Tower Construction, Tower Standards and Failure Prevention

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ANSI/TIA-1019 (DRAFT)
Structural Standards for Installation, Alteration and Maintenance of Communication Towers, Antennas and Antenna Supporting Structures
Historical Development of Standards

- SEI/ASCE 37 – 02 Design Loads on Structures During Construction: Approved in 2001

- TIA-1019 Gin Pole Standard was approved January 9, 2004.

- TIA-222-G
  - Revision of TIA/EIA-222-F
  - Standard for design of communication structures – Aug. 2005

- TIA-1019- Construction Standard scheduled for approval in the Fall of 2009
  - Includes the Gin Pole Standard
• This standard does not account for construction equipment loading, removal of members, uneven guy wire forces, or loading on the tower in its unfinished state.
The New Standard will incorporate the existing gin pole standard
TIA STANDARD

Structural Standards for Steel Gin Poles Used for Installation of Antenna Towers and Antenna Supporting Structures

TIA-1019

TELECOMMUNICATIONS INDUSTRY ASSOCIATION
What is a Gin Pole

- It is a device unique to the Telecommunications and Broadcast Industries used to raise successive sections of tower steel and equipment into position.
- This temporary device allows headroom above the highest fixed point of a tower or structure to place equipment or materials.
Gin Pole in Use
Development of Gin Pole Standard

- Standard developed mostly by ERI after a conversation between Ernie Jones and me
- I asked for safe gin poles for our tower construction business
- Ernie indicated that it was impossible to guarantee that a gin pole could be properly designed because there was no design standard for gin pole design
The development started with laboratory tests of scale models.
This was followed by full scale tests
Testing to Failure
TR 14.7
Gin Pole Sub-Committee Concerns

• Continual construction failures and the impact those failures had to our industry and to personnel.

• The additional loading construction equipment has on the structure and the methods used while applying those loads.

• The need for a standard combining tower construction concerns with the current gin pole standard and specific construction loading.
TIA-1019 (Draft)

The current plan:
Adapt TIA-1019 in 2009
Advantages for the Broadcaster

• Adherence to Standard could reduce insurance costs

• Adherence to standard will not only make construction safer but also will reduce risk of broadcast platform failure

• Makes construction procedures consistent
  – If contractor doesn’t use standard, broadcaster is assuming more risk
Scope and Objective of New Construction Standard

• Structural Loading effects on the Structure due to Construction Equipment loading will be known.
  – Cranes
  – Gin Poles
  – Lifting Blocks
  – Attached Rigging

• Develop a standard to allow an engineered approach to complete work safely throughout the construction process.
• 1.0 General
• 2.0 Construction Considerations
• 3.0 Gin Pole Operation and Use
• 4.0 Supporting Structure Loading During Construction
• 5.0 Gin Pole Analysis and Design
• 6.0 Gin Pole Construction
• Annex A Procurement and User Guidelines
• Annex B Gin Pole Engineering Design
• Annex C Evaluation of Existing Gin Poles
• Annex D Rigging Plans
• Annex E Wire Rope End Connections
• Annex F Evaluation of a Communication Tower Site
• Annex G Referenced Standards
General

• Definitions
• Symbols and notations
Definitions

- **Competent Rigger**: a person knowledgeable and experienced with the procedures and equipment common to the Communication Structures Industry, and trained to identify hazards with authorization to take prompt corrective measures.

- **Qualified Person**: a person knowledgeable, experienced, trained and capable of developing rigging plans and that has successfully demonstrated the ability to solve, resolve and coordinate construction related to the Communication Structures Industry.

- **Qualified Engineer**: a professional engineer knowledgeable and experienced in the Communication Structures Industry.
Competent Rigger

• Must have a minimum of 5 years construction experience in Broadcast or Telecom structures.
• Training in rigging practices and in the proper use of rigging equipment is required. This can be obtained from the following sources:
  – Industry related rigging manuals
  – Industry related rigging handbooks
  – Applicable video training programs
  – Manufacturers training presentations
• Should be a Competent Climber and if not, have the knowledge of the Competent Climber requirements.
Qualified Person

• Have met all the qualifications of a Competent Rigger.

• Have a basic understanding of sections 1, 2, 3, 4.3 and 4.5 of TIA/1019.

• Have a basic understanding of Appendix A, C, D, E and F of TIA/1019.

• Be able to communicate with the Competent Rigger and the Qualified Engineer using industry accepted terminology.
Qualified Engineer

• Must be a licensed professional engineer.

• Should be knowledgeable and competent regarding the EIA/TIA-222F, TIA-222-G and TIA-1019 standards.

• Should be knowledgeable in the terminology and industry practices used in rigging applications for the construction industry.

• Be able to communicate with the Competent Rigger and the Qualified Person using industry accepted terminology.
Rigging Plan Requirements

• A rigging plan shall consider the following:
  – Operational and Non-Operational loads.
  – Construction equipment.
  – Support structure and construction equipment strength.
  – Construction sequence
  – Load testing
  – Field monitoring
Rigging Plan Work Description

- **Class 1**
  - Removal or addition of antennas, mounts, platforms, etc. that are light in comparison to the overall supporting structure and do not require the use of a gin pole or a gin pole not rated higher than Class A.

- **Class 2**
  - Rigging plans utilizing pre-approved installation methods.

- **Class 3**
  - Custom or infrequent installation methods, removal of structural members, special engineered lifts, and unique situations
## Rigging Plan Classifications

<table>
<thead>
<tr>
<th>Class</th>
<th>Definition</th>
<th>Minimum Level of Responsibility</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Removal or addition of antennas, mounts, platforms, etc. that are light in comparison to the overall supporting structure and do not require the use of a gin pole or a gin pole not rated higher than Class A.</td>
<td>Competent Rigger</td>
</tr>
<tr>
<td>II</td>
<td>Rigging plans utilizing pre-approved installation methods.</td>
<td>Qualified Person</td>
</tr>
<tr>
<td>III</td>
<td>Custom or infrequent installation methods, removal of structural members, special engineered lifts, and unique situations</td>
<td>Qualified Person with Qualified Engineer</td>
</tr>
</tbody>
</table>
Construction Considerations

- Scope
- Construction equipment
- Lifting devices
- Effects of gin pole jumping and lifting
- Hoist
- Temporary supports
- Rigging components
- Dismantling/Modification of existing antennas or structures
- Rigging plan requirements
- Load testing and verification
- Monitoring During Lifting Operations
- Safety climb facilities site inspection
Climbing Facilities

- Maintain the climbing pathway clear of obstructions
- Consideration shall be given when adding mounts and antennas
- All damaged climbing facilities must be evaluated and shall be repaired, replaced or removed as required.
- When obstruction of a climbing facility is unavoidable signage shall be provided in accordance with TIA-222-G.
Engineered Hoist anchorages shall be capable of resisting 2 times the maximum anticipated load.

In lieu of calculations a proof load of 1.5 times the lift may be used to verify adequacy of the hoist anchorage.

Twisting and turning shall be restricted.
Types of Hoist Anchorage

- Hoist On Trailer Anchored with Vehicle (Will Require Load Testing)
- Hoist Anchored to a Dead-Man Anchor
- Hoist Anchored to a Foundation Top
Hoist Load Tests

- If slip resistance is counted on for restraint a load test is required.
- Load test to 1.5 times the anticipated load.
Supporting Structural Loading During Construction

- Scope
- Design standards
- Structural loads
- Load combinations
- Wind loadings
Tower Leg Capacity

- Example

- Tension Capacity is 50 Kips

- Compression capacity 100 Kips

- \( \frac{50}{100} \times 100\% = 50\% \)

- Leg tension capacity is 50% of the legs compression capacity.
Guy Wire Installation

- Guy wires are typically installed sequentially from the bottom to the top.
- All forces on members during the pulling up of guys shall be considered.
- When pulling up wires for a specific level, equal or near equal forces shall be applied.
- Vertical alignment shall be maintained at a ratio of 1/120 per fixed guy level.
Temporaries

Rigging plan will specify where temporary guys are needed during construction.
Guy Anchor Temporary Support

- Slip resistance of an object (Dozer) can be calculated by using a coefficient of friction of 0.20.

- If slip resistance of the object is known then it can be used.

- Factor of Safety of 2 should be used for the allowable resistance.
Non-Slip End Connections

- End Connections that when properly installed have not had a history of slippage problems

[Diagrams of different end connections: Preformed End, Swage End, Turn Back End, Wedge Socket End]
Slippage Connections

• When frictional clamping devices are used that may slip during construction, the forces on the structure due to potential effects from slippage or cable release must be considered.
• The structure shall be analyzed for this potential slippage.
Guy Slippage

- Unequal forces on the structure shall be considered due the potential of connection slippage!
- Can the structure withstand the unequal load?
- Temporary guy wires may be required

Slippage Im = 1.3
Release Im = 2.0
Temporary Backup System

- The backup system shall be of non-slip wire rope termination arranged to limit slippage to ½ face width of tower, but not less than 12 inches or more than 36 inches.
Temporary Support Guy Replacement

- Temporary guy wires are required when replacing existing guys, except when an engineering analysis indicates otherwise.
- The B.S. of the temporary guy wire assembly shall not be less than 50% of the wire being replaced unless an analysis indicates otherwise.
• Block forces transmitted to the structure must be properly evaluated and accounted for.
Working on Existing Antennas or Structures

- Weights may be unknown.
- Structural condition may be questionable.
- Special inspection will be necessary.
- Verify weight and geometry within plus or minus 5%.
- Special lifting procedures may be required.
Lifting Existing Loads from Structures

• Unless the load weight is confirmed by accurate documentation or by calculation, the weight shall be field verified prior to making the lift.

• Weight verification may be accomplished by loosening fasteners or by providing longer fasteners to allow movement while controlling the load.
  – Using a load measuring device
Temporary Member Supports

- Consult an engineer to complete an analysis.
- A temporary brace equal in strength shall be installed prior to removable, unless the engineering analysis indicates other options are feasible.
- There shall be a documented procedure for the process as outlined in the standard.
Gin Pole Operation and Use

- Scope
- Gin pole
- Lifting personnel
- Gin pole inspections
- Load chart for gin poles in a vertical position
- Tilted gin poles
- Special engineering lifts
Classification Of Gin Pole

Class A Gin Pole – <1000 lbs Lift Capacity
Class B Gin Pole – 1000 lbs to <3000 lbs Capacity
Class C Gin Pole – 3000 lbs to <10,000 lbs Lift Capacity
Class D Gin Pole – above 10,000 lbs Lift Capacity
Monitoring a Lift

• Load Testing
• Questionable tower movement
• Special Engineered Lift
Expected Gin Pole Deflection
Tip Deflection Helps Verify Lifted Load is Within Lift Parameters

Hface distance measured at Bridle verifies a lift is within charted load line angles
Degree to Distance Conversion Chart

\[ ha = La \times \tan \theta \]

<table>
<thead>
<tr>
<th>La' in Feet</th>
<th>( \theta ) in Degrees</th>
<th>( \theta ) in Inches</th>
</tr>
</thead>
<tbody>
<tr>
<td>20'</td>
<td>3° 12'</td>
<td>5° 21'</td>
</tr>
<tr>
<td>25'</td>
<td>3° 16'</td>
<td>5° 26'</td>
</tr>
<tr>
<td>30'</td>
<td>3° 19'</td>
<td>5° 31'</td>
</tr>
<tr>
<td>35'</td>
<td>3° 22'</td>
<td>5° 37'</td>
</tr>
<tr>
<td>40'</td>
<td>3° 25'</td>
<td>5° 42'</td>
</tr>
<tr>
<td>45'</td>
<td>3° 28'</td>
<td>5° 47'</td>
</tr>
<tr>
<td>50'</td>
<td>3° 31'</td>
<td>5° 52'</td>
</tr>
<tr>
<td>55'</td>
<td>3° 34'</td>
<td>5° 58'</td>
</tr>
<tr>
<td>60'</td>
<td>3° 37'</td>
<td>5° 63'</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

La' IN FEET  \( \theta \) IN INCHES

PBS
Changing Degrees to Inches

Hface
Monitoring During Lifts

• During lifting operations, deflection of the tip of the gin pole and/or the supporting structure shall be monitored to ensure deflections are within the anticipated magnitudes.

• Without verification by analysis keep deflections with the following limitations:
  – Guyed Tower deflection limit is $\frac{1}{2}$ of the tower face width.
  – Self Supporting tower deflection limit off 1% of structure height.
Special Engineering Lift

1. It is the intent of this standard for lifts to be within the ratings allowed in the “Load Chart” as defined by this standard. (Load Charts are based on minimum 3 degree load line angles)

2. Any lifts to be allowed on a special basis, which is outside of the standard “Load Chart”, shall only be allowed at the direction of a qualified engineer.

3. Special monitoring and measuring conditions, as specified by the engineer, shall be provided and used in the field during all “Special Engineered Lifts”.
Requirements for Special Engineered Lifts

1. Engineering Evaluation is Needed to Determine that Gin Pole Lift Capacity has all Required Factors of Safety.
2. Load Line Angles Cannot be Considered Less than 1 Degree.
3. Tip Deflection of the Pole and the Location of Load Line During Lift Must be Monitored in the Field.
“Special Engineered Lifts” can be based on lifting with load Line angles Less than 3 Degrees

<table>
<thead>
<tr>
<th>LOAD CHART (lbs.)</th>
<th>La 30 ft</th>
<th>La 40 ft</th>
<th>La 50 ft</th>
<th>La 60 ft</th>
<th>La 65 ft</th>
<th>La 70 ft</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PARAMETERS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wt.</td>
<td>15,500</td>
<td>12,000</td>
<td>9,500</td>
<td>7,500</td>
<td>6,750</td>
<td>6,000</td>
</tr>
<tr>
<td>Rbr.</td>
<td>2,670</td>
<td>2,410</td>
<td>2,260</td>
<td>2,180</td>
<td>2,180</td>
<td>2,180</td>
</tr>
<tr>
<td>Rba.</td>
<td>910</td>
<td>960</td>
<td>1,020</td>
<td>1,090</td>
<td>1,140</td>
<td>1,190</td>
</tr>
<tr>
<td>Rv.</td>
<td>45,440</td>
<td>39,240</td>
<td>34,820</td>
<td>31,280</td>
<td>29,950</td>
<td>28,620</td>
</tr>
<tr>
<td>T.</td>
<td>3,200</td>
<td>2,470</td>
<td>1,960</td>
<td>1,550</td>
<td>1,390</td>
<td>1,240</td>
</tr>
<tr>
<td>D.</td>
<td>43.2</td>
<td>53.7</td>
<td>64.2</td>
<td>74.7</td>
<td>80.0</td>
<td>85.2</td>
</tr>
<tr>
<td>dpt.</td>
<td>5.6</td>
<td>7.1</td>
<td>8.5</td>
<td>9.6</td>
<td>10.2</td>
<td>10.6</td>
</tr>
</tbody>
</table>

| Load Angle $\theta = 5^\circ$ | Tag Angle $\alpha < 60^\circ$ |          |          |          |          |          |
| Wt.               | 19,250   | 15,250   | 12,250   | 9,750    | 8,750    | 7,750    |
| Rbr.              | 2,110    | 1,970    | 1,900    | 1,870    | 1,880    | 1,880    |
| Rba.              | 840      | 880      | 930      | 990      | 1,030    | 1,070    |
| Rv.               | 49,770   | 43,170   | 38,220   | 34,090   | 32,440   | 30,790   |
| T.                | 2,220    | 1,760    | 1,410    | 1,120    | 1,010    | 890      |
| D.                | 30.6     | 36.9     | 43.2     | 49.5     | 52.6     | 55.8     |
| dpt.              | 5.1      | 6.5      | 7.7      | 8.7      | 9.2      | 9.6      |

| Load Angle $\theta = 3^\circ$ | Tag Angle $\alpha < 60^\circ$ |          |          |          |          |          |
| Wt.               | 22,750*  | 18,500*  | 15,000*  | 12,000*  | 10,750*  | 9,500*   |
| Rbr.              | 1,540    | 1,500    | 1,490    | 1,500    | 1,530    | 1,550    |
| Rba.              | 760      | 790      | 820      | 860      | 890      | 920      |
| Rv.               | 53,750   | 47,070   | 41,570   | 36,860   | 34,890   | 32,930   |
| T.                | 1,250    | 1,010    | 820      | 660      | 590      | 520      |
| D.                | 21.2     | 24.3     | 27.5     | 30.6     | 32.2     | 33.7     |
| dpt.              | 4.6      | 5.8      | 6.9      | 7.7      | 8.1      | 8.3      |

Special Lift Provisions Required
Monitoring During a Lift
Shot Thru Transit
No-Load Condition

Cross hairs on the edge of the leg
Load off the Ground with Minimum Tag
Maximum Tag Load “Verification”
Regular Tag Situation
Gin Pole Back to Original Unloaded Position
Bridle Slings

- Controls the stability and keeps the pole vertical.
- Is the upper most attachment point, usually where the cantilever distance starts.
- Should be flat to the horizontal.
- Should be a minimum of 45 degrees.
Basket Slings
Straight and Trolley Tag Systems
Tag Line Angle
Controlling the Load Line
Vertical Gin Pole Load Chart

### Parameters

<table>
<thead>
<tr>
<th>Parameters</th>
<th>20% L (La= ft)</th>
<th>30% L (La= ft)</th>
<th>40% L (La= ft)</th>
<th>50% L (La= ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wt</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hleg</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hface</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Htip</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rbr</td>
<td></td>
<td></td>
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<tr>
<td>Rv</td>
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<tr>
<td>T</td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

### Notes
- Maximum operational effective wind speed at gin pole 35 mph.
- Unless special engineered lift parameters are satisfied, gross load capacities shall not be increased for load line angles of less than 3°.
- Capacities for lifting personnel, tools, equipment and rigging shall not exceed 50% of the charted values (no other loads shall be lifted simultaneously).
- Interpolation between minimum and maximum load angles and cotrailer lengths is allowed.
- Reactions Rbr, Rba & Rv include an impact factor of 1.3.

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**Vertical Gin Pole Load Chart**

(Pole Identification
- Pole Size
- Class
- Capacity
- Load Line Restraint Required
- Yes
- No
- Load Line Size
- Number of Parts
- Overall Length (Rooster to Basket)

Hleg = LOAD LINE STANDOFF DISTANCE FROM LEG (in.)
Hface = LOAD LINE STANDOFF DISTANCE FROM FACE (in.)
Htip = HORIZONTAL TIP DEFORMATION OF GIN POLE TOP (in.)
K = OVERALL GIN POLE EFFECTIVE LENGTH FACTOR
L = CANTILEVER LENGTH (ft) [Distance from Bricle to Rooster Head]
Wt = GROSS LOAD (lbs) [Lifted Weight + All Rigging Weight]
Rbr = HORIZONTAL REACTION AT BRICLE (lbs.)
Rba = HORIZONTAL REACTION AT BASKET (lbs.)
Rv = VERTICAL REACTION AT BASKET (lbs.)
K = (define)
T = TAG LINE FORCE (lbs.)
β = LOAD LINE POSITIONING ANGLE (degrees)
θ = MAXIMUM TAG LINE ANGLE AT GROUND (degrees)
Operational Conditions

- Conditions in which the structure is subject to additional loading during a lifting sequence.
- Wind load
- Bridle forces
- Basket forces
- Block loading
- Hoist anchorage
Operational and Non-Operational Conditions

• **Operational**
  – Loading conditions of a structure during the actual lifting sequence.
  – Typically governs the strength requirements for lifting devices and their associated rigging.
  – (gin pole and attached rigging equipment loads)

• **Non-Operational**
  – Loads on a structure when lifting is not performed.
  – Typically govern the strength requirements for the structure under construction.
  – (wind load conditions based on construction duration factor)
Operational and Non-Operational Wind Speed

- **Operational Wind Speed**
  - A uniform effective 30 mph 3-sec gust wind speed.
- **Non-Operational Wind Speed**
  - Varies from 45 mph to 90 mph based on the construction duration period.
## Non-Operational Wind Loads During Construction

<table>
<thead>
<tr>
<th>Construction Period</th>
<th>Minimum Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Continuous work period</td>
<td>0.50 (0.5 x 90 mph = 45 mph)</td>
</tr>
<tr>
<td>Less than 24 hours (overnight conditions)</td>
<td>0.60 (54 mph)</td>
</tr>
<tr>
<td>24 hours to 1 week</td>
<td>0.67 (60 mph)</td>
</tr>
<tr>
<td>1 week to 6 weeks</td>
<td>0.75 (67.5 mph)</td>
</tr>
<tr>
<td>6 weeks to 6 months</td>
<td>0.80 (72.0 mph)</td>
</tr>
<tr>
<td>Greater than 6 months</td>
<td>1.00 (90 mph)</td>
</tr>
</tbody>
</table>

Wind Speeds are 3-Second Peak Gust
Tilted Gin Pole Use to be Covered

LOAD LINE

JUMP BLOCK*

LOAD BLOCK

JUMP LINE*

LOAD LINE

CHOKER
(Base Pivot System)

* Jump Block & Jump Line
Often used as Luffing (Booming) System.
Inspection Criteria

• A competent Rigger shall complete a visual inspection after assembly
• A Qualified Person shall perform a detailed inspection yearly
• Allowable deformation and condition of members shall be within tolerances noted in this standard
• Wear shall be checked in bridle and basket attachment points
• Rooster head shall be checked for wear
• Rigging hardware shall be checked for proper condition
Repairs and Modifications

- Repairs made with same or similar materials.
- Qualified Engineers shall be consulted for repairs.
- Qualified welders and Fabricators shall be used when making repairs.
Inner Bracing Member Inspection

- Tolerance 1/500.
- Diagonal length 24 inches.
- 24” allowable = .048 inches.

Also; check for rust, cracks or wear!
Leg Inspection Criteria

- Tolerance 1/500.
- Since this is a dent in the leg instead of a general bow the measuring point is the distance between the diagonals (24”).
- Tolerance is 0.048 inches in this case.
Overall Gin Pole Straightness

- Tolerance 1/500.
- Pole 60 feet long.
- Tolerance 1.55 inches.
Re-Use of Gin Pole Fasteners
High Pole Above Top Level of Guys

• Is when the pole is positioned above the highest level of guys.

• This can only be allowed if the structure can meet the following wind load conditions:
  • 45 mph during the day
  • 54 mph overnight
Bridle and Basket Forces

- The gin pole attachment forces, where connected to the structure, shall be considered.

- The local forces on individual tower members must be evaluated.

- The overall loading on the structure must also be considered.
Gin Pole Analysis and Design

- Scope
- Classification of gin poles
- Impact factors for gin pole lifts, 1g
- Design method
- Gin pole forces and reactions
- Analysis models
- Effective slenderness ratios for compression members
- Connections
- Rooster head
Gin Pole Design Method

- ASD – AISC-13th Edition

- ASD is the desired design method since the field methods of control and verification are governed by actual deflection of the gin pole and supporting structure under a lifted load condition.
Loading of the Gin Pole
Combined Axial and Bending Effects Considered

For latticed gin poles:
\[ \frac{P_{br}}{F_{apole}} + \frac{M_{br}}{F_{aleg}} \leq 1.0 \]

For tubular gin poles:
\[ \frac{P_{br}}{F_{apole}} + \frac{M_{br}}{F_{b}} \leq 1.0 \]
Gin Pole Free Body Diagrams for Engineering Use
# Overall Gin Pole Buckling K-Factors

## Table 5.1a Vertical Gin Pole

<table>
<thead>
<tr>
<th>Load Line Restraint</th>
<th>K Factor Based Upon Cantilever Length, La</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>20% L</td>
</tr>
<tr>
<td>No</td>
<td>5.3</td>
</tr>
<tr>
<td>Yes</td>
<td>5.2</td>
</tr>
</tbody>
</table>

## Table 5.1b Tilted Gin Pole

<table>
<thead>
<tr>
<th>Kt Factor Based Upon Total Gin Pole Length, L</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cantilever Length</td>
</tr>
<tr>
<td>0% L</td>
</tr>
<tr>
<td>1.00</td>
</tr>
</tbody>
</table>
Impact Factors for Gin Poles (Im)

- Class A Pole – $Im = 1.45$
- Class B Pole – $Im = 1.35$
- Class C Pole – $Im = 1.25$
- Class D Pole – $Im = 1.20$

For all other cases $Im = 1.3$
Factors Affecting Gin Pole Loading

- The cantilever height of the gin pole above the bridle.
- The overall length of the pole.
- The load line angle at the rooster head at the top of the pole.
- The offset of the rooster head.
- The number of attachment points to the structure.
- The positioning and angle of the tag line.
- Restraint of the load line as it passes thru the center of the pole.
- The flexibility of the pole as well as the structure it is attached to.
Load Line in Center of Pole

- Restricting, or holding, the load line as it passed down thru the pole helps make it less flexible and can increases its lift capacity.
Design Section for Rooster Heads

Rooster Heads

Bearing
Rooster Head
Rooster Head Design

Figure 3-3: Typical Rooster Head Assembly
Track Loading and Design
Rigging Accessories

- 5 to 1 Factor of Safety (10 to 1 if Personnel Involved)
- Rooster Head Sheaves and Bearings
- Load, Jump and Tag Lines
- Blocks
- Headache Ball
- Wire Rope Slings, Shackles, Chains, Links and Hooks
Support Conditions Affect Gin Pole Capacity

**Pole Load Parameters:** Overal Length—180’, Cantilever Height—70’, Load Angle—3°

<table>
<thead>
<tr>
<th>Tower Stiffness</th>
<th>Brace &amp; Basket</th>
<th>Brace &amp; Basket w/Tie</th>
<th>Brace &amp; Basket &amp; MI Support</th>
<th>Brace &amp; Basket &amp; MI Support w/Tie</th>
</tr>
</thead>
<tbody>
<tr>
<td>SOFT</td>
<td>22,000 LB</td>
<td>26,300 LB</td>
<td>22,100 LB</td>
<td>26,700 LB</td>
</tr>
<tr>
<td>MILD-STIFF</td>
<td>22,850 LB</td>
<td>26,500 LB</td>
<td>24,300 LB</td>
<td>28,500 LB</td>
</tr>
<tr>
<td>STIFF</td>
<td>24,000 LB</td>
<td>26,900 LB</td>
<td>28,300 LB</td>
<td>31,800 LB</td>
</tr>
</tbody>
</table>
Cantilever Height

- Excessive deflections and high tension loading on leg splices are typical concerns with cantilevers under construction.
# 250’ Tower-Strength Requirements

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Top Deflection</th>
<th>Leg Compression</th>
<th>Leg Tension</th>
</tr>
</thead>
<tbody>
<tr>
<td>54 mph wind</td>
<td>24 inches</td>
<td>14,900 lbs</td>
<td>13,800 lbs (61%)</td>
</tr>
<tr>
<td>Stacking Deflection</td>
<td>12 inches</td>
<td>9,200 lbs</td>
<td>7,100 lbs (31%)</td>
</tr>
<tr>
<td>Guy Wire Slippage (Impact at 1.3)</td>
<td>15 inches</td>
<td>8,100 lbs</td>
<td>12,000 lbs (53%)</td>
</tr>
<tr>
<td>Guy Wire Breakage (Impact at 2.0)</td>
<td>15 inches</td>
<td>12,400 lbs</td>
<td>18,400 lbs (82%)</td>
</tr>
</tbody>
</table>

**Leg Splice Tension Capacity**

<table>
<thead>
<tr>
<th>Compression Capacity</th>
<th>Capacity</th>
<th>Tension</th>
</tr>
</thead>
<tbody>
<tr>
<td>100%</td>
<td>22,500 lbs</td>
<td></td>
</tr>
<tr>
<td>50%</td>
<td>11,250 lbs</td>
<td></td>
</tr>
<tr>
<td>33%</td>
<td>7,500 lbs</td>
<td></td>
</tr>
</tbody>
</table>
Guy Anchor Rod Corrosion
Probability, Detection & Prevention

Dave Davies
Director of Structural Products and Services
Electronics Research, Inc.
Guy Anchor Rod Corrosion
Foundation Steel Corrosion

• Explanation of the Corrosion Process
• How to Self Evaluate Corrosion Risk Probability
• Anchor Rod Inspection Methods
• Corrosion Prevention Methods
In a recent advertising campaign, NATE (National Association of Tower Erectors) recommended anchor rod inspection prior to any tower work, out of concern for climber safety.

Why would this national organization make a recommendation that will double or triple the expense of annual tower inspection and smaller projects?
Tower Failure due to Anchor Rod Corrosion

Because of a Desire for Self Preservation!
What caused this tower collapse?
Under ground and thus undetected guy anchor shaft corrosion.
Explaining the Corrosion Process.
Will all Steel Corrode? NO!

- In non corrosive environments steel naturally forms a protective, tight, non-conducting oxide film on its surface. This process is called “Passivation” because the steel remains passive against its environment.
Why does Steel Corrode?

• If this protective film is removed, Corrosion will occur.
• Once Removed all corrosion is the result of a galvanic cell.
Galvanic Corrosion “un-refines” the metal

• Galvanic corrosion is an electrochemical process where metals deteriorate through a reaction BETWEEN or WITHIN the metals.
  – Between (External) – metals with different electromotive potentials. Copper and Steel.
  – Within (Internal) difference in the environment of two sections of the same metal. Soil and Concrete or Sand and Clay.
Basic Corrosion Cell
Internal or External Corrosion

• 4 Elements of a Corrosion Cell. All must be present for the cell to be active.
  – Anode
  – Cathode
  – Electrical Path (conductor)
  – Electrolyte

• These four elements are present in both External (between metals) and Internal (same metal) corrosion.
What removes the protective film?

- Electrical Current flow on the surface can cause the protective film to erode.
- Chemicals can erode the film. Highly Acidic or Base soil, farm products, waste.
- Microbiological bacteria can erode the film. Sulfate reducing bacteria resulting in sulfide ions can promote ion flow and limit oxygen in soil.
Causes of Electrical Current

- Difference in the electrical potential of dissimilar connected metals.
- External “Stray” Electrical Current.
- Difference in the conductivity of the environment for a continuous piece of metal.
Electrical Current
From Dissimilar Metals

- The voltage difference or potential between copper (-0.43) and carbon steel (-0.68) is .25 volts.
- One ampere - year current flow = loss of 20 pounds of steel.

<table>
<thead>
<tr>
<th>Metal / Alloy</th>
<th>Potential (Volts)</th>
<th>Reactivity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Magnesium</td>
<td>-1.55</td>
<td>More Reactive</td>
</tr>
<tr>
<td>Zinc</td>
<td>-1.10</td>
<td>1.55</td>
</tr>
<tr>
<td>Aluminum</td>
<td>-0.86</td>
<td>1.10</td>
</tr>
<tr>
<td>Cadmium</td>
<td>-0.77</td>
<td></td>
</tr>
<tr>
<td>Cast Iron</td>
<td>-0.68</td>
<td></td>
</tr>
<tr>
<td>Carbon Steel</td>
<td>-0.68</td>
<td></td>
</tr>
<tr>
<td>Stainless Steel</td>
<td>-0.61</td>
<td></td>
</tr>
<tr>
<td>Lead</td>
<td>-0.57</td>
<td></td>
</tr>
<tr>
<td>Solder</td>
<td>-0.52</td>
<td></td>
</tr>
<tr>
<td>Tin</td>
<td>-0.49</td>
<td></td>
</tr>
<tr>
<td>Copper</td>
<td>-0.43</td>
<td></td>
</tr>
<tr>
<td>Aluminum Bronze</td>
<td>-0.41</td>
<td>Less Reactive</td>
</tr>
</tbody>
</table>

Steel = .68
Copper = .43
External Corrosion caused by
*Dissimilar Metals* in Guy Tower Anchor
External Corrosion caused by “Stray Currents” in a guyed tower
Internal Corrosion caused by Dissimilar Environments in Guy Anchor
Internal Corrosion caused by *dissimilar environments* in Self Support Base

*Photo 15 - Typical fixed breaking where anchor bolt failures within the bolt stem occurred.*

- Anchor bolts failed in tension within bolt shaft buried in pedestal unit.
Internal Corrosion caused by *dissimilar environments* in Self Support Base
Internal Corrosion caused by *dissimilar environments* in Anchor Bolts
Why doesn’t hot dip galvanizing protect the steel from corrosion?

• The main component of galvanizing is zinc. Zinc is very high in the galvanic series and acts as an anode with the coated steel acting as the cathode. When exposed to the atmosphere (CO2) zinc quickly forms its own passivation film.
However, the zinc coating is unstable in the absence of air and quickly erodes.
How to Evaluate Corrosion Risk Probability?

• From Geo Tech Report
• From Visual, On Site Inspection
• From On Site Electrical Testing
Soil Parameters
from Geo-Tech Report

• The Soil Classification elements which have the most effect on the corrosion rate are:
  – particle size and aeration
  – moisture content
  – Bacteria and microbiologic
  – pH
  – Other natural chemical elements
Three ways to report Soil Particle Size
From Geo-Tech report

<table>
<thead>
<tr>
<th>#1 Soil Type</th>
<th>#2 Particle Size</th>
<th>Corrosion Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand</td>
<td>.07 to 2 mm</td>
<td>Low</td>
</tr>
<tr>
<td>Silt</td>
<td>.005 to .07 mm</td>
<td>Moderate</td>
</tr>
<tr>
<td>Clay</td>
<td>less than .005 mm</td>
<td>High</td>
</tr>
</tbody>
</table>

- Low Corrosion Rate – Coarse grain soil, less than 50% passing through a # 200 sieve (#3)
- Higher Corrosion Rate – Fine grain soil, more than 50% passing through a #200 sieve.
Soil Particle Size

• Generally, large particles like rock and sand are well-aerated soils less likely to contribute to corrosion.
• Small Particle, aggressive soils would include:
  ✓ Clay, Silt and compact Peat
  ✓ Sandy-Silt in salt water or tidal marshes
## Aggressive Soil Types

**From Geo-Tech report, Soil Classification**

<table>
<thead>
<tr>
<th>Soil Symbol</th>
<th>Soil Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pt</td>
<td>Peat and other highly organic soils</td>
</tr>
<tr>
<td>OH</td>
<td>Organic clay</td>
</tr>
<tr>
<td>CH</td>
<td>Inorganic clay</td>
</tr>
<tr>
<td>MH</td>
<td>Inorganic silts and very fine sands</td>
</tr>
<tr>
<td>OL</td>
<td>Organic silts</td>
</tr>
<tr>
<td>CL</td>
<td>Inorganic clays, silty clays, lean clays</td>
</tr>
<tr>
<td>ML</td>
<td>Inorganic silts with fine sands</td>
</tr>
<tr>
<td>SC</td>
<td>Clayey sands, sand-clay mixtures</td>
</tr>
<tr>
<td>SM</td>
<td>Silty sands, sandy silts</td>
</tr>
</tbody>
</table>
Soil Parameters
from Geo-Tech Report

• The following parameters are just a Snap Shot of soil conditions and will change seasonally.
• For reference the following values are for soil which is 75 degrees Fahrenheit.
✓ A 20 degree temperature change will double or half corrosion rates.
Moisture Content
From Geo-Tech Report

- Usually represented in % moisture by soil weight, or
- Difference between in situ soil weight and dry soil weight.

 UAE Generally, the greater the moisture content the greater the corrosion probability. Above 15% moisture by weight would be considered aggressive soil.
Bactria and Microbiologic Content
From Geo-Tech report

• High levels of bacteria in the soil tend to consume oxygen, thus making the soil poorly aerated and accelerating corrosion

✓ Bacteria levels can be requested during a geo-tech investigation and should be expected in organic soils like peat or near animal waste sites
Hydrogen Ion Activity (pH)  
From Geo-Tech Report

• Extreme corrosion rates are to be expected in soils having Low or High pH. The pH range is from 0 to 13, with 7 considered neutral.

✓ A reading below 6 or above 8 should be considered as aggressive soil.

✓ These soils could include:
  – Cinder, ash, or slag fills
  – Organic fills, mine or industrial waste
Chloride Concentration
From Geo-Tech Report

- Chloride ions facilitate the corrosion process.
- High levels are typically found in areas of historic salt water.
- May also result from de-icing operations.

✓ Chloride concentrations in the soil above 50 ppm is considered aggressively corrosive for steel.
Soils with Sulfur
From Geo-Tech Report

• Sulfur or sulfur forming soils can produce very acidic soil conditions when exposed to air.

✓ This often occurs in tidal flats or near mining activity where the soil is exposed and well drained.

Anchor Shaft
Visual and Agriculture Data
Water Level and Rain Fall

- The longer steel remains wet, the higher the corrosion rate.
- Also, plentiful rainfall typically translates into soils that are more acidic and thus, more corrosive.
Visual Inspection
Evaluate Site Soil

Road Side Excavation
Sandy Soil has low cohesion
Slanted Face
✓ Non aggressive soil

Road Side Excavation
Clay has high cohesion
Steep Face
✓ Aggressive soil
Visual Inspection
Evaluate Site Soil

Surface Observation
Clayey Soil has high cohesion
✓ Aggressive soil

Shallow Digging
Clayey Soil has high cohesion
✓ Aggressive soil
Another easy way to view soil classification and particle size is through Color.

- Tan, Red or Light Brown color indicates large particle size, well-aerated soil with low moisture content, limited wet duration.

- Less Corrosion Probability.
Another easy way to view soil classification is through Color.

- However, Gray Soils can indicate a Dangerous Situation.
Another easy way to view particle size is through **Color**.

- Gray and greenish-gray soils indicate small particle size with poor aeration.

✓ Aggressive soil.

Anchor shaft installed less than one year
Using visual inspection or your nose.

pH and Bacteria levels can also be obtained from agricultural equipment supplier at no or little cost.
Visual Inspection of Anchor Shaft
Visual Inspection
Look for evidence of Pipe Lines and other stray current sources
National Pipeline Mapping System (NPMS)
www.npms.phmsa.dot.gov
National Pipeline Mapping System (NPMS)
www.npms.phmsa.dot.gov

Pipeline operator contact for the geographic area you specified. (Do another search)

<table>
<thead>
<tr>
<th>Pipeline Operator Name</th>
<th>Person to Contact</th>
<th>Entity to Contact</th>
<th>Contact Address</th>
<th>Phone/Fax/Email</th>
</tr>
</thead>
<tbody>
<tr>
<td>BP PIPELINE (NORTH AMERICA) INC.</td>
<td>Bobby Roye (Compliance Team Leader)</td>
<td></td>
<td>4502 E. 41st St., Suite 300, Tulsa, OK 74135</td>
<td>Phone: 8005486482 Email: <a href="mailto:royebw@bp.com">royebw@bp.com</a></td>
</tr>
<tr>
<td>TEXAS GAS TRANSMISSION LLC</td>
<td></td>
<td>Gas Control - Texas Gas Transmission, LLC</td>
<td>P.O. Box 20008 3800 Frederica Street, Owensboro, KY 42301</td>
<td>Phone: 2706896800 Email: <a href="mailto:Mike.K.Nance@txgt.com">Mike.K.Nance@txgt.com</a></td>
</tr>
</tbody>
</table>
Visual Inspection
Look for Other Sources of Stray Currents

- Sources of Direct Electrical Current Generation or Use.
  - Plating works
  - DC supply systems in industrial plants
  - Large direct drive motors
  - Welding Equipment
  - DC communications
Soil Properties, On Site Testing

Megger type of test

- High soil resistivity generally equates to a low corrosion rate, and conversely
- Low soil resistivity can lead to a high corrosion rate.
  - Soils with a resistance of less than 10,000 Ohm-Cm would be considered corrosive.
On Site Testing
System Resistance and Current Flow

• Measuring the resistance and current in the grounding rod – anchor rod circuit can also be instructive.
Predicting Active Corrosion Cell by Resistance and Current Measurements

- Single 10’ ground rod resistance of less than 16 Ohms indicates more aggressive soil.

- Direct Current flow in excess of 15 mA indicates an aggressive soil.
Predicting Active Corrosion Cell by Current Measurements

- Current discharge will cause corrosion loss at the rate of 20 pounds of steel in one year per ampere of discharge.
Predicting Active Corrosion Cell by Direct Current Measurements

- 1 amp-yr = 20 # steel
- 27 mA = .027 amps
- .027 amp x 20 # steel = .54 pounds of steel of steel loss in 1 year
Anchor Rod Inspection Methods

- Limited Excavation – limited value
- Total Excavation – accurate but expensive and time consuming
- Cylindrical Guided Wave-Ultra Sound
Limited Excavation

- Hand digging around anchor shaft
- Typically 12” to 24” in depth
- Assumes “if Corrosion is found need to dig up anchor.”
- If “Not found no need for further investigation.”
Limited Excavation

Not representative of Rod condition
Limited Excavation
Total Excavation
Total Excavation

- Expensive
- Can be destructive
- Dangerous
- Difficult to repeat
Sometimes you can’t Dig
Ultrasound: Longitudinal Wave
Ultrasound: Longitudinal Wave

Entry surface
Back-wall reflection

Unflawed Anchor
Typical of planar flaw (crack)

Rawed Anchor
Typical of wastage

Flawed Anchor
Ultrasound: Limited Surface Area, so Small Transducer limits testing ability
## Beam Spread

<table>
<thead>
<tr>
<th>Transducer Diameter</th>
<th>Beam Spread</th>
</tr>
</thead>
<tbody>
<tr>
<td>3/8 inch</td>
<td>48 degrees</td>
</tr>
<tr>
<td>1/2 inch</td>
<td>34 degrees</td>
</tr>
<tr>
<td>3/4 inch</td>
<td>22 degrees</td>
</tr>
<tr>
<td>1 inch</td>
<td>16 degrees</td>
</tr>
</tbody>
</table>
Field Application of Longitudinal Wave with Small Transducer

No Back Wall Reflection
Field Application of **Longitudinal Wave Stress Cracks in Anchor Shaft**
Ultrasound: Shear Wave, also called “Guided Wave”
Ultrasound: Shear Wave
Ultrasound: Shear Wave

Loud Entry Noise

No Back Wall Reflection
Making Longitudinal Wave Ultra Sound Work

- Problems
  - Can’t dig
  - Can’t get to the end of the shaft
  - Shaft is too long for Shear wave method

Time to be inventive!
Making Longitudinal Wave Work
Making Longitudinal Wave Work

Typical Corrosion

Small Back Wall

Loud Entry Noise
Limiting Factors in using Ultra Sound

- Diameter of anchor rod. Small diameter offers increased resistance.
- Length of anchor rod. Longer rod offers increased resistance.
- Access or insertion point. Determines the size and type of probe to be used.
- Altering Anchor Rod requires Structural Analysis
- Ultra Sound is the most promising method of anchor rod inspection.
Especially if you can change the design.

**ULTRA™ Guy Anchor Rod** by *ERI*
20’ x 2-1/2” dia Rod, 25% x-section area removed. Test area, 12” in length, 6.5’ from one end.
ULTRA™ Test Results
Ultra Sound Field Results
Corrosion Prevention Methods

• If we can disrupt the electrical circuit we can reduce the corrosion rate.
  – Concrete Encasement
  – Coatings
  – Impressed Counter Current
  – Sacrificial Anodes
Concrete Encasement

- Associated Problems
  - Expense
  - Corrosion can still occur under the concrete
  - Cracks
Coatings

Anchor shaft with Plastic Tape

Anchor shaft with tar adhesive
Coatings

Associated Problems

• Difficult to apply in the field
• If factory applied, susceptible to shipping and installation damage
• If damaged, accelerated corrosion
Impressed Counter Currents

Associated Problems

- Expensive
- Difficult to Maintain
- Over protections can lead to corrosion
- May lead to increased corrosion rate in non protected structures
Sacrificial Anodes

Associated Problems

- Maintenance
- Can increase Grounding System Resistance
Increased Electrical Resistance as a Result of Galvanic Corrosion Action
A Better Sacrificial Anode

MAG-Rod™ by ERI

- Chemical Grounding Rod.
- Sacrificial Anode
MAG-ROD™ Galvanic Corrosion Protection
Summary

• Corrosion begins when the steel loses the protective film.
• The film is destroyed by its environment or electrical current.
• Zinc Galvanizing alone is not sufficient protection.
Summary

- Evaluate the corrosion risk by knowing the soil characteristics, visual observations, and/or by measuring current flow.
- Interrupting the galvanic cell will reduce corrosion possibility.
- Reversing the polarity of the galvanic cell will prevent corrosion.
Summary
Ultra Sound is the most promising Inspection Method for Inspection and Detection.
Questions

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Construction Standards
&
Guy Anchor Rod Corrosion
Probability, Detection & Prevention

See us at the
’09 NAB in Booth C1307!