Supplemental to Report No. SRR-91
Final Report

DEVELOPMENT OF A RELIABILITY-BASED DESIGN PROCEDURE FOR HIGH-MAST LIGHTING STRUCTURAL SUPPORTS IN COLORADO

SELECTION GUIDE
AASHTO DETAIL CATEGORY *E*

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March 2006

COLORADO DEPARTMENT OF TRANSPORTATION

SAFETY AND TRAFFIC ENGINEERING BRANCH
AND
STAFF BRIDGE BRANCH

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by

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Sponsored by the
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CHAPTER 1
RELIABILITY-BASED DESIGN METHODOLOGY

1.1 Design Methodology Background

The design method consists of several design charts for four factors considered in its development. Included among these factors are variations in outside diameter, wall thickness, section length or height of the structure, and luminaire structure projected area. Excluded are two of the more sensitive factors, structure damping and wind velocity coefficient of variation (COV) for the parent distribution. Thus, at this time, a damping ratio for the structure is assumed to be 1% and the wind velocity COV is assumed to be 25%. Other studies, however, have concluded that an appropriate COV for wind-loading is 35%, thus yielding an approximate COV of 25% for wind velocity. The luminaire structure weight is not considered as a factor in the design charts. The luminaire structure weight was determined to not severely affect the fatigue life or reliability of the HML structural support. The luminaire projected area was more critical in this aspect. Any luminaire structure that would be used would have a given weight and projected area. Thus, from these two factors it is concluded that the projected area of the luminaire structure is more important.

The first set of design charts, given in Section A.2, were developed based on changing factors independently of each other based on the benchmark HML structural support as given in Section 1.2. Target fatigue life's were varied for 25 years, 50 years, and 75 years. As a result of this, reliability indices were calculated for each variation of a particular factor and mean wind velocity for a given target fatigue life. 50-year wind velocities, or design wind velocities, were unable to be produced based on the sole knowledge of the parent wind velocity distribution. Thus, the use of the design charts requires the knowledge of the mean, or average, wind velocity for a particular site in Colorado. The appendix of this report provides an initial summary of mean wind velocities for various sites in Colorado. However, the data used to compile this summary is limited and should not be used exclusively. Use of the design charts, based on a given factor or parameter value such as outside diameter, target fatigue life and mean wind velocity produces a reliability index. A summary of the design method used in conjunction with the design charts given in Section A.2 is presented in Section 1.3.

The first set of design charts were developed based on the assumption that only a single parameter, such as wall thickness, is changing from the benchmark HML structure as outlined in Section 1.2. As this is likely never the case, a second set of design charts for multiple parameter variations have been developed and are given in Section A.3. The design charts given in Section A.3 do not require the use of the design charts given in Section A.2. A summary of the design method used in conjunction with the design charts given in Section A.3 is presented in Section 1.4.

1.2 Benchmark HML Structural Support

To develop the design method, a benchmark, or representative, HML structural support was needed. Structural drawings were provided by CDOT. This submittal was in reference to the I-25 / Broadway Viaduct Phase II project and prepared by Dynalectric Company. Figure 1-1 illustrates the benchmark HML structural support used in this project. For each section shown in Figure 1-1, a corresponding table of properties for that given section is given in Tables 1-1 – 1-4.

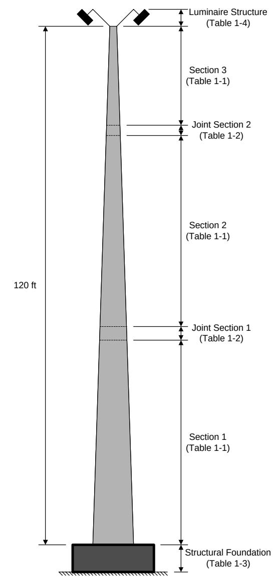

Figure 1-1: Benchmark HML Structural Support in Colorado

Table 1-1 provides the properties for pole sections 1 – 3 from Figure 1-1. Properties for each section were directly obtained from the specification submittals obtained from CDOT.

Property	Section 1	Section 2	Section 3
Total Length	53.49 ft (16.30 m)	52.52 ft (16.01 m)	20.16 ft (6.14 m)
Bottom Outside Diameter	26.00 in (660.40 mm)	19.50 in (495.30 mm)	13.00 in (330.20 mm)
Top Outside Diameter	18.51 in (470.15 mm)	12.15 in (308.61 mm)	10.18 in (258.57 mm)
Taper	0.14 $^{in}/_{ft}$ (11.67 $^{mm}/_{m}$)	0.14 $^{in}/_{ft}$ (11.67 $^{mm}/_{m}$)	0.14 $^{in}/_{ft}$ (11.67 $^{mm}/_{m}$)
Wall Thickness	0.375 in (9.525 mm)	0.250 in (6.350 mm)	0.2391 in (6.0731 mm)
Yield Strength	65 ksi (448 MPa)	65 ksi (448 MPa)	55 ksi (379 MPa)
Modulus of Elasticity	29,000 ksi (200 GPa)	29,000 ksi (200 GPa)	29,000 ksi (200 GPa)
Mass Density	15.235 $^{slug}/_{ft^3}$ (7850 $^{kg}/_{m^3}$)	15.235 $^{slug}/_{ft^3}$ (7850 $^{kg}/_{m^3}$)	15.235 $^{slug}/_{ft^3}$ (7850 $^{kg}/_{m^3}$)
Poisson's Ratio	0.3	0.3	0.3

Table 1-1: HML Structural Support Properties – Pole Sections

Table 1-2 provides the properties for joint sections 1 and 2 from Figure 1-1. As indicated in the specifications, these joint sections are characterized as lap-splices, one section overlapping the other section. Thus, all section properties are identical to those given in Table 1-1. These joints do however affect the stiffness of the structure due to the overlapping of the sections as indicated with the effective wall thickness given in Table 1-2. Properties for each joint section were directly obtained from the specification submittals obtained from CDOT.

Property	Joint Section 1	Joint Section 2
Section Type	Lap-Splice	Lap-Splice
Sections Joined	1 – 2	2 – 3
Effective Wall Thickness	0.625 in (15.875 mm)	0.4891 in (12.4231 mm)
Overlap Length	3.492 ft (1.064 m)	2.683 ft (0.818 m)
Height of Overlap	53.49 ft (16.30 m)	102.59 ft (31.25 m)

Table 1-2: HML Structural Support Properties – Joint Sections

Table 1-3 provides the properties for the structural foundation. The foundation is modeled as a set of translational and rotational springs. For this project, springs were assumed to have a stiffness representing a fixed structural boundary condition for the foundation. A fixed structural boundary condition is a conservative assumption in determining the fatigue life of the structure.

Property	Spring Stiffness
Axial Stiffness	1×10^{30} lb/in (1.75×10^{29} kN/m)
Lateral Stiffness	1×10^{30} lb/in (1.75×10^{29} kN/m)
Overturning Stiffness	1×10^{30} lb*in/rad (1.75×10^{29} kN*m/rad)

Table 1-3: HML Structural Support Properties – Boundary Support Conditions

Table 1-4 provides the properties for the luminaire structure mounted at the top of the HML structural support. Properties for the luminaire structure were directly obtained from the specification submittals obtained from CDOT.

Property	Luminaire Structure
Mounting Height	120 ft (36.576 m)
Weight	666 lbs (302 kg)
Projected Area	11.50 ft^2 (1.0684 m^2)

Table 1-4: HML Structural Support Properties – Luminaire Structure Properties

1.3 Design Method – Single Variable

The design charts of Section A.2 were developed based on the assumption that only a single parameter, or factor such as outside diameter, is changing from the benchmark HML structure given in Section 1.2. If, however, it is known that only one parameter is being varied from the benchmark HML structure, then the design procedure for determining the single parameter based on a target reliability index, β_{HML}, can be summarized as:

Step 1: Determine detail category at the base of the HML structural support based on AASHTO specifications: *E* or *E′*.
Step 2: Select single parameter to be varied: pole outside diameter, pole wall thickness, pole length, or luminaire structure projected area.
Step 3: Determine the appropriate mean wind velocity, target fatigue life, and target reliability index, β_{HML}.
Step 4: Using the appropriate design chart based on the single parameter and target fatigue life, determine the single parameter value based on mean wind velocity and target reliability index, β_{HML}.
Step 5: Determine all physical properties of HML structural support.

Step 5 requires that the properties of the benchmark HML structural support be modified. Table 1-5 provides the properties for this benchmark structure based on the four design parameters. Tables 1-6 through 1-8 provide further details for pole outside diameter, pole wall thickness, and pole section length. Table 1-9 provides further details for luminaire structure projected area. If the single parameter varied is the pole outside diameter, pole wall thickness, or pole section length then modification of the parameter must be done for all points along the height of the pole. For example, if from Step 4, the pole outside diameter was found to be 20.8 in (528.32 mm) for a particular mean wind velocity, target fatigue life, and target reliability index then the corresponding reduction in all outside diameters along the height of the pole would be 20%. Thus, reading from Table 1-6, all other outside diameters for the three sections that comprise the pole could be easily determined. For cases in which the percent reduction or increase is not given in the tables, linear interpolation is permitted.

Property	Benchmark HML Structural Support
Outside Diameter (Base of Structure)	26.00 in (660.40 mm)
Wall Thickness (Base of Structure)	0.375 in (9.525 mm)
Total Length	120 ft (36.576 m)
Luminaire Structure Projected Area	11.50 ft^2 (1.0684 m^2)

Table 1-5: Benchmark HML Structural Support Properties

Pole Outside Diameter		Benchmark Properties (No Change)	-30%	-20%	-10%	+10%	+20%	+30%
Section 1	Bottom of Section	26.00 in (660.40 mm)	18.2 in (462.28 mm)	20.8 in (528.32 mm)	23.4 in (594.36 mm)	28.6 in (726.44 mm)	31.2 in (792.48 mm)	33.8 in (858.52 mm)
	Top of Section	18.51 in (470.15 mm)	12.957 in (329.11 mm)	14.808 in (376.12 mm)	16.659 in (423.14 mm)	20.361 in (517.17 mm)	22.212 in (564.18 mm)	24.063 in (611.20 mm)
Section 2	Bottom of Section	19.50 in (495.30 mm)	13.65 in (346.71 mm)	15.6 in (396.24 mm)	17.55 in (445.77 mm)	21.45 in (544.83 mm)	23.4 in (594.36 mm)	25.35 in (643.89 mm)
	Top of Section	12.15 in (308.61 mm)	8.505 in (216.03 mm)	9.72 in (246.89 mm)	10.935 in (277.75 mm)	13.365 in (339.47 mm)	14.58 in (370.33 mm)	15.795 in (401.19 mm)
Section 3	Bottom of Section	13.00 in (330.20 mm)	9.1 in (231.14 mm)	10.4 in (264.16 mm)	11.7 in (297.18 mm)	14.3 in (363.22 mm)	15.6 in (396.24 mm)	16.9 in (429.26 mm)
	Top of Section	10.18 in (258.57 mm)	7.126 in (181.00 mm)	8.144 in (206.86 mm)	9.162 in (232.71 mm)	11.198 in (284.43 mm)	12.216 in (310.29 mm)	13.234 in (336.14 mm)

Table 1-6: Pole Outside Diameter Properties

Pole Wall Thickness	Benchmark Properties (No Change)	-30%	-20%	-10%	+10%	+20%	+30%
Section 1	0.375 in (9.525 mm)	0.2625 in (6.6675 mm)	0.3 in (7.62 mm)	0.3375 in (8.5725 mm)	0.4125 in (10.478 mm)	0.45 in (11.43 mm)	0.4875 in (12.383 mm)
Section 2	0.250 in (6.350 mm)	0.175 in (4.445 mm)	0.2 in (5.08 mm)	0.225 in (5.715 mm)	0.275 in (6.985 mm)	0.3 in (7.62 mm)	0.325 in (8.255 mm)
Section 3	0.2391 in (6.0731 mm)	0.16737 in (4.2512 mm)	0.19128 in (4.8585 mm)	0.21519 in (5.4658 mm)	0.26301 in (6.6805 mm)	0.28692 in (7.2878 mm)	0.31083 in (7.8951 mm)

Table 1-7: Pole Wall Thickness Properties

Pole Section Length	Benchmark Properties (No Change)	-30%	-20%	-10%	+10%	+20%	+30%
Section 1	53.49 ft (16.30 m)	37.443 ft (11.4126 m)	42.792 ft (13.0430 m)	48.141 ft (14.6734 m)	58.839 ft (17.9341 m)	64.188 ft (19.5645 m)	69.537 ft (21.1949 m)
Section 2	52.52 ft (16.01 m)	36.764 ft (11.2057 m)	42.016 ft (12.8065 m)	47.268 ft (14.4073 m)	57.772 ft (17.6089 m)	63.024 ft (19.2097 m)	68.276 ft (20.8105 m)
Section 3	20.16 ft (6.14 m)	14.112 ft (4.3013 m)	16.128 ft (4.9158 m)	18.144 ft (5.5303 m)	22.176 ft (6.7592 m)	24.192 ft (7.3737 m)	26.208 ft (7.9882 m)
Total Length	120 ft (36.576 m)	84 ft (25.6032 m)	96 ft (29.2608 m)	108 ft (32.9184 m)	132 ft (40.2336 m)	144 ft (43.8912 m)	156 ft (47.5488 m)

Table 1-8: Pole Section Length Properties

Luminaire Structure Projected Area	Benchmark Properties (No Change)	-30%	-20%	-10%	+10%	+20%	+30%
Projected Area	11.50 ft^2 (1.0684 m^2)	8.05 ft^2 (0.74787 m^2)	9.2 ft^2 (0.85471 m^2)	10.35 ft^2 (0.96155 m^2)	12.65 ft^2 (1.1752 m^2)	13.8 ft^2 (1.2821 m^2)	14.95 ft^2 (1.3889 m^2)

Table 1-9: Luminaire Structure Projected Area Properties

Based on a verification of the design method for a single variable, the design charts are, on average, approximately 1% conservative. Due to the complexity of the analysis, however, it is possible to achieve reliability indices that are less than those determined from the design charts. However, the resulting reliability indices will still be within 5% and thus still considered reasonably accurate.

1.4 Design Method – Multiple Variables

The design charts of Section A.3 were developed based on assumed values for pole outside diameter, pole length, and luminaire structure projected area. Reasonable values were assumed for these three variables. Pole wall thickness values were varied for several combinations of the three assumed variables. Prior conversations with CDOT personnel conveyed the desire to select the pole outside diameter and pole wall thickness for a given pole length and luminaire structure. Thus, the design procedure for determining the parameters based on a target reliability index, β_{HML}, can be summarized as:

Step 1: Determine detail category at the base of the HML structural support based on AASHTO specifications: *E* or *E′*.
Step 2: Select pole length, or height of the HML structural support, from three choices: 100 ft (30.48 m), 120 ft (36.576 m), or 140 ft (42.672 m).
Step 3: Select luminaire structure projected area from three choices: 7.5 ft^2 (0.6968 m^2), 9.5 ft^2 (0.8826 m^2), or 11.5 ft^2 (1.0684 m^2).
Step 4: Determine the appropriate mean wind velocity, target fatigue life, and target reliability index, β_{HML}.
Step 5: Select an appropriate pole outside diameter from three choices: 23.4 in (594.36 mm), 26 in (660.4 mm), or 28.6 in (726.44 mm).
Step 6: Using the appropriate design chart based on the pole outside diameter, mean wind velocity, and target fatigue life, determine the pole wall thickness based on the pole length, luminaire structure projected area, and target reliability index, β_{HML}.

Step 7: Determine all physical properties of HML structural support.

Step 7 requires that the properties of the typical HML structural support be modified. As before, Table 1-5 provides the properties for this typical structure based on the four design parameters. Tables 1-6 through 1-8 provide further details for pole outside diameter, pole wall thickness, and pole section length. Table 1-9 provides further details for luminaire structure projected area. The same procedure as was explained for Step 5 of the design method for a single variable is applicable to Step 7 for the design method for multiple variables.

Based on a verification of the design method for multiple variables, the design charts are, on average, approximately 2% conservative. Due to the complexity of the analysis, however, it is possible to achieve reliability indices that are less than those determined from the design charts. However, the resulting reliability indices will still be within 1 – 2% and thus still considered reasonably accurate.

1.5 Example 1 – Single Variable

Illustrative example 1 considers an HML structural support design for a mean wind velocity of 12 MPH (19.31 km/hr) with a target fatigue life of 50 years and detail category *E*. A target reliability index, β_{HML}, of 3.0 is desired for the HML structural support. Only pole wall thickness is considered to vary from the benchmark HML structural support used in this study. All other factors, pole outside diameter, pole length, and luminaire structure projected area, are considered to be consistent with the benchmark HML structural support. Therefore, there values are 26 in (660.4 mm), 120 ft (36.576 m), and 11.5 ft^2 (1.0684 m^2) respectively.

Using the design charts for a single variable from the supplemental report for detail category *E* with a mean wind velocity of 12 MPH (19.31 km/hr), a target fatigue life of 50 years, and a target reliability index of 3.0, the pole wall thickness is determined as shown in Figure 1-2.

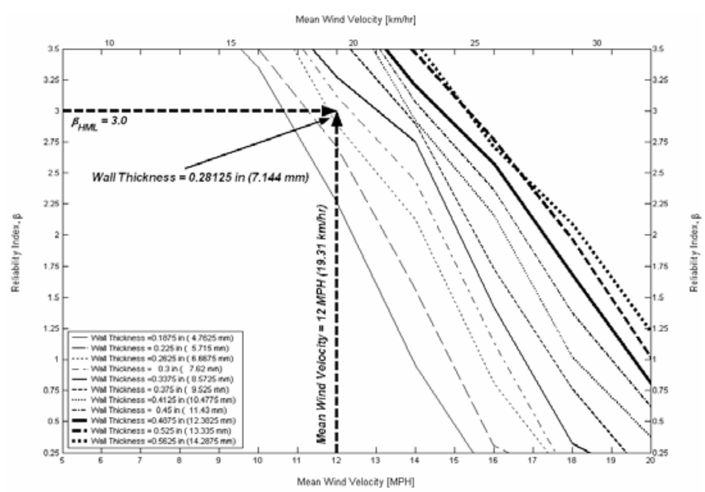

Figure 1-2: Example 1 – Single Variable

Based on the results from Figure 1-2, the wall thickness has been reduced 25% to 0.28125 in (7.144 mm) compared to the benchmark HML structure wall thickness of 0.375 in (9.525 mm) at the base of the structure.

The target reliability index for the structure is 3.0. A full analysis using the computer simulation program written by the authors determined that the reliability index of the structure used in this example was 2.972. Recall that the design method proposed for a single variable produces, on average, designs that are approximately 1% conservative. For this example, the target reliability index of 3.0 is 0.9% higher than the calculated reliability index of 2.972.

The final step in the design process that must be completed is the adjustment of the physical properties of the HML structural support, or Step 5 in the design process for a single variable. The wall thickness of the entire structure must be reduced by 25% at all points. There were no changes to the outside diameter, length, or luminaire structure projected area. Therefore, their values remain at 26 in (660.4 mm), 120 ft (36.576 m), and 11.5 ft^2 (1.0684 m^2) respectively.

1.6 Example 2 – Multiple Variables

Illustrative example 2 considers an HML structural support design for a mean wind velocity of 14 MPH (22.53 km/hr) with a target fatigue life of 50 years and detail category *E′*. A target reliability index, β_{HML}, of 2.5 is desired for the HML structural support. Initial requirements for pole length and luminaire structure projected area are 100 ft (30.48 m) and 9.5 ft^2 (0.8826 m^2) respectively. Values for pole outside diameter and pole wall thickness are thus needed for the desired target reliability index. It is assumed that the pole outside diameter is set at 23.4 in (594.36 mm). Thus, the pole wall thickness is considered to vary.

Using the design charts for multiple variables from the supplemental report for detail category *E′* with a mean wind velocity of 14 MPH (22.53 km/hr), a target fatigue life of 50 years, a pole outside diameter of 23.4 in (594.36 mm), and a target reliability index of 2.5, the pole wall thickness is determined as shown in Figure 1-3.

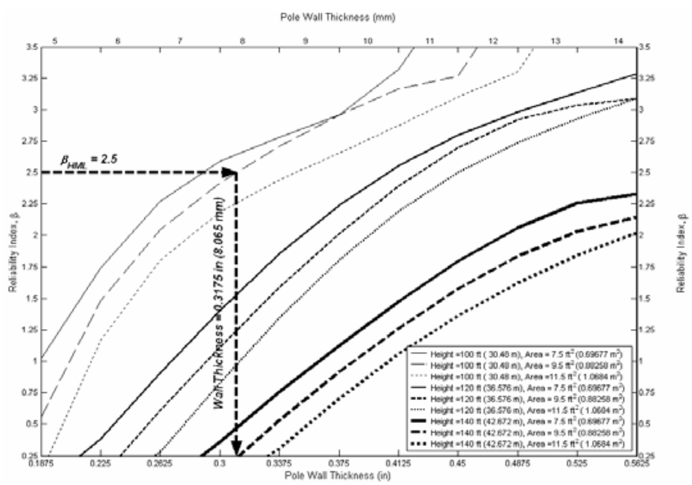

Figure 1-3: Example 2 – Multiple Variables

Based on the results from Figure 1-3, the wall thickness has been decreased 15.33% to 0.3175 in (8.065 mm) compared to the benchmark HML structure wall thickness of 0.375 in (9.525 mm) at the base of the structure. Furthermore, the pole outside diameter has been reduced 10% to 23.4 in (594.36 mm) compared to the benchmark HML structure outside diameter of 26 in (660.4 mm) at the base of the structure. The pole length has been decreased 16.7% to 100 ft (30.48 m) compared to the benchmark HML structure length of 120 ft (36.576 m). Finally, the luminaire structure projected area has been decreased 17.4% to 9.5 ft^2 (0.8826 m^2) compared to the benchmark luminaire structure projected area of 11.5 ft^2 (1.0684 m^2).

The target reliability index for the structure is 2.5. A full analysis using the computer simulation program written by the authors determined that the reliability index of the structure used in this example was 2.472. Recall that the design method proposed for multiple variables produces, on average, designs that are approximately 2% conservative. For this example, the target reliability index of 2.5 is 1.1% higher than the calculated reliability index of 2.472.

Again, one final step in the design process that must be completed is the adjustment of the physical properties of the HML structural support, or Step 7 in the design process for multiple variables. The outside diameter and wall thickness of the entire structure must be decreased by 10% and 15.33%, respectively, at all points.

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APPENDIX A

A.1 Selected Mean Wind Velocities

A preliminary survey of readily available data for locations within Colorado was conducted to determine mean wind velocities at the characteristic height of 33 ft (10 m). This data was obtained from the Plains Organization for Wind Energy Resources (POWER) and Energy and Environmental Research Center (EERC) at the University of North Dakota. This data is available online with the Internet address provided under the caption of the figure. Data was recorded hourly. Table A-1 summarizes the data obtained and Figure A-1 provides the locations given in the table.

Location	Record Length	Mean Wind Velocity MPH (km/hr)	Mean Standard Deviation MPH (km/hr)	Mean Turbulence Intensity (COV) %
Boulder	4 years	8.38 (13.49)	1.57 (2.53)	18.68
Calhan	1 year	13.03 (20.97)	2.39 (3.85)	18.34
Cheyenne Wells	1 year	13.29 (21.39)	2.34 (3.77)	17.59
Genoa	1 year	13.72 (22.08)	2.38 (3.83)	17.31
Gobblers Knob (East)	1 year	13.45 (21.65)	2.25 (3.62)	16.74
Gobblers Knob (West)	1 year	12.90 (20.76)	2.29 (3.69)	17.73
Livermore	1 year	14.93 (24.03)	2.94 (4.73)	19.71
Mesa de Maya	1 year	12.08 (19.44)	2.31 (3.72)	19.09
Pawnee Buttes	1 year	16.21 (26.09)	2.48 (3.99)	15.31
Peetz	1 year	14.34 (23.08)	2.49 (4.01)	17.37
Wauneta	1 year	15.04 (24.20)	2.50 (4.02)	16.62

Table A-1: Mean Wind Velocities for Selected Locations in Colorado

Figure A-1: Selected Locations in Colorado

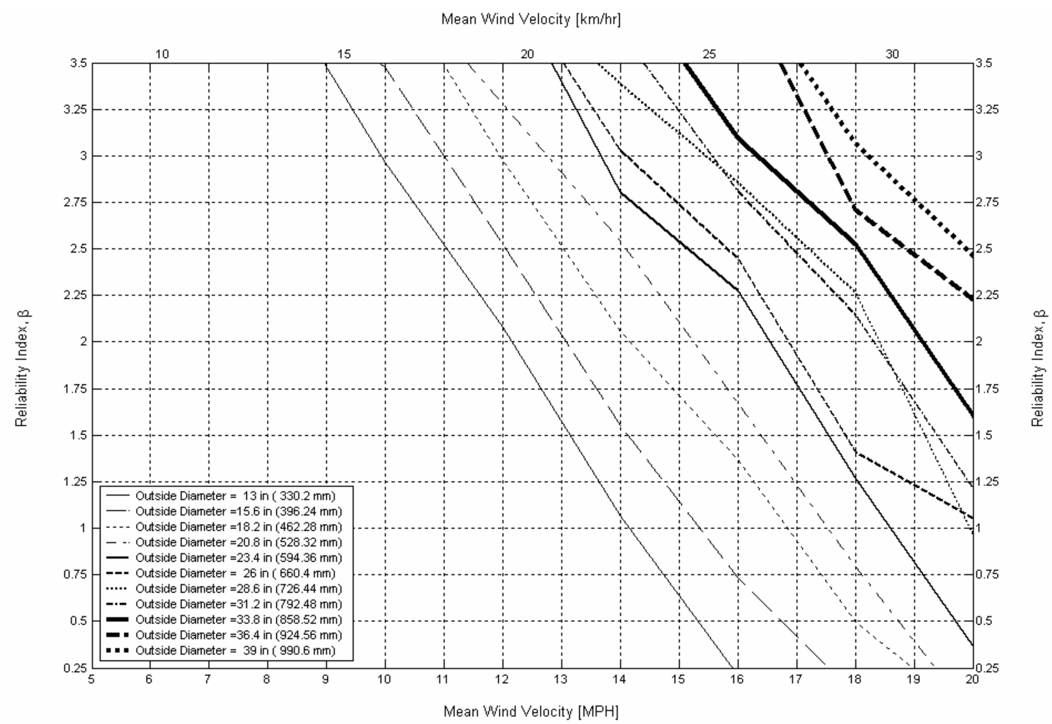
(Table A-1 and Figure A-1: http://www.undeerc.org/wind/winddb/COwindsites.asp)

A.2 Design Charts – Single Variable

The design charts for a single variable and detail category *E*, designated by "SV-*E*" in the figure title, that follow, for variations in pole outside diameter, pole wall thickness, pole length, luminaire structure weight, and luminaire structure projected area, are those referenced in Section 1.3.

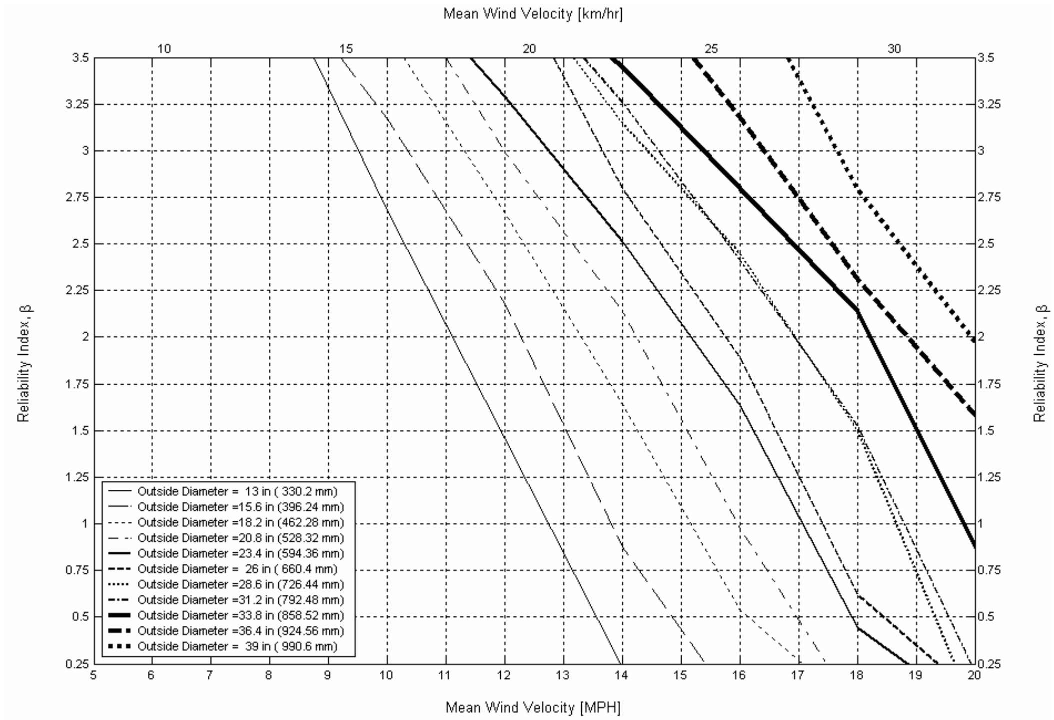
Pole Outside Diameter

Figures A-2 (a), (b), and (c) provide the design charts for changes in the pole outside diameter for target fatigue life's of 25 years, 50 years, and 75 years, respectively. Note that outside diameter values listed in Figures A-2 (a) – (c) are for the base diameter. These figures were developed for changes in the outside diameter along the entire height of the pole. For example, a corresponding base outside diameter of 18.2 in (462.28 mm) represents a 30% reduction from the benchmark base diameter of 26 in (660.4 mm). Thus, all points along the height of the pole have had the outside diameter reduced by 30%.

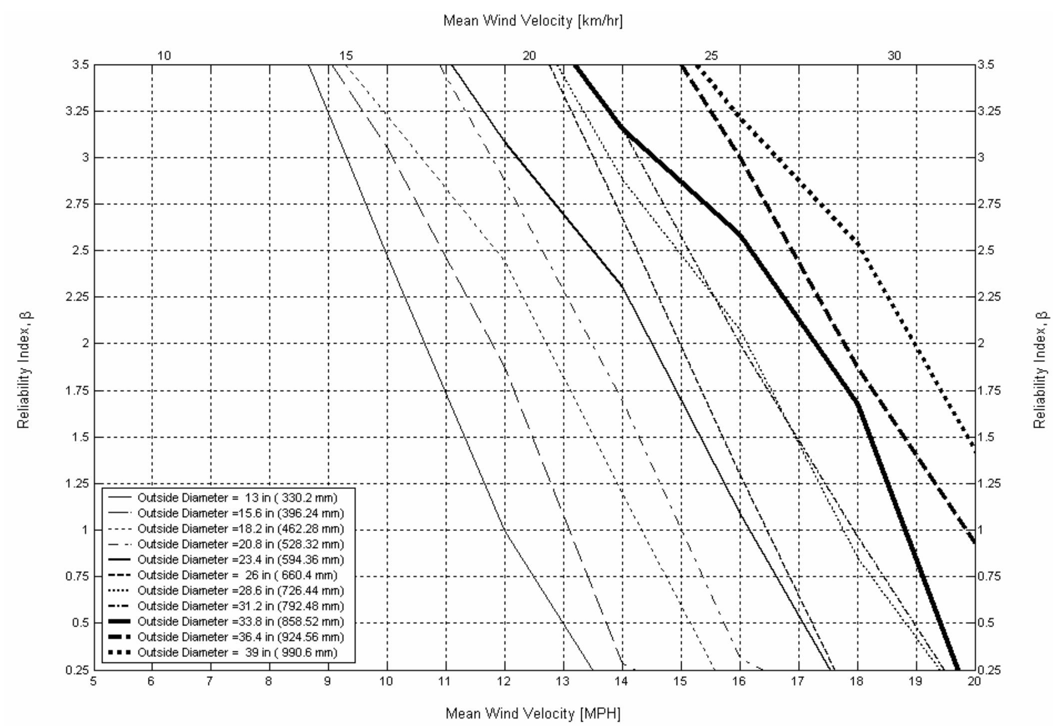


(a): 25-Year Target Fatigue Life

Figure A-2: Design Chart (SV-*E*) – Pole Outside Diameter



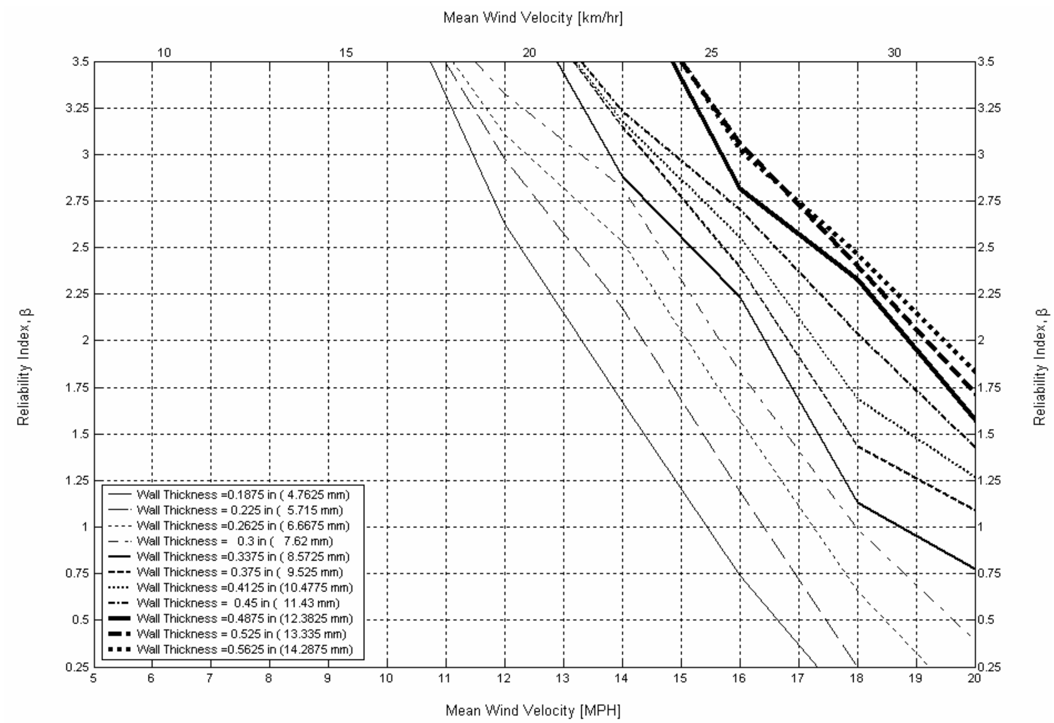
(b): 50-Year Target Fatigue Life



(c): 75-Year Target Fatigue Life

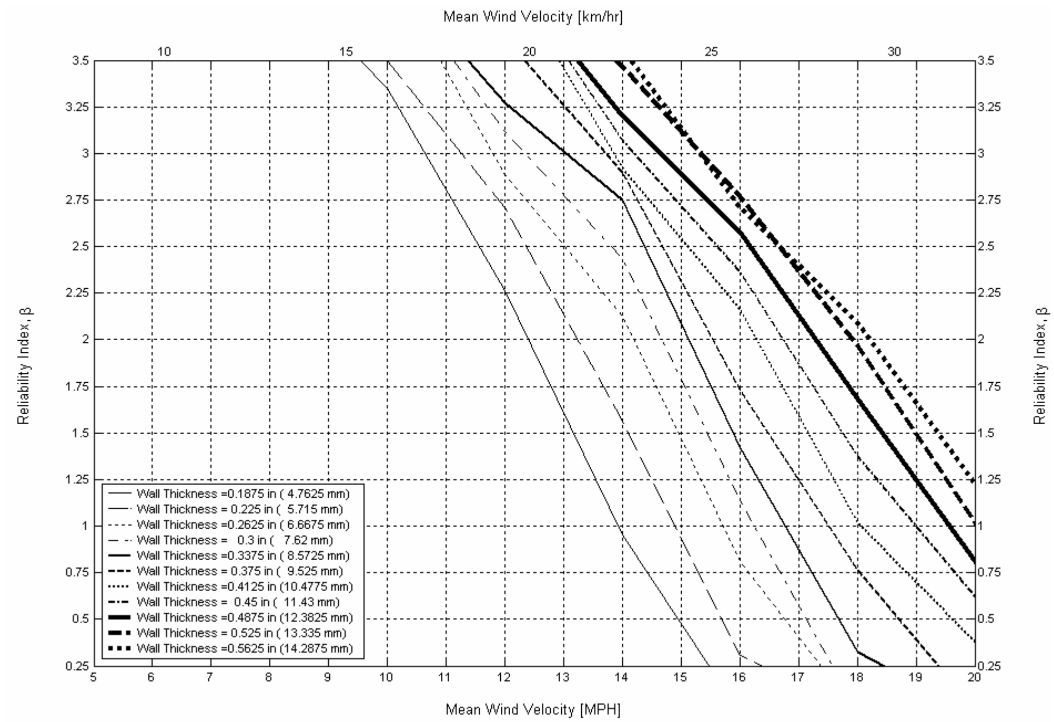
Figure A-2 (cont.): Design Chart (SV-*E*) – Pole Outside Diameter

Pole Wall Thickness
Figures A-3 (a), (b), and (c) provide the design charts for changes in the pole wall thickness for target fatigue life's of 25 years, 50 years, and 75 years, respectively. Note that wall thickness values listed in Figures A-3 (a) – (c) are for the base wall thickness. These figures were developed for changes in the wall thickness along the entire height of the pole. For example, a corresponding base wall thickness of 0.2625 in (6.6675 mm) represents a 30% reduction from the benchmark base wall thickness of 0.375 in (9.525 mm). Thus, all points along the height of the pole have had the wall thickness reduced by 30%.

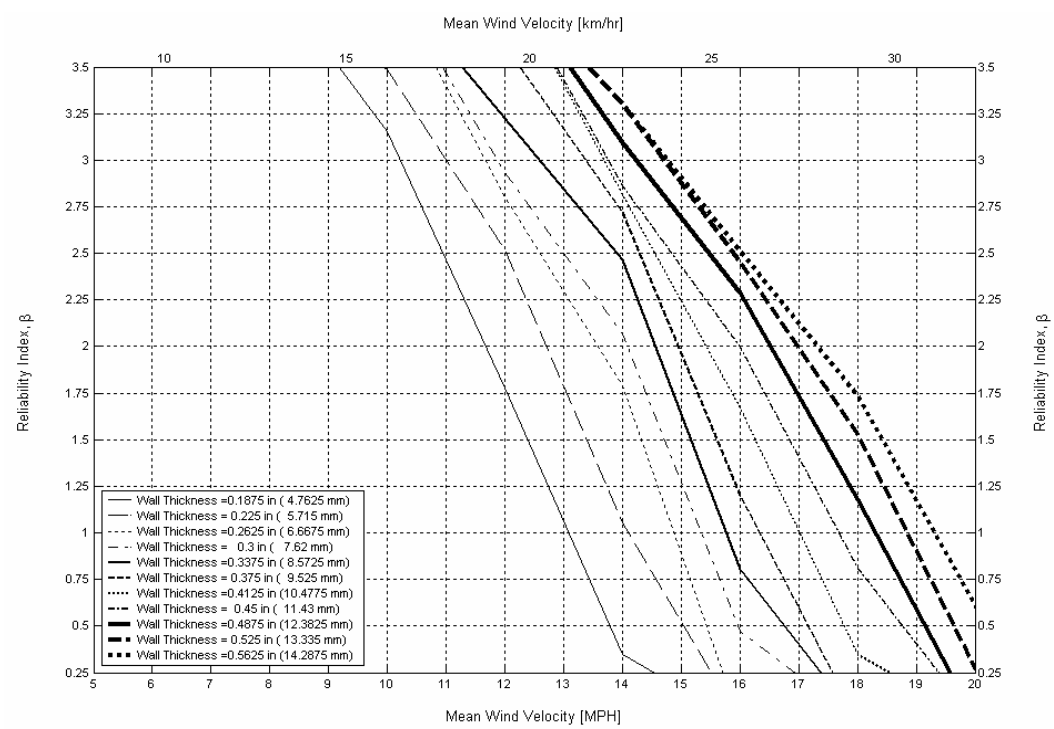


(a): 25-Year Target Fatigue Life

Figure A-3: Design Chart (SV-*E*) – Pole Wall Thickness



(b): 50-Year Target Fatigue Life

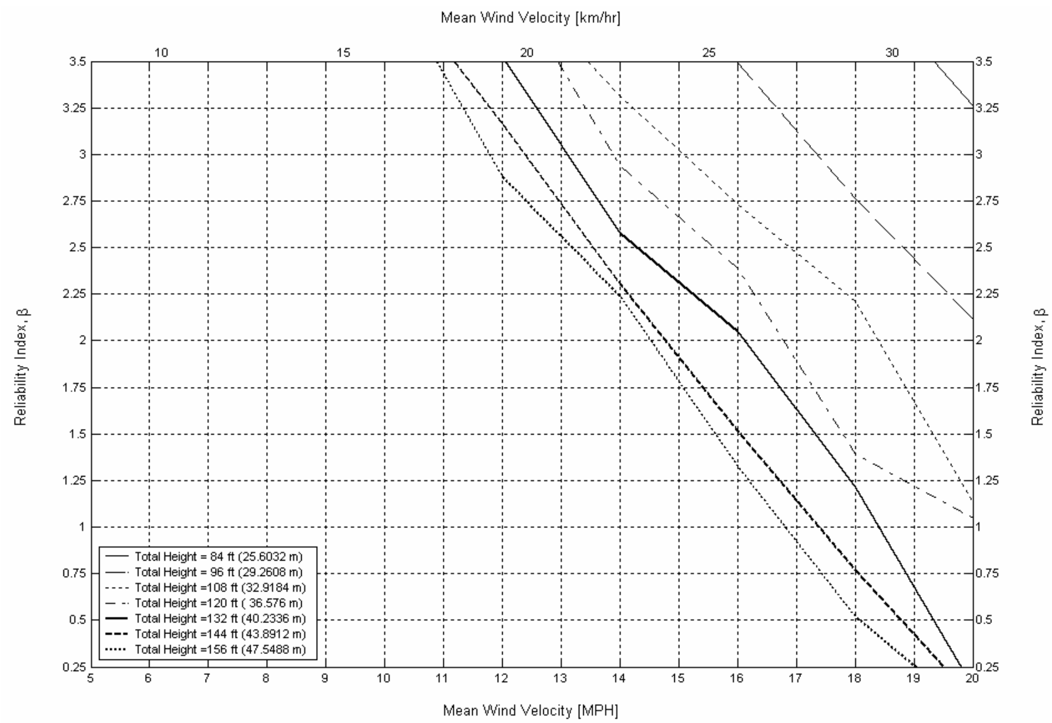


(c): 75-Year Target Fatigue Life

Figure A-3 (cont.): Design Chart (SV-*E*) – Pole Wall Thickness

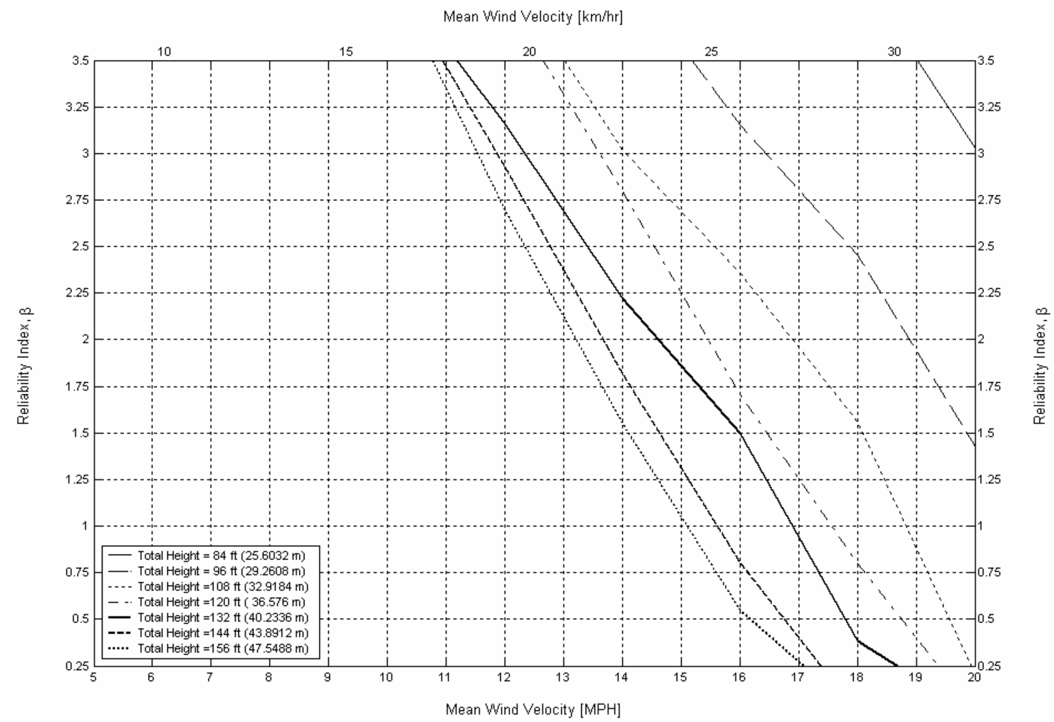
Pole Length

Figures A-4 (a), (b), and (c) provide the design charts for changes in the pole length for target fatigue life's of 25 years, 50 years, and 75 years, respectively.

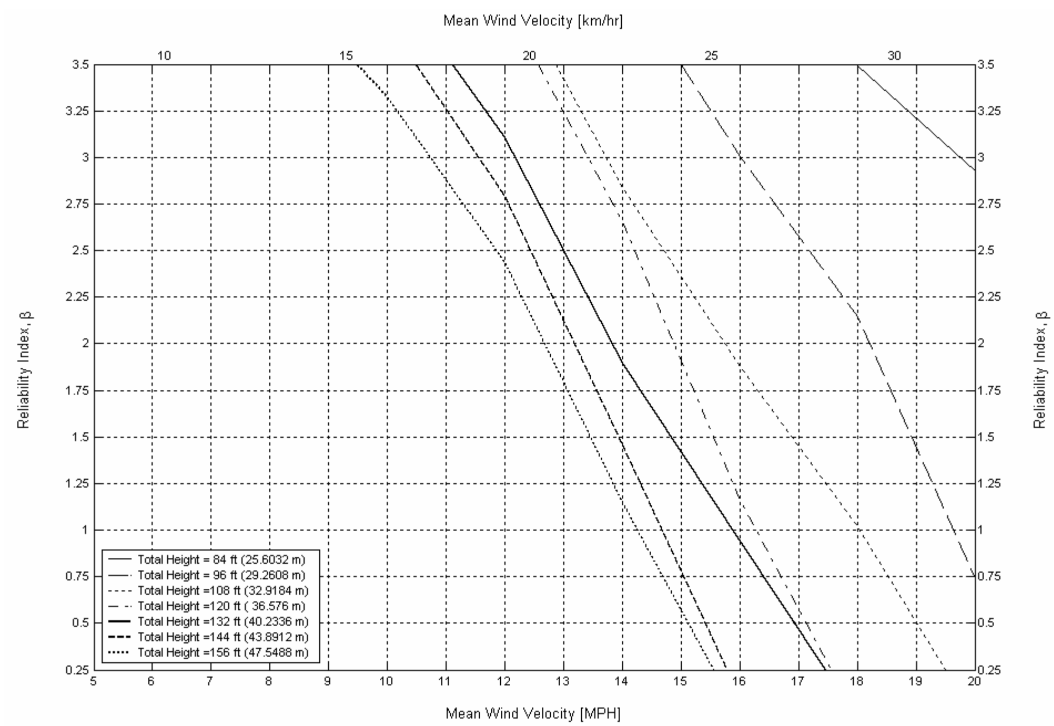


(a): 25-Year Target Fatigue Life

Figure A-4: Design Chart (SV-*E*) – Pole Length



(b): 50-Year Target Fatigue Life

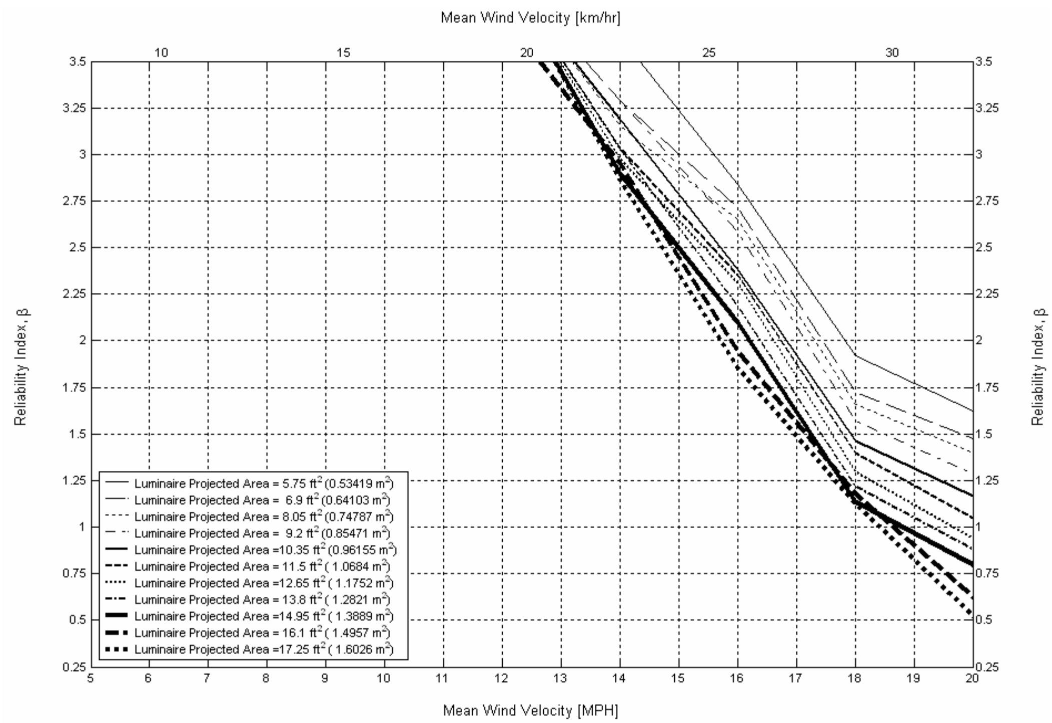


(c): 75-Year Target Fatigue Life

Figure A-4 (cont.): Design Chart (SV-*E*) – Pole Length

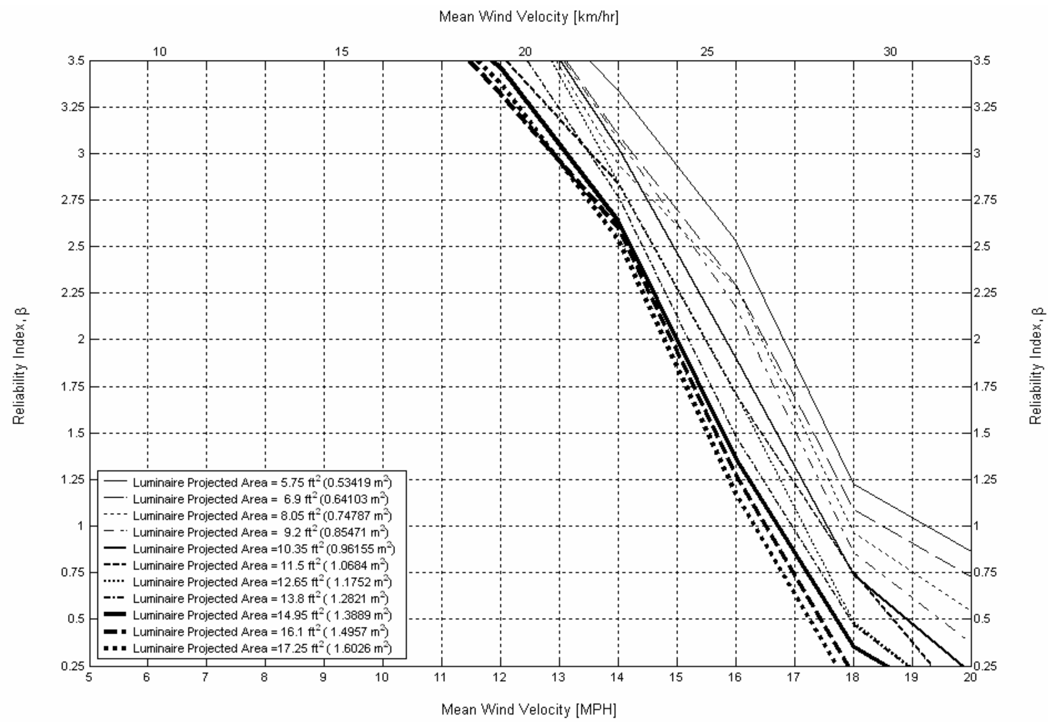
Luminaire Structure Projected Area

Figures A-5 (a), (b), and (c) provide the design charts for changes in the luminaire structure projected area for target fatigue life's of 25 years, 50 years, and 75 years, respectively.

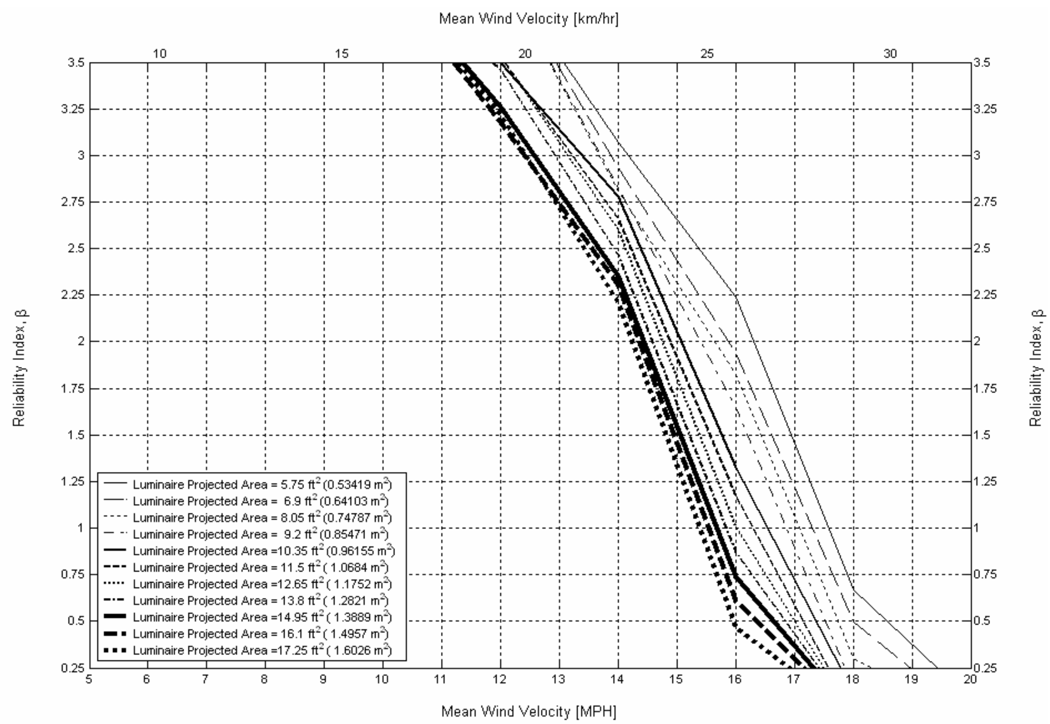


(a): 25-Year Target Fatigue Life

Figure A-5: Design Chart (SV-*E*) – Luminaire Structure Projected Area



(b): 50-Year Target Fatigue Life



(c): 75-Year Target Fatigue Life

Figure A-5 (cont.): Design Chart (SV-*E*) – Luminaire Structure Projected Area

A.3 Design Charts – Multiple Variables

The design charts for multiple variables and detail category *E*, designated by "MV-*E*" in the figure title, are those referenced in Section 1.4.

Mean Wind Velocity = 6 MPH (9.66 km/hr)
Figure A-6 provides the design charts for multiple variables for pole outside diameters of 23.4 in (594.36 mm), 26 in (660.4 mm) and 28.6 in (726.44 mm) for a mean wind velocity of 6 MPH (9.66 km/hr). Figure A-6 is representative of three fatigue life targets of 25, 50, and 75 years.

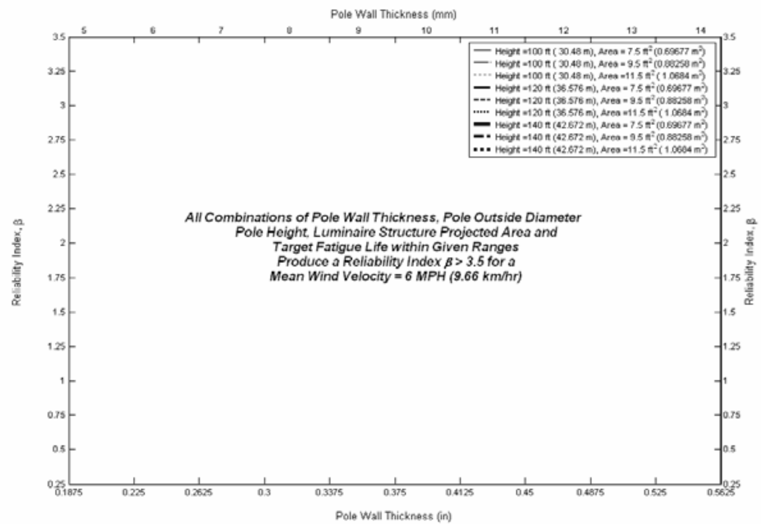


Figure A-6: Design Chart (MV-*E*) – Mean Wind Velocity = 6 MPH (9.66 km/hr)

Mean Wind Velocity = 8 MPH (12.87 km/hr)
Figure A-7 provides the design charts for multiple variables for pole outside diameters of 23.4 in (594.36 mm), 26 in (660.4 mm), and 28.6 in (726.44 mm) for a mean wind velocity of 8 MPH (12.87 km/hr). Figure A-7 is representative of three fatigue life targets of 25, 50, and 75 years.

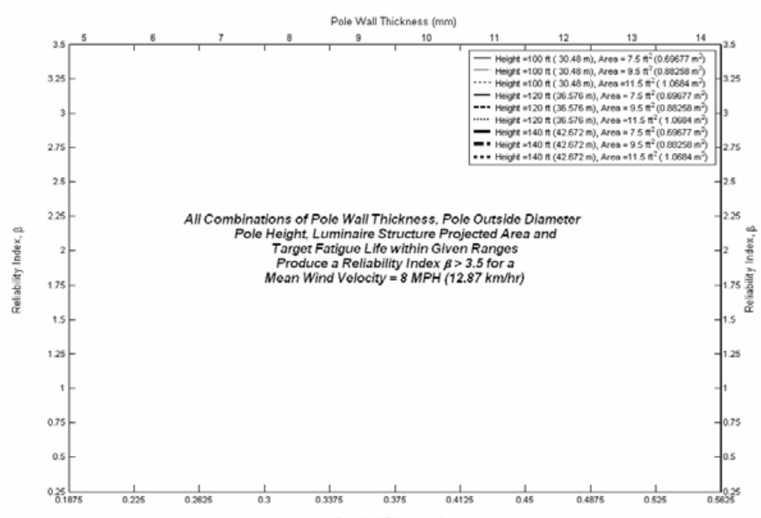
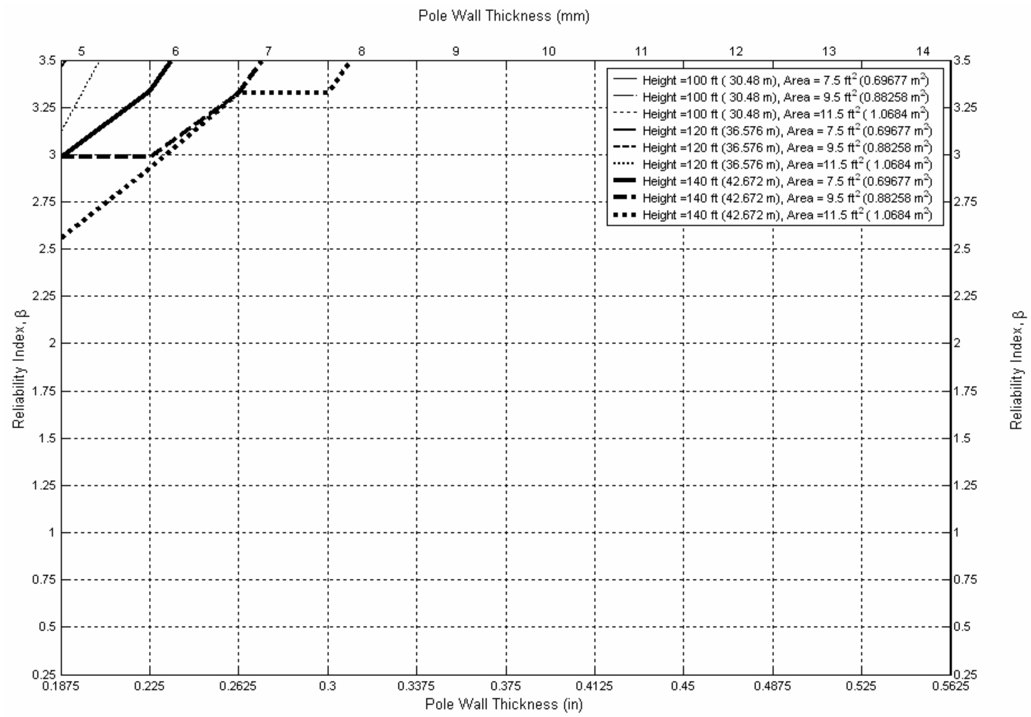


Figure A-7: Design Chart (MV-*E*) – Mean Wind Velocity = 8 MPH (12.87 km/hr)

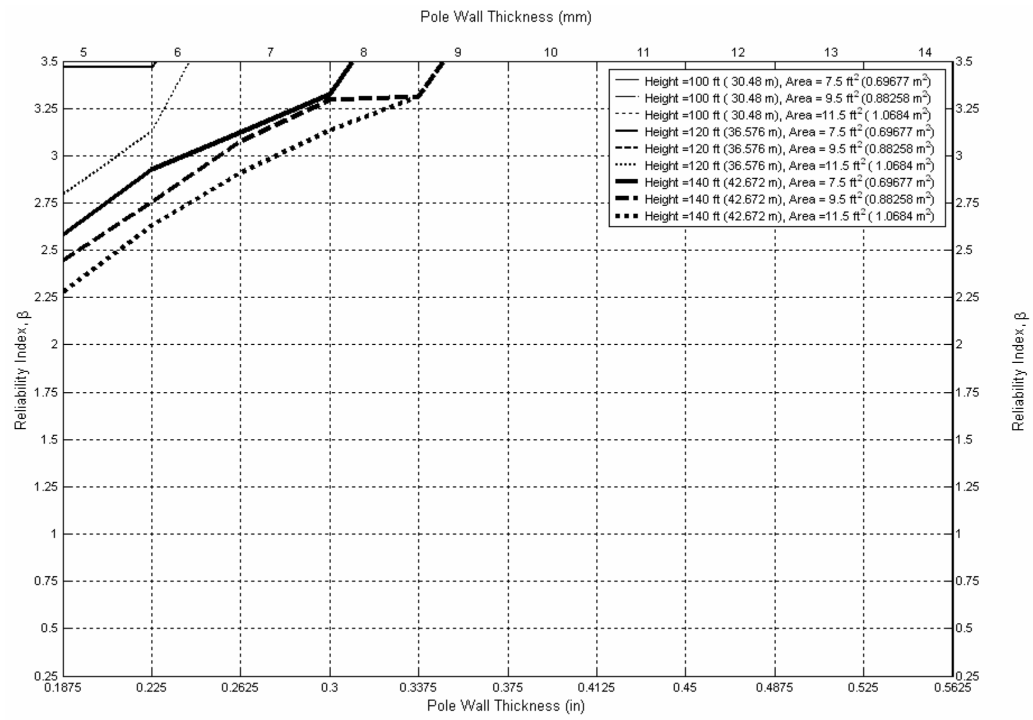
Mean Wind Velocity = 10 MPH (16.09 km/hr)

Figures A-8 (a) – (c) provide the design charts for multiple variables for pole outside diameters of 23.4 in (594.36 mm), 26 in (660.4 mm), and 28.6 in (726.44 mm) respectively for a mean wind velocity of 10 MPH (16.09 km/hr). Each set of figures is also provided with three fatigue life targets, 25, 50, and 75 years respectively, indicated by the subscript on the figure number.

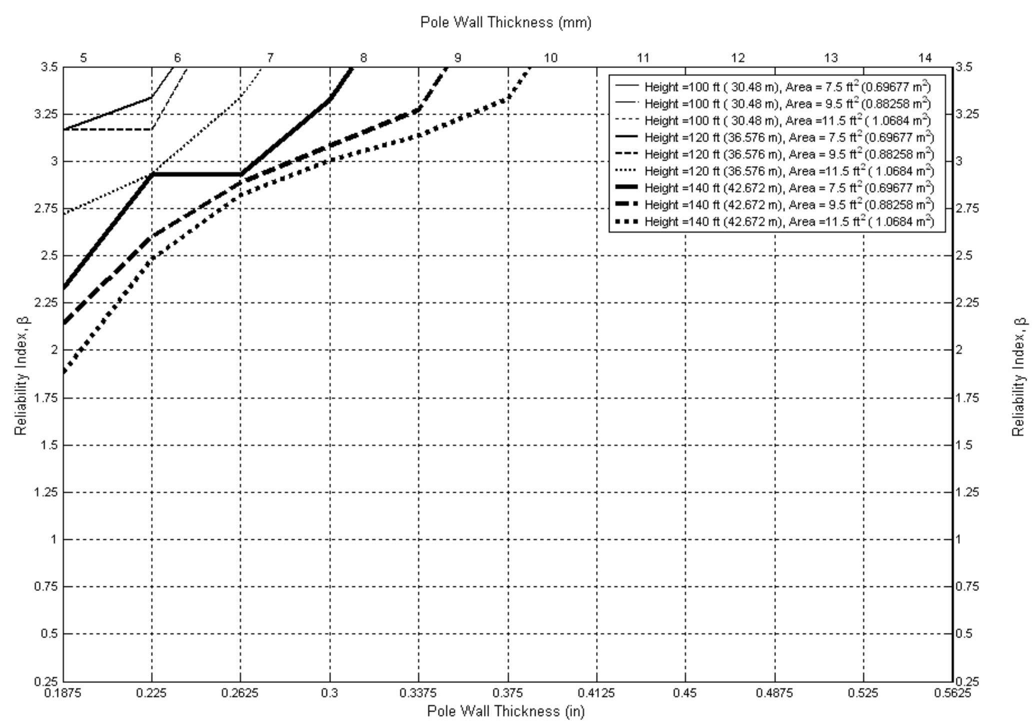


(a_{25yr}): Outside Diameter = 23.4 in (594.36 mm)

Figure A-8: Design Chart (MV-*E*) – Mean Wind Velocity = 10 MPH (16.09 km/hr)

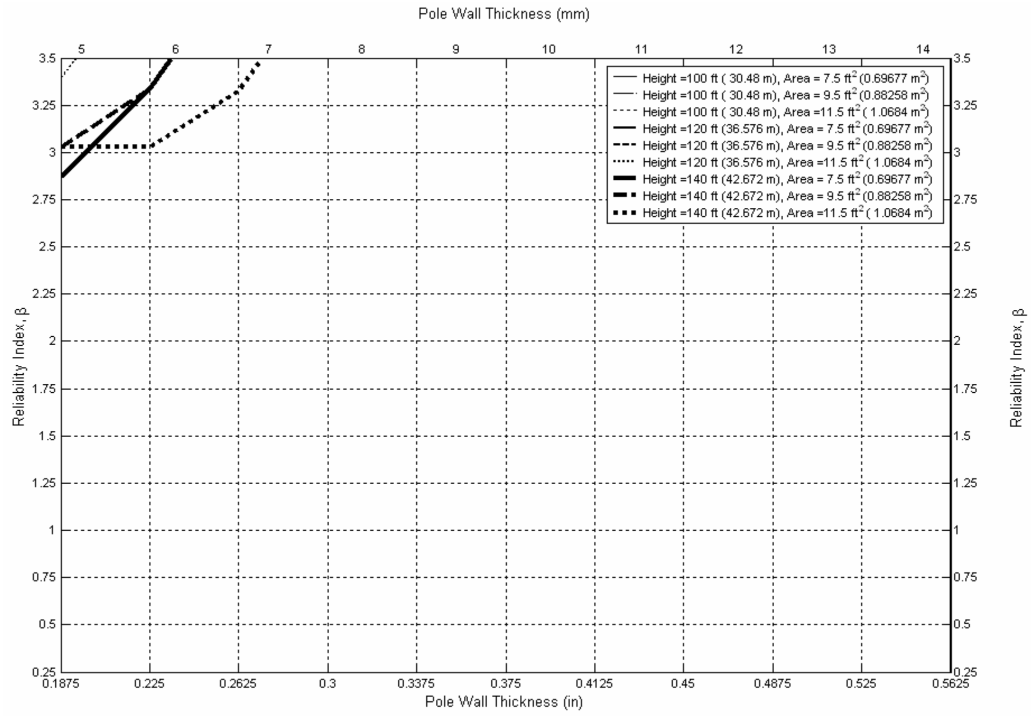


(a_{50yr}): Outside Diameter = 23.4 in (594.36 mm)

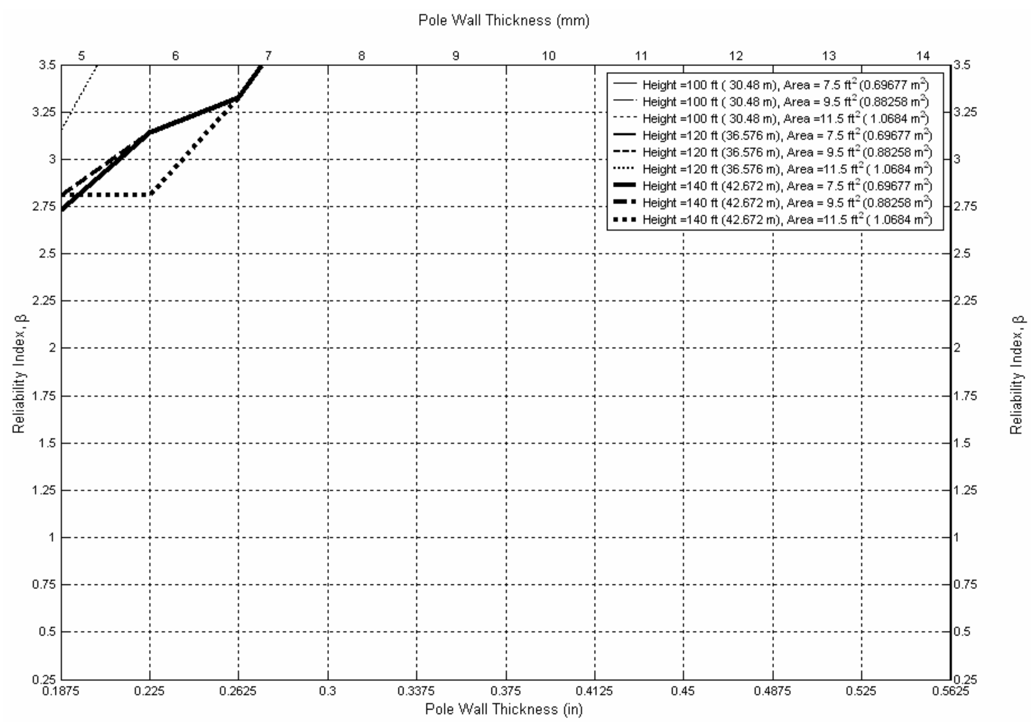


(a_{75yr}): Outside Diameter = 23.4 in (594.36 mm)

Figure A-8 (cont.): Design Chart (MV-*E*) – Mean Wind Velocity = 10 MPH (16.09 km/hr)

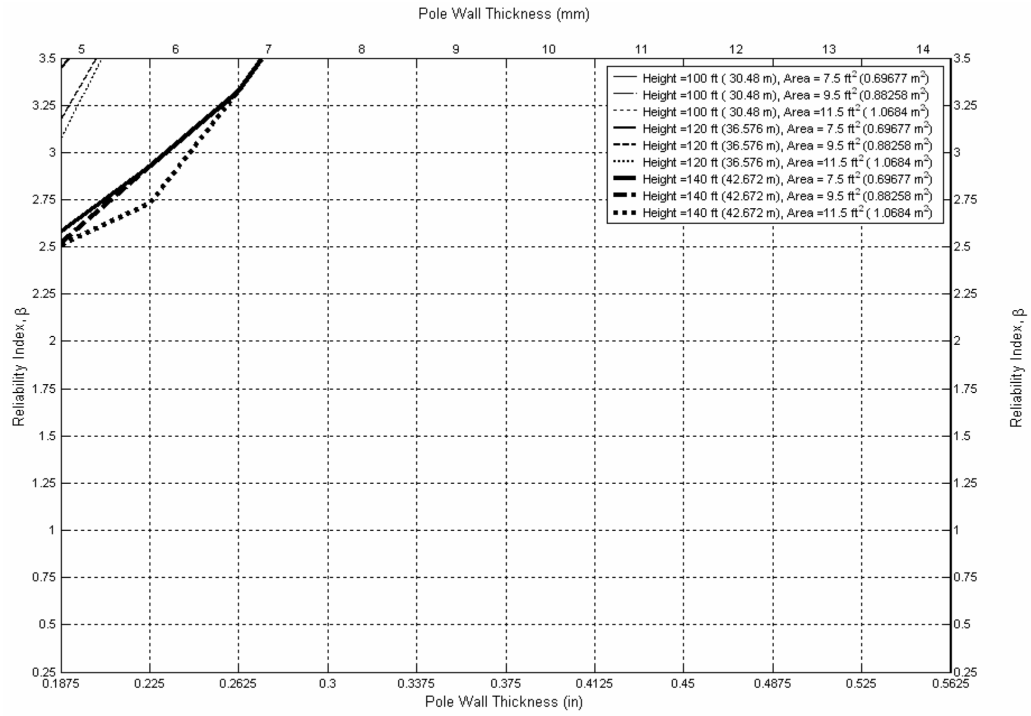


(b_{25yr}): Outside Diameter = 26 in (660.4 mm)

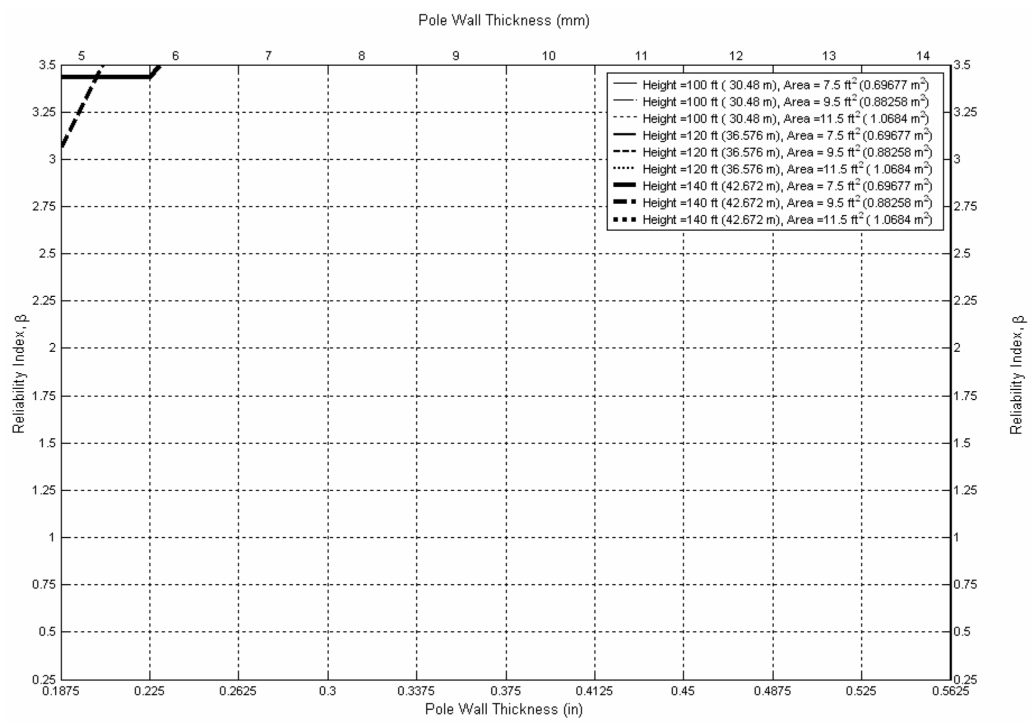


(b_{50yr}): Outside Diameter = 26 in (660.4 mm)

Figure A-8 (cont.): Design Chart (MV-*E*) – Mean Wind Velocity = 10 MPH (16.09 km/hr)

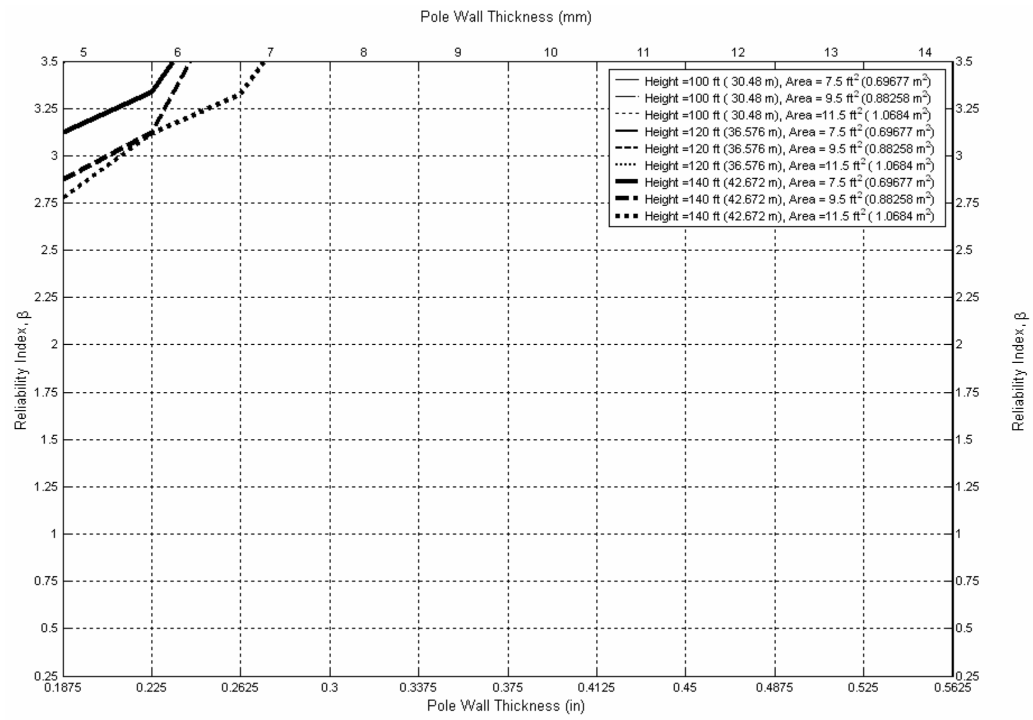


(b_{75yr}): Outside Diameter = 26 in (660.4 mm)

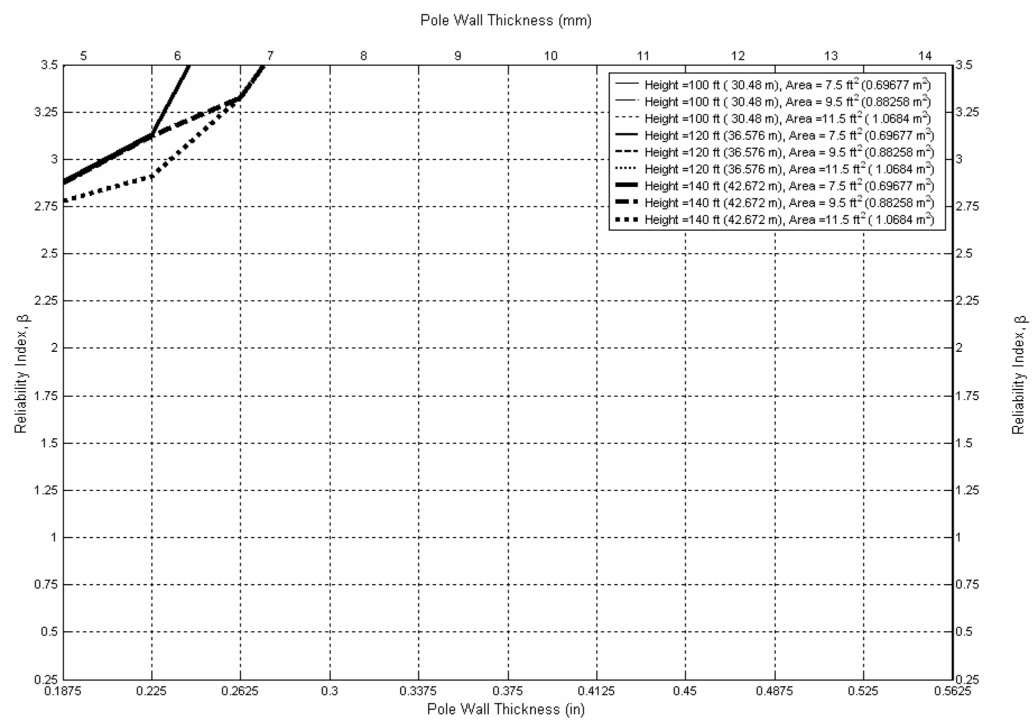


(c_{25yr}): Outside Diameter = 28.6 in (726.44 mm)

Figure A-8 (cont.): Design Chart (MV-*E*) – Mean Wind Velocity = 10 MPH (16.09 km/hr)



(c_{50yr}): Outside Diameter = 28.6 in (726.44 mm)

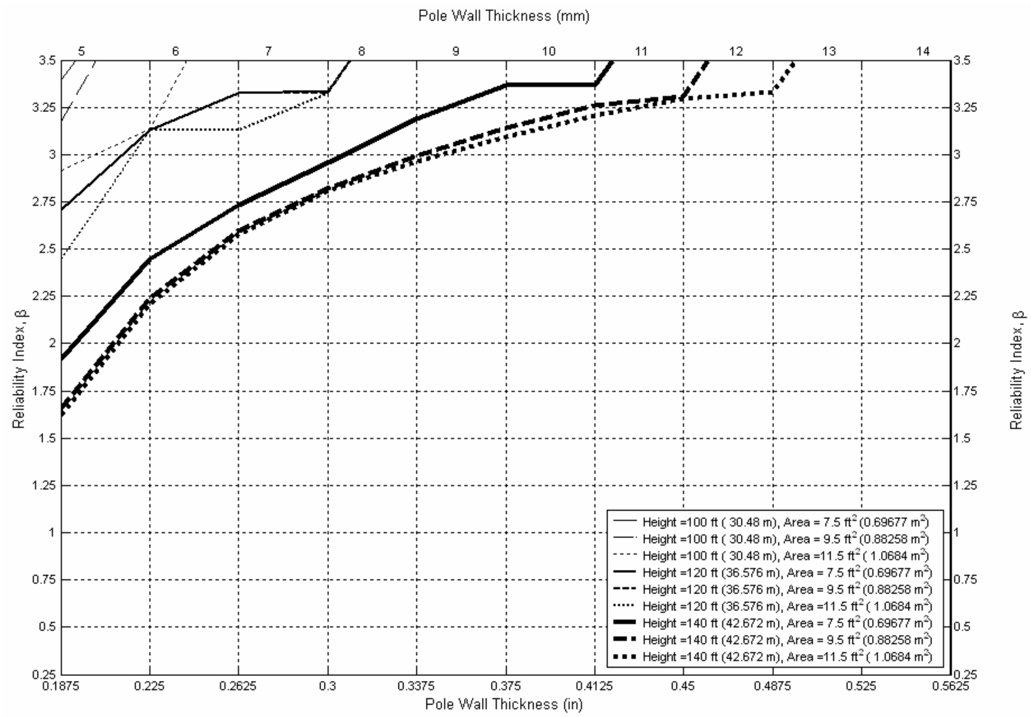


(c_{75yr}): Outside Diameter = 28.6 in (726.44 mm)

Figure A-8 (cont.): Design Chart (MV-*E*) – Mean Wind Velocity = 10 MPH (16.09 km/hr)

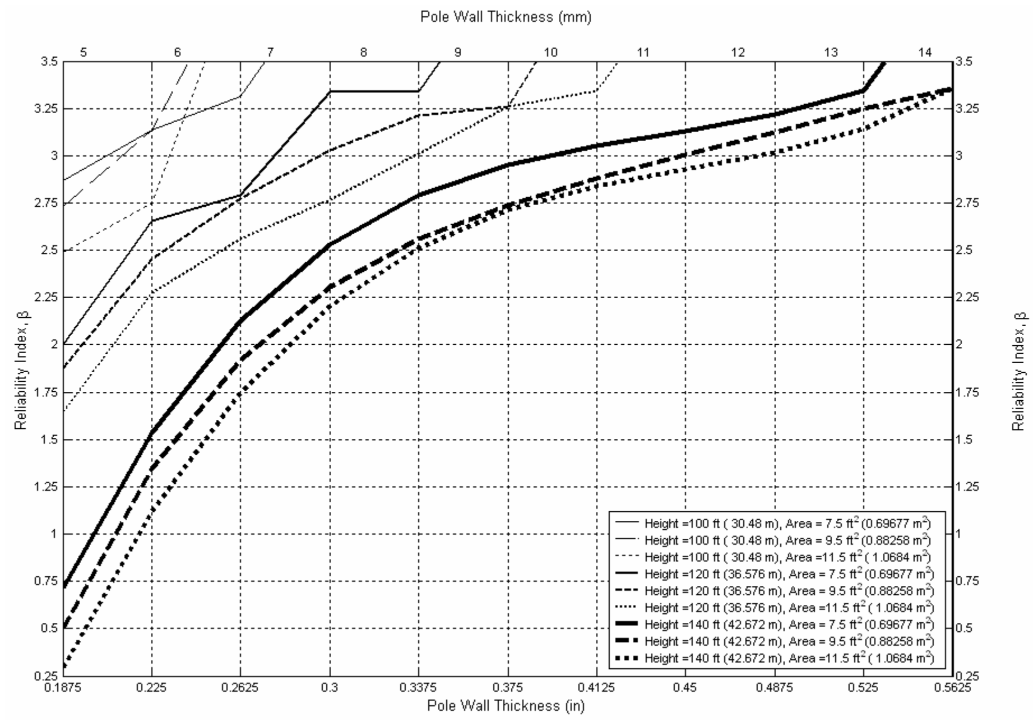
Mean Wind Velocity = 12 MPH (19.31 km/hr)

Figures A-9 (a) – (c) provide the design charts for multiple variables for pole outside diameters of 23.4 in (594.36 mm), 26 in (660.4 mm), and 28.6 in (726.44 mm) respectively for a mean wind velocity of 12 MPH (19.31 km/hr). Each set of figures is also provided with three fatigue life targets, 25, 50, and 75 years respectively, indicated by the subscript on the figure number.

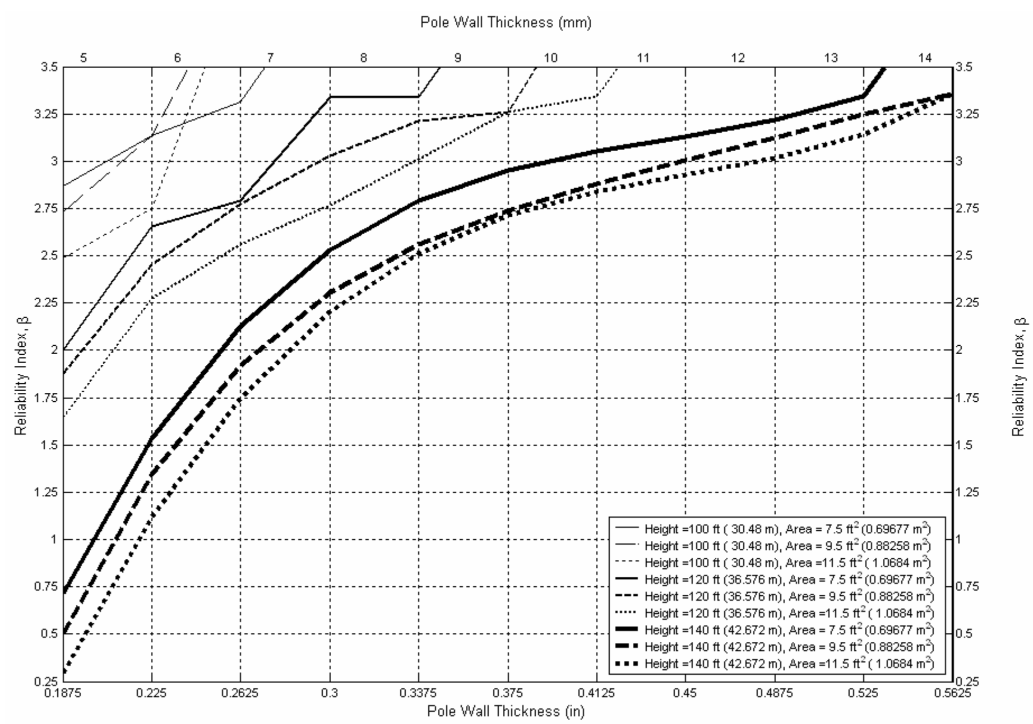


(a_{25yr}): Outside Diameter = 23.4 in (594.36 mm)

Figure A-9: Design Chart (MV-*E*) – Mean Wind Velocity = 12 MPH (19.31 km/hr)

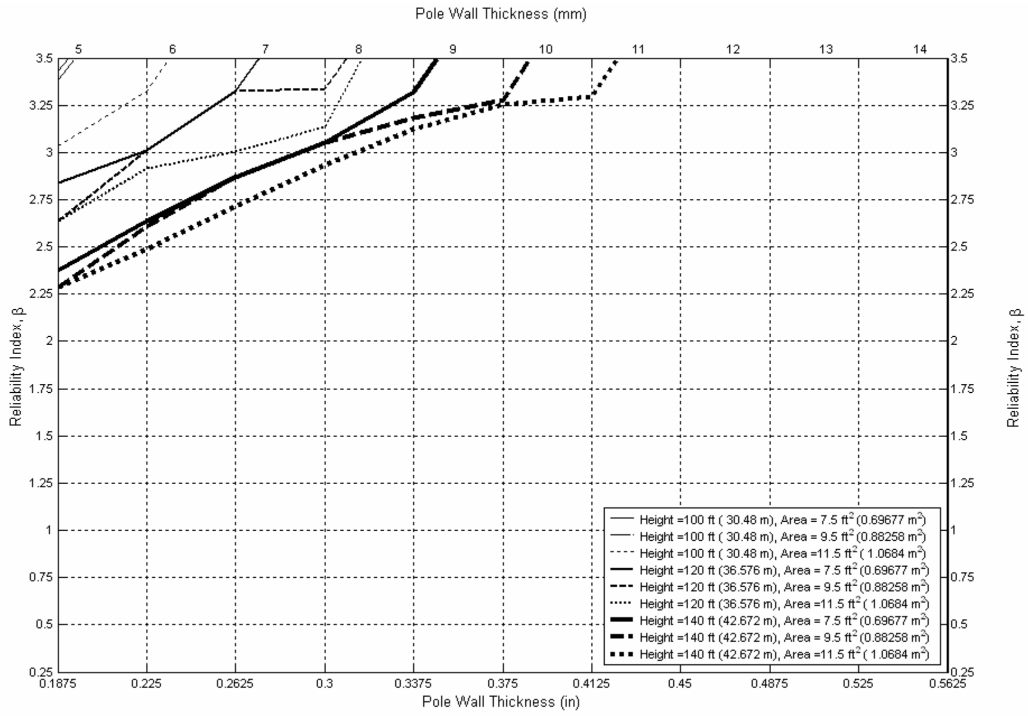


(a_{50yr}): Outside Diameter = 23.4 in (594.36 mm)

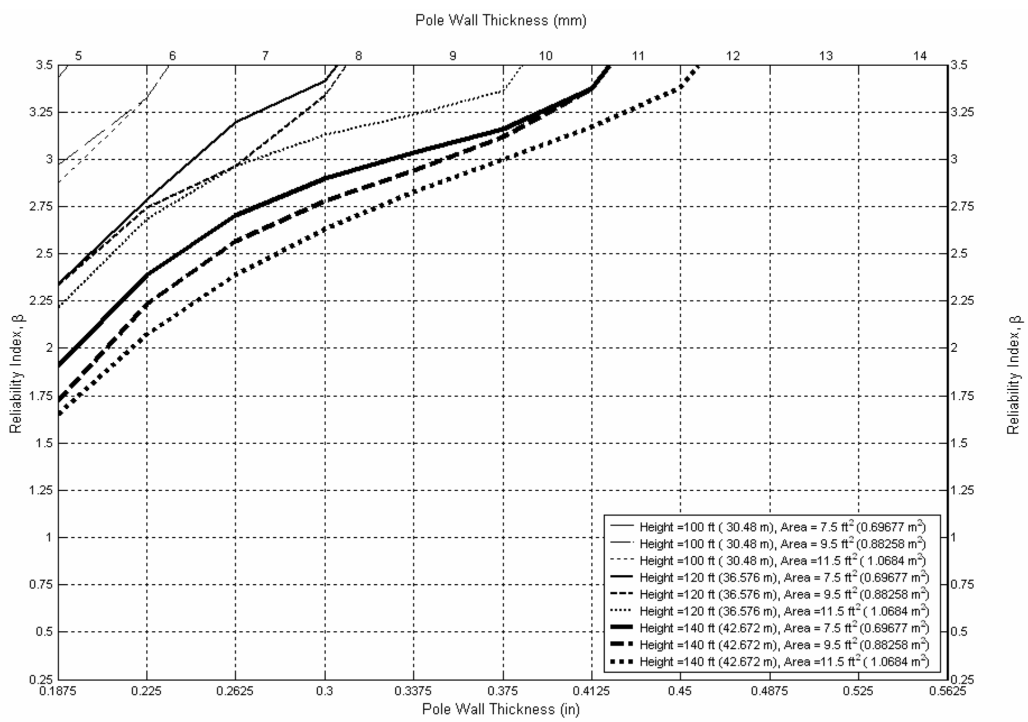


(a_{75yr}): Outside Diameter = 23.4 in (594.36 mm)

Figure A-9 (cont.): Design Chart (MV-*E*) – Mean Wind Velocity = 12 MPH (19.31 km/hr)

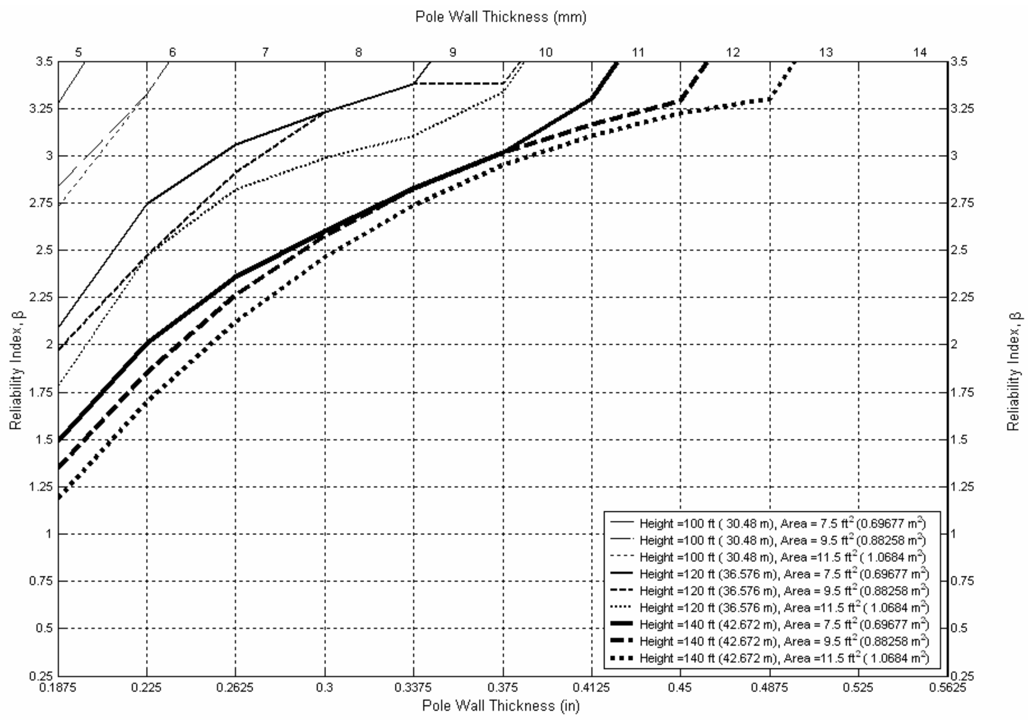


(b_{25yr}): Outside Diameter = 26 in (660.4 mm)

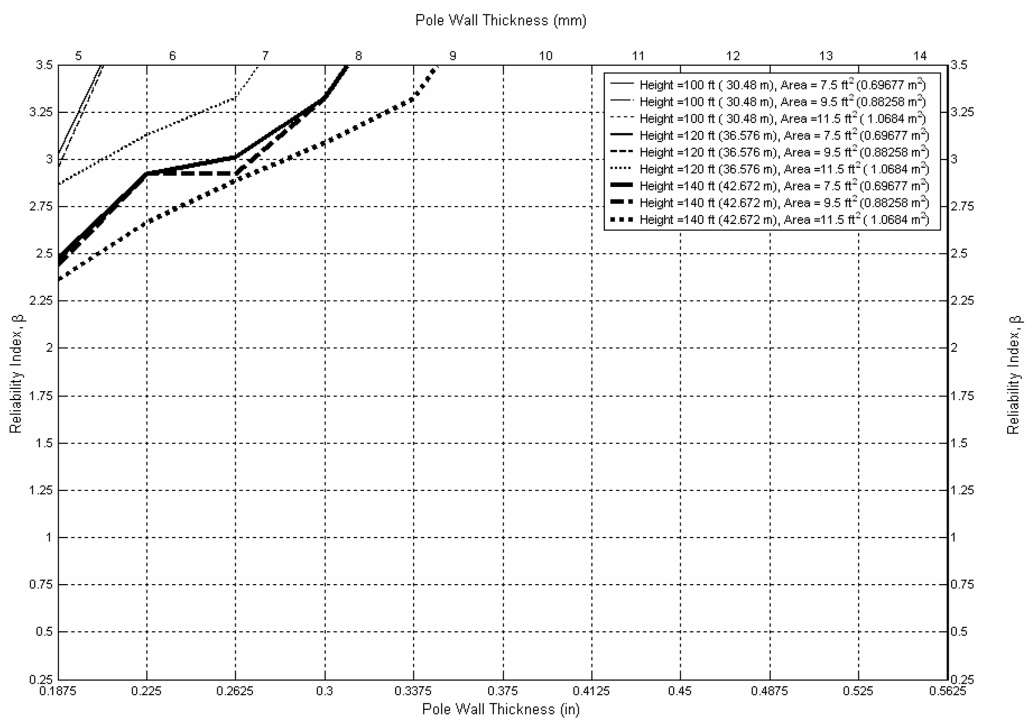


(b_{50yr}): Outside Diameter = 26 in (660.4 mm)

Figure A-9 (cont.): Design Chart (MV-*E*) – Mean Wind Velocity = 12 MPH (19.31 km/hr)

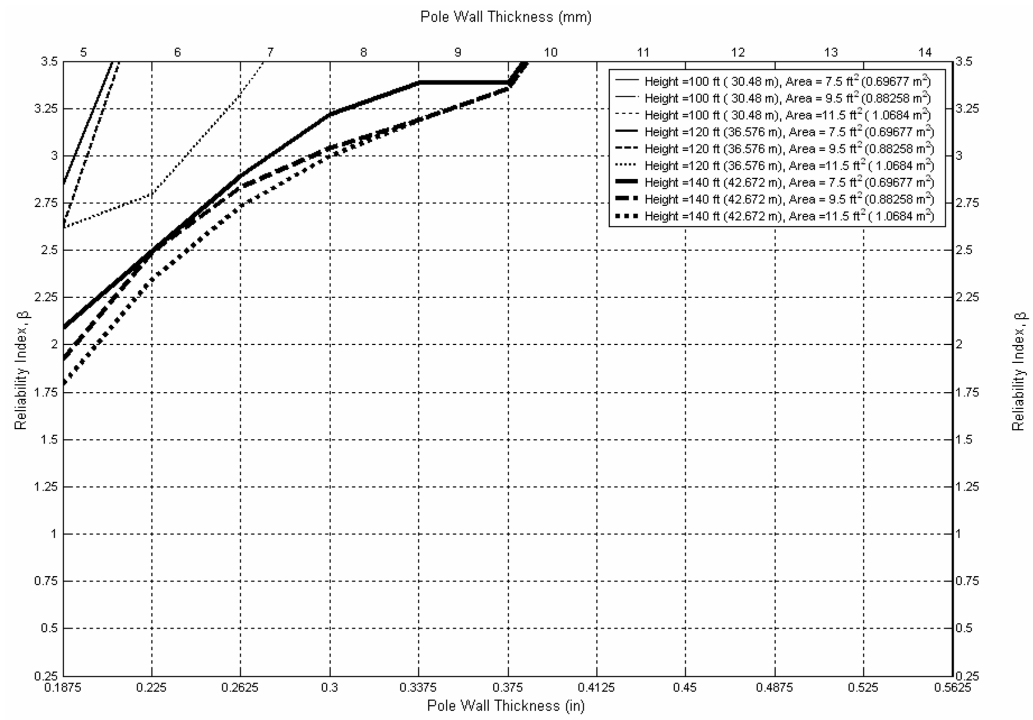


(b_{75yr}): Outside Diameter = 26 in (660.4 mm)

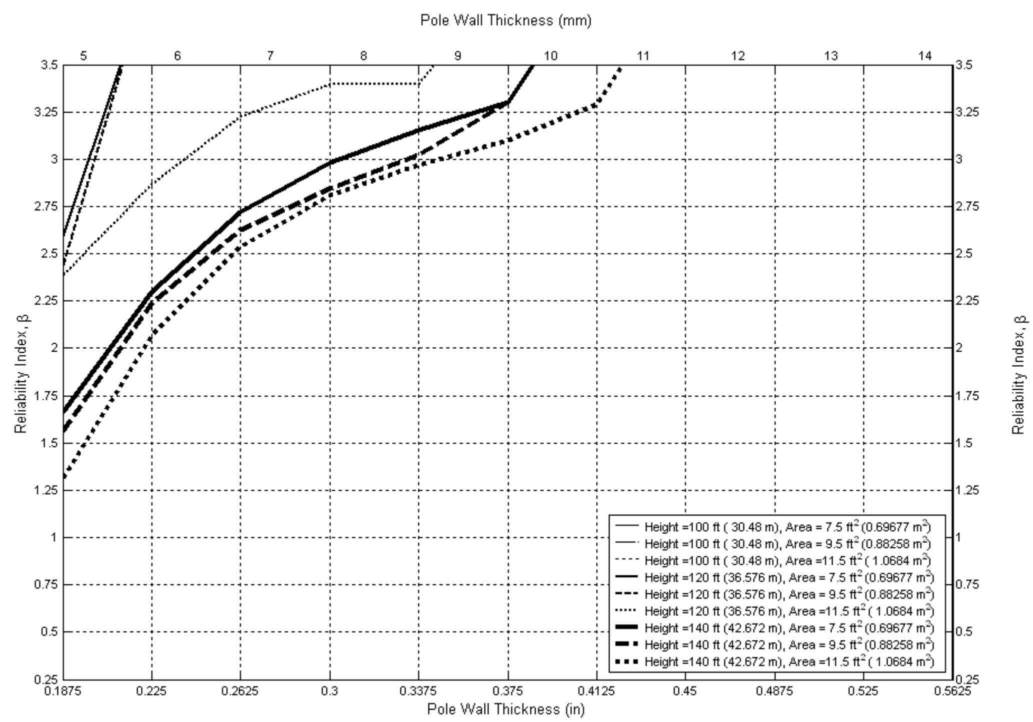


(c_{25yr}): Outside Diameter = 28.6 in (726.44 mm)

Figure A-9 (cont.): Design Chart (MV-*E*) – Mean Wind Velocity = 12 MPH (19.31 km/hr)



(c_{50yr}): Outside Diameter = 28.6 in (726.44 mm)

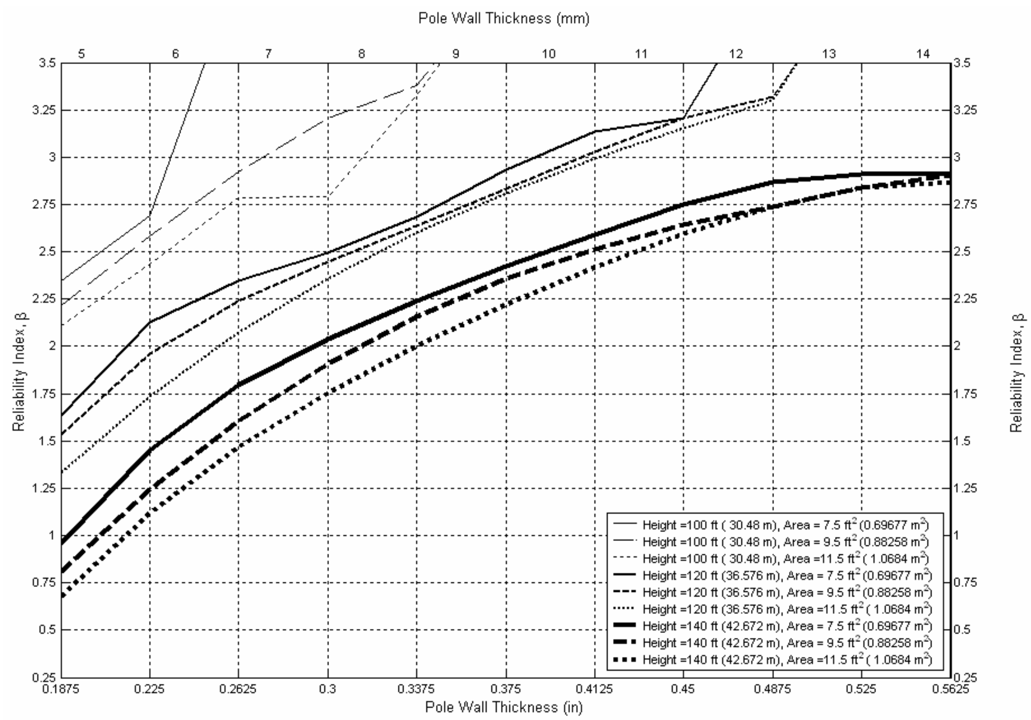


(c_{75yr}): Outside Diameter = 28.6 in (726.44 mm)

Figure A-9 (cont.): Design Chart (MV-*E*) – Mean Wind Velocity = 12 MPH (19.31 km/hr)

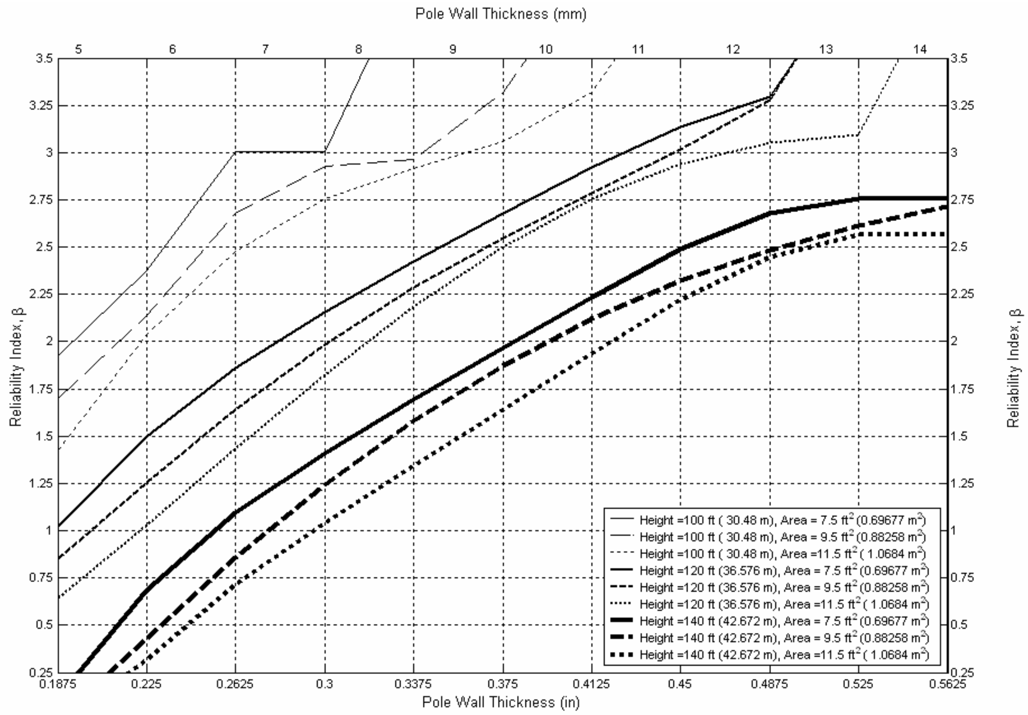
Mean Wind Velocity = 14 MPH (22.53 km/hr)

Figures A-10 (a) – (c) provide the design charts for multiple variables for pole outside diameters of 23.4 in (594.36 mm), 26 in (660.4 mm), and 28.6 in (726.44 mm) respectively for a mean wind velocity of 14 MPH (22.53 km/hr). Each set of figures is also provided with three fatigue life targets, 25, 50, and 75 years respectively, indicated by the subscript on the figure number.

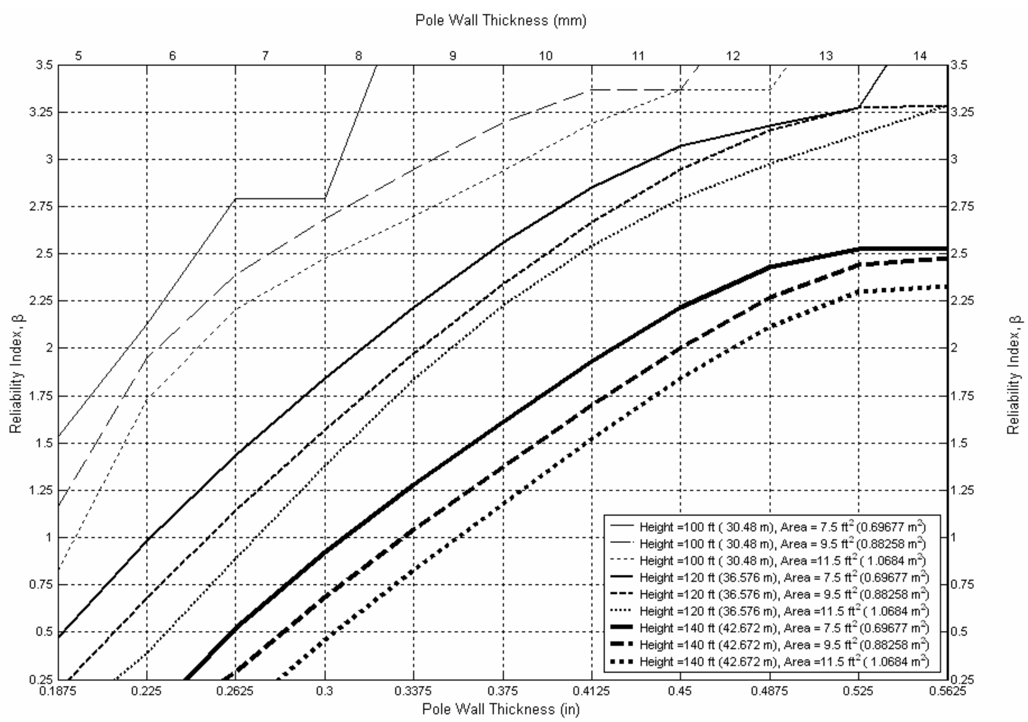


(a_{25yr}): Outside Diameter = 23.4 in (594.36 mm)

Figure A-10: Design Chart (MV-*E*) – Mean Wind Velocity = 14 MPH (22.53 km/hr)

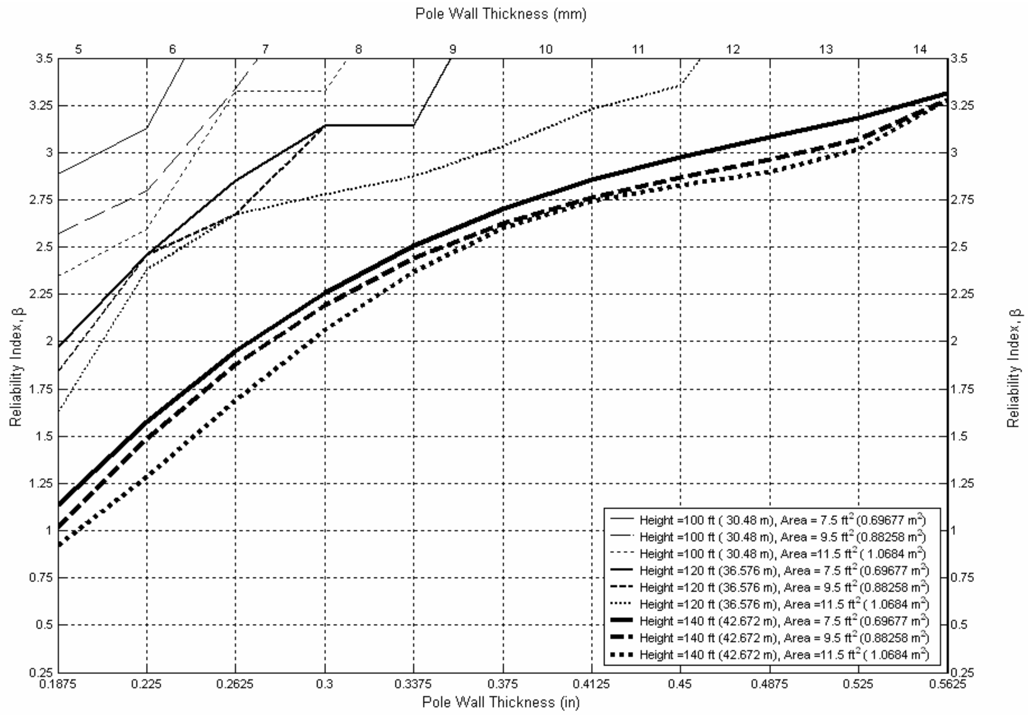


(a_{50yr}): Outside Diameter = 23.4 in (594.36 mm)

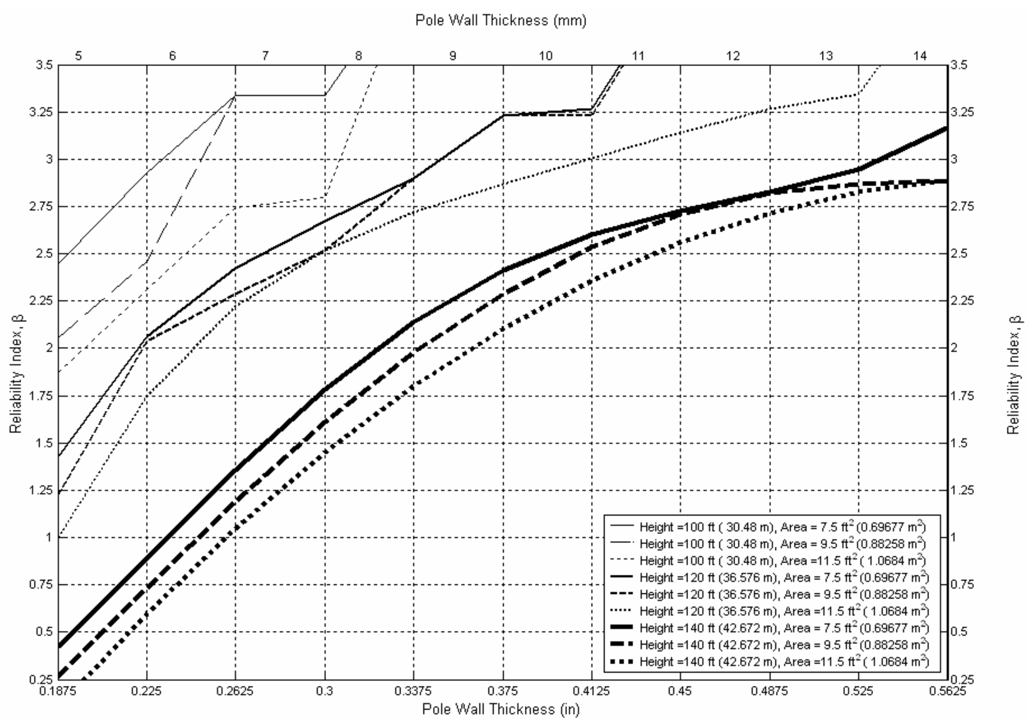


(a_{75yr}): Outside Diameter = 23.4 in (594.36 mm)

Figure A-10 (cont.): Design Chart (MV-*E*) – Mean Wind Velocity = 14 MPH (22.53 km/hr)

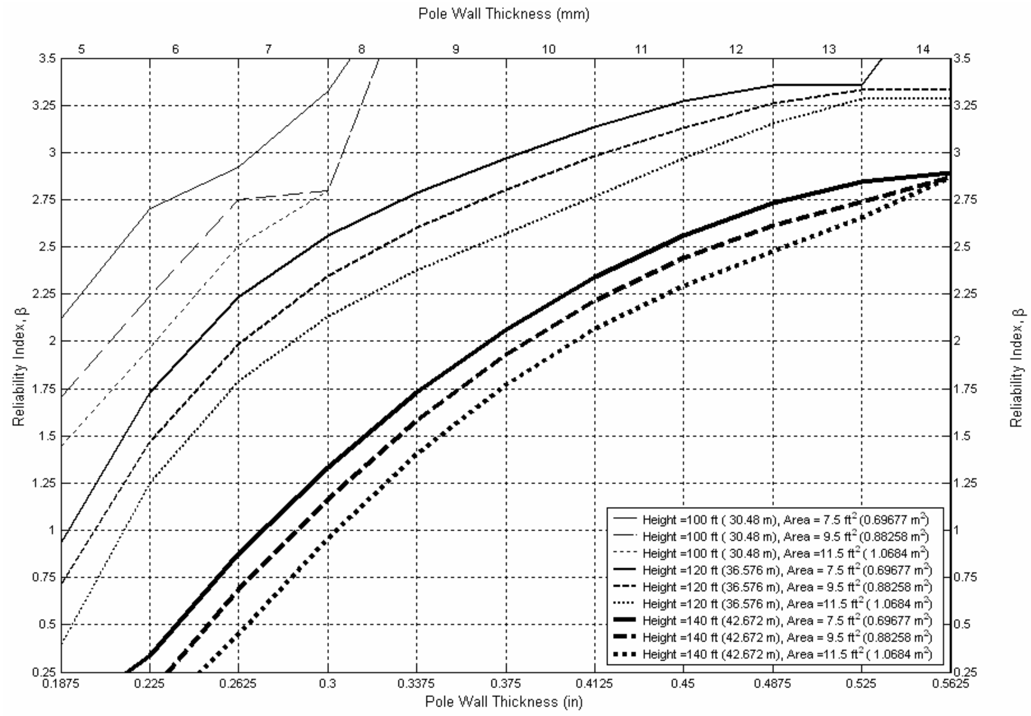


(b_{25yr}): Outside Diameter = 26 in (660.4 mm)

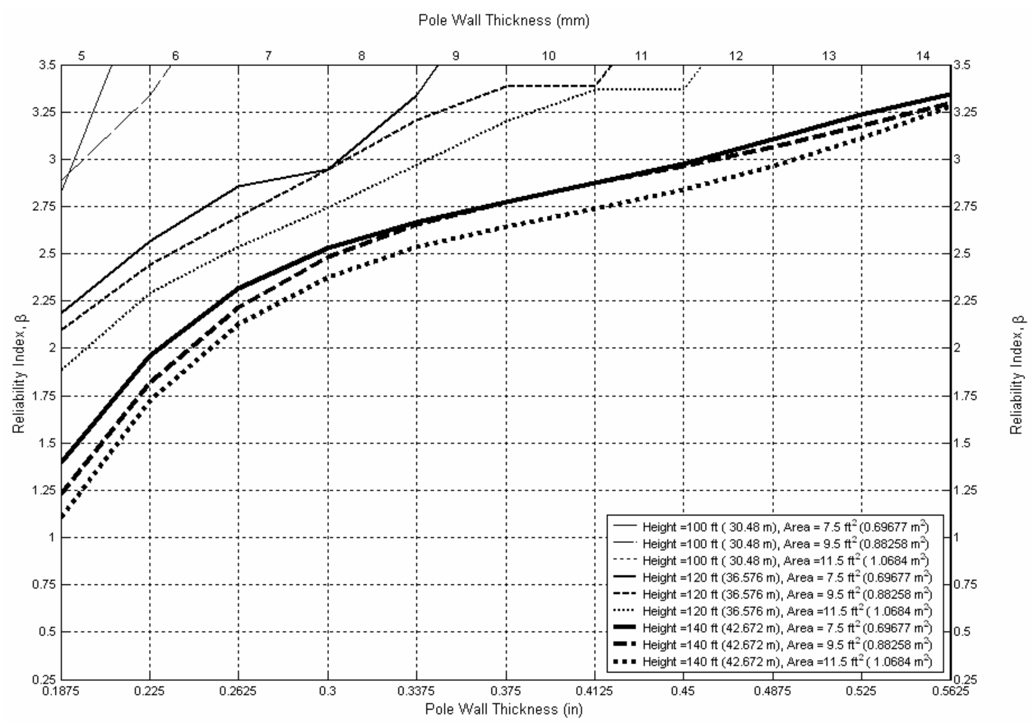


(b_{50yr}): Outside Diameter = 26 in (660.4 mm)

Figure A-10 (cont.): Design Chart (MV-*E*) – Mean Wind Velocity = 14 MPH (22.53 km/hr)

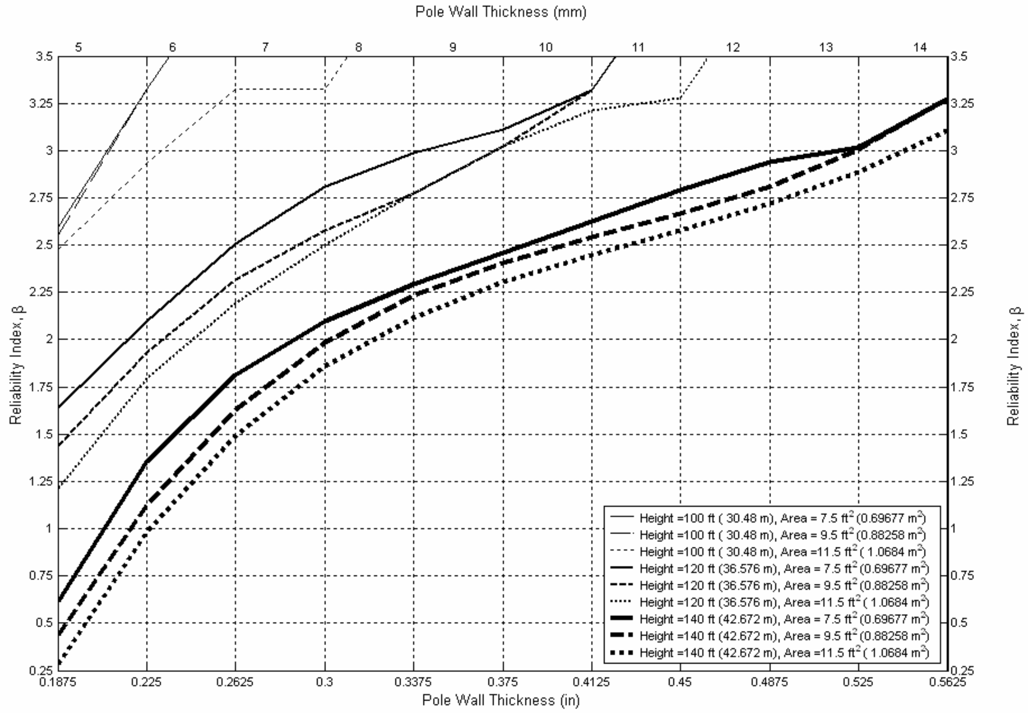


(b_{75yr}): Outside Diameter = 26 in (660.4 mm)

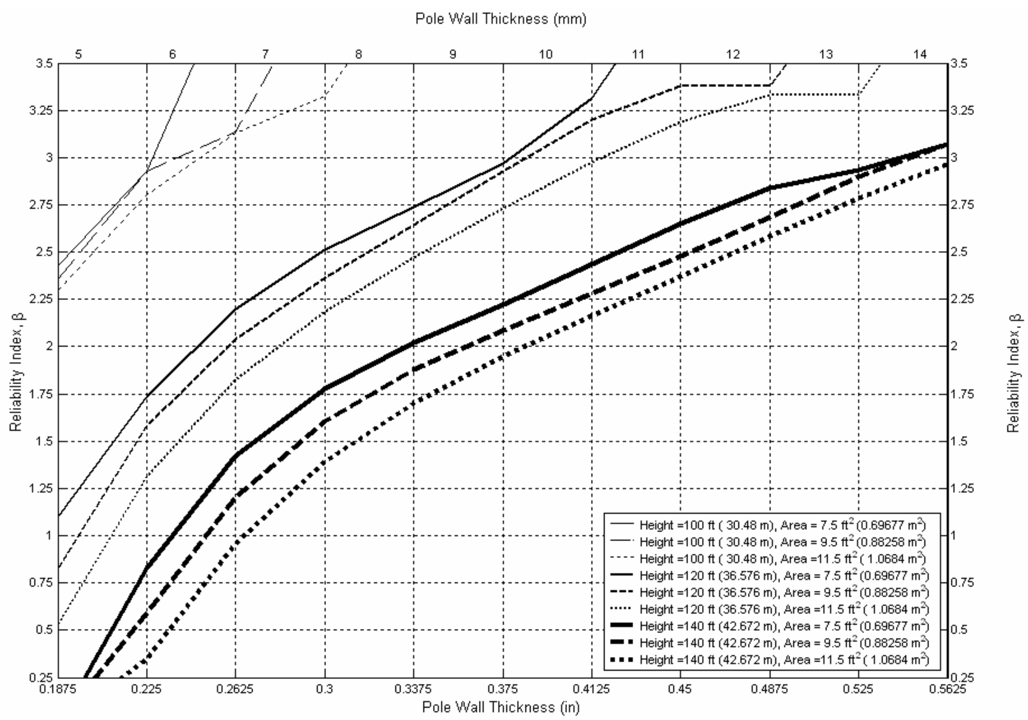


(c_{25yr}): Outside Diameter = 28.6 in (726.44 mm)

Figure A-10 (cont.): Design Chart (MV-*E*) – Mean Wind Velocity = 14 MPH (22.53 km/hr)



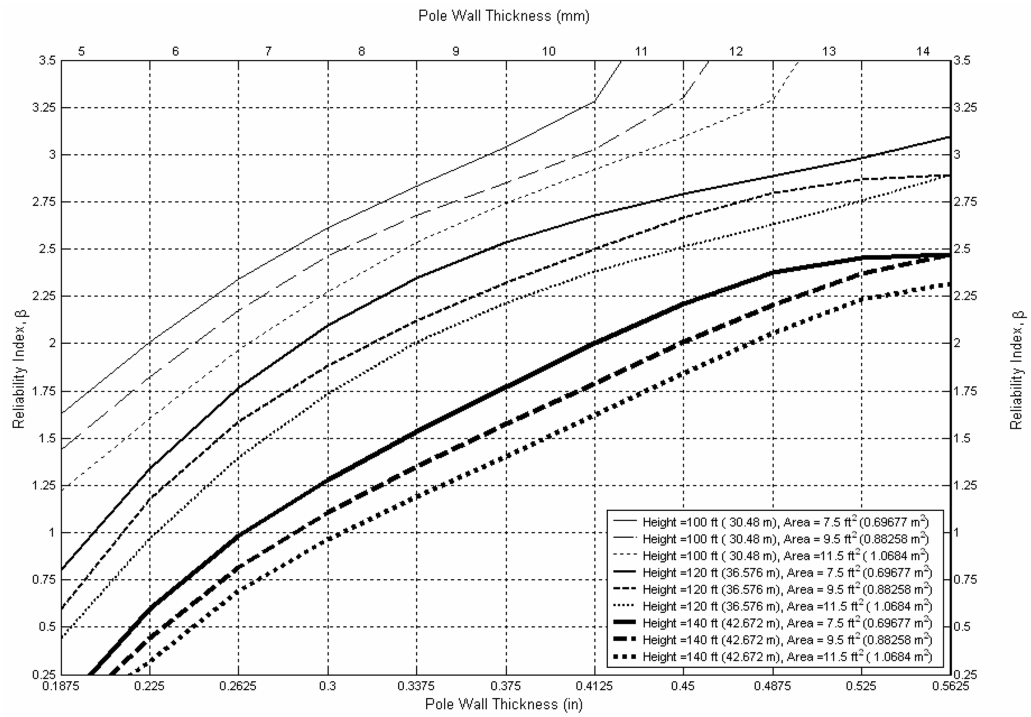
(c_{50yr}): Outside Diameter = 28.6 in (726.44 mm)



(c_{75yr}): Outside Diameter = 28.6 in (726.44 mm)

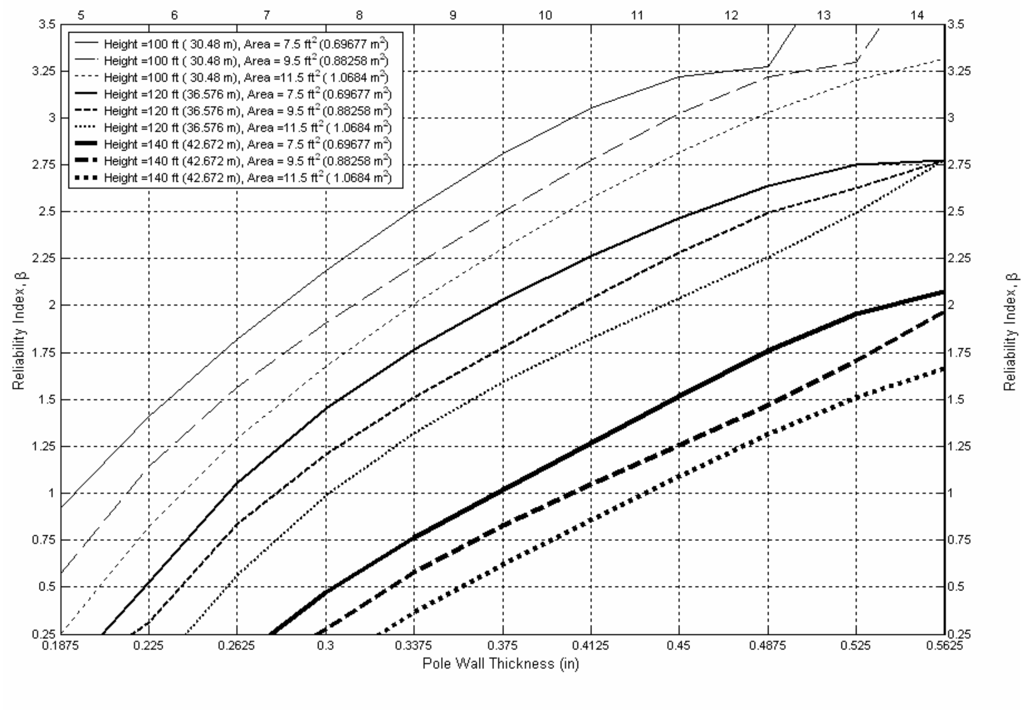
Figure A-10 (cont.): Design Chart (MV-*E*) – Mean Wind Velocity = 14 MPH (22.53 km/hr)

Mean Wind Velocity = 16 MPH (25.75 km/hr)
Figures A-11 (a) – (c) provide the design charts for multiple variables for pole outside diameters of 23.4 in (594.36 mm), 26 in (660.4 mm), and 28.6 in (726.44 mm) respectively for a mean wind velocity of 16 MPH (25.75 km/hr). Each set of figures is also provided with three fatigue life targets, 25, 50, and 75 years respectively, indicated by the subscript on the figure number.

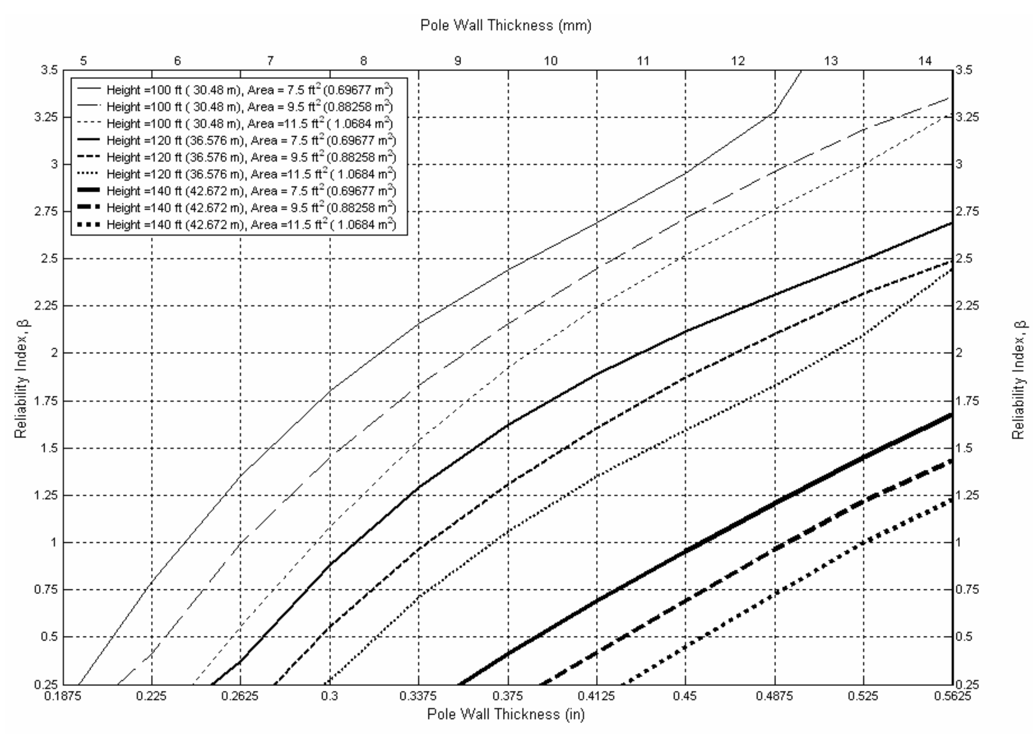


(a_{25yr}): Outside Diameter = 23.4 in (594.36 mm)

Figure A-11: Design Chart (MV-*E*) – Mean Wind Velocity = 16 MPH (25.75 km/hr)

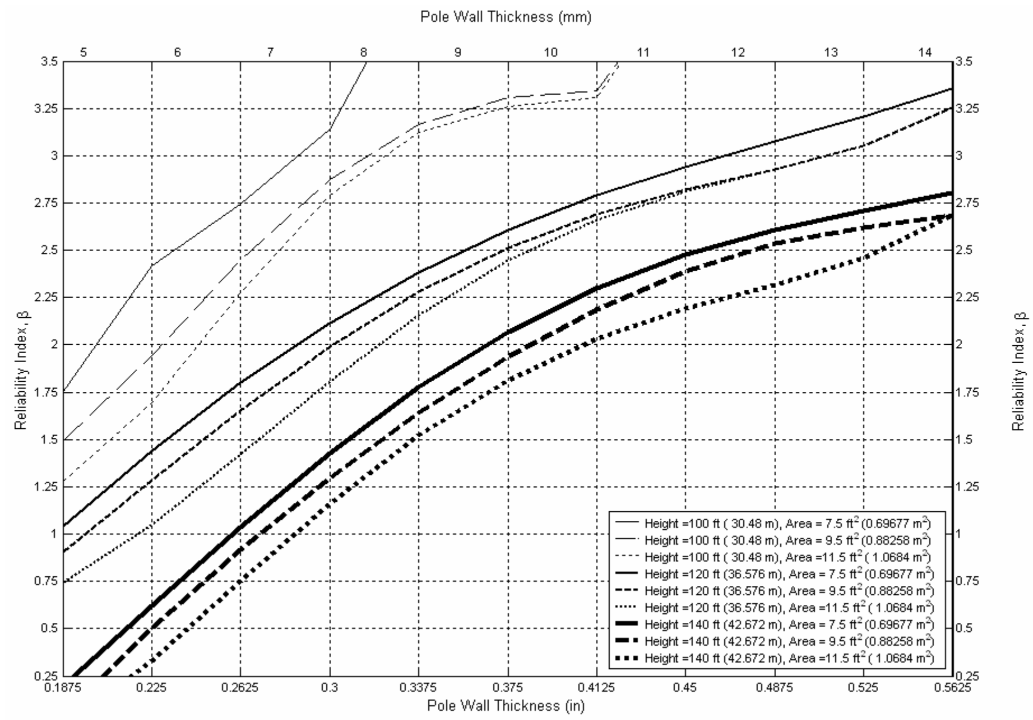


(a_{50yr}): Outside Diameter = 23.4 in (594.36 mm)

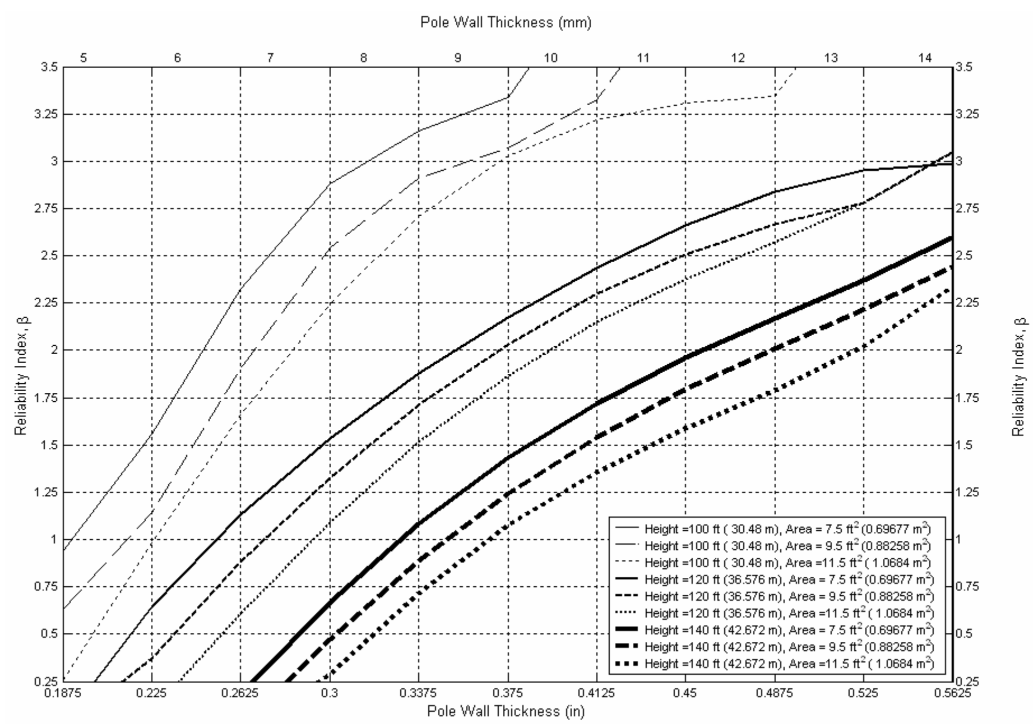


(a_{75yr}): Outside Diameter = 23.4 in (594.36 mm)

Figure A-11 (cont.): Design Chart (MV-*E*) – Mean Wind Velocity = 16 MPH (25.75 km/hr)

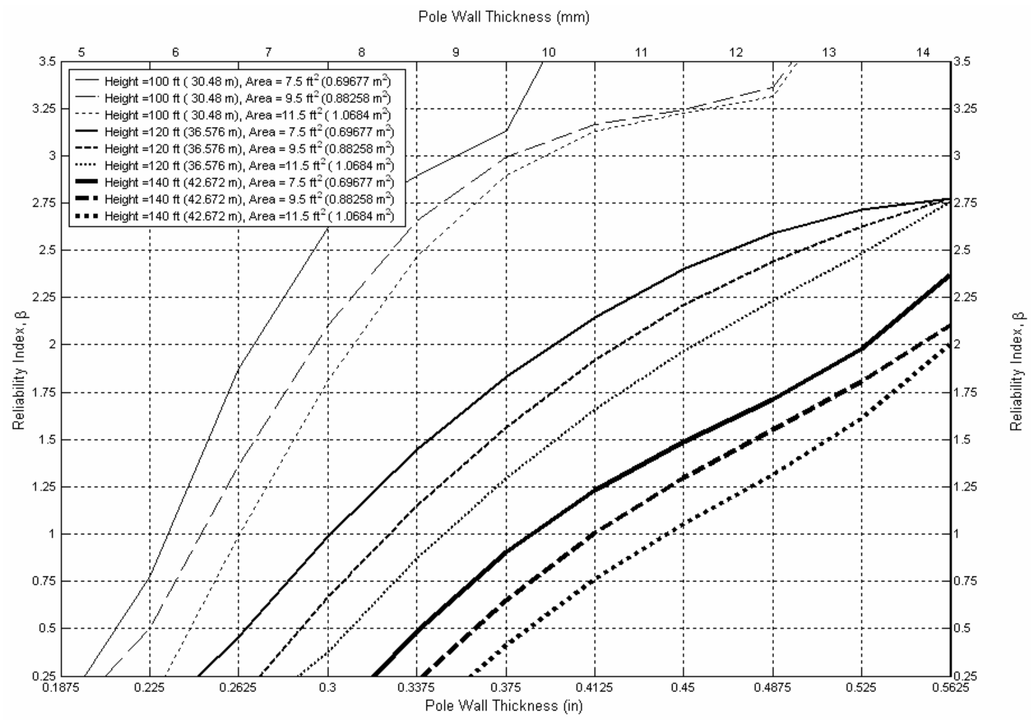


(b_{25yr}): Outside Diameter = 26 in (660.4 mm)

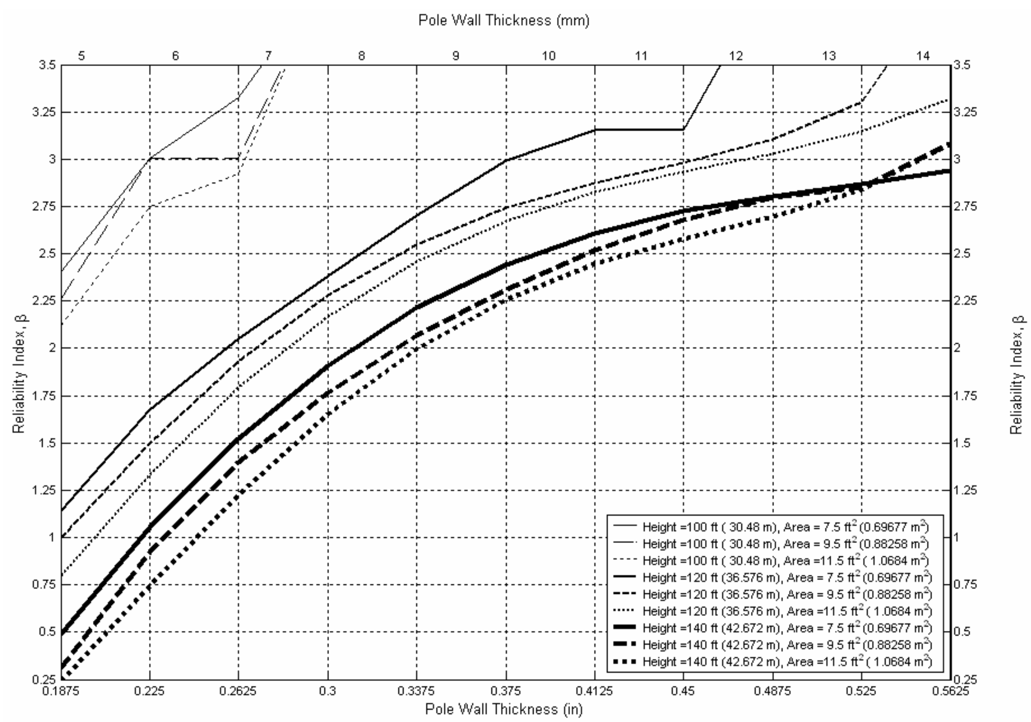


(b_{50yr}): Outside Diameter = 26 in (660.4 mm)

Figure A-11 (cont.): Design Chart (MV-*E*) – Mean Wind Velocity = 16 MPH (25.75 km/hr)

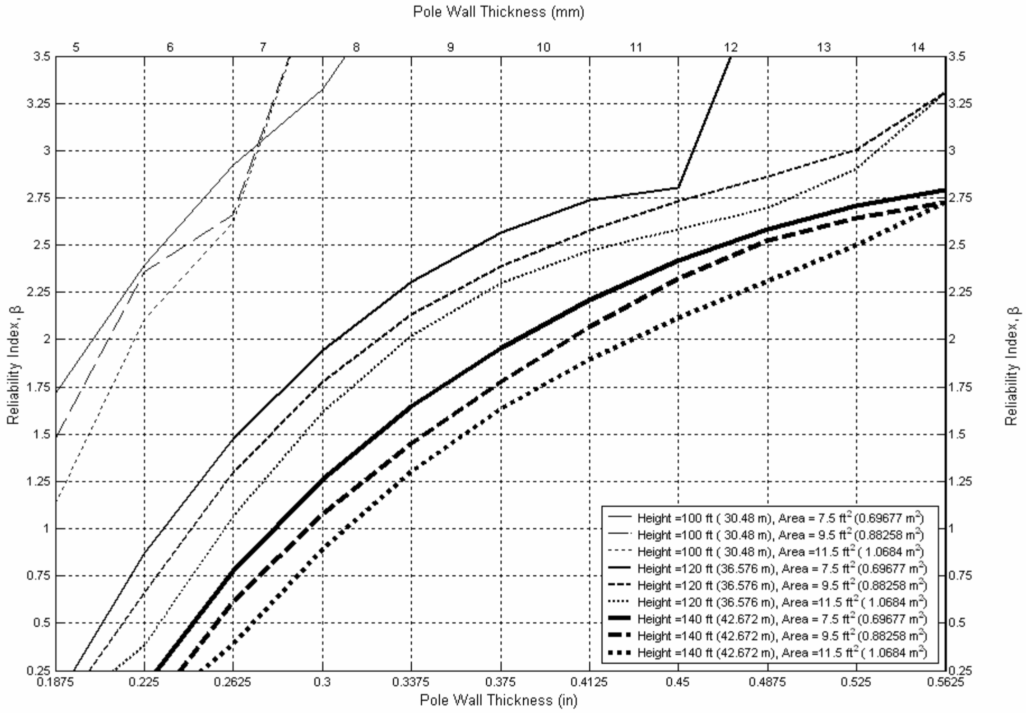


(b_{75yr}): Outside Diameter = 26 in (660.4 mm)

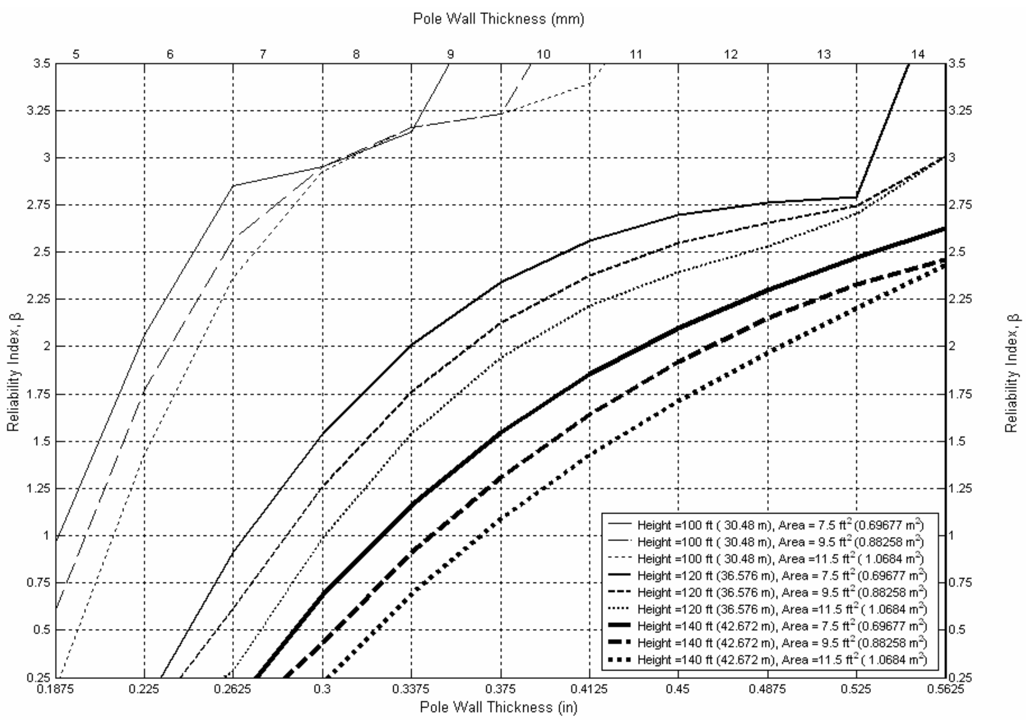


(c_{25yr}): Outside Diameter = 28.6 in (726.44 mm)

Figure A-11 (cont.): Design Chart (MV-*E*) – Mean Wind Velocity = 16 MPH (25.75 km/hr)



(c_{50yr}): Outside Diameter = 28.6 in (726.44 mm)



(c_{75yr}): Outside Diameter = 28.6 in (726.44 mm)

Figure A-11 (cont.): Design Chart (MV-*E*) – Mean Wind Velocity = 16 MPH (25.75 km/hr)