velocity-Anchorage Requirement curves showing the variations due to wind angle for each model tested are to be found on pages 83 to 93 in the Appendix.

ANALYSIS OF STRAIN GAGE DATA

The analysis of the data obtained from the strain gage readings proceeded along the same lines as that for manometer data. Curves were plotted for the lift and drag forces and the moment which in this series had been determined from the model directly instead of from the digital computer program. It was necessary, however, to make corrections to the raw values to take care of some instrumental errors.

In order to eliminate experimental errors, ratios were also established between the manometer test values and duplicate values derived from the strain gages and these ratios were then used to make corrections in the strain gage tests for which no manometer data were available.

The results of the strain gage analysis are shown in the Appendix on pages 55 to 93 along with those of the manometer analysis.

SHAPE COEFFICIENT RESULTS

The shape coefficients shown on pages 55 to 71 in the Appendix can be used to determine the force of the wind acting on the coach and tending to move the mobile home downwind. This may be of considerable importance in those instances where the mobile home is not yet set at the time of a wind storm. The value of the force would be determined by use of equation (2) along with the gust factor of 1.3 from page 8.

As an example, assume a 50 foot mobile home is on a dealer's lot and a wind of 50 miles per hour comes up. Assume also that the wind is approaching the coach at an angle of 30°. The longitudinal drag force is primarily of interest since the coach will roll on its wheels in that direction. The chart on page 66 shows that the longitudinal drag coefficient is 0.828. The end area of the mobile home is assumed as 80 square feet. The force tending to move the unit then becomes

$$F = D_L \times 1.3 \times 0.002558\ V^2A$$

$$F = 0.828 \times 1.3 \times 0.002558\ (50)^2 \times 80$$

$$F = 892 \text{ lbs.}$$

Maximum values for the transverse drag coefficient are obtained when the wind angle is 90° in most cases. Occasionally the maximum is reached with a wind angle of 120°. The maximum longitudinal drag coefficients are generally found with wind angles of 0° or 30° and the maximum lift coefficients are found with the wind angles at 45°, or 315° in some cases.

A comparison of the maximum transverse drag coefficients, D_T, is shown in Figure 16. The value for this coefficient varies little for the 40, 50, or 60 foot units, averaging about 1.22. The 25 foot unit shows a smaller coefficient.

When a skirt is added to the unit this coefficient tends to become larger. The value of 1.31 is the only value which could be approximately checked from published data and agrees quite well with the Iowa[3] value of 1.33 for a flat roofed building having a length to width ratio of 4.

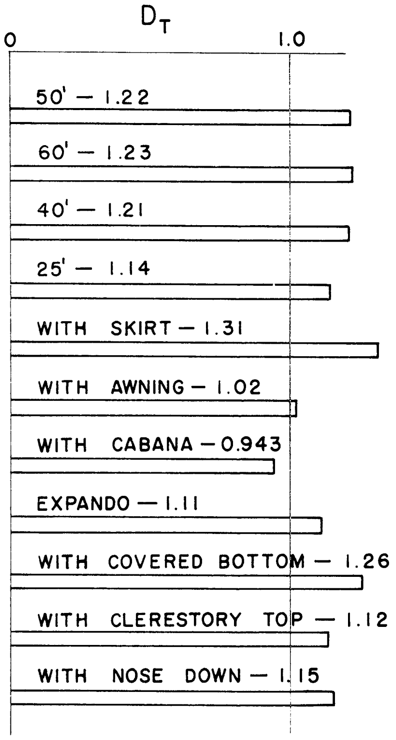


Figure 16.
Maximum Transverse Drag Coefficients, D_T

Even though the awning is along about half the length of the unit the transverse drag coefficient decreases. When the awning is enclosed and becomes a cabana the coefficient decreases still further. This represents a measurable amount of shielding by the awning and cabana.

The expando unit on the coach side seems to have a slight reducing effect on the transverse drag, probably because it tends to present a smaller frontal area to the wind and tends to somewhat streamline the model.

Covering the bottom increases the transverse drag effects; while the changes in top configuration apparently decrease them. The value of D_T also is lowered when the nose of the unit is depressed.

Maximum longitudinal drag coefficients are compared in Figure 17 and show a wider variation in their values. The maximum coefficient decreases with an increase in basic model length at almost a uniform rate above a length of 40 feet. The addition of a skirt increases the drag in about the same order as was the increase for transverse drag.

The model with the awning, cabana and expando units show large increases due to the added end area. The model with the awning increased the area by about 11% while the coefficient increased 54%. The cabana increased the area by about 112%

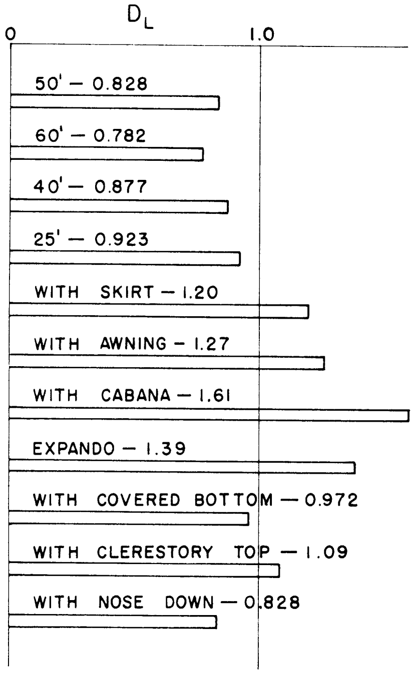


Figure 17.
Maximum Longitudinal Drag Coefficients, D_L

and the coefficient increased 94%. A similar increase in area due to the expando unit amounted to 73% while the coefficient increased 68%. It will be noted that these increases are about the same as the increase in area, but in the case of the awning it is much greater than the area, which is indicative of the change in general shape of the total unit.

When the model with the bottom covered was tested, a slight increase in coefficient was found and with a clerestory top a considerable increase occurred. Again, these changes are indicative of the change in configuration. This is further supported by the fact that the maximum longitudinal drag coefficient, D_L, for the coach with the nose down is the same as the 50 foot reference model.

Figure 18 compares the maximum lift coefficients. Again the coefficient decreases with an increase in model length and this change appears to be nearly linear above the 40 foot length.

The increase in coefficient for the skirted unit is attributed to the lack of negative, or downward, pressure associated with the passage of the wind beneath the unit.

Since the awning is attached to the mobile home, both in the field and in the test, part of the lifting force on the awning proper is transmitted to the unit. This added force appears in

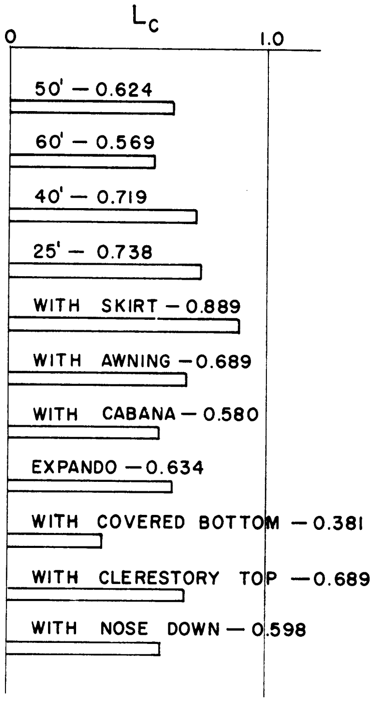


Figure 18.
Maximum Lift Coefficients, L_C

these results as an increased lift coefficient. Most of the lifting force on the cabana attachment is assumed by the cabana itself. The expando unit appears to have little if any effect on the lift coefficient.

One of the most notable differences in the values for L_C is that for the model with the bottom covered. Because of the air foil like nature of this bottom, a large negative, or downward, pressure was produced which reduced the lift coefficient. In this instance the reduction amounts to 40%. The clerestory top, on the other hand, exhibited the opposite effect and the coefficient was increased about 11%. Reported field experiences seem to verify these results.

The lift coefficient for the 50 foot unit with its nose down was found to be a little lower than when the unit was level. This also seems to be in agreement with field experience.

ANCHORAGE REQUIREMENT RESULTS

Figure 19 shows the maximum Wind Velocity-Anchorage Requirement curves for the four basic models with the wind angle indicated which produced the curve. It will be noted that the greatest values are obtained when the wind is at an angle to the coach. As was the case with the shape coefficients, the 40, 50, and 60 foot models have similar curves at least up to a velocity of 110 miles per hour. Above this speed the curves tend to diverge. The 25 foot model curve is generally lower throughout the entire range of wind speeds.

A similar comparison for the remainder of the cases is shown in Figure 20. With the exception of the unit with the cabana and the one with the skirt, all those which involve a change in shape of the model have larger anchorage requirements than the 50 foot reference model. This is particularly so at the lower wind velocities, and reflects the greater moments of the drag forces as well as the greater lifts for these units. The only anchorage values which lie wholly below the 50 foot reference for all wind speeds are those obtained when the nose is depressed which is not the case when the unit is set on its blocking in the field.

INTERFERENCE TESTS

Since many mobile homes are situated in mobile home parks, a number of tests was run to obtain some evaluation of

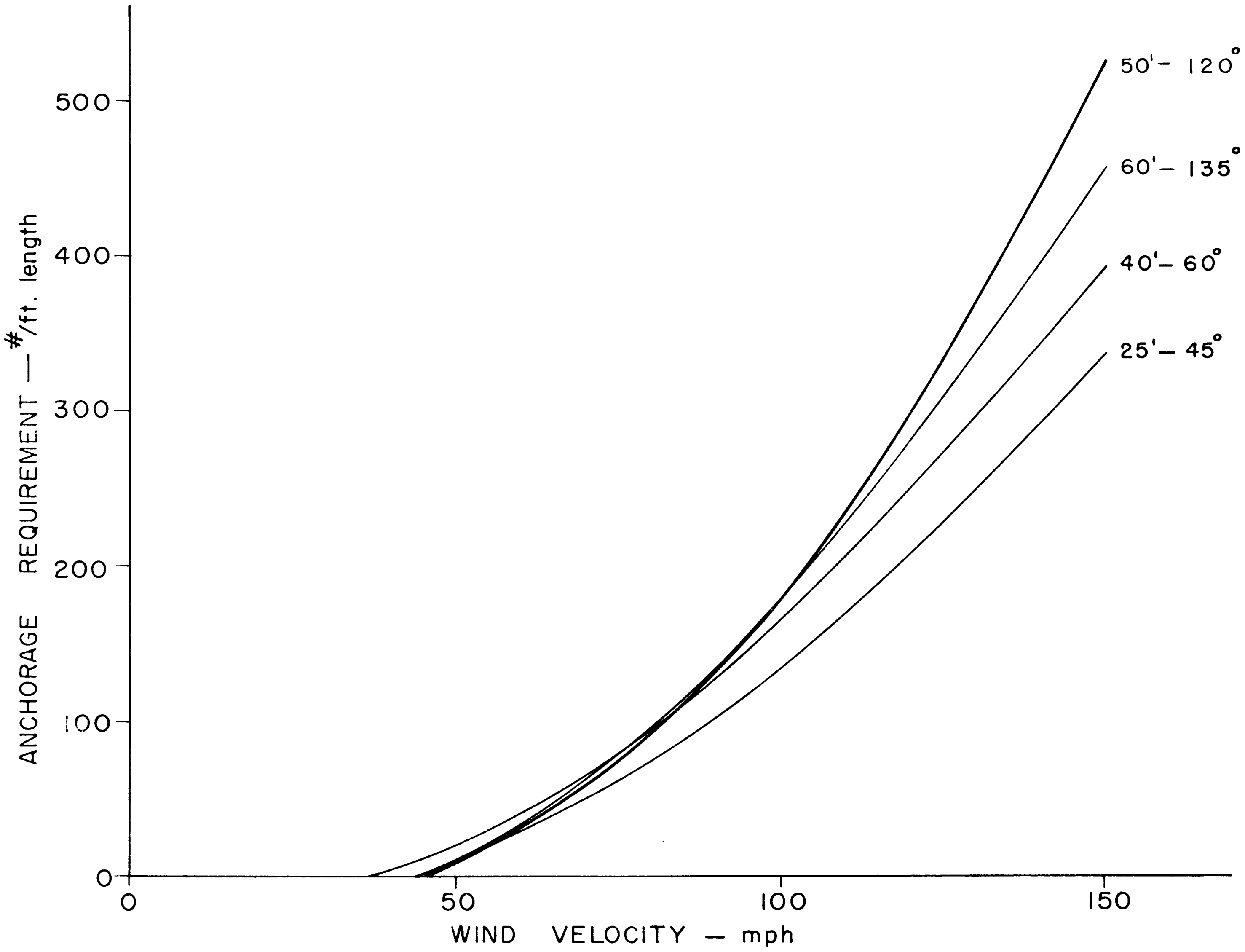


Figure 19.
Maximum Wind Velocity-Anchorage Requirement Curves
For Basic Models

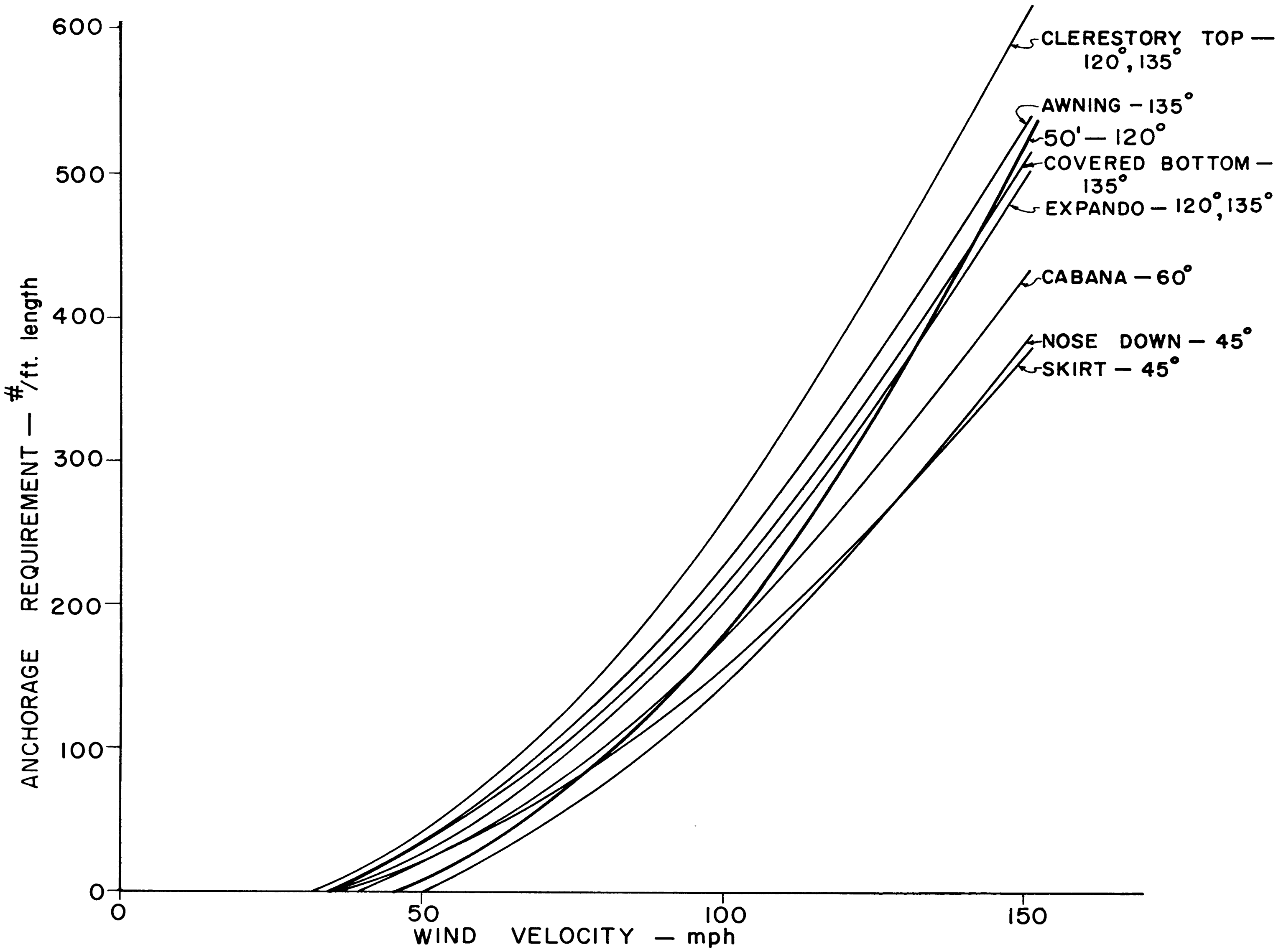


Figure 20.
Maximum Wind Velocity-Anchorage Requirement Curves
For Various Models

the interference effect of one unit on another. Wind angles of 0°, 45°, and 90° were chosen.

Three of the test set-ups, designated I1, I2, and I3, were made with the units 3 inches apart and staggered 10 1/2 inches equivalent to 4 feet and 14 feet in the field. I1 had the test model on the downwind side, I2 had the test model on the upwind side while I3 had the test model midway between two other units.

Test set-ups I4, I5, and I6 were similar to I1, I2, and I3 except that the stagger was eliminated and the units were all in a row. Set-up I7 was the same as I4 (the test unit downwind) but the distance between the units was increased progressively from 3 inches to 7 1/2, 15, and 22 1/2 inches.

Figure 21 compares the Wind Velocity-Anchorage Requirement curves for the normal wind angle, 90°, and for tests I1, I2, I3, and I5. All these curves fall below the 50 foot reference model curve indicating an effective shielding of the test unit. Tests I4 and I6 with the 90° wind angle were so well shielded that no anchorage was required at any wind speed. Tests I7 were run with a 90° wind angle only since it was evident that this would produce the most severe results. Again the shield was completely successful even at the maximum spacing used, which was equivalent to 30 feet in the field. It should be pointed out, however, that this represents an unnatural field condition since seldom would winds act continuously at this wind angle. With winds at other angles the shielding effect is greatly reduced and the anchorage requirements approach those of the single coach.

Figure 22 compares the test results for wind angles of 45° and 0°. Test I3 gave the greatest values for the 45° wind angle, and the Wind Velocity-Anchorage Requirement curve is above that of the 50 foot reference. The curve is about the same as that of the 50 foot unit with the awning shown in Figure 20.

CONCLUSIONS

From the results presented in the above sections of this report it can be concluded that it is possible to anchor mobile homes against the action of high winds with safety and economy. The testing program has provided the needed pressures and forces acting on these units but makes the assumption that the unit will remain intact at high wind speeds. No attempt has been made to evaluate the strength of the unit itself which must play an important part in determining the maximum wind velocity which can be sustained.

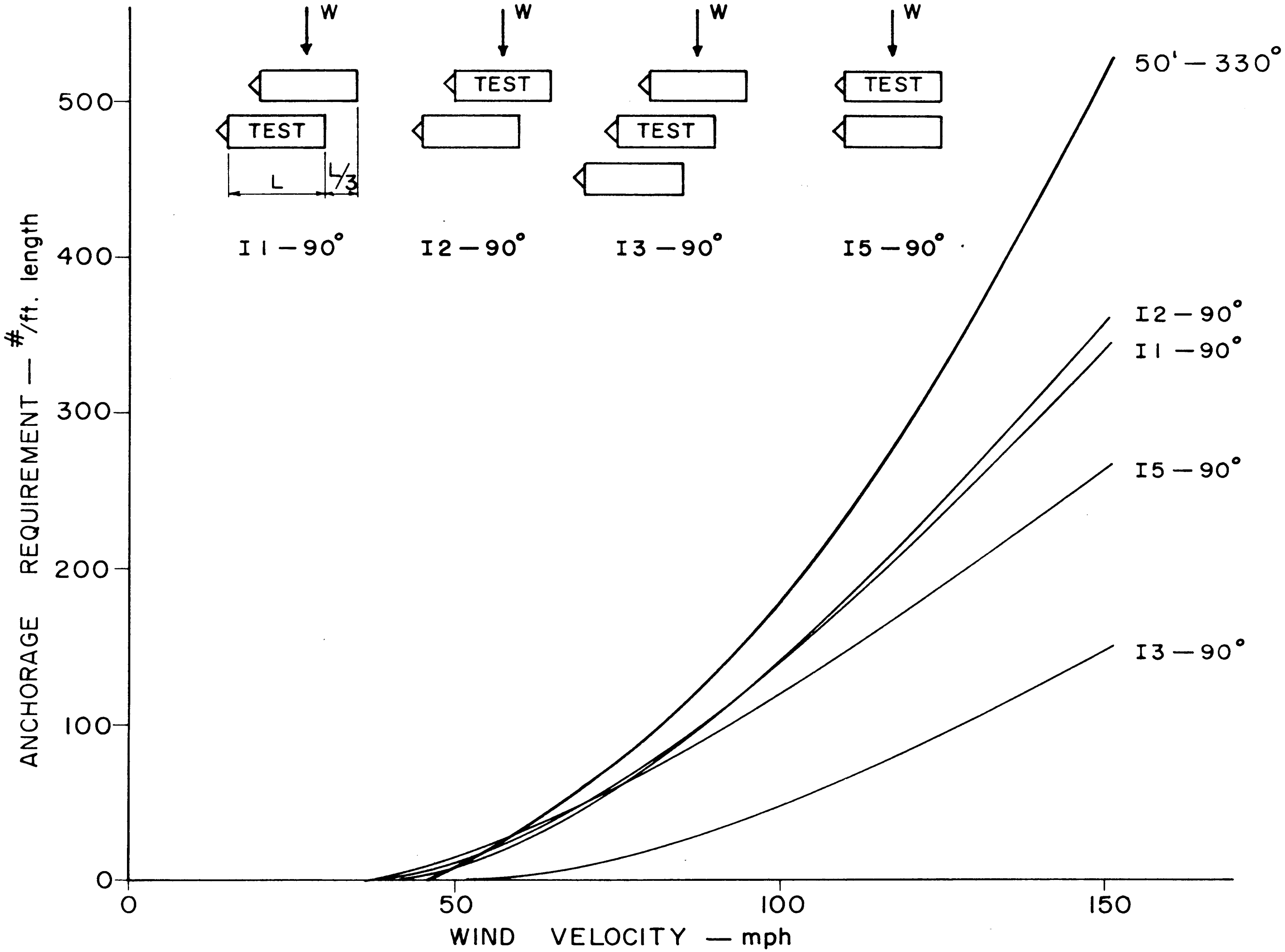


Figure 21.
Wind Velocity-Anchorage Requirement Curves
For Interference Tests
With Wind Angle Equal To 90°

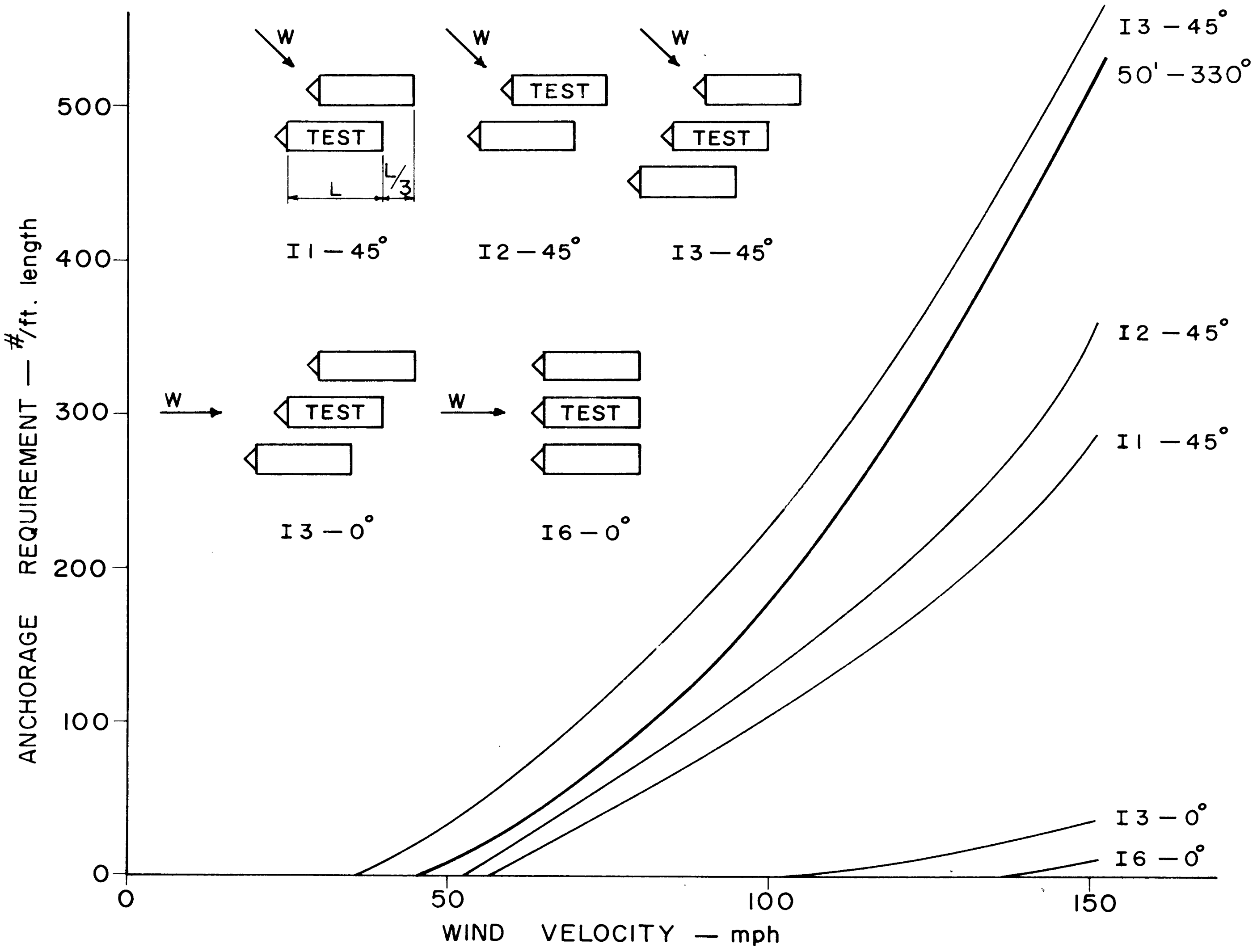


Figure 22.
Wind Velocity-Anchorage Requirement Curves
For Interference Tests
With Wind Angles Of 45° And 0°

The results have been found to be in agreement with observed field condition reports in a number of instances. One such report to the writer was unexpectedly obtained from a practice of the Mackinac Bridge Authority. In order to prevent mobile homes from overturning, they move them across the bridge in the lea of a heavier vehicle when winds at right angles to the bridge exceed 30 miles per hour. It can be assumed that the speed of travel would be nearly 30 miles per hour also, thereby producing an active wind of about 42 miles per hour at 45° to the mobile home. If the mobile home were unescorted, this wind speed and angle would be sufficient to overturn the coach and is in agreement in both angle and magnitude with the testing program described here. (See Figure 19).

The practice on the part of mobile home owners to skirt the space beneath the coach seems to be a questionable practice, but is no more severe than other alterations made by the user. Some users construct wheel pockets and set the mobile home at a lower level. This practice would seem to have little value and in some cases might be more harmful than helpful.

The practice of lowering the tongue and facing the end of the coach into the wind when a storm is approaching seems to be an excellent maneuver and probably should be encouraged. This is particularly applicable to those units on dealer's lots and to unblocked units.

The addition of large awnings, cabanas, and similar structures increases the need for anchorage especially at the lower wind speeds. In many instances these elements would blow away at high wind speeds and the coach would then tend to become more stable. The expando unit also requires an increase in anchorage capacity over the coach without such an attachment.

Coaches with the bottom covered appear to be more stable in winds that act at wind angles of about 90°. However, this advantage seems to be lost or ineffective when the wind approaches a parallel with the coach.

The most severe anchorage requirement found for the models tested was that with the clerestory roof. It is concluded that projections above the basic top level of the mobile home tend to increase moments of the drag forces at that level thereby increasing the overturning moment and subsequently the anchorage requirement.

The interference tests indicate that the effect of the wind is not more severe on a group of coaches than on a single coach. If mobile homes are in close proximity as is the case on storage lots, the shielding is considerable even if as much as 30% of a single coach is exposed directly to the wind. Shielding can also be expected in many mobile home parks from other coaches, trees, adjacent buildings and similar elements.

RECOMMENDATIONS

From the results of this study it is recommended that mobile homes be anchored with suitable anchors spaced at intervals along the mobile home perimeter. The total amount of this anchorage should be proportional to the possible 50 year wind to be expected in any given area. A map for this purpose furnished by the U. S. Weather Bureau, Office of Climatology, is reproduced on page 39 in the Appendix.

The Wind Velocity-Anchorage Requirement curve on page 40 in the Appendix is recommended for use in determining the anchorage requirement needed. This curve provides for the basic shape and alterations made by the addition of awnings, cabanas, etc.

A choice of anchor type may be selected from the minimum sizes and depths for Type A, AA, B, and C Anchors illustrated on pages 42 to 44 in the Appendix.

Charts have been prepared to relate the anchorage requirements and soil conditions to the required spacing for the type of anchor desired. These are found on pages 45 to 47 in the Appendix. These are simple to use, requiring only an identification of the soil at the location of the anchor. In the instance where a large number of anchors are to be installed, pull-out tests can be conducted and the anchor spacing determined without a soil identification. Pull-out tests should always be conducted if there is a reason to question the anchoring capacity of any type of anchor.

As an example of the use of these charts, let it be assumed that a mobile home is to be anchored somewhere along the sandy coast of North Carolina. From the 50 year recurrence map (page 39), the wind velocity is determined as 120 miles per hour. From the Wind Velocity-Anchorage Requirement chart (page 40), the anchorage requirement is determined as 390 pounds per foot. Entering the Anchor Spacing chart (page 45), at the 390 figure, a straight line is drawn across to the soil condition at the site, say well graded sand, and a spacing of 8 feet read on the Type AA line. If Type A Anchors are to be used they would need to be installed at a 5 foot spacing.

Recommendations for the installation of the anchors are listed below and are illustrated in Figure 23.

1. Blocking should be installed beneath the main longitudinal frame

of the mobile home at the same interval of spacing as the tie-down anchors and should be in line with them.

2. Blocking should be of steel or concrete. If concrete building blocks are used, cores should be placed vertical with a solid 4 inch concrete cap block on the top beneath the frame. Class "A" block should be used which meets American Society for Testing and Materials Specifications for manufacture.

3. Footings beneath blocking should be firm, in good condition, and not less than 16 x 16 inches in plan dimension. Footing thickness should be a minimum of 6 inches. If a concrete slab at least as wide and as long as the mobile home is used the thickness may be a minimum of 4 inches.

4. Shimming between the blocking pier and the steel frame should be of treated wood of first quality or other firm material. Shims should be fitted tightly to prevent rocking of the unit under the action of wind gusts.

5. In the absence of test information on the strength of the coach, anchor ties either attached to the ends of the outriggers of the frame or passing over the coach may be accepted. The anchor ties to the frame outriggers appear to be sufficient at this time and have the prior recommendation.

6. Ties passing over the coach should be at least 1/4 inch diameter wire rope, 1/2 inch diameter manila rope, 3/8 inch diameter nylon rope, webbed straps, or equal. Over the coach ties should be able to sustain a minimum load of 2,800 pounds before breaking for an anchor spacing of 10 feet. Ties should be doubled or of increased capacity for greater anchor spacings.

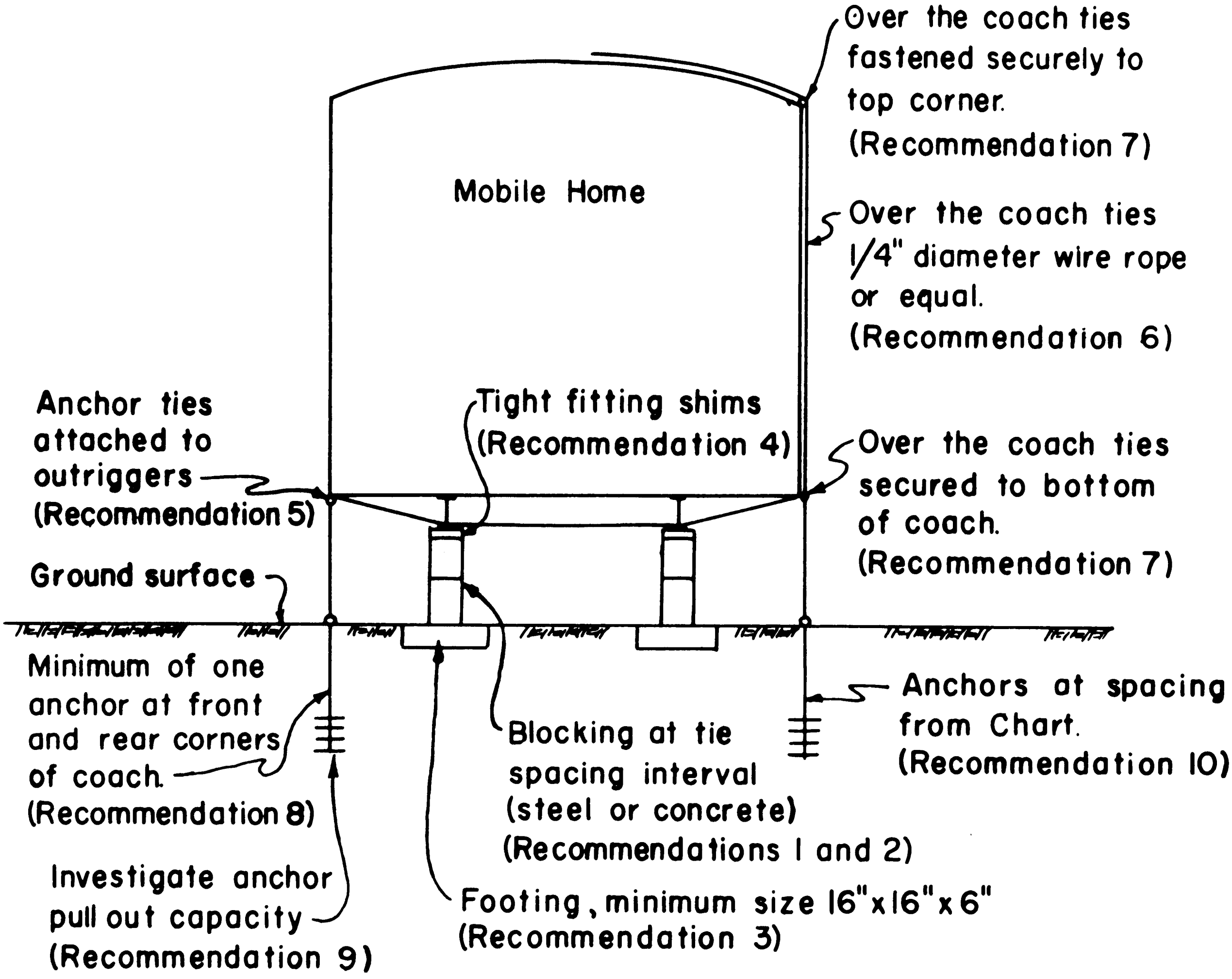


Figure 23.
Summary Of Recommendations
For Installation Of Anchors

7. Ties passing over the coach should be snug and fastened to the coach body at both top corners. In addition ties passing over the coach should be perpendicular to the ground and secured to the coach body as close to the bottom as practical.

8. At least one anchor should be placed near each front and rear corner of the coach.

9. If a quantity of a particular type of anchor is to be installed in a given area, or if any installation is to be made in an area of uncertain soil conditions, a special investigation of ultimate pull out capacity of the anchor should be conducted in the field.

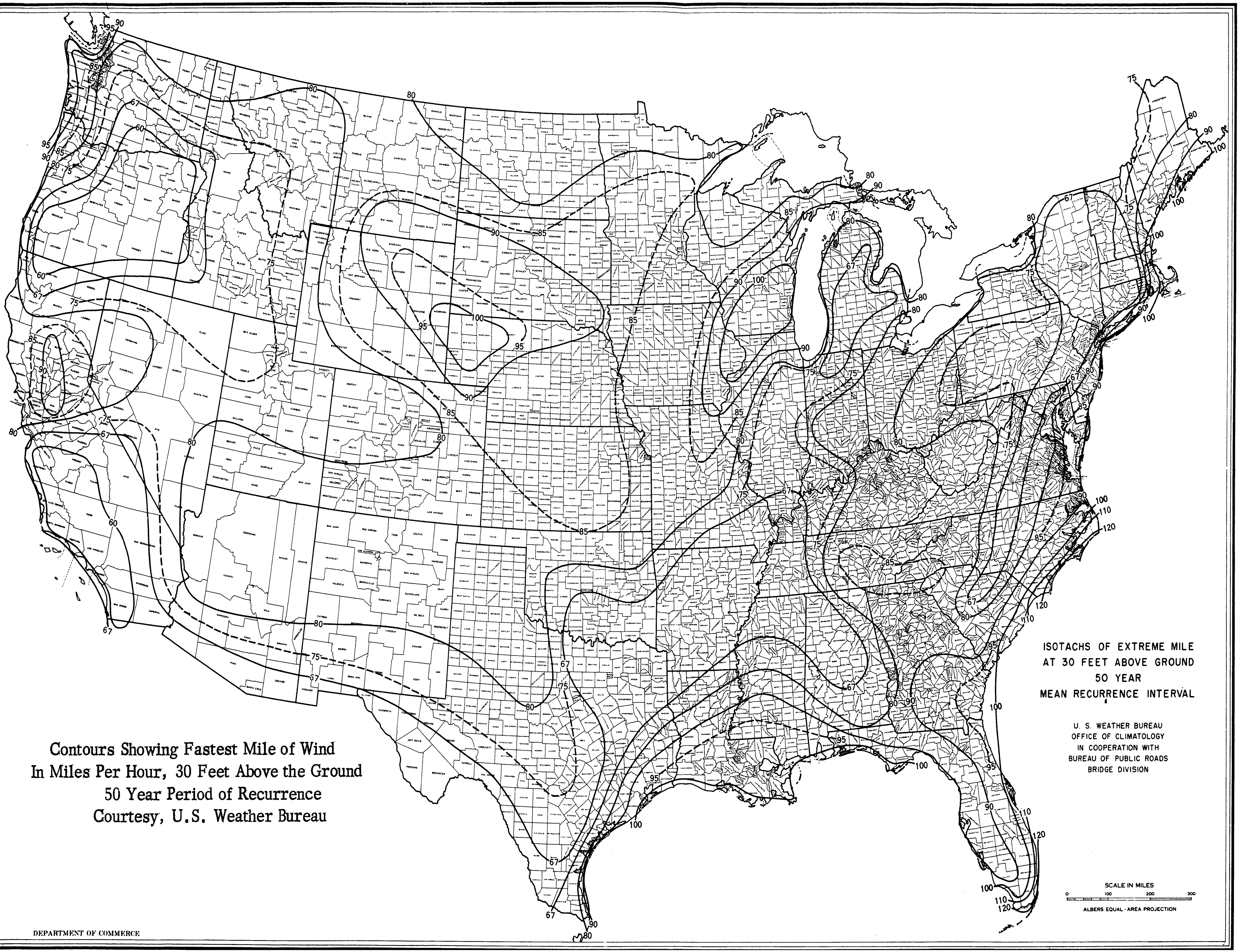
10. A recommended safety factor of 1.5 and a gust factor of 1.3 may be applied to the ultimate pull out capacity giving a total factor of safety of 2.0 and the anchor spacing can be determined from the chart on page 47 in the Appendix.

In addition to the above recommendations for installation, it is recommended that when skirts are used they should be of the free-standing variety and not attached to the coach. They should also have perforation or lattice configurations.

In those instances where coaches are on dealer's lots, a practice of providing temporary anchors at a 50% capacity, or double spacing, would appear to be sufficient to protect the units and adjacent property.

While it is undoubtedly up to the mobile home owner to provide for his own anchoring protection, certainly new mobile home parks should have anchors installed at the time of construction along with other facilities such as water, sewer, power, etc. It could also be profitable for present park operators to install the anchors as a service to their tenants.

APPENDIX

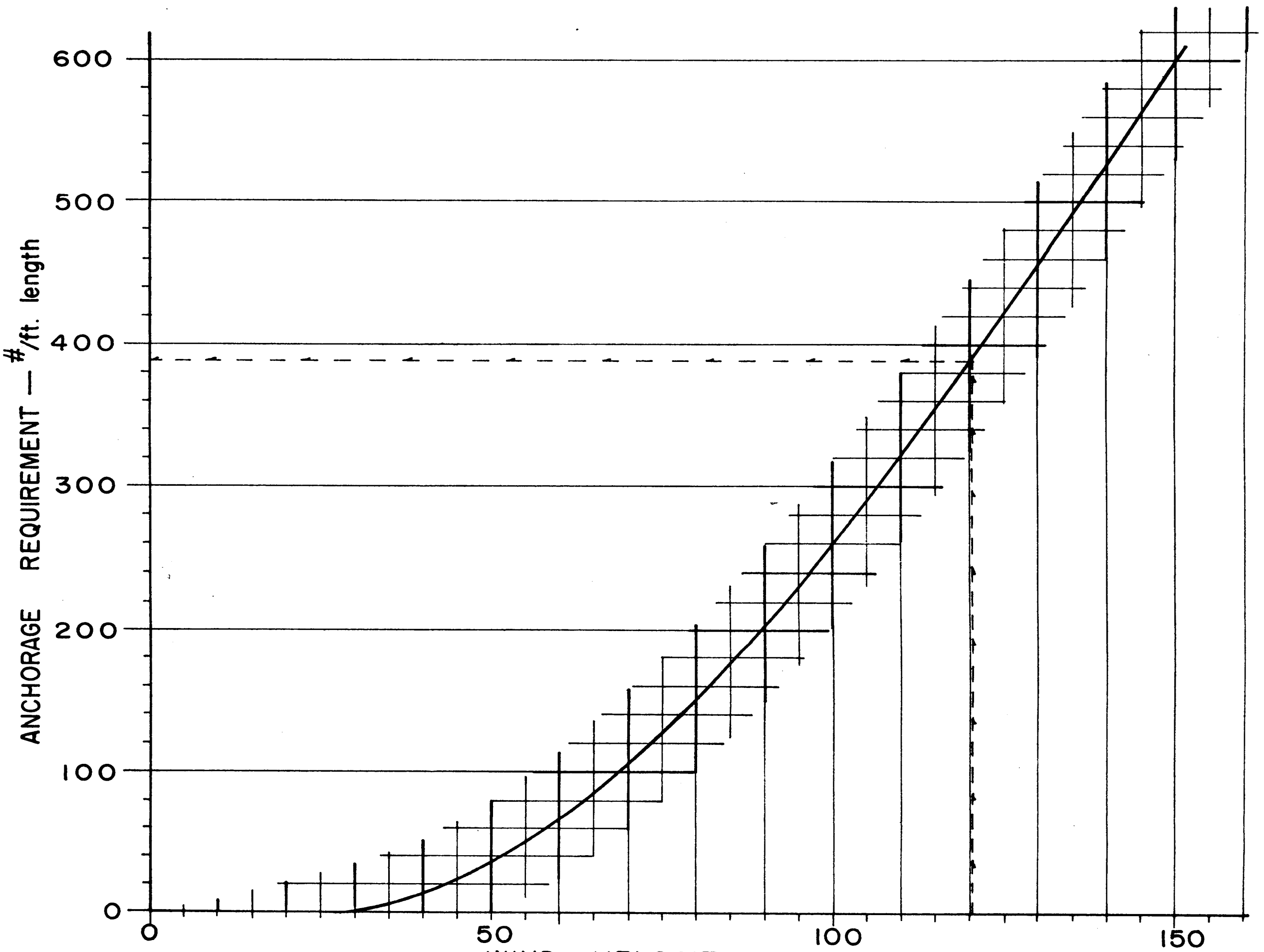


ISOTACHS OF EXTREME MILE
AT 30 FEET ABOVE GROUND
50 YEAR
MEAN RECURRENCE INTERVAL

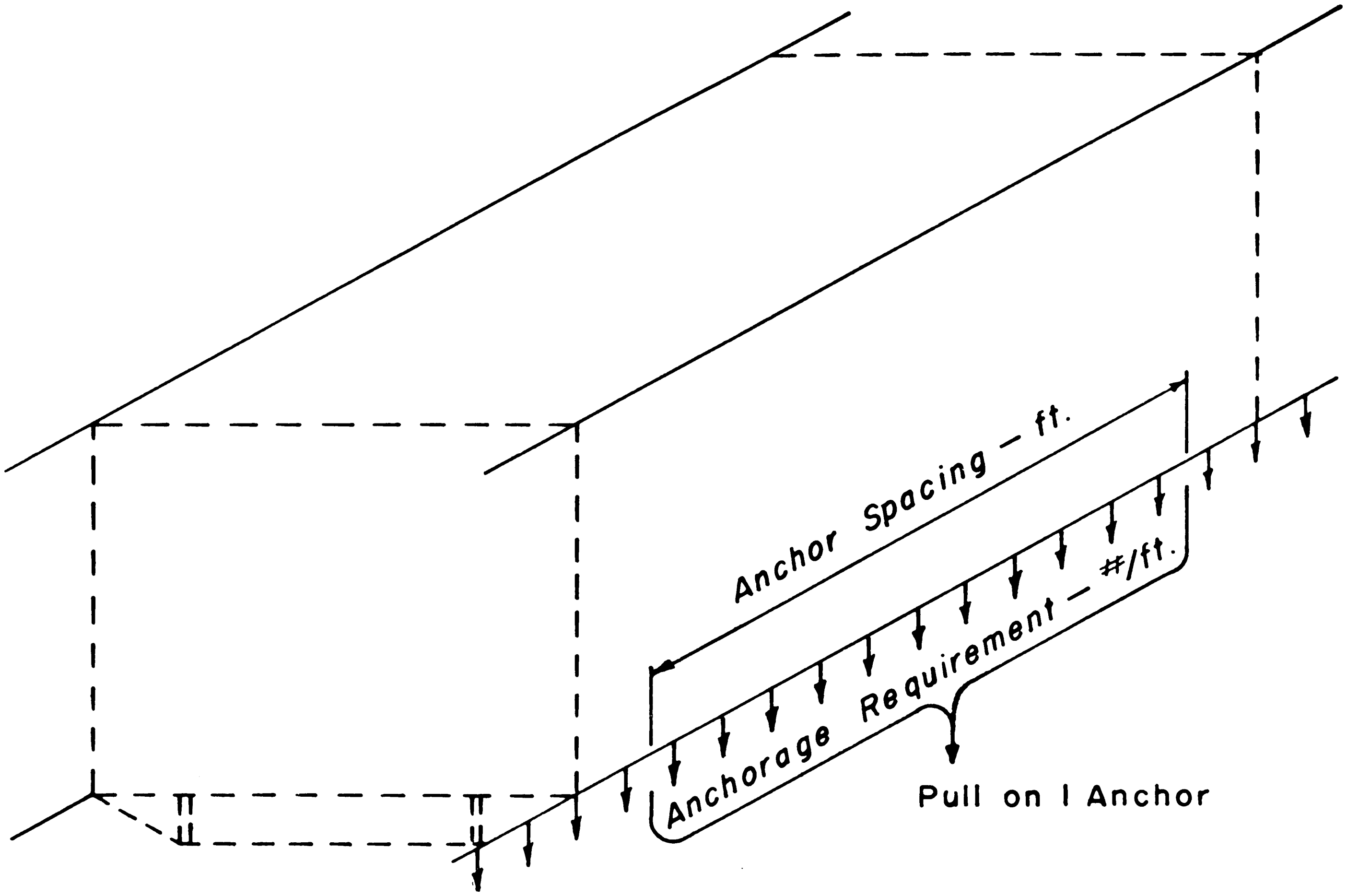
U. S. WEATHER BUREAU
OFFICE OF CLIMATOLOGY
IN COOPERATION WITH
BUREAU OF PUBLIC ROADS
BRIDGE DIVISION

Contours Showing Fastest Mile of Wind
In Miles Per Hour, 30 Feet Above the Ground
50 Year Period of Recurrence
Courtesy, U.S. Weather Bureau

DEPARTMENT OF COMMERCE



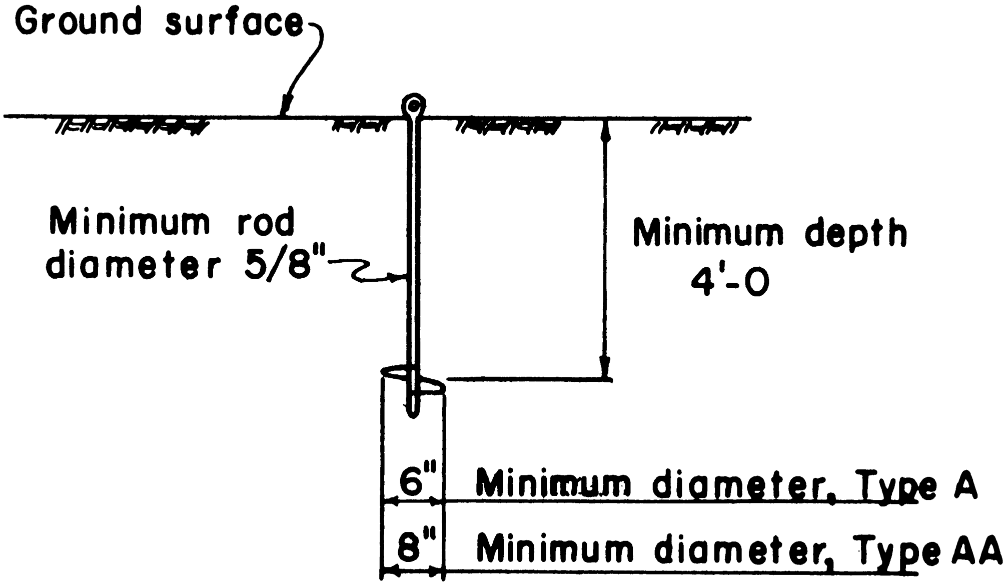
Recommended Wind Velocity - Anchorage
Requirement Curve



Relationship Between Anchor Spacing
And Anchorage Requirement For The
Pull On One Anchor

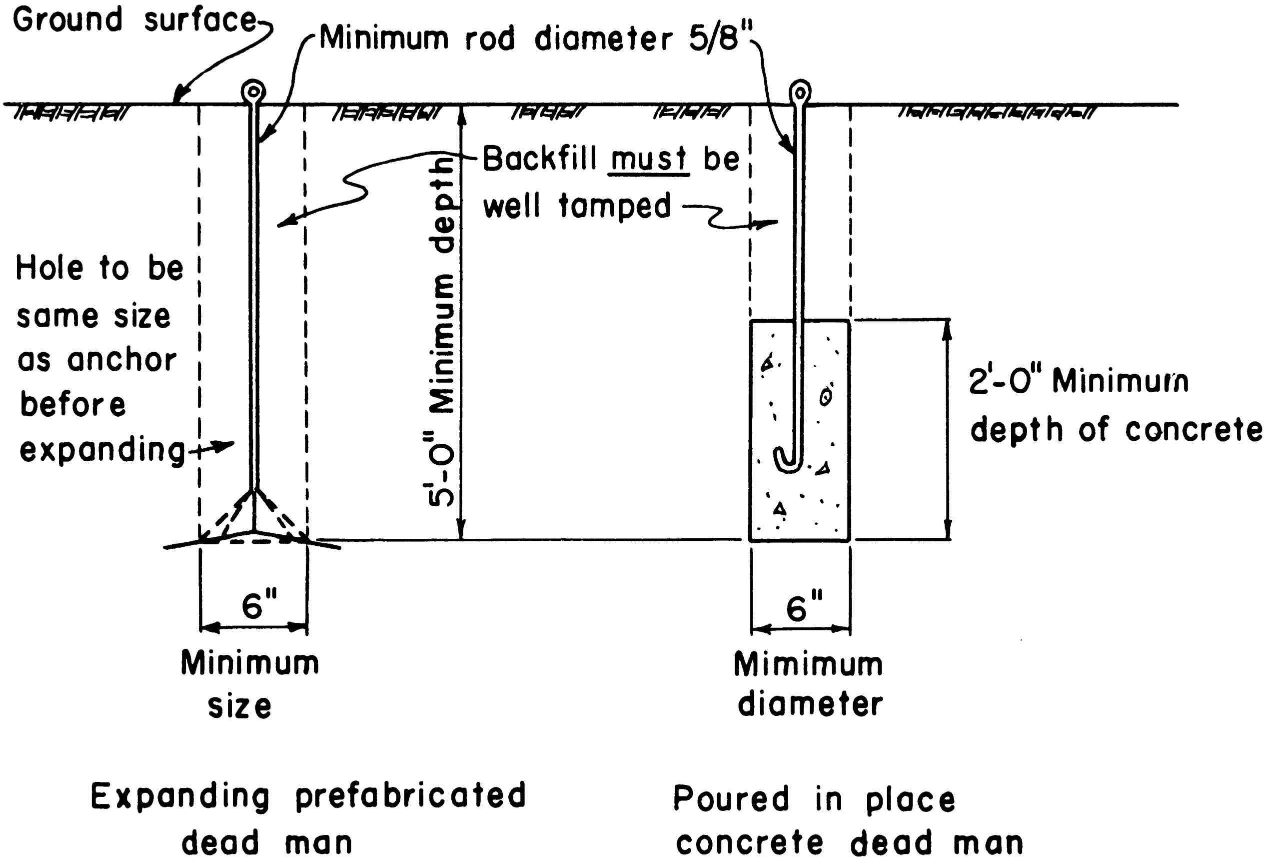
Type A - A screw auger of minimum auger diameter of 6 inches with a minimum 5/8 inch diameter rod installed with a minimum depth of 4 feet. Also 8 inch size Arrowhead anchor.

Type AA- Same as Type A except minimum auger diameter is 8 inches. Also 10 inch size Arrowhead anchor.



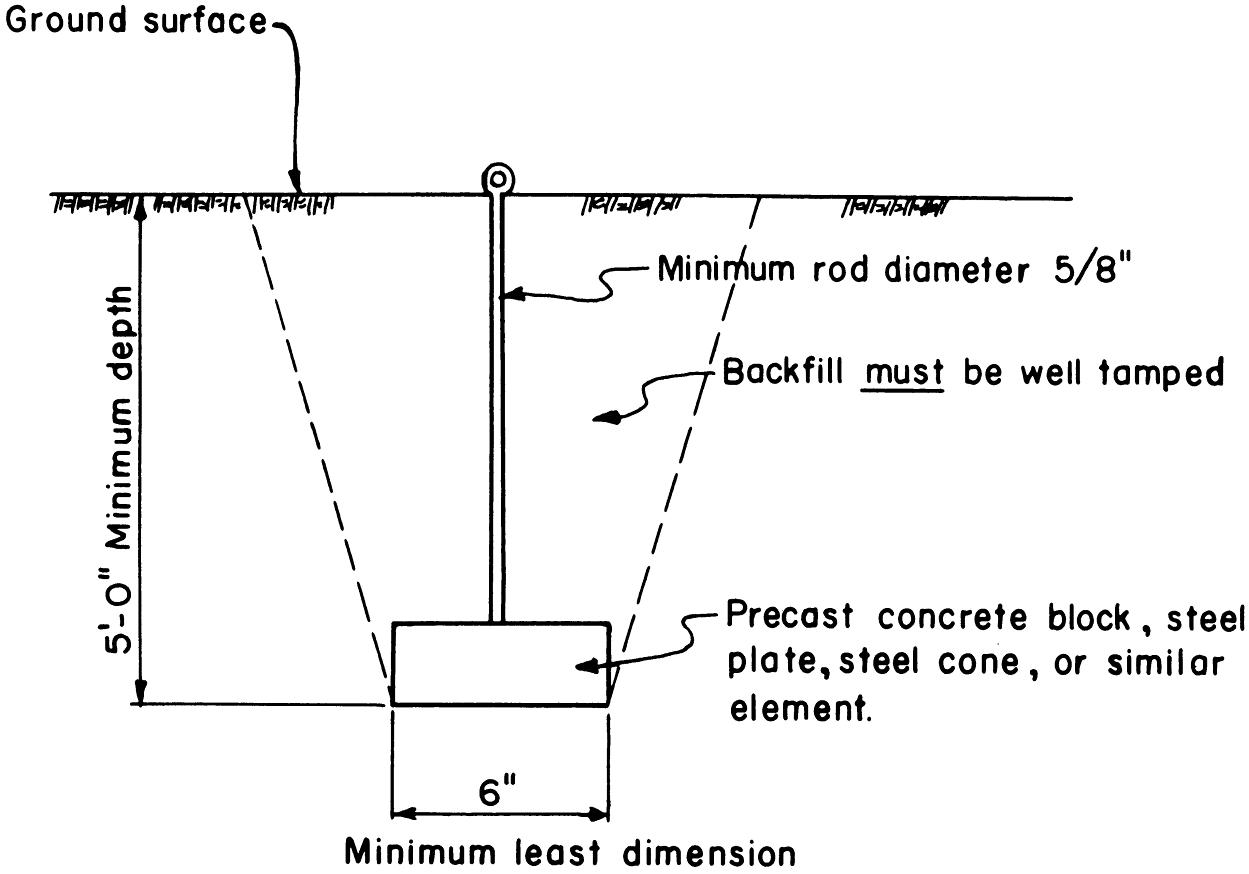
TYPE A & AA ANCHOR

Type B - An expanding prefabricated dead man of 6 inch minimum size or a minimum 6 inch diameter poured in place concrete dead man at least 2 feet in length. The bottom of each hole to be a minimum of 5 feet beneath the ground surface. Back fill must be well tamped. Minimum rod diameter to be 5/8 inch.

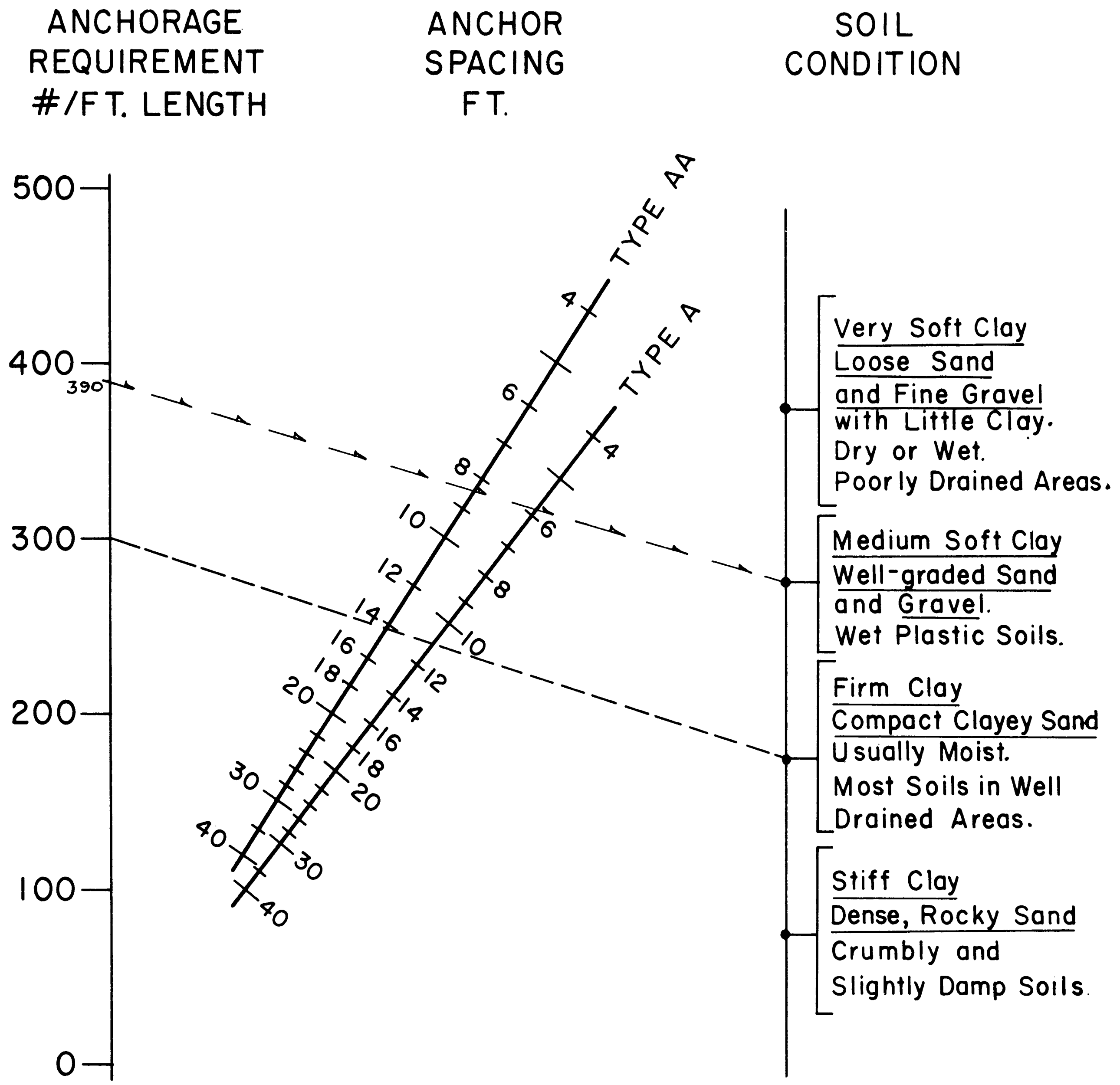


TYPE B ANCHOR

Type C - A precast concrete block, a steel or cast iron cone or plate, of minimum least dimension perpendicular to the anchor rod of 6 inches. The bottom of each hole to be a minimum of 5 feet beneath the ground surface. Back fill must be well tamped. Minimum rod diameter to be 5/8 inch.

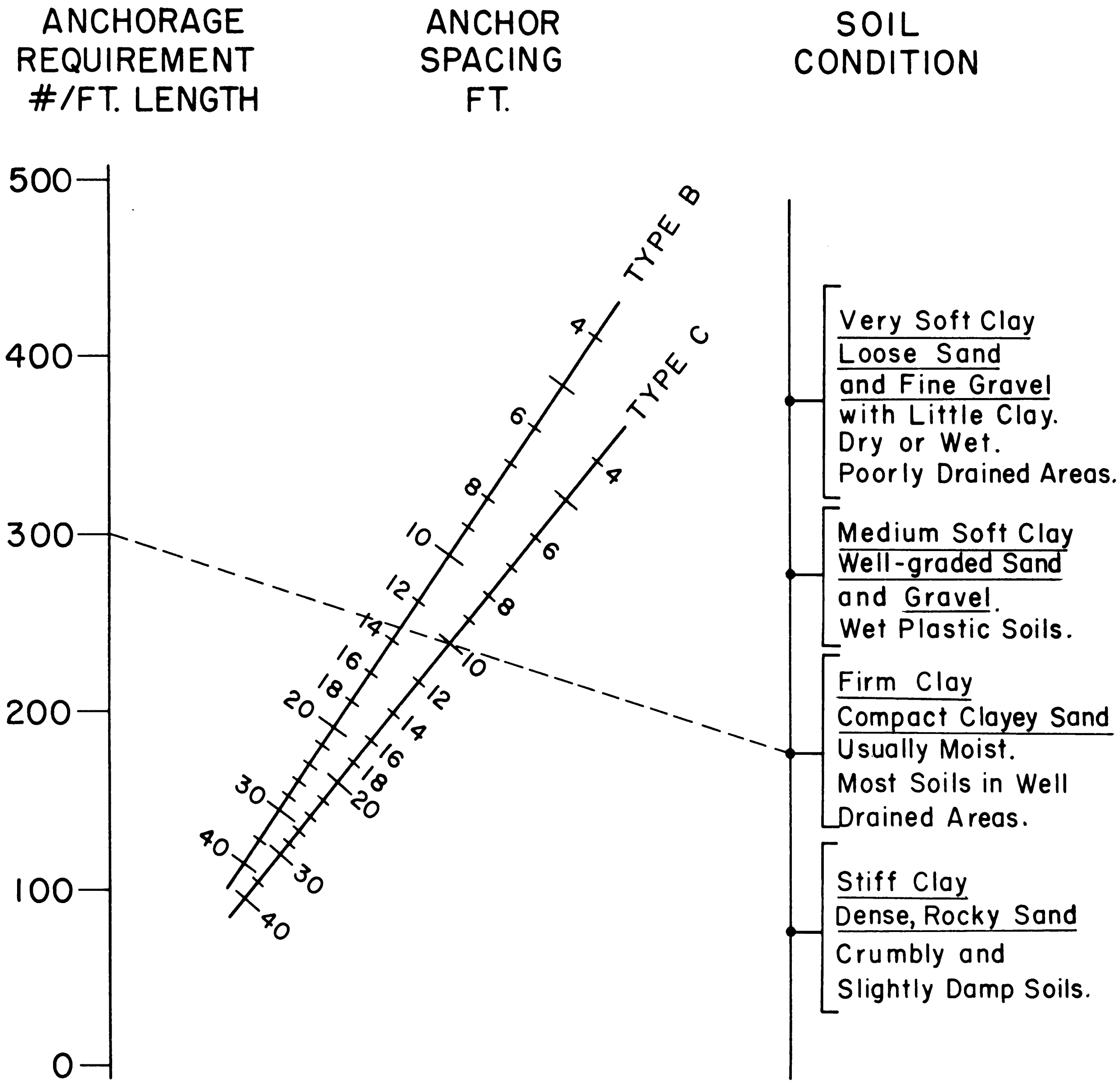


TYPE C ANCHOR

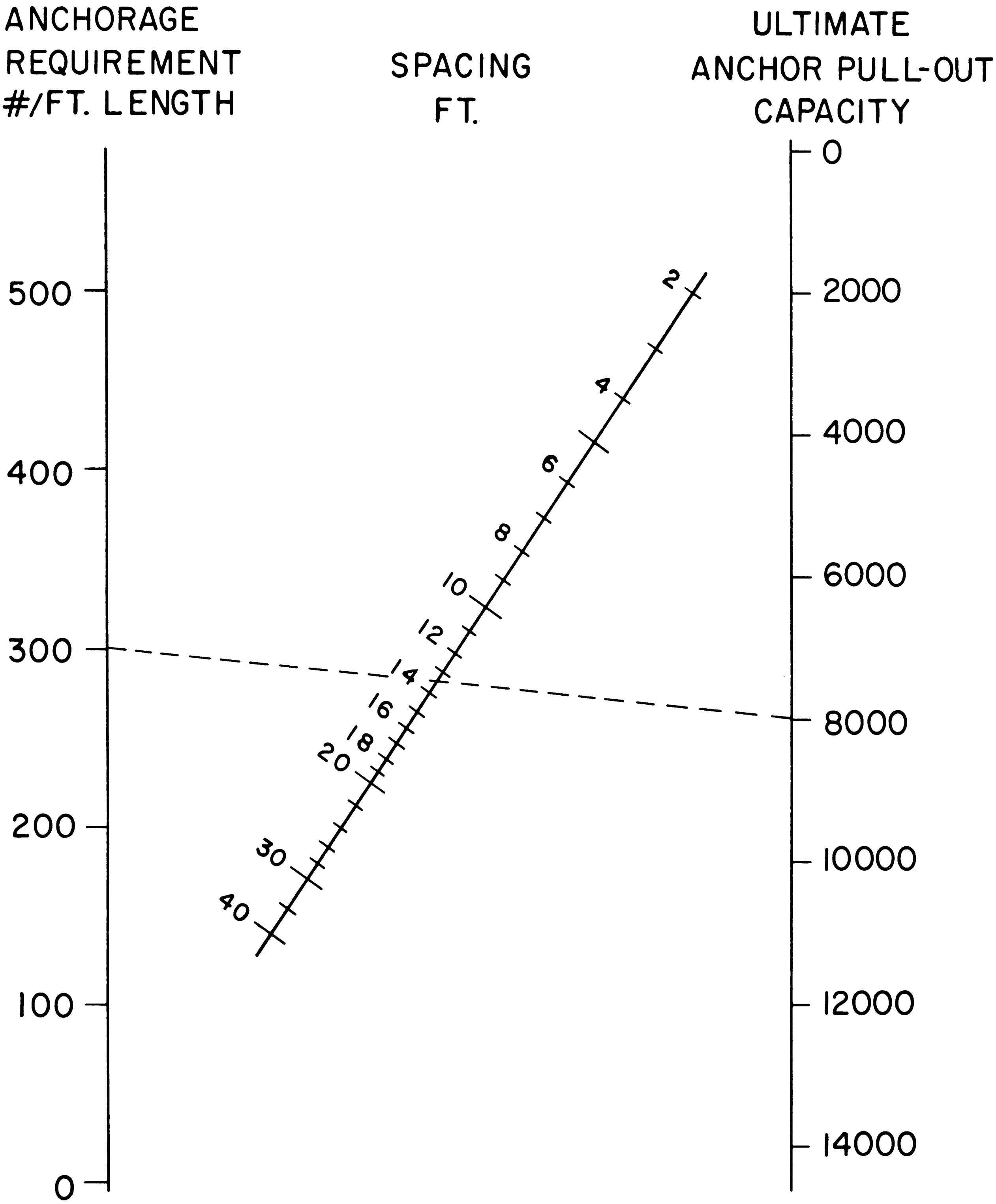


ANCHOR SPACING CHART

TYPE A AND AA ANCHORS



ANCHOR SPACING CHART
TYPE B AND C ANCHORS



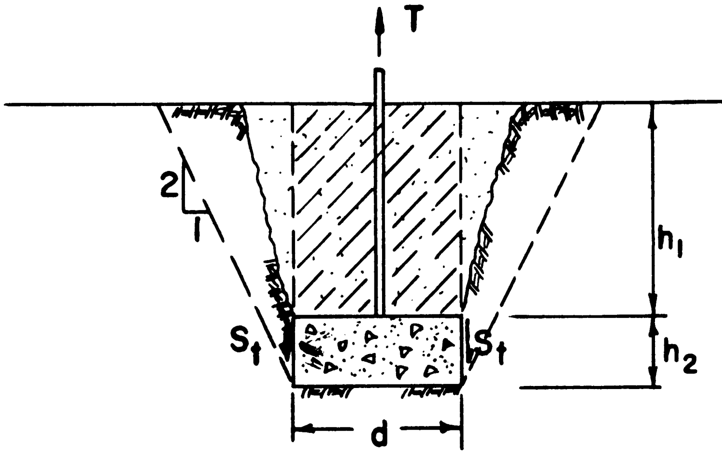
ANCHOR SPACING CHART

ANCHORS WITH KNOWN PULL-OUT CAPACITY

(FACTOR OF SAFETY EQUAL TO 2.0)

SOIL ANCHOR EVALUATION

DEAD-MAN ANCHOR



w_s = 110 p.c.f., soil

w_c = 150 p.c.f., concrete

$w_{ave.} \approx$ 110 p.c.f.

Equation Ⓐ:

$$T_{(design)} = \underbrace{\frac{\pi d^2}{4}\left[h_2 \times w_c + h_1 \times w_s\right]}_{\text{static weight}} + \underbrace{\pi\, d \times h_2\, S_t}_{\text{side shear}}$$

Equation Ⓑ:

$$T_{(design)} \leq \left[\frac{\pi(d+h_1+h_2)^3}{4 \times 3} - \frac{\pi d^3}{4 \times 3}\right] \times w_{ave.}$$

Suggested values for S_t (Side Shear) at approximate 4 foot depth (Including safety factor).

V. Loose sand Peaty sand	S_t = 80 p.s.f.
Loose sand Soft clay	S_t = 150 p.s.f.
Compact clayey sand	S_t = 250 p.s.f.
Stiff clay	S_t = 600 p.s.f.

SOIL ANCHOR EVALUATION

DEAD MAN ANCHOR (CONTINUED)

Example computation

Let $h_1 = 3'$

$h_2 = 2'$ Loose sand , $S_t = 150$ p.s.f.

$d = 1'$

Equation Ⓐ : $T_{(design)} = \frac{3.1416 \times 1}{4} \left[2 \times 150 + 3 \times 110 \right] + 3.1416 \times 1 \times 2 \times 150$

$= .785 \left[300 + 330 \right] + 944$

$= 495 + 944 = \underline{\underline{1439 \text{ lbs.}}}$

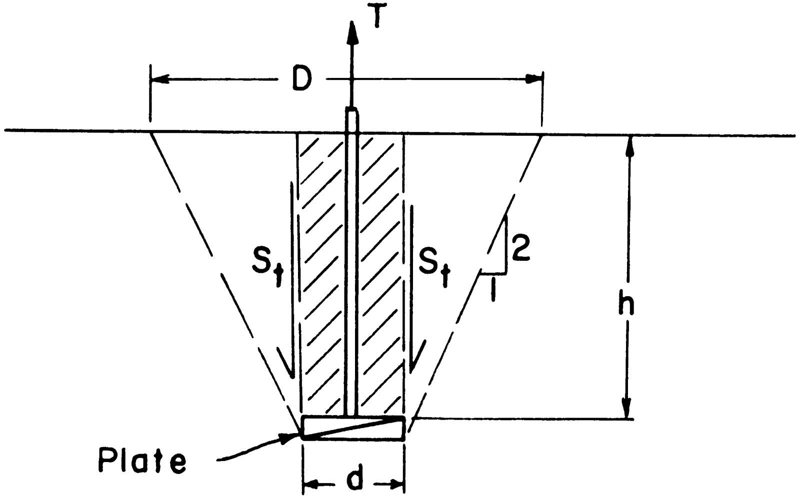
Check:

Equation Ⓑ: $T_{(design)} \leqq \left[\frac{3.1416 \times 6^3}{12} - \frac{3.1416 \times 1^3}{12} \right] 110$

$\leqq \left[56.5 - .26 \right] 110 = 6{,}180 \text{ lbs.} > 1439 \text{ lbs.}$ $\underline{\text{o.k.}}$

SOIL ANCHOR EVALUATION

SCREW AUGER ANCHOR

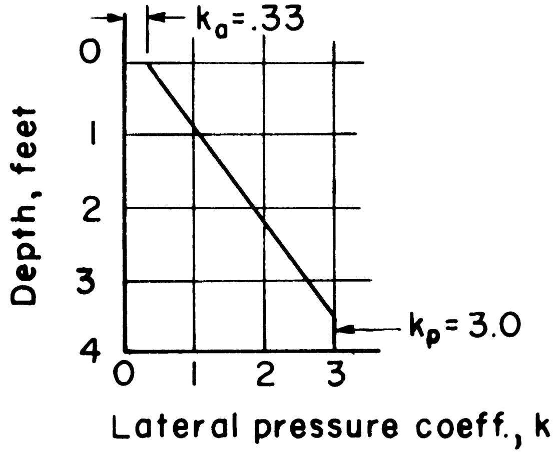


Analysis of typical screw anchor in medium sand

d = 6"   h = 48"   Manufacturer's suggested design T = 2500 lbs.

Ⓒ: Side shear on projected plate area

$$S_{(ave.)} = T/\pi d h = 2500/3.1416 \times \frac{6}{12} \times \frac{48}{12}$$
$$= 400 \text{ p.s.f.}$$



Consider that k_p (passive pressure) controls lateral pressure on shear surface for a distance "d" above plate, then decreases to k_a (active pressure) at ground surface.

SOIL ANCHOR EVALUATION

SCREW AUGER (CONTINUED)

Side shear in sand

$S_f = w\,h\,k \tan\phi$

$T = S_f \times \pi d h = (w\,h\,k \tan\phi)\pi d h$

from 3.5' to 4' depth, $\tan\phi = 1$ (sand on sand)

$\Delta T = (110 \times 3.75 \times 3.0 \times 1.0) \times 3.1416 \times 6/12 \times 6/12$

$= 1240 \times .785 = 975^{*}$

from 0' to 3.5' depth

$k = 0.33 + (3 - 0.33) \times h'/3.5 = 0.33 + 0.76h'$

$\Delta T = \int_0^{3.5} 110 \times (0.33 + 0.76h')h' \times 3.1416 \times 6/12 \times dh'$

$$= 110 \times 1.570 \times \int_0^{3.5} (0.33 + 0.76h')h'\,dh' = 110 \times 1.570 \left[\frac{0.33h^2}{2} + \frac{0.76h^3}{3}\right]$$

$= 110 \times 1570 \; [2.02 + 10.9] = 2230$ lbs.

$\Sigma T = 975 + 2230 = 3205$ lbs. (side shear limit)

Ⓓ: Static weight limit of projected cone

$D = d + h = 6" + 48" = 4.5'$; $H = 48" + 6" = 4.5'$

$$V = \frac{\pi D^2 H}{4 \times 3} - \frac{\pi d^2 (H-h)}{4 \times 3} = \frac{3.1416 \times 4.5^2 \times 4.5}{12} - \frac{3.1416 \times .5^3}{12}$$

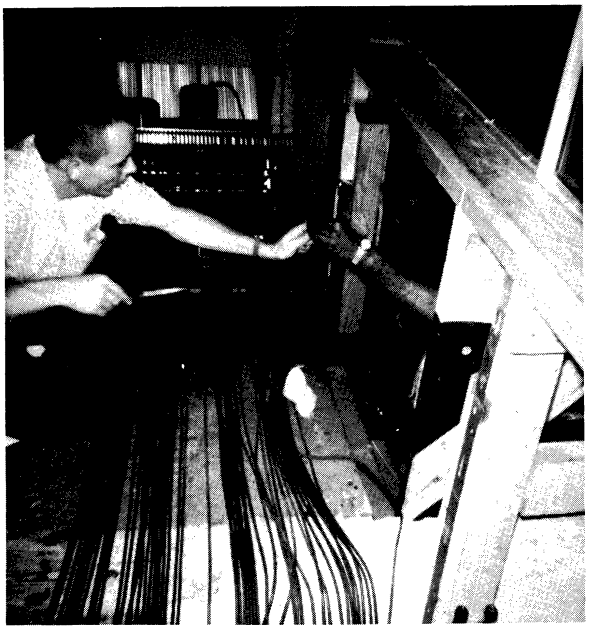
$= 23.9 - .0328 = 23.87 \approx 24$ cu. ft.

Wt. $= 110 \times 24 = 2540$ lbs. $\approx$ 2500 design

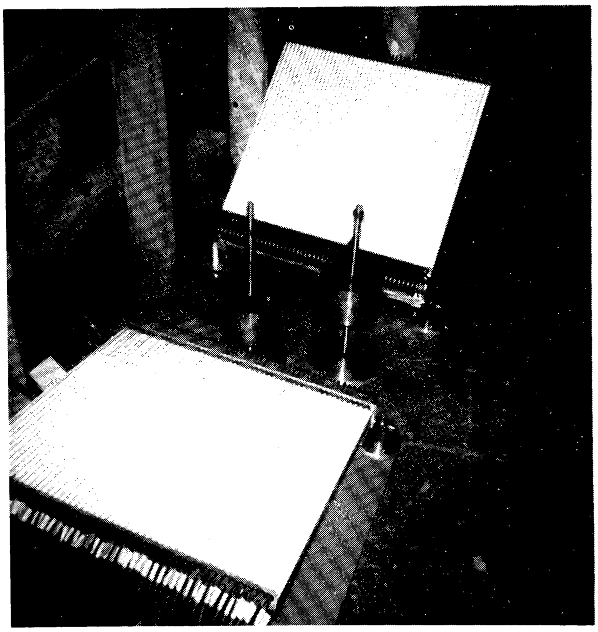
Recommend safety factor equal 1.5 for temporary load

$T_{(design)} = 3205 \div 1.5 = \underline{\underline{2130 \text{ lbs.}}}$
(in medium sand)

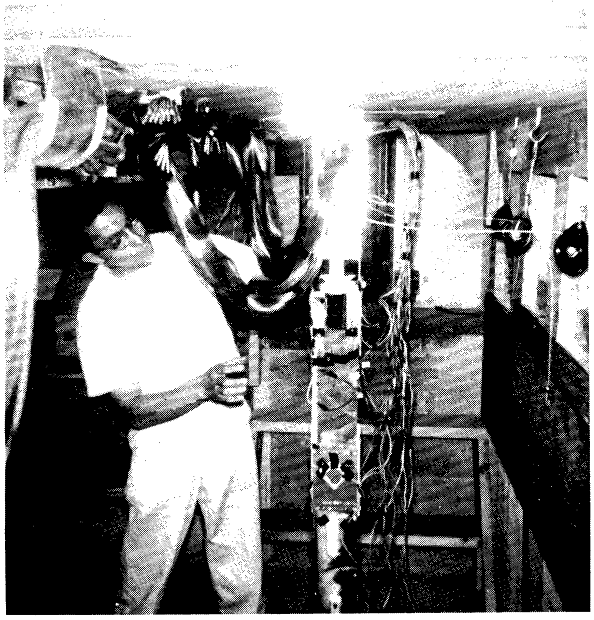
Check: Wt. $= 2540 > T_{(design)} = 2130$ (o.k.)



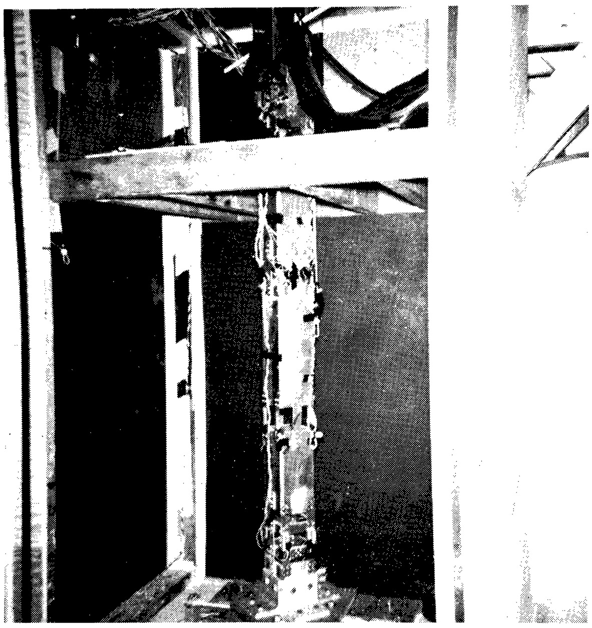
(a) Installing Manometer Tubing



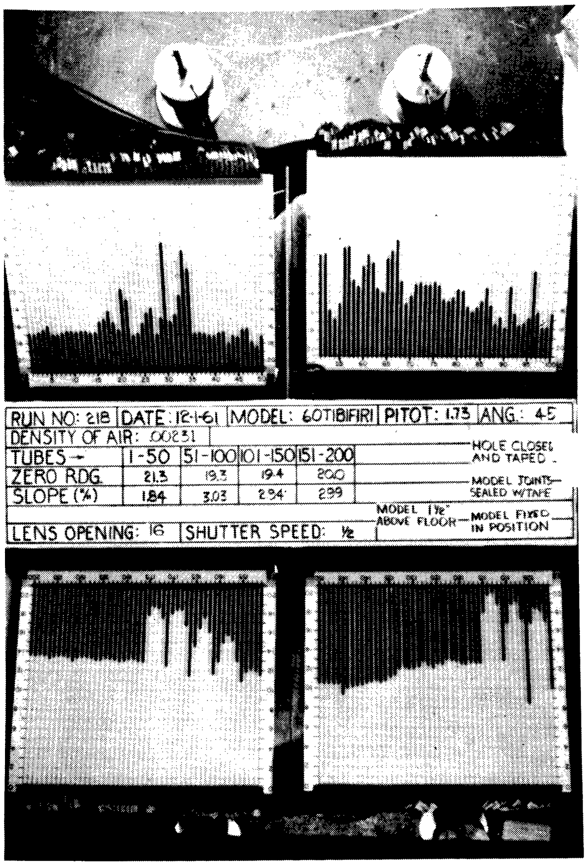
(b) Two Manometer Boards in Place For Testing



(c) Support Column Showing Manometer Tubing And Strain Gages



(d) Support Column Ready For Testing



RUN NO: 218 DATE: 12-1-61 MODEL: 60T1B1F1R1 PITOT: 1.73 ANG.: 45

DENSITY OF AIR: .00231

TUBES →	1-50	51-100	101-150	151-200
ZERO RDG.	21.3	19.3	19.4	20.0
SLOPE (%)	1.84	3.03	2.94	2.99

HOLE CLOSED AND TAPED

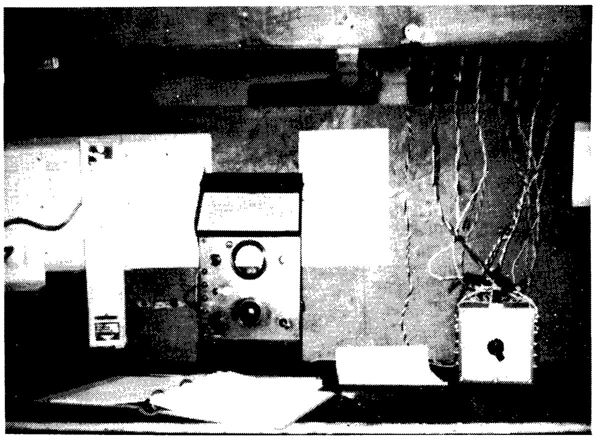
MODEL JOINTS SEALED W/TAPE

MODEL 1½" ABOVE FLOOR

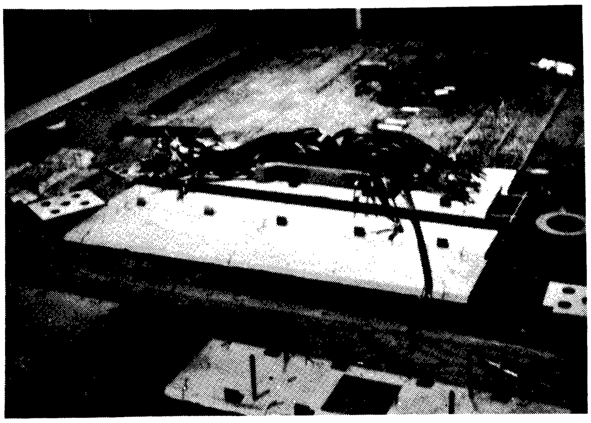
MODEL FIXED IN POSITION

LENS OPENING: 16 SHUTTER SPEED: ½

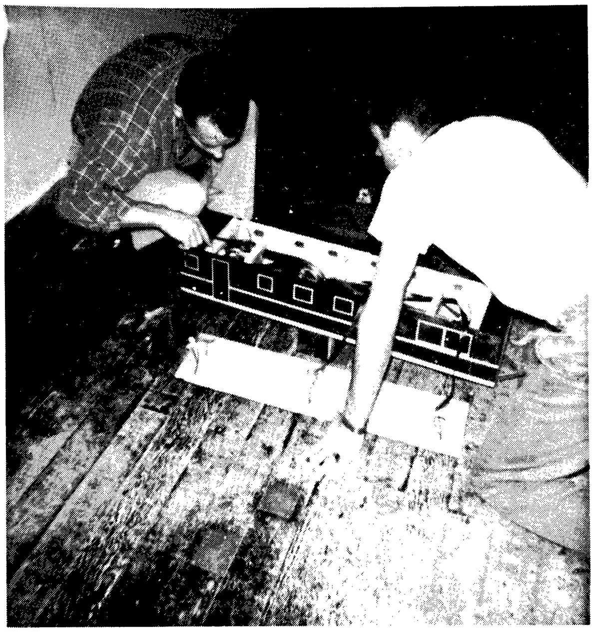
(ℓ) Typical Manometer Data Photograph



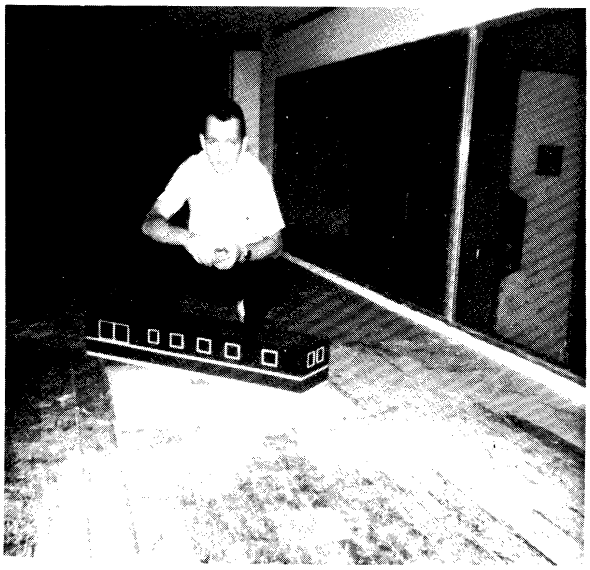
(f) Strain Gage Analyzer, Switch Box, And Pitot Tube Manometer



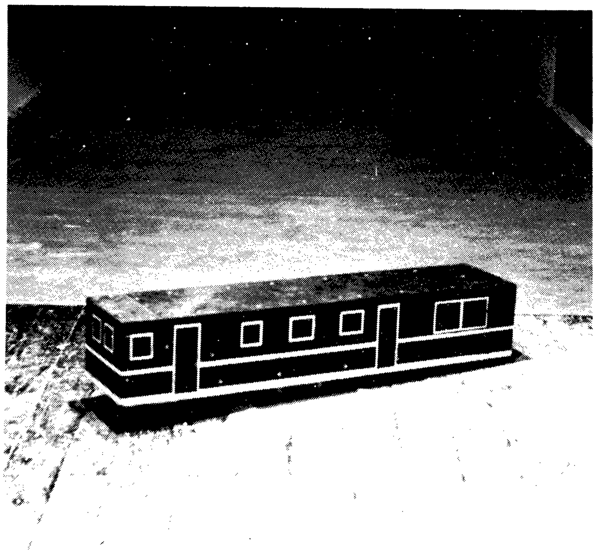
(g) Start Of Assembly Of Model In Wind Tunnel. Tubes Projecting From Support Column Top



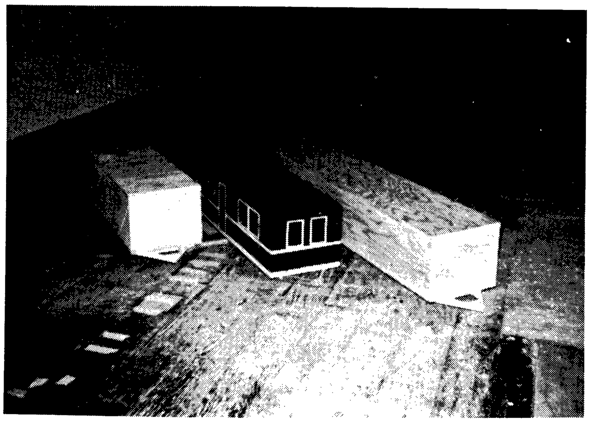
(h) Checking Manometer Connections Inside A Typical Model



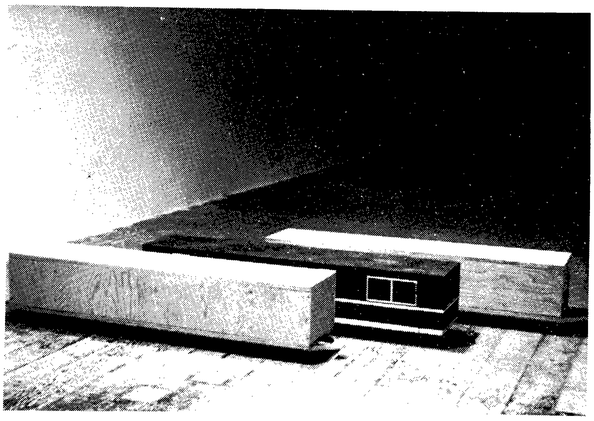
(j) Model Ready For Testing In Wind Tunnel



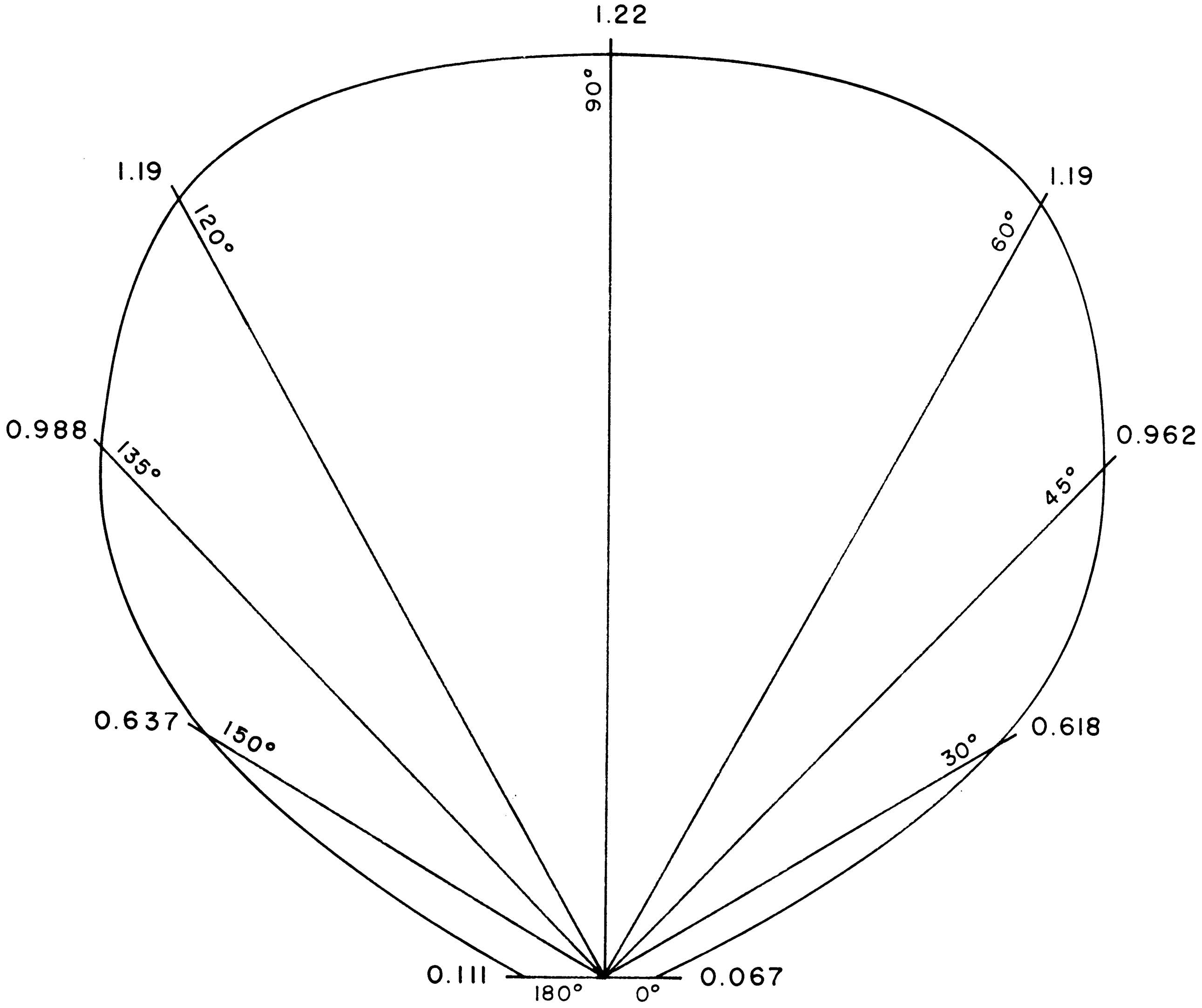
(k) Model In The Nose Down Position



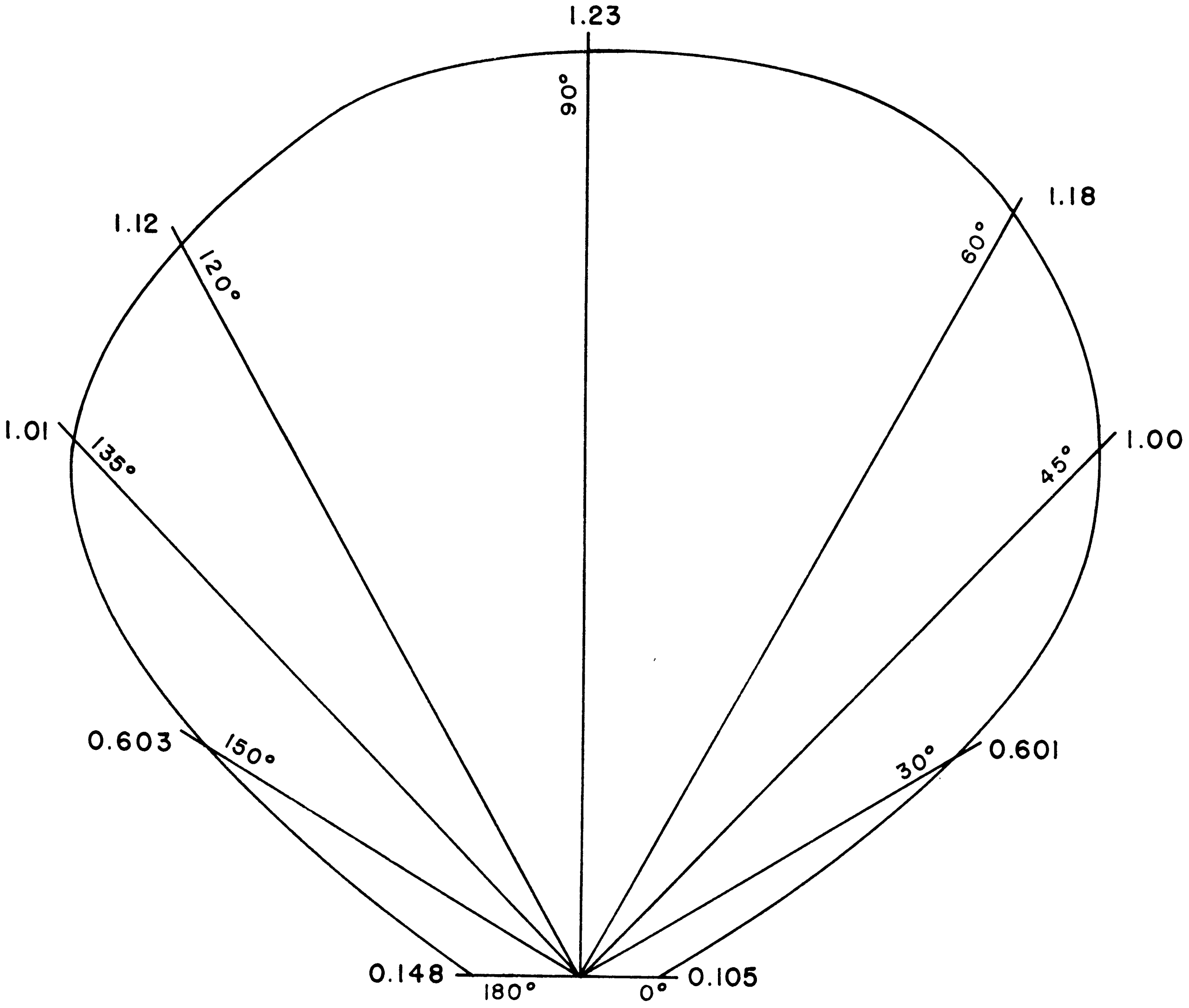
(ℓ) Model In Position For Interference Tests At 45°



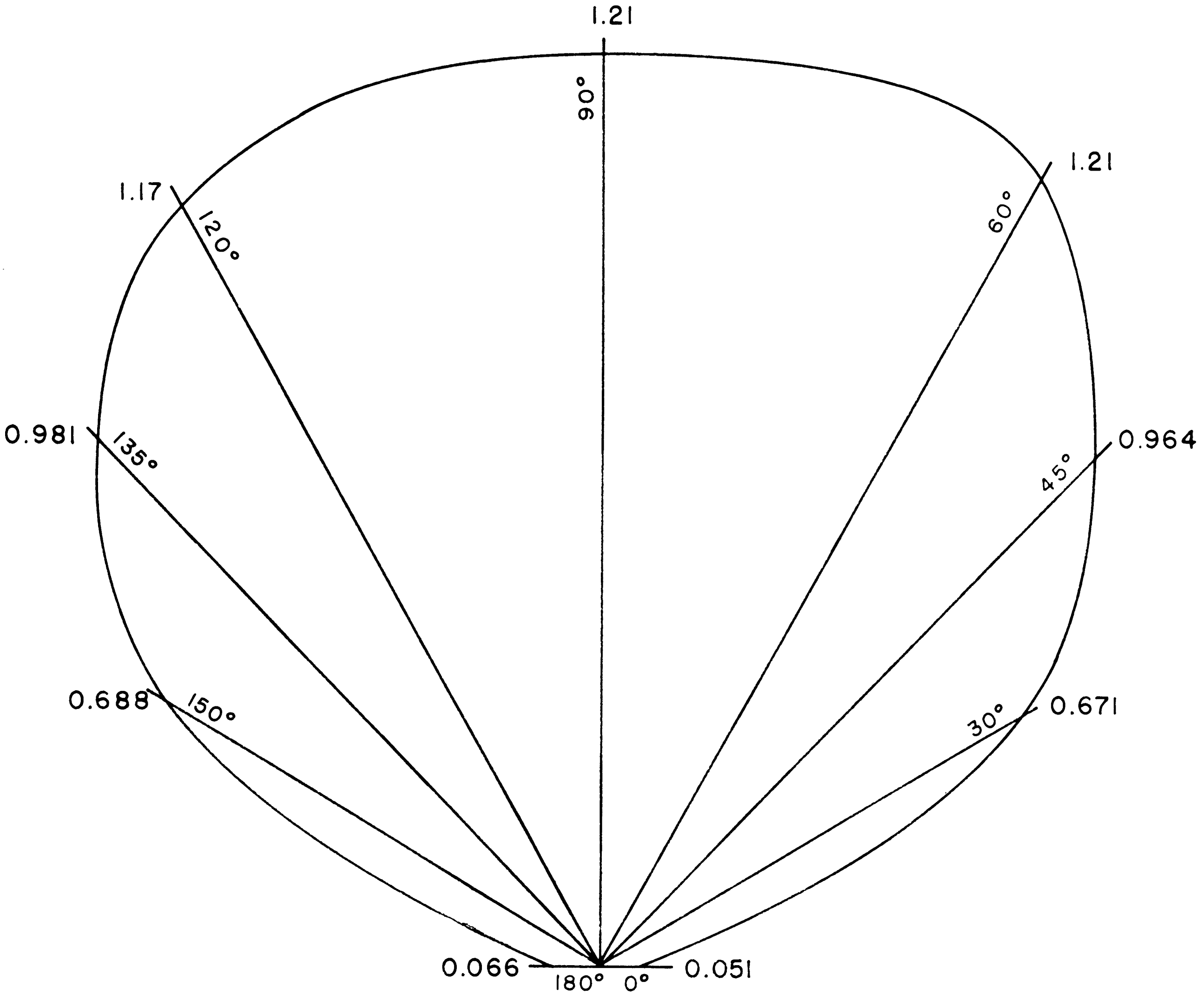
(m) Model In Position For Interference Tests At 90°



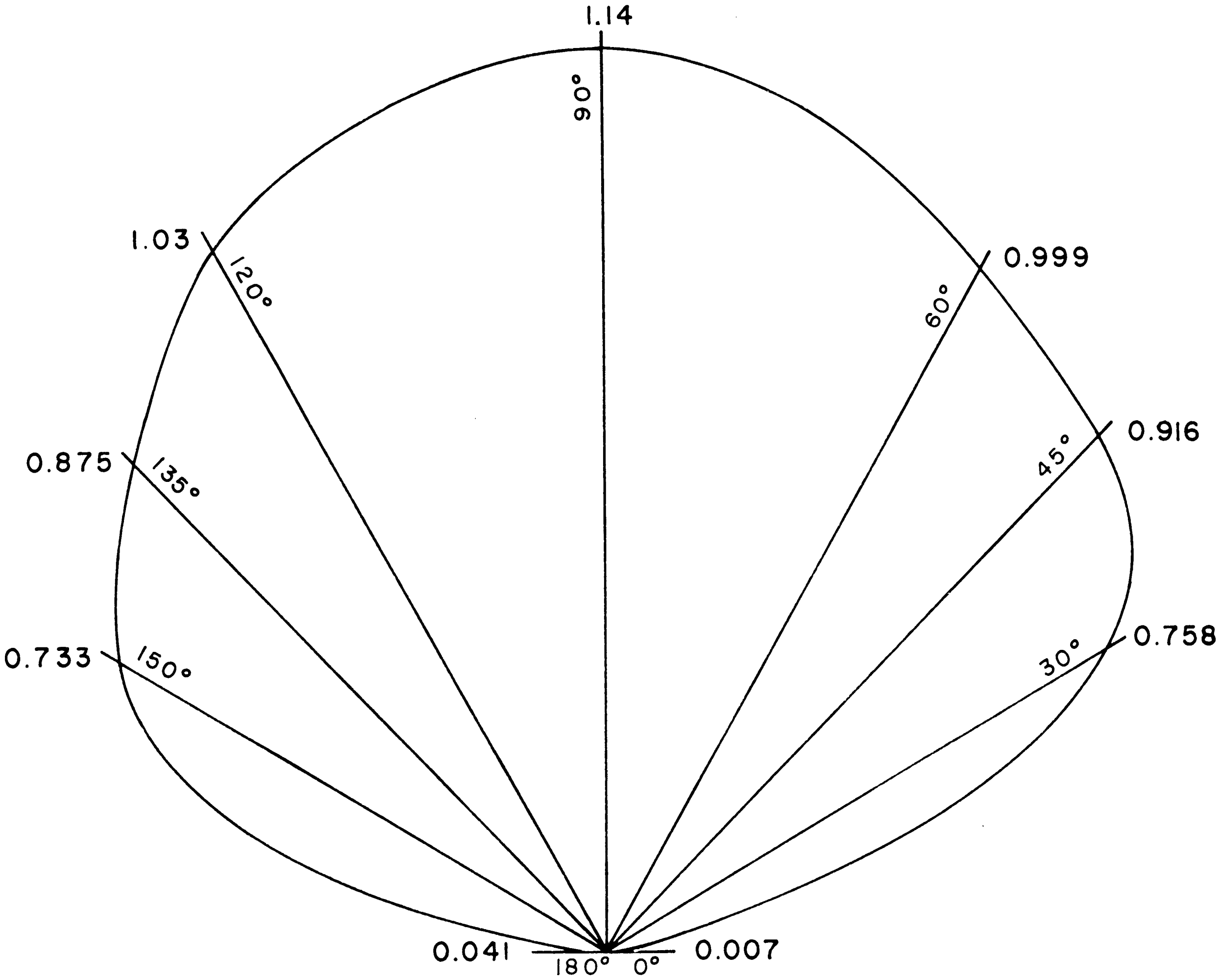
Transverse Drag Coefficients By Wind Angle
50 Foot Mobile Home



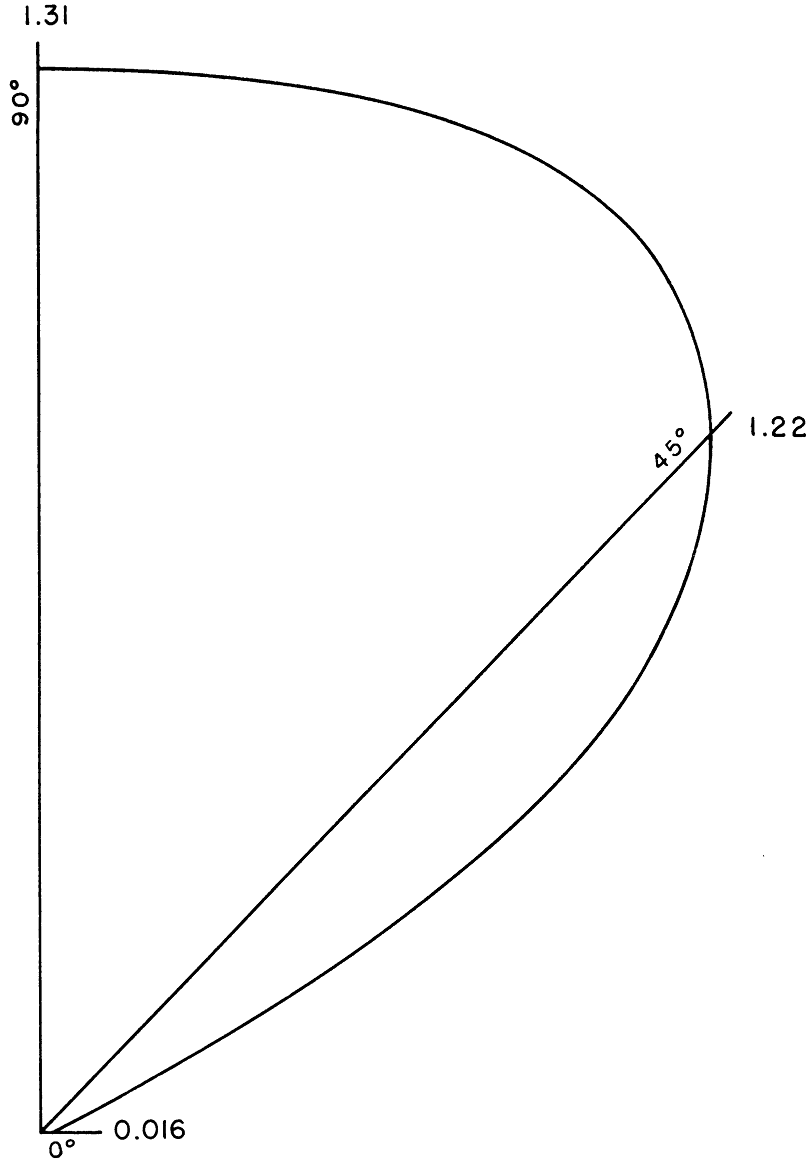
Transverse Drag Coefficients By Wind Angle
60 Foot Mobile Home



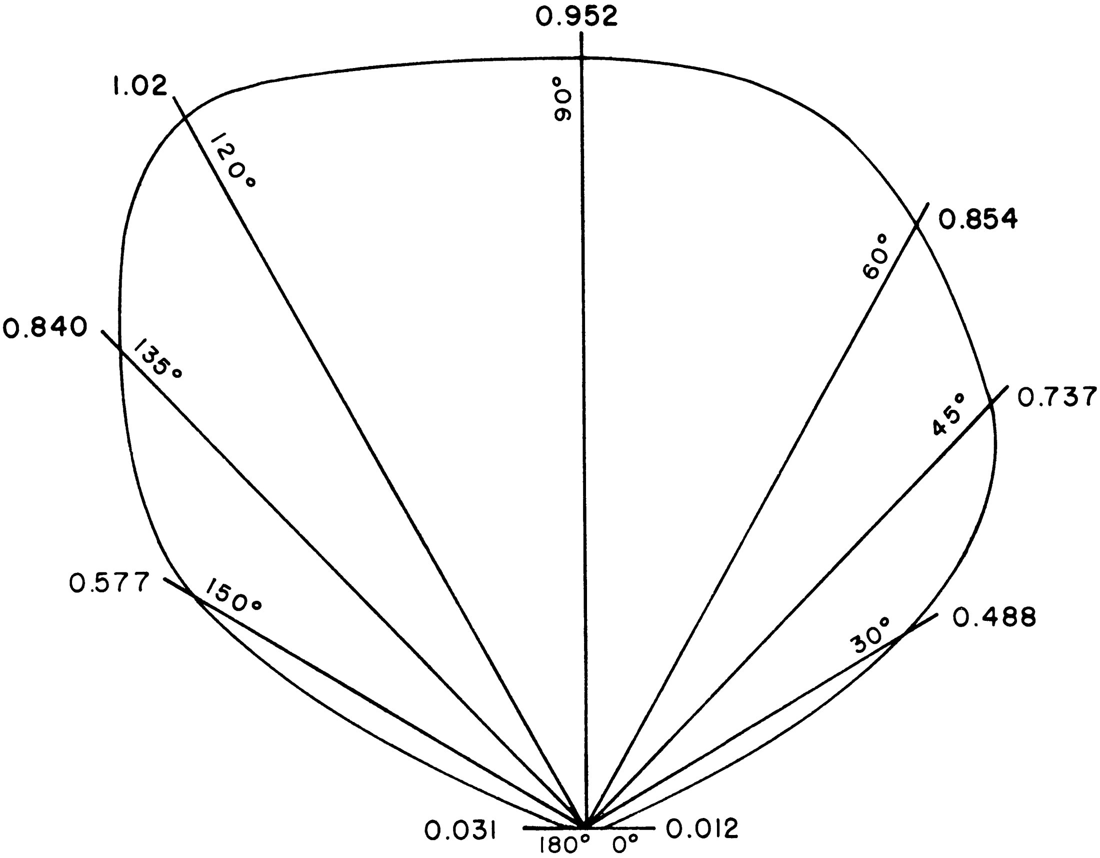
Transverse Drag Coefficients By Wind Angle
40 Foot Mobile Home



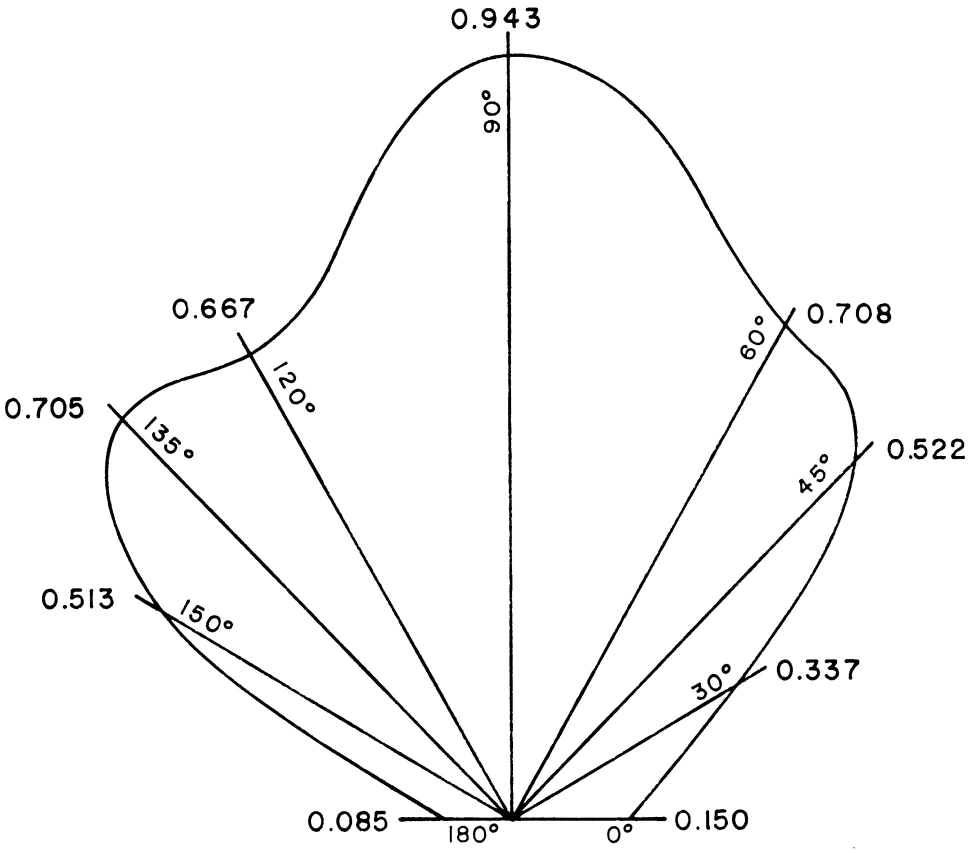
Transverse Drag Coefficients By Wind Angle
25 Foot Mobile Home



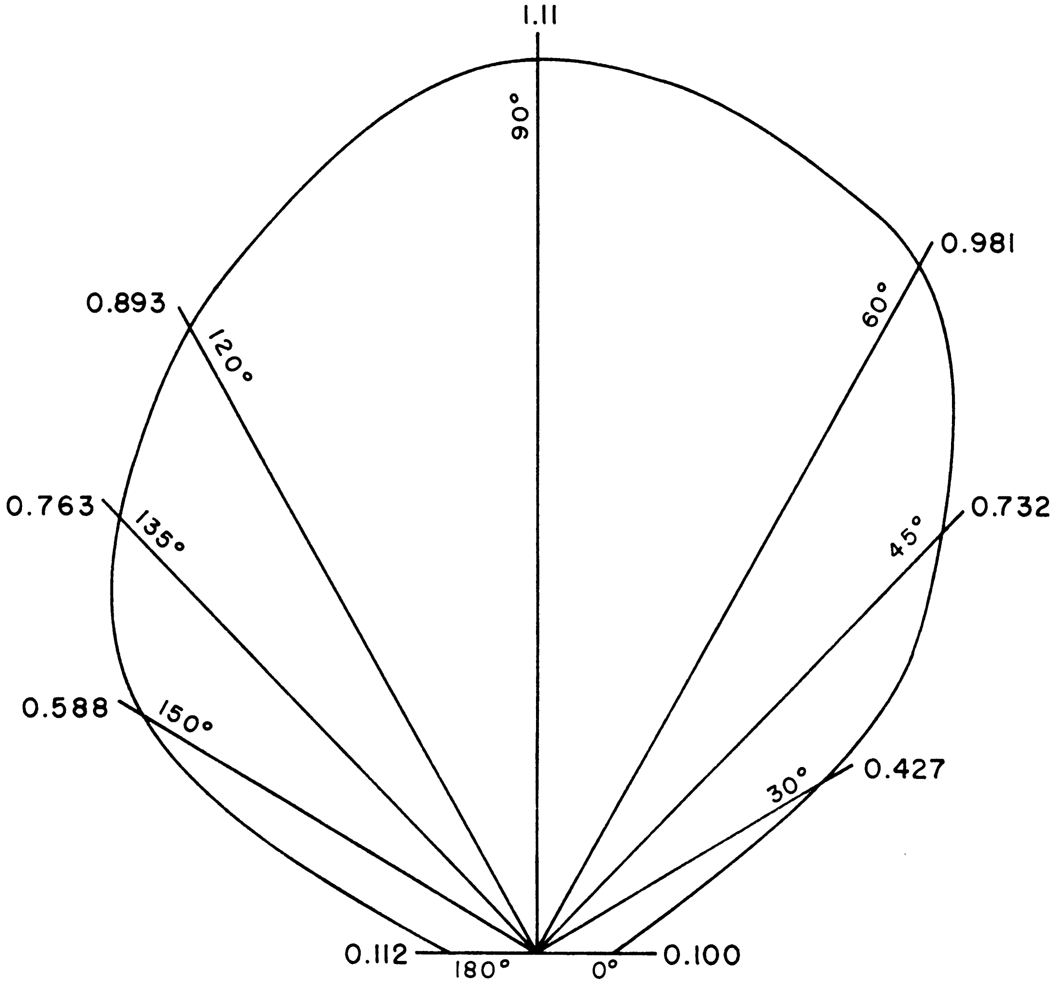
Transverse Drag Coefficients By Wind Angle
50 Foot Mobile Home With Skirt
(Only 0, 45, and 90 Degree Wind Angles Tested)



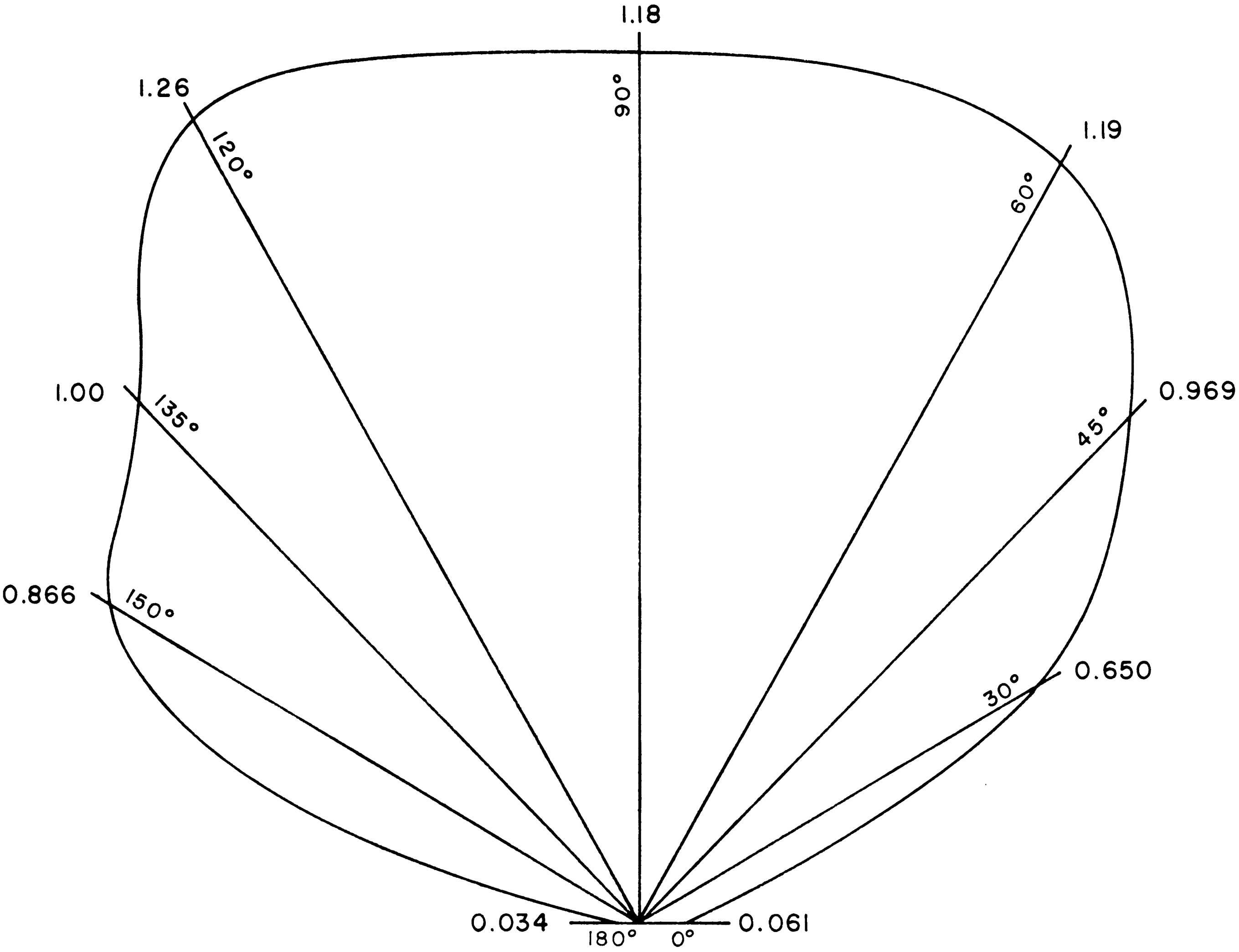
Transverse Drag Coefficients By Wind Angle
50 Foot Mobile Home With
Awning Along One Half Length



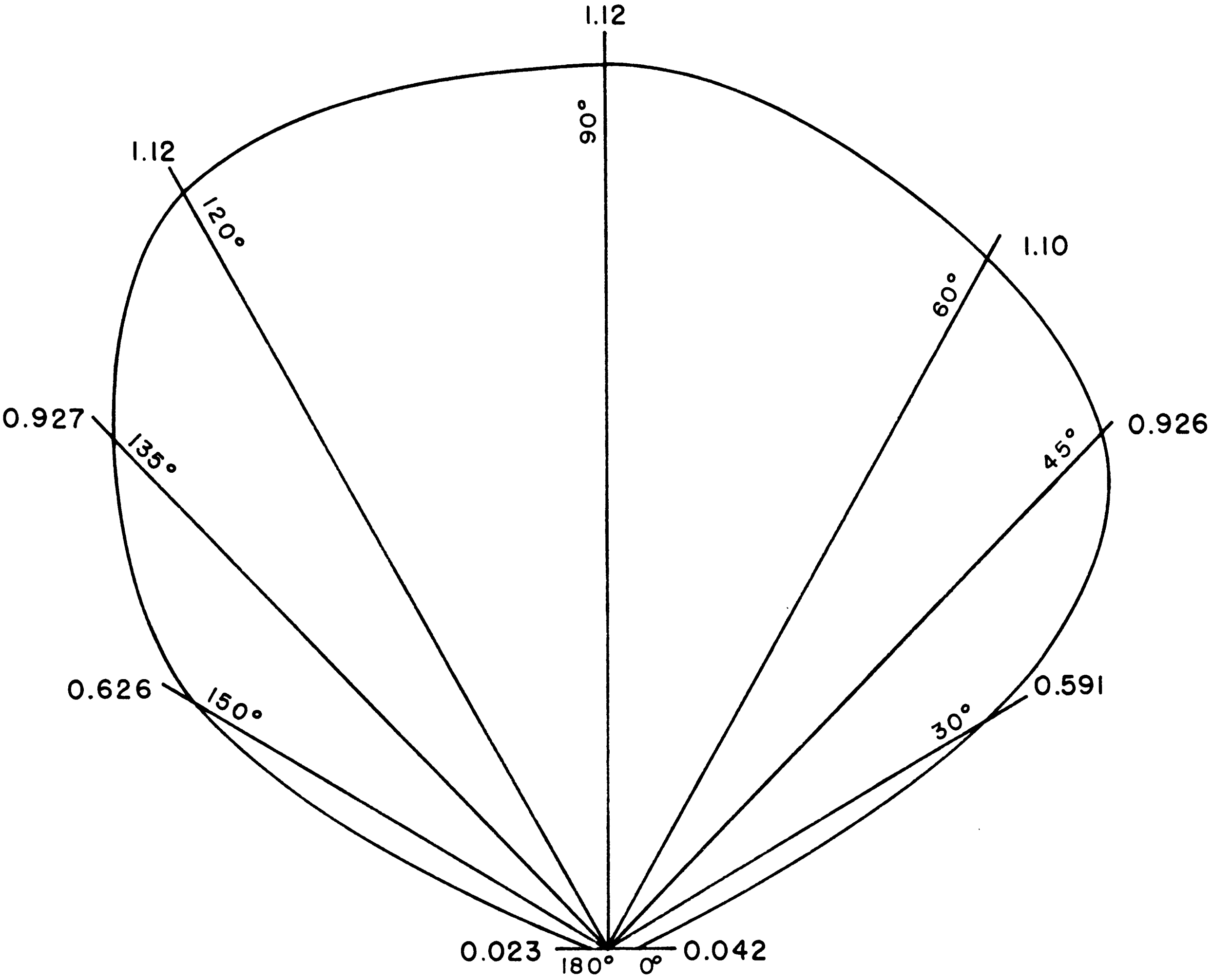
Transverse Drag Coefficients By Wind Angle
50 Foot Mobile Home With Cabana
Along One Half Length



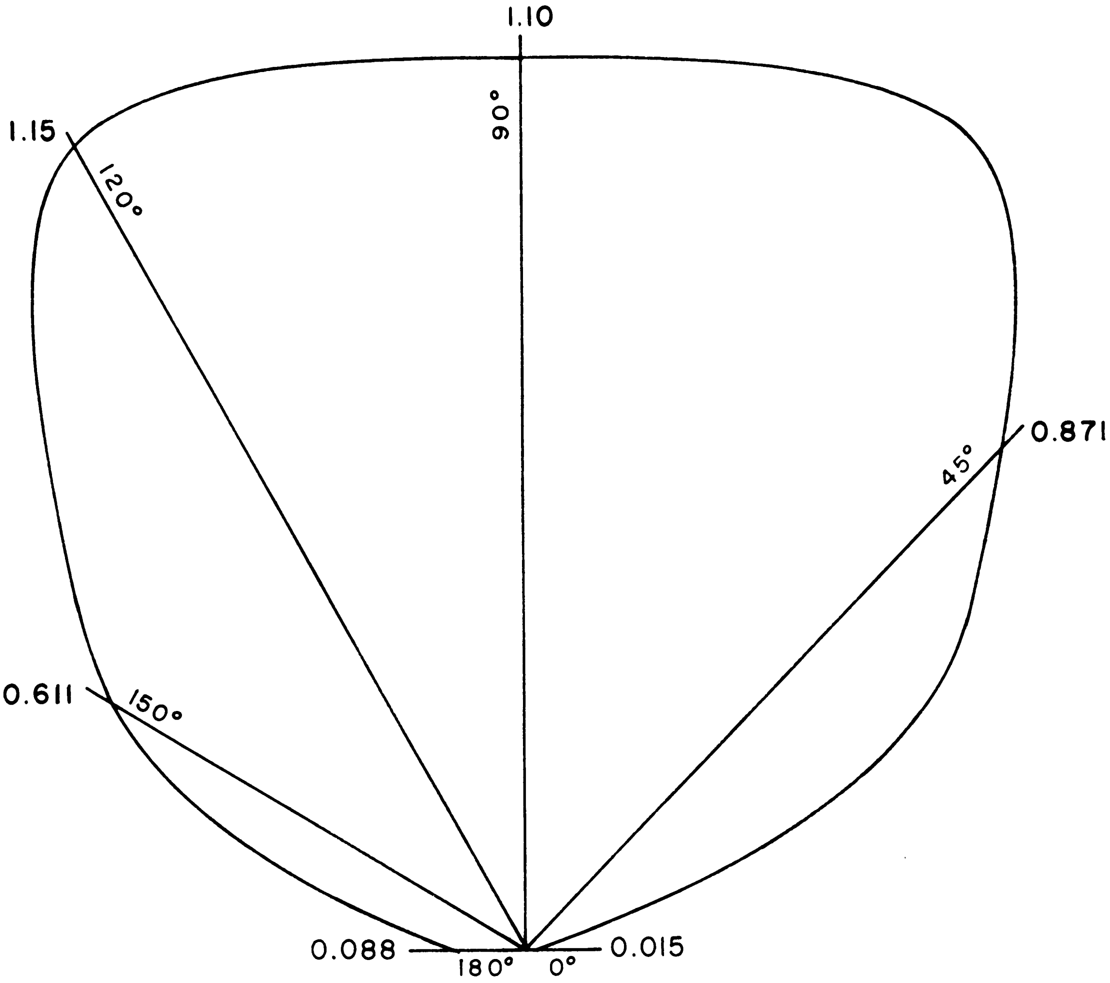
Transverse Drag Coefficients By Wind Angle
50 Foot Mobile Home With Expando Unit



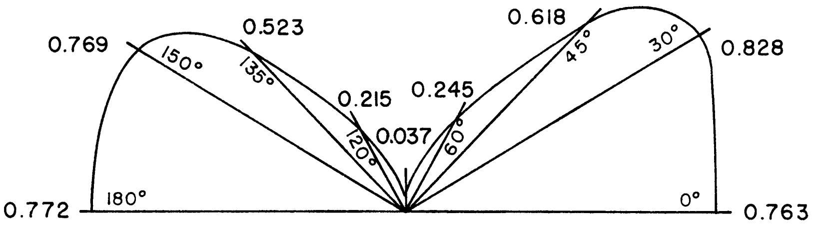
Transverse Drag Coefficients By Wind Angle
50 Foot Mobile Home With Bottom Covered



Transverse Drag Coefficients By Wind Angle
50 Foot Mobile Home With Clerestory Top

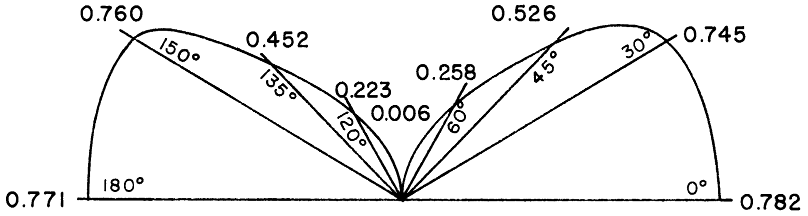


Transverse Drag Coefficients By Wind Angle
50 Foot Mobile Home With Nose Down



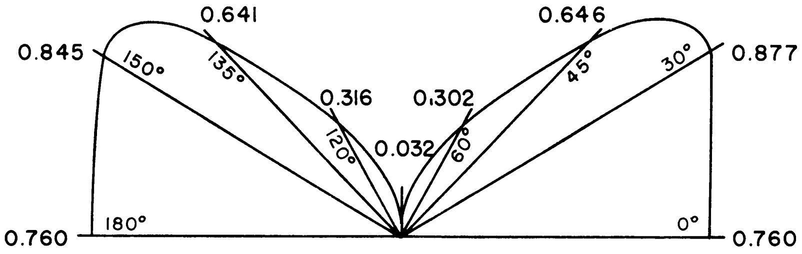
(a)

Longitudinal Drag Coefficients By Wind Angle
50 Foot Mobile Home



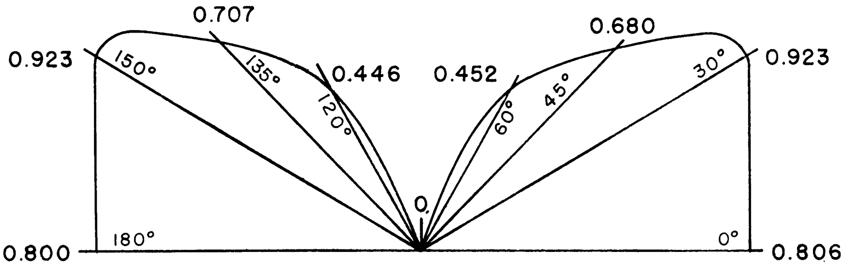
(b)

Longitudinal Drag Coefficients By Wind Angle
60 Foot Mobile Home



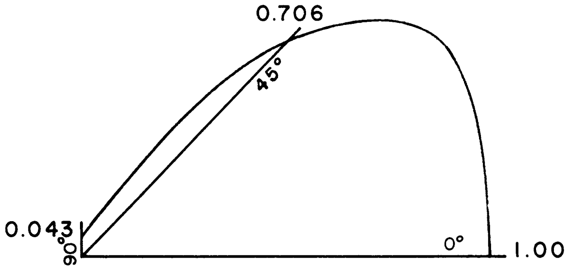
(a)

Longitudinal Drag Coefficients By Wind Angle
40 Foot Mobile Home



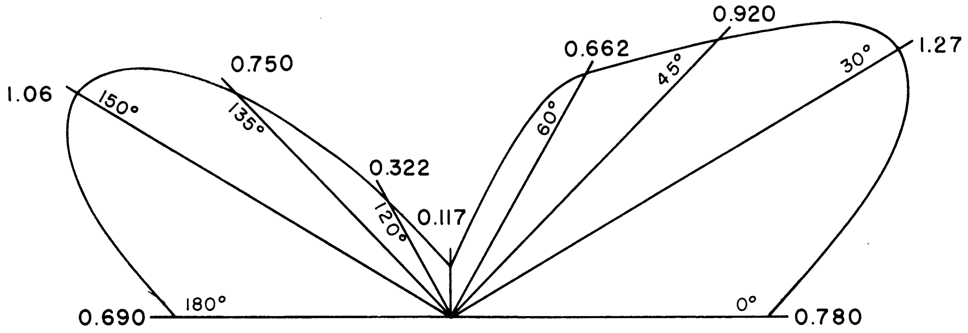
(b)

Longitudinal Drag Coefficients By Wind Angle
25 Foot Mobile Home



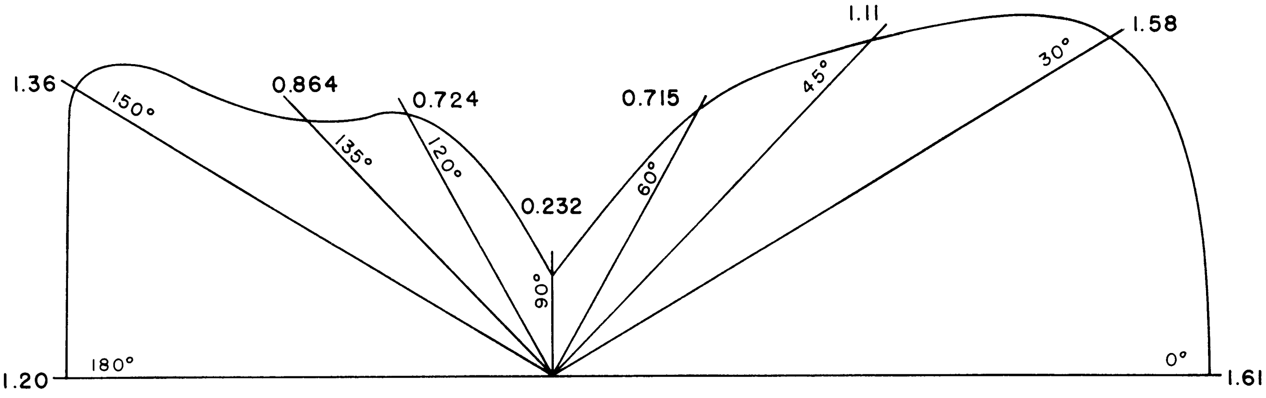
(a)

Longitudinal Drag Coefficients By Wind Angle
50 Foot Mobile Home With Skirt
(Only 0, 45, and 90 Degree Wind Angles Tested)



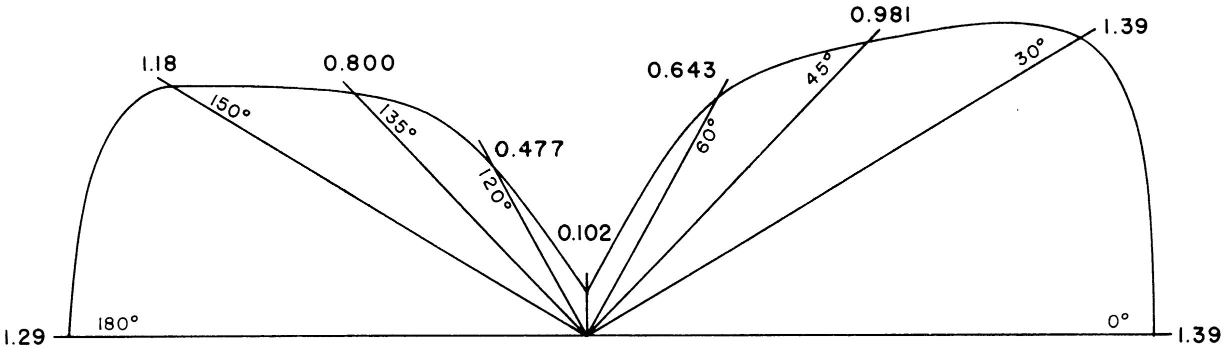
(b)

Longitudinal Drag Coefficients By Wind Angle
50 Foot Mobile Home With Awning
Along One Half Length



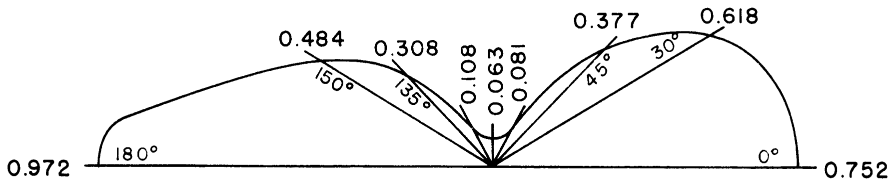
(a)

Longitudinal Drag Coefficients By Wind Angle
50 Foot Mobile Home With Cabana
Along One Half Length



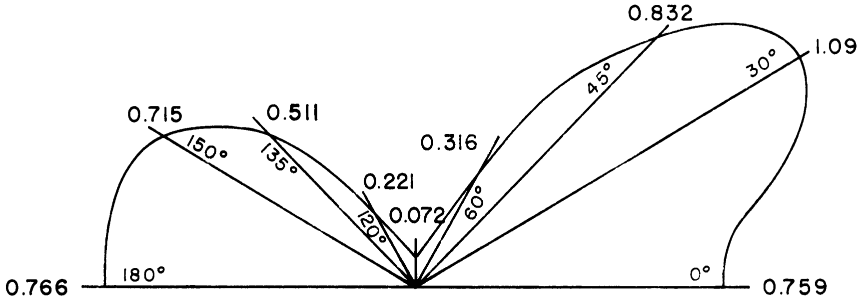
(b)

Longitudinal Drag Coefficients By Wind Angle
50 Foot Mobile Home With Expando Unit



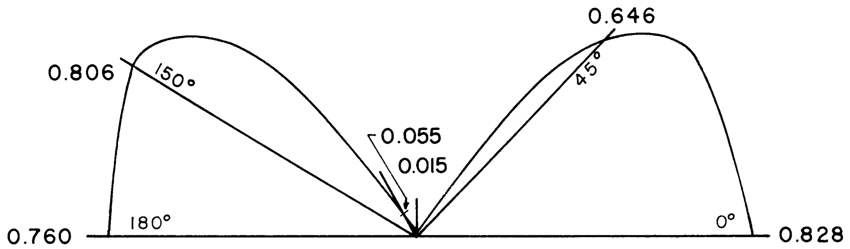
(a)

Longitudinal Drag Coefficients By Wind Angle
50 Foot Mobile Home With Bottom Covered

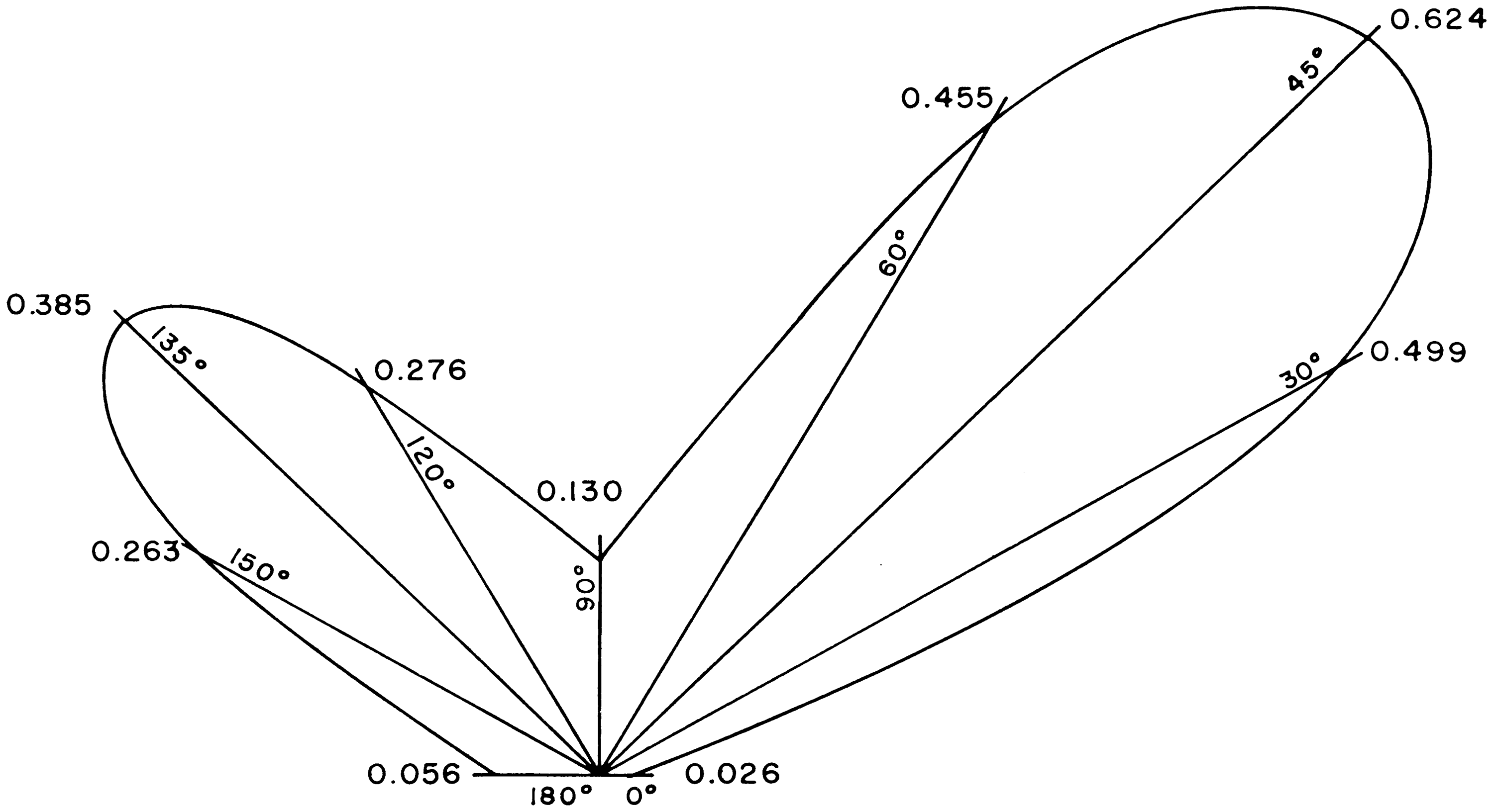


(b)

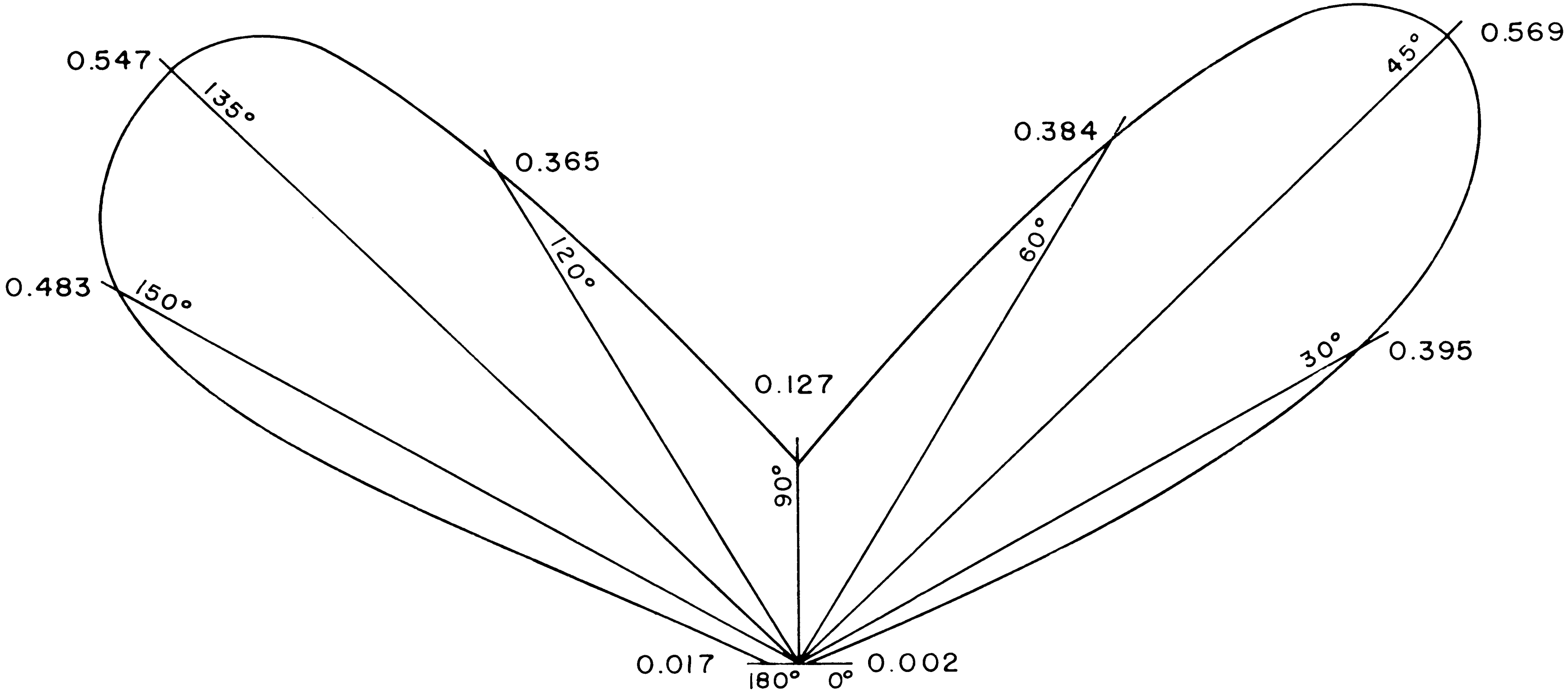
Longitudinal Drag Coefficients By Wind Angle
50 Foot Mobile Home With Clerestory Top



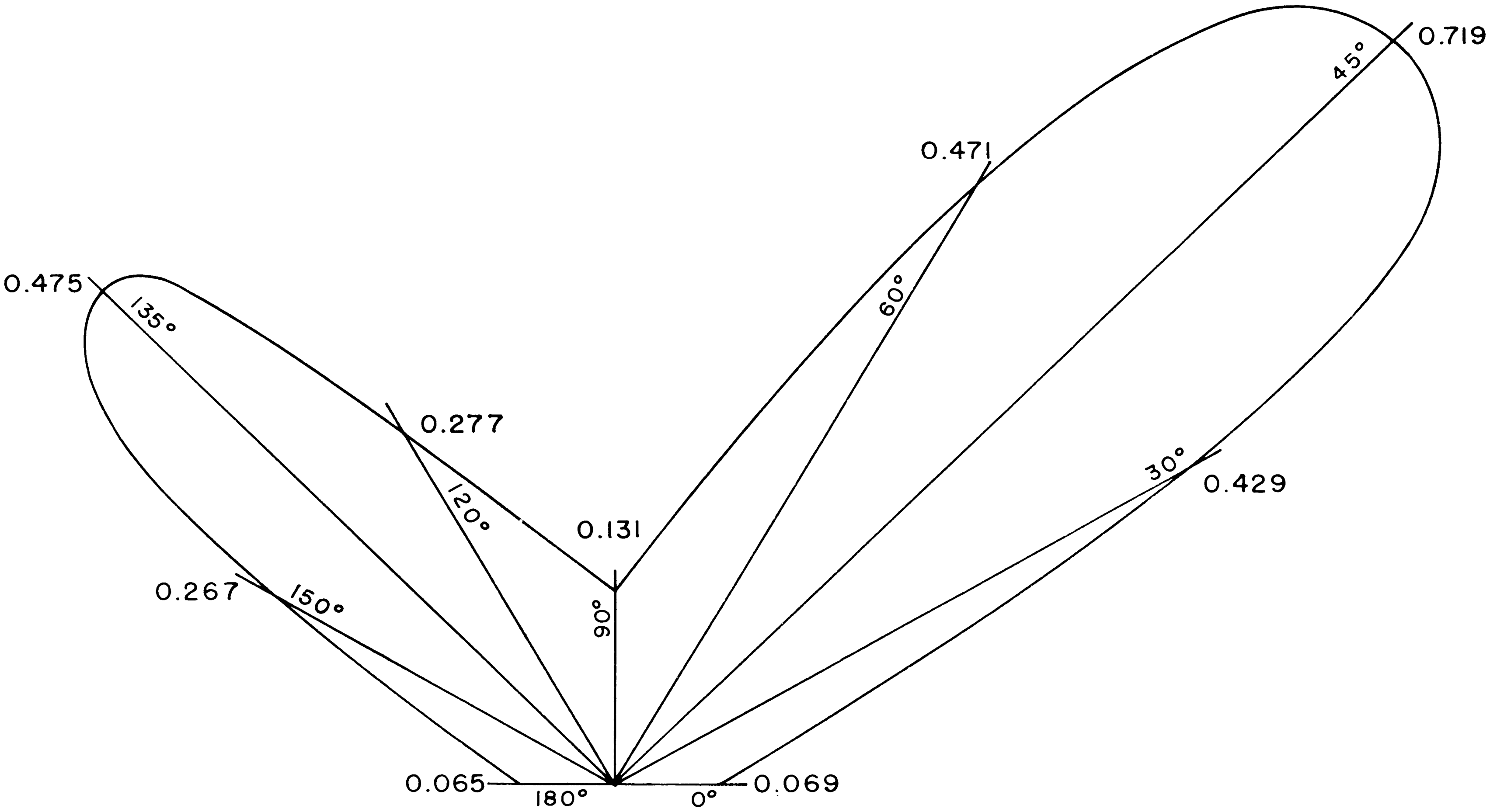
Longitudinal Drag Coefficients By Wind Angle
50 Foot Mobile Home With Nose Down
(Only 0, 45, 90, 120, 150 and 180
Degree Wind Angles Tested)



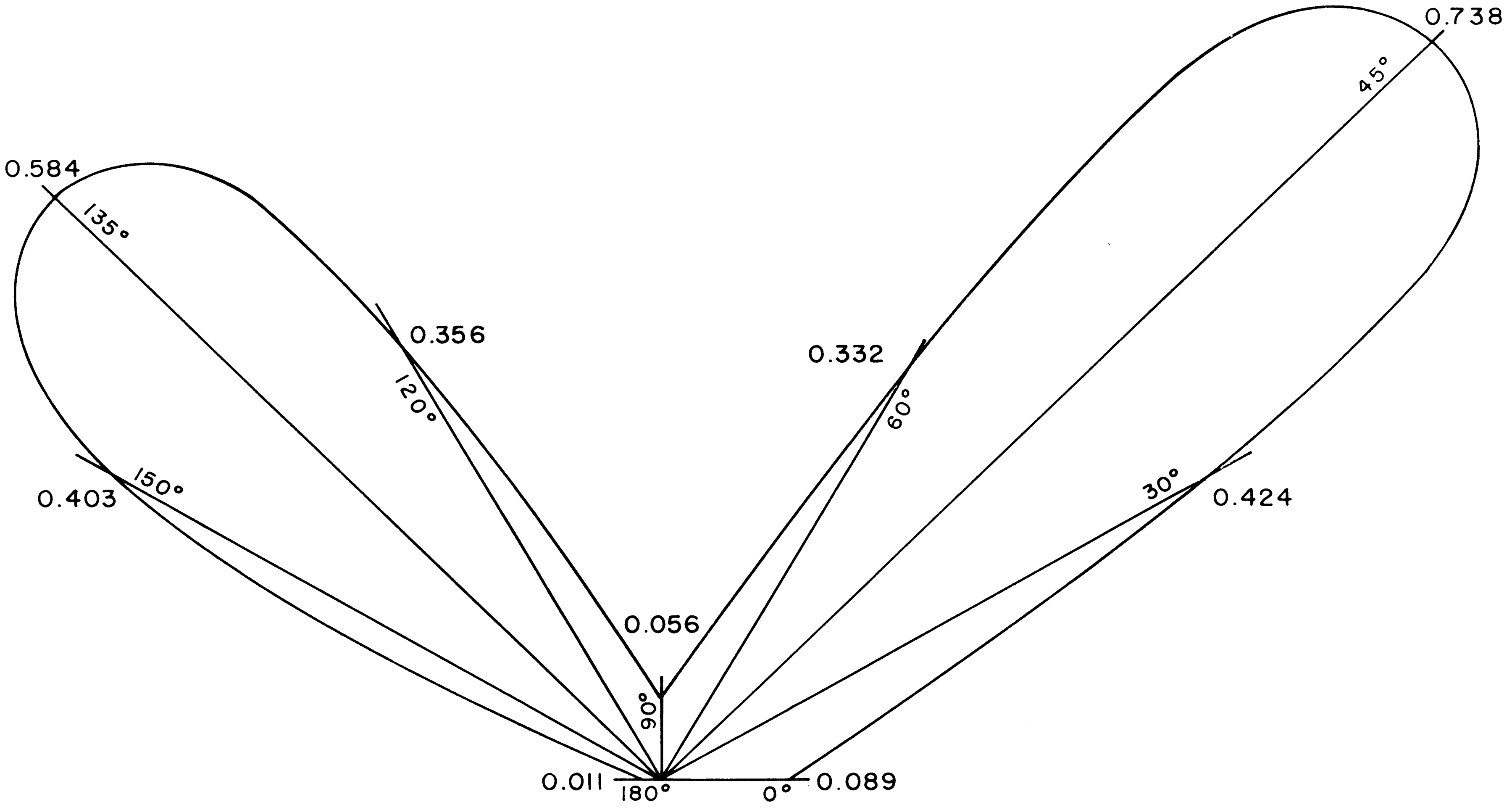
Lift Coefficients By Wind Angle
50 Foot Mobile Home



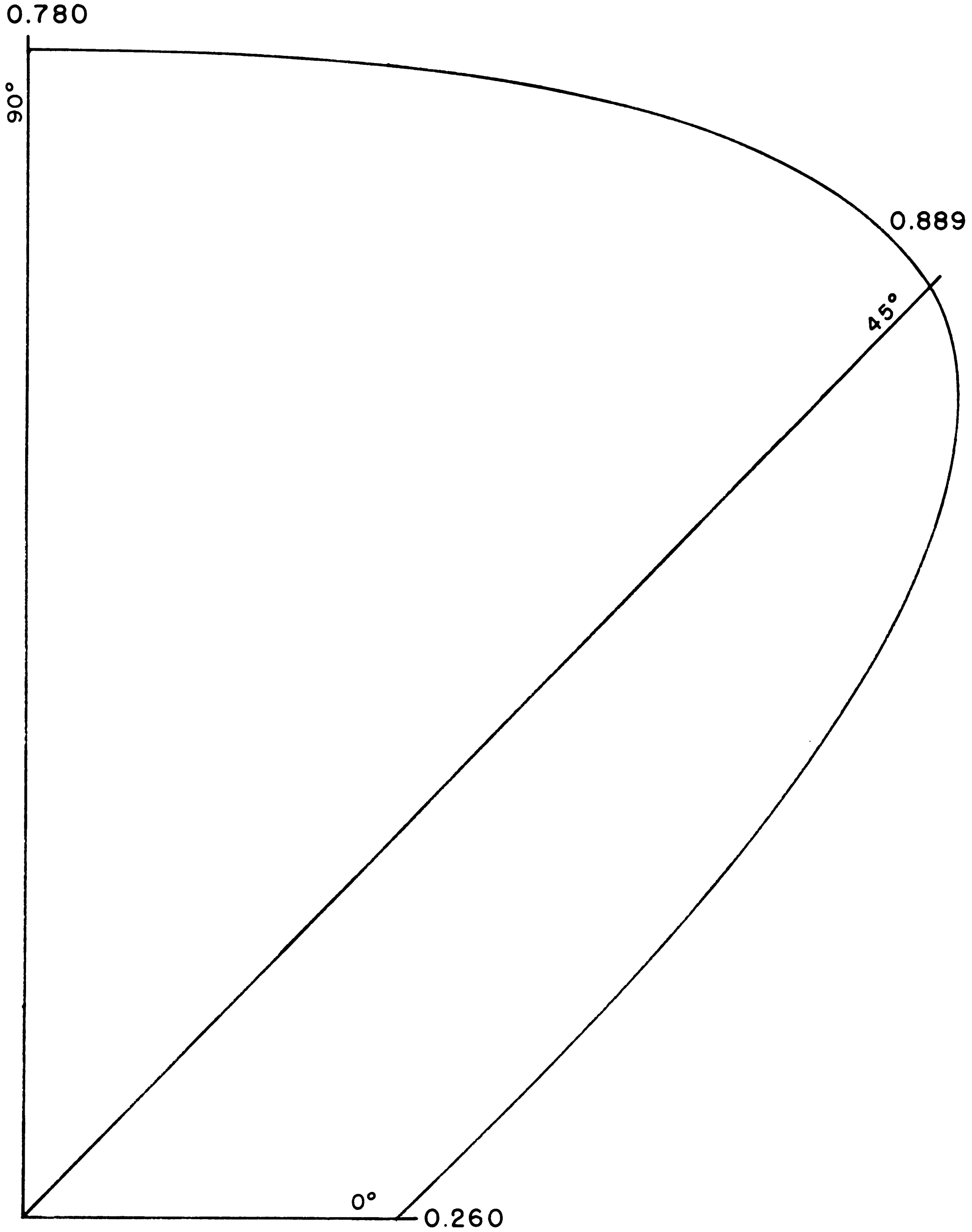
Lift Coefficients By Wind Angle
60 Foot Mobile Home



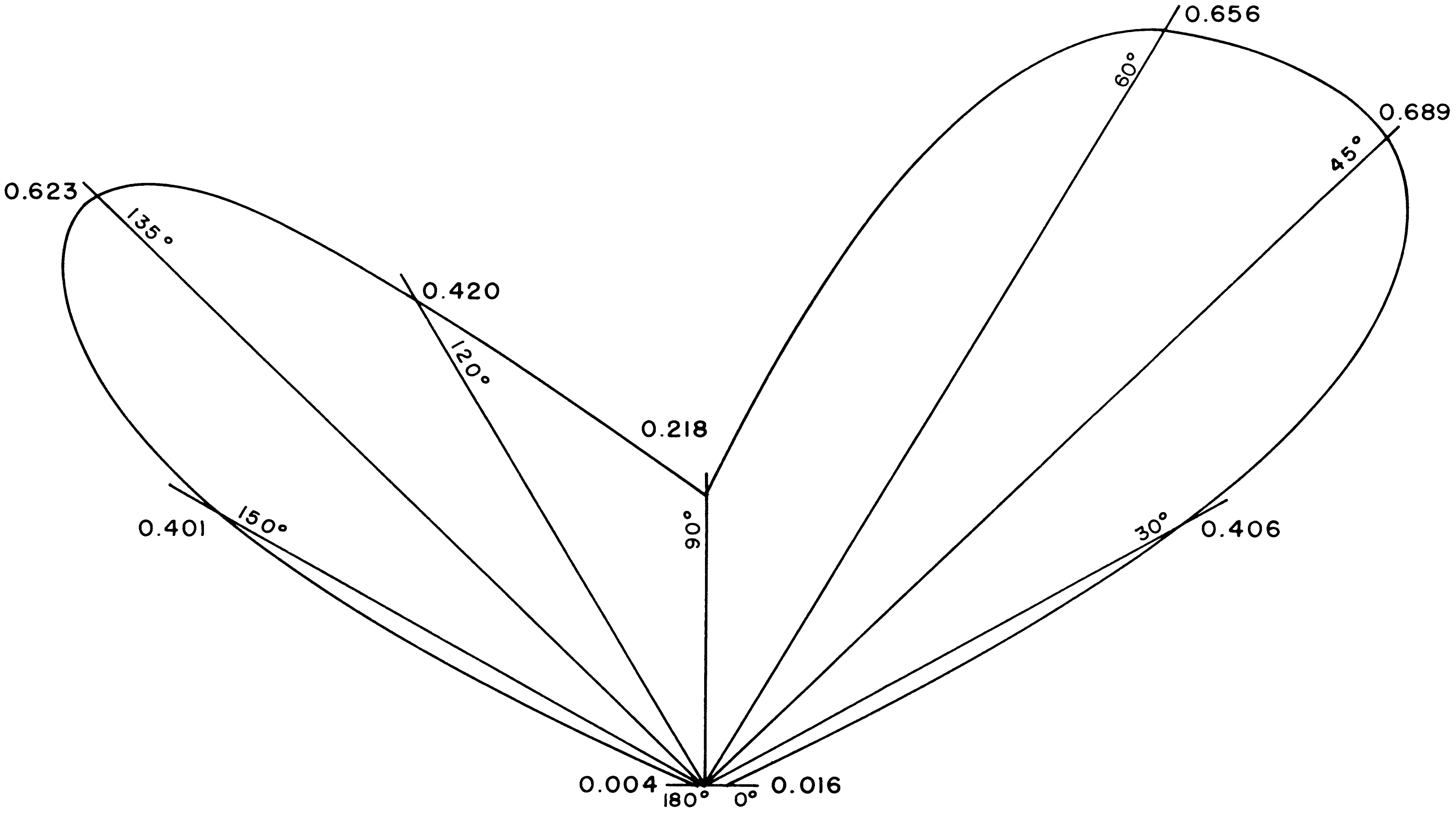
Lift Coefficients By Wind Angle
40 Foot Mobile Home



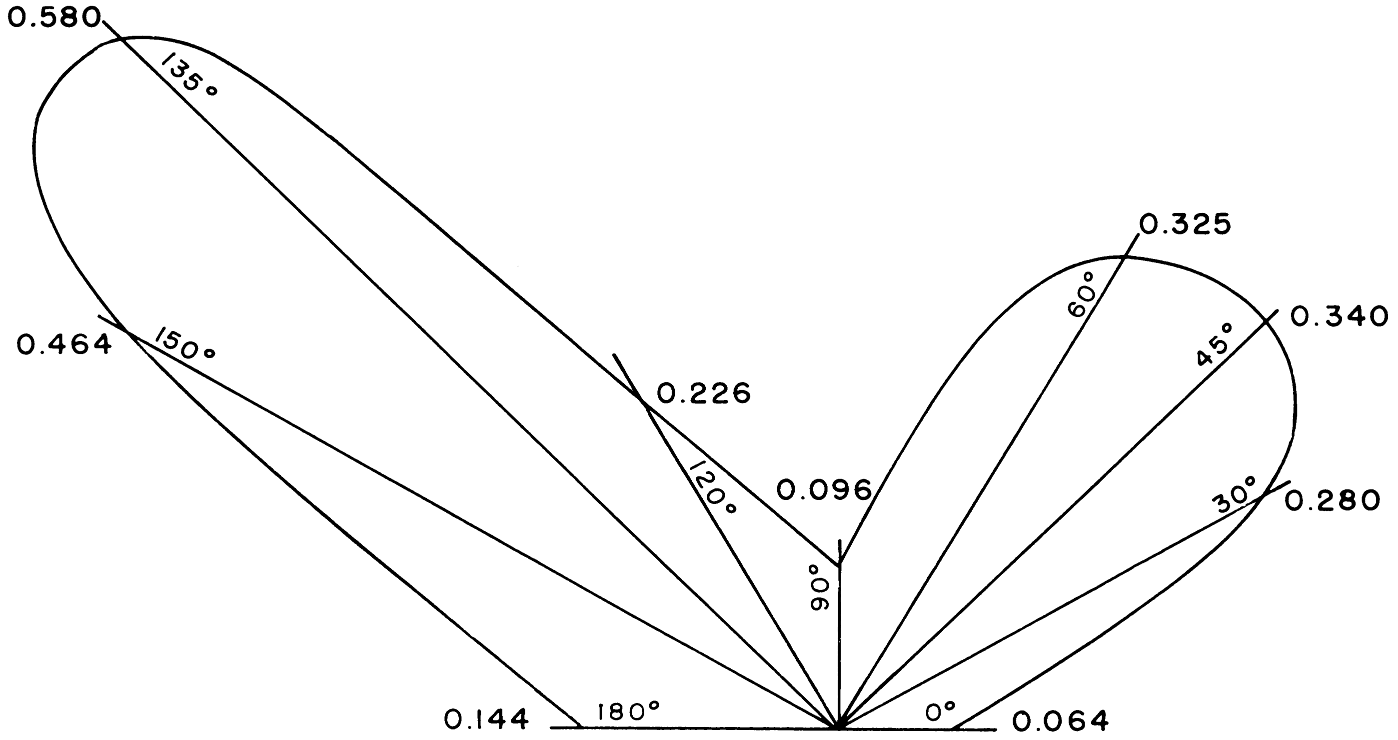
Lift Coefficients By Wind Angle
25 Foot Mobile Home



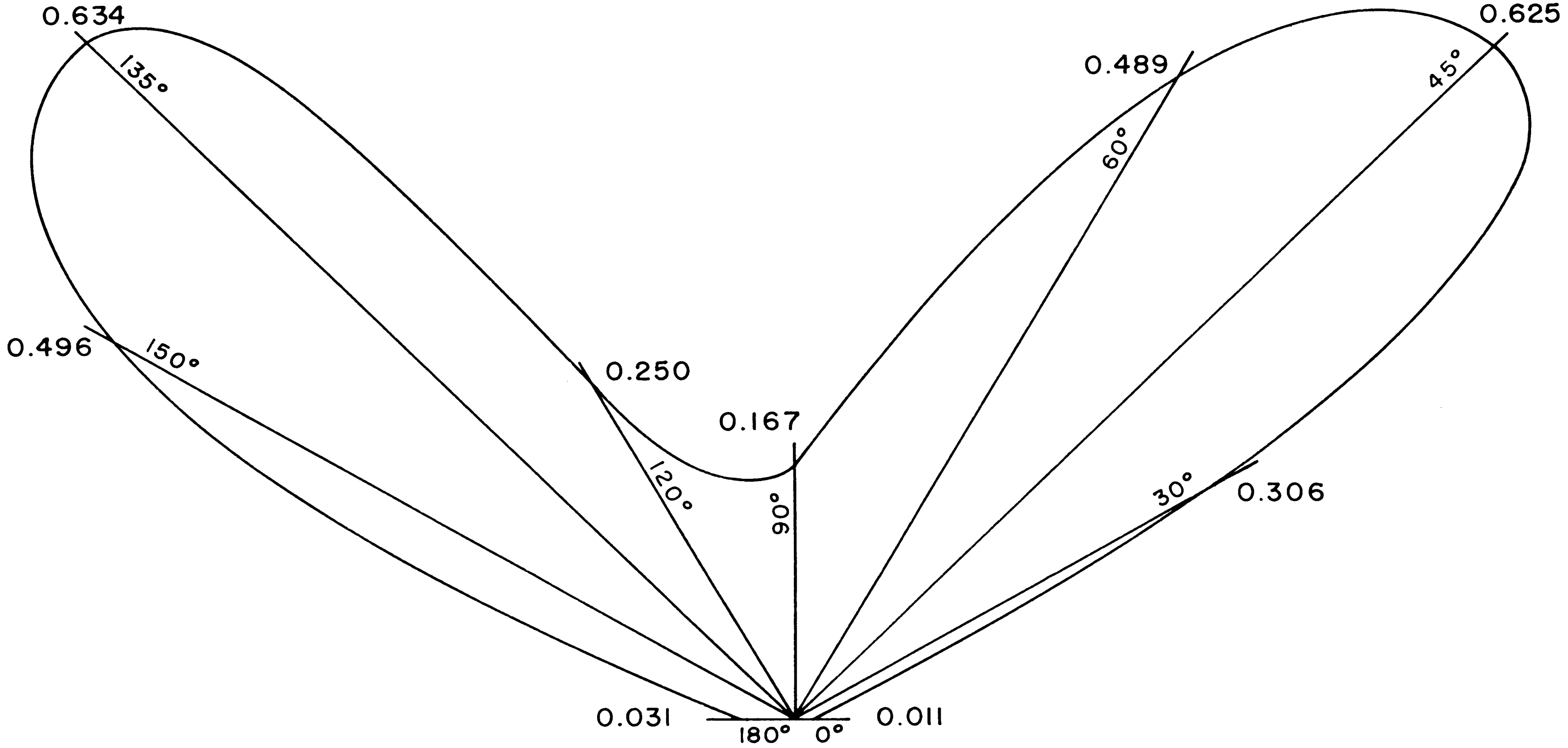
Lift Coefficients By Wind Angle
50 Foot Mobile Home With Skirt
(Only 0, 45, and 90 Degree Wind Angles Tested)



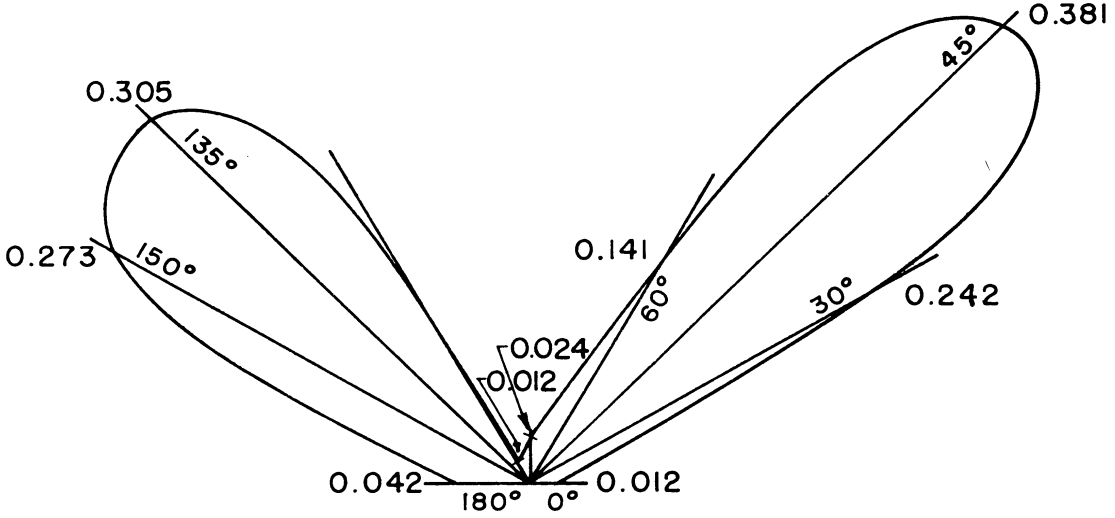
Lift Coefficients By Wind Angle
50 Foot Mobile Home With Awning
Along One Half Length



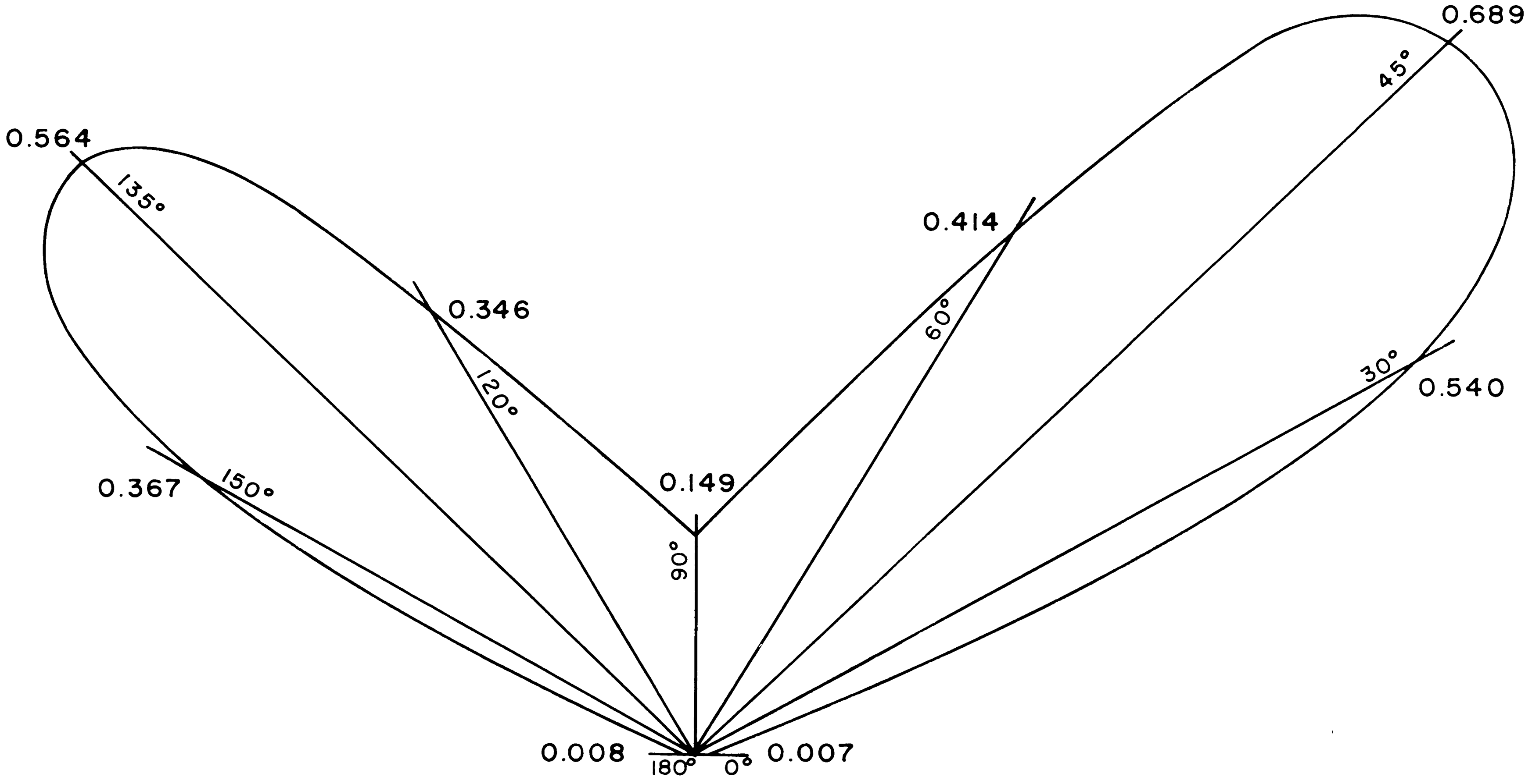
Lift Coefficients By Wind Angle
50 Foot Mobile Home With Cabana
Along One Half Length



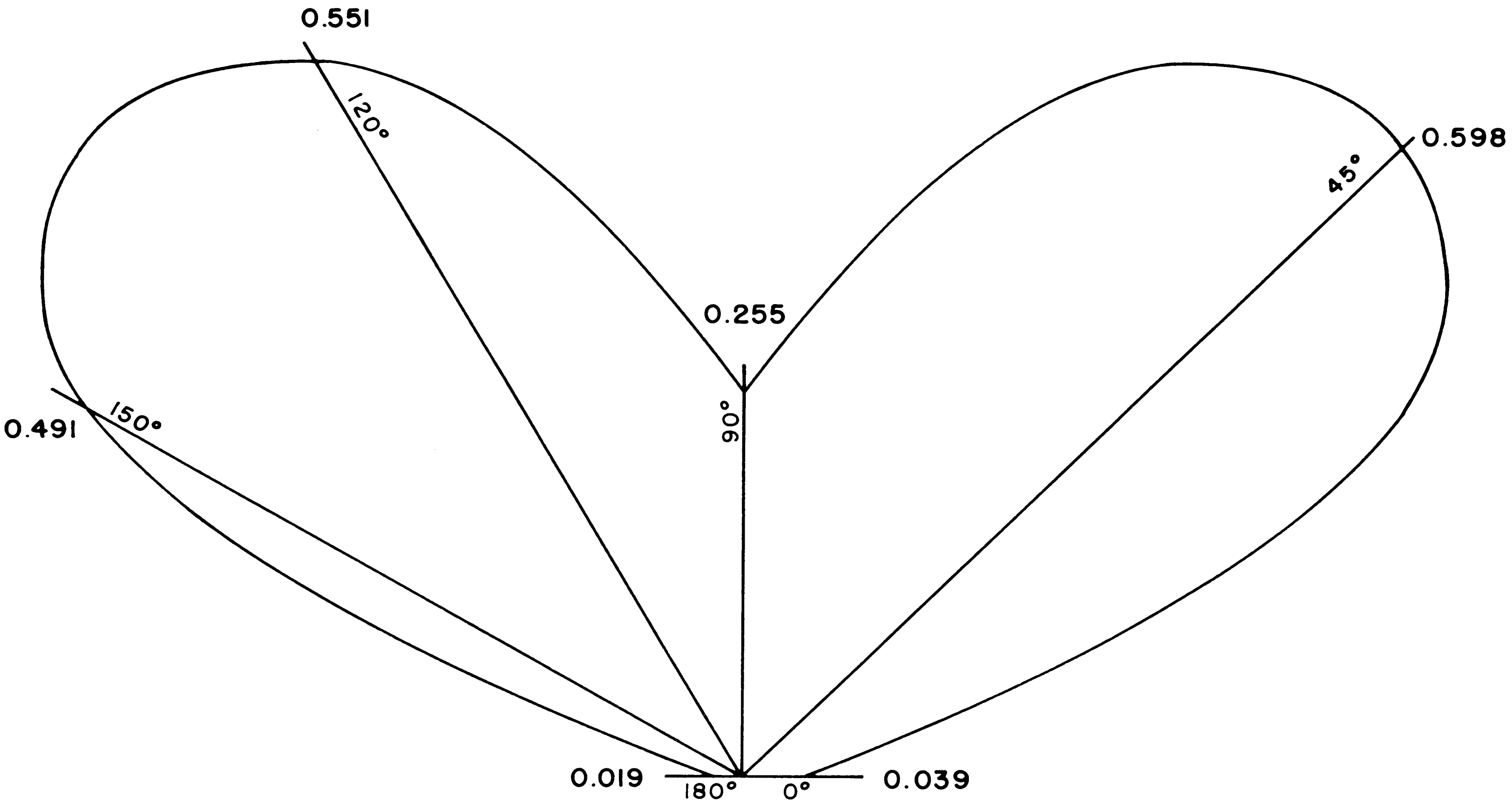
Lift Coefficients By Wind Angle
50 Foot Mobile Home With
Expando Unit



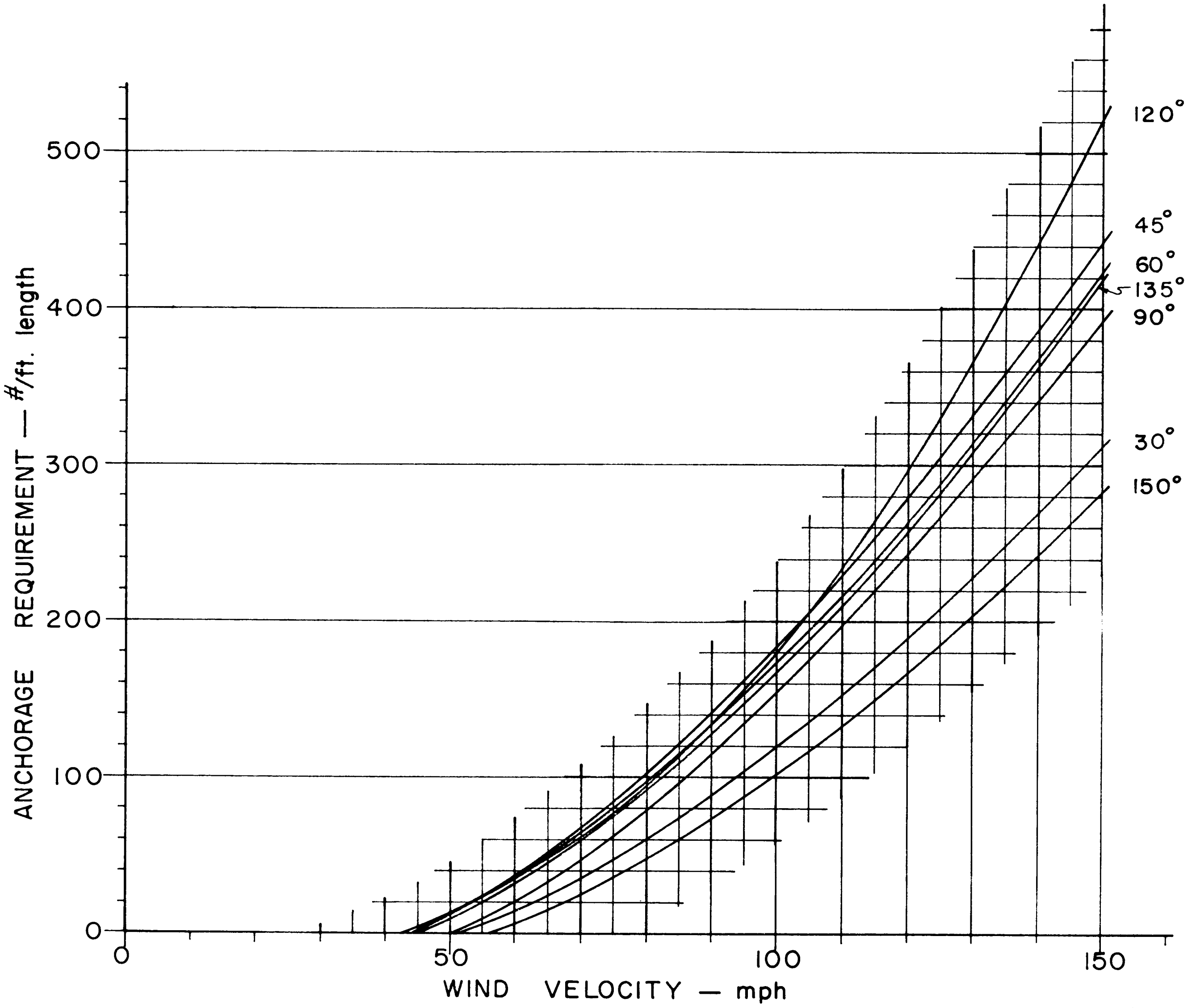
Lift Coefficients By Wind Angle
50 Foot Mobile Home With
Bottom Covered



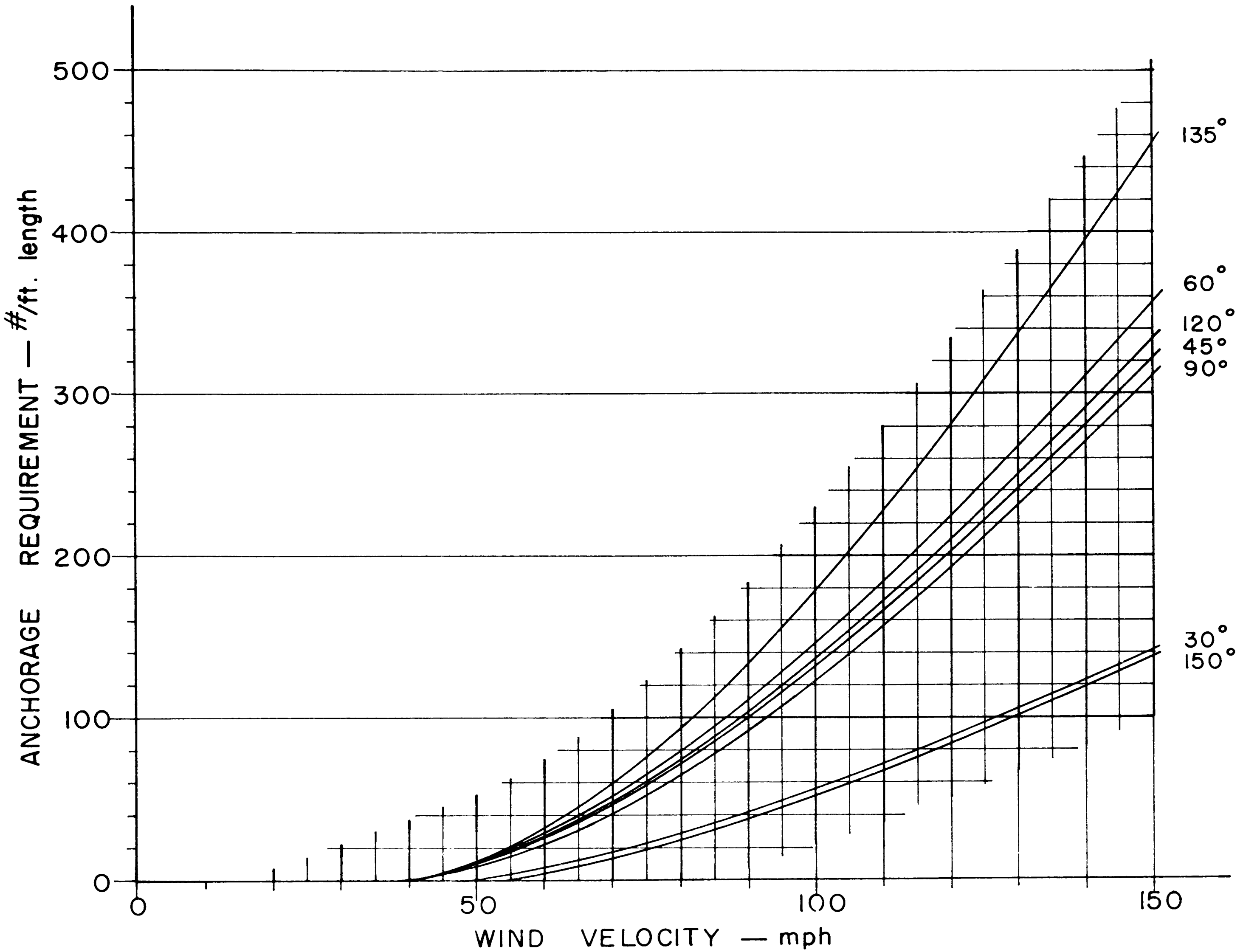
Lift Coefficients By Wind Angle
50 Foot Mobile Home With
Clerestory Top



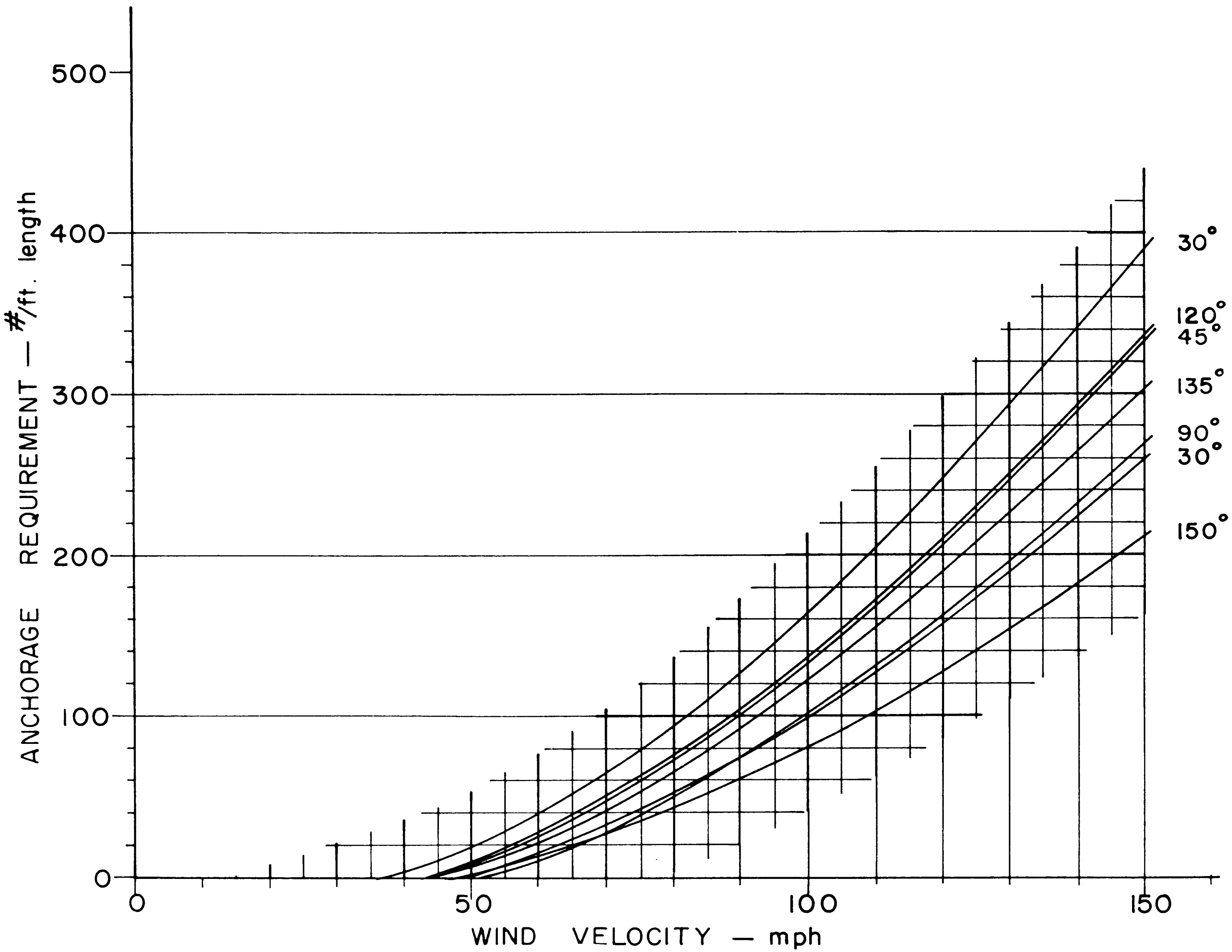
Lift Coefficients By Wind Angle
50 Foot Mobile Home With Nose Down
(Only 0, 45, 90, 120, 150 and 180
Degree Wind Angles Tested)



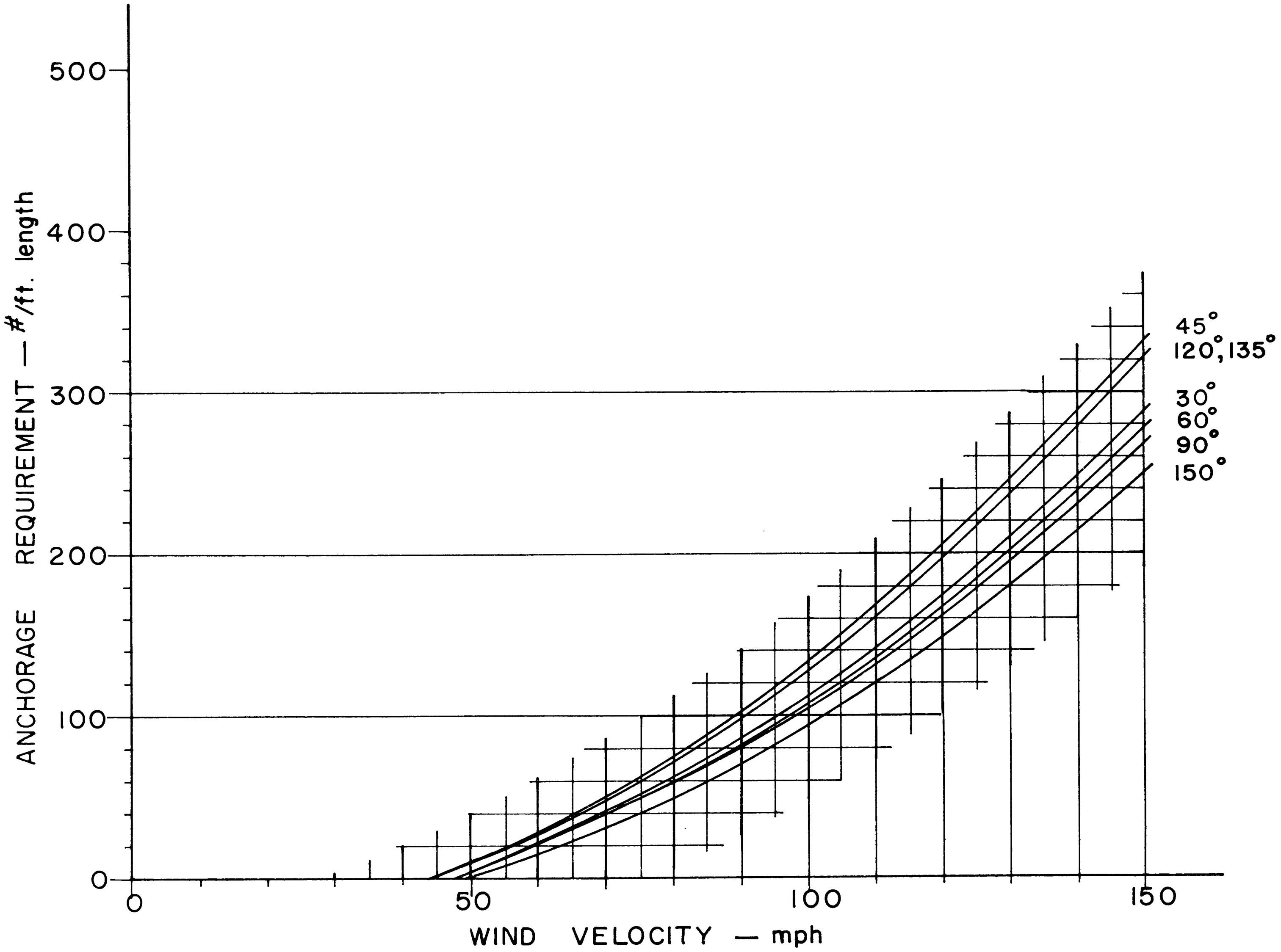
Wind Velocity - Anchorage Requirement Curves
For Various Wind Angles
50 Foot Mobile Home



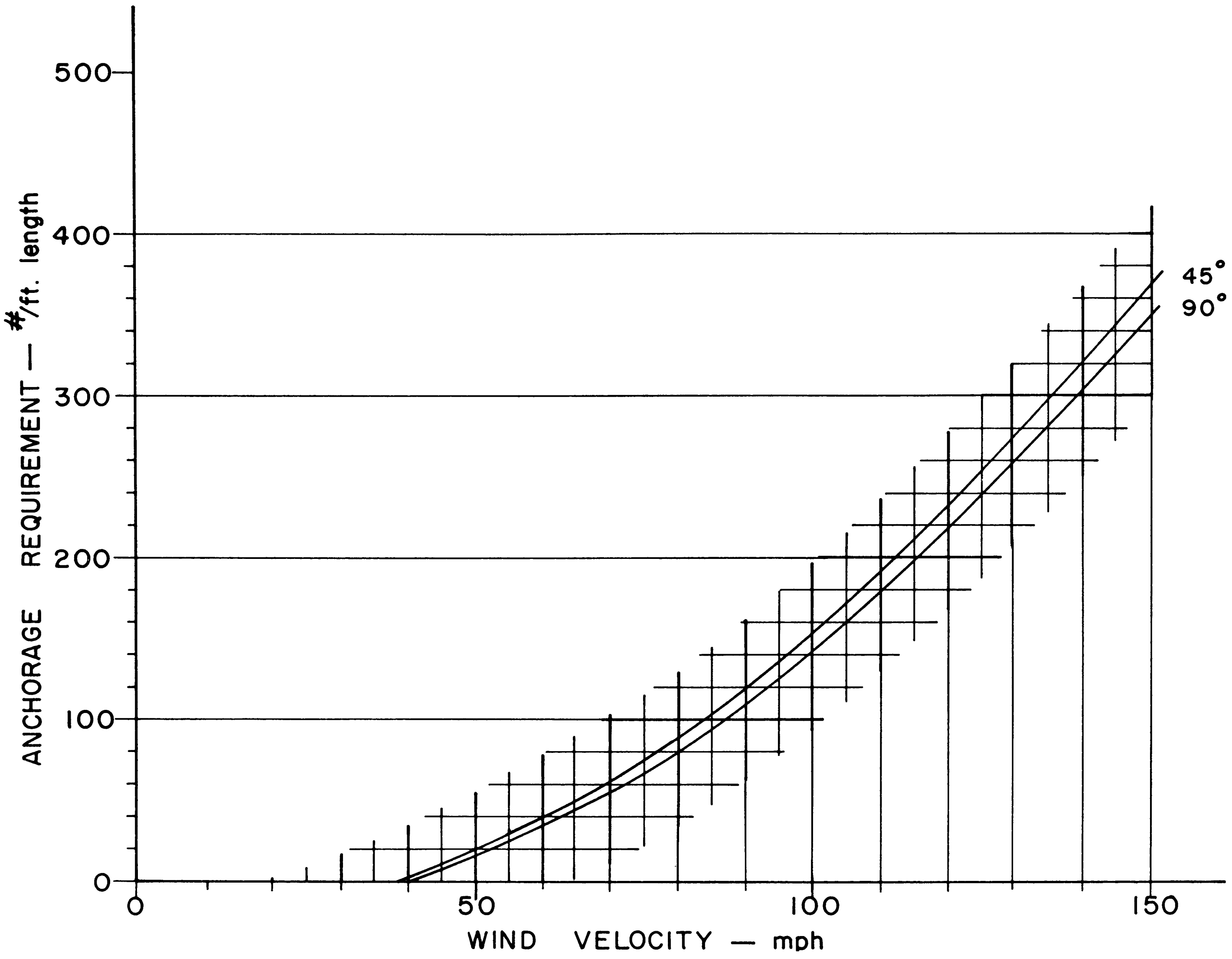
Wind Velocity - Anchorage Requirement Curves
For Various Wind Angles
60 Foot Mobile Home



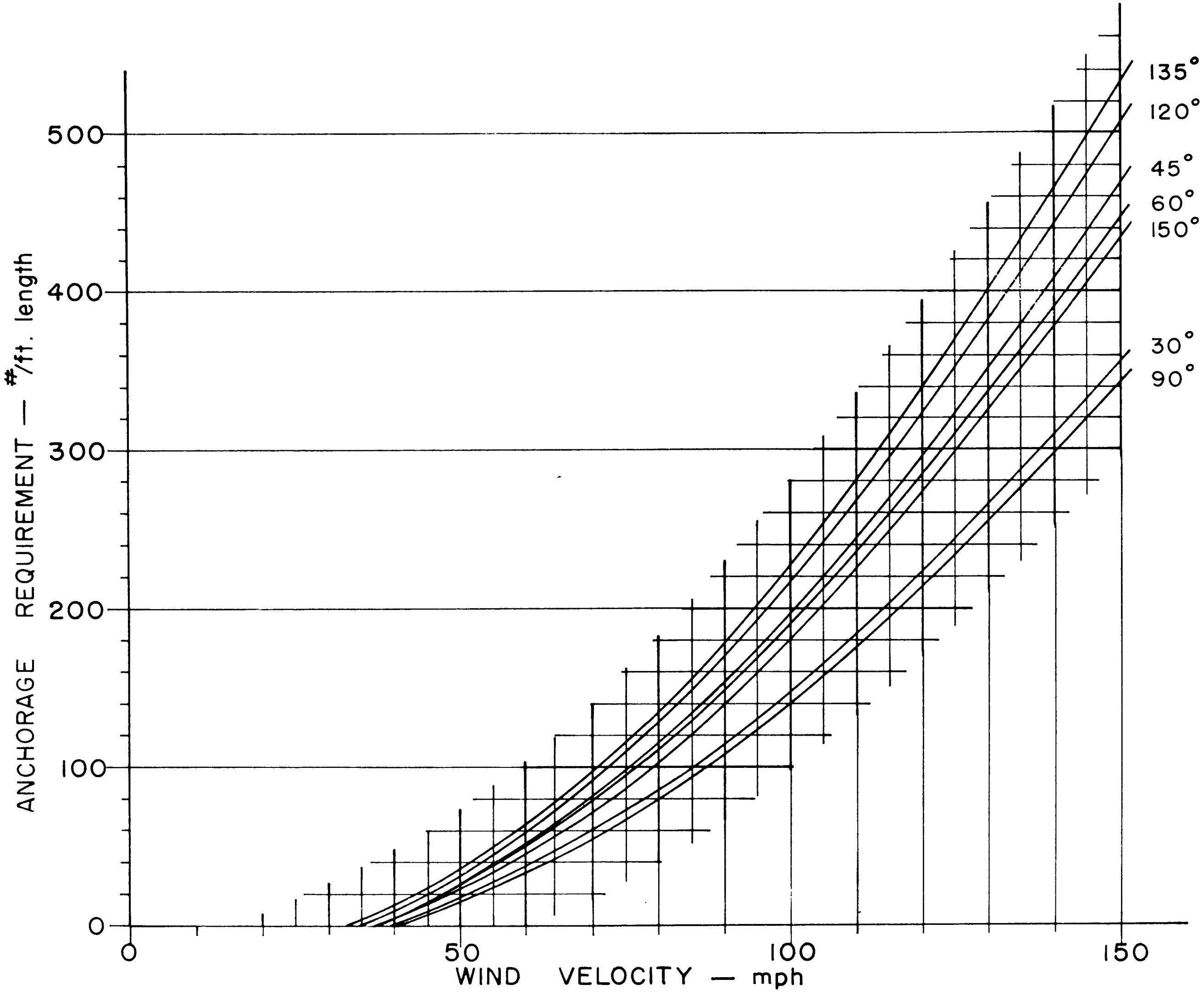
Wind Velocity - Anchorage Requirement Curves
For Various Wind Angles
40 Foot Mobile Home



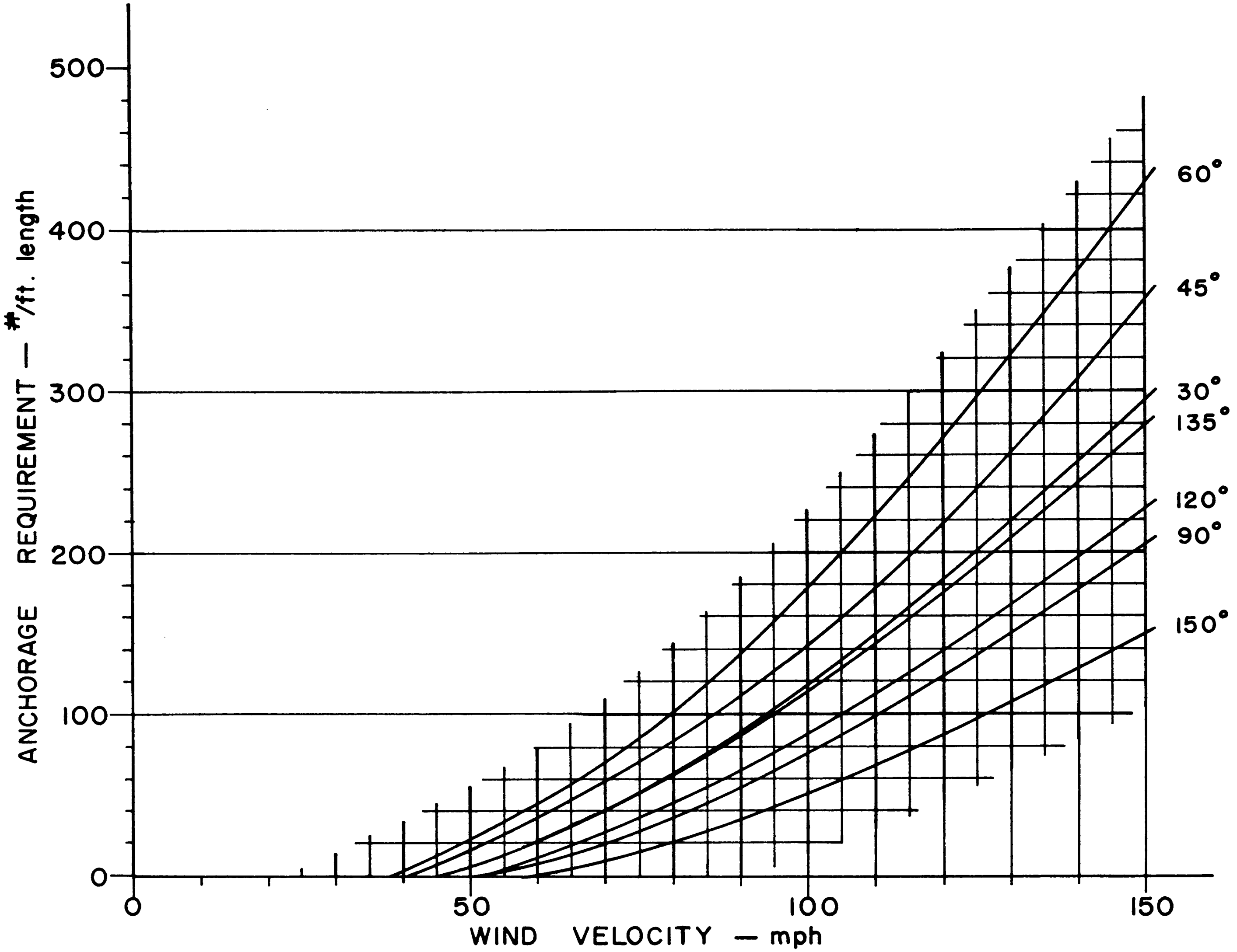
Wind Velocity - Anchorage Requirement Curves
For Various Wind Angles
25 Foot Mobile Home



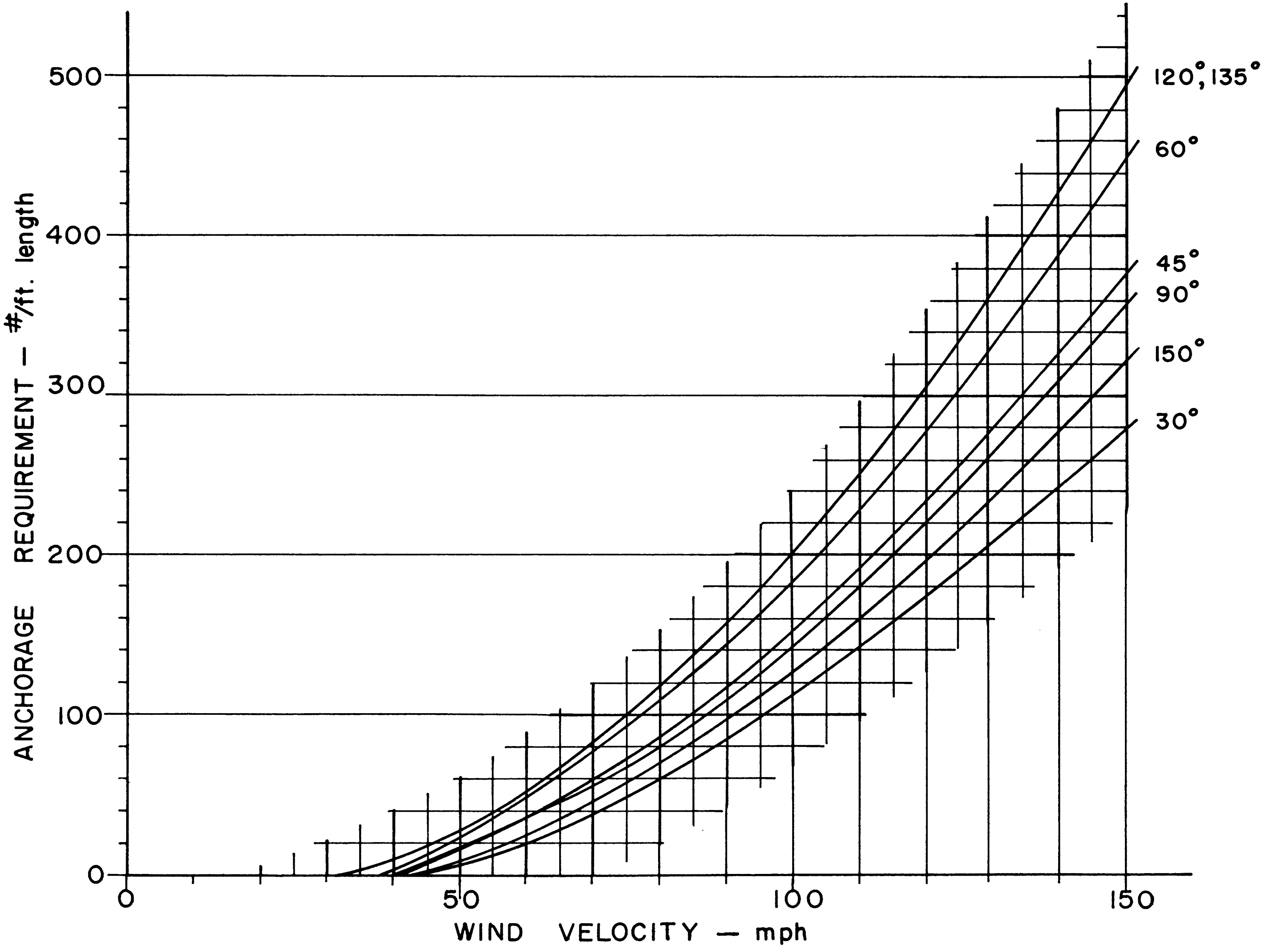
Wind Velocity - Anchorage Requirement Curves
For Various Wind Angles
50 Foot Mobile Home With Skirt



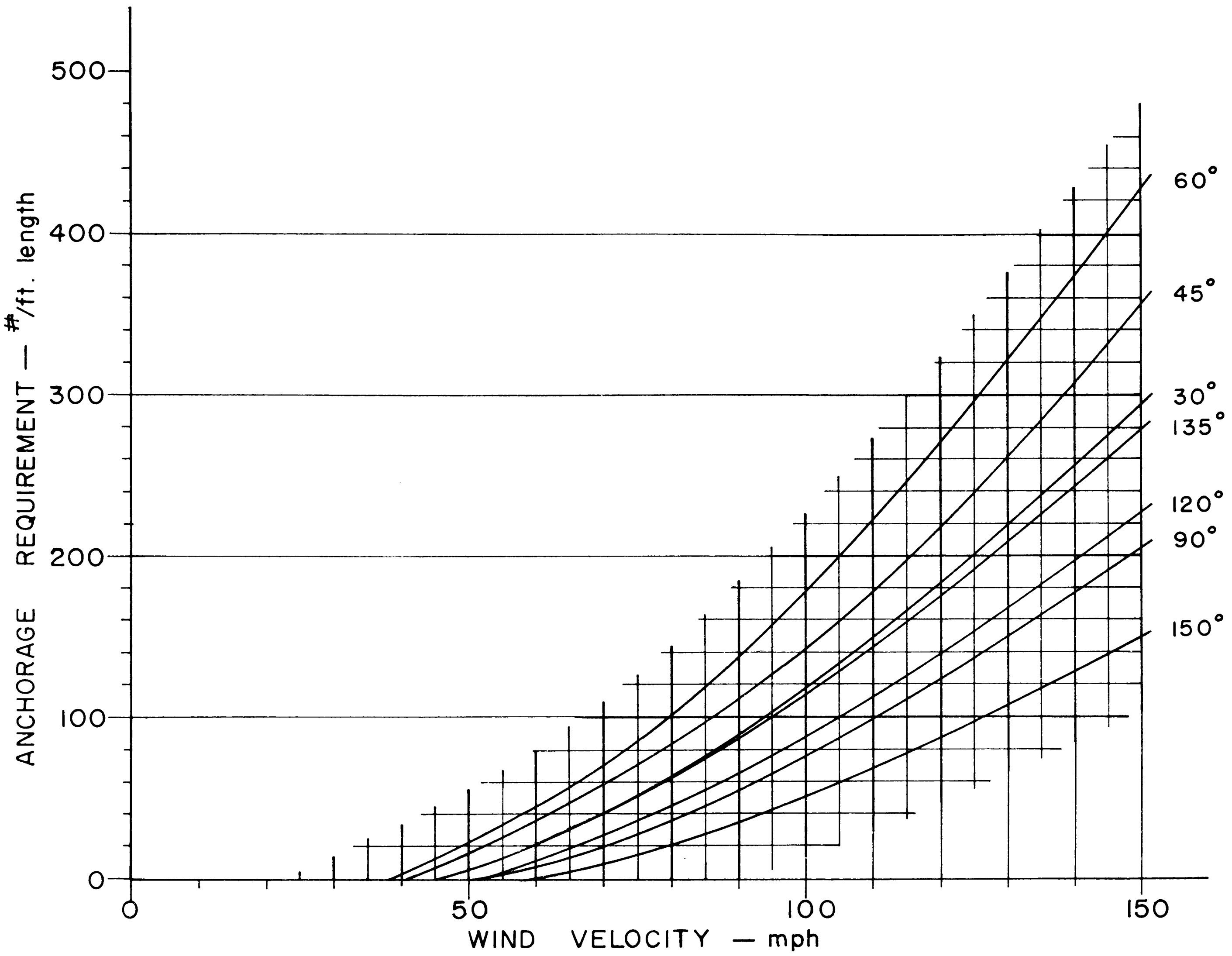
Wind Velocity - Anchorage Requirement Curves
For Various Wind Angles
50 Foot Mobile Home With Awning
Along One Half Length



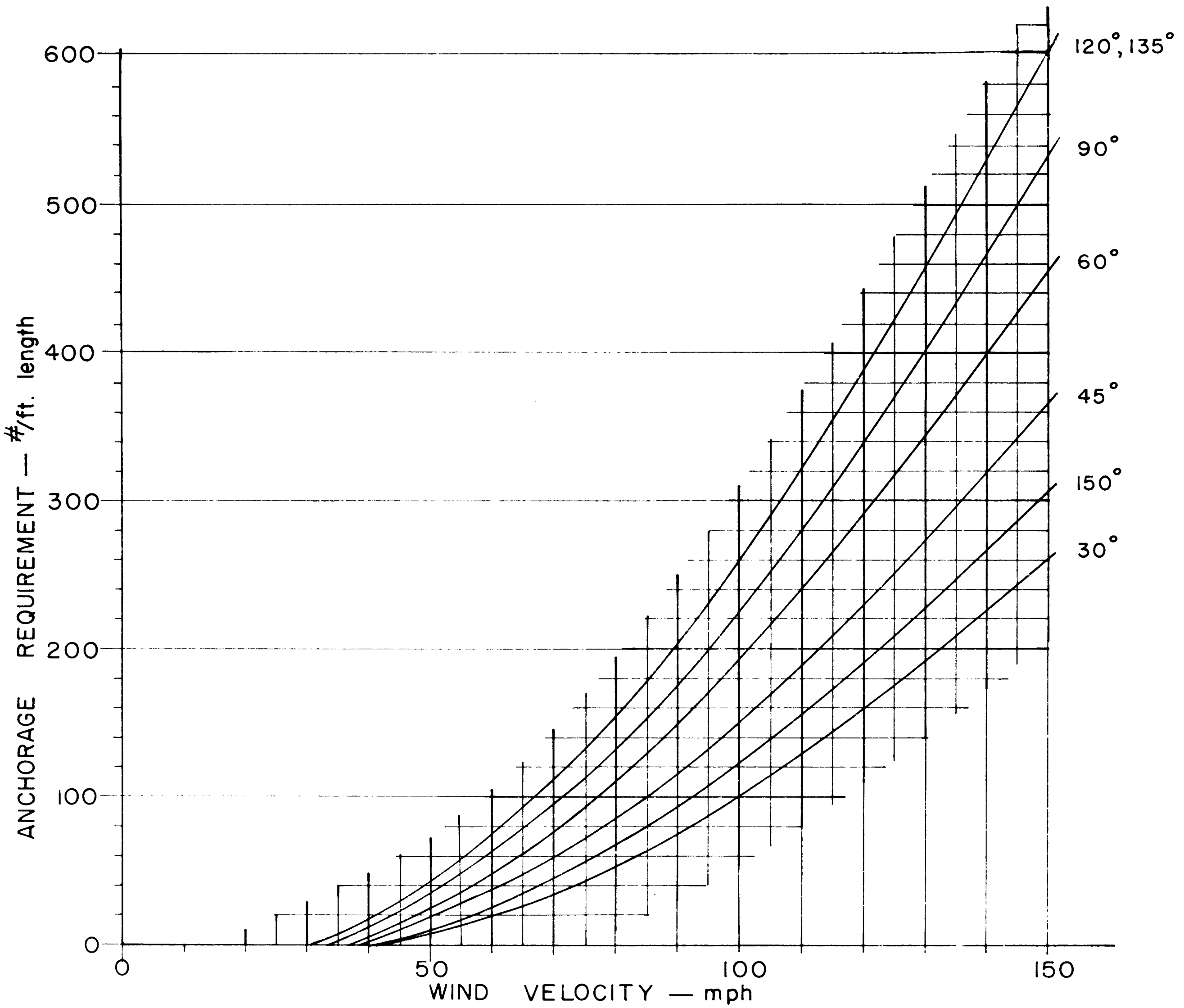
Wind Velocity - Anchorage Requirement Curves
For Various Wind Angles
50 Foot Mobile Home With Cabana
Along One Half Length



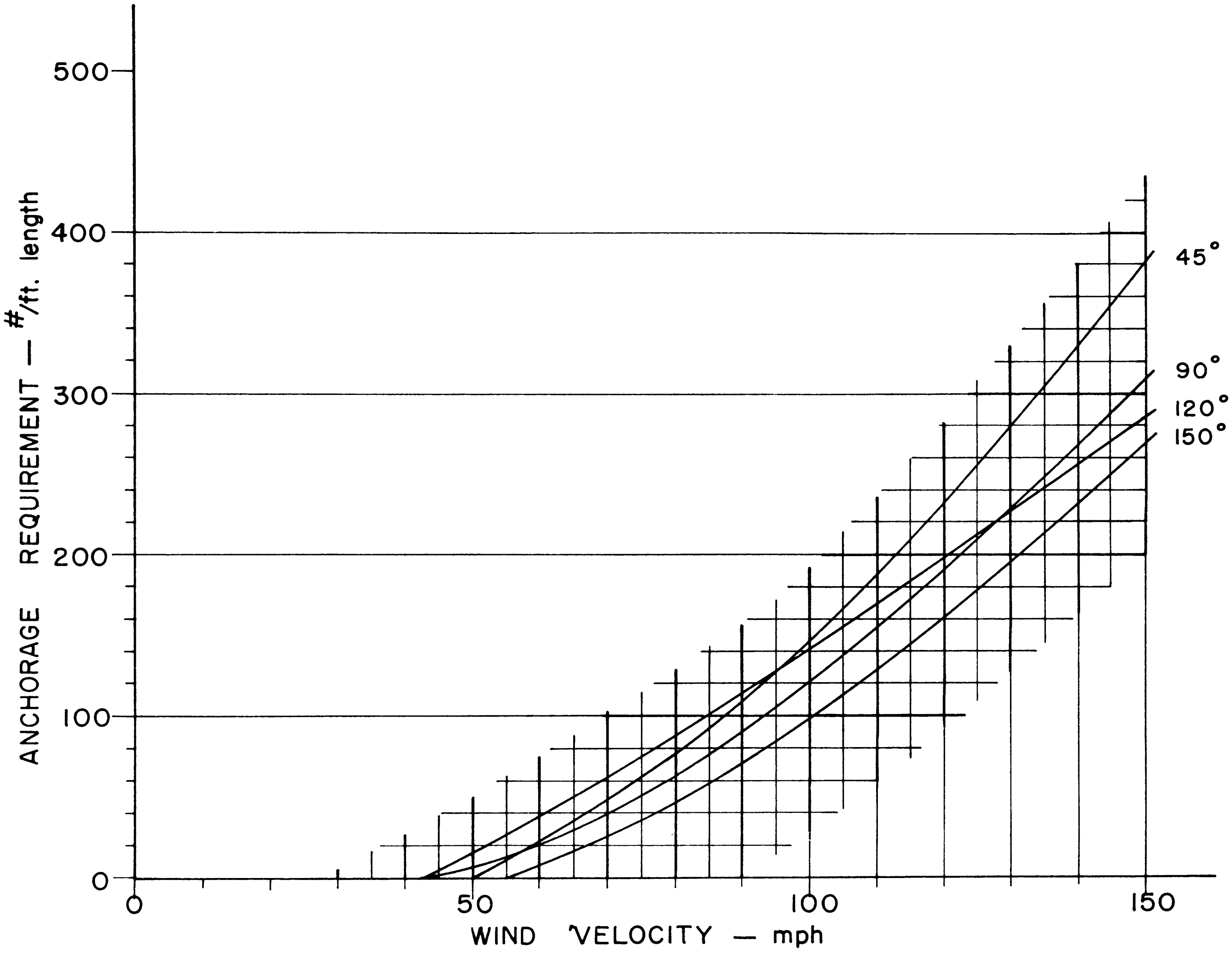
Wind Velocity - Anchorage Requirement Curves
For Various Wind Angles
50 Foot Mobile Home With Expando Unit



Wind Velocity - Anchorage Requirement Curves
For Various Wind Angles
50 Foot Mobile Home With Bottom Covered



Wind Velocity - Anchorage Requirement Curves
For Various Wind Angles
50 Foot Mobile Home With Clerestory Top



Wind Velocity - Anchorage Requirement Curves
For Various Wind Angles
50 Foot Mobile Home With Nose Down

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[1] Brekke, Guttorm N., "Wind Pressures in Various Areas of the United States," Building Materials and Structures Report 152, United States Department of Commerce, National Bureau of Standards, 1959.

[2] Thom, Herbert C. S., "Distribution of Extreme Winds in the United States," Journal of the Structural Division, Proceedings of ASCE, Vol. 86, No. ST4, April, 1960, p. 11.

[3] Chien, N., Feng, Y., Wang, H. J., Siao, T. T., Wind-Tunnel Studies of Pressure Distribution on Elementary Building Forms, Iowa Institute of Hydraulic Research, State University of Iowa, 1951.

[4] Woodruff, Glenn B. and Kozak, John J., "Wind Forces on Structures: Fundamental Considerations," Journal of the Structural Division, Proceedings of ASCE, Vol. 84, No. ST4, July, 1958.

5 Sherlock, R. H., "Variation of Wind Velocity and Gusts with Height," Transactions of ASCE, Vol. 118, 1953, p. 463.

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