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# STRUCTURAL ANALYSIS REPORT

**PREPARED FOR:**

**JEFFERSON COUNTY**

**120 FT SELF-SUPPORTED TOWER**
**EQUIPMENT INSTALLATION**
**SULLIVAN TOWER**
**SULLIVAN, WISCONSIN**

**EDGE PROJECT NUMBER:**
**10125**

**JUNE 12, 2014**

# STRUCTURAL ANALYSIS REPORT

| | |
|---|---|
| **Project Information:** | Sullivan Tower<br>N4889 Pioneer Road<br>Sullivan, WI 53178 |
| **Client:** | Jefferson County<br>411 South Center Ave.<br>Jefferson, WI 53549<br>Contact: Todd Lindert<br>Phone: (920) 674-7346 |
| **Consultant:** | Edge Consulting Engineers<br>624 Water Street<br>Prairie du Sac, Wisconsin 53578<br>Contact: Michael Muehrer, P.E.<br>Phone: (608) 644-1449 |
| **Edge Project Number:** | 10125 |
| **Date:** | June 12, 2014 |


Edward J. Sippel
Edward J. Sippel, E.I.T.
Structural Engineer

6/12/14
Date

WISCONSIN PROFESSIONAL ENGINEER
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6/12/14
Date

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# SECTION 1
# EXECUTIVE SUMMARY

Site Name: Sullivan Tower
Site Location: Sullivan, Wisconsin
Purpose: Equipment Installation
Tower Type: 120 ft. Self-Supported Tower

We have completed a structural analysis for the above described tower. One loading scenario was considered in the analysis. The loading condition takes into account the existing tower loading along with the proposed loading. The loading condition is described in Section 3.2, with reference to the feedline placement diagram (Figure 1).

Under the TIA-222-G requirements, the completed a structural analysis is considered a feasibility analysis since information regarding the tower structure, foundation system, and/or soil conditions were not available at the time of the study. The following information was not available and is required for a rigorous analysis to be completed:

- Geotechnical Report
- Foundation Design Documents and Drawings

The results of our feasibility analysis indicate that the existing tower may be capable of supporting the proposed change in loading. However, per TIA-222-G, final acceptance of the changed condition must be based upon a rigorous structural analysis. Refer to Section 3.5 for additional information regarding assumptions for this analysis.

Please refer to the report which follows this summary for further information. Feel free to contact us if you have any questions or concerns.

# SECTION 2
# INTRODUCTION

## 2.1 PURPOSE OF REPORT

Edge performed a structural analysis of the existing tower to determine whether the tower is structurally adequate to support both the existing and proposed loads pursuant to the Structural Standard for Antenna Supporting Structures and Antennas, ANSI/TIA-222-G. This assessment was completed using background information provided by the client and/or obtained in the field (where noted) and in conformance with current applicable codes, client directed protocols, and the judgment of the structural engineer.

## 2.2 SCOPE OF SERVICES

The scope of services for this project included structural analysis and modeling of the tower structure in accordance with client supplied information. A feasibility analysis was completed. It should be noted that per the TIA-222-G standard, changes to the tower structure or loading cannot be performed without a rigorous analysis. See Executive Summary for information required for a rigorous analysis to be completed.

This report summarizes the structural analysis results.

# SECTION 3
# ANALYSIS

## 3.1 BACKGROUND INFORMATION

The subject tower is an existing 120 foot tall self-supported tower. Based on available information, it was not definitely known the manufacturer or date designed; however, the tower was likely designed by Pirod. It is our understanding that the tower geometry has not been altered from the original design. We were provided the following information at the project outset:

1. Structural Tower Mapping: Edge Eng. File: 10125 dated 6/11/2014
2. Proposed antenna and feedline loading configuration

## 3.2 LOADING CONDITION

The listed heights for microwave dishes are representative of the antenna centerline. For dipole antennas the listed heights represent the base of the antenna.

The following loading condition was considered during this analysis:

| Antenna Height | # | Manufacturer & Model # | Mounting Type | Technology / Notes | Coax Details | | Carrier / Owner | Status |
|---|---|---|---|---|---|---|---|---|
| | | | | | (#) Size | Location | | |
| 89' | 1 | Andrew DB224-A | 3' Side Mount | Dipole | (1) 7/8" | Leg A | County | Proposed |
| 115' | 1 | Andrew D8C-22 | Pipe Mount | Dish | (1) EW90 (To Be Removed) | Leg A | County | Existing (Remove Dish) |
| 115' | 1 | Scientic Atlanta Box | Wire | TMA | (1) 5/8" (To Be Removed) | Leg B | County | Existing (Remove Antennas) |
| 119' | 1 | Andrew DB224-A | 3' Side Mount | Dipole | (1) 7/8" | Leg A | County | Proposed |
| 120' | 1 | Radiowaves HP3-11EX | Pipe Mount | Dish | (1) EW90 | Leg A | County | Proposed |

The loading condition is further described in the Designed Appurtenance Loading table provided in Appendix B.

The feedline placement associated with the proposed loading condition which was considered in this analysis is attached as Figure 1.

## 3.3 ANALYSIS CRITERIA

This analysis was performed in accordance with TIA-222-G per the current Wisconsin Commercial Building Code (IBC 2009). The basic wind speed for Jefferson County, Wisconsin is 90 mph with no ice, 40 mph with 0.75 inches of ice, and a 60 mph service wind speed for deflection calculations.

This analysis utilized the following Tower Structure Class, Topographic Category and Exposure Criteria:

Tower Structure Class: III
Topographic Category: 1
Exposure Criteria: C

These criteria were selected based on the location and use of the subject tower (per TIA-222-G). The client and/or tower owner must review these criteria for applicability and notify Edge Consulting if a different tower structure class, topographic category, or exposure criteria are warranted.

Definitions of the different categories and criteria were taken from the TIA-222-G standard and are provided in Appendix A.

### 3.4 ANALYSIS METHOD

Structural analysis computations and modeling of the tower structure were performed using TNX Tower Version 6.1 software. TNX Tower is a general-purpose modeling, analysis, and design program created specifically for communications towers using the TIA-222-G (including Addenda No. 1 and 2) or any previous TIA/EIA Standards back to RS-222 (1959). Steel design is checked using the AISC ASD $9^{th}$ Edition or the AISC LRFD Specifications. This program automatically generates nodes and elements for a subsequent finite element analysis (FEA) for standard tower types including self-support towers, guyed towers and monopoles. It allows entry of dishes, feedlines, discrete loads (loads from appurtenances) and user defined loads anywhere on the tower. TNX Tower uses wind effects from multiple directions and ice loads to develop pressure coefficients, wind pressures, ice loads and resulting forces on the tower per TIA code requirements.

The tower foundation system was also reviewed for the resulting applied forces due to the proposed change in loading. Items reviewed include checking the global overturning and shear of the foundation system. In addition, the anchor bolts and guy anchors (where applicable) were also reviewed for structural adequacy.

### 3.5 ASSUMPTIONS

As the tower drawings were not available for this analysis, the grade of the materials used was not available. Using the specifications from similar towers along with the AISC steel manual, a steel grade of A572-50 was assumed for the solid round members, a steel grade of A36 was assumed for the angle members, and a steel grade of A687 was assumed for the anchor bolts. If it is determined that these assumptions are not accurate, this analysis is void and an additional analysis should be performed.

# SECTION 4
# RESULTS

## 4.1 TOWER STRUCTURE

The results of our feasibility analysis indicate that the existing tower may be capable of supporting the proposed change in loading. However, per TIA-222-G, final acceptance of the changed condition must be based upon a rigorous structural analysis. Refer to Section 3.5 for additional information regarding assumptions for this analysis.

The results of the analysis are shown in the following table. The ratio listed for each tower element represents the capacity ratio calculated for the controlling member(s) for each element type.

| Capacity - Results | | |
|---|---|---|
| Tower Structure Elements | Capacity Ratio (%) | Comment |
| Legs | | |
| 0'-20' | **49.2%** | **Adequate** |
| Diagonals | | |
| 70'-90' | 48.3% | Adequate |
| Girts | | |
| 70'-90' | 18.5% | Adequate |
| Bolts | | |
| 30'-50' Diagonals | 19.1% | Adequate |

Diagrams of the towers maximum deflection, tilt, and twist are provided in Appendix B.

## 4.2 TOWER FOUNDATIONS

The results of our feasibility analysis indicate that the existing tower anchor rods may be capable of supporting the proposed change in loading. However, per TIA-222-G, final acceptance of the changed condition must be based upon a rigorous structural analysis. Refer to Section 3.5 for additional information regarding assumptions for this analysis.

Refer to Appendix B for support calculations.

## 4.3 RECOMMENDATIONS

The client and tower owner shall closely review this report including assumptions made, analysis criteria selected and loading conditions modeled. Any questions or discrepancies with these items shall be clarified with the engineer.

Edge recommends that qualified personnel assess the physical condition of the tower, in accordance with the guidelines and frequency provided in the TIA-222-G standard.

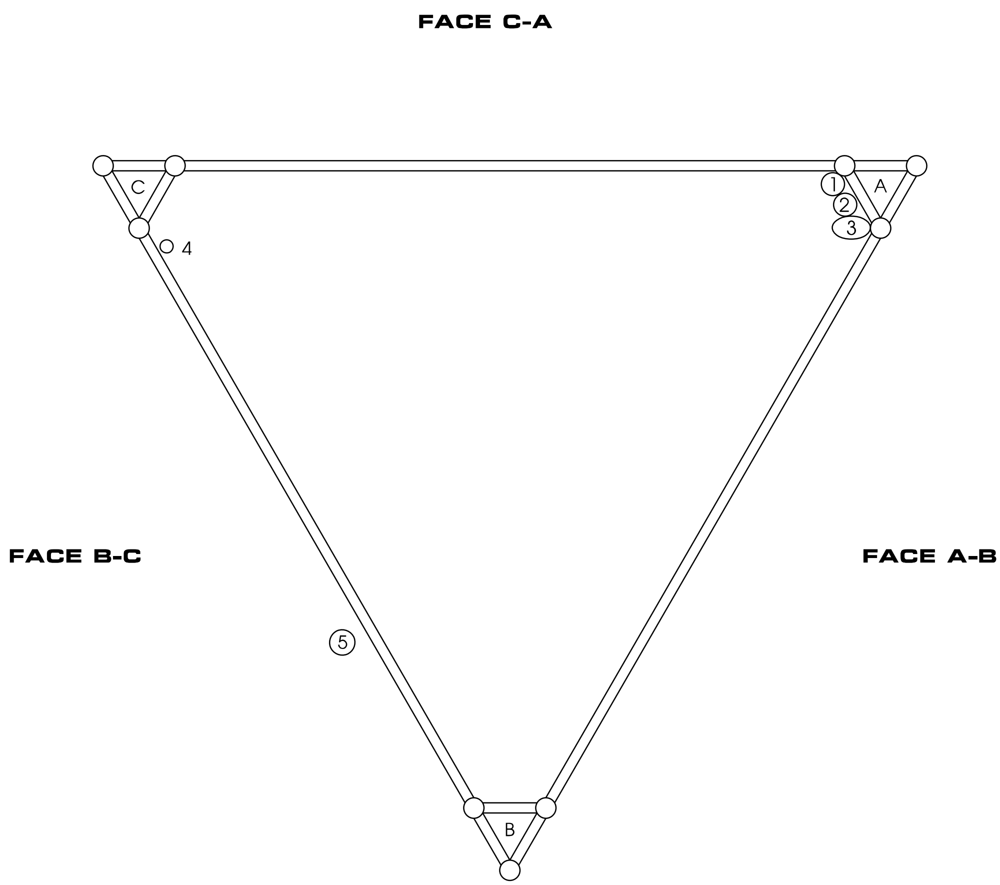
If the proposed loading condition is altered from that analyzed, this report shall be deemed obsolete and further analysis will be required.

# SECTION 5
# LIMITATIONS AND RESTRICTIONS

1. This report was prepared in accordance with generally accepted structural engineering practices common to the tower industry and makes no other warranties, either expressed or implied, as to the professional advice provided under the terms of the agreement between Engineer and Client. This report has not been prepared for uses or parties other than those specifically named, or for uses or applications other than those enumerated herein. The report may contain insufficient or inaccurate information for other purposes, applications, and/or other uses.
2. This report is intended for the use of the client, and cannot be utilized or relied upon by other parties without the written consent of Edge Consulting Engineers.
3. Edge consulting Engineers is not responsible for any, and all, tower modifications completed prior to, or hereafter, which Edge Consulting Engineers was not, or will not, be directly involved.
4. The model, conclusions, and recommendations contained within this report are based upon the supplied and attained information as described within the report. If it is known, or becomes known, that any item(s) are in conflict with what is described within this document, this report should be considered void and Edge Consulting Engineers should be contacted immediately.
5. Edge Consulting Engineers disclaims all liability for any information, conclusion, or recommendation that is not expressly stated or represented within this report.
6. Edge Consulting Engineers shall not be liable for any incidental, consequential, indirect, special or punitive damages arising out of any claim associated with the use of this report.
7. The scope of worked performed for this analysis is limited to the items in which we were furnished complete and accurate information.
8. Accessories and appurtenances such as antenna mounts, feed line ladders, climbing ladders, lighting mounts, etc. were not analyzed as part of this work, and Edge Consulting Engineers, Inc. makes no claim as to their adequacy of their design or their installation.
9. This analysis was performed under the assumption that all tower elements are in like new condition, free from rust and other deterioration. It is also assumed the tower was properly installed per construction documents, and that the tower and all associated appurtenances were originally designed and fabricated in accordance with all applicable codes and standards. Edge Consulting Engineers cannot account for, nor be held responsible, if tower elements are deteriorated, damaged, and/or missing.
10. This tower analysis was performed based upon the antenna, feed line and other appurtenance loading and placement as described within this report. Any alterations to the described loading or placement will require re-analysis of the tower, and the findings contained in this report are not valid.
11. The loading conditions utilized for this analysis is based on information provided by the client, and readily available manufacturer/vendor information (antenna and mount projected areas, weight and shape factors). However, if the described loading criteria and design assumptions within this report are not accurate, are altered, or changed in any form, this analysis shall be considered void and an additional analysis must be performed.
12. It is the responsibility of the client and the tower owner to thoroughly review the existing and proposed loading, and bring any discrepancy to the attention of Edge Consulting Engineers.
13. Modification designs are to be based upon a rigorous analysis per the TIA-222-G standard. As such designs assume any suggested modifications are installed as recommended and are not intended to address temporary conditions on the tower as modifications are being performed. It is strongly recommended that the Installer of any tower modification thoroughly assess installation procedures and how temporary conditions present while modifications are being performed influence tower members. Installer is responsible for sequence of operation and any required temporary bracing or strengthening of tower during modification operations.
14. Site-specific loading or local building code requirements may be more stringent than the minimum loading requirements specified in the Standard. These and other unique loads or loading combination requirements are to be specified by the owner (in the procurement specifications).
15. Supplementary rime ice and in-cloud ice loadings (including thickness, density, escalation with height and corresponding wind speed) are to be included in the procurement specification when appropriate for a given site location.
16. The service loads and deformation limits specified in the Standard are the minimum requirements for communication structures. When more stringent requirements are required for a specific application, the serviceability limit state basic wind speed and, if required, the serviceability limit state design ice thickness; the deformation limitations (twist, sway and horizontal displacement) and the location/elevation where the deformation limitations apply are to be included in the procurement specification.

# FIGURE 1

# FEEDLINE PLACEMENT DIAGRAM


## TOWER COAX ROUTING

| Coax # | Size | Mounting Type | Carrier / Owner | Termination Height | Status |
|---|---|---|---|---|---|
| 1 | 7/8" | Snap-in | County | 89' | Proposed |
| 2 | 7/8" | Snap-in | County | 119' | Proposed |
| 3 | EW90 | Snap-in | County | 120' | Proposed |
| 4 | 3/8" GRND | Zip-Tie | Tower | 120' | Existing |
| 5 | 3/4" | U-Bolts | Tower | 120' | Existing |

# APPENDIX A

# TIA-222-G ANALYSIS CRITERIA DEFINITIONS

Feasibility Structural Analysis

A feasibility structural analysis is used as a preliminary review to identify the impact of proposed changed conditions. This type of analysis determines the overall stability and the adequacy of the main structural members to support a proposed changed condition. A feasibility structural analysis does not include the evaluation of connections and may consider that the structure has been properly installed and maintained.

The reactions from a feasibility structural analysis may be compared to the original design reactions to identify the impact on foundations due to proposed changed conditions. When the original design reactions are based upon an Allowable Stress Design procedure, the original reactions shall be multiplied by a 1.35 factor for comparison to the reactions determined in accordance with this Standard.

Rigorous Structural Analysis

A rigorous structural analysis is used to determine the final acceptance of proposed changed conditions and/or required modifications. This type of analysis determines the overall stability and the adequacy of structural members, foundations and connection details. A rigorous structural analysis may consider that the structure has been properly installed and maintained.

For a rigorous analysis of a foundation, site specific geotechnical and foundation data are required.

Note: Certain foundation details and connection details (such as inside weld sizes of flanged leg connections) cannot be determined without dismantling the structure or extensive field nondestructive testing. The assumptions regarding these types of details shall be documented along with the results of the rigorous structural analysis.

Tower Structure Class:

Class I

Structures that due to height, use or location represent a low hazard to human life and damage to property in the event of failure and/or used for services that are optional and/or where a delay in returning the services would be acceptable.

Class II

Structures that due to height, use or location represent a substantial hazard to human life and/or damage to property in the event of failure and/or used for services that may be provided by other means.

Class III

Structures that due to height, use or location represent a high hazard to human life and/or damage to property in the event of failure and/or used primarily for essential communications.

## Topographic Categories:

### Category 1

No abrupt changes in general topography, e.g. flat or rolling terrain, no wind speed-up consideration shall be required.

### Category 2

Structures located at or near the crest of an escarpment. Wind speed-up shall be considered to occur in all directions. Structures located vertically on the lower half of an escarpment or horizontally beyond 8 times the height of the escarpment from its crest, shall be permitted to be considered as Category 1.

### Category 3

Structures located in the upper half of a hill. Wind speed-up shall be considered to occur in all directions. Structures located vertically on the lower half of a hill shall be permitted to be considered Category 1.

### Category 4

Structures located in the upper half of a ridge. Wind speed-up shall be considered to occur in all directions. Structures located vertically on the lower half of a ridge shall be permitted to be considered as Category 1.

## Exposure Criteria:

### Exposure B

Urban and suburban areas, wooded areas, or other terrain with numerous closely spaced obstructions having the size of single-family dwellings or larger. Use of this exposure shall be limited to those areas for which terrain representative of Exposure B surrounds the structure in all directions for a distance of at least 2,600 ft. or twenty times the height of the structure, whichever is greater.

### Exposure C

Open terrain with scattered obstructions having heights generally less than 30 ft. This category includes flat, open country, grasslands and shorelines in hurricane prone regions.

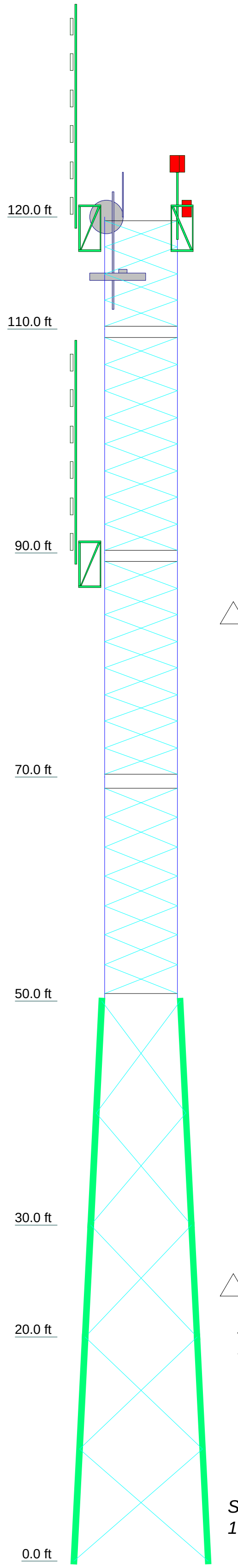
### Exposure D

Flat, unobstructed shorelines exposed to wind flowing over open water (excluding shorelines in hurricane prone regions) for a distance of at least 1 mile. Shorelines in Exposure D include inland waterways, lakes and non-hurricane coastal areas. Exposure D extends inland a distance of 660 ft. or twenty times the height of the structure, whichever is greater. Smooth mud flats, salt flats and other similar terrain shall be considered as Exposure D.

# APPENDIX B

# STRUCTURAL CALCULATIONS

| Section | Legs | Leg Grade | Diagonals | Diagonal Grade | Top Girts | Bottom Girts | Face Width (ft) | # Panels @ (ft) | Weight (lb) |
|---|---|---|---|---|---|---|---|---|---|
| L1 | SR 1 3/4 | | SR 3/4 | | | | | 4 @ 2.36458 | 658.4 |
| L2 | SR 2 | | SR 7/8 | | SR 1 1/8 | SR 1 1/8 | | 16 @ 2.38021 | 1525.8 |
| L3 | | | | A572-50 | | | 6.5 | | 1525.8 |
| L4 | SR 2 1/4 | A572-50 | SR 1 | | SR 1 1/4 | SR 1 1/4 | | 8 @ 2.61905 | 1849.3 |
| T1 | Pirod 105216 | | L2 1/2x2 1/2x5/16 | | | | 7 | | 2385.3 |
| T2 | Pirod 105244 | | | A36 | N.A. | N.A. | 9 | 5 @ 10 | 1433.2 |
| T3 | Pirod 105216 | | L3x3x5/16 | | | | 10 | | 2786.2 |
| | | | | | | | 12 | | 12164.1 |




## DESIGNED APPURTENANCE LOADING

| TYPE | ELEVATION | TYPE | ELEVATION |
|---|---|---|---|
| Mid Beacon (Tower) | 124 | 6'x2" Antenna Mount Pipe (Tower) | 118 |
| Mid Beacon (Tower) | 124 | Scientific Atlanta Box (18"x8"x8") (County) | 115 |
| 10'6"x4" Pipe Mount (County) | 120 | Dish Face Mount (County) | 115 |
| Lightning Rod 5/8x4' (Tower) | 120 | DB224-A (20' Dipole) (County) | 89 |
| Flash Beacon Lighting (Tower) | 120 | Pirod 3' Side Mount Standoff (1) (County) | 89 |
| HP3-11EX w/Shroud (County) | 120 | | |
| 2' Standoff (Tower) | 119 | | |
| DB224-A (20' Dipole) (County) | 119 | | |
| Pirod 3' Side Mount Standoff (1) (County) | 119 | | |

## MATERIAL STRENGTH

| GRADE | Fy | Fu | GRADE | Fy | Fu |
|---|---|---|---|---|---|
| A572-50 | 50 ksi | 65 ksi | A36 | 36 ksi | 58 ksi |

## TOWER DESIGN NOTES

1. Tower is located in Jefferson County, Wisconsin.
2. Tower designed for Exposure C to the TIA-222-G Standard.
3. Tower designed for a 90 mph basic wind in accordance with the TIA-222-G Standard.
4. Tower is also designed for a 40 mph basic wind with 0.75 in ice. Ice is considered to increase in thickness with height.
5. Deflections are based upon a 60 mph wind.
6. Tower Structure Class III.
7. Topographic Category 1 with Crest Height of 0.00 ft
8. Weld together tower sections have flange connections.
9. Connections use galvanized A325 bolts, nuts and locking devices. Installation per TIA/EIA-222 and AISC Specifications.
10. Tower members are "hot dipped" galvanized in accordance with ASTM A123 and ASTM A153 Standards.
11. Welds are fabricated with ER-70S-6 electrodes.
12. TOWER RATING: 49.2%

*ALL REACTIONS ARE FACTORED*

*MAX. CORNER REACTIONS AT BASE:*
*DOWN: 74185 lb*
*SHEAR: 8181 lb*

*UPLIFT: -63200 lb*
*SHEAR: 6877 lb*

*AXIAL 52850 lb*
*SHEAR 3540 lb*
*MOMENT 258108 lb-ft*
*TORQUE 1350 lb-ft*
*40 mph WIND - 0.7500 in ICE*

*AXIAL 15469 lb*
*SHEAR 10993 lb*
*MOMENT 717369 lb-ft*
*TORQUE 2674 lb-ft*
*REACTIONS - 90 mph WIND*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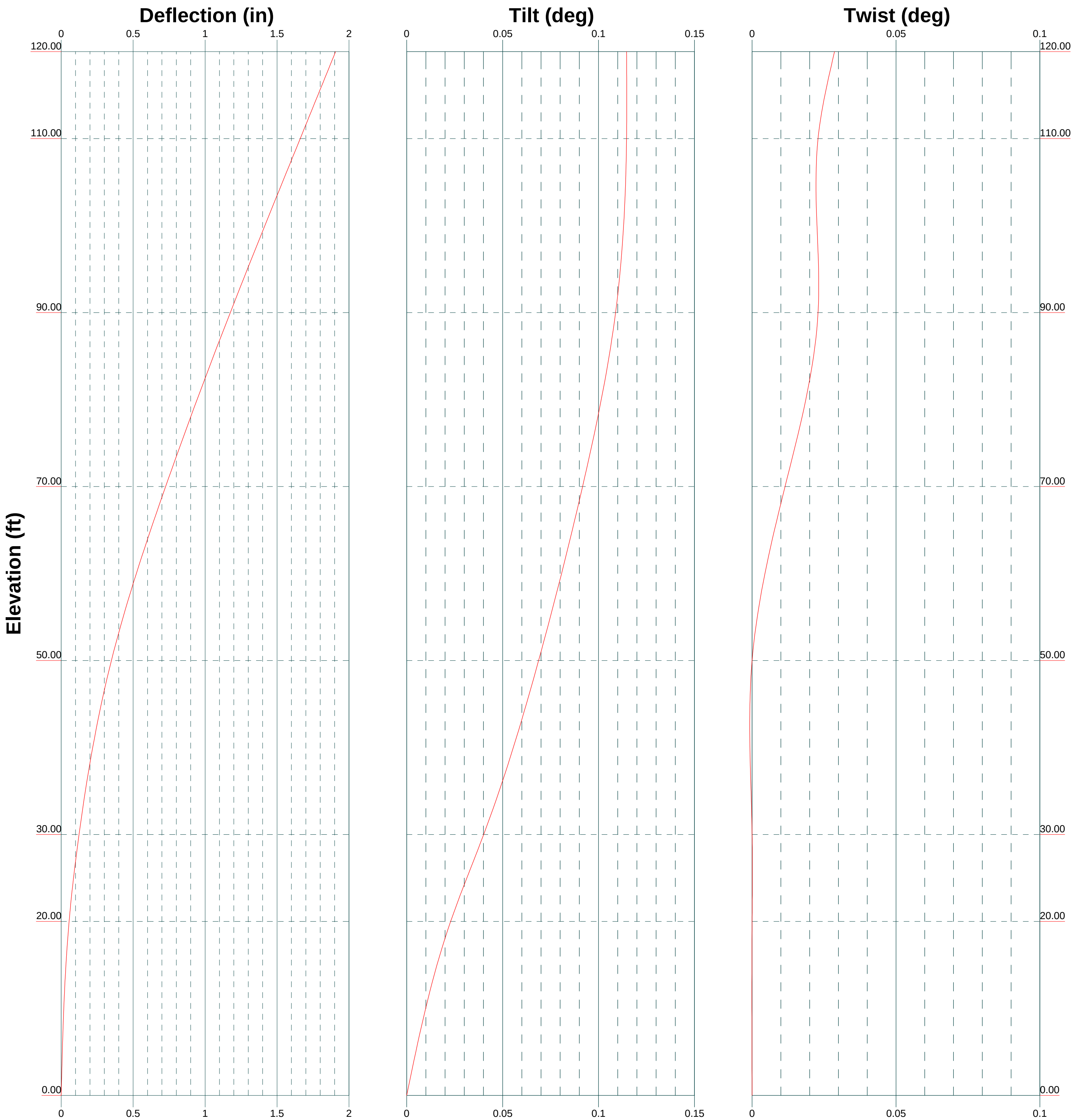
| | | |
|---|---|---|
| Job: **Sullivan Tower** | | |
| Project: **10125** | | |
| Client: Jefferson County | Drawn by: esippel | App'd: |
| Code: TIA-222-G | Date: 06/11/14 | Scale: NTS |
| Path: \\edgeex02\active_projects\10100\10125\Structural\Tower Model\Sullivan Tower_TNX Tower_2014-06-10.eri | | Dwg No. E-1 |

# TIA-222-G - Service - 60 mph

**Maximum Values**

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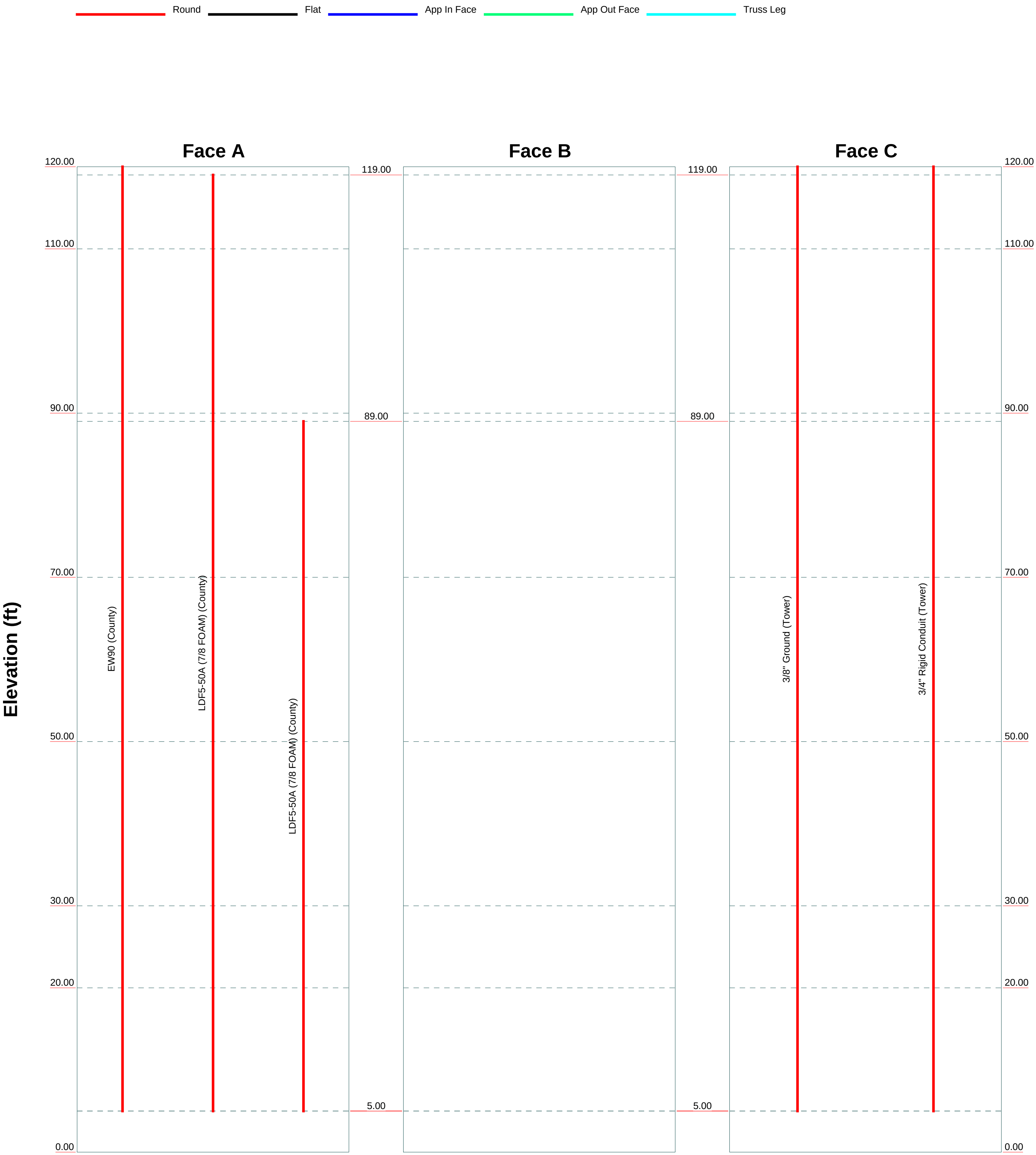
| | Code: TIA-222-G | Date: 06/11/14 | Scale: NTS |
| | Path: \\edgeex02\active_projects\10100\10125\Structural\Tower Model\Sullivan Tower_TNX Tower_2014-06-10.eri | | Dwg No. E-5 |

## Feed Line Distribution Chart
## 0' - 120'





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| Project: **_10125_** | | |
| Client: Jefferson County | Drawn by: esippel | App'd: |
| Code: TIA-222-G | Date: 06/11/14 | Scale: NTS |
| Path: \\edgeex02\active_projects\10100\10125\Structural\Tower Model\Sullivan Tower_TNX Tower_2014-06-10.eri | | Dwg No. E-7 |

# Anchor Rod Calculations

**Project Name - Sullivan Tower []**
**Sullivan, Wisconsin**
**Edge #10125**

Edge Consulting Engineers, Inc.

Completed By: EJS
Checked By: BPB

**Anchor Rod Parameters:**

*Per ANSI/TIA-222-G, Section 4.9.9

| | | |
|---|---|---|
| Detail Type = | d | |
| Detail Factor (η) = | 0.50 | |
| Distance from TOC to Bottom of Leveling Nut ($l_{ar}$) = | 3.00 | in |
| Number of Rods ($N_b$) = | 6 | |
| Rod Diameter ($D_b$) = | 1.00 | in |
| Coarse Threads Per Inch (n) = | 8.00 | |
| Area of Rod ($A_b$) = | 0.79 | $in^2$ |
| Rod Yield Stress ($F_y$) = | 105 | ksi |
| Rod Tensile Strength ($F_u$) = | 125 | ksi |
| Max Compression per Leg ($C_{max}$) = | 74.2 | kip/leg |
| Max Tension per Leg ($T_{max}$) = | 63.2 | kip/leg |
| Max Shear per Leg ($V_{max}$) = | 8.2 | kip/leg |

$$A_n = \frac{\pi}{4}\left(D_b - \frac{.9743}{n}\right)^2$$

Area using Tensile Root Diameter ($A_n$) = 0.61 $in^2$

**Ultimate Anchor Rod Demand and Resistance**

$$V_u = \frac{V_{max}}{N_b}$$

Applied Shear per Rod ($V_u$) = 1.36 kip/rod

$$P_u = \frac{P_{max}}{N_b}$$

Applied Axial per Rod ($P_u$) = 12.36 kip/rod

$$\phi R_{nt} = 0.8 \cdot (F_u \cdot A_n)$$

Available Tensile Strength ($\phi R_{nt}$) = 60.57 kip/rod

**Combined Shear and Tension Check [Applicable for Detail Type d]:**

$$Ratio = \frac{l_{ar}}{1.0 \cdot D_b}$$

Unity = 3.00

$$\phi R_{nv} = 0.75 \cdot (0.45 \cdot F_u \cdot A_b)$$

Available Shear Strength ($\phi R_n$) = 33.1 kip/rod

$$Z = \frac{\left(D_b - \frac{.9743}{n}\right)^3}{6}$$

Plastic Section Modulus of Rod (Z) = 0.113 $in^3$

$$Unity = \left(\frac{V_u}{\phi R_{nv}}\right)^2 + \left(\left|\frac{P_u}{\phi R_{nt}}\right| + \left|\frac{0.65 \cdot l_{ar} \cdot V_u}{0.9 \cdot F_y \cdot Z}\right|\right)^2 \le 1.0$$

Shear & Tension = 0.207 **OK**