

# TIPS ON ANALYZING, MODIFYING AND MAINTAINING GUYED BROADCAST TOWERS

**Thomas J. Hoenninger, P.E.**  
VP Operations and Chief Engineer, Stainless LLC  
North Wales, PA, USA

There have been approximately 30 guyed broadcast tower collapses in the last 15 years. 30% have collapsed due to ice or combination ice and wind, 20% have collapsed due to hurricanes and tornados, 10% have collapsed due impact from airplanes, 5% have collapsed due to corrosion and 35% have collapsed during construction activities.

Risk is the possibility of suffering loss. Risk Management is the development and implementation of policies and procedures in your business to recognize and evaluate risk and to reduce risk to acceptable levels. The following 20 tips are presented to assist the guyed broadcast tower owner in reducing risk. Tip #2 thru Tip #6 deal with analyzing towers, Tip #7 thru Tip #11 deal with modifying towers and Tip #12 thru Tip #20 deal with maintenance of towers.

## **TIP #1 PURCHASE A COPY OF ANSITIA/EIA 222-G.**

This is the new structural standard for antenna supporting structures and antennas and the projected publish date is the 2nd quarter of this year. However, 222-G won't become effective until the 4th quarter of this year. If it is not available purchase 222-F in the interim. Annex A deals with procurement and user guidelines. Also, purchase a copy of the current edition of the NAB Engineering Handbook. Section 2 of the handbook deals with broadcast towers and systems. These documents are both good references for analyzing, modifying and maintaining tower structures.

## **TIP #2 HAVE AN ANALYSIS PERFORMED ON THE TOWER WHEN THERE IS A CHANGE IN EQUIPMENT, DESIGN PARAMETERS AND/OR OPERATIONAL REQUIREMENTS.**

Minor changes to equipment can be evaluated by a tall tower engineer quickly and probably at very little or no cost. Major changes in equipment loading will take longer and at a higher cost. Having the tower analyzed to the current design standard, when the tower was built under a previous design standard, will normally be very time consuming for the first time. Subsequent analyses to the current standard would get processed faster unless the proposed equipment created major

overstresses on the tower. Having towers analyzed specifically for a change in operational requirements are rare but do happen. Tower slope, deflection and twist under operational loads are a concern and adhering to antenna manufacturers requirements should be followed.

## **TIP #3 BEFORE IMPLEMENTING ANY CHANGES AND UPGRADES TO THE TOWER MAKE SURE A RIGOROUS ANALYSIS HAS BEEN PERFORMED.**

There are two types of analyses that are being performed in our industry today. Feasibility Studies and Rigorous Analyses. Feasibility Studies are a very good tool to evaluate if a certain change to the tower is a structurally or economically viable solution. But a Feasibility Study does not investigate the adequacy of the tower member connections and foundations. A Feasibility Study may also make assumptions with regards to tower member material grades. The modifications should never be based on a Feasibility Study. If, after a review of the Feasibility Study, the tower owner wants to move forward with implementing this change a Rigorous Analysis must be performed. A Rigorous Analysis will include a capacity check on the tower member connections and foundations. It will confirm and use the actual material yield strengths. This may require a site visit to perform nondestructive tests on the foundations and measurements on the tower. It may also require testing samples of the tower steel to attain material chemical and mechanical properties.

The process outlined above will be a mandatory requirement in 222-G. Note, any assumptions used in the analysis and noted in the analysis report become the owners risk and not the engineers. So it is to the owner's advantage to eliminate or minimize the number of assumptions used in the analysis.

## **TIP #4 HAVE YOUR TOWER ANALYZED TO THE CURRENT DESIGN STANDARD.**

This should not be much of a problem for shorter towers originally built prior to 1987 and upgrading to the current standard. This is due to the changes in how

wind and ice loads are calculated and differences in tower member safety factors from prior design standards to the current standard. For taller towers it is just the opposite. This has made it very economically challenging or even structurally impossible to upgrade a significant number of tall towers to the current standard.

Currently it is not a concern to insurance carriers as to which design standard the tower conforms to. However, it could be some day and some changes proposed on towers may require a building permit which would require the tower upgrades to conform to the requirements of the local building code which would more than likely reference the current TIA-222 standard.

Every effort should be made to upgrade towers to the current standard. However, when it is estimated that it is structurally or economically challenged to upgrade to the current standard the following steps should be performed:

- a. Have the analysis performed to the current standard.
- b. Have the analysis also performed to the original design standard. If this is a design standard published prior to 222-C use 222-C.
- c. Discuss the results with the tall tower engineer.
- d. Evaluate the risk associated with conforming to the original design standard and not the current standard. Most insurance carriers are not concerned as to which design standard the tower is in accordance to.
- e. Investigate conforming to the original design standard and also performing additional upgrades to attain the highest wind speed and ice loading to the current standard as structurally or economically possible.

**TIP #5 BECOME FAMILIAR WITH THE DESIGN STANDARD THAT YOUR TOWER CONFORMS TO AND ALSO BECOME FAMILIAR WITH THE CURRENT DESIGN STANDARD.**

A few of the requirements are listed below:

- a. EIA RS-222-C
  - i. Wind load is based on wind pressure. The standard lists minimum wind pressure by county.
  - ii. Wind load is calculated by multiplying wind pressure times the projected area times the drag coefficient. In general, round members have a drag coefficient of 0.67 and flat members 1.00.
  - iii. Generally the wind pressure is constant for the height of the tower.
  - iv. Ice loading is not required. However, ice should be considered in ice prone areas. The

wind speed and ice thickness requirements from ASCE 7 (American Society of Civil Engineers Standard 7 – Minimum Design Loads For Buildings and Other Structures) should be used. The recommended wind speed from ASCE 7 will have to be converted to wind pressure to be used with the 222-C standard.

- v. Member capacities are based on an allowable stress design method. No allowable stress increase is allowed.
- b. ANSI/TIA/EIA 222-F
  - i. 222-D, 222-E and 222-F are very similar. Use 222-F if the original design is any one of the three.
  - ii. Wind load is based on the fastest mile basic wind speed. Fastest mile wind speed is defined as measuring the time it takes for a particle of wind to travel one mile. The standard lists minimum wind speed by county. Wind load is calculated by converting wind speed to wind pressure and then multiplying wind pressure times the projected area times the drag coefficient. In general, round members have a drag coefficient ranging from 0.6 to 1.2 and flat members range from 1.0 to 2.0.
  - iii. The wind speed escalates with height and therefore so does wind pressure and wind load since they are dependent on wind speed.
  - iv. Ice loading is not required. However, when it is considered the loading recommended in 222-F is ½” radial ice combined with a basic wind speed of 86.6% of the no ice basic wind speed. Ice should be considered in ice prone areas. Instead of using the recommendation listed in 222-F use the wind speed and ice thickness requirements from ASCE 7. The recommended wind speed from ASCE 7 will have to be converted to a fastest mile wind speed to be used with the 222-F standard.
  - v. Member capacities are based on an allowable stress design method. One-third allowable stress increase is allowed for towers up to 700 ft in height. No allowable stress increase is allowed for towers over 1200 feet in height. Linear interpolation is used to calculate the allowable stress increase from 700 to 1200 feet in tower height.
- c. ANSI/TIA/EIA 222-G
  - i. Wind load is based on a three-second-gust basic wind speed. Three-second gust basic wind speed is defined as the highest averaged wind speed measured over any three second time interval. The standard lists minimum basic wind speed by county. A 75 mph fastest mile wind speed is equivalent to a 90 mph three-second-gust wind speed. Other factors

that effect wind load and must be determined by the tower owner are:

- a. **Structure Classification.** The classifications deal with risk. The classification is selected based on site conditions and service requirements. The default is Class II. Refer to Table 2-1 and 2-3 in 222-G for a detailed explanation. The classification determines the importance factor, which is a factor that is multiplied to the wind pressure. The higher the classification the higher the importance factor.
  - b. **Exposure Category.** The exposure category is dependent on the ground conditions (obstructions) in proximity of the tower. The default exposure category is "C". Refer to Section 2.6.5 and Table 2-4 of 222-G for a detailed explanation.
  - c. **Topographic Factor.** The topographic factor is dependent on the topography in proximity of the tower. If the tower is located on a hill, escarpment or ridge the wind pressure on the tower may be increased. The default value is Category 1. Refer to Section 2.6.6.2 of 222-G for a detailed explanation.
- ii. Wind load is calculated by converting wind speed to wind pressure and then multiplying wind pressure times the projected area times the drag coefficient. In general, round members have a drag coefficient ranging from 0.6 to 1.2 and flat members range from 1.0 to 2.0.
  - iii. The wind speed escalates with height and therefore so does wind pressure and wind load since they are dependent on wind speed.
  - iv. Ice loading is required except for Class 1 structures. Ice thickness escalates with height. The wind speed and ice thickness requirements follow the requirements of ASCE 7. The standard lists minimum basic wind speed and basic ice thickness by county.
  - v. Member capacities are based on an ultimate strength design method. This means the loading is multiplied by a load factor. The load factor is defined as a factor that accounts for deviation of the actual load from the nominal load and the probability that more than one extreme load will occur simultaneously. The factored member load is then checked against the ultimate strength of the member. No stress increase is allowed.

- vi. Another loading that must be considered in the analysis is earthquake loading. The standard lists earthquake parameters by county. Earthquake loads will not govern in most counties.

As an aid to assist the tower owner in determining if it is feasible to upgrade the tower from 222-C to 222-F, 222-C to 222-G or 222-F to 222-G please refer to Figures 1, 2 and 3. Figures 1, 2 and 3 are graphs comparing wind loading of an older standard to a newer standard from 100 feet to 2000 feet in tower height. To use the graph locate the minimum basic wind speed or wind pressure for the county the tower is located in from the county listing in the two standards being compared. Find the points on the line that correspond to the minimum basic wind speed or wind pressure and tower height for both the older and newer standard. If the point on the line corresponding to the older standard is to the right of the point on the line of the newer standard then if the tower is modifiable for the older standard it is probably modifiable for the newer standard.

#### **TIP #6 DEVELOP AND IMPLEMENT ANTENNA AND TRANSMISSION LINE MANAGEMENT.**

Include the following:

- a. Make sure the antennas and transmission lines match the equipment inventory and location used for the analysis. Check all tenants leases versus actual installation. Make sure the antenna model number, antenna elevation, transmission line size and transmission line location in the tower cross-section noted in the lease agreement and analysis matches the actual installation.
- b. Reorganize the transmission lines location in the cross section of the tower to minimize wind load. This should include arranging flex lines in circular bundles. Analyses are only valid when the transmission lines are located in accordance with the analysis.

#### **TIP #7 WHEN MODIFICATIONS ARE RECOMMENDED FROM A RIGOROUS ANALYSIS MAKE SURE THE TOWER WAS REANALYZED WITH THE MODIFICATION MATERIAL IN PLACE.**

The modification material can affect the loading applied to the tower and therefore alter the results. Also, the modification material can change the stiffness of the tower or guy assemblies and also alter the results. In addition, make sure the capacity of the connections of the upgraded members to the existing tower members were checked. For example, when a guy level is changed out the new higher capacity guy assemblies are checked to make sure their capacity is

greater than the maximum actual load but in addition to that the guy lug connection to the guy end fitting is checked, the guy lug connection to the tower leg is checked, the tower bracing gusset plate to tower leg is checked, the horizontal connection to the bracing gusset plate is checked and the horizontal itself is checked to make sure the capacity is greater than the maximum actual load. The same is performed on the anchor end of the guy assembly.

#### **TIP #8 REQUIRE A RIGGING PLAN FOR INSTALLATION OF MODIFICATION MATERIAL IN THE ERECTORS SCOPE OF WORK.**

Require that a rigging plan be developed by the erector and reviewed by an engineer with guyed tower rigging experience. If the erector does not have one on staff require the erector to subcontract it. The rigging plan should include all lifts associated with installing the rigging on the tower, all lifts required for the installation of the equipment and modification material and all lifts associated with derigging. The rigging plan should also include the maximum loads and location of those loads imposed on the tower.

#### **TIP #9 REQUIRE THAT AN ENGINEER EVALUATE THE STRUCTURAL INTEGRITY OF THE TOWER DUE TO THE RIGGING LOADS IMPOSED ON THE TOWER DURING INSTALLATION OF MODIFICATION MATERIAL.**

This can be included in the erectors scope of work if the erector's engineer is familiar with the tower. If the erector cannot provide this service then the tower owner will need to contract with the engineer that performed the Rigorous Analysis. It is best that the engineer who performed the Rigorous Analysis investigate the tower's response to the rigging loads.

#### **TIP #10 SELECT A CONSTRUCTION METHOD THAT BEST SUITS YOUR BUSINESS.**

Two very common methods are the Traditional and Design-Build method of construction. A brief description of each follows:

- a. The traditional method would require a contract for an engineer to:
  - i. Perform the Rigorous Analysis and prepare the report.
  - ii. Prepare design drawings to be used for the fabricators and erectors to bid their portion of the work.
  - iii. Approve the fabricator's shop and erection drawings.
  - iv. Inspect the tower after installation to insure the installation was performed in accordance with the design.

- v. It may also include an evaluation of the tower response to the rigging loads.

A second contract would be required for a fabricator to:

- i. Prepare the shop and erection drawings.
- ii. Submit the shop and erection drawings to the engineer for approval.
- iii. Fabricate the material to the drawings.
- iv. Ship the material.

A third contract would be required for an erector to:

- i. Prepare a rigging plan.
  - ii. Have the rigging plan reviewed by an engineer.
  - iii. Install the material in accordance with the erection drawings.
  - iv. Fix all items noted by the engineer's inspection.
  - v. It may also include an evaluation of the tower for the rigging loads.
- b. The design-build method would consist of one contract to perform all the tasks listed above. This is accomplished by one company having the skills, products and services to deliver a complete package or by having a group of company's partner where one of the companies would be designated as the general contractor.

The design-build method of construction eliminates the finger pointing among the suppliers of the products/services from the eyes of the customer. The design-build method also reduces the overall time duration required to complete the project.

#### **TIP #11 DEVELOP AND IMPLEMENT A PRE-QUALIFICATION PROCESS FOR THE ENGINEER, FABRICATOR AND ERECTOR.**

Depending on the type of work being performed the prequalification process should include many of the requirements listed below:

- a. Insurance
  - i. Errors and omissions for engineering firms.
  - ii. General liability.
  - iii. Product liability.
  - iv. Builder's risk.
  - v. Umbrella.
  - vi. Automobile.
  - vii. Make sure the policy limits match the risk.
  - viii. If design-build construction method is used make sure the general contractor has sufficient insurance. This could be an area of concern if the engineering firm is acting as the general contractor.
- b. Safety/Training
  - i. ComTrain Certification-which is a 3rd party training program.
  - ii. Fall protection training.

- iii. Personal Protection Equipment (PPE) training.
- iv. Equipment meets OSHA requirements.
- v. Drug Program.
- vi. Man rated hoists if personnel will be riding the line.
- vii. Rigging plan documentation.
- c. Reference list
- d. Notification and approval if general contractor subcontracts any portion of the work.

**TIP #12 ADHERE TO A TWO-YEAR MAXIMUM INTERVAL BETWEEN INSPECTIONS.**

In addition have your tower inspected in accordance with the following:

- a. After every severe wind and/or ice storm or any other extreme condition.
- b. One-year maximum interval for Class III structures. Refer to Table 2-1 of 222-G for a definition of each class. Most guyed broadcast towers will be Class II.
- c. At the completion of any major installation/maintenance performed on the tower. Have the work inspected to insure the installation was performed in accordance with the design. Also, damage to tower members can occur from the rigging required for the installation. The two most common damages are bent members due to improper rigging connections to the tower and burning grooves in tower members due to the load line being too close to the tower face.
- d. Use the maintenance and condition assessment guidelines from Annex J of 222-G.
- e. Include an inventory of existing equipment with the inspection. See Tip #6.

Studies have shown that approximately 10% of guyed broadcast tower inspections performed last year resulted in discovering at least one major structural item that required repair/replacement.

Adhering to these guidelines will minimize the occurrence of major maintenance/installation issues.

**TIP #13 DEVELOP AND IMPLEMENT A PLAN TO MINIMIZE COSTS ASSOCIATED WITH PROPERLY MAINTAINING THE TOWER LIGHTING SYSTEM.**

Maintaining a properly functioning lighting system is the major maintenance issue with most tower owners. Develop a procedure to respond and resolve NOTAM's. Investigate remote monitoring systems, preventive maintenance schedules and service contracts offered by the lighting suppliers and other service companies. Start including maintenance costs in your lighting maintenance log. Review your log for frequency of bulb replacement and the replacement of

other parts. Look for trends. If trends are discovered perform a cost/benefit analysis on replacing bulbs and/or other parts on a predetermined interval instead of after a functioning problem. Also, investigate new products such as LED's. Refer to section 2.2 of the NAB engineering handbook for details of the FAA/FCC lighting requirements or contact the FAA and FCC directly.

**TIP #14 DON'T LET CORROSION REDUCE THE STRUCTURAL INTEGRITY OF THE TOWER.**

Maintain a comprehensive inspection/maintenance program. There are areas on a tower where corrosion cannot be detected by just a visual inspection. Tube members can corrode from the inside out so make sure the inspection includes additional nondestructive testing of the tube wall thicknesses. This should include performing ultrasonic testing on suspect areas observed from the visual inspection and also randomly selected areas. Anchor steel corrosion is another area that needs additional inspection. AnchorGuard, a corrosion control system supplier for tower anchors, has recommended a procedure to follow prior to climbing the tower due to their experience with tower failures from anchor steel corrosion. The procedure states:

Do not climb guyed towers unless one or more of the following is in place or has occurred:

- a. The anchor shafts are totally encased in concrete to above grade.
- b. The anchors were previously inspected and have had cathodic protection in place and working since the inspection.
- c. The anchors are dug up and inspected immediately before climbing and show no signs of structural damage due to corrosion.

Refer to Annex H of 222-G for a description of additional corrosion control for anchor steel.

**TIP #15 CONSIDER UPGRADING THE LIGHTNING PROTECTION SYSTEM.**

222-G specifies the minimum requirements for a protective grounding system. If this system is not adequate information on additional protection is discussed in Section 2.3 of the NAB Engineering Handbook. In addition to upgrading the protective grounding system it may be prudent to investigate surge suppression systems and lightning prevention systems.

**TIP #16 INSTALL HIGH FREQUENCY DAMPERS ON THE GUY ASSEMBLIES.**

High frequency low amplitude vibration (Aeolian) can fatigue guy wire assemblies. Fatigue failure is a failure

mode that occurs when the member is exposed to excessive number of low stress level loading cycles. Signs of initial failure could be observing one or more broken wires. Another vibration mode of failure is low frequency high amplitude vibration (Galloping). As stated in Section A7.5 of 222-G Annex A, low frequency high amplitude vibration is hard to predict prior to installation due to unique site and environmental variables. The tower can be retrofitted with dampers after tower installation when necessary.

**TIP #17 KEEP YOUR TOWER SITE SECURE.**

The two major issues that effect insurance premiums are site security and the physical location of the tower with regards to general public activities.

**TIP #18 MAKE SURE YOUR TENANTS IMPLEMENT COLLOCATION IN ACCORDANCE WITH THE CONTRACT DOCUMENTS.**

Check all existing tenant leases versus actual installation. Check that there is an analysis that supports the installation. For proposed tenants make sure installation matches the equipment in the lease, make sure there is an analysis that supports the installation, make sure the actual installation matches the analysis, make sure T/L installation is in accordance with the manufacturer recommendations.

**TIP #19 KEEP ACCURATE AND DETAILED RECORDS.**

Maintain files on tower inspections, maintenance work, analysis reports, structural upgrades and tenants equipment installation.

**TIP #20 CHECK YOUR INSURANCE POLICY EXCLUSIONS.**

Many exclude corrosion and when work is being performed on the tower.

Guideline To Determine Tower Modification Feasibility For Rev. C vs Rev. F

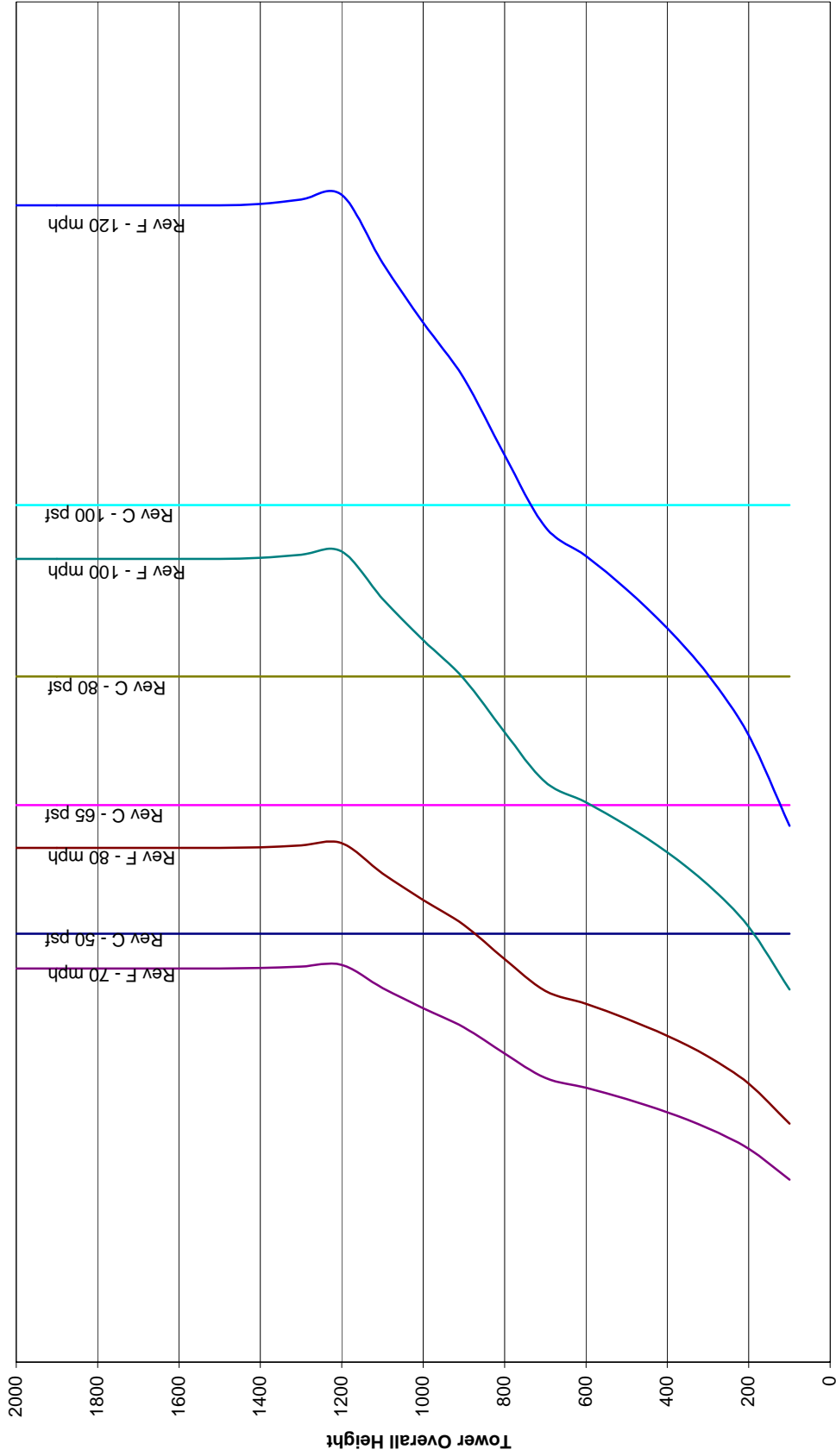


Figure 1  
Wind Loading Index  
This Chart Does Not Consider Ice Loading

Guideline To Determine Tower Modification Feasibility For Rev. C vs Rev. G

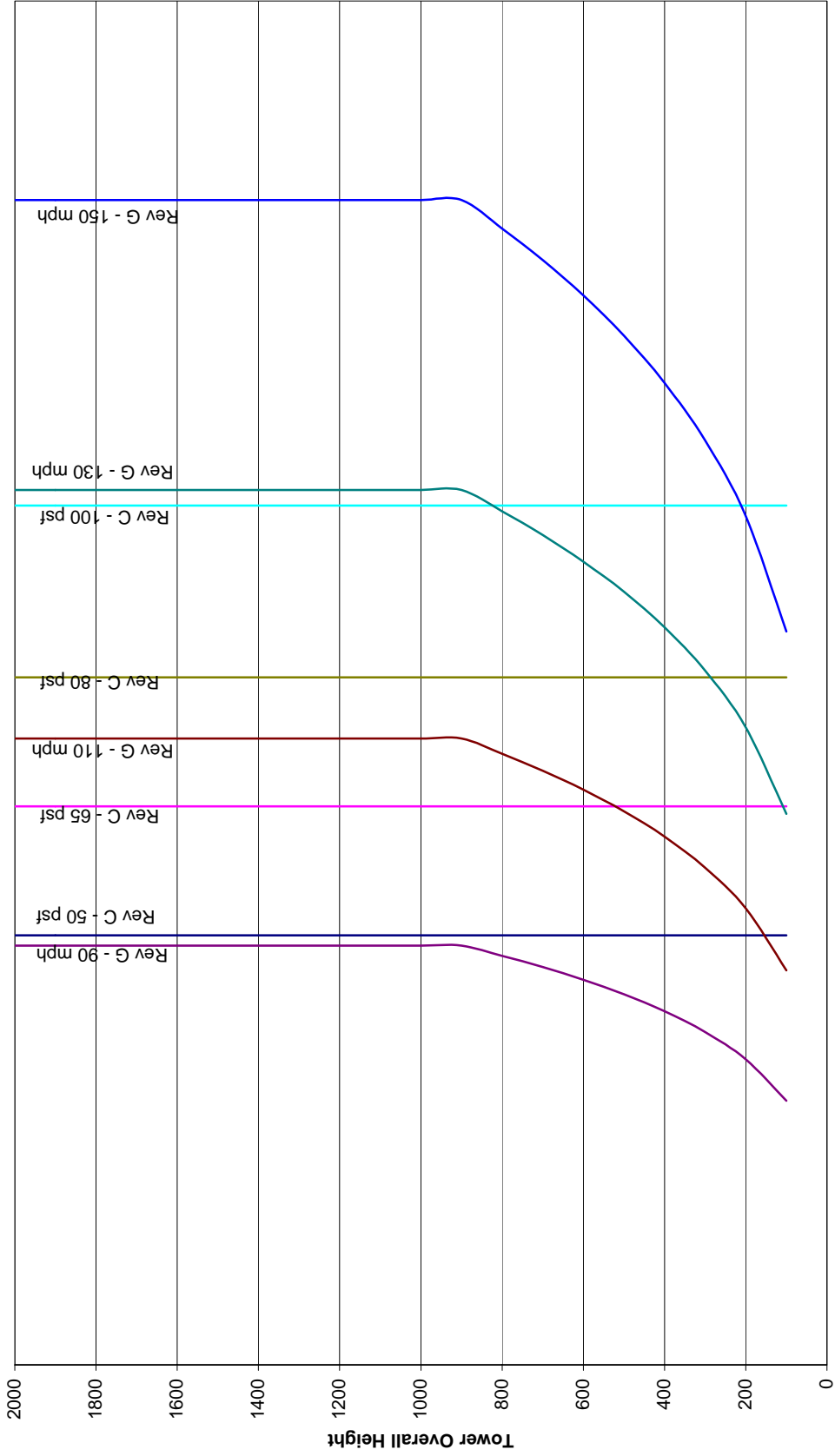


Figure 2  
Wind Loading Index  
This Chart Does Not Consider Ice Loading

Guideline To Determine Tower Modification Feasibility For Rev. F vs Rev. G

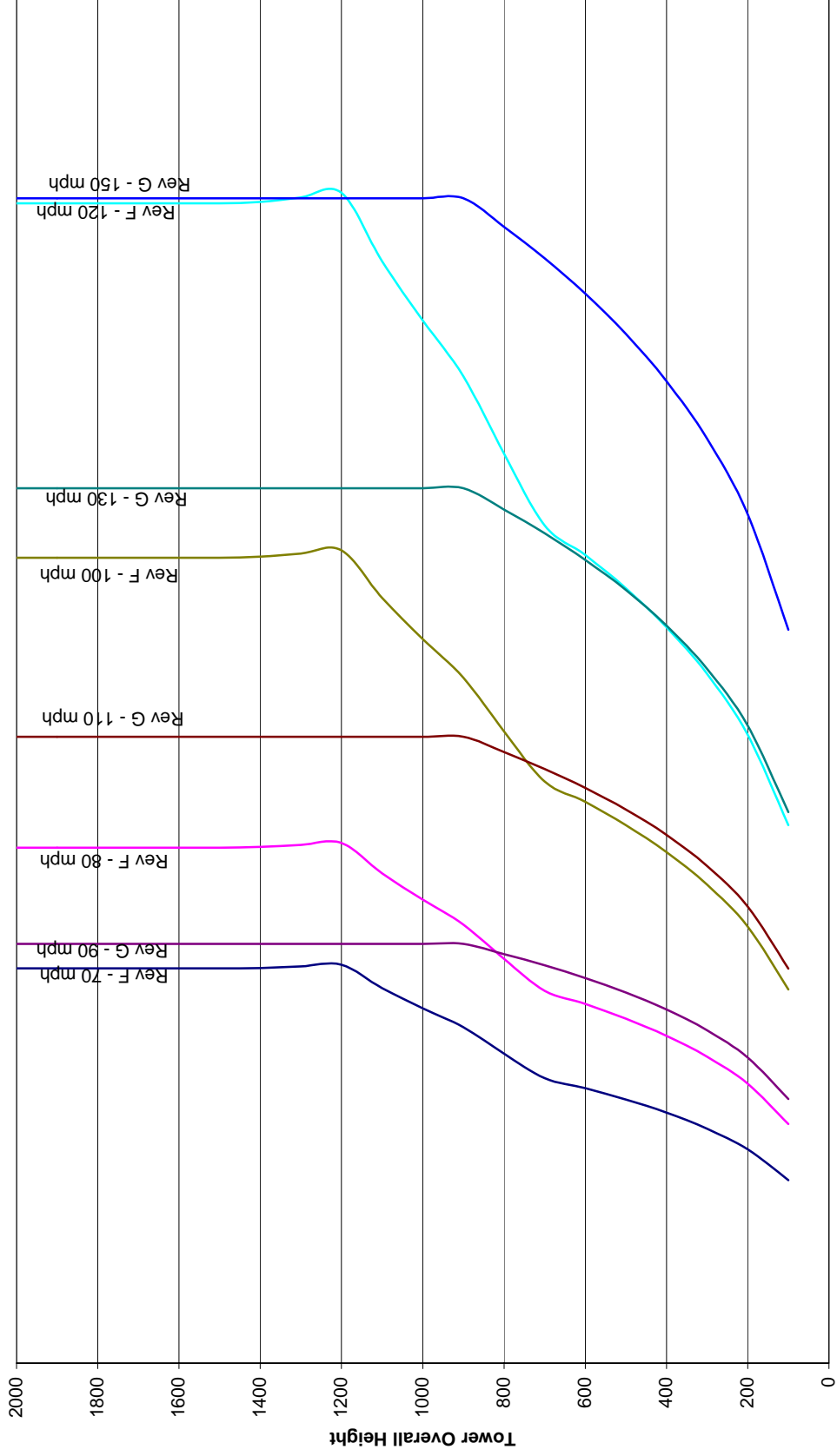


Figure 3  
Wind Loading Index  
This Chart Does Not Consider Ice Loading