Introduction

This document is a compilation of written commentaries by many people. As such, it is meant to be a reference resource to find the opinions and experiences of our peers about topics related to communication towers. It is not an ultimately authoritative compendium of all knowledge on the subjects, so care should be exercised in applying its contents.

The original editor, Mark Lowell, N1LO, started this collection of tower related information by painstakingly sifting through the archives of the TowerTalk reflector. Below are Mark's comments from his website.

GUYED TOWER TOPIC SUMMARY - Still under construction..
Version: 01-19-2000

Check http://www.qsl.net/n1lo for the latest update
The existence, accuracy, content and organization of any section may change at any time as new discoveries, understandings, and concepts arise. I add new sections whenever appropriate.

By Mark D. Lowell, N1LO. First posted in November 1998

This document is a series of notes that I have made concerning guyed towers and installation that started after reading and digesting the message archives of the TowerTalk forum sponsored by the folks at www.contesting.com. The archive is located at:

http://www.contesting.com/_towertalk/

I have also combined ideas from other readings and personal experiences as well. I have paraphrased some subjects after reading the general consensus of many messages. In other cases, the originators of these messages have already addressed the topic in the most eloquent form, and I have simply copied their messages here.

I have concentrated mainly on subjects relating to standard, Rohn, guyed towers, and not crankup or self-supporting types. I most whole-heartedly agree with an opinion once expressed on the TowerTalk reflector: "There is nothing stronger, safer, or more cost effective than a good guyed tower."

WARNING
Tower climbing can be hazardous to your health! You can hurt yourself and others very easily while engaging in climbing and rigging. The information here is provided on an as-is basis and, naturally, I can assume no responsibility for your safety, or how you interpret or implement the techniques I have described here. Do not perform a procedure that you are not comfortable with. Think ahead, get familiar with all of your materials, and teach the people assisting you about the methods and dangers. Again, in all matters, *you* are the one who is the most in control of your own safety. A complete understanding of both the risks you take, and the solutions available to you, are the best tools at your disposal. I bid you safe journeys.
WARNING
This is a work in progress, growing as I gather information from individual postings by experienced professionals and amateurs in many walks of life, from all over the globe, and from my own personal experiences. I present it for personal use and benefit of all who read it and find something

of value. I have nothing to gain from this except the joy of learning itself, and the satisfaction of helping others. And, of course, it will help me put up my own tower!

If this information has helped you, I would enjoy receiving a QSL card or email from you.

Mark, N1LO - n1lo@hotmail.com

Pat Thurman, K7KR, added considerable effort to take the original plain text version and convert it to .PDF format with hyperlinks to make it a very user friendly resource.

Both N1LO and K7KR have given permission for their work to be made available on the K7NV web site. Kudos go to Mark and Pat for doing such a fine job, and THANKS!

It is my hope that this document continues to grow in its scope and depth of collected knowledge about tower related things. Those wishing to contribute more knowledge to this collection may contact k7nv@contesting.com

73, Kurt, K7NV

GUYED TOWER TOPIC SUMMARY

GUIDES

TOWER CONSTRUCTION GUIDES

See the Frequently Asked Questions (FAQ) page for the TowerTalk reflector at http://www.contesting.com/towertalkfaq.html. This resource is quickly becoming the internet's Bible on tower construction techniques, and you will also find a link to the latest version of this document.

Steve, K7LXC, of Champion Radio, sells copies of this catalog and other publications concerning tower erection, such as "The 10 Most Common Tower Building Mistakes"

De Steve K7LXC:
On a commercial note, my company - Champion Radio Products, 888-833-3104,(http://www.championradio.com) was formed to provide tools, equipment and resources for amateur tower and antenna building projects. If you're interested in a catalog, an SASE to Box 572, Woodinville, WA, 98072, will get you one. Topics of reprints (they're almost free!) available from Champion Radio include grounding for amateurs, building a one tower station, etc.

TOWER ENGINEERING GUIDES

Rohn's consumer catalog is regarded as the engineering Bible to define the right way to erect a tower, with outlines of height and guying plans to meet windload criteria. Copies of the latest Rohn color Amateur catalog are available from Rohn dealers or Champion Radio (888-833-3104, http://www.championradio.com)

The commercial tower erection standard is EIA/TIA-222-E. This document contains all of the currently accepted engineering standards, reference materials, and equations for the safe design of towers. The -222- spec may be obtained from Global Engineering Documents, 1-800-854-7179 (for those who need it).

LIGHTNING PROTECTION AND GROUNDING GUIDES

Anyone interested in understanding lightning protection and grounding systems should get themselves a copy of MIL-HDBK-419A. Some consider this to be the best single reference source on this subject. This manual is also available online as an Adobe PDF file.

However, they still permit the download of the document in .PDF format. This distribution mechanism is still free of charge. And it does not require any registration number to obtain. Please note that if your browser does not have the Adobe Acrobat .PDF viewer plug-in installed, you will not be able to download the information. Here is what I did just a few minutes ago.

1. Point browser to: <http://dodssp.daps.mil/> This is the Department of Defense Single Stock Point for Military Specifications, Standards, and Related Publications web site.
2. Look at the left side of the page. Click on the link titled "ASSIST Quick Search!" This link requires no registered account or password.
3. In the entry panel titled "Title", type (or paste) the following: GROUNDING, BONDING. Do not fill in any other panels or add anything to this one other than what is shown here.
4. Click on the "submit" button. This will return a panel showing several records found, one of which will be the 419 handbook.
5. Click on the 419 link to go to the profile page for this document and once there, click the pages icon in the top line where it says "click here to access document images. Finally, you arrive to the page where the document is located.
6. Under the "Media" heading in the leftmost position in the revision history panel, click on the "document image" icon (Acrobat .PDF file icon). This action will fire up your Acrobat plug-in and begin the handshaking. If you use IE, right click on the PDF icon and use save as.
7. In the browser pulldown menu area select "file" and then select "save as". Then configure the save as dialog window to put the file where you want it and name it like you want it. Click "OK".
8. Go get a cup of coffee. Step 7 is where the file is actually downloaded to your box in its complete form.

BTW, the NFPA document is now called NFPA 780. Here is the URL to the spot on the NFPA site where this reference can be obtained: http://www.nfpa.org/home.html You will have to follow the links in this order: 1) On Line catalog, 2) Codes and Standards, 3) NFPA 780: Standard for the Installation of Lightning Protection Systems, 1997 Edition.

CLIMBING GUIDES

"On Rope", by Padgett & Smith is a truly excellent source of information on climbing: ropes, knots, gear, techniques. The equipment and techniques described here adapt very well to tower climbing. The new, second edition has 380 pages and 700, (repeat: 700!!) drawings. Check it out from your local library or buy one of your own.

TOWER TYPE SELECTION

For towers up to 40 feet, you can eliminate the expense and work or guying by using Rohn 45 and bracket mounting it next to a house or garage roof eave. Rohn 45 has more foot room for standing on rungs. However, it is heavier and requires more care to assemble. Rohn 25 is much lighter. First decide what antennas you want to mount and collect all of their weight and windload information. Then, refer to the Rohn catalog for the allowable total windload areas of various configurations of tower.

Definitely select Rohn 45 or 55 if you plan large beam antennas in the future such as 40m beams or multiple stacked beams.

BRACKET SUPPORTS

If you don't have the Rohn catalog, my recommendation is to get it. It has house bracketed and freestanding specs in it. For example, 50 feet of 25G bracketed at 36 and 18 feet will take 14.6 square feet of load at 70 MPH;

50 feet of 45G (same brackets) will take 34.8 square feet. Either choice will give you a respectable load capability and reliability.

BASES

SELECTING BASE TYPE

Most guyed towers are built on top of a concrete base that has a pier pin or bolt embedded in it, rather than embedding a tower section in the base. If you use a pier pin, not only do you not have to worry about having the bottom section plumb, you also achieve the following benefits:

- You don’t have to worry about water in the tower legs, as it will naturally pour down the legs and out the weep holes in the base plate.
- You are in essence putting a bit of a shock absorber on the base of the tower, the tower can turn a bit from side to side to absorb torque in high winds, resulting in less stress on the bottom section(s) of tower.
- You don’t have to worry about how the tower “short base section” will interfere with the steel re-bar in the tower base.

The purpose of the base on a guyed tower is two-fold: to keep the tower from sinking under the dead weight of not only the tower but also the pressure of the guy wires, and to keep the base from kicking out. A pier pin/base plate somehow seems easier to deal with than worrying about making a base section plumb. The only drawback is the requirement of having to put temporary guys on the first tower section(s) when the tower is being erected or dismantled.

It is much easier to construct this way, and use a base plate adapter. This method actually allows the tower to rotate a little on its base which helps dissipate torsional stresses in a high wind situation rather than wrenching the bottom of the tower. The weep holes in the base adapter completely eliminate the potential problem of water collection and corrosion of the bottom of the legs. Alignment of the tower is much simplified, although it is more difficult to erect the first few sections, which will require temporary guying. In the case of Rohn 25G, however, you may be able to assemble the first three sections with guys on the ground and then stand it up.

DIGGING THE HOLE

Bases for smaller towers aren’t too bad to dig by hand, but this quickly changes for larger ones, particularly the self-supporting, un-guyed types. Hiring someone who owns a backhoe and is experienced with it makes all the difference. An experienced operator can make short work of digging your hole. It is important that the base be surrounded by undisturbed earth to help keep it from shifting. Take care not to dig away more dirt than is necessary to form the sides. If necessary, have the backhoe operator dig to rough dimensions and touch up the walls by hand.

If you use or contract for a backhoe to dig the holes for your bas and anchors, plan on their final volume being larger than you expected. Since the backhoe isn’t always precise, you may get larger dimensions. Also, if dirt falls off of the sides (sloughs) into the hole, which is common in larger holes, your hole will become bell shaped after you remove the loose dirt. The end result is that you may end up needing at least 25% more concrete (or greater) than you originally thought.

Try to avoid using wood forms below grade. Over time, the wood will rot, and a mushy gap will form around the concrete, reducing its stability. If your soil is poor enough that you must use forms, remove them after curing and take care to thoroughly tamp the soil against the concrete to try and restore some of the stability of the undisturbed soil condition.

THE RE-BAR CAGE

A re-bar cage is required to give your concrete the tensile strength it needs to support the load of your tower. Re-bar is sized in reference to 1/8" steps in diameter. For instance, #4 re-bar is ½" diameter (4/8) and #6 re-bar is ¾" (6/8) diameter, etc. Re-bar of any grade should be adequate for your tower base as long as it is the right size. Here are some do's and don'ts for re-bar:

1. Welding weakens re-bar. Tie the pieces together with wire ties cut from steel or copper wire.
2. Keep re-bar away from any outside concrete surface. The purpose of the cover concrete cover for re-bar is to keep it from corroding. If re-bar starts to corrode inside of the concrete it will expand and cause spalling of the concrete. Where concrete is cast against and permanently exposed to earth (bottom and sides), the cover should be 3" minimum. Where the concrete is exposed to weather (portion above grade), the cover for bars larger than No. 6 should be 2" minimum and for No. 5 and smaller it should be 1.5" minimum.
3. Use a minimum size of #5 re-bar (5/8" diameter).
4. Cut re-bar easily with an abrasive cutoff blade in a grinder or circular saw.

Three ways of addressing # 2 above are as follows:

a) Support the cage on bricks, broken-up pieces of concrete step stones, or home-made concrete pedestals to keep re-bar "within" concrete. You can use the small cardboard tube forms for testing concrete to pour little pedestals. Alternately, you may be able to buy some 3" 'dobie' blocks with wires at your local building materials yard. These are 3" square blocks with tie wires embedded in them made for just this purpose.
b) Pour 3" of concrete first and let it cure a little before placing your cage, and;
c) Pour most or all of the concrete with the re-bar cage resting on the bottom and then use hooks to pull the cage up about 3 inches. It will SLOWLY move with some force. Decent concrete should pass a slump test (and not be so watery) so that the re-bar won't sink. Just make sure that you tie the cage together with the appropriate twist tie wires and it will hold together, allowing the whole thing to be moved upwards.

THE CONCRETE

Mixing concrete your self is a lot of work. One 80 pound bag of Quickrete will make 2/3 cubic feet of concrete. It takes about 10 minutes to mix one bag of this in a wheelbarrow and dump it into the base. A tower base 3'x3'x3' is one cubic yard, or 27 cubic feet, requiring 40 bags! That would be 400 minutes or over 6 hours of mixing by hand! For smaller bases, such as a 2'x2' diameter base with a 2x2 square top extending 4" above grade, the volume is only about 8 cubic feet and can easily be mixed up by hand. For the larger bases, though, it is much easier to order 1 cubic yard of concrete and use wheelbarrows to shuttle the concrete from the truck to the pour site. Another option is to rent a concrete mixer on site. If you have concrete delivered, and the concrete truck cannot get to your anchor and base excavations, you can set up a brigade with several friends using multiple wheelbarrows to carry the concrete to the holes. You can also rent a motorized wheelbarrow, which takes a lot of the strain out of the job. Alternately, contract for a concrete pumper truck, some of which can deliver their loads up to 400 feet away from the truck.

You can also purchase dye to color the concrete that will show above grade to match the landscaping. A company named Colorcrete makes a range of dyes that you can purchase from your local concrete plant. Colorcrete #CC50, used at the rate of at least 2 pounds per yard, or 2-4 heaping tablespoons per 80 lb bag of Quickrete, makes a pleasing, light rusty brown concrete, similar to the color of exposed aggregate concrete. Quickrete also sells a limited number of shades at home centers.

For hand mixing, a large wheelbarrow and a hoe will be required. Use about 1-1/2 gallons of water per 80 pound bag of Quickrete. In any case, a tamping/vibrating tool is a must for flowing the concrete into your form and around your re-bar cage. For large pours of several yards, you can rent a flexible concrete vibrating tube to make the concrete flow. For smaller pours, you can make a manual tool by screwing a 3" diameter disc cut from ½" thick scrap plywood to the end of a 6 foot long piece of 1x2 board stock. The plane of the disk should be at right angles to the length of the board. When you submerge the disk and shake the stick, the vibrations will make the concrete flow and level itself nicely. Take care not to use the vibrator too much or the gravel will begin to sink to the bottom, weakening the concrete. Use only enough vibration to make the concrete flow and level.

Setting bolts into existing concrete bases can be done. For minor stuff, expanding anchors will suffice. Since they'll never come out unless you chisel out the concrete around them, the stainless steel version is preferred. Waterproofing hint: put some Araldite (an epoxy glue) in the hole before setting the anchor. As the anchor expands, it pushes the Araldite into all the voids that would otherwise retain water & eventually wick through the concrete. For any serious stuff - the pier pin for Rohn 45 would probably count - use Hilti brand anchors. This company makes literally dozens of different anchors for concrete. They have a whole series of chemical anchors, which would be perfect for the application. They come with either a plated or stainless steel threaded rod & a glass epoxy-filled cartridge. Drill the hole, blow out the dust, drop in the cartridge, drive the rod in with a hammer to break the cartridge, attach drill chuck to end of rod & drive it home (which mixes the epoxy at the same time). About 20 minutes later, you have an anchor that is stronger than the concrete it's set in.

CONCRETE DO'S AND DON'TS

Concrete continues to gain strength as long as it stays moist. Concrete does not "dry," it undergoes a reaction called hydration, which requires water. The longer you can keep the concrete moist, the longer it hydrates, and the stronger it gets. If it dries, then the reaction stops and it stops gaining compressive strength.

Concrete gains strength with decreasing momentum, i.e. most of it's strength is gained early on in the curing period. If you have a proper mix of "Cement", sand and gravel and not too much water (this is a strength killer) the majority of the strength will occur in the first ten days or so. The consensus seems to be to wait at least 7-10 days before putting stress on the concrete.

Here is a guide for concrete strength versus curing time taken from a civil engineering handbook. The percentages are of the concrete's normal rated strength, and apply only as long as the concrete is still moist and hydrating!:

Days	Strength
3	25%
7	60%
28	100%
90	120%
180	125%

Strength Killers:

1. Sun beating on freshly poured concrete. Keep it covered with wet straw (or old wet rug) plus plastic or tar paper.
2. Excessive heat. Don't pour concrete when the temperature is high.

3. Pouring concrete into a hole that is dry. Wet the bottom and sides of the hole prior to pouring concrete otherwise the dry soil will suck the water out of the concrete and you will surely have a weak mix when it cures.
4. Stressing the fresh concrete by rocking the tower base or premature assembly and climbing.
5. Letting the surface get dry while it is curing. Give it a spray with water as often as possible to keep it wet because it **WON'T CURE IF IT GETS DRY, IT WILL ONLY GET DRY**.

CONCRETE STRENGTH

- ULTIMATE STENGTH (these materials just break without yielding - brittle)
- Bricks, common light red - 40 (tension), 1,000 (compression)
- Portland Cement, 1 month old - 400 (tension), 2,000 (compression)
- Portland Cement, 1 year old - 500 (tension), 3,000 (compression)
- Portland Concrete, 1 month old - 200 (tension), 1,000 (compression)
- Portland Concrete, 1 year old - 400 (tension), 2,000 (compression)
- Granite - 700 (tension), 19,000 (compression)

Note the difference in tension and compression for the rock-types. This is why re-bar is used in concrete, to add tensile strength for a better composite building material. Fiberglass is another example of this. The resin has compressive strength and the cloth has the tensile strength. The tensile and compressive strengths of metals are much more evenly matched, but can still vary.

Take care to level the surface of the base before the concrete cures. The plumb of the base section of your tower will partly depend on how well you do this. Also, the compressive loading of the tower legs will be better equalized with a flatter, level base top. Your re-bar cage should not touch the pier pin and should not come within 3 inches of any surface of the concrete.

For the embedded tower section method only, your foundation will have a hump that causes water to run away from the legs. No cavities in the foundation near the legs for water (or mud!) to accumulate. Foundations should rise several inches above the surrounding soil so that mud cannot wash onto the foundation and accumulate. After the concrete has fully cured for at least 30 days, seal the exposed concrete with "wet-or-dry" asphalt roof cement - it's asphalt with encapsulated asbestos, and appears to drive out or absorb water at the adhesion surface with tin roofs, concrete, you name it. Cost is good too - only about $4 per gallon!

MAST AND BOOM MATERIAL SELECTION

DO NOT use common water pipe unless the mast will only extend a few feet above the last tower section.

Use “structural tubing” instead of “pipe” for strength and known strength properties, and buy it new for assurance of its properties.

PROPERTIES OF MATERIALS

STRENGTH

Rohn offers a 2” x 10’ High strength galvanized steel mast, Part Number is M200H I believe. When I checked with them years ago, the spec was that this is a 50,000 psi mast. It is **VERY** heavy, I think the wall thickness is 0.125”.

The strength of a mast, or any metal part, for that matter, is highly dependent on the composition of the metal and its treatment, resulting in a specific yield stress value. The yield strength of a material is the stress, expressed in pounds per square inch (psi), at which a material begins to deform permanently, resulting in some sort of lasting change of shape after the stress is removed.

The ultimate strength, usually somewhat higher, is that where the material has already yielded, and stretched or bent, and finally breaks. You generally want to design things to stay below 50-67% of the yield strength of the material (safety factor between 1.5 to 2). The translation of the stress level to the actual allowable loads on the part in question, and vice-versa, is the tricky part that requires an analysis of the geometry and math. Those calculations can get hairy!

The strength of metals varies greatly with the method of their manufacture and composition.

1) Quenching, cooling very rapidly from a glowing hot temperature, can dramatically increase the hardness, but introduces brittleness.

2) Tempering, re-heating to a lower temperature followed by a slow cooling, ‘draws’ the hardness back down, reducing the brittleness and adding some toughness.

3) Annealing, heating to a high (glowing) temperature and allowing to cool slowly, softens a metal, reducing hardness and adding considerable ductility (ability to be bent and formed).

4) Cold working, when parts are bent, mashed, drawn, hammered (wrought), flattened, etc, by machine or by hand, causes the hardness and strength to go up somewhat.

5) Repetitive bending causes fatigue and drastic strength loss. This, in turn, can further cause your wallet and credibility to vaporize if you have not accounted for it!

Different metals and alloys of the same metal respond very differently to these treatments. It gets complicated!

It depends on the alloy **and** the treatment.

The point to remember is that identifying the type of metal is **far** different from knowing its actual strength. The advice of not using a pipe or tube of unknown origin for a mast is good because even though you may know that it is steel or aluminum, you still don't know it's properties unless you bought it from a manufacturer or reseller or have it tested. Of course, you can always count on minimum strength values for types of metals, with the knowledge that it may still be much stronger.

Hardness has an excellent correlation with the strength of the metal. The harder it is to prick with a center punch, the higher its yield strength.

Again, It depends on the alloy **and** the treatment.

Here is some data from Machinery's Handbook, 23rd edition:

SOME REPRESENTATIVE YIELD STRENGTHS

Aluminum, 6061-O (fully annealed) - 8,000 (surprise!)

Aluminum, 6061-T4 - 24,000 (surprise!)

Aluminum, 6061-T6 - 40,000 psi (surprise! - it's the treatment)

Brass, cast - 12-15,000 psi

Brass, wrought - up to 62,000 (what the book says)

Copper, annealed (soft) - 10,000 psi

Copper, wrought, up to 53,000 (what the book says!)

Steel, stainless, 304L & 316L, annealed, 30,000 psi (at its softest)

Steel, stainless, 304 & 316, annealed, 35,000 psi (at its softest)

Steel, Stainless, 316, tempered and work hardened, up to 100,000

Steel, common structural (I-beams, etc) - at least 33,000 psi

Steel, 1025 low carbon (cheap fasteners) - 50,000

Steel, 1050, quenched and tempered "typical" - 95,000

Tool steel, 4140, quenched, tempered to 1200F - 95,000 (tough)

Tool steel, 4140, quenched, tempered to 400F - 238,000 (!)(brittle)

(4140 is commonly referred to as 'chrome-moly steel')

Wrought iron - 23,000 to 32,000 psi

Wrought Steel (water pipe) - 23,000-32,000

Ok, you see that the alloy and the treatment affect the properties.

Be very careful to know what the alloy is and what the heat treatment is. The little "T6" behind the 6061 aluminum is easy to overlook but is SOOOO important.

By the way, 6061-T6 is one of the most common structural aluminums.

4140 is but one of many, many tool steel alloys.

SIZE DATA FOR WATER PIPE (INCHES) (count on about 20,000 psi yield)

SIZE,	**SCHD,**	**ID,**	**OD,**	**WALL THK**
1.25,	40,	1.380,	1.660,	.140
1.25,	80,	1.278,	1.660,	.191
1.50,	40,	1.610,	1.900,	.145
1.50,	80,	1.500,	1.900,	.200
2.00,	40,	2.067,	2.375,	.154
2.00,	80,	1.939,	2.375,	.218

I don't know if the MARC program accepts input of yield strength information for materials and independent sizes in the calculation of mast strengths, but this data along with the size data will tell you **approximately** what a mast will take, provided you ***know the alloy and the treatment***

If in doubt, go and buy something of known properties.

STIFFNESS AND ELASTICITY

Greetings from Virginia's Middle Peninsula,

At the risk of boring some, I will make an attempt to describe and quantify 'stretching' for those who are interested. Forgive me if the majority have no interest in this level of detail or consider the topic already beaten to death. Reviewing it sure helps me, anyway.

The phenomenon that is being described, "stretch", is elastic deformation (also deflection), a temporary change of shape that makes a material act like a spring. Materials can stretch elastically (temporary), plastically (permanent), or a combination of both, in any direction.

Just about any part will act like a spring under certain conditions. When a load is applied to a part, it moves a little (deformation). Strain is actually defined as the amount of movement per unit length of the part. If its yield stress was not exceeded, it moves back to its original shape, and that is called elastic deformation (deflection). In this manner, a part (such as a boom, mast, or guy wire) acts like a spring. If it deflects too far and its yield stress was exceeded, however, it may move back toward its original shape, but it will retain some amount of permanent change of shape (elastic deformation + plastic deformation) and the material suffers damage in the form of a permanent bend.

We want to avoid the permanent, plastic deformation! We design parts to be strong enough so that they don't break (yield stress is not exceeded). However, and this is the point: Just because a part won't break does **not** mean that it will not bend elastically and be quite springy! And sometimes more than you intended! Parts have to be designed to control their deflection (related to springiness) as well as their ultimate strength. Who else has tried to straighten some wire from a spool or your whip antenna? (who else has had to use their 2m whip to unlock their car door? <grin>) You have to bend it way back in the opposite direction (elastic), and then carefully a little more (exceeding the part's yield stress) to get the right amount of permanent bend (plastic) so that when you let go it has the shape you want.

The relationship between the size of the load and the amount of deflection (elastic movement) is controlled by the size and shape of the part and the "Modulus of Elasticity" (modulus for short) of the material that the part is made from. Just as the yield stresses can vary for different materials, the modulus is also dependent on the type of material. The higher the modulus, the **less** a part will change shape elastically. The modulus of steels is well known, and varies very little for different steels. I don't have data for aramid fiber. Perhaps Kurt can find this or someone will contact Phillystran's manufacturer for this data.

Fiberglass is a composite material, and has a wildly different modulus depending on the direction in which the load is applied compared to how the glass strands are oriented. Quad spreaders are quite elastic in bending, but much stiffer in tension. I have no data for these materials. Now we're really getting complicated!

We tend to think of wire cables as fixed in length, but they will deform with a load, and we hope they will always be elastic deformations! A straight, solid rod is easy to analyze for strain. As you can imagine, a lot of force is required to make it change length (high spring constant). Plain, straight rod makes a crummy extension spring, but a spring nonetheless! However, if you coil it, the stress is applied in a different way, and there's much, much more length of wire per unit of length. When you pull on a coil spring, you are actually causing the wire to twist in torsion rather than just extend in length. You can get a lot more elastic movement from this shape without exceeding the yield stress (lower spring constant).

Think about the shape of a piece of EHS guy wire. Its strands are twisted into a gentle spiral. Nothing like a coil extension spring, but some small amount of torsional loading will occur, slightly increasing the overall deflection/change in length. Also, there is less cross-sectional area of steel as compared to a solid rod of the same diameter, also increasing the deformation.

Now, for those of you who haven't hit delete yet, and without dragging you through too much more mumbo-jumbo, here are a few numbers to give you a feel for the amount of movement we're talking about:

EXAMPLE: 100 feet of **solid** steel cable, with a 400 pound tension:

DIAMETER,	**TENSILE STRESS,**	**TOTAL CHANGE IN LENGTH**
1/8,	32,600 psi,	1.3 inches
3/16,	14,600 psi,	0.58 inches
1/4,	8,148 psi,	0.33 inches

You see how using a part that is way oversized for stress alone helps control deflection. {deformation/springiness}. I don't have data in my handbooks for the modulus of wire rope in tension, but the above numbers should be a good starting point. I would venture a guess as 10% more for EHS.

This means that when you pre-load your 3/16 guys, for example, they will stretch elastically somewhere around ¾ inch, I'd say, just due to the change in length. Something else happens, too. Guy wires have droop, or sag, which, due to gravity, requires more length of cable between two points because it's not in a perfectly straight line. This introduces yet another potential for elastic change in length. Let's now guess about 1 inch of total change in length for our 3/16 cable. Once the sag is pulled out of your guy, not too many turns of your turnbuckle are needed to raise the tension!

Reducing sag and the spring effect it introduces is another reason for proper pre-loading of guys. Bigger guys are heavier, will sag more, and will require more pre-load. It seems to me now, after thinking about all that I have learned about towers here on the reflector, that the 10% of breaking strength rule of thumb helps out here.

OK, long again as usual... for those of you who are still reading... What happens to the tension in guys and to the movement of the tower when the wind blows on it?

As the wind forces build, the tower moves a little. This movement stretches the upwind guy(s) elastically, adding to the pre-load tension on the upwind guys and resisting the movement. However, the downwind guy(s) will **release** their pre-load and lose tension, also resisting the movement. In this system, the guy forces react synergistically to hold the tower closer to, but not exactly in its original position. The more the guys act like springs the more the tower will move in the wind. The more the tower moves, the more fatal bending moment will be applied to the tower section. Therefore (I must be getting toward the end), larger guys made from materials with a greater modulus will control your tower better and keep the bending forces lower.

Thank you for the bandwidth. This post turned out longer than I wanted, but I hope it helps someone understand some of the engineering and materials a little better. And if so, then they will build their towers more safely.

Hi Mark, good explanation! I found some info on the aramid cable. A rigging supplier in Portsmouth, RI provided the data. They specialize in marine rigging For the sake of others who haven't been exposed to modulus of elasticity values, here is a list:

Note: Msi stands for millions of Psi:

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Fiberglass 3.5- 4.0 Msi, (epoxy/e-glass Mil Spec G-10 material)
Aluminum 10 Msi 9(common 6061 & 6063 alloys)
Aramid fiber 18 Msi (Kevlar 49 used for most aramid guying cable -
Phillystran)
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Aramid fiber 25 Msi (Kevlar 149. Only listings for 8600Lb - 32500 Lb. cable)
Steel 29 Msi (commonly used steels mild, chrome-moly, and stainless)
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I think the bulk of aramid cable sold to amateurs is Kevlar 49, the 149 is more expensive, but it can be had.

THRUST BEARINGS

Use two separate thrust bearings, one on the top plate, and one below the top plate, only when you have a long mast that you need to keep steady. This way a rotor can be made removable without making the mast unsteady or unsupported. Leave the lower bearing loose while the rotor is in place. This is important because it is extremely difficult to line up both bearings AND the rotator without having the mast bind up somewhere. Rotors are designed to hold the vertical weight of a mast, and that weight helps the races in the rotor wear evenly. Raise the mast and tighten the lower bearing only when you need to remove the rotor for servicing. However, if you have a long, very heavy mast, you could tighten both bearings to support the entire mast and use a short connecting section with a flexible coupling between the rotor and bottom of the mast. All rotors will eventually need service and this scheme makes maintenance easy.

The Rohn TB-3 has aluminum races. It does not have to be packed with grease to extend its life.

The most secure way to support a heavy mast with antennas is to place a muffler clamp around the mast just above the bearing and use the bolts of the bearing mostly as guides to center and snug the mast. Over tightening of these bolts can flare their tips, making them impossible to remove from the bearing.

PROTECTING THRUST BEARINGS FROM SNOW AND ICE

Are you concerned about accumulation of ice on your thrust bearing or pointy top? This is not a problem with all types of installations, but some almost encourage water and ice to build up. One way to add protection is to mount a rubber sewer fitting on the mast with a hose clamp. The fitting in question adapts a small size pipe (your mast in this case) to a much larger size pipe (the area you are trying to protect in umbrella fashion, in this case). Water runs away from the thrust bearing or pointy top with this arrangement. Works slick. Looks neater if you think about it before you install the mast, but it can even be installed after everything is in the air.... just cut the adapter with a pocket knife and seal it back up with RTV once it's fitted over the mast. One manufacturer of these rubber fittings is "Furnco", and some people refer to these fittings as "Furnco's."

ANCHORS

SOIL MECHANICS PRIMER

The 400 psf/ft of depth figure (pounds per square foot of anchor area per foot of depth buried below the surface), mentioned in the Rohn drawings for "normal soil," is for lateral bearing of guy anchors. The value does not contain the required factor of safety of 2. If you work in allowable stresses you end up with 200 psf/ft of depth with a maximum of 2000 psf/ft. Now you need to know the depth and thickness of your anchor. For towers having anchors less that 10 feet deep, start by finding the depth to the center of the anchor block and call it D. Next, multiply D by 200 psf/ft and you will get the allowable lateral bearing pressure for the foundation, called Q. The lateral side bearing area of your anchor, multiplied by Q, must be greater than the horizontal load for the guy anchor to prevent anchor pullout.

Now for your question of "What is normal soil?" It is a cohesive soil with no water (water table below foundation depth). What is cohesive? Soils are classified by their grain size. In layman's terms—there are boulders, gravels, sands, silts, and clays (large to small). Solid rock has its own system with RQD's and other properties (another subject). Soils come in various mixtures and have two major properties—angle of internal friction (ϕ) and cohesion C. To simplify - pure sands have ϕ and pure clays have C. This is definitely an oversimplification! Soils are hardly ever just one type, so most soils are classified according to charts rating their grain size. This test can be done in the laboratory with a grain size analysis (a series of various size screens) or it can be done by hand and "feeling" the soil.

A sand will feel gritty and a clay will feel smooth. A silt is in between and can fall either way. Silts are the most difficult to classify. There are some beach sands that are classified as silts and have phi angles and some silts are hard as clays. Hard silts will lose strength when wetted and clays don't. Now what is Normal Soil? Normal soil is a cohesive soil - normally a clay but could be a silt. To make a comparison - take Q from above and if it greater than C (cohesion) it meets or exceed the normal soil parameters. C can be measured by various means. The laboratory test - unconfied/2, The standard penetration test (N /8), The pocket penetrometer test /3. There is even a system of estimating C using your thumb nail. The answer to which test to use depends on your available equipment and experience.

ANCHOR TYPES

There are many types of earth anchors and their strength depends on the type of soil they are installed in. You must determine the type of soil you have to determine the pullout rating of an anchor. The anchors are critical. They are truly the only thing that keeps a tower in the air. When you lose a guy, you lose your tower.

The concrete type anchors specified by Rohn in their catalog have greater holding power than the screw type anchors, but they require more effort and cost to construct.

SCREW ANCHORS AND STRENGTHS

Some screw-type earth anchor information available from one of the largest manufacturers, AB Chance Co. @ http://www.hubbell.com/abchance. The Virginia distributor is JA Walder, P.O. Box 1272, Ashland, VA 23005. Their website: http://www.walder.com, email is email@walder.com , and their telephone is 1-800-335-3605.

The pullout strength of anchors is highly dependent on the properties of the soil. Here are some pullout strengths for AB Chance screw-anchor models for 'NORMAL SOIL'. I don't know how to adjust the ratings exactly for other types.....(* indicates galvanized). Soils with clay will provide more pullout strength. Softer soils that have more sand and loam, or that become saturated with water during season rainfall will have much less holding power.

MODEL #	SCREW DIA	SHAFT LENGTH	PULLOUT	PRICE
315SA	3 IN	15 IN	200 LB	$5.25
330SA	3 IN	30 IN	1400 LB	$6.00
430SA	4 IN	30 IN	2500 LB	$7.50
404	4 IN	40 IN	3000 LB	$12.90
604	6 IN	48 IN	4000 LB	$15.24
*4345	4 IN	54 IN	3000 LB	$26.76
*6346	6 IN	66 IN	4500 LB	$34.08
*816	8 IN	66 IN	10000 LB	$52.86

Clearly, there is a relationship between the screw diameter, depth, and the pullout strength. For a 100' or taller tower, screw anchors should be down about 6 feet, and have a minimum 6" diameter screw. You can get 6 ft. anchors from a cable tv supply company. An 8 inch model has nearly enough reserve strength for the full breaking strength of 3 3/16” guys (12000 lb).

It may also be possible to buy ground anchors from the local electrical power company.

INSTALLATION OF SCREW ANCHORS

My first set I screwed into the ground (clay!)... enough of that nonsense...since then I use a post hole digger (power where possible, by hand elsewhere)... I drop a half bag of Quikcrete down the hole, then screw the auger down the hole until it bottoms, and backfill... pull tests with my backhoe have convinced me that the guy wires (4000#) will part long before the anchor fails...

Water softening the ground will help if you insist upon doing them the hard way. Don’t waste too much water, the ground can only soak up so much. A 2-3 day rain tends to soften up the ground considerably. After this you may have to try the anchor at different angles until it grabs, then slowly start tilting the anchor back toward the tower at the average angle of the guy cables. I would wait a week after installing to allow the ground to dry before putting any load on the anchor in that case. It may be easier to dig part way down with post hole diggers to help set the screw. Then back fill the hole, tamping firmly every 6 inches. Another trick to help start these is to have someone pound the end with a sledgehammer while two others turn it using a 5 foot section of 1” pipe for a torque bar.

GUY CABLES

GUY CABLES ACT LIKE SPRINGS

Refer also to the above section on springiness of materials. Guy cables that are not perfectly vertical act like extension springs in two ways:

Mode 1) They change length relatively easily without significant elastic stretching as the droop in them is pulled tight, resulting in a very low spring rate until all the slack is pulled out, as you approach the proverbial “straight line between two points.”

Mode 2) Once they are tight, they can still change length mostly by stretching elastically, although only with much larger changes in tension (much larger spring rate)

HOW GUY CABLES STABILIZE YOUR TOWER

So....before a guy wire can really do its thing, which is to keep the tower legs from moving, (ideally), it must pull tight for upwind guys or already be tight for downwind guys. Upwind guys will increase their tension, and downwind guys will release their tension to balance the forces (of wind, let's say) that are trying to move the tower. But because of the elasticity effect, the tower **must move** first to reach a new equilibrium. It flexes.

ORIGIN OF THE 10% PRELOAD RULE

How do you decide when you have pulled all the slack out? Thanks to gravity, it is very difficult to get the guy wire to be a perfectly straight line unless it is vertical. There will always be a "catenary" curve in it that includes excess slack, even when the cable is pulled well beyond 10% of its breaking strength. Well, at some point, you have to pull it so tight that the tension starts to make the guy wire stretch elastically (going from mode 1 to mode 2 above.) And the cable still isn't perfectly straight. I believe that the 10% of breaking strength rule has been worked out to where, for the weight of a typical cable, practically all the slack has been pulled out, putting the cable into mode 2 as described above. If you preload your wire with much more tension, you are simply reducing its ability to absorb additional load from wind before you reach its breaking strength. However, (don't we always run into these), if you reduce your guy anchor spacing from the base below the 80% of tower height, then an increase of guy preload to 15% of breaking strength (600 lb for 3/16 EHS) helps compensate and control tower flex without cutting too far into your reserve cable strength.

EFFECT OF GUY SIZE

Another factor: the larger the diameter of the guy, for the same material, the higher will be its spring rate, and the better it can resist a change in length (and movement of your tower) for the same loading force. Since it is heavier, it requires more preload tension to pull out the slack. Thus, the 10% rule keeps up with things. Using a thicker guy gives you more control over the flexing of your tower since it has a much higher spring rate, and much larger forces are required to make it change length. If you play a stringed instrument, you can see this effect when you change, say, from extra-light gauge strings to medium gauge. It's a lot tougher on your fingers to fret them!

TYPES

3/16" type EHS galvanized wire works well. Preforms, or "dead ends" are the most reliable and easiest way to terminate the guys. Old type cable clamps are cheaper but tend to loosen with age as the joint forms itself to the cable after tightening. Use thimbles at ALL terminations. Although the tower leg gives you a nice convenient radius for the preforms, this technique does nothing for the wind-induced torque that will try to twist your tower down. This is the function of the guy assemblies; to add torque resistance. There is a specified size of thimble for each part of the guy wire system; i.e. a 3/16" preform grip takes a 7/16 to 3/8 inch thimble. BTW, the 'seat diameter' (which is the distance/radius required) for a 3/16" preform is one inch minimum. Since 25G is 1.25 inch OD, it does give an acceptable seat diameter for installing the preform grip directly on the leg. A ¼" EHS guy cable takes a ½" thimble to properly match the bend radius. Have you ever seen a ¼" thimble floating inside the loop of a ¼" guy grip? The mismatch makes the thimble essentially useless.

Moving along, you'll need to use thimbles when using the guy assemblies but they are smaller diameter than the legs and you shouldn't have as much trouble getting the thimbles over them. There are different kinds of thimbles. Many are teardrop-shaped; these are the ones that you'll have to open up when installing them. Check with your local suppliers; there are also thimbles that are U-shaped with enough clearance in the mouth that you should have a minimum of fuss installing them. Yes, the whole process is tedious but just think how well you'll sleep nights knowing you did everything correctly. You can easily bend the thimbles open using two adjustable wrenches. Place one on each free end of the thimble and bend them away from each other, perpendicular to the plane of the thimble's curve. What you end up with is sort of a spiral, creating a large opening in the thimble end.

3/8" EHS guy cable (7 strands, 0.138" dia each) is rated at 15,400# breaking strength, 5/16" EHS guy cable (7 x 0.104") is rated at 11,200#. ¼" EHS (7 x 0.080) is rated at 6600#. 3/16 EHS (7 x 0.063") is rated at 3990# strength. This material is called galvanized guy strand, and should be made to ASTM spec # A475-78, grade EHS. Back calculating from these numbers, the steel in this case, has an ultimate tensile strength of about 185,000 psi, except for the 3/8", which works out to about 145,000 psi. The yield strengths would be about ¾ of these values.

Phillystran is a non-conducting guy wire material made out of aramid fiber and is like Kevlar - strong and lightweight. It comes in different diameters and strengths. It appears Texas Towers may be the only Phillystran supplier in the ham market.

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HPTG1200I - 1200 pound strength (545 kg), .19 inch diameter (4.8 mm)
HPTG2100I - 2100 pound (953 kg),          .24 inch diameter (6.1 mm)
HPTG4000I - 4000 pound (1816 kg),         .30 inch diameter (7.6 mm)
HPTG6700I - 6700 pound (3,042 kg),        .37 inch diameter (9.4 mm)
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Phillystran consists of a Kevlar (aramid fiber) fiber core and a PVC jacket. The purposes of the jacket are: 1) to protect the cable from abrasion during installation, 2) to prevent moisture from wicking into the core and 3) most importantly, to protect the core from UV damage. Phillystran has only been manufactured since 1974 so thus far the longest service life of the product has been 23 years. No one knows how long it'll last past that because it hasn't been around long enough. 40-50 years? Maybe. The service life may also be related to the region and environment; the more UV, heat, wind, etc. may have an impact on how long it retains its characteristics. Some of the oldest Phillystran (with the old jacket material) is still being used in southern Florida. In places the jacket has disappeared and the core is out in the Florida sun. After 23 years in this worst case scenario, it still retains 75% of its rated tensile strength.

Bottom line? It'll last a long time and is a worthwhile investment particularly if you're planning on having a populated tower/antenna system and want to minimize any potential interaction problems. You need to use factory preformed guy grips for the bigger sizes but for boom trusses using the smallest size, cable clamps are okay. It is a commercial product and its PVC jacket gives abrasion and UV resistance so that its service life is probably 20 years or longer. Phillystran can be terminated with a special preformed grip made by Preformed Products.

Pultruded fiberglass rod has been proposed by some for use as guy material. The elastic modulus is 4.83 times less than steel, however, meaning that it is much more elastic. In order to have the same spring rate as steel guys, and therefore the same ability to stabilize your tower in the wind, the cross-sectional area of the fiberglass must be 4.83 times that of the steel. This works out pretty close to double the EHS diameter when you account for the stranding. So, the equivalent solid fiberglass rod diameter would be twice the EHS size you want to replace. With this rule of thumb, 3/8" solid, pultruded fiberglass rod makes a good substitute for 3/16" EHS guy cable.

EHS guy wire has a different twist than wire rope, and requires preformed grips made for that specific type of wire.

Using Rohn's guy assemblies (not torque arms) allows a secure attachment for the guys (as opposed, for example, having them looped around the legs where you have the forces being held by the diagonal welds). Imagine a force big enough to pull the leg out, bending it and possibly breaking a weld or two. This would not happen with a guy assembly. The guy assemblies allow the forces to be spread across the faces of the tower instead of just a leg. (See 'big force' above.) The guy assembly allows Rohn towers to comply with the TIA-222-E structural tower standards. Lack of guy assembly makes them non-compliant and probably has an impact on their rated wind load figures as well. Rohn came out with the current product to upgrade to one of the recent TIA-222 revisions. When they did their calculations, they found the "old" torque arms really didn't contribute anything to the torsional resistance of the tower. What they did do was keep the twist down as it was being climbed. They discontinued the old product but hams put up such a fuss that they re-introduced them. If you use the current guy attachments and tension the guy wires properly, there's not much need to have the old torque arms installed.

Although it entails two more guy ends and hence ups the cost per guy it seems like the EHS pigtail at both ends of a Phillystran guy is a nice inexpensive comfort margin. I am thinking in terms of tool buckets, climbing belts and the like bouncing off Philly as a potential source of problem, if you bump into EHS who cares!

As far as down below and sizes that fit, etc.....what we use at the equalizer plate IS the turnbuckle. The lower end eye of the turnbuckle is sandwiched between the equalizer plates.

This is nice in that it "freezes" the lower end of the turnbuckle from rotation. When you are done tensioning everything you just need to "freeze" the top half of the turnbuckle and the center of the turnbuckle which can be accomplished with a single loop of cable through those two. Watch the combination of bolt size that the equalizer plate uses with eye size on the turnbuckle, make sure the eye is big enough to handle that diameter bolt. This will present the top end of the turnbuckle as what you need to actually connect the guy to. A simple thimble through the eye of the turnbuckle (I prefer the eye type over the jaw type as there is fewer things to go wrong [K.I.S.S.]) and a preform and you are good to go!

Cutting EHS cable can be difficult without bolt cutters. One method is to use a hand grinder. Tape the place where you want to make the cut and it'll zing through it in less than 10 seconds. The tape keeps the strands from unraveling after its cut. If you don't have a hand grinder, you can use a steel-cutting aggregate blade in your skill saw. They only run four or five bucks. BE REAL CAREFUL - use eye protection when doing this because you'll be throwing sparks all over the place. This method also works for cutting concrete rebar. Another method is to use a steel "cold chisel." Place the guy wire across any metal surface (metal that is softer than the chisel!), put the chisel on the wire and strike with a 2 lb. or bigger hammer. Wear safety glasses!

USING PREFORMED GUY GRIPS AND THIMBLES

Please be aware that Rohn recommends only the "Big Grip" series of guy grips for tower installation. The regular grips sold by most supply houses are for utilty pole guying applications and much shorter then the Big Grips. There are even some brands of utility type grips with only three strands of steel instead of the four in a Big Grip. Grips are also called 'preforms', since the are literally pre-formed for a thimble and spiraled ends for wrapping.

Preforms are color-coded for EHS wire sizes. The coding is:

1/8″	Blue
3/16″	Red
1/4″	Yellow
9/32″	Blue
5/16″	Black
3/8″	Orange

The colored marks on the grip have two functions:

- indicate the size and,
- mark the cross-over spot - which is where you start wrapping the legs around the cable.

There are two crossover paint marks - the first is for normal cable and the second (farthest from the termination loop) is for use with insulators. The end of the cable of interest should extend at least to the crossover marks. If they are longer and extend past the marks, it is of no consequence. Wrap the first leg (either one) at least 2 wraps around the cable. Then wrap the second one insuring that the wrap starts at the crossover mark. Continue wrapping one leg until it is about ¾ done, then wrap the other leg to that point. Finish the short leg first, then the longer leg. The grips are designed to be installed by hand so you may need to bend the cable in order to seat the ends. Do not completely apply the wrap - leave the last inch un-snapped into place until you are sure and all your lengths have been adjusted. Trying to unwrap them (as you probably have found) is a LOT easier is you don't have to use the pliers to get at an end....oh, and one other thing...watch out for the loose flesh of your finger tips and palms as - they can be pinched as the wrap snaps into place creating some massive blood blisters! Attach a black tie wrap or end sleeve to the end of the grip to prevent it from unraveling. Repeat as many times as necessary.

The preformed grips can be removed and reapplied twice if necessary to readjust guy wires. If removal is necessary after a guy grip has been installed for a period longer than three months, it must be replaced. No thimbles are needed when using an insulator. But be sure to use the SECOND crossover paint mark when installing a preformed grip through an insulator. If you use the first mark on insulators, the grip has too acute an angle and puts more strain on it.

When you are ready to set the grip completely, use a flat sided that has a square shank. Installation is much easier if you install the short leg first, followed by the longer leg. The legs are different lengths to ease installation. When you use the screwdriver to wrap that last turn onto the EHS you should have the tip of the screwdriver bearing on the cable, NOT the free end of the grip. You can do it either way, but when the tip bears on the central EHS you cause the grip to follow the guy wire, and voila - success. By putting the screwdrivers tip on the end of the guy grip you will get that sloppy result where you have to push on the grip to get it to seat properly.

Putting Preformed grips on Phillystran isn't as easy as installing them on stiff EHS. I've found the best thing to do is to do only 3-4 inches or two complete wraps at a time on both legs. It keeps the Phillystran from bunching up which necessitates un-doing and re-doing it. The first leg goes on with no problem. The thing that works the best on the second leg is to push/bend the leg that you're winding on slightly towards the loop in the grip. That is, pull the two legs apart as you're winding the second one while you're turning it on and it should work better. If possible, put some tension on it after the first few wraps.

The local tower guru also strongly recommends installing the metal "ice sleeves" on the upper end of any grip that's installed so that water can run down into the end of the wrap. Apparently the freezing of the water can exert enough force to begin a sequential unwrapping (gets worse with each freeze). They only cost a few cents apiece and drove readily on the end. Tape wraps about the end of downward-pointing guy grips may not be the best way to do this. On the upper end of the guys the tape creates a place for water running down to accumulate, and stand, causing the guy wire to rust. Preformed has what they call an end sleeve but is commonly referred to as an ice cap. It is a small tapered sleeve where the little end is on the guy wire and the bigger end goes over the end of the Preform grip. They're easy to apply and their purpose is just what you described - that is, to keep ice from getting under the grip strand ends and lifting (and unwinding) them. There are other products (the Ice Knocker comes to mind) that are bigger cones/devices that go over the guy wire and are supposed to shed any ice coming down the guywire. You can also install cable clamps over the ends of the grips to keep them from unwinding.

The purpose of the thimble is to keep a constant radius on the termination. An insulator already has adequate 'seats' built-in and doesn't need a thimble. You won't find thimbles big enough to fit through the insulators anyway so don't worry about it.

To clarify some confusion on thimble sizes:

- If cable clamps are used to terminate guy wire, the thimble size is 1/16" larger than the wire.
- If preformed grips are used, the thimble size is 1/8" to ¼" larger than the wire. Pick the thimble that best matches the curve in the grip.
- If 4000lb Phillystran is used with Preform Grips, the thimble is 7/16".
- If 6700lb Phillystran is used with Preformed Grips, the thimble is 1/2".
- If Phillystran is used with cable clamps (highly not recommended) use one size smaller than above.

In all cases the heavy duty version of the thimble is used.

TENSIONING

Rohn specifies that guys should be tensioned to 10% of the breaking strength of the guy size that is recommended for a particular tower. One rule of thumb is 8% if the guy is out at 100% of tower height, 10% if at 80% of tower height (standard Rohn drawings) and up to 15% if the anchor point is at 65% of tower height. You lose a lot of wind load in this last type of installation.

For Rohn 25, 3/16 EHS is recommended, having a breaking strength of 4,000 lb. Therefore, 400 lb. of tension is appropriate for Rohn 25 tower. The primary failure mode for Rohn 25 is in compression of the legs, so it is important not to over tension the guys, resulting in greater compression of the tower legs.

¼ inch EHS is has a breaking strength of 6650 lb. and the preload tension should be 665 lb. for towers where Rohn specifies ¼.

For Phillystran, there is some new information from the factory and it looks like it doesn't stretch as much as it 'relaxes'. What they recommend is that the Phillystran be initially tensioned to 15% of its ultimate breaking strength and then over time, it will 'relax' to the 10% desired tension. According to their chart, It goes from 15% down to 12% within about 10 hours and then finally reaching 10% within 30 days (a guess since their graph doesn't extend out that far).

The TIA-222 tower spec allows a tolerance of 1 part in 400 for tower alignment; that's 3 inches per 100 feet so your tower doesn't have to be perfectly plumb. Start with the bottom set of guys and an intermediate tension around 100 pounds, verify the plumb (or pull into plumb) using a long level (4-6 feet) and then adjust to the final tension. If all the guy anchors are at the same level, you only have to measure one guy; they should all be the same. Once you've got your intermediate tension and plumb, it doesn't take much travel in the turnbuckle to get to the final tension - maybe as little as 1 turn. Actually, using this method you don't need much turnbuckle to adjust. Going from 100# to 400# tension might be less than 6 turns of the TB, so there's not much problem with pulling the tower out of plumb. Move up to the next set and repeat until finished.

Use your arithmetic measurement for how long the guy should be and then make the piece of guy wire closest to the ground on that first one 10 feet too long. Since you are splicing the guys by insulating them this first one will give you a good feel for how close your arithmetic guesstimate is. i.e. if you have ten feet too much your math is one hell of a lot better than mine! I assume you are using a bolt cutters for cutting your EHS...they can be had cheap at flea markets...you have seen them they have the big long red handles and menacing black jaws. If you are using an AB Chance or similar anchor into the ground/concrete you have a closed eye that is your attachment point. You need to pass something through that eye which will act as a place for you to attach a come-along. Depending on the installation you use this will vary as you will need to try and avoid the actual guy wire's path as best you can. If you have an equalizer plate you can use an adjacent hole on the plate as an attachment point.

With the come-along and a Chicago grip (or another, second, guy grip applied several feet up the guy wire) moderately tension the guy wire. I say moderately so you don't pull the tower over or throw it out of plumb from the start. Once the guys are moderately taught check the tower for plumb, adjust the guy that needs to be tighter first and, if necessary, later on you can let out the far side guy(s). If you can tighten that first guy and bring the tower into plumb there is a good chance you will have also tightened the other guys in the process. If increased tension does not plumb the tower, then you should consider letting out on the other guys. You will have a loose end pointing at your guy anchor with the come-along doing the work. I recommend you have a turnbuckle there as it will allow you to fine tune your adjustments later on. Start with the turnbuckle ¾ out. With the force on the come-along, and the bottom side of the turnbuckle attached to your anchor you know how long the wild end of the cable needs to be. Cut it so that it corresponds to where it should end at the high side of the turnbuckle. Trim it, and marry it to the turnbuckle's upper end with a preformed guy grip. It should only take a couple of twists of the turnbuckle at this point to transfer the load off the come-along and onto the turnbuckle. It will take a couple of hits/misses for you to find how far up the guy wire to attach your come-along/Chicago grip so that you will not interfere with the turnbuckle, still be able to take up, and - be able to reach that upper point! Don't make it too high.

We have had great luck with using the Loos gauge as a method for equalizing the force on the guy wires. While it may not give an exact number it does give you a repeatable number, strive to have all your guys have equal tension (this assumes the end points are all the same distance from the base of the tower, of course). If you are going into an equalizer plate, remember that as the other upper guys attach to the plate it should want to change its angle with respect to the ground as the later guys attach to it. This creates a situation where the bottom set will be drawn tighter than when initially installed. The best way to handle this is to compensate for it by having several inches of extra take up on the lower turnbuckle when it is originally installed so that they can be backed out as the upper guys tighten, allowing the eq plate to rotate. I encourage you to purchase a Chicago-Grip (the Florida Rednecks call it a Pork Chop...when you see it you will know why) - this device when used with the come-along makes the job of tightening the guy wires no big deal. Having a second person is a big plus on this job as you can really zip from one to the other with one guy in charge of attaching the hardware and the other in charge of tightening, etc.....I recommend a Dad!

After you have done the first level (assuming you took my advice and got that pork chop - don't leave home without it) you will zip through the subsequent guy levels. If you are a member of a club you might want to encourage the club to buy a pork chop for all the members to use. We have used these techniques successfully, repeatedly. Oh yeah, one other thing - the pork chop is a great way to grab the lower end of your tram line when you are putting up your antennas....but, we will wait for you to ask about that in a month or so :-)

Using preforms, you do not cut the turnbuckle end of the guy wire at all. Just let it lay on the ground or coil it up if you like. Only when you are sure your tower has grown tall enough would you cut the excess length with bolt cutters.

Make sure you put a cable, or one of the long ends through all the turnbuckles to prevent them from loosening. Also, loop a cable through all of the thimbles (in a circle) in case one of the turnbuckles breaks. If you are afraid of vandalism, you should put the loop through the centers of the turnbuckles as well, rather than the loose end serving this purpose. The advantage of using the loose end, is that tightening of the turnbuckles requires less time, since no cable clamps need be removed.

To tighten the guys, I use a preform about 6' up each guy wire and a come-along attached to the preform (lever end of come-along). The cable end of the come-along hooks at a convenient place on the anchor or equalizer plate. Make sure the tower is vertical to the first set of guys via 4' level (what I use) or plumb bob (never tried this). Then, as long as the first part of the tower is vertical, you can site up the legs to see which way you need to go with the rest of the guys. There will be interaction between adjustments of sets of guys.

GUY TENSION MEASUREMENT

USING LOOS BRAND TENSION METERS FOR GUYS

The best, easiest and cheapest way to measure guy wire tension is with a LOOS guy wire tension gauge. It can measure 3/16 to 9/32 sizes, which is perfect for hams. The LOOS guy tension gauge works on Phillystran about as well as EHS wire.

Loos & Co., Inc.
Cableware Technology Division
900 Industrial Blvd.
P.O. Box 7515
Naples, FL 33914-7515

1-800-321-LOOS (5667)
1-813-643-LOOS (5667)

One friendly distributor, well known in some tower circles, is:

Champion Radio Products
http://www.championradio.com

LOOS model B calibration chart

SCALE	3/16	7/32	1/4	9/32
10		240		
15		320		
18		380		
20		420	300	
22		480	360	
24		540	410	250
26		620	480	280
28		740	560	340
30		880	660	400
32		1080	780	480
34		1400	960	580
36		1210	680	
38	1600	840	400	
39	1850	940	460	
40	1060	530		
41	1210	600		
42	1460	670		
43	1800	750		
44	850			
45	980			
46	1120			
47	1330			
49	2000			

The Model B also works well with 5/16” guy wires if you file away a small amount of the rivet that blocks 5/16” cable from entering the mouth of the gauge. Currently, no data is available to create a calibration chart for 5/16” EHS.

Here is the calibration chart for the PT-2

SCALE	3/16”	7/32”	1/4”
13	300/6%		315
18	500/11%		385
21	640/14%		438
24	840/18%	500/8%	500
28	1240/26%	740/12%	615
32	1060/17%	780/9%	780/9%
34	1300/21%	900/11%	900/11%
36	1680/27%	1100/13”	1100/13%
38			1300/16%
40			2000/24%

CHECKING GUY TENSION BY COUNTING OSCILLATIONS

Here is an interesting technique that one person has described. He has 100 feet of Rohn 45 up and guyed like Rohn. What he did was install an “in line” tension measuring device (dynamometer) and crank the tension to the prescribed amount. Note that a Loos tension meter could also be used here. He then set the guy wire into oscillation by gently pushing it sideways with his fingers. It takes a dozen or so pushes to get it moving. He carefully observed that it was not oscillating in more than one section meaning that it was oscillating at its fundamental frequency rather than a harmonic. The oscillations are slow, like one per second or so. He counted them for one minute, timed with a stop watch, and recorded the number of oscillations. The frequency will be different for each level of guy since it depends on guy length, wire size, and tension so you have to install the dynamometer at each level to determine the correct frequency for that set. He then removed the dynamometer, reattached the guy to the tower and tensioned it until its oscillation frequency was the same as before (this is much simplified with the Loos-type clip-on tension meter). To check guy tension now, all he has to do is check the oscillation frequency with his stop watch against the numbers recorded originally. No computer. No software. The key, of course, is to own (or borrow) a tension measuring device. BTW, you can check the accuracy of the device you use by hanging known weights from it.

THERMAL EFFECTS ON GUY TENSION

Guy tension can change from natural temperature induced expansion/contraction. Here is the temperature change information relating to ambient temp and guy wire tension at 10% of breaking strength (these are the values for desired tension at different temperatures):

3/16 inch EHS

120 degrees F	300# tension
90	350#
60	400#
30	450#
0	500#

1/4 inch EHS

120 degrees F	500# tension
90	585#
60	665#
30	750#
0	830#

You can see that these are basically linear relationships. These figures include the effect of tower height change. This information is taken from the Rohn Tower Inspection Manual. So you can see that you need to compensate for temperature. If the initial tension was done in the winter, then they will 'loosen' up due to higher temperature expansion. But if you use the above factors, the tension should be within spec for the whole year no matter when the reading was taken.

When Phillystran introduced the new jacket material a couple of years ago, they didn't have any Phillystran grips so they initially allowed using cable clamps. Unfortunately there was deformation of the strands and cold flow problems caused by the cable clamps. Now Phillystran Big Grips are available and they are the ONLY termination devices approved by the factory. Always do what the manufacturer specifies.

MEASURING TOWER PLUMB

Now that your guys are in place and your ready to fine-tune the guy tension, you need to have a way of measuring how plumb your tower is. One of the least sophisticated methods, yet highly effective and often recommended is to use a plumb bob. Suspend one from the center of the tower at the first guy point and adjust the guys to plumb this lower section of tower. If your first tower section is embedded in concrete, use a long spirit level to make the first section as plumb as possible before the concrete cures.

The wind will tend to push the plumb bob around, depending on how heavy the weight is. Place a bucket of water at the base of the tower (or whatever will fit through the rungs) to dampen the swinging of the bob. Once you get the first section (or lowest guyed sections(s)) plumb, you can simply sight up the tower legs. Even slight bowing is readily apparent with this method. A low-tech but very effective technique to check the plumb of the higher sections is an extension of this same idea, using a portable plumb bob. This can be improvised with some string and any heavy object. Hang it from a tripod or ladder. Sit on the ground with the bob line between you and the tower. Line up the edge of the string and the tower with your eye to check plumb. Perform this from two positions, 90 degrees apart from each other. For taller towers (over 120 feet), use a transit from two positions, 90 degrees apart to sight the tower legs for plumb.

TEMPORARY GUYING

While assembling your tower, you will inevitably encounter stages of construction where the tower extends above the last guy point. The first few sections above the base won't have any guys at all, for that matter. Temporary guys do not have to withstand the full loads that permanent guys will take, such as wind. Assuming that you only assemble your tower when the weather is fair, and that you will finish with permanent guys before your construction session for each day is over, temporary guys can be much lighter. The important thing is to choose a material that has very low stretch, such as lightweight steel cable, or static-type rappelling rope accessory cord, having kernmantle construction. Twisted polyester also has very low stretch, compared to nylon. The typical nylon you get from the hardware store will stretch. In any case, even ropes that stretch somewhat are much better than having no temporary guys.

Most people seem to feel comfortable climbing two sections above the last guy point. The more adventurous go three before adding temporary or permanent guys. Some professionals feel comfortable climbing 4 sections before attaching the next set of guys, but the sway becomes so great that it would be extremely unnerving and disorienting for all but the most seasoned climber. I think a good rule of thumb would be to use temporary guys any time you are 20 feet (2 sections) or more above the last permanent guy set.

For towers that start with an embedded base section, things are simpler. Once the concrete has cured, you can climb the first section and add the next, then attach temporary guys until you get to the next section and the first set of permanent guys.

For pier-pin based towers, things are a little different. DO NOT CLIMB a tower having a pier-pin base without having temporary guys in place! The single bolt on the base plate is not designed to resist bending at all! The way this is usually accomplished is by pre-assembling the first 2 or 3 sections of tower, complete with permanent or temporary guys, then standing it up, setting it in place on the base, and attaching the guys to their anchors. Only then can you start climbing.

TEMPORARY GUYS FROM EHS

With this method, you use the precut top set of permanent guys or some of the same material from which your permanent guys are made. In either case, you need spare grips that are matched to the size EHS cable that you will use. If you pre-cut your permanent guys, use the top set of guys as temporary guys. To accomplish this, partially attach the grips (3-4 turns) on the tower ends of your top guys. Use carabiners or quick links (single chain loops with a threaded fitting that opens on one side of the link) to attach the grip to a tower brace. Use a partially attached grip through your anchors to hold the other end of the temporary guy. As long as you do not fully wrap the grips, you will be able to remove them. If you are using guy bracket assemblies (stronger) to attach your guys to the tower, you can go ahead and fully seat the upper grip ahead of time, since it will be retained by a bolt on the assembly and will not have to pass around a tower leg.

TEMPORARY GUYS USING ROPES

This method is easier and faster, since ropes are easier to work with than the steel. The best rope to use would be kernmantle construction, low stretch static rope, such as Blue Water II. 6 or 7mm climber's accessory cord, such as PMI 6mm would also be acceptable. Obtain three lengths, each long enough to reach from the anchors up to the highest guy point required. Stuff (not coil) each rope into its own nylon ditty bag, and place the bags adjacent to each tower leg. As an alternate, pile (again, do not coil) each rope, hand-over-hand, on the ground next to each leg. Tie the upper, free end of each rope to the corresponding anchor using a figure-eight knot. Note that since the anchor eye is closed you will have to tie these in a special way. Tie a single figure-eight first, with an extra long loose end. Pass the loose end through the anchor, and 'chase' it back through the knot to complete it (see the knots references for more information on this must-know technique).

Pick up each rope at the base and take them up with you as you climb. It helps to clip a carabiner over them so that the rope can pay out straight up from the ground, through the 'biner, and out to the anchors as you go up. You can also tie a tag line to the 'biner, climb up, then pull the anchor ropes up.

Once you arrive at the temporary guy position, separate and tie each rope to the tower. To accomplish this, pull up some extra slack in each rope and form a closed loop in the rope (this is called a bight). Keep the bight closed and use it as if it were a free end. Pass the bight around a tower leg, and tie a taught line hitch around the portion connected to the anchor. Now, Boy Scouts, adjust your taught line hitch to apply tension to your temporary guys. Alternately, if you have three ascenders (a one-way sliding climbing device), you can simply attach the ascenders to the tower with carabiners and pull the ropes tight through the ascenders to hold tension. Once you have installed the next set of permanent guys, untie the ropes and repeat as necessary. No one on the ground has to get involved, and you control the tensioning process so you will not get jerked around accidentally.

LIGHTNING ABATEMENT

LIGHTNING PROTECTION THEORY

This is a two-step process. First, you can prevent or reduce the static buildup which allows the strike. Second, (preferably starting from a point above your antennas) you provide a very low impedance path to a good ground to handle the energy from strikes that you can?t prevent. There are several companies that sell the equipment and monitors/alarms. Basically they sell or install a good ground system, and a static dissipation system. A static dissipator is typically a spike ball, really a bundle of sharp spikes/wires, bent so the tips are at different angles, looks like a ball at a distance. When the static charge between cloud and ground starts to build the corona from the spikes prevents the charge for rising to a level which would support a strike. The charged cloud passes over the protected area without a strike.

A cone of protection is provided by providing a high strike point to create a desired spot for a strike, but preventing a strike is still more desirable. This can be accomplished by letting your mast extend above any antennas. There will be some noise from the static discharge corona. There is a company in Boulder, CO (I've don't remember the name) that manufacturers the prevention equipment. That have sufficient proof that it works.

Coiling your feedlines and control lines will add extra impedance to them that will make lightning energy look elsewhere for a better path to ground, such as your shield ground, MOV's and your coax lightning arrestors at the base of your tower.

HOMEBREW STATIC DISSIPATORS

One method is to use a piece of solid 1-¼" aluminum bar stock, drill it full of holes and cut up a bunch of old CB whips into about 200 6" pieces. Spin one end on the fine grindstone to a sharp point, stick all of the blunt ends into the holes (Snug fit) and, with a dull punch(like a nail set) lock each one into its hole by a sharp rap on the punch at the top edge of each hole. Then bolt the "Porky" (it kind of looks like one!~) to the top of the tower at the base of a mast or on an outrigger. Another method, if you're using steel EHS guys, is to simply leaving the guy wire ends untrimmed at the top. Unfurl them and sharpen the points, and aim them up and away from the tower.

Another very simple one can be home-brewed with a bundle of sharp wires sharp on one end and stuffed, blunt end first, into a heavy electrical terminal of good size(#4 or even as large as 1/0. A properly tightened set screw and shaping the the wire into a ball like a "Porky," and it's ready to attach to mast or tower top.

Frayed stainless steel wire rope (SA) would work, of course, if one separated the wires completely and secured the ball with a low resistance means on the way to a good ground. Any number of sharp points, from 1 up to 1000 is good.

Here's another one. Go to Lowes and get some of that galvanized fence wire, cut it into about 2 ft. lengths. Make sure that you cut the wire at an angle, so that its pointed on the end. Then take a piece of 1 inch x 4 or 5 ft. electric conduit, cut some vertical slices into one end and spread them apart slightly. Then jam as many peices of the fence wire in it as you can. You only need to put the fence wire in a couple of inches. Clamp the wire in the conduit with a stainless steel hose clamp. Then take your handy-dandy torch and some good flux and solder the whole thing.

Now if you spread the wires out they will form a ball. It ends up looking kind of strange. Make sure you bend the conduit at the bottom (where you would attach it to the tower). The bend should be about 35 degrees.. so that when attached it will stick out from the tower. Connect the “spline balls” to the conductor mentioned above and thats it.

For static discharge problems across insulators, such as when an electrical storm is in the area, drain resistors may help. Put some 100 Kilo ohm, 2 watts resistors across the points where it’s arcing. The resistors will keep the arcing from creating carbon tracks across the insulators, and will help keep your (localized static generated) noise levels lower.

GROUNDING FOR LIGHTNING PROTECTION

Nothing in a ground path should be attached by soldering alone - everything should be clamped only. The reason is that a soldered connection might heat to the point of melting and separating the connection if it is required to carry a large amount of current. This then causes that joint to have a relatively high impedance, causing the current to seek a different path - one you might want it to take. Joints should be clamped first, then soldered to preserve the best electrical properties.

I would put out a spread of 2 or more ground rods, spaced 16 feet apart, and running heavy, bare wire from rod to rod. Even 1 extra rod will help tremendously... if you don’t have enough of a yard for a spread of rods, then run them around the perimeter of the house. Studies show that a ground rod will drain excess charge (in average ground) for a radius of (roughly) 8 foot. Putting the rods too much closer than 16 foot apart overlaps their influence area. Conversely, much more than 16 foot will allow a significant charge to build between rods. In dry, sandy soil you might close them in about 25%, and in wet, highly organic soil, spread them out 25%.

In general a large diameter conductor is better than a smaller diameter. a flat ribbon, 2” or 3” wide, cut from aluminum roofing flashing (copper would be great, but expensive) will have lower inductance and be even better. a parallel run of smaller conductors will also lower the inductance per foot, compared to a single larger conductor. #6 gauge solid copper should be considered a minimum size.

The ground wire should run over to and up the leg so that it makes a very gentle angle; no right angles are allowed as they present a high impedance point to the charge that’s trying to get to ground.

The whole point of a ground system is to have all of the conductors at the same voltage potential so that the voltages all rise and fall at the same rate. If they have different potentials, then you’ll get arcing and damage. BTW, if your guywires are not insulated and not grounded, a lightning strike will probably weld the turnbuckle threads together.

The consensus seems to be to connect ground straps to each of the three tower legs and run them down like radials to at **least** three ground rods adjacent to the tower base. The radials can be up to 50 feet long for maximum effect, with appropriately spaced ground rods. Lightning energy will not travel much beyond this distance. The radials and straps should be buried below your local frost line, and at least 6 inches.

Again, the idea is to collect and/or dissipate charge from/to the earth. a single ground rod alone cannot do this effectively. One rod saturates an area around it radially out to a distance about equal to its depth. Therefore, adjacent, 8 foot rods should be spaced 16 feet apart. Three rods spaced to form an equilateral triangle, 16 feet on a side, around your base would be a minimum start. The rods should also be connected to each other in a ring with straps that would trace the circumference of this triangle. This makes an effective connection to a **much** larger volume of earth. For best performance, add 3 more rods for a total of 6 rods. Number 8 gauge is a little small. One approach is to use ¾ common copper water pipe for ground rods and straps (HQ to the rescue!) to make most efficient use of the copper, accounting for skin effect. Connect the ends by flattening them, drilling holes, and joining with a copper split bolt, to keep all similar metals. a joint compound with copper particles would be ideal between mating surfaces (Penetrox E). This way there are no dissimilar metals, promoting greatest longetivity for the joints. I'm not sure that just soldering them together is good enough for underground service.

Here is some ASCII ART (view or print this with a monospaced font) to illustrate:

```
             o
             |
             |
             |
             o
            /|\
           / | \
          /  T  \
         /  / \  \
        / /     \ \
       |/         \|
s-------o-----------o
      /             \
     /               \
    /                 \
•   o
```

This is not quite to scale, of course. "T" is your tower base. "o" is a ground rod. The radials, tied to the tower legs, spread outward, with 8 foot deep ground rods connected every 16 feet. The first set of rods is connected together to form a triangle. There should also be a ground strap from this system to the ground system for your home (service entrance, "s").

a separate wire from the lightning rod on top down to the ground system is probably not required if there is good contact all the way through the tower legs. For a crankup/foldover, you may need a jumper across pivot joints or rollers, as these might not be reliable conductive paths like bolted leg joints. Some companies insist on a separate copper conductor running up the tower, which is the best way to absolutely assure a good path, but I don’t think this will be necessary in fixed towers.

All grounds are tied together, as you can see from the “art”. Multiple rods are what you are counting on to dissipate the strike current without making it want to ‘search’ elsewhere for a ground path.

EXAMPLE TOWER GROUNDING METHOD FOR LIGHTNING PROTECTION

After perusing the load of messages in the archives about tower grounding methods and materials, I used the following scheme to build a low-impedance grounding system for my planned tower. In true Ham fashion, I improvised with very commonly available materials wherever possible. Let me share this method as one example of ‘how-to’ that I chose.

1) Use 1 ground radial per tower leg, 2 ground rods per radial, 6 rods total.
2) On each radial, the 1st ground rod is spaced 8 feet from base, 2nd rod 24 feet from base (16 foot rod spacing). For better or worse, I did not encircle the base with a ring.
3) Use ¾” x 10’ type L (heavy wall) common copper water pipe (about 80 cents/foot) for both radials and ground rods. This pipe provides lots of smooth copper surface area for low impedance, yet enough total copper cross section for current-carrying capacity.
4) Provide a flexible connection between the radials (rigid) and tower legs using 2, 5/8” diameter by 3’ long sections of flexible copper refrigeration tubing in parallel. These come up out of the ground from the radial end, and arc up, parallel to the tower leg, and are easy to bend, yet provide lots of smooth copper surface area. Since the wall thickness is lower than the ¾” pipe, two in parallel are required for current capacity.
5) Make connections in the ¾” pipe (radials & rods) by flattening the ends, polishing with Scotchbrite abrasive pad (no metal wool!), and joining with #6 size copper split bolts. A ½” through hole is just right for these bolts. Since these bolts don’t have much of a shoulder on them, they must be modified. Modify the split bolts by flattening (in a vise) the 2 little staked ‘wings’ that capture the anvil (the little jaw that slides in the slot) in the nut so that you can take the nut off and leave the anvil. Put the bolt and anvil through your drilled hole from one side so that the ‘T’-shaped anvil head helps provide a shoulder to keep the small bold head from

pulling through, and apply the nut, of course, to the other side. This little exercise earns you a copper bolt to avoid dissimilar metals.

6) Use copper-filled antioxidant liberally on all the copper-to-copper joints. An excellent source is Versachem anti-seize paste #13, available from Advanced Auto parts. It comes in a container with a brush attached to the lid and is a heavy grease LOADED with copper particles. Hey, you can also use this stuff on fasteners in your engine! After bolting the connections, seal the antioxidant in the joint with electrical tape such as Scotch Super 88.
7) Drill weep holes vertically through radial pipes every 4 feet or so before burying. You don't want steam-flashover during a strike to explode your work (wouldn't it be neat to watch, though)! I used shallow V-trenches, 4 inches deep, for the radials.
8) Sink the ground rod pipes by making them into water drills. Flatten one end to form a nozzle with about a 1/8" elongated opening. Solder a garden hose adaptor assembly on the other end. I used 2 90 degree street els, a pipe thread adaptor, a ¼" lever valve, and a garden hose adaptor in my assembly. Using the 30-40 psi water from my well pump, and twisting the pipe like a drill bit, back-and-forth, while pushing down, I was able to sink each 10 foot pipe in less that 5 minutes. Don't sway the pipe side-to-side, or you will make the hole too wide. Use the minimum valve opening to make it work, so you don't wash out too much dirt and compromise the contact between the pipe and ground. Take it all the way below grade in your trench, then raise it up 6" or so (tap it back down in the trench later after connecting to radial). Then, cut off the water, cut off the pipe with a tubing cutter just below the adaptor assembly, and carefully desolder the stub so you can reuse the assembly on the next rod. Flatten the end with 2 hammers for electrical connections per above.
9) Connect the flexible jumpers to the tower legs by first gently hammering the ends flat against the leg to form a large, curved contact patch over 2" long. Apply a piece of stainless steel shim stock over the tower leg, and clamp the tubing ends over the shim with all stainless hose clamps. Use Noalox on all surfaces as an antioxidant. Don't use the copper-filled stuff between the stainless and the galvanized tower leg (bad metal combination). I found a perfect source of stainless steel sheet metal by using the tubular shaped element that comes in the flexible compression pipe couplings used to join sections of abs pipe. These little jewels, also in the plumbing aisle, have a tubular rubber boot, a stainless cuff, (essentialy a rectangle of thin sheet formed into a tube), and 2 hose clamps. Sorry, I don't know what they are called.
10) Extend one radial up to your house and tie it in with the service ground. Bring the pipe above ground to an entrance panel for your cables. Solder the pipe together above ground using tees. Since this section is primarily for dissipating surges and not direct strike current, soldered joints should hold up fine, and are easier to make. Leave the branch of the tee open so the pipe cannot collect water. Stuff the branch opening with a copper potscrubber to keep bugs out.

Ok, it was long, but I hope you enjoyed reading about how I went about the grounding. Thanks to all who have contributed to the reflector and spawned my ideas. I hope this post helps someone else build a good ground system. I feel that this will give me much protection from lightning when a hit occurs, and I will sleep better at night when those 2am boomers roll through. Well worth the $200 or so I spent in copper.

Now, I am shopping for tower sections......

Mark, N1LO, Gloucester, VA

GROUNDING GUY CABLES

What I did was to use regular guy cable clamps to fasten short straight lengths of guy wire to each guy near the anchor. The short pieces (4 in my case because there are four levels of guys) are then clamped together in a clamp designed for grounding a copper ground wire to galvanized water pipe. These clamps are relatively cheap and designed to segregate the copper wire from the galvanized pipe (wire). The bundle of guy wire stubs is put where the water pipe would normally go. If you need to increase the effective diameter of the guy wire bundle, you can insert short segments of extra guy wire in the middle of the bundle as “shims”. I put the pipe clamp about one foot above ground and use a heavy copper ground wire from the small hole in the clamp down to the ground rod.

While there are clamps made specifically for this application (they’re a little expensive), most people use regular cable clamps. Since you’re connecting a round object to another round object, you don’t get a whole lot of contact area; hence the aforementioned clamp blocks. Make sure you don’t have any sharp bends in the ground wire and have it drop straight down to your ground stake and that should do it.

One word of caution. At some point you’ll have dissimilar metals in contact (steel and copper). Since attaching the copper wire to your guy wire will cause long-term corrosion to occur (interestingly enough, usually ONLY the strand that is in contact with the copper as it washes off the galvanized coating), use steel wire attached to the guy and move the steel to copper contact point to the ground stake. As always, use an appropriate anti-oxidant material on all joints.

If the purpose of guy wire grounding is for lightning protection, soldered connections are good for ONE hit. After that, the solder has been melted and you don’t have a connection anymore. The only acceptable ground wire connections allowed by the NEC are either compression (like a clamp) or exothermic (like a cadweld). Using solder introduces yet another dissimilar metal to your guywires. This is another situation that is not recommended.

GROUNDING FEEDLINES

Yes, all coax lines should be grounded to the tower at the antenna and At the base of the tower before the cable goes into the conduit or Before it goes into a junction box. Yes, use feedthroughs (or better, a PolyPhaser lightning arrestor) and use pl-259s on the cable. Then water proof the connections.

You must establish a single point ground, preferably just outside your shack outside wall. PolyPhaser goes into detail on this in their “grounds for lightning protection” book.

Simply burying the cables help reject the pickup of additional rf energey from nearby strikes in the section that is buried, but by itself, burying is inadequate.

If you really want your cables to be protected, they should be grounded at the top of tower where the cable run begins, grounded at the point at which they leave the tower and turn towards the building and then grounded at the building entry where your Single Point Ground System bus resides. THEN you can consider your cables protected. Note: I’m skipping the part about the rest of the ground system.

Merely disconnecting your cables is a false hope. An average direct lightning strike won’t think twice about jumping from the end of your disconnected cables to another convenient place that offers a lower resistance path to ground. It could be the adjacent radio, telephone, computer, the cable on your TV, etc. The main thing that you’re trying to do is to keep the lightning transient OUT OF THE HOUSE in the first place. If you do a good job of that, it really doesn’t matter what you do IN the house. By having your cables in the house unprotected but disconnected, you’re still inviting that massive voltage and current into the house.

Eight-pin connectors allow you to disconnect the cables from the boxes within seconds (easy slip in - slip out connectors) anytime you are leaving the operating position or whenever you hear distant rumbles of thunder heralding an approaching storm.

Each wire going into/out of your shack must be protected, in some way, from lightning. That means a dc-blocked unit in series with coax cables, shields shorted to ground at the antennas and at the base of the tower and at the single point ground, and other lines (control lines) parallel connected to MOV's to ground at the base of the tower. PolyPhaser sells the latter too.

I have every control line connected to a PolyPhaser antenna control lightning protector (MOV unit) inside the box at the base of each tower. The PolyPhaser unit has eight (8) wire capability per unit. You must verify that your operational voltages (rotor control, relay control voltages) do not exceed the threshold voltage of the MOV's. The MOV voltage can be specified to PolyPhaser for unique applications.

As an additional measure of protection, recommended by Polyphaser, you can add MOV's to tower ground at the top of the tower for those control lines that are the upper most lines on the tower. That is, the highest antennas/rotors/relays on the tower have another set of MOV's to ground at their mounting point on the tower.

COMMERCIAL FEEDLINE GROUNDING CLAMPS

Take a look at the grounding blocks offered by Industrial Communications Engineers (ICE) in Indianapolis. They are heavy machined aluminum blocks that clamp around up to 4 coax shields with a mating ground bar to attach to the tower. First, you remove about 1 inch of the coax jacket of each feedline. Then you apply the supplied anti-corrosion compound to smear between the braid and the clamp. Last, you close the clamp and attach the assembly to a tower leg. Each block can handle up to 4 coax's and there are 2 models - one for RG8x type and one for the larger stuff (9913 etc).

ICE also has other goodies-preamps; "lightning arrestors" for coax, open wire, phone lines, and control cables; and transformers to use surplus 75-ohm TV hardline.

ICE - Industrial Communication Engineering
1-800-ICE-COMM/ (800) 423-2666

HOMEBREW FEEDLINE GROUNDING CLAMPS

One method for coaxial cable starts with a piece of ¾ inch aluminum plate about 2 inches square. Drill the appropriate size hole through the plate for the outer shield (you have to strip a short section of the outer insulating jacket). Then flip the piece 90 degrees and drill two 11/32 holes on each side of the center hole and perpendicular to it through the edge of the plate for the 5/16 inch clamp/mounting bolts. Then saw the whole thing in half and the saw cut provides about the right crunch. Depending on where it is going, you can make the clamp/mounting spacing fit a U bolt and then grind/file radius to fit tower leg. When clamping to a tower leg, use a stainless steel bolt, and a thin piece of stainless sheet (machinist's shim stock) between the aluminum block and the galvanized tower leg with lots of anti-ox compound. Also apply anti-ox to the socket where the clamp grips the coax. Then seal the clamp, leg and cable like it was a coax joint to keep the water out. No moisture means no electrolysis. It is cheap and takes about 15 minutes to make with a drill press, band saw and grinder.

Another method is simply to cut the coax at the grounding point and install PL-259's on each end. Join them with a barrel connector. Us the silver plated types, please. This provides an exposed electrical terminal for the shield. Make a strap from a thin piece of stainless steel sheet and clamp the exposed silver to the tower leg. Apply anti-oxidant compound first, of course, and then weatherproof the joint.

Here's another method. Strip off the jacket for an inch, and lay a ½ inch wide copper foil along the braid with two flying (free) ends.

Tightly wrap the shield to the foil with a single flat layer of thin CLEAN solid buss wire, about number 22, and flash solder the wire ends in place.

Then weather-proof the whole joint. The copper foil leads hanging out can be grounded to the tower leg or entrance panel. When connecting the copper to a dissimilar metal, apply anti-ox xompount and separate the two metals with a piece of stainless steel sheet or shim stock.

A method that does not break the coax should be more reliable than adding two connectors and a barrel, especially if one is careful in the weatherproofing stage of the process.

ASSISTING FEEDLINE AND CABLE GROUNDING WITH CHOKE COILS

Form a coil of several turns in each cable just before the cable passes through the entry panel of the shack. This is just like an air-core balun that you would make at the feedpoint of a dipole. This coil, commonly referred to as a 'solenoid coil' or 'choke coil', forms a high impedance to lightning-induced energy (mostly RF) and helps force this energy into the grounding points up stream at the tower. The coil is no longer the 'path of least resistance', or in this case, the 'path of least reactance.' This also will choke off other sources of coaxial feedline radiation and EMI interference.

HOMEBREW GROUNDED ENTRANCE PANEL

Here is one approach to protecting your gear from lightning. You can make a 'grounding switchboard' that fits in a window. The approach is simplistic, inexpensive, and effective, based on the following goals:

- Disconnect of all conductors between tower and shack when not operating.
- Shunt all conductors from the tower to a low impedance ground when not operating.
- Allow varied rig/antenna connections.
- Isolate gear from ground when not operating.
- Do not operate during threatening weather.
- Develop a habit of always disconnecting after operating.
- Don't spend too much money!
- Don't drill holes in your walls and aggravate the XYL!
- Have fun building something that really works!

Here is the scheme, in summary:

1) Install a conductive panel in a window.
2) Bond the panel to the electrical service and tower ground system (single point) with a low impedance conductor, such as copper pipe or wide strap.
3) Connectorize and label all cables coming into the shack.
4) Make shorting plugs that mate with the connectors and shunt all conductors to the panel. They should be quick "push-on" types so it will be easy enough that you will actually **use** them! :~)
5) Make choke coils in the conductors between the tower and shack.

In practice, the switchboard is real easy to use - which is a key element in human habits! Just reach over to the panel, pull the shorting plugs out of the jacks you want to use, and plug in your jumpers. At this point, the rigs also become grounded through the shields of the jumpers. It's essentially a switchboard, too, so you can connect any rig to any antenna. When done, pull off the jumpers and push on the shorting plugs. Rigs become ungrounded and present no path to stray lightning energy.

You can build an insert for one of your shack windows. It consists of a rectangular, 1/8" thick aluminum plate (try 5052-H32 soft temper, easy to drill, from an **old** road sign <uhh- *sheepish grin*>), framed with pressure treated lumber. Rabbet the edges of the frame with a router to fit the contours of the sill and the sliding operator such that the insert is captured and secured when the window is closed on it. Paint the frame with a suitable primer and paint to match your window. Add some self-stick weather-stripping “V” tape to complete the seal.

Install Amphenol UHF female bulkhead connectors in the plate for each coaxial cable desired, plus spares.

Make a rain shield from a piece of 1/16” aluminum or stainless sheet. Mount it with screws to the upper frame piece on the outdoor side. Make it long enough and bend it out such that even rain coming down at an angle can’t hit the connectors.

For each wire antenna fed with open wire line, install two bulkhead connectors and use shielded parallel lines from two conductors of RG-58 (see ARRL antenna handbook). If you like remote baluns, you can get by with a single connector and one coax.

For rotors and switchbox control cables, use 6 or 8-pin, molded trailer connectors. You can make a clip that retains the tower side connector in a cutout in the panel.

Make insulation panels from pieces of celotex sheathing. Use the kind that has aluminum foil bonded to the outsides for a nice look. Cut holes in the sheathing for each connector and glue one to each side of the aluminum panel.

Acquire some PL-259 quick ‘push-on’ adapters. These have an SO-239 female connector on one end and a PL-259 male connector on the other. However, the threaded female ferrule on the male side has been replaced by a springy, slotted sleeve that allows the fitting to be pushed on to another SO-239. To make these into shorting plugs, solder L-shaped pieces of 12 gauge copper wire into the center sockets of the female UHF side of the adapter, with the short legs soldered to the edge adjacent to the threaded part. Don’t let the short legs jut out past the threads. Then, using a vise, press 2” long pieces of ½” PVC over the threads on the female sides, making short, insulating handles. Then, fill the PVC cavities with hot melt glue. Paint them, if you like, for a neat look.

You can make a shorting plug for the rotor or switchbox cables using mating connectors. Solder all the wires from the connector (wires are already molded into it) into one large copper cable lug and bolt the lug to the panel. When you mate the connectors, all of the conductors are shunted to the panel.

Next, make jumpers of RG-8X for every single antenna connection for all of your rigs and put push-on adapters on the panel ends. Make a jumper for the rotor or switchbox using a short length of control cable and the mating connector for the one in the panel. Label and color-code all ends.

Put a little silicone grease on the quick disconnects and connector pins.

One cheap source is dielectric boot grease at an auto parts store.

You can ground your panel to ground using ¾” common copper water pipe for its large, smooth surface area. If it is convenient to run your cables alongside the ground pipe, as in the case of a second story shack window, install 8-10” stub legs in it using “T”’s every few feet to cable tie the hardlines and coaxes to it for support. To attach the pipe to the panel, hammer the pipe flat and bend it over at a right angle. Drill holes in it and the panel for ¼” stainless bolts. Don’t forget to use pieces of stainless such as washers or foil, plus antioxidant paste, wherever the copper and aluminum mate.

GROUND ROD METAL SELECTION

The corrosivity of the soil is another important issue. One should measure the pH of the soil, preferably at the depth at which the grounding system is to be installed. The pH testers sold at spa and swimming pool places will suffice for ascertaining whether your soil is acidic or alkaline. Other kits, designed specifically for soil testing, may be found in lawn-and-garden shops (check Home Depot) and feed-and-seed type businesses such as Southern States. Dig down to the area where your grounding system will be (generally 6-18” or more depending on how far the soil freezes during the winter) and collect a small sample of dirt in a container that you have thoroughly cleaned and rinsed with distilled water. If you are using a pool/spa type kit, take some of your sample dirt and put it in the test tube with some distilled water, shake it up, and test with the strip. If you bought a kit designed for soil, follow the instructions that came with your kit.

If your soil is acidic (most of the eastern US is), you want to go with galvanized, tin, or aluminum-clad products because the acid will attack the copper. If your soil is alkaline, however, you want to avoid galvanized, tin, and aluminum grounding components because those metals are quickly attacked in that environment.

If you are installing galvanized towers and galvanized guy anchors side by side with copper ground rods, then it looks like you’re creating an electrochemical corrosion cell, and accelerating the already corrosive effects on the galvanized steel. So unless you’re using copper for towers and copper for guy anchors, I’d use the SAME material as the guy anchors/towers for ground rods driven within several feet of the anchors. Yes, they’ll corrode. But won’t they corrode anyway? And wouldn’t it corrode faster if dissimilar metals are used as you pointed out seeing in pipes that were side by side? And would it not be better for the ground rod to corrode than the guy anchor holding up your towers? It’s a hellava lot easier to replace ground rods than anchors!

It’s the copper rod that causes the galvanized steel anchor to corrode at a faster than normal rate. It is clear there is a BIG problem in some areas with corrosion. It’s probably OK to use copper rods (with tinned copper wire) in most places in the antenna system like for the interconnecting grounding between ham shack, AC, telco, tower radials, and so on; however, you should definitely consider using galvanized steel rods for the grounding of guy wires near galvanized steel guy anchors and maybe the tower base, at least in certain parts of the country.

SINKING GROUND RODS

To drive ground rods the traditional way, try a steel fence post driver, available from a farm-supply store or fencing distributor. a faster way is to rent an electric jackhammer that has a chuck that will fit around the top of your ground rod. The water method is an easier way to sink ground rods than just wailing on them (or your knuckles) with a maul. a bucket full should do the job. Dig a small hole where the rod is going and pour a quart of water in the hole. That way you can keep the hole full and it will self- feed the water down along the ground rod. Don't get in too big of a hurry doing this job. Let the soil have time to soak up the moisture. Ram the rod up and down by hand. Somewhere around the four or five foot depth, pull the ground rod all of the way out and fill the hole again. Go get a cup or coffee or a soda and let it soak for 10 or 15 minutes. From that point on, you will not need anymore water. You may need to take a hammer and drive in the last two feet. Wear some gloves because blisters will appear quickly and be cautious when pushing the rod in on top of the water else it will squirt back at you with vigor.

IMPROVING GROUND ROD EFFECTIVENESS

There is a mix of chemicals to be used for grounding electrode backfill that promotes excellent contact with ground, possibly even available as premix in bags. It is possible to have a drilling company buy the separate components for you and mix them on site.

The formula is:

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75% Gypsum

20% Bentonite Clay

5% Sodium Sulfate
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This is available from galvanic protection distributors and is known as "standard galvanic anode backfill". I'll know for sure in a day or two. These items are all dry powders, and mixing them on a windy site is difficult.

Anyhow, it works this way. The gypsum absorbs and retains water. So the moisture level seen by the bentonite in the mix does not vary enough to cause the shrinkage problems. The Gypsum has very little expansion or shrinkage due to external moisture level variations and it improves the conductivity of the mix. There is enough bentonite so that the expansion of the bentonite still operates to pressurize the electrode and hole walls for good contact.

For this to work, the mix must be put in dry and then have moisture added. The sodium sulfite is probably not strictly necessary in a system with no continuous source of DC current for the earth terminal. But it helps prevent polarizing the earth terminal if there is some DC flow.

CLIMBING GEAR

CLIMBING BELT

Climbing is arguably the most dangerous activity you will ever engage in. It is probably more dangerous, statistically, than driving your car. The most common home accident is falling off a ladder. However, if you have the right equipment, climbing your tower will be much safer than climbing the familiar ladder because you will be hooked in to your tower 100% of the time. The safest, most comfortable, and most versatile type of climbing belt is a seat harness type that has the following features:

1. Positioning D-rings. One at each hip, for use with a positioning lanyard that goes around or through the tower, that is rigged once you reach your work position.
2. A suspension D-ring ring, in the center, just above your navel, for your "cowtails", a V-shaped, double ended climbing/suspension lanyard that you use to hook yourself in while you climb, or when you hook to a single place such as a mast or climbing rope.
3. If you are a professional tower climber, you will need to follow OSHA requirements for your harness. In this case, you will have to have a "fall arrest' type harness, typically having a full body arrangement and a specific, fall-arrest ring between your shoulder blades.
4. Wide straps around your legs and under your seat, that let you sit and take the weight off of your feet. Loads on the center D-ring from suspending, or short falls, are not applied to your lower back.
5. A belt around your waist having accessory loops for tool buckets and carabiners. It's great to have one for tools, another for parts, and another for snacks and/or drinks (a break in the middle of a work session works wonders!).

6. Lightweight. Most are made of nylon and already are. Stay away from leather belts which are no longer approved by OSHA. The leather can dry out and become seriously weakened without appearing to be.
7. Easy to get into and out of, and comfortable to wear for long periods.
8. Cost. Can you place a cost on your life? Medical bills? Permanent disability? For God's sake don't fool around with ordinary garment belts and dog leash chains! A harness with the above features can be had (in 1998) for between $100 and $200, the best insurance you will ever buy! Isn't that cheap, in the grand scheme of things? You will **feel** safer on the tower, and more at ease, allowing you to concentrate on your work, making you even safer.

The best harness I have seen for this purpose is a cross between the mountaineering/caving style and the industrial work positioning style. It is the Navaho Vario, part #C79, made by Petzl. See Petzl on the web at http://petzl.com and their technical reference page at http://www.petzl.com/FRENG/toc.html.

You will have to download their work/rescue catalog supplement in PDF format from http://www.petzl.com/work/work.html to see the description of this versatile harness. This harness gives you a tremendous degree of freedom since it has no shoulder straps to confine your upper body and chafe your neck. It is also one of the easiest to put on.

Some tower climbers are switching to the OSHA-approved, full fall arrest harness with positioning belt D-rings, such as the model #3520 by DBI/SALA. It has the positioning rings at the hips, a chest ring for suspension, and a fall arrest ring in the back. You have all sorts of options here. It's safer than the simple old lineman's belt because you have a second, fall arrest lanyard that is attached to the tower in addition to your positioning lanyard. However, with this design, the fall arrest D-ring is on the back, between your shoulder blades, and the fall arrest lanyard is longer and less convenient to work with. If you do fall, you won't go far, but you will be jerked around more violently than the shorter cowtails arrangement that connects in the front.

SOME THOUGHTS ABOUT FALL ARREST

Again, for industrial/professional use, you will need an industrial "fall arrest' rated harness to comply with OSHA (Occupational Safety and Health Association)regulations. Amateurs maintaining their own towers do not have to be OSHA compliant. This is an example of an industrial requirement that, although it may save your life, still only comes in to play **after** you have begun to fall, and may still leave you with injuries.

There are many different types of harnesses available for different applications. Although harnesses designed for mountain climbing, caving, rescue and industrial suspended work are not specifically designed for tower climbing, and may or may not be OSHA approved, they are also, nonetheless, designed to protect the wearer's life and, wherever possible, to **prevent** a fall from occurring. Your climbing methods and equipment should be tailored to prevent a fall in the first place. The ultimate decision is up to you, to determine which product keeps you the safest, and how much risk you are willing to take when climbing. Again, in all matters, **you** are the one who is the most in control of your own safety. A complete understanding of the risks you take and the solutions available to you is the best tool at your disposal.

CLIMBING LANYARDS

OK, now that you have a good harness, on to lanyards. Here are the three most useful types:

1. A cowtails lanyard, attached in the front, with two, 20-30" tails and two hooks, that you use to hook yourself in 100% of the time you are above the ground. Imagine the shape of the letter "V": the bottom vertex of the "V" connects to your front suspension ring, and the two free ends connect to whatever you are suspended from. This lanyard is similar to the one used by rock climbers, mountaineers, and cavers, where the term originated, except that both legs are the same length. Typically you would make your own from a good quality, 'dynamic' (stretching) climbing rope, and use 3, readily available, locking carabiners for the attachment points, tied on using figure-eight knots. When you use this lanyard properly, alternating the hook points in a leapfrog method as you move up or down, you can't fall more than a few inches if you slip or lose your grip, limiting the shock and injury potential to a minimum.
2. A fall arrest lanyard, attached in the back, having a single, 36-72" line and hook that is designed to slowly break your fall. Typically, it is constructed with fan-folded, stitched web that rips open in a controlled way to absorb the energy of your fall as it pulls tight. Obviously, its shock absorption capability is destroyed by any fall and must be replaced. These cannot be homebrewed, are harder to find, but are available commercially. If you lose your grip you will fall far enough to develop enough momentum for a serious jerk! Since the fall arrest ring in a full body harness is behind your back, you will be pitched forward into the tower, putting you at risk for a head injury if you are not also wearing a helment. If you use this method, you must keep your fall arrest lanyard clipped as far overhead as possible to minimize your fall.
3. A positioning lanyard. This is a single line, 30-40" long, fixed or adjustable, having a hook at each end. The positioning lanyard goes around or through the object you are climbing and

clips on to the D-rings at your hips to steady your torso while you are working. This is the lanyard most people are familiar with, the strap that linemen and loggers use to place around a pole or tree. These are readily available commercially, but are most easily homebrewed with a length of ‘static’ (non-stretching) climbing rope and carabiners, tied on using figure-eight knots. You can make more than one with different lengths inexpensively, for use with different size towers.

CARABINERS

Carabiners are the handiest devices for climbers. They are sort like an oversized, oval-shaped single link of chain, where one side of the link is hinged to allow it to open and form a hook, and then snap closed again. The swinging portion is called the gate. Carabiners come in a variety of shapes, and fall into two basic classes: locking and non-locking. The locking variety use a small threaded, or spring loaded ferrule that screws over the joint in the gate to prevent it from opening if the carabiner is pressed against another object.

You should always use the locking type carabiners for your personal safety lanyards. One particularly fast type of locking carabiner uses a spring-loaded ferrule that releases the gate only after a quarter-turn twist. This type can be opened very quickly with a simple, but deft move of the fingers of one hand to both rotate the ferrule, and press the gate open in the same movement, yet remain immune to accidental openings after locking. This type is called the auto-locking carabiner, and is particularly well suited to personal lanyards. My favorite auto-locking carabiner, which uses the above twist-locking scheme, is the HMS Munter Auto-lock by Omega (available from Rock ‘n’ Rescue).

Non-locking carabiners are handy for hooking ropes, loads, and gear together. They’re faster and far more trustworthy than a hasty knot tied by an inexperienced person on your ground crew. Miniature carabiners are also handy only for hooking small tools to your harness for work up the tower.

CLIMBING SAFELY WITH HARNESS AND LANYARDS

Again, your climbing method should be tailored to prevent a fall in the first place, whenever possible. When you work on your tower, you need a combination of two lanyards: the cowtails or fall arrest lanyard to keep you hooked in while climbing, and the positioning lanyard. Don’t be tempted to use a positioning lanyard by itself and simply drag it up the tower as you climb.

Although it is safer than free climbing, if you lose your grip or foothold, you can still slide all the way down to the next antenna, guy attachment point, or the ground, whichever comes first, gathering momentum and most likely injuring yourself as you try to grab back onto the tower.

Even worse yet, DO NOT FREE CLIMB if you can possibly avoid it! It's fast and very tempting. As far as climbing a tower goes, when you climb with no safety equipment attached to the tower, it is known as "free climbing". In the workplace, it is illegal per OSHA rules to free climb and you're supposed to be attached to the tower 100% of the time. Since people working on their own towers or anyone doing tower work for free are not subject to OSHA rules, your own method is up to you. Don't take unnecessary risks! Imagine having a dizzy spell or muscle cramp coming down a tower - you want to be attached at all times. Although climbing with lanyards is much slower, you are **so** much safer. If you are in a hurry, then you shouldn't climb anyway. It's a compromise you can live with.

When you climb up with a fall arrest lanyard, start by hooking it above you. Climb up above the hook, stop, reach down, unhook the lanyard, re-hook it above you, and repeat. Notice that you are hooked most of the time but not while you are repositioning the hook. If you slip at this point, you are gone. To stay connected to the tower 100% of the time, you have to thread another lanyard, such as your your positioning lanyard, around the tower while you reposition the fall arrest lanyard. Pretty slow, but you stay 100% connected. When you need a rest, you must hold on with one arm while you set your positioning lanyard around or through the tower, and hook it before you can lean back and fully rest. However, if your fall arrest harness is not too long, you could possibly climb down or bend your knees to transfer your weight to the lanyard, and "hang" in your harness to rest. This isn't always too comfortable.

When you climb using cowtails, start by hooking one tail above you. Climb up above the first tail, hook the second tail above you, reach down, unhook the first tail, and repeat. Notice now that you are hooked **100%** of the time, even while you are repositioning each hook. When you need a rest, simply bend your knees to transfer your weight to the upper tail and you can "sit" quite comfortably to rest at a moment's notice! When you get where you're going on the tower, you can clip both tails at the same brace and remain partially suspended while you work. If your cowtails are just the right length, your weight will divide between your feet and the lanyards. Notice here, that since the lanyards are already taught, and your feet are placed, you **cannot** fall at all. This is fall prevention at its best. Then, of course, you still have your positioning lanyard, which you carry up with you, and you can connect this to your side rings for the ultimate stability.

CARRYING TOOLS

You can purchase or make pouches for carrying tools and parts with you up the tower. This keeps your hands free for climbing at all times. A pouch fixed to your harness is handy enough, but you still have to reach around your side to retrieve the tools or parts. See the sources section for places to purchase these. For convenience, you can remove the pouch from your harness and clip it to the tower adjacent your your work area, to keep things ready at hand.

HOMEBREW TOOL AND PART POUCHES

You can make a nice tool pouch that is especially well suited to tower work with a minor adaptation of readily available tool pouches. In my case, I purchased a 10-pocket, suede tool pouch from Wal-Mart. Cut a piece of ½" diameter wooden dowel to the same length as the belt loop in the pouch. Insert the dowel through the belt loop right at the top and secure this in two places by driving short tacks through the loop from the back side into the dowel. Next, pinch the loop tight around the dowel and cut a vertical slit in the leather just below the dowel, at the balance point. Attach an oval carabiner at this point and orient it such that it hooks through the pouch, around and under the dowel, and the gate faces away from the front of the pouch.

Now, you can easily clip this pouch onto your harness as you climb, then remove it and clip it to a horizontal tower brace right at your work position. Since the back side of the pouch is flat, it fits very nicely at your side or on the face of the tower. Make a second one for parts.

ROPES & KNOTS

The venerable bowline has, heretofore, probably been the most widely used knot for forming a loop. However, the figure-eight knot is now gaining more general acceptance as the knot of choice for those who trust their lives to rope in fire, rescue, and recreational climbing activities. The figure-eight knot is easier for most people to tie, has a larger bend-radius (stronger), is more resistant to self-untying, and yet is easier to untie than the bowline after strain-tightening. Use the figure-eight to tie ropes off to objects, form loops in the ends of ropes, attach carabiners, or for a stopper knot on the free end of a rope.

Along with the figure-eight, the prussic knot is also indispensable. It is related to the taut-line hitch and has a remarkable capacity to grab onto a vertical rope, pipe or mast without slipping. The knot will not slip when tension is applied to the free loop, yet it can be slid back and forth easily by pushing directly on the knot itself. A prussic loop is a 12-18" diameter loop of smaller, 6mm cord, formed by tying the ends of a single piece (around 48" long) together using fisherman's knots, forming a simple rope ring. Make up several prussic loops and keep them on hand. Grab a loop and tie it around the rope or pipe or mast you want to lock onto, for the prussic knot, and use the resulting short loop as an attachment point for your carabiner. This technique is extremely useful, for instance, to set a pulley on your mast to use for tramming an antenna or other hauling purposes, where there are no braces to hook a carabiner. You can also use the prussic to anchor your cowstail or fall arrest lanyard.

Here are a couple of excellent places on the web to learn how to tie these useful knots and more:

The Cave Training Manual:

http://www.nottingham.ac.uk/~styms1l/cave/

The Roper's Knots Page:

http://huizen2.dds.nl/~erpprs/kne/kroot.htm

Two good places to purchase harnesses, ropes, carabiners, and other climbing gear:

REI outdoors:
http://www.rei.com
http://www.rei-outlet.com

Inner Mountain Outfitters:
http://www.caves.org/imo/default.htm

Rock 'n Rescue:
http://www.rocknrescue.com/default.htm

MAKING YOUR OWN LANYARDS

COWTAILS LANYARD

Obtain a 115 inch long piece of 10.5mm dynamic climbing rope. That seems like too much rope, but figure-eight knots use quite a lot of rope. It's possible to use a non-stretching rope, but the dynamic type will produce less shock if you fall. The figure-eight knots will also absorb shock as they tighten during a fall. Fold the rope in half and tie a figure-eight knot in the center, forming a small eye loop for your center carabiner. This is the vertex loop that attaches to your center suspension ring on your harness. Attach a locking-type carabiner to the vertex loop (a screw-locking type is best here, since you won't be opening it often). Now tie figure-eight loops in each end, for the climbing hooks. You should leave about 3-4 inches of excess in the loose end of the knot for now. Attach auto-locking carabiners to these end loops. Now put on your harness and take the cowtails lanyard over to your tower. Hook the vertex on to your suspension ring, and hook one tail to a tower rung. Climb up a little and hook the remaining tail as high as it will go, which will put the tail ends around 4 feet apart. Adjust the tail end knots such that the two tail carabiners reach their nearest tower rungs easily without much slack. Don't make them too long, or you will have to bend down too far to reach the lower tail when climbing. You must be able to reach the lower end easily after setting the upper. After you are satisfied with the lengths, tape the loose ends from the knots to the main rope for neatness and an extra measure of security that the knot will not come undone.

POSITIONING LANYARD

This plan will make a lanyard that is just right for Rohn 25 tower. For Rohn 45, add about 8 inches to the raw length measurements. Obtain a 90" piece of 7/16" (11mm) diameter static (low-stretch) rope, such as Blue Water II. Also obtain a 24" piece of 1" diameter tubular webbing, in the color of your choice (also available where you buy climbing rope). Tie a figure-eight knot in one end of the rope, leaving a small loop for one auto-locking carabiner. Slide the webbing over the free end, and tie another figure-eight knot in the free end, capturing the webbing and making another small loop for the second auto-locking carabiner. You should have about 3-4 inches in the loose rope end adjacent to each knot. Try the lanyard out on your tower, passing it around or through the tower in various combinations. Once again, after you are satisfied with the length, tape the loose ends from the knots to the main rope for neatness and an extra measure of security that the knot will not come undone. Notice that the webbing acts as a sacrificial abrasion element for the main rope, and also as a color code. If you climb more than one size of tower and make more than one lanyard, assign a different webbing color to identify the lanyard length.

CORROSION PREVENTION

DISSIMILAR METALS AND GALVANIC ACTION

These corrosion problems can be prevented by using a joint compound which can cover and prevent the bridging of moisture between the metals. The most popular compounds use either zinc oxide or copper particles embedded in a silicone grease. As the joint pressure is increased, the embedded particles dig into the metals and form a virgin junction of low resistivity which is void of air and its moisture.

The following is a list of paste and grease-like products for the prevention of oxidation of aluminum in electrical connections and antenna installations:

Manufacturer:

Butternut Electronics Company
831 North Central Avenue
Wood Dale, IL 60191
Tel: (708) 238-1854
Fax: (708) 238-1186
Product Name: Butter-It's-Not
Source: Direct if not stocked by local authorized dealer.
Price: $3.50/ Envelope
NOTES: Contains copper dust in a molybdenum suspension.

Manufacturer:

GB Electrical
6101 N. Baker Road
Milwaukee, WI 53209
Tel: 1-800-558-4311
Product Name: OX-GARD
Source: Available from many electrical supply houses and retail outlets such as Sears, Home Depot, Ace and True Value Hardware stores. No Factory direct sales.
GB catalog number OX-100B.
PRICE: APPROXIMATELY 3.00/ 1-OZ TUBE

Manufacturer:

Ideal Industries, Inc.
Becker Place
Sycamore, IL 60178
Tel: 1-800-435-0705
and: 1-815-895-5181

Fax: 1-800-533-4483

Product Name: NOALOX

Source: Distributors (Call 800 number for nearest one)

Price: Ideal list price $2.58/ half oz tube (#30-024) and $8.64/8oz bottle (#30-030).

NOTES: Also available from many electrical wholesale supply houses.

No factory direct sales. Contains zinc particles suspended in a carrier.

Manufacturer:

KLM Antennas Inc.

PO Box 694

Monroe, WA 98272

Tel: 1-360-794-2923

Fax: 1-360-794-0294

Product Name: Conductive Paste

Source: Factory direct and larger dealers.

Price: $3.50 plus shipping & handling/ 1 ounce containers

NOTES: Anti-seize thread compound Hi-Temperature MIL-A-907E.

Contains copper and graphite flakes suspended in a petroleum base.

Manufactured for Mirage/KLM by Chemical Commodities Agency, Inc. of Highland, CA per MIL-A-907E.

Manufacturer:

Sanchem, Inc.

1600 S. Canal Street

Chicago, IL 60616

Tel: 1-800-621-1603

Out of State: 1-312-733-6111

Fax: 1-312-733-7432

Product Name: NO-OX-ID

Source: Direct from Manufacturer

Price: $11/16oz can or $8.80/8oz tube (plus shipping) Minimum order - $35

NOTES: NO-OX-ID comes in several consistencies. NO-OX-ID “A” and NO-OX-ID “A-Special” are suitable for most antenna installations. NO-OX-ID “A-Special” is similar to NO-OX-ID “A” but has a small amount of solvent added for ease of application.

Manufacturer:

Thomas & Betts Company

1555 Lynnfield Road

Memphis, TN 38119

Tel: 1-800-888-0211

Fax: 1-800-888-0790

Product Name: Aluma-Shield

Source: No direct factory sales. Available from many electrical supply distributors.

Price: Approximately $11.44/ 8oz can.

NOTES: Customer may call 800 number for location of nearest distributor. Contains zinc particles suspended in a petroleum base.

Manufacturer:

Burndy Electrical

101 E. Industrial Park Dr.

Manchester, NH, 03108

Tel: 1-800-346-4175

Fax: 1-800-346-9826

Product Name: Penetrox (PEN-A)

Source: Electrical wholesalers

Price: Approx. $6/ 3oz tube

NOTES: Zinc particles suspended in a natural based compound. Penetrox A is a natural (petroleum) based compound with evenly suspended zinc particles. It is recommended for aluminum to aluminum, aluminum to copper, and aluminum to plated copper connections. It is not recommended for use with rubber or polyethylene insulated conductors. UL listed to 600V.

Penetrox A-13 is a synthetic base compound with evenly suspended zinc particles. It is recommended for aluminum to aluminum, aluminum to copper connections. It is compatible with rubber, polyethylene and other insulating materials. UL listed for all voltages.

Penetrox E is a synthetic base compound with evenly suspended copper particles. It is recommended for copper to copper, copper threads, and all grounding applications. UL listed.

Manufacturer:

Ilsco Corporation
4730 Madison Road
Cincinnati, Ohio 45227
Tel: 1-513-533-6200
Fax: 1-513-533-6274
Product Name: DE-OX
Source: No factory direct sales. Available from electrical supply wholesalers and distributors. Customer may call for nearest distributor. Price: Approximately $2.90/ 1oz, $4.90/ 4oz and $7.30/ 8oz squeeze bottle.

NOTES: Used in the electrical trade for Al/Cu and Al/Al connections.

Green colored grease with no noticeable particles in suspension.

Manufacturer:

Antennas West
PO Box 50062
Provo, Utah 84605
Tel: 1-801-373-8425
Fax: 1-801-373-8426
Product Name: Goose Grease
Source: Factory direct sales only.
Price: $1.00/ 1oz + and $1.00 p&h.
NOTES: Transparent silicone grease. Antennas West also recommends this product for ground rod clamp connections.

Manufacturer:

Mosley Electronics, Inc.

10812 Ambassador Blvd.

St. Louis, MO 63132

Tel: 1-800-966-7539

and: 1-800-325-4016

and: 1-314-994-7872

Fax: 1-314-994-7873

Product Name: 1) Mosley Penetrox (Conductive Grease) 2) Weather Guard (Clear spray coating)

Source: Factory direct sales only.

Price: Mosley Penetrox- $4.45 / packet + postage.

Weather Guard- $12.75/ 8oz spray can + shipping

NOTES: Mosley Penetrox is a grease like product. Weather Guard is a clear spray especially recommended for marine and coastal environments. Weather Guard cannot be shipped via the post office; UPS required.

Manufacturer:

Loctite Corporation

1001 Troutbrook Crossing

Rocky Hill, CT 06067-3910

Tel.: 800-842-0041

Product Name: Permatex ANTI-SEIZE LUBRICANT

Source: Many Automotive Supply Distributors

Price: N/A

NOTES: Comes in 1 oz squeeze tube, 8 fluid oz brush top container, and a 12 oz aerosol can. Can be used on the threads of U-bolts to prevent “seizing, galling, and corrosion.” It aids in the disassembly of the antenna’s hardware. Not for use on electrical connections. The part no. on a 1 oz tube is 133A.

The connection of a copper wire to galvanized tower leg should be avoided even if joint compound is used. The primary problem here is that due to dissimilar metals, the galvanizing will eventually be eaten away. In addition, there is very low surface-area contact of the round wire with the (round) tower leg. A copper strap should be used instead. In this case, use a washer material between the copper grounding strap material and the tower legs. The most common thing to do is use a thin sheet of stainless steel (machinist's shim stock). You could also use lead, tin, or silver, or you can simply tin (soft solder) the end of the copper conductor that will be clamped to the galvanized steel. Consider using a clamp such as or similar to the PolyPhaser TK series stainless steel clamp as shown on page 53 of the '90-'91 Catalog. The TK clamp will help increase the surface area of the connection as well as provide the necessary isolation between the dissimilar metals. Be sure to use antioxidant/joint compound on all contact points. For an even more effective connection, use copper strap in place of the wire with the TK series. Beyond that, it would be very beneficial to seal the connection with your favorite "liquid tape" or Scotchkote and vinyl electrical tape to keep moisture out of the joint. The moisture is the electrolyte that turns the dissimilar metal joint into a battery.

Silver oxide is the only oxide (that we know of) that is conductive. This is one reason why PolyPhaser's N-type coax connectors are all silver with gold center pins. Copper oxide is not conductive and the proper application of joint compound will prevent oxidation.

Knowledge of corrosion can make the difference between a good site that stays on the air and one which needs a lot of maintenance after a short period of time.

Noble Metal Table: Accelerated corrosion can occur between unprotected joints if the algebraic difference in atomic potential is greater than +-10.3 volts.

	MAG.	ALUM.	ZINC	IRON	CAD.	NICK.	TIN	LEAD	COPPER	SILVER	PALL.	GOLD
MAGNESIUM	0.00	-0.71	-1.61	-1.93	-1.97	-2.12	-2.23	-2.24	-2.71	-3.17	-3.36	-3.87
ALUMINUM	0.71	0.00	-0.90	-1.22	-1.26	-1.41	-1.52	-1.53	-2.00	-2.46	-2.65	-3.16
ZINC	1.61	0.90	0.00	-0.32	-0.36	-0.51	-0.63	-0.64	-1.10	-1.56	-1.75	-2.26
IRON	1.93	1.22	0.32	0.00	-0.04	-0.19	-0.30	-0.31	-0.78	-1.24	-1.43	-1.94
CADMIUM	1.97	1.26	0.36	0.04	0.00	-0.15	-0.27	-0.28	-0.74	-1.20	-1.39	-1.90
NICKEL	2.12	1.41	0.51	0.19	0.15	0.00	-0.11	-0.12	-0.59	-1.05	-1.24	-1.75
TIN	2.23	1.52	0.63	0.30	0.27	0.11	0.00	-0.01	-0.47	-0.94	-1.12	-1.64
LEAD	2.24	1.53	0.64	0.31	0.28	0.12	0.01	0.00	-0.46	-0.93	-1.11	-1.63
COPPER	2.71	2.00	1.10	0.78	0.74	0.59	0.40	0.46	0.00	-0.46	-0.65	-1.16
SILVER	3.17	2.46	1.56	1.24	1.20	1.05	0.94	0.93	0.46	0.00	-0.19	-0.70
PALLADIUM	3.36	2.65	1.75	1.43	1.39	1.24	1.12	1.11	0.65	0.19	0.00	-0.51
GOLD	3.87	3.16	2.26	1.94	1.90	1.75	1.64	1.63	1.16	0.70	0.51	0.00
LESS NOBLE												

CATHODIC PROTECTION

Cathodic protection is a process of using the known variables of a corrosion cell to effectively mitigate the detrimental effects of corrosion. There are two types of cathodic protection commonly used. The easiest is known as galvanic anode protection. This is accomplished in tower anchor systems by electrically bonding sacrificial anodes to the anchor support, making the galvanic corrosion cell current flow away from the sacrificial anode and toward the anchor shaft and copper ground rod. Because the anode is higher on the galvanic chart, it will corrode instead of the anchor or tower components.

Sacrificial anodes vary widely in their sizes, shapes and make-up. Anodes are typically made of magnesium or zinc. The anode is usually placed in a cotton bag surrounded by a gypsum, bentonite and sodium sulfate mixture. This mixture is used for the purpose of assisting in the activation of the current flow and to ensure that moisture remains around the area of the anode. A wire is attached to the inner core of the anode and is designed to be bonded electrically to the member to be protected.

Following installation of the galvanic anode cathodic protection system, it is essential that it be monitored regularly to ensure its proper operation. A DC volt meter and copper/copper sulfate reference electrode (half-cell) is the most common method of checking the system after its installation. The tip of the half cell is placed in the soil with one lead of the volt meter connected to it and the other to the structure being tested. The measurement should show a voltage shift from the same test conducted on the structure before the system installation.

PROTECTING ANTENNAS FROM CORROSION

One good way of protecting your shiny new aluminum and copper contraptions from corrosion is to paint them with a protective paint. There are two types you can use. Clear acrylic lacquer will do a good job for at least a few years. Another product that has lasted 15 years near a salt water environment is X-I-M 900, a clear metal primer, which may be harder to find. You may have to visit a professional paint store to find it. In any

case, clean the metal thoroughly with a scotchbrite pad. DO NOT use steel wool or sandpaper, both of which will leave behind residues. Then, degrease it with rubbing alcohol, let it dry, and apply 3 coats of the paint.
If the paint you use is not a spray paint, the best thing to use is a paint mitt. First, put a plastic baggie over your hand, put the mitt on, dip it in the bucket and grab the surfaces with up/down or back/forth motions.
The mitts are available from CESCO and other suppliers. Get several pairs and throw them away when you're done.

DO NOT paint polycarbonate plastic parts (Lexan), such as the element clamps on KLM beams. The paint WILL react with the plastic and result in fatal cracking.

You should be VERY careful about approaching polycarbonate plastic with ANY volatile hydrocarbon solvent in general (paints, adhesives, lubricants, threadlockers). Until you know for sure that the stuff is compatible with the plastic, keep it away!

PROTECTING THREADED FASTENERS

The Principles, behind seizing prevention are not very different from those of applying "GOO" to your antenna electrical connections. Both types of "joint compound" have a liquid vehicle to carry some kind of solid particles into the connection.

Regardless of the application (electrical or mechanical), the purpose of the liquid vehicle is to readily allow the application to spread and deposit the suspended solid particles to all mating surfaces.

Once, this has been accomplished, the job is really done by the solids. The materials were designed this way, and our experience verifies it! Any of us, who have applied some kind of "Goo" to a connection have observed that after some amount of time, the compound dries up and all that is left in the connection is the solid material. This is caused by a natural leaching process, whereby the repeated depositing and flushing activity of moisture in the connection washes the liquid vehicle out of the connection.

We also observe that some of the solids are also washed out, but fortunately, some of them are left in the connection to do their job.

In the anti-seizing application, the solids are almost always softer than the parent materials (parent materials refers to the material on either side of the connection, like 300 series stainless in the nut & bolt of a connection, or forged steel on each side of a good turnbuckle.)

They are also trapped in between the mating thread interfaces mechanically by the pressure created by tightening the fasteners. When we come along years later to undo the connections, the trapped soft particles get chewed up and destroyed, preventing the parent materials from coming into contact with each other and galling.

As stated in the previous post, identical parent materials will want to gall, or deform equally together to distort each other, causing a mechanical lock. Sometimes, an effective anti-seizing solid may be harder than the parent materials. In this case, the joint will come apart, but damage will be done to the parent materials requiring replacement.

The key for the anti-seize solid to be effective is for it to have a different hardness than the mating surfaces. The softer solid is preferred as it allows the mating parts to be reused. The galvanic corrosion problems with certain solids are addressed above.

The selection of an anti-seizing compound is directly connected to the environment your hardware will be exposed to. If the connection is going to be flooded with repeated moisture on a daily basis, you need to use a compound that will ~ot completely exit the connection. If your environment is relatively dry (moisture condensing on the hardware 1/3 of the year) you can use almost anything.

There is a product called “LeadPlate” that can be used in a variety of applications. Several of the applications have been high temperature aerospace. The really neat aspect of this type of product is the extremely soft nature of the lead solids. They seem to very easily deform and stick to the mating surfaces. When the vehicle goes away, the lead particles are still stuck to the mating surfaces, by virtue of soft malleable nature of the lead, so that the connections always came apart.

Permatex™ anti-seize can be used on all threaded connections. This compound is very clearly silver in color. It can protect fasteners even after 10 years.

The toughest application is for hardware on sailing yachts. The empirical history on this experience has proven that all common anti-seize compounds behave well initially. When they are exposed to daily washings of condensation, as is experienced by anything on the ocean, all of the good stuff goes away, and the poor guy trying to take the hardware apart ends up spending 80% of his time getting it apart, 10% of his time getting the local machine shop to make new parts, and 10% of his time putting it all back together.

So, what is the good stuff? Its name is Tef-Gel. It is Teflon based and is not cheap. Both the vehicle and the solid seem to stay in the connection! This product is still there, to do its job, where all of the others were washed away. Reminder, this discussion is aimed at preventing things that must move from getting locked up!

Tef-Gel is sold in the marine distribution chain. I would suggest that you look for general marine retail outlets. In the U.S. there is a company called “Port Supply” that has several retail outlets along both the western and eastern coasts.

THREAD LOCKING

Time to get back to some of the simple stainless connections on amateur antennas and towers that we don’t need to move, but need to stay put. Simple thread-locking compounds can be used with success. The fascinating thing about these connections is that, the “thread-locking” Blue Loctite provides enough lubrication to the connection to prevent galling. The compound cures properly, when the parts are not contaminated with oils, it seals the connection off from moisture, and its eventual corrosion, and is easily disassembled later.

When we put a thread-locking compound into a threaded connection, the outer threads, exposed to the air do not completely cure. The material inside the outer thread rings completely cures.

The next neat little feature of the thread-locking materials is that when they cure, they expand. The expansion of the compound applies pressure to the mating thread faces and locks the fastener. Better antenna building through modern chemistry! The locking feature of the compound is essential, as the anti-seizing compounds cannot provide a lock. They are designed to prevent a lock. Gets confusing, Eh?

- Blue compounds are the low strength type. They are usually called "threadlocker" or some such name.
- Red compounds are the medium strength type. They are called "bearing mount"
- Green compounds are high strength types and should be associated with terms like "nuclear bomb" or "cruise missle" when thinking about getting them apart.

If you are putting semi-permanent stainless fasteners together, use the "Blue" thread-locking Loctite. Critical connections that make masts fall down and kill people get the "Red" or "Green" Loctite. Things that require regular service and lubrication get the Tef-Gel (like noisy tubular towers).

Again, you should be VERY careful about approaching polycarbonate plastic (such as the Lexan parts on KLM antennas) with ANY volatile hydrocarbon solvent in general (paints, adhesives, lubricants, threadlockers). Until you know for sure that the stuff is compatible with the plastic, keep it away!

WATERPROOFING CONNECTIONS

Having been involved with DB Vapor wrap, Scotch 88 tape and ScotchKote on hundreds on professional and amateur antennas over the past 20 years, I would like to make an observation.

#1 Putting a wrap or two of 88 tape on the connector and or feedline and then putting the Vapor Wrap on top will keep water out in 75% of the installations. Why only 75%? Well, 25% of the time air is trapped and leaves a gap. Where there is air, there will be water.

#2 When Vapor Wrap is put right on the connector and then 3 wraps of 88 tape are put on top, followed by ScotchKote (left to dry for a few hours) and 1 more wrap of 88 tape, our connections have been 100% waterproof.

#3 I have never had trouble taking Vapor Wrap off of a connector. It takes some practice, but you can use the wrap to stick to itself and it peels off.

#4 I have HAD trouble taking COAX SEAL off any connector where a ham called me in to find out why water got in his coax.

#5 If you don’t put a wrap of tape over the ScotchKote you will find that the ScotchKote will be gone in about a year. The sun dries it up and allows it to flake away. Put a wrap of 88 tape on top and it is there for a long time.

Black-colored Liquid Electrical Tape (LET), made by Starbrite, can also be used in place of the ScotchKote. It may even be preferred since ScotchKote is not rated for UV exposure, and the black LET is. You can restore old containers of LET that have become thick and gummy by thinning the contents using small amounts of the solvent MEK (methyl Ethyl Ketone.)

CoaxSeal, or similar products, is used as a vapor barrier to keep moisture out of a coax connector joint. I’m not a big fan of CoaxSeal because it’s not a quality vapor wrap like what professional communications installers use.

Tower Tech carries a butyl rubber vapor wrap by DB Products, a supplier of professional communications products and we sell it by the foot. It runs $3.00 per foot (it’s 3 inches wide). The most important thing to remember when using any material like this is that you need to apply electrical tape over the connector FIRST, and then apply the vapor wrap.

Pull the tape very firmly over changes in diameter to eliminate as many wrinkles as possible. Wrinkles in the tape are death to a good seal! Putting CoaxSeal directly on the connector renders the connector unusable if you ever try to reuse it—it just gunks everything up. Put 2 layers of tape over the vapor wrap and that’ll give you a professional, bombproof joint.

Here’s another hint: apply the last layer of electrical tape (you are using Scotch 33 or 88, aren’t you?) so that it runs UP the coax. Then let the tape relax before you apply the very end; that’ll minimize the flagging that can take place. That way water will run down the layers of tape and not INTO them. It’s like shingles on your roof; if the tape is applied in a downward direction, the tape laps actually channel running water into the joint.

BTW, ScotchKote is a liquid that is applied to the electrical tape when you finished the above steps and it gives additional weather proofing to the joint. By coincidence, Tower Tech has it for $16.00 per bottle.

An extra measure of oxidation prevention can be achieved by applying a light coat of silicone grease to the contacts in the RF connector. The best grease to use is Dow Corning’s “silicone high vacuum grease”. By preventing the intrusion of any moisture or other contaminants, (electrolyte is excluded), corrosion cannot form.

ACCESSORY MATERIALS AND SERVICES

INSULATING MATERIAL

High pressure phenolic laminated sheet makes an excellent insulating material for antenna systems. In the industrial plastics world this material is known as "Grade LE Phenolic Laminated Sheet" and any industrial plastics company should have it. A trade name for this material is Garolite. McMaster-Carr carries it. The material is extremely strong and completely impervious to weather (I've had many pieces in use for over 25 years with no significant deterioration!) Standard thicknesses include .250 .312 .375 .437 .500" If u can't find a supplier, I purchase mine from Read Plastics in Rockville MD, (301)881-7900.

ELECTRICAL TAPE

Don't bother using anything other than Scotch Super 33 or 88. Nothing else stands up to the weather or sunlight.

ACCESSORY STEP

The general consensus is that these slip on shelves for Rohn towers, although convenient, tend to just get in the way.

ROTOR REPAIR

Norm's Rotor Service: http://www.rotorservice.com
and can be reached at 301-874-5885.

C.A.T.S. (formerly RotorDoc): http://www.rotordoc.com
craig@rotordoc.com
7368 S.R. 105, Pemberville, OH 43450, 1-419-353-2287 Fax: (419) 354-7746
1-800-3ROTORS

Linda at Hy-Gain (everybody buys their parts from the factory) is at 402-465-7021.

FIBERGLASS SPREADER RODS

Max Gain Systems

221 Greencrest Court

Marietta, Ga. 30068   770-973-6251

http://www.mgs4u.com

Cubex Co.

CRIMP-ON PL-259 CONNECTORS

Connectors Unlimited

P.O. Box 5973

Manchester, NH 03108-5973

Phone 603-668-5926 Fax 603-641-1179

Their catalog has a lot of connectors (F, UHF, N, BNC, etc) for dozens of cable sizes. And the appropriate crimp tools. With prices.

PULLEYS

REI/Recreational Equipment Incorporated, 800 426 4840 www.rei.com.

Pulley	REI#	ropes	side	sheave	strength	wt	price(May 97)
REI Blue	471-424		alum	nylon	4500lb	2oz	$10.00
CMI RP101	471-211	5/8	alum	nylon	3500	5oz	$19.25
CMI RP103	471-210	5/8	alum	alum	5000	6oz	$39.00
CMI RC104	471-073	5/8	steel	steel	10000	1lb	$48.50
CMI RP108	471-084	5/8	steel	alum	16000	2lb	$65.00

TOWER BOLTS

I got a large shipment of Rohn bolt kits in yesterday so I can fill your orders again. Here are the items and prices of the stuff I can supply:

JR45A U-bolt with nuts for AS25G (25G rotator shelf)	.32 each
JR51A U-bolt with nuts for AS455G (45G/55G rotator shelf)	.83 each
25JBK 25G bolt kit (6 bolts, 6 nuts)	1.44 each
45JBK 45G bolt kit (6 bolts, 6 nuts)	3.14 each
55JBK 55G bolt kit (6 bolts, 6 nuts)	3.87 each

Here is the procedure: You determine which items you need and how many. Figure the cost of the items and send me an email showing your totals and your mailing address, including zip code. I will package the items, have them weighed at the local post office to determine the shipping charges, and send you an email with the grand total, including shipping charges. You send me your check, Postal Money Order, or cash (slightly risky) and I will send you your hardware. The UPS office is 15 miles from here and using "Mail Boxes Etc." is way too costly. The Post Office is only 4 blocks and is the least expensive.

Stan w7ni@teleport.com

TOOL AND PART POUCHES

There is a guy that makes handy little pouches for tower work. No other number on his literature. Tower-Mate 25 $15.95, Tower-Mate 45 $19.95

Tower-Mate
PO Box 601616
Sacramento, CA 95860-1616
Fax #916-481-5381

Champion Radio Products
888-833-3104
http://www.championradio.com

COLD GALVANIZING PAINT

KLEIN or LPS make high content, zinc-bearing paint. DAP also makes GALV-A-GRIP in quart cans.

ROTATORS

SELECTION

Data taken from manufacturer's web pages. Price is lowest price found in 1998.

Rotating and Braking torque in ft-lbs.

Model	Price	Rotating	Braking	K-factor
Yaesu G450	239	40	217	722
HyGain CD45	320	50	67	1200
Wilson WR-500	???	65	108	
HyGain HamIV	440	67	416	2800
Yaesu G800	400	79	288	1299
Yaesu G1000	480	79	433	2020
HyGain T2X	530	83	750	3400
Create RC5A2	670	116	1443	
Emoto 1200FXX	780	143	1290	
Create RC5A3	770	159	1443	
Create RC5B3	1300	159	1804	
Yaesu G2800	1150	181	1808	6870
M^2OR 2800P	1270	208	1416	
Emoto 1300MSAX	1300	215	1792	
HyGain HDR300	1100	417	625	5000

You can find some of this data and a LOT more at:

http://www.hy-gain.com/hy-gain/rotors.htm
http://www.yaesu.com/rotors.html
http://www.m2inc.com/

The following rotors will fit into Rohn 25G tower sections without modifying the tower:
Yaesu G450, G800, G800SDX, HyGain Ham IV.

The following rotors will NOT fit into a Rohn 25G tower section unless a brace is bent or removed:
HyGain T2X.

ROTOR WIRING

COLOR CODING TIP. To use, just take the two heavier conductors (if there are any in your cable) and attach them to pins 1 and 2 (alphabetically), then take the remaining wires and attach to pins 3 through 8, alphabetically. Voila!

Most rotators use a similar scheme for motor control and indicator. Their operation is sensitive to voltage drop so the proper sized cable is real important. Hy-Gain recommends the following:

Max. length	**Gauge for Terminals 1 & 2**	**Term. 3-8**
125’	#18	#22
200	16	20
300	14	18
500	12	16
800	10	14

If you’ve got some smaller wire, you can twist multiple conductors together to give you a ‘bigger’ wire size. The rule is: two wires of the same size are equal to one wire which is two sizes larger. The well-known technique of mounting the Hy-Gain starting capacitor close to the rotator is a good one. The Japanese rotators use DC motors.

ROTOR WEIGHT DISTRIBUTION

The bearing in most rotors are designed to accommodate the vertical weight load placed on them by a mast and antenna assembly. Relieving this vertical load completely through the use of thrust bearings may actually shorten the life of the rotor in a windstorm since the bottom end of the mast may be more prone to dancing around if all the weight is being supported up higher by the thrust bearing. The preferred method is to let the entire weight of the mast and antenna assembly bear on the rotor and to gently snug up the thrust bearing centering bolts.

However, if the mast and antennas are exceptionally heavy, some load can be shared by the upper thrust bearing.

Again, the use of two thrust bearings would prevent the mast end from moving around too much and damaging the rotor. The trick here is not to tighten both thrust bearing bolts snugly against the mast, but only enough to keep it from flopping around. This also allows the mast weight to bear on the rotor, stabilizing its bearings.

PHYSICAL INSTALLATION TIGHTENING SEQUENCE

Here is a neat, simple trick to insure the best alignment. This is a specific sequence of hardware tightening that helps insure good physical alignment.

1. Close, but don't tighten, the mast clamp bolts of the thrust bearing.
   If you are using a second, lower thrust bearing, leave its clamp bolts loose. The mast should be gently centered by the uppermost thrust bearing, but not prevented from moving vertically.
2. Clamp the rotator to the mast.
3. Tighten the rotator mounting bolts to the rotator plate.
4. Tighten the U-bolts of the rotator plate to the tower legs.
5. Tighten the mast clamp bolts on the uppermost thrust bearing.
6. Do not tighten the mast clamps bolts on the lower, intermediate thrust bearing, to account for any slight bow in the mast or misalignment of the rotator itself.

TROUBLESHOOTING ROTATION PROBLEMS

If you have a brand new installation, stop and check if you used the proper gauge rotor wire to account for the length of your installation, and that you used the two heaviest gauge wires on the appropriate terminal numbers. This varies with the rotor make and model, so refer to the manufacturer's literature. Undersized rotor cable causes a voltage drop that will interfere with proper operation. Also, double-check your terminal and connector pin wiring and color codes with the literature. Make clear diagrams of all of your connections to be sure you made them correctly. When your new rotator still doesn't seem to be working properly, or when an existing installation stops working, a friend and a tower climb are in order to perform a series of checks to determine where the real problem is. Take your HT with you up the tower and ask a friend to stand by in your shack with his HT so you can coordinate the tests. Check the entire length of the rotor cable from the shack to the rotator for damage as you go up. First, loosen the rotator's mast clamps and attempt to turn the mast and antennas by hand. See if the mast is binding in any particular portion of its rotation. If so, this could indicate a problem with the thrust bearing or some other mechanical interference with the antennas, feedlines, or perhaps nearby obstacles.

If you suspect the thrust bearing, loosen the mast clamp bolts on it and try turning the mast again. If free, your thrust bearing may be clogged with debris or corroded. If you cannot clear the problem, leave the clamp bolts slightly loose and re-clamp the rotator. It should work fine even if the thrust bearing race is not turning with the mast.

If the mast and antennas turn ok, call your friend and have them run the rotator back and forth between its limits. Watch and listen for smooth, continuous motion and sound from the rotator throughout its range of motion. If there is a problem here, you may see some erratic motion or even hear sounds from the gearbox that always occur in the same portion of movement. If you see any of these problems or if your rotator is ten years old or more, you probably need to service it or replace it.

If the rotator does not start turning readily when it is loosened from the mast, your motor starting capacitor (usually in the control head) may possibly need to be replaced.

If both the mast and the rotator turn freely separately, but not together, you may have an alignment problem. Work back through the tightening sequence in the previous section. If you still have a problem, look for physical problems that may prevent the rotor from being level or centered in the tower, that may not be accounted for in the tightening sequence. This may become obvious if you encounter binding of a component during the sequence. You may also have a rotator that does not have self-centering clamps. These types require a shim for smaller diameter masts to keep the mast centered when the clamps are tightened.

HYGAIN ROTOR PRIMER

The following was provided by Gary Kunkee, rotator repair man at Telex-HyGain, an authority on the Ham-M, II, III, IV, V series rotators. The basic hardware of the rotator hasn't changed much with the notable exception of a change from a zinc gear to steel and an internal wiring change (different ordered use of the 8 terminals). Most all parts are interchangeable to this day.

HYGAIN ROTOR IDENTIFICATION

There were 5 series of Ham M until 1972 whereupon the name changed over time to Ham II, III, IV and V. Look for a four digit number on the Brake Casting (one with terminal strip on it). Some units may not have this number (I think). The first digit may be 1 through 5 indicating Series 1 through 5 of the Ham-M. The Ham II, etc. should be stamped as such (Roman Numeral number). I think the Ham V is actually a Ham IV with a fancier control box. The next three digits indicate the week (2 digits) and year of manufacture.

HYGAIN ROTOR LUBRICATION

Grease is used modestly, not "packed" as may be commonly thought. Currently they use a product called Nyogel 727F but a low temperature white lithium grease is usable instead. Nye Lubricants, New Bedford, MA, Ph: (508)996-6721.

HYGAIN ROTOR INTERNAL WIRING

The main control box transformer is either a 120 or a 240 VAC input winding. It puts out typically 30VAC under load. But 26 to28VAC is okay too. He usually measures 1.5A up to 2.0A current draw. If more than 2 amps is drawn he usually changes the motor. The Series One and Two can be internally rewired to the later standard and be used with the newer control boxes. One giveaway (internally) on these two series is a wire between the pot and to limit switches. Later models do not have this wire. Measurements made on the various terminal combinations with certain results can determine which of the two wiring standards you have.

The motor start capacitor, in the control box, is a 130 microfarad, 110-125VAC, non-polarized electrolytic. A similar replacement is available from Grainger. Grainger part number "4X059" is a 130-156mfd, 110-125VAC, non-polarized electrolytic. Physically it fits in the existing mounting clip, but rather than axial leads, it has two "plug in prongs" at one end, so you need to save the longer leads from the old unit and solder them to the prongs. There's also a physically identical part "4X058" which is 108-130mfd. Since the original is 130mfd, the 4X058 would probably work as well.

HYGAIN ROTOR TYPICAL ELECTRICAL MEASUREMENTS

Typical Measurements on Rotator Terminal Strips:

Ham-M Series 1 & 2 Between terminals:

```
1&2  0.75 Ohms Brake Solenoid
1&3  2.5 Ohms Motor Winding
1&4  2.5 Ohms Motor Winding
1&5  2.5 Ohms Motor Winding
1&6  2.5 Ohms Motor Winding
3&4  5.0 Ohms Whole Motor
3&5  Short
```

4&6 Short

3&7 500 Ohms Position Feedback Pot.- end to end

3&8 0 to 500 Ohms Pot.- One end to wiper arm

8&7 0 to 500 Ohms Pot.- Other end to wiper arm

Wiper is No. 8 on this series

Ham-M Series 3 to 5, Ham II, III, IV, V

Between terminals:

1&2 0.75 Ohms Brake Solenoid

1&8 2.5 Ohms Motor Winding

1&4 2.5 Ohms Motor Winding

1&5 2.5 Ohms Motor Winding

1&6 2.5 Ohms Motor Winding

8&4 5.0 Ohms Whole Motor

8&5 Short

4&6 Short

3&7 500 Ohms Position Feedback Pot.- end to end

3&1 0 to 500 Ohms Pot. One end to wiper arm

1&7 0 to 500 Ohms Pot. Other end to wiper arm

YAESU ROTOR PROBLEMS

There have been several problems reported with the 400, 800, and 1000 series Yaesu rotators, relating to the control box drive motor and circuitry.

The early ones seemed to have cheap drive motors in the control box. the motor commutator segments were too soft and after some time the copper would wipe and fill the commutator gaps. If not caught quickly enough this can smoke the two small current-limiting resistors in the drive circuit. it seems like the resistors act as fuses and protect the drive transistors, so bigger resistors may not be the fix here. The replacement motors seem better so maybe they found a better one.

Here’s a temporary fix for the motor on the G-1000 SDX control unit:

Unplugging the control cable should cause the needle to go to the counter clockwise stop on the indicator. If not, it probably means the indicator drive motor is bad. This is a common problem with the Yaesu G series of rotors.

For a quick check to see if that is the problem do the following:

1. Remove the metal cover (2 screws on sides and 4 feet)
2. Remove front panel (3 screws on bottom, 2 on top)
3. Pull front panel out about 1-2cm and look in to the gear mechanism on the left side. you should see a small pulley with a rubber belt on it.
4. Plug in the rotor power but remove the control cable. Be careful, there are exposed connections where line power is available but they are on the bottom side of the front panels on the other side of the indicator at the switch.
5. Turn on the rotor. With a small screwdriver, gently try to turn the small pulley with the rubber belt. If it starts to slowly turn the needle, it confirms the motor is the problem. If it doesn't start operating, it could still be the motor, but may also be the control board. If it goes back at full speed, it might have been a mechanical jam but that is less common.

What typically happens is that the commutator segments in the motor are too soft so after a while the metal 'wipes' and powders enough to get in between the commutator segments and essentially shorts out the motor. If the controller is left on for long periods in this condition it can also burn up the 2 current limiting resistors and/or drive transistors on the little circuit board behind the motor (see below). Giving the motor a push gets it past the shorted spot and at least shows you that the rest of the drive and control stuff is working, but it won't last.

A temporary fix goes as follows:

1. Starting from where you left off above, pull the power plug.
2. Remove the small circuit board behind the drive motor (4 screws)
3. With needle nose pliers, uncrimp the 3 crimps that hold the plastic back onto the metal case of the motor.
4. Very gently pry the plastic back off the motor.
5. Using a needle or other very small type of dental pick tool, carefully scrape the gunk out from between the segments of the commutator. You can remove the small nylon washer on top of the shaft for better access.
6. Use a paper clip or small pair of tweezers inserted through the small slots on the plastic back to hold the commutator brushes out of the way and carefully replace the plastic back.
7. Re-crimp the metal back and replace the circuit board. This should restore operation for a while, but eventually the motor will need to be replaced. This process is much more involved as you have to disassemble basically the whole front panel to get to it.

R1 and R2, referred to above, are 120 ohm, .5 watt resistors in the control head. The control head motor draws about 40 ma when working (no binding etc) so that draws .2 watts of power through either one of the resistors. If the motor binds/stalls or shorts, the current goes up to 110ma which means about 1.5 watts in R1 or R2. This is a significant overload. You can replace them with 5 watt 150 ohm units from the junk box and run the unit with the motor shorted (clip lead) for several hours. It will get warm but will survive. Q1/Q2, the motor drive transistors, actually show very little temperature rise during this, indicating that they are not being worked very hard. If the tower-mounted pot opens (or the leads are off etc) the control box will turn the pot motor to one end and then stall, and if left would burn out the factory resistors. So if you just energize the control box WITHOUT the pot in the rotor connected, you will cause either one of R1/R2 to deal with 1.5 watts, a 300% overload. This is not what you'd call an intelligent design. And you won't see any warnings about this in the manual......Any shorts external to the rotor would not cause R1/R2 to be damaged as they are several levels removed from the output. However, anything that causes the bridge balance to be upset enough that the motor/pot in the indicator cannot find the null will cause the motor to stall out at one end or the other.

If you transmit and the indicator moves, you have an RF problem. Higher wattage resistors prevent damage, but they are not the cause or cure of the original problem. You can test your unit on the bench using an external 500 ohm pot on terminals 2 and 3 to simulate the pot in the rotor. If the motor shows no signs of binding, but then only works for a day or so when put back into service, you have to assume that there is a problem with the pot or cabling in the actual rotor.

The other common problem is the mast clamp castings, which are brittle and tend to break on installation.

ATTACHING COAX AND CONTROL WIRES

ROUTING CABLES

Run your coax cable and control wires up inside the framework of the tower, next to one of the legs. This way, the tower provides two types of protection. First, the tower will protect the lines mechanically from falling/flying tree limbs, tools, antenna parts, etc (during tower work or a storm), haul lines, or anything else that may bang into or snag on the tower. Second, the tower cage acts like a faraday shield to help protect the lines electrically from EMP (nearby lightning) and direct tower hits from lightning.

ATTACHING CABLES TO TOWER

Scotch 33+ or 88 makes an excellent cable clamp that, when applied correctly, will withstand the rigors of weather, the sun, and time. Do NOT use cheap vinyl electrical tape unless you like climbing and duplicating your efforts. Start taping at the top and work your way down, taping every 5 feet - that's twice per tower section. Lift the lines up slightly before each taping to take the strain off of the cables. This way, each tape wrap is only supporting the weight of the 5 feet of cabling below it. Start each tape point with two turns around the tower leg itself, then 4 turns around the cables, snugging them gently with moderate tension. Apply each new turn over the previous one with 100% overlap - do not spread the turns out. Cut the tape free from the roll, do not pull it off until it breaks. Now wrap 4 turns in the opposite direction with light tension. Cut it free from the roll and do NOT apply any tension to the tape on the last turn. This way, residual tension in the tape will not pull the free end loose over time, avoiding “flagging.” Using screw clamps or beefy cable ties pulled tight may run the risk of squashing coax cables enough over time to disturb their transmission characteristics.

FORMING ROTATION LOOPS IN THE COAX

You must allow the coax some extra slack to flex as your rotator moves the antennas back and forth. The first step is to set the rotator to the middle of its stroke, halfway between stops. If you rig your loop this way, it will only have to withstand half of the rotor’s full stroke each way. Secure the cables to the mast below the bottom antenna. This can be done with tape, followed by gently snugged cable ties (for extra strain relief, since this is a stress point), covered with more tape to protect from UV. Wrap the coax/cables around the mast 2 times, forming a loose, 8 inch diameter spiral below the tape point. This can also be performed by loosening the mast in the rotor, and spinning the mast and antennas around. Don’t pull these turns tight around the mast. They should have a diameter no smaller than recommended for the size coax you are using. Certainly not smaller that 8 inches in diameter for the RG-8/RG-213 sizes. The spiral of extra turns distributes the twisting along a longer section of cable, resulting in far less fatigue that the usual loop that just comes out sideways and back to the tower.

If you have a tapered top tower, at this point, you can secure the coax/cables to the tower as above, starting from the top and going down. However, if you have a flat top tower, the top plate will have some rough edges that will tend to chafe the cables’ jacketing. Bolt or clamp a short pipe to one of the tower legs that rises a few inches above the plate’s edges. Begin attaching the cables to this riser and work your way down the tower. The riser will keep your cable spiral from catching on the top plate.

MAINTAINING ANTENNA SWITCHBOX RELAYS

The most likely problem here are the relay contacts. These may develop poor contact over time for a number of reasons. If you experience poor swr through a switch after testing with a dummy load, inspect and clean the relay contacts.

CARE AND FEEDING OF RELAY CONTACTS

NEVER ever ever use anything abrasive on a plated relay contact!!! The contacts are either gold flashed, or silver flashed, with various alloys added to modify the surface for different current requirements. If you remove even a few tenths of an inch (meaning ten-thousandths in plating slang) of surface, you'll absolutely destroy the alloy that keeps contact resistance low. The MOST you should ever use on a plated relay contact is something about as abrasive as cardboard. You can use a thin cardboard like off a matchbook cover soaked in toluene, xylene, or one of the other nasty solvents that evaporate without any residue to clean crud out of the contacts. Some have found that the paper in a dollar bill has about the right consistency for this task.

This gentle cleaning does not apply to starter solenoids, or other hundred-ampere, non-plated contacts. They can be cleaned with a grinding wheel since they are not plated, but don't try that on gold or silver alloy flashed contacts typical in low or medium current relays.

Relays get "dirty" for two main reasons: 1) They are not plated; 2) They have had the plating ruined by hot switching or "cleaning"; 3) They have debris trapped on the contacts; 4) They aren't in an application where they carry a required minimum current that "wipes" the contact. Number four is a major problem with amplifier relays. The receive contacts technically require a different alloy than transmitting contacts, because one carries virtually no current while the other carries several amperes. Since they are in one relay, you're stuck compromising. An antenna relay is the same. When they "get dirty", and they usually will because the material is a compromise, all they need is a VERY light wiping (like with cardboard) to remove surface contamination. Just be sure to blow any paper fibers out with air or freon when you are done, and NEVER coat the contacts with any "stuff".

What type of relay is it that is the problem? Maybe it's the wrong type? Relays rated for hot switching higher currents, while impressing customers, make very poor antenna relays. They are great for starting motors, but not designed to maintain low contact resistance under conditions of low current flow.

THRUST BEARINGS

ROHN TB3 THRUST BEARING

This bearing is engineered to be dry. Lubricating it will actually cause premature failure because the grease will hold onto any contaminants that are blown through in the wind (dust, rain, etc.). The same is true for crankup cables: do not use grease on them. If the bearing isn't turning freely, disassemble it and clean it as described below. If in doubt - throw it away and get a new one, they are relatively inexpensive.

If you take a close look at your TB3, you will see a set screw inside which, when removed, allows the bearings to come out. There is really nothing that keeps this set screw in the right place. It could work its way in too far and cause the bearings to bind as they pass the end of the set screw. It could also work its way out too far (limited by running into the mast) such that a ball bearing can drop into the hole that is supposed to be filled by the set screw. The set screw is free to move within its threads for a few turns. There is an optimum place for that set screw to be and that is when it just fills the hole such that the bearings run smoothly past the end of it and there is no space for a single bearing to drop into.

New TB3's have a punch mark on the threads to keep the set screw from moving too far. This is an easy way to keep it under control.

Another easy way to keep it in place is to simply use grade blue thread-locking compound (removable) on it.

Here is a step-by-step method for refurbishing a Rohn TB-3. This procedure is only intended to help improve the operation of a reasonably "healthy" unit. If you find serious problems, like cracked castings, broken or missing ball bearings, extreme wear, or cross-threaded screws - please do the wise thing and replace it with a brand new thrust bearing.

Here's what you'll need:

1. A clear, well-ventilated, well-lighted workspace
2. A 16" x 24" or larger tin baking sheet with edges [so you don't lose the ball bearings]
3. A rag for cleaning
4. Mineral spirits for cleaning
5. 3/16" Allen key [preferably with a 6" handle and "rounded" end for insertion at an angle]
6. Miscellaneous filing tools [i.e. small hand files - round, flat; a Dremel tool with fine grinding capability]
7. Wrenches

Procedure:

1. Remove all the bolts and nuts that secure the bearing to the tower and the mast into the bearing.
2. OVER THE BAKING TIN, CAREFULLY remove the Allen set screw located on the inside wall [where the mast goes through].
3. The ball bearings will begin to fall out of the set screw hole. Rotate and lightly shake the bearing to coax the ball bearings out of the hole.
4. The unit was built with 32 [THIRTY TWO] ball bearings. Make sure you have them all! Set them aside.
5. Separate the top and bottom castings of the bearing.
6. Clean both castings and all the ball bearings with the rag and the mineral spirits or other grease-cutting cleanser.

   Note: It is normal for some dirt and metal powder to accumulate. The bearing should not contain grease. This unit is designed to run dry.
7. Inspect the ball bearing races. Look for unusually worn areas, pitting, cracks. Try rolling a ball bearing in suspect areas to see if it will get "hung".
8. Using your filing tools, smooth out any rough areas so the ball bearing can roll without resistance.
9. Do this for both castings. Note that your mast will be pushing down on the upper casting. This will cause the bearings to press against the top of the race in the upper casting, and against the bottom of the race in the lower casting. Pay close attention to these areas.
10. Make sure you look carefully at the area of the race in the upper casting near the set screw. Wear in this area will cause the thrust bearing to stick.
11. Insert the set screw - don't cross-thread it! Adjust it to the point where a ball bearing can run across it smoothly. Note, from the insertion side, how far the set screw is screwed in. Remove the screw and set it aside.
12. Reassemble the thrust bearing by holding the castings together and inserting the ball bearings back into the set screw hole one at a time. You'll have to rotate and jiggle the unit to find space for the last 5 or 6 ball bearings. Do this over your baking tin so that WHEN [not IF] you drop a ball bearing, it falls in the tin, not in the air conditioning vent.
13. Replace the set screw. Apply blue thread-locking compount to it and insert it until it is at the point you noted in Step 11. It should be roughly flush with the inside wall of the upper casting. Be careful not to cross-thread the set screw.
14. Now it's time to give the bearing a spin. It should run much smoother, and should not "stick" at all.
15. If you think the bearing could operate a little smoother, try adjusting the set screw in or out a bit. Remember, the ball bearings must go by the set screw smoothly.
16. If the unit still sticks . . . return to Step 2. If this is your second time through the process and you're still not satisfied - THROW IT AWAY and go shopping for a new one.

INSPECTING YOUR TOWER

INSPECTING NEW TOWER SECTIONS

When picking up new tower sections from a dealer, inspect each section for defects before accepting them. Look for:

1) Bent or twisted sections (sight along their length).
2) Deformed or bent ends (6 places).
3) Mis-aligned joint sleeves on Rohn 45 & up (3 places).
4) Welds with cracks or multiple pinholes.
5) Gaps, flakes or separations in the galvanizing.
6) Missing assembly bolts. There should be a plastic tube containing the assembly bolts stuffed into the bottom of one leg.
7) For Rohn 25 only, to make sure you are not accidentally getting Rohn 20, verify the presence of 8 horizontal rungs, not 7.
8) Bent braces
9) Improperly drilled bolt holes. The holes should be oriented such that the bolt’s axis points toward the geometric center of the tower cross-section.

INSPECTING USED TOWER SECTIONS

Take plenty of time to inspect every inch of used tower sections. Tiny defects may be hard to spot, but they could still seriously weaken the tower’s structure and ability to carry stresses. Watch out for:

1) Bent or twisted sections (sight along their length).
2) Deformed leg ends that have been flattened out-of-round by over-tightening the joint bolts. Deformed ends may be accompanied by the presence of bent horizontal braces adjacent to each end of the section, where excessive jacking force was required to separate the sections.
3) Elongated or drilled-out bolt holes.
4) Cracks and splits anywhere on the 3 legs of each section. Hairline cracks caused by trapped, frozen water will be thin and run in the same direction as the leg.
5) Cracks or multiple pinholes in the welds (inspect every weld). These should be obvious without magnification.
6) Cut and spliced or bent braces.
7) Legs that you cannot see light through, that are clogged with debris.

8) Rust that is more than light, dusty surface rust. If there are flakes of rust and a scaly appearance of the metal, it is probably deep enough to weaken the leg. Use a flashlight to peer inside of each leg for interior rust.
9) Legs that have been repaired or welded to, other than the original factory brace and joint-sleeve (on R45 & up) welds. These welds are often easily identified by surface rust.

ASSESSING BENDS IN TOWER LEGS

If you run across a tower section that is bent, examine the metal closely. The structural integrity is compromised only if the leg section has become kinked or distorted out-of-round. The steel in the legs is ductile enough to let you correct minor bends without damaging the tubular shape. The biggest problem with a minor bend is that you'll have a heckuva time assembling sections involving a leg that is bent more than about a half an inch or so out of alignment.

Champion Radio sells a good gadget for this called a Leg Aligner, which allows you to hook on to both ends of the mating leg sections and lever them into alignment.

CORRECTING MINOR BENDS

Here is one way to straighten a bent leg and maintain structural integrity. Slide a close-fitting pipe over the bent leg end and use the leverage to gently bend it back into alignment. Align the end of the pipe with the bent area to apply the corrective bend to the area that needs it. If it returns to its original shape and alignment with no trace of buckling, kinking, or other noticeable distortion (usually the case with small bends), you can be reasonably sure of it's original integrity. However, once a piece of metal has been bent many times, it can become weakened. If you see a leg that looks like it has been bent back to shape, but still has some residual curves (roller coaster shape) or a crack across it, pass it over for purchase.

The tin is very ductile and should flow with minor bend correction. If a bend is severe enough to crack or flake the galvanizing, the leg is probably a goner per above distortion criteria.

INSPECTION CHECKLIST FOR GUYED TOWER INSTALLATIONS

Here are some mixed ideas/stories.

Every Spring and Fall I inspect my towers and antennas thoroughly so that I can plan needed corrective work during the rest of the year.

With high winds expected tomorrow and a beautiful warm sunny day today, I decided to begin my ritual inspection of my guy anchors, including guy wires, guy tension, turnbuckles and fasteners. Imagine my shock when I got to one of the guy anchors, and the guy wire was not there! This was one of my very few guy anchors that does not use a turnbuckle, this anchor rod has a “fist” style termination commonly used by utility companies. The “missing” guy was hanging down the tower, with the end on the ground near the tower base. This is a ¼” EHS guy and all seven strands were fractured where they had passed thru the guy anchor, the three Crosby clips were still in place. The guy has now been repaired and re-attached. I have no idea why the EHS cable snapped where it passed thru the “fist”... This is the first time I’ve experienced a failure of a guy cable.

Additional inspections planned this spring:

Each tower base will be examined for evidence of rust or other deterioration and all accumulated dirt or other winter debris will be completely removed. Tower plumb will be checked from top to bottom with a transit and corrected by re-tensioning the guys if necessary.

All tower ground wires and ground rods will be inspected. All RF and control cables fastened to sides of the tower will be inspected and fasteners replaced if there is any evidence of deterioration. Electrical connections to rotors and antennas will be inspected. All tower bolts and nuts will be visually inspected for tightness.

This twice a year inspection routine has served me well over many years. I highly recommend that all tower owners follow a similar policy.

During moderate to high winds, inspect your installation for any unusual movement, especially large or oscillating motions of a part that might cause fatigue in a metal part.

Inspect cable clamps for looseness, and deformation or breakage of cable strands.

Clear concrete bases above grade of any debris such as leaves and pine needles, that could retain water and hold it against your tower legs and base hardware.

There is evidence of mechanical wear on the broken guy wire (shiny galvanize on either side of the break, loss of galvanize, loss of steel and some rust only on the strands in direct contact with the anchor). The break occurred on the part of the cable that took the heaviest load (midway around the “fist,” directly opposite the direction of pull on the guy wire).

Over a ten year period the guy must have gradually worn from moving in the anchor “fist”! After two or three strands wore partly thru, the remaining strands simply snapped!

Thanx for encouraging me to look more closely at the damaged guy wire!
Fortunately most of my guy cables are not fastened in this way (most use preformed grips and heavy duty thimbles). I'll very soon replace all of my remaining guy wires that have been installed this way for the last ten years
In hind sight, its apparent that the closest Crosby clip must be close enough to the anchor to prevent the cable from moving in the anchor during high winds
According to my 1994 Crosby catalog application information, the clip (cable clamp) should be installed "as near the loop or thimble as possible".

Your annual tower inspection should include having a wire brush and can of cold galv so you can fix any rusty spots as you find them.

Anchors

At time of construction

Volume and depth of concrete?
Rebar present?

Maintenance

Deadman:

Any visible corrosion, wear or damage?

Spreader:

Any visible corrosion, wear or damage?
Are nuts and bolts tight?
Turnbuckles:

Any visible corrosion, wear or damage?

Guy wire clamps or Preforms (Big Grips):

Any visible corrosion, wear or damage?

Safety Wire:

Present?

Any visible corrosion, wear or damage?

Ground Rod:

Necessary?

Present?

Bonded to metallic guys?

Any visible corrosion, wear or damage?

Guy Sets from the Ground:

Any visible corrosion, wear or damage?

Is all hardware present and not visibly loose?

Any visible corrosion, wear or damage to guy wires, thimbles, and clamps (or Preforms/Big Grips)?

Tower Base

At time of construction:

Height and depth?

Rebar present?

At time of each inspection:

Any visible corrosion, wear or damage?

Any sign that water has frozen inside the vertical tubes?

Lightning Protection System and Safety Grounding

Ground Rods:

Any visible corrosion, wear or damage?

Hardware tight?

Meet NEC?

Tower:

Any visible corrosion, wear or damage?

Is tower vertical and straight (i.e., not bowed)?

Have all joints between sections been inspected?

Guy Sets from the Tower:

Any visible corrosion, wear or damage?

Is all hardware present and not visibly loose?

Any visible corrosion, wear or damage to guy wires, thimbles, and clamps (or Preforms/Big Grips)?

Support Arms:

Any visible corrosion, wear or damage?

Is all hardware present and not visibly loose?

Antennas:

Any visible corrosion, wear or damage?

Is all hardware present and not visibly loose?

Cables and Electronics:

Are cables attached to the tower at least every ten feet of travel?

Notes on cures to items found:

As with any outdoor building material, it is possible to discover items requiring maintenance. Where problems exist, cures are often obvious. For example:

```
Loose nuts and bolts—tighten
Rusted nuts, bolts, clamps—replace
Rust on galvanized steel—wire brush and cold galvanizing compound
Frayed guy wires—splice or replace
Ground wire broken—reground.
```

There is virtually nothing that cannot be repaired or replaced on an amateur radio antenna support structure.

ASSEMBLING TOWER SECTIONS

Break your tower installation task into the smallest bits that you can. When installing a guyed section, pull the guys up separately; not attached to the section. However, pre-installing guy attachments is a good idea, due to their complexity. When installing an antenna, do not bring up the coax attached - use a pigtail jumper from the feedpoint to the feedline. Use an antioxidant between nesting sections. Install bolts with the nuts on the inside of the tower to reduce the protrusion on the outside legs, which will snag your climbing lanyard, clothes, and skin (ouch!).

PRE-ASSEMBLY ON THE GROUND

This is one of the best things you can do to make a tower erection go smoothly. A little planning goes a long, long way in this department.

Guy attachment points.

Figure out ahead of time which section and rung your guys will attach to and install the guy bracket assemblies. Go ahead and install the outer bolts, connection links, and thimbles, too, but don't fully tighten all the bolts until after installation of the guys. If you are not using guy bracket assemblies (you should), mark the guy attachment points with tape. For the top section, it is a good idea, especially if you are raising lighter 25G, to pre-install your rotor plates and thrust bearings.

Guy cables

Break out your calculator and figure out how long each guy cable will be, then add 10 feet and pre-cut all the guys. Mark each guy with a tag identifying which guy it is for (top, mid, bottom, etc.) Pre-install the guy grips on one end of each cable, but only halfway. Wrap one side of the grip only, so that when you raise it up to the guy bracket, you can slip the free end of the grip through the thimble and link and finish the wrap in a flash while you're up on the tower.

Top Section

Pre-install your top-plate adaptor, rotor shelf, and secondary thrust bearing, if used. If possible, go ahead and install your rotor, assuming that your gin pole and haul line can take the weight. Check the balance point of the section and mark the appropriate rung with tape so that the ground crew will know where to connect.

GIN POLES

GIN POLE TYPES

1) Construction Plans: I built a gin pole which I have been using for a number of years. It is made from a 14.5 foot piece of 2" aluminum pipe (2" ID, 6063 alloy) and a rectangular aluminum plate, approximately 18" x 8" x 3/8". The pipe is held to the plate by two U-bolts, and the plate is mounted to a tower leg using two more U-bolts. A hole is drilled through the top of the pipe for an eye bolt which holds the pulley. It's simple to use, although not quite as convenient as

the Rohn ginpole. I've used it on Rohn 25 and several crankup towers. To be useful on a crankup tower, you need to have several inches of offset between the pipe and the tower legs so the pipe clears the bottom tower sections when the tower is nested. Total cost of the plate and pipe from an aluminum supply shop was about $75.

Now some info on addresses, pricing, and the like:

1. IIX Equipment Ltd.
   4421 W. 87th St
   Hometown, IL 60456
   (708)423-0605
   e-mail iix@interaccess.com
   Fax (708)423-1691

   $189.95 for a kit that includes gin pole head and mounting bracket only. (pole itself is not supplied). Unfortunately, this kit uses a flat pulley sheave, and should be upgraded to a grooved/cupped sheave for reduced friction.

2. WB0W, Inc.
   1210 Midyett Road
   Saint Joseph, MO 64506-2407

   (800)626-0834
   Fax (816)364-2619
   e-mail wb0w@ibm.net

   The WB0W GIN POLE can now be ordered with a V pulley for cable, or cupped pulley, or the standard flat pulley for rope. Unfortunately, the flat pulley allows the rope to rub on the side of the pulley body. Using maybe ¾" hemp line would probably be OK, but it may not work well with small synthetic line. You should definitely order the cupped pulley for ropes.

3. Antenna Mart/Max Gain Systems

   221 greencrest Ct, Marietta, GA, 30068

   770-973-6251

   Part # AMQ-SGP-2

   Price: $347.50 + S&H

   email: mgs@avana.net

   web: http://www.mgs4u.com

Two piece design, will ship via UPS.

Easy to transport

Length approximately 12 ft. 6 in.

Weight 36 lbs.

Shipping weight 40 lbs.

Special, large lathe turned rope pully.

Heavy duty design.

Mounts and unmounts in seconds.

Uses up to 7/8″ rope or ¾″ aircraft cable.

Machined pully is high impact plastic. Aluminum pully is $10.00 extra cost option.

HOMEBREW GIN POLE MAST

Here's how I made my own gin pole mast with just a little machine work with hand tools at home. I wanted a 12-foot long, two-piece unit so I could pack it inside my car or van. I bought five, 6-foot long sections of aluminum pipe from Texas Towers in the following sizes:

6061-T6 EXTRUDED TUBING:

2.0″ OD, 1.760″ ID, 0.120 wall, 6′ long, qty 2

6061-T6 DRAWN TUBING:

1.750″ OD, 1.634″ ID, 0.058 wall, 6′ long, qty 1

1.625″ OD, 1.509″ ID, 0.058 wall, 6′ long, qty 1

1.500″ OD, 1.384″ ID, 0.058 wall, 6′ long, qty 1

These are all conveniently UPS shippable and inexpensive!

Notice that these sizes all telescope closely, one inside the other. I nested the three drawn sizes together and carefully aligned one end. Then, with one saw cut, I cut a 16” long section from the group, and carefully filed the ends square and flush with each other, effectively creating a 16” long coupling that is 1.750” OD and 1.384” ID.

Using a handheld de-burring tool (see Home Depot), I very thoroughly radiused the inside edges of each end of the coupling, so that the haul rope would pass through it very easily without snagging. The sections fit so closely together that they appear to be one piece.

I placed the coupling ½ way (8”) into one of the 2” OD extruded pieces and clamped the works in a vise. Next, I drilled, tapped and countersunk four holes to accept #10, flat head countersunk machine screws. I placed 2 of the screws approximately 3 and 6 inches away from the end of the mast half (where the joint will be), and the other two in the same spacing but 180 degrees from the first two. I trimmed the screws for length such that when they were fully seated, flush with the outside, the ends are just flush with the inside of the coupling and do not extend into the rope path. I applied a thread sealant (Loctite blue) to these four screws before final installation so that the coupling will stay permanently attached to one side of the two-piece mast.

Next, I slipped the remaining mast half over the coupling and prepared four more screws and holes. I did not seal this second set, since this will be the side of the joint that comes apart.

Since I drilled all the holes by hand and eye, I punched index marks where the two mast halves meet at the joint so that I could always mate the screw holes.

The joint is surprisingly tight and there is no noticeable play on the resulting, 12’ mast. It’s real handy to be able to break it down into 6’ sections for storage. The screws fit flush on the OD of the mast, allowing it to slide through the gin pole’s clamp assembly nicely.

GIN POLE ROPE

The general consensus is to use a braided, ¾” Dacron rope, if you can afford it. A braided rope, rather than a twisted type, avoids the unwind/wind cycles that occur under load. Braided rope is also far easier to coil. Dacron rope is generally considered the best, but it is the most expensive. Nylon is more readily available in the home stores, but it stretches quite a bit, reducing your control of lifted objects. However, this stretching helps reduce shock loading if items are dropped.

Larger sizes, such as 5/8 and ¾, although far stronger than necessary to do most jobs, are much easier to grip. 5/16” is the smallest size you would want to use, and has plenty of strength (around 1200 lb for braided Dacron). The length you need will be approximately twice your tower height plus an appropriate length (at least 50 feet) for the ground crew to use while maintaining a safe distance away from the bottom of the tower. For a 100 foot tower, then, your rope should be at least 250 feet long.

The easiest way to store this rope is inside a tall, round trash can. The rope can simply be fed into the can without coiling and will come out readily without tangling. Smaller ropes may also fit very nicely into a plastic 5-gallon bucket. Pick up one of those plastic seat lids that fits on the bucket and you have a nice carrying case for your rope.

RIGGING THE GIN POLE AND TURNING BLOCK

Be sure to use a turning block at the base of the tower to keep the haul line lined up with the axis of your gin pole and to prevent side loads. Your turning block **must** lock onto the tower with a safety hook and catch, a locking carabiner, or a screw link. DO NOT CUT CORNERS HERE! Don't play around with hooks that don't have safety latches. Nothing will cause a disaster faster than having your turning block break loose in the middle of a lift!

The turning block should have a pulley sheave diameter of at least 2" for best operation, and a safe working load (SWL) at least equal to the heaviest load you want to lift. Again, keep in mind that the safe working load of an item is usually only 20% of its breaking strength or less. The position you select for the turning block will determine which leg the gin pole will have to be mounted to keep the rope lined up. If there is a particular side of the tower you want to lift items on, place the turning block closest to the desired leg in that direction.

When you mount the gin pole, mount it on the leg that places it as close as possible to directly above the turning block to reduce rope friction. It is imperative that the haul line remain free when manipulating items up and down during placement.

Keep the mast of the gin pole retracted, if possible, while repositioning it for best control. Mount it as high as possible on the tower leg such that it is directly above the turning block at the base of the tower. When extending the gin pole, turn the pulley out so that it faces away from the tower to reduce the friction during the long hauling stage of each lift. Only at the end of the lift do you swing the item over the tower, causing the rope to wrap somewhat around the gin pole.

GIN POLE KEEPER LOOP

A 'keeper loop' is a handy way to speed up rigging and de-rigging the haul rope in your gin pole. The 'keeper loop' is simply a length of small rope that is long enough to go through the gin pole and back around to itself. Tie the ends together to form a loop. When you need to thread the gin pole with your haul line, untie the keeper loop, and tie one end to the free end of your haul line. Use the keeper loop line to pull your haul line through the gin pole. Stow the keeper line during gin pole use. When you are ready to de-rig the pole, reverse the process, pulling the keeper line back into the pole for storage.

RAISING MASTS

When raising very long masts, you can tape the top of the mast to the haul rope to stabilize it and keep it vertical while you are raising it. When the mast reaches the top, you cut the tape as it passes by you. Another technique is to have the pick point on the mast above the midpoint; then it goes up vertically (up-side down) with no problem. What you do at the top of the tower when the haul line knot hits the top of the gin pole is to flip the mast 180 degrees. Since you've got it captured at the gin pole, it will just rotate until you have the short end in your hand (a short rope attached to the 'top' will allow you to pull it down to you). Then you just lower it through the thrust bearing/tower top. This produces the maximum 'pucker factor' when dealing with masts but it does work well. It actually is easier than it sounds.

CLIMBING MASTS

Of course you want to make sure that the mast is safe to support a person on it, such as a chromoly mast, secured at the bottom with dual thrust bearings, or one thrust bearing at the top of the tower and the rotor at the bottom of the mast. **MAKE SURE** that the mast is not just a piece of thin wall something or other. It's a pretty good-sized mental adjustment to be able to climb a mast but remember the load is all vertical and the tower is capable of handling big loads. Compared to big wind stresses, one 200 pound climber isn't going to make much of an impact on the installation.

You can make temporary steps to use with your tower working tools and equipment. Use 2" channel iron 15" or 16" long. (Channel is more secure than angle.) Cut "V" notches in both flanges to match your mast diameter but don't cut all of the way to the flat part. Drill holes for two U-bolts (second one is for safety). Cut along the flange bend about ¾" from each end on the top flange only and bend the ends of the flange (about a half inch) up 90 degrees (keeps your foot from sliding off of the end of the step). Take a cold chisel and using the corner, beat a huge number of indentations into the top surface of the step to make it less slippery. Try raising ridges of steel by increasing the angle of the chisel. Buy the U-bolts just long enough to pass through the step or cut off the excess so your cloths don't catch on the ends of the bolts. You're all set, except for the courage. Mount the first one a foot or so above the last spot that you can stand on. Put another one (if required) a foot or so above that. Now you've got a temporary ladder to get you up the mast. While most people wrap their belt around the mast a couple of times to secure themselves, a good tip is to have a separate short lanyard (about 2 feet long) that is just used for mast work (tnx to K6NA for this tip).

RAISING ANTENNAS

CHECKING ANTENNA TUNING BEFORE RAISING

Don't fall into the trap of assuming that a brand new antenna that you have just assembled, even though the manufacturer's literature may say that no tuning is required, will have a satisfactory SWR curve.

Consider checking side-mounted antennas on their mounts at a temporary location near the bottom of the tower, so you can easily tweak them when they are interacting with the nearby tower.

Here is another point to consider. There is a tendency of HF beam elements (especially the longer ones) to couple with the earth when they are close to ground, making their frequencies of best resonance lower that when it is raised in the air. If possible raise the antenna 20-40' in the air using a non-conductive tram line or other overhead line that you can rig. Try lashing the antenna to a 20 foot extension ladder with a temporary mast and stand the assembly up with some friends while checking the SWR using a temporary pigtail extension for the feedline.

If you perform your tuning close to the ground, the best resonance frequency may rise higher than you wanted once the antenna is installed on the tower. Plan ahead to check this before or during the installation process before all your ham friends call it a day and start digging into your beer, barbeque, and doughnuts!

TRAMMING

Tramming is the best way to raise a large or bulky beam assembly to the top of the tower. A 1/8" steel cable is installed from the ground, up to a point on the mast above the attachment point, usually through a temporary pulley, and then back down to ground directly opposite of the originating point to provide a balanced stay. A traveling pulley attached to one side of this tram wire carries the antenna suspended below it up the wire directly to the mast. Attach the pulling line to a short piece of pipe attached to the antenna boom. This pipe will stay pointed at the mast, parallel with the tram line, as the antenna rises, keeping it properly oriented with the boom perpendicular to the tram line. A second pulley can be added at the end of the pull pipe for even more stability. If a rope is used for the tram line instead of a cable, the antenna can be tested before permanent mounting by pulling it only part way up in the air with a temporary feedline. It can be quickly lowered again to fix any swr problems before permanent mounting.

Using powered machinery to raise antennas should be avoided unless the operator has absolute control over the hoisting device and has direct communication with someone on the tower who is watching the assembly raise up.

REMOVABLE TAG LINES

The antenna tag line ends have to be reachable from the tower. Use a clove hitch to secure them to the boom. Then take them out to a convenient element and then wrap them around the element 2 or 3 times to provide a little friction for the rope. (BTW, two tag lines, one on each side of the boom, is handy.) Finally, tape the tag line to the element out far enough so that you won't bend the element by pulling on the tag line but enough that you can get some leverage while pulling on the rope. After applying the tape (2 or 3 wraps of electrical tape is usually fine), work the tag line back and forth a couple of times pulling it through the tape to loosen up the grip a little. After the antenna is up at the top of the tower but before it's clamped to the mast, you untie the clove hitch on the boom, making sure that there are no knots in the line. Next you have your ground guy start pulling the tag line. He'll be pulling it through the tape and when you get to the end, have the ground guy give a little extra pull as you launch the end of the rope in the direction of the tape. As he pulls, it'll slide through the tape and fall to the ground. All that's left is a piece of tape that'll probably fall off in a couple of years and a successful antenna installation.

ALIGNING BEAMS

Finding true north

In principle, north can be located by using a magnetic compass and making an appropriate correction. Magnetic north is substantially off from true north—the exact amount varies by location. But there are better ways. Polaris, the north star, can be used, but this is inconvenient—

you have to wait for a clear night—and not entirely accurate either. The most accurate way to find a true north south orientation is by using the sun itself to find the direction of a shadow cast by a vertical object when the sun is at its zenith. This is easier than it sounds, and can be done by measuring the length of the shadow cast by the upright before and after noon.

Set up a vertical pole (or use a rope with a weight) to cast a shadow on the ground. If you use a rope you will need to make the reference point somewhere near the top to cast a visible shadow—like a stick knotted into the rope. The base of the shadow will be the first point for your south-north axis and the reference point or top of the pole will trace the second point. At some time in the morning, mark the spot on the ground where the reference point casts its shadow. Measure the length from the base to the end of the shadow, and using a string of that length, trace out a semi-circle on the ground with the base of the shadow as its center point.

As the sun rises higher in the sky, the shadow will first shorten as noon approaches, and then will lengthen. At some point in the afternoon it will reach the semi-circle you traced in the morning. Note the spot when it crosses the arc the second time. The midway point between the morning and afternoon points, will be directly north of the base point of vertical object."

Here's a simplified version of this scheme. Look up the sunrise and sunset times in the newspaper for the day. Calculate the time that is exactly halfway (the "transit time") between them. All shadows will point true north at this time.

There is a website you can visit that will calculate the transit time for you for any date and location. You will need to know your local longitude and latitude. Visit http://aa.usno.navy.mil/AA/data/docs/RS_OneDay.html to obtain the transit time.

MINIMIZING ANTENNA INTERACTION

Turning 2 beams that are stacked vertically such that one beam is pointed 90 degrees from the other minimizes interaction. This 90 degree misalignment is compensated for when aiming that particular beam.

CHILD PROOFING A TOWER

ANTI CLIMB DOCUMENTATION

If you live in a neighborhood where there may be a likelihood of kids playing on or around your tower, you may want to consider some anti climb panels on the bottom section to block access to the tower rungs. A warning placard would also be appropriate. Photograph the installation to document it for future legal concerns.

METHODS

One way to keep people from climbing your tower (especially kids) is to build a cover for the base. Just take a sheet of marine grade plywood. Cut to fit on 2 sides. Notch a 2 x 4 for backing and drill, install carriage bolts and washers. The 3rd side cut to fit and hinge it to one of the other sides, At least 3 hinges, drill and use carriage bolts and washer. washers and nuts on inside all three sheets, Take a hasp and install on the other side and padlock it. Paint it and will last for 20 years. When you climb, unlock, swing open, and climb. Then when you come down, swing back and padlock.

Another way is to use standard galvanized hardware mesh. It wraps around Rohn 25 nicely, and you can lace it with some galvanized wire. To climb the tower, put a 6 foot step ladder up against the side to get above the mesh. This method is much cheaper than the Rohn flat metal guards, and it is probably as effective.

Anti-climb methods will prevent kids and pranksters from climbing, but someone who is dead set on climbing is going to find a way around your efforts. After you make your anti-climb sections, take a few photos of them as installed and file them away so you'll have them if anything ever happens, and you need to show the court how you made a reasonable attempt to prevent unauthorized climbing.

TOWER STRENGTH INFORMATION

"Does anyone know what safety factor Rohn uses for 25G, 45G and 55G? Can you refer me to the drawing or page that says it?"

First a word about the weight of each type. For each 10-ft section, the weights are: 25G-40 lb, 45G-70 lb, 55G-90 lb. Sorry, but the safety factor is not 3:1. I wish it was. The EIA-222 standard requires a 2:1 safety factor on the guy wires. I have done comparison calculations and I come up with about the same thing they have in their literature. Everyone should do a sanity check calculation like this to make sure they are doing it right. The tower buckling load has a safety factor on it that varies with height.

As an example, drawing CB70488 R1 shows a 190’ tower in a 90 mph wind zone. The base load for this tower is 9,870 lbs. The same drawing shows the base load for the 70’ tower at 3,010 lbs. Now this is the same section of tower but the applied load is different while the guy spacing is almost the same (31’ vs. 32’). So I guess you could say that it has a 3:1 or better in this particular case.

In both cases the limiting factor is the guy strength available in the top 3/16” guy wire. Now if you would use ¼” guy wire (6700#) versus 3/16” guy wire (4000#) on a 70’ tower, you won’t get anywhere near the 9,870 lbs of base load so you won’t over load the tower section, but you should be able to get about 60% increase in antenna wind load available. This is provided the guy anchors don’t pull out of the ground and you use the GA25GD guy bracket to get the load properly distributed into the tower - especially for the top guy. The second set can still be 3/16” and looped around a tower leg.

The Rohn catalog contains drawings for each type of tower section that list engineering properties. For quick reference here are some facts for Rohn 25:

The maximum allowable bending moment on a section of Rohn 25 is 7,000 foot-pounds. The compression strength of Rohn 25 is 8430 lb. per leg, or 25,290 lb. total compression at the bottom of the tower.

CALCULATING WIND LOAD AREA AND WIND LOAD

WIND SPEED ZONE

First, determine the maximum design wind speed for your tower. The industry standard is contained in the TIA-222-E specification. The EIA/TIA-222-E wind Map is available at: http://www.pirod.com/wszmap.html.

CALCULATION METHOD

I want to calculate the effective wind area of a 2” diameter mast that is 72” long. Therefore 72” x 2” = 144 sq.in = 1 sq.ft.

The calculation above would be accurate if the mast were square. But because it’s round isn’t there a constant I need to multiply the result by.

You're just about there. The round-member multiplier, or drag coefficient, is 0.67. It is used by Dave Leeson, W6QHS, in his book "Physical Design of Yagi Antennas", page 7-6.

One caution when using this factor to reduce the area of round members. I noticed that there are TWO figures for wind loading capability in the current Rohn Catalog shown on the guying charts. One figure is for flat members and the other figure, a larger one, is shown for round members. So I think Rohn is already taking the shape of the antenna load into consideration in publishing two numbers for wind loading. I think it would be incorrect for you to use Rohn's wind loading number for round members and then also reduce the area of your antenna and mast by 2/3. I believe this amounts to using the same factor twice when it should only be used once.

Years ago the "conventional wisdom" said that one should combine element and boom areas according to the Pythagoreum theory to obtain a net effective area (if you payed attention in Trig class it uses the $A^2 = B^2 + C^2$ formula). This has since been proven wrong. The maximum effective area of any antenna is simply the largest of either the elements or the boom.

When calculating forces, the shape factor is the number that you are looking for. For round members, the shape factor is 1.0. For a flat surface the shape factor is 1.6.

This all factors into the equation: Load in Lbs. = 0.00256 x (V^2 mph) x Shape Factor x Projected Area.

This is from Section 25 of the National Electrical Safety Code, ANSI C2-1997. (The bible of electric utilities). This section has its roots in the UBC regarding wind loads. It also contains some nifty parts about calculating the wind load on a lattice work tower and some caveats regarding the use of extreme wind loading.

From: "Match Your Antenna To Your Tower", Roger a, Cox, WB0DGF (Telex/HyGain), HAM RADIO, June, 1984.....

$$F = PA$$

where F is wind force in pounds, P is the wind pressure in **lb./ft²**, and
a is the antenna wind area in **ft².**

$P = 0.004\ V^2$, for FLAT SURFACES where V is wind velocity in MPH
$P = 0.004\ (0.667)\ V^2$ for ROUND surfaces, where 0.666 is the shape factor

Examples:

```
At 80 MPH, P = 25.6 lb./sq. ft. (Flat)
```

```
At 100 MPH, P = 40 lb./sq. ft.   (Flat)

for a 10 sq. ft. antenna, F = 256 lb. @ 80 MPH,
and 400 lb. @ 100 MPH (flat)etc.
```

Note: The equation $P = 0.004 V^2$ accounts for gusts and turbulence;
for steady laminar flow, $P = 0.00256 V^2$ should be used.

Although the formula $P = 0.004 V^2$ is nice and simple, and was used for years, there are newer formulas used by EIA-222-D (effective June 1, 1987) and the -E version (if I can find my copy of it in the stack somewhere).

2.3.10 The design wind load (Fc) on a discrete appurtenance such as an ice shield, platform, etc (excluding solid microwave antennas/reflectors) shall be calculated from the equation:

$F_c = q_z \cdot G_h \cdot \left[\sum C_A \cdot A_C\right]$ (lb) [N]

q_z is the velocity pressure, calculated based on the centerline height of the appurtenance, $q_z = .00256 \cdot K_z \cdot V^2$ (lb/ft ^{2}), where $K_z = [z/33]^{2/7}$ for z in ft. V is in **mph**. z is the height above average ground in **ft**. to midpoint of section. K_z is the exposure coefficient.

G_h is the gust response factor, calculated based on the total height of the structure, $G_h = 0.65 + 0.60/(h/33)^{1/7}$ for h in **ft**, 1.00 <= G_h <= 1.25.

C_A is the force coefficient applied to the projected area (**ft ^{2}**) of a discrete appurtenance (A_C). If the aspect ratio <= 7 (member length/member width), then a cylindrical shape has C_A = 0.8. If the aspect ratio > 7, then C_A = 1.2. For flat members, use 1.4 or 2.0.

A_C is the projected area of the appurtenance in **ft ^{2}**.

As you can see, it is much more complex now. I still like the old formula best. There really isn't any difference in the formula for wind load for appurtenances (antennas). The main difference is in Table 3, Appurtenance Force Coefficients. For an aspect ratio <= 7, C_A = 0.8 for cylinders. For an aspect ratio >= 25, C_A = 1.2. For ratios in-between, use linear interpolation. If I read this right, most HF antennas would fall into the C_A = 1.2 category. This is dramatically different from the old 2/3 shape factor! The effective area spec on our antennas already have this 2/3 shape factor built in, so you might want to multiply by 3/2 to get the projected area. Other manufacturers may do this differently. The most accurate method is to find the maximum **PROJECTED** antenna area (either the boom or the elements only) **AND** use the EIA-222-E formulae.

NEWER CALCULATION METHODS

Basics:

All antenna area calculations start with the simple determination of the projected areas of the antenna components. The projected area is calculated by multiplying the length x width. A piece of tubing that is 2” dia x 24” long has a projected area of 48 SqIn. Next, all of the pieces in a specific component of the antenna (like an element or boom) are added up to get the total. Usually, the total is divided by 144 to get the area in SqFt. Then the element areas are added up to get the total elements area when the wind is parallel to the boom. The boom area applies to when the wind is parallel to the elements. So, we have the flat projected area of the antenna at two azimuth angles, 0 & 90 degrees.What happens after this is what can cause confusion.

Problems:

Effective area Methods:

Back in 1992, when I wrote the 1st version of YagiStress, there was a popular concept that said the maximum antenna area could be found by solving the Pythagorean equality ($A^2 + B^2 = C^2$) using the total element and total boom areas.

$\text{Max area} = \sqrt{(\text{Boom area})^2 + (\text{Element area})^2}$. This always produced a value that was larger than either of the two areas and it occurred at azimuth angles near 45 Deg. I’m pretty sure that Hygain and Force 12 were using this method to generate their spec’s. Leeson (W6QHS now W6NL) and I were also using it. I was never able to figure out what the others were doing.

Drag Coefficients:

All recognized standards, for analyzing structures subject to wind loading, allow for the application of a drag coefficient to account for the shape of the structural members. This is often referred to as a “shape factor”. EIA-222-C (1976) used .666, EIA-222-D (1986) used 1.2, UBC (1988) used .8. All of the factors reduce the flat projected areas by some amount to arrive at the “Effective Area” for an antenna using round members.

I think that some Mfgr spec’s used this reduction and others may have not. It is very clear that the spec’s did not describe what the value represented. Some manufacturers, in other publications clarified their calculations.

Confusion:

It was never very clear in my mind what the numbers represented. In some cases it was clearer than others, but trying to make intelligent comparisons was impossible. Now, maybe I was the only one who was confused. I'm sure most people thought the areas were derived in the same fashion and could be compared. I am convinced that this was not true.

New Methods:

In the Spring 1993 issue of Communications Quarterly, Dick Weber, K5IU, published a paper describing wind flow over cylinders at various wind attack angles. The methods described resulted in very different values from what many of us were getting. Leeson and myself independently made some test antennas and separately arrived at the conclusion that the Weber method was correct. I know that Roger Cox at Hygain, and Tom Schiller at Force 12 also picked up on it. I have no direct knowledge about the others.

Leeson changed his spreadsheets, but couldn't change his book. I made the changes for YS 2.0.

Here are the changes that come out of the new method. It's termed "The Cross Flow Principle" by Weber, or the "Sin ^{2} Behavior of Cylinders in Yaw," by Leeson: The wind flow over the cylinders results only in loads that are perpendicular to the axis of the cylinder.

This means that all element loads result in forces along the boom axis. Asymmetric element placement along the boom does not result in a wind torque imbalance. This makes the Leeson element torque compensator unnecessary and ineffective.

The Max Projected Area of a Yagi is the largest value determined for the boom or the elements. If the boom area is larger than the total for the elements, the boom area is the max area. The minimum is somewhere in between 0-90 deg azimuth. The min area angle is determined by the ratio of the elements to boom area. If the boom and elements areas are equal the minimum area occurs at 45 deg.

What do users need from an antenna area spec? I define a user as one who will use the information to evaluate it and make decisions, or a designer who will use the info to determine loads on a structure. The first thing most recipients of a specification do, is make an attempt to compare the area values to other spec's to determine which is "best" or which best suits their application.

The second thing a user might do with the area value is design, or have his installation designed. In the U.S., some municipalities require UBC compliance, others require EIA. I'd guess that differences exist in Europe also. If the antenna area values are " flat projected areas", it is clear what the values means and the designer can proceed with applying the appropriate shape factor and wind pressures according to the code. If the areas have been already factored, and the spec doesn't tell what was done, the information is useless. It actually can be dangerous, if the designer is forced to guess what the value means!

The third thing a user might attempt to do with the information is select a rotator. Efforts to match antennas and rotators, based on area alone, are useless. That is another discussion for another day.

Suggestion for a Standard Antenna Area measurement:

Manufacturers should calculate the flat projected areas of the antenna at 0 Degrees & 90 Degrees azimuth, and present them as such. That's it! The user can decide what shape factors and wind loads to apply for determining loads on the mast and tower. It is important to list both values. Some antennas have more area at 0 Deg, others more at 90 Deg.

Example: Most 20 meter yagi's with 4+ elements have more element area than boom area. 10 & 15 meter yagi's tend to have more boom than element area. This assumes that the designer has tried to minimize area. We need both 0 & 90 Deg areas to determine the loads on a mast or rotating tower. The max loads will usually occur at either of the two angles, unless we're lucky enough to get them equal at both. Another antenna property that we need, but has not been a consistent part of the antenna spec's is antenna torque. There is only one generic value, for Mfgr's to define here.

It is the torque developed when the boom is broadside to the wind. This is caused by either placing the mast connection away from the center of the boom. Or, coax and balun loads that will cause an imbalance. There is another (usually small) antenna torque developed by the connection to the mast (or tower), when the antenna is pointed into the wind. If we mount the antenna to a 2" Dia or other common size mast, the Mfgr can provide this torque value. Since, the Mfgr has no control over how we will mount the antenna to a tower sidemount or TIC ring., he can't determine what this value is. That's our job!

Just getting the torque value for the wind broadside to the boom case would be a great improvement! It might make some Mfgr's stop trying to attach the mast to an antenna at the weight balance point, which is usually not at the zero wind torque location. At the very least, providing this value, would allow us to understand why some antennas are "Wind Vanes" and avoid them, unless we plan to overpower the problem with a more robust rotator!

The equation used in TIA/EIA 222-F, which is the latest revision, and the UBC defines the basic wind speed stagnation pressure (a datum) value as:

$$Q_s = 0.00256 \cdot V^2$$

This is based on Bernoulli's equation which can be arranged to give:

$$Q_s = 1/\left(2 \cdot \rho_{\text{air}} \cdot V^2\right)$$

Density(air) at 59 deg F and 29.92 in Hg is 0.0765 lbs/cft

ρ =Density/g: ρ_{air} =.0765/32.2

To express in MPH

$$Q_s = \frac{\rho \cdot V^2}{2g} = \frac{0.0765 \cdot V^2}{2 \cdot 32.2} \cdot \left(\frac{5,280}{3,600}\right)^2$$

$$Q_s = 0.00256 \cdot V^2$$

I don’t know of any safety factor in this.

Hank / KR7X

Previous references to the older EIA 222 Rev C stated the formula in that spec was .004V ². Here is why it is different. The Rev C spec included a built in 30% increase for wind gusts. If we start with the fundamental .00256V ² and add the 30% increase in wind speed we get a 69% increase in windload. If we multiply the original formula by 1.69 we end up with .004V ² . That’s where that formula came from.

ANOTHER TAKE ON EFFECTIVE PROJECTED AREA

Here is one way of finding “EPA”. There are a number of variations and interpretations that can be used to arrive at slightly different answers. Calculating EPA is an art form and is subject to one’s own style and taste. The end result should be within 10% to be called “close enough.” Let’s define some terms: PA - Projected Area - length x width. FPA - Flat Plate Area: converts round areas to flat areas by multiplying PA times .67 EPA - Effective projected area: The projected area (PA) times the shape factor. (PA x Ca). The term Ca varies with the shape (round, flat, other) and the length to width ratio. Ca - shape factor of appurtenance. For rounds, Ca varies between .8 and 1.2 for L/W = 7 to 25 respectively. For flats, varies from 1.4 to 2.0 for L/W = 7 to 25 respectively.

Where did the confusion on EPA, FPA and PA come from? The EIA-222 specification has had various revisions, resulting in a proliferation of methods. For Rev C, the world used FPA, and when Rev D came out, the procedures were changed to EPA. Many antenna manufacturers have still not updated their catalogs. They may not like the larger EPA numbers or they may have limited manpower. There are a lot of antenna manufacturers and many of them use different values and don’t say which method they are using.

The EIA-222-F (current version) spec says that if the antenna is made up of rounds, you can conservatively multiply FPA by 1.8 to get EPA. One of the best methods that some antenna manufacturers publish is the thrust value (T) and the wind speed (V).

To get EPA = T/(.00256 x V x V) (I can’t do the squared thing in plain text) Now the problem gets worse, because almost none of the antenna manufacturers publish information on their antennas with “ICE” and ice controls the design of guyed towers (but it is “optional” whether or not to design for ice and how much ice).

The majority of commercial towers are designed for ½” radial ice with 75% of the basic wind speed wind pressure. So the trick is to figure out which is the value given in: PA, FPA, or EPA. This is mainly done by looking at the antenna and determining the length and width of each antenna element and find its Ca x PA. The total of all elements is the EPA. For ice, you can repeat the process by adding 1” (for ½” radial ice) to all lengths & widths. Or for a quick approximation, if the antenna is made up of many different diameters, take the (EPA/1.2) and divide it by the total length of all the round elements. This will give the average diameter. Then EPA(1/2”) = (D+1”) x (L +1”) x 1.2

MISCELLANEOUS TOWER TIPS

REFURBISHING USED TOWER

TOUCHING UP RUST SPOTS

As long as the tower sections are not corroded to the point where their physical integrity is suspect, surface rust spots and new, bare steel parts can be touched up and fresh, protective galvanizing coating applied with a zinc-bearing paint commonly referred to as cold galvanizing compound. Prep the surface by wire brushing, followed by a scrub with a piece of 3M scotchbrite and clear table vinegar. After drying, paint on the cold galvanizing compound. This paint should contain 90% or more zinc, and the good stuff will weigh about 25 pounds/gallon, 6.5 pounds/quart. It will also be expensive, up to $20-30 or so per quart, $60-80 per gallon. Some good brands are Klein, LPS (cold galvanize), ZRC (Galvilite, www.zrcworldwide.com), Sherwin Williams (Zinc Clad #5), Rust-Oleum (#2185) and DAP (galv-a-grip). LPS also makes an excellent spray-on cold galvanizing product, although spraying makes less efficient use of the product on the round tower members than flat plates.

SEPARATING OLD TOWER SECTIONS

I bought an automobile scissors jack at a garage sale and modified it by having my neighbor weld some small steel angle pieces on the top and bottom of it such that when I expand it inside of either 45 or 25 tower, it allows me to easily separate them. I also had him weld a small bar on the jack where the handle used to be inserted so I can easily hand crank it on the tower. He also welded a short length of chain with a clip on the end of it for attaching it to the tower so I won't drop it one someone's head below.

A tip for using this jack: Insert it in the tower and crank it up against the tower section horizontal cross braces. With all the bolts removed from the section you are taking down, reach up a couple of feet and vigorously jerk the tower leg back and forth several inches. The tower legs should separate a little. Tighten the jack again and shake some more. Continue this until the sections separate.

ADAPTING CATV HARDLINE FOR AMATEUR USE

CHOOSING LENGTH

If you make your CATV aluminum sheathed coax 224.5 feet long it will act like a linear transformer and if you feed it with 50 ohms, you will get 50 ohms out of it at the other end on the frequencies listed above. The minor difference between 1.775 and 1.8-2.0 MHz is minuscule and it will be great for all the other bands!!!! Dunno about WARC. Haven't done any calculations for them. The velocity factor of CATV foam filled aluminum exterior coax is 0.81. The velocity factor for some air-dielectric types is 0.91.

For foam dielectric, if you want it to be half waves or multiples there of at 1.775, 3.550, 7.100, 14.200, 21.300, and 28.400 MHz, use the formula:

984/1.775 and it will give you the answer of 554.366 feet.

That is the length of a full wave length at 1.775 MHz.

Half that for a halfwave and you get 277.183 feet.

Multiply that by the velocity factor of the coax (.81) and you get

277.183 x .81 = 224.5 feet!

HARDLINE CONNECTORS FOR AMATEUR USE

Now for the next problem: connectors.

AD4KT Charlie Davis, Woodland Creek Antennas in Jefferson, GA ,manufactures PL259 coax plugs for ½ and ¾ inch hardline. He is a physicist at the Univ of GA. His price is about $8 for the ½ inch and $13 for the ¾ inch. These are very nice product for CATV hardline and I have one in my hand. His connectors are the appropriate size brass compression copper tubing fitting machined to fit the PL259. Solder the center conductor, apply Pentrox to aluminium /brass surface contact area, tighten the compression fitting and you are done!

You may contact Charlie at 706-367- 8069, cdavis@hal.physast.uga.edu

11 Old Pendergrass Rd., Jefferson, GA 30540

Another source for hardline connectors:

DAVIS RF Co., Commercial wire/cable, RF connectors, custom cable and connector design.

Discounts to hams. Visit their web site at www.davisRF.com.

1-800-328-4773 (1-800-DAVIS RF) POC: Steve Davis, K1PEK

If you want to home brew:

Go to your local Lowes Store (or Home Depot or whatever) and look for a ½" to 3/8" pipe coupling. It is made by Anderson-Barrows. Its Anderson-Barrows designation is U50. The description on the outside of the package says:

`Tubing to Female Pipe Coupling, Part No. BP966-P, ½" x 3/8"`

Remove the inner (loose) tubing and discard it. Place the sleeve end over the ½" aluminum tube and move it back a ways. Take a pipe cutter and cut the aluminum at 7/8" back from the end and then (by taking a utility knife and cutting through the shield along the axis of the coax, using care to not cut oneself) remove the 7/8" aluminum shield and cut away the foam from the center conductor while being careful to not scrape off the copper plating of the center conductor. When you have accomplished that, you are ready for the next part.

Now take the previously-obtained Amphenol barrel connector (designation 83-1J... that's important), carefully examine both ends. On one end you'll see a small c-ring insert. Taking a narrow-bladed hacksaw, cut the end of the barrel connector along the axis of the barrel connector so that the blade bisects and cuts the middle of the c-ring insert.

Voila! The insides now fall out! You'll find you have two plastic inserts and a center conductor. The barrel center conductor will fit over the end of the coax center conductor. Solder it to the coax center conductor so that the closest part of the barrel's center conductor from the aluminum jacket on the coax is 7/16".

Insert one of the plastic inserts back into the barrel so that the end that was not cut will capture the insert. Take the end of the barrel that was cut by the hacksaw and screw it into the threaded end of the U50 coupler. Now take the U50 outer section and (after first putting Penetrox A around the outer portion of the aluminum jacket from the edge to about ¾” back) slide the sleeve portion up and screw the outer portion into it. As it is being screwed together, two things happen:

- The compression fitting clamps down on the aluminum sleeved coax.
- The end of the barrel’s center conductor will come right up snug with the end of the barrel.

You are now an expert! You can go fit the other end with much greater ease!

It works great. Be sure and waterproof it with Starbrite Liquid Electrical Tape or Scotch 33 or Scotch 88 plus some coax seal on top of that, plus another layer of Scotch 33 or Scotch 88 on top of that and you have yourself one Hell of a connection!

The folks at N6IJ, have recently found a quick, simple termination to our 75 ohm surplus CATV coax (.75”) used in longer runs at the site. Simply hacksaw the aluminum jacket, in quarters, about 1” along the axis of the coax, and use an Xacto knife and Needle Nose pliers to tear out the foam dielectric, about ¾” deep into the clean cut end, and insert a Barrel UHF fitting, hose clamping the jacket tightly to the barrrel, and seal with tape. Use NoAlox sparingly between the barrel and the inside of the jacket. Do not use too much NoAlox, or else it may cause a short between the center and jacket.

For another description and photos for making these CATV connectors, see May, 1992 QST under Hints & Kinks, or the ARRL UHF/Microwave Projects Manual.

Here’s another description for terminating hardline:

For the ½ inch CATV try using a reducing compression union, 5/8” to ½” (True Value part 286-738). Cut the plastic coating (if it has it) back about 1.75”. Cut the aluminum jacket about 1.5 inches from the end of the CATV. Use a plumber’s tube cutter for clean edges. Then strip about ¾” of the dielectric away from the center conductor. Put the ½” nut and the compression ring over the aluminum jacket. Shove the dielectric and center conductor into the compression union just as far as you can, making sure that the aluminum jacket gets inside the seat of the ½” end of the union. You should have an ample amount of the center conductor coming out the 5/8” end of the union. Slip the compression ring down on the seat of the union followed by the nut. Tighten it down. Take a UHF barrel and shove it on the center conductor. Make sure it also engages the seat of the compression union. The center conductor should go no more than halfway into the barrel. If you have extra on the center conductor, trim it to make it fit. Put the 5/8” compression ring on the UHF barrel followed by the nut. Crank it down making sure that things are tight and secure. When you put it up on the tower, take either some silicon tape or liquid rubber with you. Apply it generously over the entire connection followed with a good wrap of electrical tape.

The center conductor of the ½" hardline may be a little bit smaller than the center of the UHF barrel. Go to the local hobby shop for some fuel line used in model airplanes, about the next to the smallest size they have. Solder a piece big enough to cover the center conductor in place and shove it into the barrel for a nice tight fit.

For the ¾ CATV, it's a different story. You will probably not find a ¾ to 5/8 reducing compression union, they are apparently rare (if they exist at all). Try a ¾" female hose thread connector that reduces to ½" female pipe thread, a ¾" to 5/8" reducing male, and the compression nut for a 5/8" union. Cut away about 1.5" of the aluminum jacket. Using the ¾ female, start it on the jacket and "score" threads into the jacket, just as far down as you can get it. Take the male and turn it into the end of the female that the CATV comes out of. Tighten it down. With as much of the dielectric as you can get into it, cut away the dielectric. Slide the UHF barrel over it, cut it where needed and secure it with the compression ring and nut. WX proof as above.

All of the compression fittings and connectors are available from True Value hardware and about three bucks apiece. helps.

- **DO NOT use penetrox because with time it will migrate and cause a blow out (always in the middle of a European run in a contest)**
- **DO use silicone grease between the aluminum shield and the barrel connector to keep corrosion down.**
- **Seal it as well as you can**
- **Do NOT use Radio Shack barrel connectors as they will invariably break down during the big JA runs in a contest**

Try to use hard splices as much as possible for the longest term solution. Use 1/8 inch hobby store brass tubing and slit it longitudinally with a dremel tool to slip over the center conductors that are butted together and soldered. Then lay the copper shield of RG-11 over the aluminum shield and smear it up with plenty of silicone grease and seal it well.

WASPS

Towers, for some reason, are a magnet for wasps that like to make their nests on them high above the ground. You will need a product like Wasp-Freeze, or Bee-Bopper to spray them from a distance if they build a nest on your tower or antennas. They are least active when it is dark and cold. Very early morning is a good time to attack them. If you get stung, the best sting remedies seem to be ammonia, and a paste made from Adolf's meat tenderizer and water, which contains an enzyme papain that will break down the poisons in the sting.

BUILDING YOUR OWN BALUN

Here's something by Ed Gilbert, WA2SRQ, on the effectiveness of homebrew choke baluns. They are cheap and effective.

Having access to a Hewlett-Packard 4193A vector impedance meter at work, I have made measurements on a number of baluns, coaxial and otherwise. For my beams I was particularly interested how many turns and on what diameter are optimum for air core coaxial baluns, and what the effect of bunching the turns was (formless). Using the remote programming capability of the HP4193A along with an instrument controller, I measured the magnitude and phase of each balun's winding impedance at 1 MHz intervals from 1 to 35 MHz. For comparison, I also made measurements on a commercial balun which consists of a number of ferrite beads slipped over a short length of coax. I've appended some of these measurements so you can draw your own conclusions.

PVC pipe was used for coil forms. The 4-1/4 inch diameter baluns were wound on thin-walled PVC labeled "4 inch sewer pipe". This material makes an excellent balun form. It's very light weight and easy to work with, and I obtained a 10 foot length at the local Home Depot for about 3 dollars. The 6-5/8 inch diameter forms are 6 inch schedule 40 PVC pipe which is much thicker, heavier, and more expensive.

Each test choke was close-wound on a form as a single-layer solenoid using RG-213 and taped to hold the turns in place. The lengths of cable were cut so there was about 2 inches excess at each end. This allowed just enough wire at the ends for connections to the HP4193A's probe tip. After data was collected for each single-layer configuration, the PVC form was removed, the turns were bunched together and taped formless, and another set of measurements was taken. I have only included the "bunched" measurements in the table for one of the baluns, but the trend was the same in each case. When compared to the single-layer version of the same diameter and number of turns, the bunched baluns show a large downward shift in parallel self-resonance frequency and poor choking reactance at the higher frequencies.

Interpreting the Measurements

All the baluns start out looking inductive at low frequencies, as indicated by the positive phase angles. As the frequency is increased, a point is reached where the capacitance between the windings forms a parallel resonance with the coil's inductance. Above this frequency, the winding reactance is reduced by this capacitance. The interwinding capacitance increases with the number of turns and the diameter of the turns, so "more is not always better".

The effects of a large increase in interwinding capacitance is evident in the measurements on the balun with the bunched turns. This is probably a result of the first and last turns of the coil being much closer together than the single-layer coil.

An important requirement of these baluns is that the magnitude of the winding reactance be much greater than the load impedance. In the case of a 50 ohm balanced antenna, the balun's winding impedance is effectively shunted across one half the 50 ohm load impedance, or 25 ohms. A reasonable critera for the balun's winding impedance for negligible common mode current in the shield is that it be at least 20 times this, or 500 ohms. The measurements show, for example, that 6 turns 4-1/4 inches in diameter meet this criteria from 14 to 35 MHz.

The measurement data also reveals the power loss these baluns will exhibit. Each of the measurement points can be transformed from the polar format of the table to a parallel equivalent real and reactive shunt impedance. The power dissipated in the balun is then the square of the voltage across it divided by the real parallel equivalent shunt impedance. While this calculation can be made for each measurement point, an approximate number can be taken directly from the tables at the parallel resonance points. At 0 degrees phase angle the magnitude numbers are pure resistive.

I didn't record the exact resonance points, but it can be seen from the tables that the four single-layer baluns are all above 15K ohms, while the ferrite bead balun read about 1.4K. These baluns see half the load voltage, so at 1500 watts to a 50 ohm load, the power dissipated in the coaxial baluns will be less than 1.3 watts, and the ferrite bead balun will dissipate about 13.4 watts (neglecting possible core saturation and other non-linear effects). These losses are certainly negligible. At 200 ohms load impedance, the losses are under 5 watts for the coaxial baluns and 53.6 watts for the ferrite beads.

Conclusions

A 1:1 coaxial balun with excellent choking reactance for 10 through 20 meters can be made by winding 6 turns of RG-213 on inexpensive 4 inch PVC sewer pipe.
For 40 or 30 meters, use 12 turns of RG-213 on 4 inch PVC sewer pipe.

Don't bunch the turns together. Wind them as a single layer on a form.
Bunching the turns kills the choking effect at higher frequencies.

Don't use too many turns. For example, the HyGain manuals for my 10 and 15 meter yagis both recommend 12 turns 6 inches in diameter. At the very least this is about 3 times as much coax as is needed, and these dimensions actually give less than the desired choking impedance on 10 and 15 meters.

Measurements

Magnitude in ohms, phase angle in degrees, as a function of frequency in Hz, for various baluns.

	6 Turns 4-1/4 in sngl layer		12 Turns 4-1/4 in sngl layer		4 Turns 6-5/8 in sngl layer		8 Turns 6-5/8 in sngl layer		8 Turns 6-5/8 in bunched		Ferrite beads (Aztec)	
Frequency	**Mag**	**Phase**	**Mag**	**Phase**	**Mag**	**Phase**	**Mag**	**Phase**	**Mag**	**Phase**	**Mag**	**Phase**
1.00E+06	26	88.1	65	89.2	26	88.3	74	89.2	94	89.3	416	78.1
2.00E+06	51	88.7	131	89.3	52	88.8	150	89.3	202	89.2	795	56.1
3.00E+06	77	88.9	200	89.4	79	89.1	232	89.3	355	88.9	1046	39.8
4.00E+06	103	89.1	273	89.5	106	89.3	324	89.4	620	88.3	1217	26.6
5.00E+06	131	89.1	356	89.4	136	89.2	436	89.3	1300	86.2	1334	14.7
6.00E+06	160	89.3	451	89.5	167	89.3	576	89.1	8530	59.9	1387	3.6
7.00E+06	190	89.4	561	89.5	201	89.4	759	89.1	2120	-81.9	1404	-5.9
8.00E+06	222	89.4	696	89.6	239	89.4	1033	88.8	1019	-85.7	1369	-15.4
9.00E+06	258	89.4	869	89.5	283	89.4	1514	87.3	681	-86.5	1295	-23.7
1.00E+07	298	89.3	1103	89.3	333	89.2	2300	83.1	518	-86.9	1210	-29.8
1.10E+07	340	89.3	1440	89.1	393	89.2	4700	73.1	418	-87.1	1123	-35.2
1.20E+07	390	89.3	1983	88.7	467	88.9	15840	-5.2	350	-87.2	1043	-39.9
1.30E+07	447	89.2	3010	87.7	556	88.3	4470	-62.6	300	-86.9	954	-42.7
1.40E+07	514	89.3	5850	85.6	675	88.3	2830	-71.6	262	-86.9	901	-45.2
1.50E+07	594	88.9	42000	44.0	834	87.5	1910	-79.9	231	-87.0	847	-48.1
1.60E+07	694	88.8	7210	-81.5	1098	86.9	1375	-84.1	203	-87.2	778	-51.8
1.70E+07	830	88.1	3250	-82.0	1651	81.8	991	-82.4	180	-86.9	684	-54.4
1.80E+07	955	86.0	2720	-76.1	1796	70.3	986	-67.2	164	-84.9	623	-45.9
1.90E+07	1203	85.4	1860	-80.1	3260	44.6	742	-71.0	145	-85.1	568	-51.2

2.00E+07	1419	85.2	1738	-83.8	3710	59.0	1123	-67.7	138	-84.5	654	-34.0
2.10E+07	1955	85.7	1368	-87.2	12940	-31.3	859	-84.3	122	-86.1	696	-49.9
2.20E+07	3010	83.9	1133	-87.8	3620	-77.5	708	-86.1	107	-85.9	631	-54.8
2.30E+07	6380	76.8	955	-88.0	2050	-83.0	613	-86.9	94	-85.5	584	-57.4
2.40E+07	15980	-29.6	807	-86.3	1440	-84.6	535	-86.3	82	-85.0	536	-58.8
2.50E+07	5230	-56.7	754	-82.2	1099	-84.1	466	-84.1	70	-84.3	485	-59.2
2.60E+07	3210	-78.9	682	-86.4	967	-83.4	467	-81.6	60	-82.7	481	-56.2
2.70E+07	2000	-84.4	578	-87.3	809	-86.5	419	-85.5	49	-81.7	463	-60.5
2.80E+07	1426	-85.6	483	-86.5	685	-87.1	364	-86.2	38	-79.6	425	-62.5
2.90E+07	1074	-85.1	383	-84.1	590	-87.3	308	-85.6	28	-75.2	387	-63.8
3.00E+07	840	-83.2	287	-75.0	508	-87.0	244	-82.1	18	-66.3	346	-64.4
3.10E+07	661	-81.7	188	-52.3	442	-85.7	174	-69.9	9	-34.3	305	-64.3
3.20E+07	484	-78.2	258	20.4	385	-83.6	155	-18.0	11	37.2	263	-63.2
3.30E+07	335	-41.4	1162	-13.5	326	-78.2	569	-0.3	21	63.6	212	-58.0
3.40E+07	607	-32.2	839	-45.9	316	-63.4	716	-57.6	32	71.4	183	-40.5
3.50E+07	705	-58.2	564	-56.3	379	-69.5	513	-72.5	46	76.0	235	-29.6

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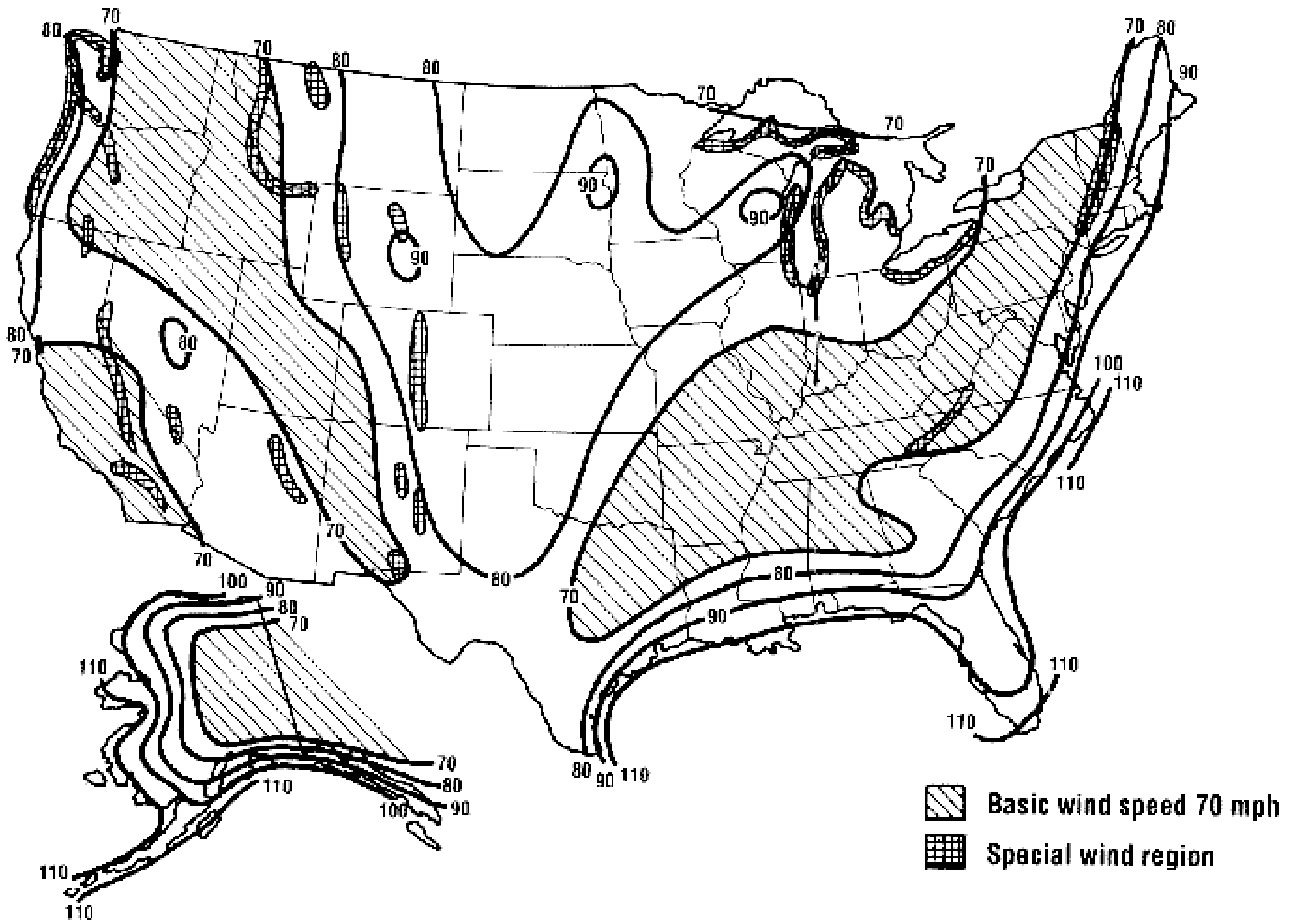
ATTACHING ELECTRICAL ENCLOSURES TO YOUR TOWER

Use some galvanized, punched strut. It’s a channel shaped material, also referred to as Kindorf, Power Strut, Uni Strut, as well as many other names. Bolt this to the tower using U-bolts, or clamps, then use strut nuts, or spring nuts inside the channel to screw the box to.

Wind Speed Zone Map for Use With EIA/TIA-222-E



Notes:
1. Values are fastest-mile speeds at 33 ft. (10m) above ground for exposure category C and are associated with an annual probability of 0.02.
2. Linear interpolation between wind speed contours is acceptable.
3. Caution in the use of wind speed contours in mountainous regions of Alaska is advised.

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