Metal & Cable Corp., Inc.
Antenna Mount Calculations - R01

B & A Project 74035

Prepared for:
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July 24, 2010

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74035 Antenna Mount Calculations
74035R01
7/24/2010

Overview

The scope of Part 1 of the project required calculations based on AASHTO standards to determine loads at the base of a mounting system used to attach a dish/panel antenna array to the side of a water tower. The calculation set is shown on pages 0 thru 13 of the attached document and is loosely based on a proposed installation in Washington state. The general arrangement of that installation can be found in Appendix 1. Some of the geometric values used in the attached calculations such as the horizontal distances between components were scaled from this document.

Multiple exceptions and assumptions were employed in the execution of the calculation set. They are listed below in no specific order of priority.

1) The height above ground of the antenna array has been arbitrarily set to 200'.
2) The antenna array was assumed to have full exposure from a rear wind situation.
3) The exposure of the vertical pole was assumed to be negligible for front & rear wind situations.
4) The exposure of the various clamps, brackets, and hardware was assumed to be insignificant.
5) Loads per magnetic bracket in some cases were assumed to be evenly distributed even though the actual distribution is statically indeterminate.
6) Allowable loads per magnet and per magnetic bracket as well as the layout of the magnets on each bracket were supplied by the client.
7) The radius of curvature of the water tank was assumed to be negligible.
8) Ice loads, if applicable, are assumed to cover the entire component in question.

Constants used in the calculation set were taken from the AASHTO standard and are included in the appendix. All wind velocities were taken from the map on Appendix 2. It should be noted here that while the nominal wind velocities were used in generating the attached values, local building codes should be consulted in areas designated as special wind regions. The exposure factor, which is based on the height of the structure being analyzed relative to the local terrain, is taken from an AASHTO table and is shown in Appendix 3. A drawing of the magnet mounting plate is shown on Appendix 5. The magnets are attached to the 0.44 diameter thru holes. Other constants used in this report are the minimum gust factor of 1.14, a wind importance factor of 1.0, a drag co-efficient of 1.12, and an ice load of 3 lbs/ft².

The scope of Part 2 of this project involved the creation of an excel spreadsheet to be used in generating approximations of loadings where the installation is similar to the condition shown in Appendix 1. The results of this spreadsheet should be considered only as an approximation as each site should be carefully reviewed to apply the appropriate AASHTO values. A digital copy of this file has been supplied under separate cover under the file name of 74035genericR01.xls. A printed copy of a completed spreadsheet based on a specific example is shown on Appendix 4. A simplified general arrangement of
the loading condition depicted by this spreadsheet is shown on page 15 of the calculation set. The tutorial on its use begins on page 14. The cells within the spreadsheet are NOT write protected. The overall accuracy can be verified using the example on pages 1 thru 13 and making allowances for round-off error.

Conclusion

Calculations for factors of safety for the conditions presented here-in are well within range of generally accepted safe working conditions.
BB  Bottom bracket
FFBB Front wind force @ bottom bracket
FFD  Wind load at front of dish antenna
FFP  Wind load at front of panel antenna
FFTB Front wind force @ top bracket
FIB  Force @ magentic bracket from ice load
FID  Ice load on dish antenna
FIP  Ice load on panel antenna
FIT  Ice load on vertical tube
FMB  Force @ magentic bracket from component mass
FP   Force @ magentic pad
FRBB Rear wind force @ bottom bracket
FRD  Wind load at rear of dish antenna
FRP  Wind load at rear of panel antenna
FRTB Rear wind force @ top bracket
FSB  Shear load @ mounting bracket
FSD  Wind load at side of dish antenna
FSP  Wind load at side of panel antenna
FST  Wind load at side of vertical tube
FSV  Vertical shear force @ magnetic pad
MD   Mass of dish antenna
MP   Mass of panel antenna
MT   Mass of vertical tube
TB   Top bracket
Wind Load Equation (AASHTO LTS-4)

\[ P_z (\text{lbs/ft}^2) = 0.00256 K_z G V_f^2 I_w C_d \]

- Drag Coefficient
- Wind Importance Factor
- Wind Velocity (mph)
- Gust Factor
- Exposure Factor *

Calculate Dish Antenna Area & Wind Load (Front or Rear Exposure)
- 25.1" Dia (given)
- Area = \( \pi r^2 = (\pi)(12.55^2) \) = 494.8 in \(^2\)
- 494.8 in \(^2\) / 144 = 3.44 ft \(^2\)
- \( P_z \) (lbs/ft \(^2\)) = (.00256(1.46)(1.14)(85^2)(1.0)(1.12) = 34.47 lbs/ft \(^2\)
- FFD = FRD = (34.47)(3.44) = 118.58 lbs.

Calculate Dish Antenna Area & Wind load (Top or Side Exposure)
- Simplified profile shown below

\[ \text{Area} = (25.1)(8.2)-(10)(7.2) \] = 133.82 in \(^2\)
- 133.82 in \(^2\) / 144 = .93 ft \(^2\)
- \( P_z \) (lbs/ft \(^2\)) = (.00256(1.46)(1.14)(85^2)(1.0)(1.12) = 34.47 lbs/ft \(^2\)
- FSD = (34.47)(.93) = 32.06 lbs.

* Arbitrarily set at 200'
Calculate Panel Antenna Area & Wind Load (Front or Rear Exposure)
- 12.7" x 42" profile (given)
- Area = (12.7)(42) = 533.4 in²
- 533.4 in² / 144 = 3.70 ft²
- P₂ (lbs/ft²) = (0.00256(1.46)(1.14)(85²)(1.0)(1.12) = 34.47 lbs/ft²
- FFP = FRP = (34.47)(3.7) = 127.54 lbs.

Calculate Panel Antenna Area & Wind Load (Side Exposure)
- 2.7" x 42" profile (given)
- Area = (2.7)(42) = 113.4 in²
- 113.4 in² / 144 = .79 ft²
- P₂ (lbs/ft²) = (0.00256(1.46)(1.14)(85²)(1.0)(1.12) = 34.47 lbs/ft²
- FSP = (34.47)(.79) = 27.23 lbs.

Calculate Panel Antenna Area (Top Exposure)
- 12.7" x 2" profile (given)
- Area = (12.7)(2) = 34.29 in²
- 34.29 in² / 144 = .24 ft²

Calculate TubeProjected Area (Front or Rear or Side Exposure)
- 4.5" OD (given) x 140" long
- Area = (4.5)(140) = 630 in²
- 630²/144 = 4.4 ft²
- P₂ (lbs/ft²) = (0.00256(1.46)(1.14)(85²)(1.0)(1.12) = 34.47 lbs/ft²
- FST = (34.47)(4.4) = 151.66 lbs.
Frontal Wind Loading

The top mounting bracket becomes the "pivot" for all horizontal forces in this configuration.

Sum Moments about FFTB (cw = +):

\[ \Sigma M @ TB = 0 = (13.5)(127.54) + (70)(118.5) - (60)(FFBB) \]
\[ FFBB = (13.5)(127.54) + (70)(118.5))/60 = 166.94 \text{ lbs} \]

Solve for FFTB:

\[ \Sigma F = 0 = 127.54 + 118.5 + 166.94 - FFTB \]
\[ FFTB = 412.98 \text{ lbs} \]
The frontal wind condition puts the top magnetic mounting bracket into compression and applies a tensile load to the lower mounting bracket. Per the equations on the previous page, that total tensile load (FFBB) is 166.82 lbs. Assuming equal distribution on all magnets, each individual magnet is subject to 166.86/24 or 6.95 lbs.
Rear Wind Loading

The "bottom" mounting bracket becomes the "pivot" for all horizontal forces in this configuration.

Sum Moments about FRBB (cw = +):

\[ \Sigma M @ BB = 0 = (60)FRTB - (73.5)(127.54) - (118.5)(130) \]
\[ FRTB = \frac{(73.5)(127.54) + (130)(118.5)}{60} = 412.98 \text{ lbs} \]

Solve for FRBB:

\[ \Sigma F = 0 = 127.54 + 118.5 - 412.98 + FRBB \]
\[ FRBB = 166.94 \text{ lbs} \]
The rear wind condition puts the bottom magnetic mounting bracket into compression and applies a tensile load to the top mounting bracket. Per the equations on the previous page, that total tensile load (FRTB) is 412.98 lbs. Assuming equal distribution on all magnets, each individual magnet is subject to 412.98/24 or 17.20 lbs.

The analysis generated to this point indicates that the tensile loads created by the wind from the rear of the structure create higher "tensile" forces on the magnetic pads than do the winds from the front of the structure.
Side Wind Loading

Two types of loads are generated by winds blowing at the side profiles of the antennae. The first type of load is a shear loading which is discussed below. The second loading produces tensile and compressive loads on the magnets and is discussed on the following page.

Side Wind Loading - Shear

The shear loads generated by winds blowing at the side profiles of the antennae are resisted by a couple centered at the midpoint of the distance between the two magnetic mounting pads. By definition, both forces of a couple are equal to each other. Therefore, for subsequent shear calculations, FSBB and FSTB are renamed simply as FSB.

Sum Moments about couple center (cw = +):

\[ \Sigma M = 0 = (43.5)(27.23) + (100)(32.06) + (35)(152) - (60)(FSB) \]

FSB = \((43.5)(27.23) + (100)(32.06) + (152)(35))/60 = 161.84 \]

Each shear load will be resisted equally by 24 magnets. The resulting individual load will be \(161.84/24 = 6.74 \text{ lbs}\).
Side Wind Loading - Tension & Compression

The relative orientation of the antennae to each other and to the magnetic brackets is shown in the plan view to the right. The antennae are offset from the magnetic brackets by the distance shown. The indicated side force creates a moment about the pad. This moment is resisted by a "couple" at the pad. Each force of the couple is located halfway from the center of the bracket to the center of its outer magnet.

\[ FSP + FSD = 59.29\# \]
\[ FST = 152\# \]
\[ 19.45 \]
\[ 12.25 \]
\[ 10.0 \]

\[ \Sigma M = 0 = (10)FP - (12.25)(152) - (19.45)(59.29) \]
\[ FP = ((19.45)(59.29) + (12.25)(152))/10 = 302 \text{ lbs} \]

Each component of the couple will be shared equally by 12 magnets/bracket. The resulting individual load will be 302/24 = 12.56 lbs
Mass Loads

Mass loads from the individual components are resisted by a force couple with its center halfway between the upper and lower mounting brackets. This couple is similar to that created by wind side loads. This force couple is solved on this page. The mass loads are also resisted by a vertical shear and are also discussed on this page.

Shear Forces from Mass Loads

The total shear force will be shared equally among 48 magnets. The load per individual magnet will be \((20 + 18.7 + 175)/48 = FSV\)

\[4.45 \text{ lbs} = FSV\]

Tensile and Compressive Forces from Mass Loads

Sum Moments about couple center (cw = +):

\[\Sigma M = 0 = (60)(FMB) - (175)(12.25) - (18.7)(19.45) - (20)(19.45)\]

\[FMB = \frac{((12.25)(175) + (18.7)(19.45) + (20)(19.45))/60 = 48.27 \text{ lbs}}{60}\]

The tensile load on the top bracket will be shared equally by 24 magnets. The load per individual magnet will be \(48.27/24 = 2 \text{ lbs}\).
Ice Loads

Ice loads resulting from the coatings on individual components are calculated in exactly the same method as were the mass loads on the previous page. The mass of the ice is based on a constant of 3 lbs/ft$^2$ of the surface being coated. Calculations of total areas and the corresponding ice masses are shown on this page.

Ice Surface Area - Dish Antenna
- Simplified profile shown below

- Area calculated via Solid Works = 8.18 ft$^2$
- FID = (8.18)(3.0) = 24.55 lbs.

Ice Surface Area - Panel Antenna
- 12.7" x 42" x 2.7" profile (given)
- Area = \([(12.7)(42)(2) + (12.7)(2.7)(2) + (2)(2.7)(42)]/144 = 9.45\ ft^2\]
- FIP = (9.45)(3.0) = 28.35 lbs.

Ice Surface Area - Support Tube
- 4.5" OD (given) x 140" long
- Area = \([(4.5)(140)(\pi) + (\pi)(2.25^2)(2)]/144 = 13.96\ ft^2\]
- FIT = (13.96)(3.0) = 41.9 lbs.
Shear Forces from Ice Loads

The total shear force will be shared equally among 48 magnets. The load per individual magnet will be \((24.55 + 28.35 + 41.9)/48 = 1.98\) lbs.

Tensile and Compressive Forces from Ice Loads

Sum Moments about couple center \((cw=+)\):

\[
\Sigma M = 0 = (60)(FIB) - (41.9)(12.25) - (24.55)(19.45) - (28.35)(19.45)
\]

\[
FIB = ((12.25)(41.9) + (24.55)(19.45) + (28.35)(19.45))/60 = 25.70\) lbs

The tensile load on the top bracket will be shared equally by 24 magnets. The load per individual magnet will be \(48.27/24 = 1.07\) lbs.
Group I combined loads - Rear Wind Situation

This per magnet loading is a combination of the following components:
- Tensile from rear wind - 17.17 lbs
- Tensile from mass - 2.0 lbs
- Tensile from ice - 1.07 lbs
- Shear from mass - 4.45 lbs
- Shear from ice - 1.98 lbs

The shear forces resulting from ice and mass act in the same direction and can be added algebraically to form a single component.
That vector is 4.45(mass) + 1.98(ice) = 6.43 lbs
Factor of Safety = 35/6.43 = 5.44

Likewise, all tensile forces are acting in the same direction and can be added algebraically to form a single component.
That vector is 17.17(wind) + 2.0(mass) + 1.07(ice) = 20.24 lbs
Factor of Safety = 100/20.24 = 4.94

Group II combined loads - Side Wind Situation

This per magnet loading is a combination of the following components:
- Tensile from side wind - 12.56 lbs
- Tensile from mass - 2.0 lbs
- Tensile from ice - 1.07 lbs
- Shear from side wind - 6.74 lbs
- Shear from mass - 4.45 lbs
- Shear from ice - 1.98 lbs
The shear forces resulting from ice and mass act in the same direction and can be added algebraically to form a single component. The shear vector from the wind load acts in the same plane but at right angles to the ice & mass vector all three can be combined per the diagram below.

\[
\begin{align*}
\text{Combined Shear} & = \sqrt{(6.74^2) + (6.43^2)} = 9.31 \text{ lbs} \\
\text{Factor of Safety} & = 35/9.31 = 3.76
\end{align*}
\]

All tensile forces are acting in the same direction and can be added algebraically to form a single component. That vector is 12.56(wind) + 2.0(mass) + 1.07(ice) = 15.63 lbs

Factor of Safety = 100/15.63 = 6.4
Note: The file 74035genericR01.xls is NOT write protected. Cells A7 thru A33 are user entered data and are relative to the geometry of specific components within the general arrangement being investigated. See page 0 of this calculation set to identify abbreviations for specific forces and reactions and see the next page to identify components and dimensions discussed below. Dimensions and mass values on the next page are marked with the appropriate cell where they should be entered (A19 thru A29). The user should not enter data into or alter any cells other than those discussed below. Note units where applicable.

<table>
<thead>
<tr>
<th>Cell</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A7</td>
<td>Wind speed (mph) at location. See Appendix 02.</td>
</tr>
<tr>
<td>A8</td>
<td>Exposure Factor based on elevation. See Appendix 03.</td>
</tr>
<tr>
<td>A9</td>
<td>Ice Load Area? See Appendix 02. Enter 3 for yes and 0 for no.</td>
</tr>
<tr>
<td>A11*</td>
<td>Antenna 1 exposure to rear winds (ft²)</td>
</tr>
<tr>
<td>A12*</td>
<td>Antenna 1 exposure to side winds (ft²)</td>
</tr>
<tr>
<td>A14*</td>
<td>Antenna 2 exposure to rear winds (ft²)</td>
</tr>
<tr>
<td>A15*</td>
<td>Antenna 2 exposure to side winds (ft²)</td>
</tr>
<tr>
<td>A17*</td>
<td>Vertical tube exposure area to side winds (ft²)</td>
</tr>
<tr>
<td>A19</td>
<td>Vertical distance between mounts. (in)</td>
</tr>
<tr>
<td>A20</td>
<td>Vertical distance - Bottom mount to antenna #1 CG. (in)</td>
</tr>
<tr>
<td>A21</td>
<td>Vertical distance - Bottom mount to antenna #2 CG. (in)</td>
</tr>
<tr>
<td>A22</td>
<td>Vertical distance - Bottom mount to vertical tube CG. (in)</td>
</tr>
<tr>
<td>A23</td>
<td>Horizontal distance - Magnet face to antenna #1 CG. (in)</td>
</tr>
<tr>
<td>A24</td>
<td>Horizontal distance - Magnet face to antenna #2 CG. (in)</td>
</tr>
<tr>
<td>A25</td>
<td>Horizontal distance - Magnet face to vertical tube CG. (in)</td>
</tr>
<tr>
<td>A27</td>
<td>Mass (lbs) of antenna #1 (manufacturer supplied data)</td>
</tr>
<tr>
<td>A28</td>
<td>Mass (lbs) of antenna #2 (manufacturer supplied data)</td>
</tr>
<tr>
<td>A29*</td>
<td>Mass (lbs) of vertical tube.</td>
</tr>
<tr>
<td>A31*</td>
<td>Ice surface area** (ft²) of antenna #1</td>
</tr>
<tr>
<td>A32*</td>
<td>Ice surface area** (ft²) of antenna #2</td>
</tr>
<tr>
<td>A33*</td>
<td>Ice surface area** (ft²) of vertical tube</td>
</tr>
</tbody>
</table>

* Requires offline user calculation
** Ice surface area = Total outside surface
Notes:
1. Values are 3-second gust speeds in m/s (mph) at 10 m (32.8 ft) above ground for Exposure C category and are associated with an annual probability of 0.02 (50-year mean recurrence interval).
2. Linear interpolation between wind speed contours is permitted.
3. Islands and coastal areas shall use wind speed contour of coastal area.
4. Mountainous terrain, gorges, ocean promontories, and special wind regions shall be examined for unusual wind conditions

<table>
<thead>
<tr>
<th>Location</th>
<th>V m/s (mph)</th>
</tr>
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<tbody>
<tr>
<td>Hawaii</td>
<td>47 (105)</td>
</tr>
<tr>
<td>Puerto Rico</td>
<td>56 (125)</td>
</tr>
<tr>
<td>Guam</td>
<td>76 (170)</td>
</tr>
<tr>
<td>Virgin Islands</td>
<td>56 (125)</td>
</tr>
<tr>
<td>American Samoa</td>
<td>56 (125)</td>
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</tbody>
</table>

Alaska Note:
For coastal areas and islands, use nearest contour.
<table>
<thead>
<tr>
<th>Height, m(ft)</th>
<th>( K_z )</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.0 (16.4) or less</td>
<td>0.87</td>
</tr>
<tr>
<td>7.5 (24.6)</td>
<td>0.94</td>
</tr>
<tr>
<td>10.0 (32.8)</td>
<td>1.00</td>
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<tr>
<td>12.5 (41.0)</td>
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<td>15.0 (49.2)</td>
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<td>17.5 (57.4)</td>
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<td>20.0 (65.6)</td>
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<td>22.5 (73.8)</td>
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<td>25.0 (82.0)</td>
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</tr>
<tr>
<td>27.5 (90.2)</td>
<td>1.24</td>
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<td>30.0 (98.4)</td>
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<tr>
<td>35.0 (114.8)</td>
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<tr>
<td>40.0 (131.2)</td>
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<td>45.0 (147.6)</td>
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<tr>
<td>55.0 (180.5)</td>
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<tr>
<td>60.0 (196.9)</td>
<td>1.46</td>
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<tr>
<td>70.0 (229.7)</td>
<td>1.51</td>
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<tr>
<td>80.0 (262.5)</td>
<td>1.55</td>
</tr>
<tr>
<td>90.0 (295.3)</td>
<td>1.59</td>
</tr>
<tr>
<td>100.0 (328.1)</td>
<td>1.63</td>
</tr>
</tbody>
</table>
Generic Antenna Approximations
74035generick03.xls
7/24/2010

User Entered Data
85.00 Wind Speed (mph)
1.46 Exposure Factor (per attached AASHTO table)
3.00 Ice (psf)
3.44 Antenna 1 Rear Exposure Area (square feet)
0.93 Antenna 1 Side Exposure Area (square feet)
3.70 Antenna 2 Rear Exposure Area (square feet)
0.79 Antenna 2 Side Exposure Area (square feet)
4.40 Vertical Tube Side Exposure Area (square feet)
60.00 Vertical Distance Between Mounts (in)
190.00 Vertical Distance - Bottom mount to antenna 1 CG (in)
73.50 Vertical Distance - Bottom mount to antenna 2 CG (in)
65.00 Vertical Distance - Bottom mount to vertical tube CG (in)
10.45 Horizontal Distance - Magnet face to antenna 1 CG (in)
19.45 Horizontal Distance - Magnet face to antenna 2 CG (in)
12.25 Horizontal Distance - Magnet face to vertical tube CG (in)
18.70 Mass of Antenna 1 (lbs)
20.00 Mass of Antenna 2 (lbs)
175.00 Mass of Vertical Mount Tube (lbs)
8.18 Ice surface area antenna 1 (square feet)
9.45 Ice surface area antenna 2 (square feet)
13.96 Ice surface area vertical tube (square feet)
Calculated Constants
30.00 1/2 distance between magnetic mounts (in)
Calculated Component Wind Loads
118.61 FR1 (wind force lbs at rear of antenna 1)
32.07 FS1 (wind force lbs at side of antenna 1)
127.57 FI2 (wind force lbs at rear of antenna 2)
27.24 FS2 (wind force lbs at side of antenna 2)
151.71 FST (wind force lbs at side of mounting tube)
Calculated Component Ice Loads
24.54 Ice Load (lbs) Antenna 1
28.35 Ice Load (lbs) Antenna 2
41.88 Ice Load (lbs) Vertical Tube
Mounting Bracket Forces From Rear Winds
413.26 FRBT (top bracket force - rear wind)
167.08 FRBB (bottom bracket force - rear wind)
17.22 Top Mount Tension per magnet from rear wind
Mounting Bracket Forces From Side Winds
163.69 FS horizontal "shear" load per bracket
6.74 Horizontal "shear" load per magnet from side wind
501.19 FP (mounting pad (lbs tension and compression) load from Side wind loads
12.55 Tension load per magnet from side wind load
Mass Loads
106.85 FSVM Vertical "shear" load per bracket
4.45 Vertical "shear" load per magnet
48.27 FP (mounting pad (lbs tension and compression) load from Mass Loads
2.05 Tension load per magnet from Mass Load
Ice Loads
94.77 FSV Vertical "shear" load per bracket
1.97 Vertical "shear" load per magnet
25.70 FP (mounting pad (lbs tension and compression) load from Mass Loads
1.07 Tension load per magnet from Mass Load
Combined Loads - Rear Wind Situation
6.43 Vertical "shear" (mass + ice)
5.45 Factor of Safety
20.30 Tensile Load (wind + mass + ice)
4.93 Factor of Safety
Combined Loads - Side Wind Situation
9.31 Combined "shear" (wind + mass + ice)
3.76 Factor of Safety
15.63 Tensile Load (wind + mass + ice)
6.40 Factor of Safety
FINISH: CLEAR ANODIZE

TAP 3/8-16 THRU (3) HOLES

TAP 1/2-13 THRU

TAP 1/4-20 THRU .50 # MASK BOTH SIDES NO ANODIZE

8.44 THRU (24)

TAP 5/16-18 THRU (24) HOLES

APPENDIX 05