Quick Hoops™ High Tunnel Bender Instruction Manual

9018.999

7030 E 46th Avenue Dr, Denver, CO 80216, United States
support@hensleyseeds.com | hensleyseeds.com

The Quick Hoops™ High Tunnel Bender creates a hoophouse at a much lower cost than with a prefabricated kit. You will be able to extend your growing season and increase both crop quality and yield by protecting your crops from wind, rain, hail, insects, and disease pressure.



April 2012, Caterpillar Tunnel trial at Broadturn Farm, Scarborough, ME

Construction Options:

There are many different options you can choose when building your tunnel. You must decide which of these options suit your immediate needs and choose accordingly. Here are some of the major considerations:

Covering Designs: We provide instruction on two common methods of covering your tunnel:

Caterpillar



Traditional



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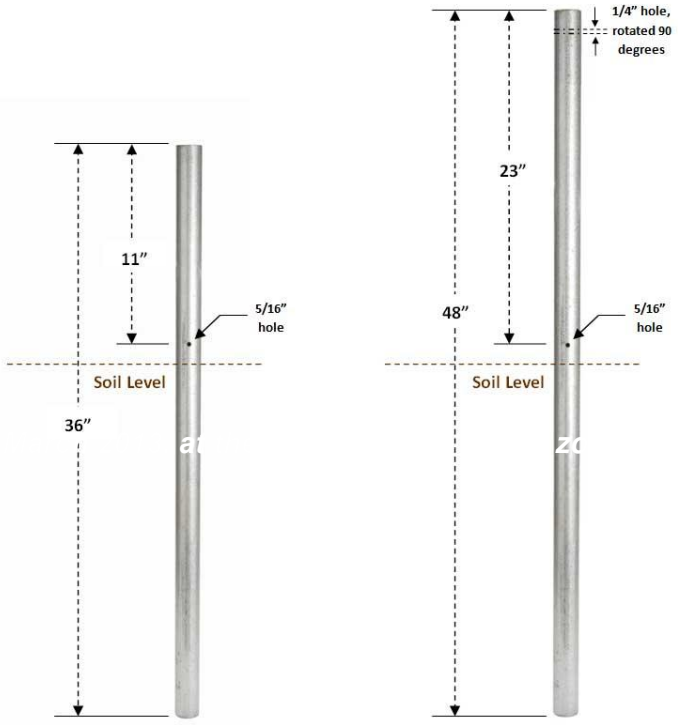
- **Caterpillar Style:** This is typically a 3-season covering that allows growers to add incremental acreage of protection at the lowest possible cost. This is great for beginning growers, established growers who want more reliable crops without the expense of a larger house, and protected cropping for those lower cash crops that could use the help of a hoophouse, but might be a long time providing an equal return for the investment. Caterpillars are also somewhat moveable, as the covering process is not as extensive, which is great for field rotation.

- **Traditional Style**: These are usually fixed structures with end walls and roll-up sides for easier venting. They serve as a great 4-season house option that is comparably lower priced than larger structures. These are also are great for use as a seedling house.

Ground Posts (i.e.: Tunnel Height): Ground posts are made from $1^{5}/_{8}$-inch chain-link fence post material, which is commonly available in 6- or 8-foot lengths. You can make ground posts by cutting either of these sizes in half and predrilling.

- **6-foot fence posts** are the cheapest option. They may be cut in half to produce 3-foot ground posts (with 2 feet in the ground and 1 foot exposed), which **results in a 7-ft. tall tunnel**.

- **8-foot fence posts** may be cut in half to produce 4-foot ground posts (with 2 feet in the ground and 2 feet exposed), which **results in an 8½-foot tall tunnel**. The reason you gain an extra 6 inches on top of the obvious extra foot is because you are only inserting the bows 6 inches into the taller posts, as opposed to 12 inches into the shorter ones. They cost a little more and require some extra drilling, but the resulting extra elbow room for people and crops and overall interior volume increase is very advantageous. It not only improves the tunnel's thermal performance by slowing its overnight temperature drop, but also allows the use of a small tractor inside the tunnel, and allows trellising three rows of vine crops as opposed to two. **Note:** You will need wide plastic, which is a little more expensive.



Contents:

- Curved bender
- Lever bar (for "finishing" the bend)
- (2) ¼" x 5" lag screws for mounting to wood surfaces and (2)¼" x 6" carriage bolts, nuts, and fender washers for mounting to metal or wooden surfaces
- Detailed instructions



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Additional Materials:

For a complete list of additional materials needed, please consult our parts calculator located in the Grower's Library on our website.

- $1^{3}/_{8}$" top rail for chain-link fence
- $1^{5}/_{8}$" fence posts for chain-link fence
- Pro 5 Weed Barrier Landscape Fabric
- Tufflite™ IV Greenhouse Film
- Cross-Connector for $1^{3}/_{8}$" pipe

SITE SELECTION:

We recommend taking a look at *High Tunnels: Using Low-Cost Technology to Increase Yields, Improve Quality and Extend the Season,* a 74 page reference guide, by Ted Blomgren and Tracy Frisch and distributed by the University of Vermont Center for Sustainable Agriculture.

It has a section dedicated specifically to site selection for your high tunnel.

MOUNTING:



The Quick Hoops™ High Tunnel Bender may be mounted to any solid surface, such as a workbench, a picnic table, hay wagon, etc. It may be lag-screwed or thru-bolted into place. $^{5}/_{16}$" mounting holes are provided on the bender and the hardware to mount it are also included. By securing the bender in a fixed position, and pulling the tubing around the bender, the operator can maintain precise control of the tubing being bent.

Wherever it is mounted, it is important to have both enough room to accommodate the infeed and outfeed of pipe, as well as some type of support at the outfeed end about ¾" above the mounting surface. This will prevent corkscrewing and ensure that the hoophouse bows created are in a single plane. This can be accomplished with 1" x 4" slats (actually ¾" thick), ¾" plywood (shown above), or some other similar material.

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BENDING THE PIPES:













1. After determining how many bows your high tunnel will have, set aside twice that many pipes to be bent.
2. Mark these pipes with spray paint or permanent marker on one end so that half are marked on the male, or swaged, end and half on the female end.
3. Insert the unmarked end of a pipe into the holding strap at the end of the bender as shown. If this is the swaged end, insert just past the swage to prevent canting or kinking that portion of the pipe.
4. With a smooth motion, pull back as if on a long oar (do not push), and bend the pipe all the way around the bender until the pipe just touches the end of the bender closest to you. Stop. Do not bend past the end, or the arc you create will not be smooth.
5. Release tension until the pipe is loose in the holding strap, and move it through the holding strap about half the length of the bender itself.
6. Repeat steps 4 and 5 until about 3 feet of unbent pipe remain beyond the closest end of the bender or if bending becomes too difficult.
7. Depending on the orientation of the pipe, insert the lever bar into the female end or over the swaged end of the unbent end of the pipe. This effectively makes the pipe longer and will instantly give you more leverage for bending the rest of the pipe.
8. Repeat steps 4 and 5 until the point where the lever bar meets the pipe is even with the closest end of the bender. Pull back and bend only half way around the bender. This will leave a straight portion that will easily slide into the ground post later on.
9. Repeat for all other unbent pipes, always inserting the unmarked end of the pipe into the bender holding strap first.

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ASSEMBLING THE BOWS:



1. Find a flat surface on which to lay 2 bent hoops. This could be the ground, a hay wagon, greenhouse table, etc. We happened to use a utility trailer on the job site shown above.
2. Insert the unmarked swaged end of one bent pipe into the unmarked female end of the other.
3. About 1 inch from the end of the outer female end, secure with two #10 x ¾" self-drilling tech screws. Remember to always keep screw heads facing away from where plastic will eventually be.



4. The bow is now complete. You will notice that the bow is actually 13–15-feet wide. That is perfect, because having preloaded stress on the bow when you compress it into 12-foot spaced ground posts will make the structure stronger.
5. Repeat steps 1–3 for the rest of the prebent hoops.

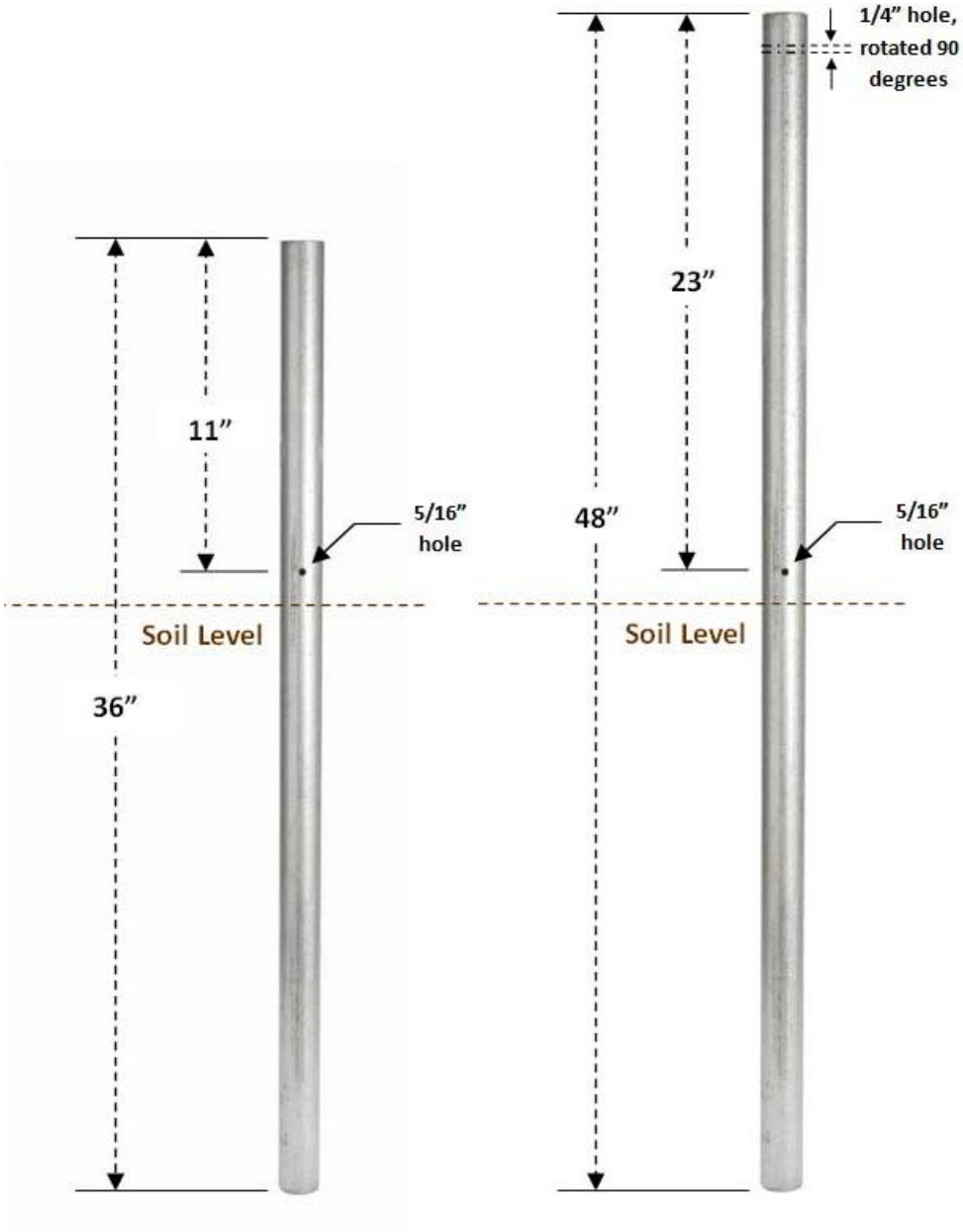


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GROUND POSTS:

Refer to page 2 for information on the benefits of each ground post height to help make your decision.

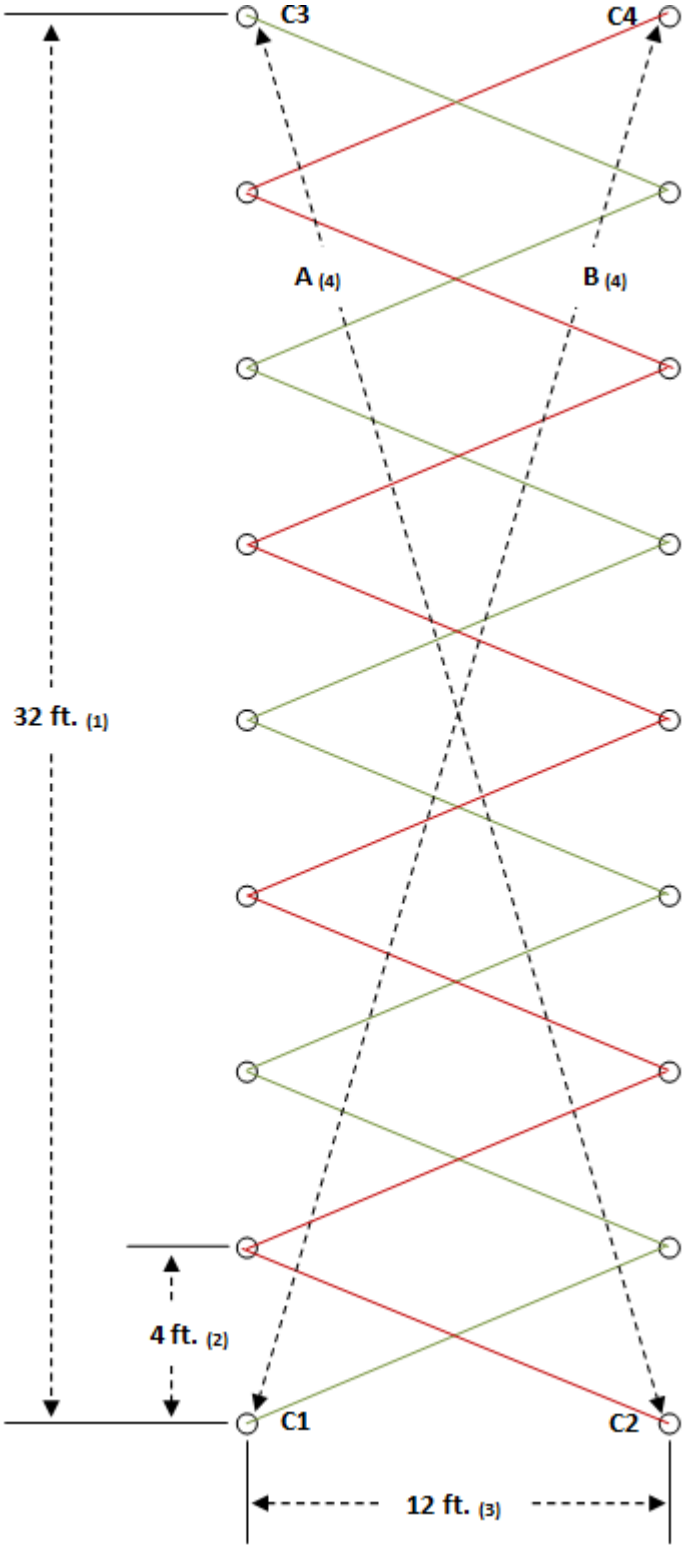
1. Determine the length and bow spacing you would like your tunnel to have and plug those values into our spreadsheet calculator. Then choose whether you would like short or tall ground posts. The calculator will tell you how many pieces and what size of line post to buy.
2. Cut them all in half with a band saw, reciprocating saw, or hack saw (if you're not doing too many) to create two vertical ground posts from each line post.
3. Predrill each per the diagram. Drill all the way through both sides. Deburr the cut end and the predrilled holes of each ground post to remove any sharp edges.
4. Make a mark 24 inches in from the bottom end as a guide for insertion into the ground.



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DESIGNING YOUR STRUCTURE:

Use the following diagram to help determine the size, spacing, and layout of your structure. For those that are building a caterpillar tunnel, the red and green lines indicate individual pieces of lacing.



Notes:

(1) Determine the desired overall length of tunnel. In this example, our tunnel is 32-feet long.

(2) Pick a distance between bows that will divide into that number. We chose 4 feet between bows because we wanted to build a strong tunnel. This could be as close or as far (within reason) as you want.

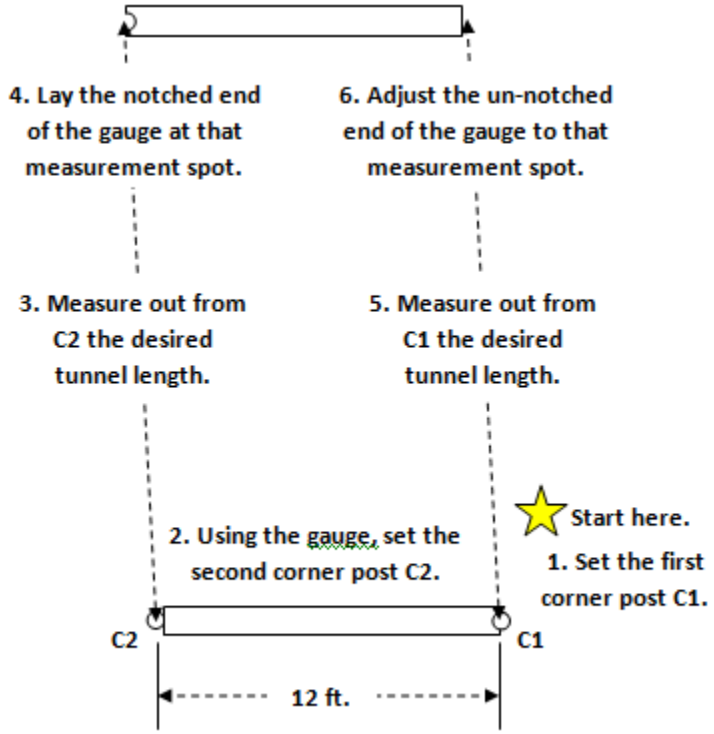
(3) The width of the tunnel will be 12 feet.

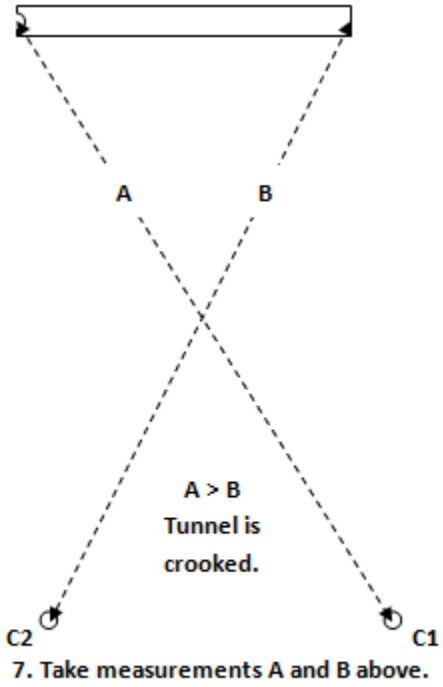
(4) Distances A and B must be equal for the tunnel to squared off and be a true rectangular shape.

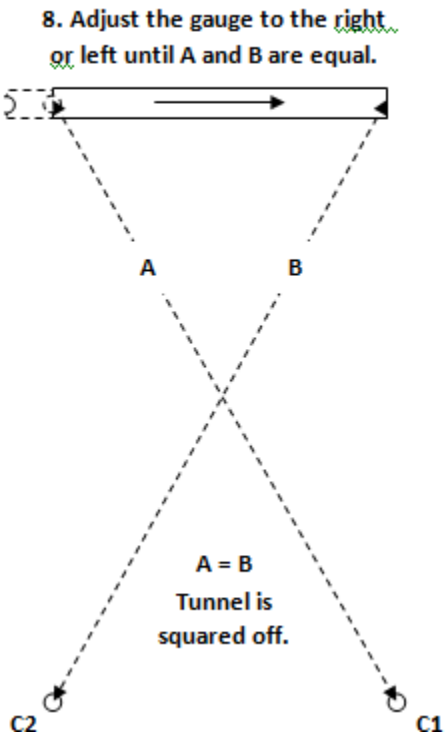
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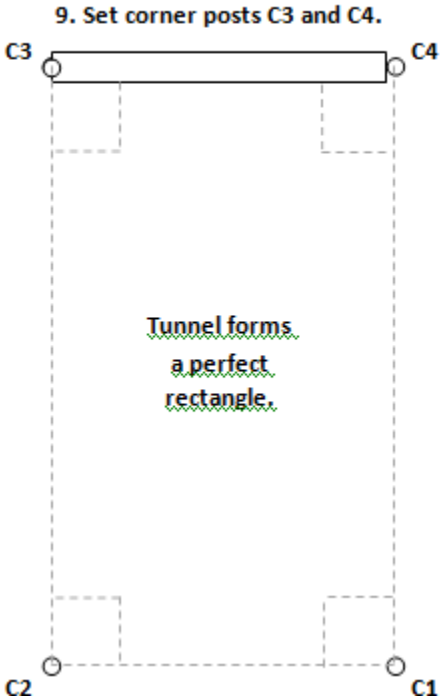
TIPS FOR SETTING THE CORNER GROUND POSTS:

Use the following diagrams to help you set the corner posts in a perfect rectangle.









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SITE PREPARATION AND SETTING THE GROUND POSTS:

1. Prepare the footprint of the tunnel as if you would open soil in a field. Do as much of the tilling, plowing, mulch-laying, etc. before the tunnel is erected to avoid having to resort to smaller equipment to accomplish these tasks later.
2. Create a gauge for setting posts by using one 2-in. x 4-in. x 12-ft. piece of wood, and simply cutting a small notch in one end. This will be the gauge between ground posts for a single bow.
3. **Weed Barrier:** An option to consider at this point is weed barrier along the edges of the tunnel. This is traditionally an area where weed control is difficult and some fabric that suppresses weeds can be very effective here. If you choose this option, proceed to step 5.



4. **If you choose to forgo weed barrier, proceed as follows:** Set the 4 corner ground posts first (refer to the diagram, on page 8 for this part of the procedure).

   a. Place the first corner post (#1 pictured above) in the desired location with the predrilled hole closest to the top. Insert the mushroom-shaped ground post driver in the top and drive it in about 2 feet with a sledge-hammer until the mark is at the soil surface.

   b. Place the notched end of the 12-foot gauge you made in Step 2 against post 1. Swing the opposite end the gauge to where you would like post 2 to be. Holding the new ground post against the unnotched end, drive it in place.

   c. Using a long tape, measure to where the opposite end of the tunnel will be. Mark approximately where you expect to put post 3.

   d. Lay the notched end of the gauge down at that spot. Lay the opposite end where your think post 4 will be. Measure from post 1 to the notch in the 12-footgauge. Then measure from post 2 to the unnotched end of the gauge. These measurements should be the same for the tunnel to be square and true. Adjust the gauge until they are.

   e. Set corner posts 3 and 4.

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f. Run the long tape from corner post 1 to corner post 4. Secure one end to post 1. Pull it tight and secure the other end to post 4. Secure with duct tape, clamps, or something similar. This will serve as a gauge as well as a straight line for setting the other posts.

g. Using the long tape measure as a guide, set the rest of the posts for this side of the tunnel.



Ground Post Driver





h. Repeat steps 4.f. and g. for the other side of the tunnel.

i. **Inspect the orientation of ground posts and adjust as necessary:** Predrilled lacing bolt holes (near the ground) should be facing outward from the tunnel to minimize adjustment later on. On taller ground posts, bolt holes for the bolts that hold the bows in place (near the top of the ground posts) should be in line with the length of the tunnel. With a pipe wrench or similar tool, rotate any ground posts as needed so that they are correctly oriented.



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5. **If you <u>do</u> choose to use weed barrier, proceed as follows:**

   a. Perform steps 4.a. through e.

   b. If you have a pair of D-handle garden forks or spades, you can quickly set up your weed barrier on a makeshift spool such as this. This makes handling and cutting to length very easy. A piece of top rail is used as the spindle. Position at one end of the tunnel location and offset, so that it faces down the side of what will eventually be the tunnel. Pull the weed barrier off the roll and walk with it down the side of the plot until you reach the opposite end. Cut it to length, leaving about 1 foot of overlap on each end. Cutting is most cleanly and easily done with a utility knife with the weed barrier laying against the ground, by drawing the knife's razor blade through it and the top of the soil at the same time.

   c. Fold the 4-foot wide weed barrier in half, making it 2-feet wide. <u>Position so that the folded edge faces the inside of the tunnel.</u>

   d. Make a 2-inch cut centered between the sides of the fabric that is about 1 foot in from one cut end. Make just a single cut in line with the length of the fabric. Slip this end of the double-layered fabric over the end post near it.

      With only a single slit, the fabric will be somewhat snug against the post, which helps prevent weeds from growing up through the hole.

      <u>A note about weed barrier</u>: Keep the top of the weed barrier fabric free of soil as best you can. If soil is allowed to collect on it, weeds will likely germinate in that soil and root through the weed barrier, which will make them difficult to kill and remove by physical means.









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e. Go to the opposite end of the fabric, pull it somewhat taught, and make a similar cut that is even with the corner ground post at that end. Slip it over the ground post and smooth out the weed barrier along the length of the tunnel.

f. Secure the edges of the weed barrier to the ground with fabric staples along its edges. A hammer is sometimes helpful in difficult soils.

g. Repeat steps 5.b through f. for the opposite side of the tunnel.

h. Run a long tape measure down the center of one of the pieces of weed barrier fabric and secure to the corner posts with clamps, etc.

i. Make 2-inch slits with a razor knife for the rest of the ground posts on that side of the tunnel. For example, make a cut every 4 feet if your tunnel will have 4-foot bow spacing.

j. Drive ground posts in each of the slits.

k. Repeat 5.h. through k. for the opposite side of the tunnel.

l. For caterpillar tunnels, predrilled lacing bolt holes should be facing outward from the tunnel to minimize adjustment later on. For caterpillars on long ground posts, preinstall J-bolts in the lower holes before driving them in. For traditionally covered tunnels, bolt holes for the bolts that hold the bows in place should be parallel to the length of the tunnel. With a pipe wrench or similar tool, rotate any ground posts as needed so that the predrilled lacing bolt holes (for caterpillar tunnels only) are perpendicular to the length of the tunnel (facing out and in).









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FRAMING THE TUNNEL:



1. Short Ground Post Procedure:

a. Make a mark on each of the bows about 13 inches from the end. This will be used as a guide for insertion into the ground posts.

b. Transport the first end wall bow to the furthest corner posts and insert to the marks made above.

c. Repeat for the rest of the bows, **keeping all the bows oriented the same** with the swaged ends of each bow on the same side of the tunnel. This will make alignment of the ridge pole much easier.



d. **Loosely attach the ridge pole.** These instructions detail installation with cross-connectors. You may also thru-bolt the ridge pole to the bows if desired.

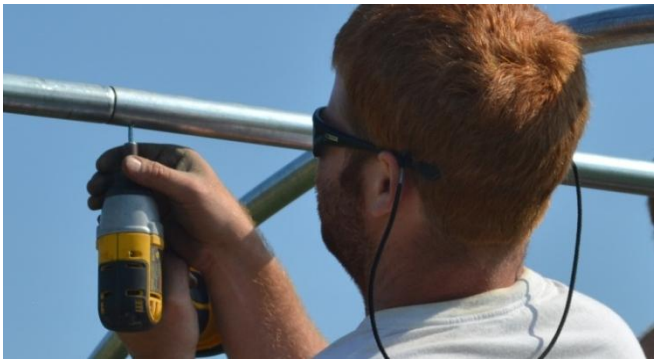
   i. Loosen the nuts on all the cross-connectors as much as possible, without taking them completely off. Slip one over the top center of each bow.

   ii. Slide a section of $1^{3}/_{8}$" top rail through the last 2–3 cross-connectors on one end of the tunnel with the female end pointing out and flush with the outside end of the first bow's cross-connector.



   iii. Repeat Step c. above with swaged ends fitting into the next pipe's female end, until they are run the entire length of the tunnel.

   iv. Similar to the bow construction, somewhere around the middle of the swaged area of each pipe (about 3 inches from the end of the outer female end), secure through both pipes with a self-drilling tech screw. Repeat for all points where the ridge pole sections come together.



   v. At this point, the ridge pole is solid and part will be extending out one end of the tunnel.

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e. Stand back and view the structure critically from the sides and very ends. Adjust the bows up or down within the ground posts until the structure is symmetrical and straight to the eye. Ensure that you can still see the metal of the bows through the predrilled holes in the ground posts.



f. Using the predrilled holes in the ground posts as a guide, with a $^{5}/_{16}$-inch drill bit, drill through the inserted portion of each bow.

g. Bolt bows to the ground posts.



i. <u>For caterpillar tunnels</u>: Select a J-bolt and thread its included $^{5}/_{16}$-inch nut all the way on, leaving about ¼ inch of thread showing on the J end of the bolt. Add a lock washer and insert through the $^{5}/_{16}$-inch hole on the end of the half bow. Add a lock washer and nut on the opposite side and tighten, leaving the tail of the J pointing down. Repeat for the rest of the ground posts.





ii. <u>For traditional coverings</u>: Lay a 1-inch x 8-inch x 16-foot piece of ledger board up against the outside of edge the ground posts; this will serves as the baseboard. **Note:** This material is a suggestion only. Other materials are available that may offer better rot resistance, etc. Using the predrilled holes in the ground posts and bows as a guide, drill through the baseboard with a $^{5}/_{16}$-inch drill bit. Select a J-bolt and thread its included $^{5}/_{16}$-inch nut all the way on. Add a flat washer and insert through the $^{5}/_{16}$-inch hole on the end of the half bow. Add a lock washer and nut on the opposite side and tighten, leaving the tail of the J pointing down. Repeat down both sides of the tunnel. Where individual pieces of board butt together, join with a small piece of scrap that overlaps the butt joint and secure with wood screws.

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h. **Tightening the cross-connectors:**

i. Once again stand back and view the structure critically from the ends.

ii. Adjust the cross-connectors from side to side until the ridge pole runs straight down the length of the tunnel.

iii. Run the long tape measure the length of the tunnel on top of the center of the bows.

iv. Tighten cross-connector at the end wall where you started. Add a tech screw through the cross-connector into the ridge pole to prevent it from pulling out (see photo below left).

v. Secure the end of the tape measure to the cross-connector at that end with a clamp. Allow the weight of the tape to hold it taught on the opposite end.

vi. Move to the next bow and using the tape measure as your guide, adjust the bow along the ridge pole so that it is exactly the same distance from the end wall bow as the spacing of the ground posts – 4 feet for us. Tighten the cross-connector.

vii. Repeat until all cross-connectors have been tightened.

viii. Add a tech screw to other end wall bow as you did in step 1.i.iv. above.

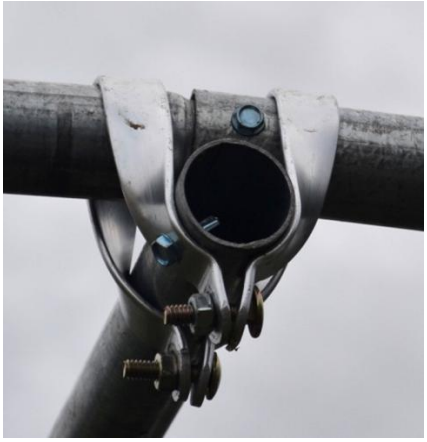
i. Cut off any excess ridge pole protruding beyond the end of the end wall bow with a hacksaw or reciprocating saw.

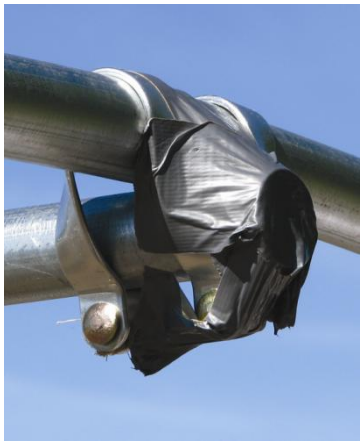
j. Install duct tape over the ends of the ridge pole and wrap the tops of each ground post to prevent plastic from being torn on any metal burrs that may be present.











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2. Long Ground Post Procedure:



a. Make a mark on each of the bows about 6 inches from the end. This will be used as a guide for insertion into the ground posts.

b. Clamp large vise grips or spring clamps onto each side of the bow just above the mark to keep it from slipping into the ground post.

c. Transport the first end wall bow to the furthest corner posts and insert to the marks made in step 2.a. above.

d. Using the upper predrilled holes in the ground posts as a guide, with a ¼-inch drill bit, drill through the inserted portion of each side of the bow. These should be aligned such that they are in line with the length of the tunnel.



e. Secure the bow to the ground post with ¼"-20 x 2" hex bolts and ¼-inch nylock nuts.

f. Repeat steps 2.a. through f. for the rest of the bows.



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g. **Loosely attach the ridge pole**.

One of the advantages of longer ground posts is that it raises the center of peak of the tunnel to 8½-feet tall. This conveniently allows access with a pickup or small tractor. We made use of that benefit when putting the ridge pole on a 200 foot. caterpillar tunnel, which made very fast work of this job.



Use the same procedure for attaching the ridge pole as for the short ground posts: steps 1.d.-1.j.

Skinning the Tunnel — Caterpillar Style: This part of the procedure describes how to create a caterpillar or walk-in style tunnel covering. Later in this manual we will discuss creating a more traditional covering style with poly latch wire, end-walls, and roll-up sides. If you would prefer that type of covering, proceed to page 23. Some growers create hybrids of both of these styles with tunnels that have end walls, but are laced and vent like a caterpillar tunnel. We encourage you to build the tunnel that best suits your own operational and financial needs.

1. Obtain 4 T-posts from your local farm supply or home improvement store. Drive 2 T-posts, side-by-side, at about a 45 degree angle, 5 feet from each end of the tunnel, using a heavy cylindrical post pounder. Drive as close together as possible, with the ribs facing toward the other T-post.



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2. **Plastic:** Save this step for the morning if possible since it is generally less windy, unless you have many hands to help and the wind is not that strong. If you have short ground posts, your greenhouse film should be 20-feet wide; if you have tall ground posts, your film should be 24-feet wide. It should also be 15–20 feet longer than your tunnel.
3. Unroll the plastic, along the side of the tunnel. You can do this by carrying the roll on a piece of pipe while the T-posts serve as a convenient clamp (as shown), or by creating a makeshift reel like we did for the weed barrier (as shown on page 11). Before you cut the plastic to length, ensure that the plastic is centered lengthwise, and that there is at least 7–10 feet beyond each end of the tunnel.
4. If you have taller ground-posts, the tunnel peak will be 8½-feet tall, which most people can't reach. Therefore, before pulling the plastic over the tunnel, it's a good idea to add ropes every 20 feet or so to aid in controlling the plastic, especially if there is any wind at all. Do that by wrapping a tennis ball in plastic near the edge that will go over the tunnel, tie some rope around it, and cast the other end over the tunnel with a small weight tied to it.
5. With everyone in place, at the ends and along the side, and some pulling on the tennis ball ropes, raise the plastic up and over the tunnel.
6. Once that plastic is on top, it will be like a big sail, so controlling it and holding it down will be key, especially on longer tunnels. Ensure that you have enough people to do so. The tennis ball ropes can also be tied off to J-hooks to temporarily hold the plastic in place.











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7. Adjust the plastic so an equal length drapes over each side along the entire length of the tunnel.
8. Secure one end of the plastic with weights, clamps, people, or the roll itself if a lot remains on it.
9. At the opposite end, with the plastic draped smoothly over the end and even laterally, gather the end of the plastic in a big pony tail. Start in the center, and work out to each side, pulling the plastic snug as you go. You should have what looks like the end of a very large bread wrapper in your hands when you are done.
10. Twist the pony tail, and with 2 helpers spreading the T-posts apart, insert the pony tail between them and slide it as close to the bottom as possible. Take care not to snag it on the ribs of the T-bars. Then, with it still twisted, wrap it around one of the T-posts and back through again.
11. While still holding the pony tail, release the T-posts and compress them onto the plastic.
12. Tie the end of the pony tail with parachute cord or rope to prevent it from uncurling. Then tie the T-posts tightly together.
13. Go to the opposite end of the tunnel. Repeat steps 10 through 12 except that this time, when you gather the plastic and insert it into the T-posts, pull it lengthwise as tightly as you can.
14. At this point the tunnel should have plastic tied off at the ends and draping loosely, but smoothly over it.







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15. **Lacing:**

Parts of this process are not unlike lacing your shoes. Refer to the diagram on page 7 for the pattern. There are many lacing materials that you could use. Source trials tested military parachute cord, which has great availability online and is low cost. It has a high tensile 550-pound test multi-strand core and a smooth over braid which slid over the plastic effortlessly. It tested very well for us, without one breakage, and we highly recommend it. The following is a 2-person operation with each person positioned on opposite sides of the tunnel.







***Note*: Do not throw the whole spool over to the other side of the tunnel.** *The cardboard ends on these spools are typically weak and will easily come off, which result in a very unwanted, tangled mess.*

a. Insert the end of the cord through a fairly full roll of duct tape.

b. Tie the end of the spool to a lacing bolt on one of the corners of the tunnel.

c. Put the spool on a large screwdriver or something similar and have one person hold it.

d. Pull enough slack cord off the spool to go over the tunnel and back, and throw the duct tape over the tunnel.

e. From the opposite side of the tunnel, the person who is not holding the spool must pull enough slack cord off the spool to go over the tunnel and back, and then throw the duct tape once again over the tunnel.

f. Loop the cord under the next bow's lacing bolt while holding some light tension on the laced cord — enough to prevent it from unhooking from the lacing bolts.

g. Keep repeating these steps until you reach the last bow at the other end of the tunnel. Temporarily tie off the cord on the last corner lacing bolt on that end.

h. Repeat steps 15.a. through h., starting at the same bow, but on the opposite side.



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16. **Tensioning:**

a. Start in the same positions you started at in step 15.b. on page 20.

b. Pick one of the cords, and with one person keeping tension, while the other cinches up the cord, working back and forth down the tunnel until you reach the end.

c. Tension and tie off permanently on the last corner's lacing bolt with a trucker's hitch, illustrated below.





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17. **Access and Venting** are accomplished the same way, by simply lifting up the plastic.



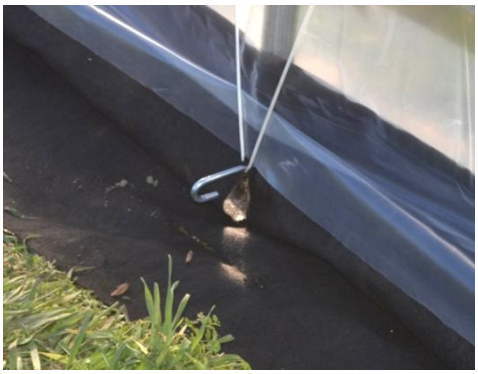
   a. Start at one end of the tunnel, grasp the bottom edge of the plastic between the first and second bows, and raise it to the desired ventilation level.
   b. Repeat down the entire length of the tunnel.
   c. Repeat for the opposite side of the tunnel to ensure good air circulation.

18. **Seasonal Caterpillar Operation:**

   a. Early spring and late fall: You will generally want to leave the tunnel sides fully closed, day and night for maximum warming.
   b. Mid-to-late spring and early-to-mid fall: Closed at night, vented a foot or two high during midday.



   c. Summer: Pretty much opened all the time, except for stormy days. This design relies on friction to hold the plastic at a given ventilation height. We found that in the intense heat of the summer, the plastic expands substantially, beyond the point of adjustment by tensioning the lacing. To avoid having to readjust the pony tails within the T-posts, we found that spring clamps were the answer. They kept the now loose plastic perfectly suspended at any height we desired. They were about $1 each at a home improvement store and well worth the investment. We also found that we could use them for extra security to hold the plastic to the bottom of the bows during storms. Shade cloth is also an option for protecting crops from summer heat.



   d. Winter operation: If you are operating your tunnel during the winter, you will want to seal the bottom outside edge. You can do that as follows if you have installed weed barrier fabric:
      i. At the base of each bow:
         1. Cut a slit in the weed barrier that is perpendicular to the tunnel.
         2. Release the lacing at the J-bolt and leave hanging.
         3. Flip the top layer of weed barrier fabric up over the J-bolt and tuck up under the edge of the plastic.
         4. Replace the lacing now over the plastic and weed barrier.
      ii. Use sandbags at the edges of the plastic near the ends to hold it down to the ground and provide a good seal there.
      iii. Internal row cover directly floating on crops or suspended by hoops will add an extra layer of protection and spur growth even earlier in Spring.



   e. Winter layup: If you choose to not use your tunnel in winter (or if you are bracing for a major storm), simply rotate the plastic all the way over to one side and leave it there. Tying it to the bows is also a good idea, to prevent wind from wreaking havoc. In early spring, the plastic can be rotated back into place and used to melt the snow, allowing an earlier start on the season.

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Skinning the Tunnel — Traditional Covering Style:

This part of the procedure describes how to create a more traditionally covered tunnel with end walls, doors, and roll-up sides. There are no hard and fast rules to tunnel construction — it depends on your operational needs as well as your financial requirements.

1. **Baseboards:** These should have been installed on the side of the tunnel per step 1.g.ii. on page 14 of "Framing the Tunnel." The picture below shows a lower cost material — 1-inch X 8-inch pine ledger board, a rough-cut wood that is used for concrete forms. Conveniently, it comes in 16-foot lengths. Some other common materials chosen for baseboards are 2-inch X 6-inch to 2-inch X 10-inch pine boards or similar. The taller the material, the more wind and cold protection it gives to the plants near the sides of the tunnel.

    a. If you have not installed these already, lay a piece of whatever material you have chosen for baseboards against the outside of edge of the bottom of the ground posts. Using the lower predrilled holes in the ground posts and bows as a guide, drill through the baseboard with a $^{5}/_{16}$-inch drill bit. Select a J-bolt and thread its included $^{5}/_{16}$-inch nut all the way on. Add a flat washer and insert through the $^{5}/_{16}$-inch hole on the end of the half bow. Add a lock washer and nut on the opposite side and tighten, leaving the tail of the J pointing down. Repeat down both sides of the tunnel. For taller materials, you may also want to install a carriage bolt above the J-bolt.

    b. Where individual pieces of board butt together, join with a small piece of scrap that overlaps the butt joint and secure with wood screws.

    c. Install 2-inch X 6-inch X 12-foot pieces of pine or similar material across the end walls to serve as the baseboards there. Predrill with a ¼-inch drill bit through the ground posts and thru-bolt with ¼"-20 X 3" carriage bolts and nuts. A thicker material was chosen for these baseboards because they will support the door frames and act as door jambs, which will likely get stepped on and take frequent abuse.



***Note:** Please disregard the lower horizontal pipes shown in these pictures. These were originally purlins that were located higher up that the owner decided not to use. They were only left in place because they function to strengthen the structure.*

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2. **Hipboards:** These provide some bracing for the tunnel and a convenient place to mount poly latch wire channel. They are typically made out of 1-inch X 6-inch or 2-inch X 6-inch board. In this picture, we used the same 1-inch X 8-inch ledger board for hipboards on this smaller tunnel. On the longer tunnels at our farm, we used 1-inch X 6-inch boards.

   a. Determine your desired venting height for roll-up sides and clamp your first piece of board to be used for hipboards to the bows so that the bottom edge is at that height and so that it is flush with one end and an even distance from the baseboard at both ends. From the inside, drill through the bow first and then through the board with a ¼-inch drill bit and thru-bolt with ¼"-20 X 3" carriage bolts and ¼-inch nuts. Repeat down both sides of the tunnel.

   b. Where individual pieces of board butt together, join with a small piece of scrap that overlaps the butt joint and secure with wood screws.

   c. Install 2-inch X 6-inch X 12-foot pieces of pine or similar material across the end walls to serve as the baseboards there. Predrill with a $^{5}/_{16}$-inch drill bit through the ground posts and thru-bolt with $^{5}/_{16}$"-18 X 3" carriage bolts and nuts. A thicker material was chosen for these baseboards because they will support the door frames and act as door jambs, which will likely get stepped on and take frequent abuse.



3. **Poly Latch Wire Channel:** This is a reusable and high-integrity connection system for high tunnel plastic and other cover materials. The extruded aluminum channel can attach to high tunnel frames, baseboards, hipboards, door frames,. It bends readily over hoops and has a machined groove to center drill bits or self-drilling tech screws when attaching. A preformed stainless spring steel wire securely locks materials into the channel by snapping over the covering and into the channel to quickly secure greenhouse film, shade cloth, etc. It also conveniently tensions the covering as the wire is installed. Safety glasses are highly recommended because the end of the wire can flop around wildly as it is being “wiggled” into place. The wire is shorter to minimize that effect.

   a. **Poly Latch Channel on Hipboards:** Hold a piece of Poly Latch Wire Channel on top of one end of a





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hipboard. Center it vertically and clamp it in place. Using #8 X ½-inch Phillips-head self-drilling tech screws, secure it in place. Phillips head screws are used to prevent damage to the plastic. Install screws every foot or so. Butt a second piece up to the end of the first and secure in place. Repeat down both sides of the tunnel. Use a hack saw or reciprocating saw to cut the final pieces to length prior to attaching.

b. **Poly Latch Channel on Baseboards:** Attach a small piece of scrap or a small precut piece of channel at the top edge of each end of each base board. This could be as short as 1½ feet or as long as the bow spacing. The latter would be desirable for longer tunnels. This will be for the draft prevention overlap layer that prevents air intrusion when the roll-up sides are closed.

c. **Poly Latch Channel on End Bows:** On the outside of the tunnel, hold a piece of channel vertically and rest it on the baseboard at the bottom of one side of one of the end bows. Clamp it tightly to the end bow. Using a #8 X ¾-inch Phillips-head self-drilling tech screw, secure it in place. With a screw now in place, loosen the clamp and squeeze the aluminum channel against the bow, forming the next couple feet of it around the curvature of the bow and over the hipboard and horizontal poly latch wire channel. Clamp it in place and cut it just below the hipboard. Clamp it again to the bow and secure with two more Phillips tech screws. Clamp the leftover piece of channel to the end bow just above the hipboard and secure in place with a tech screw. Form the next couple feet around the curvature of the bow and clamp in place. Secure with tech screws about every foot or so. Attach the next piece butted up to it in a similar fashion as before. Continue up and over the peak as shown in the inset photo below and down over the opposite side of the bow. Repeat for the opposite end of the tunnel.







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4. **Doors:** There are many ways to do doors. This is how we did ours. We were going for maximum light and minimum cost.



   a. Determine your desired door width. You certainly would want it wide enough for tiller access. You may even want to build a ramp on either side of the baseboard for easier access. Our width was based on the material we used for the door and being able to access with a tiller.

   b. We wanted our door to have a Clear Polycarbonate roofing panel in it. These come in 26-inch X 8-foot corrugated sheets. To create a frame for it, we needed (2) 2X4s on the top and bottom that were the width of the panel, plus 2 times the width of the 2X4 itself. The 4-inch side of a 2X4 is actually 3½ inch, but we have to account for a channel we would mill in the edge of the 2X4s that is ¾-inch deep. So, 26 inches +(2*3½) - (2*¾ inch) = 31½-inch wide. The height of the door has to be a bit less than the end wall bow height. This one was going on a tunnel that had short ground posts, so we made it 64½-inch long (the remaining length of a 2X4 that is 8-feet long).

   c. Before cutting, using a table saw and a dado blade, we milled a channel in the edge of the 2X4s about ¾-inch deep. You can also run the boards over a standard table saw blade several times, moving the guide over an ⅛ inch or so each time (about the “kerf” or cutting width of the blade) in order to achieve the same effect.

   d. Cut the 4 boards for each door to length and assemble the door loosely as shown above. Check for square and clamp in place. Using 4-inch wood screws, secure each corner from the outside of the longer boards into the end of the smaller boards. Predrilling first and counter-sinking each hole are also recommended.

   e. We also attached 1X4 boards with 1½" wood screws across the center of each side of each door for added strength.



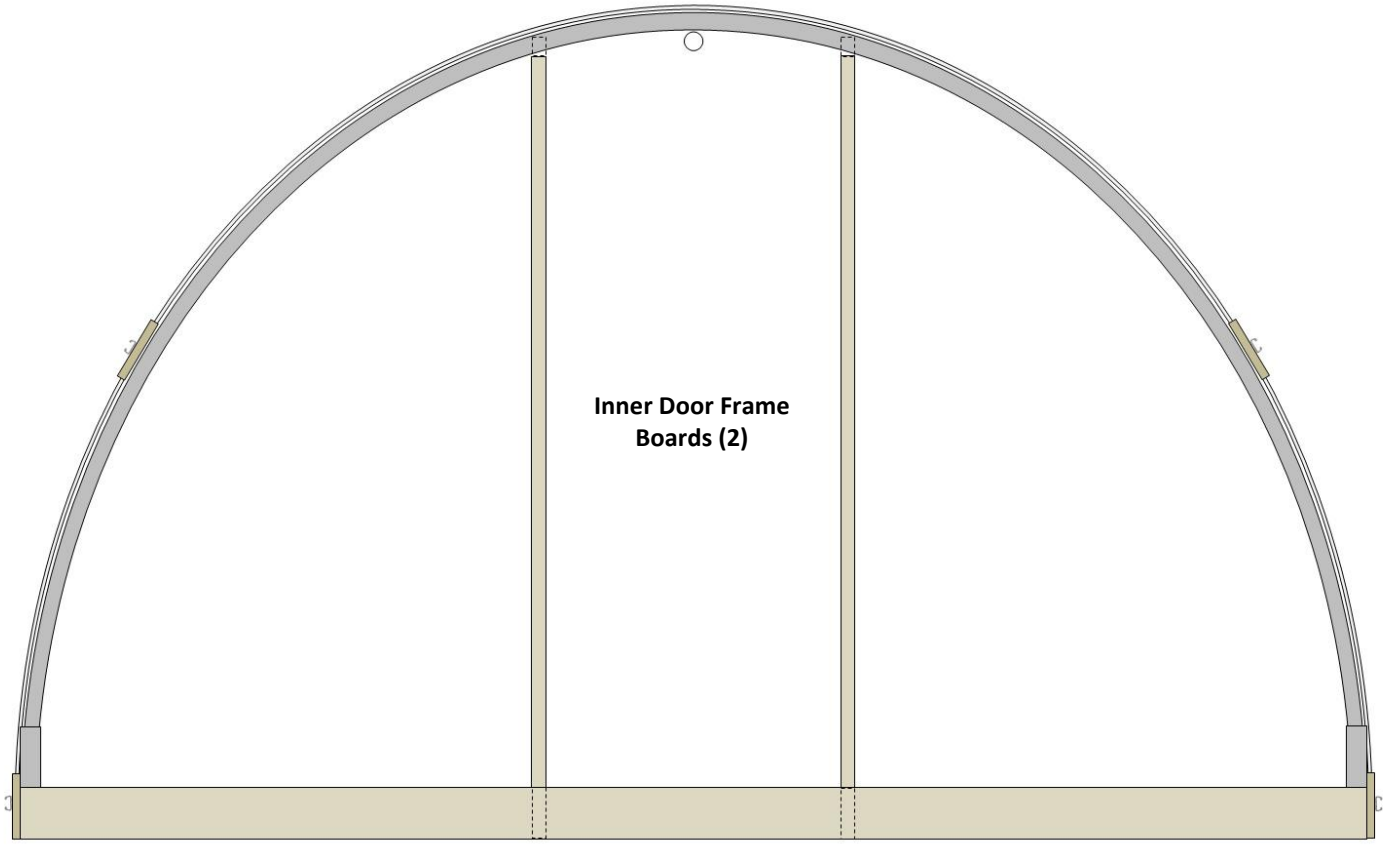
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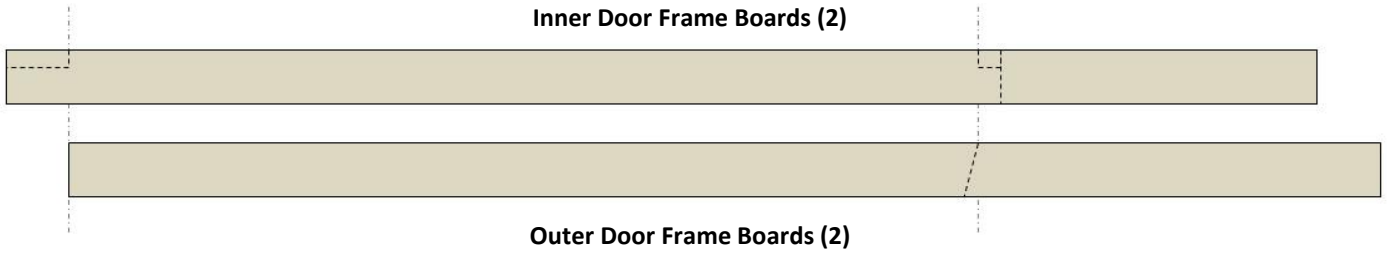
5. **Door Frame and End Wall:** Again, there are many ways to do this. This is how we did ours:

   a. **Doorway width:** Starting on one end of the tunnel, find the center of the end wall baseboard and make a mark. Measure out to the left from that mark one half the width of the door (15¾ inch) and make a mark. Repeat to the right as well.

   b. **Inner door frame boards:** Stand a 2X4 vertically on end up to the edge of one of these marks so that it is just inside the end wall baseboard and the end wall bow. Position it such that its widest side is facing you the 2X4 should be touching the ground and should be to the inside of the mark to allow the door to overlap. Clamp or hold a level up to the side of the 2X4 and position it so that it is plumb (perfectly vertical) and clamp it to the bow. Make a mark on the 2X4 just under and just above the bow as well as just above the baseboard. Make a mark on the bow also, even with the inside of the 2X4. With a “try square” or “L square,” draw lines to cut the 2X4 to length and to cut notches for the bow and baseboard as shown above.

      Cut out the notches with a saw. Stand the 2X4 back up where it was, check it for plumb, and clamp it in place. Secure from the outside on the bottom with 2½-inch wood screws. On the top, predrill horizontally through the bow and then through the notched end of the 2X4 with a ¼-inch drill bit, and secure the top of the 2X4 with a ¼" x 4" carriage bolt, washer and nut. Repeat for the opposite side.

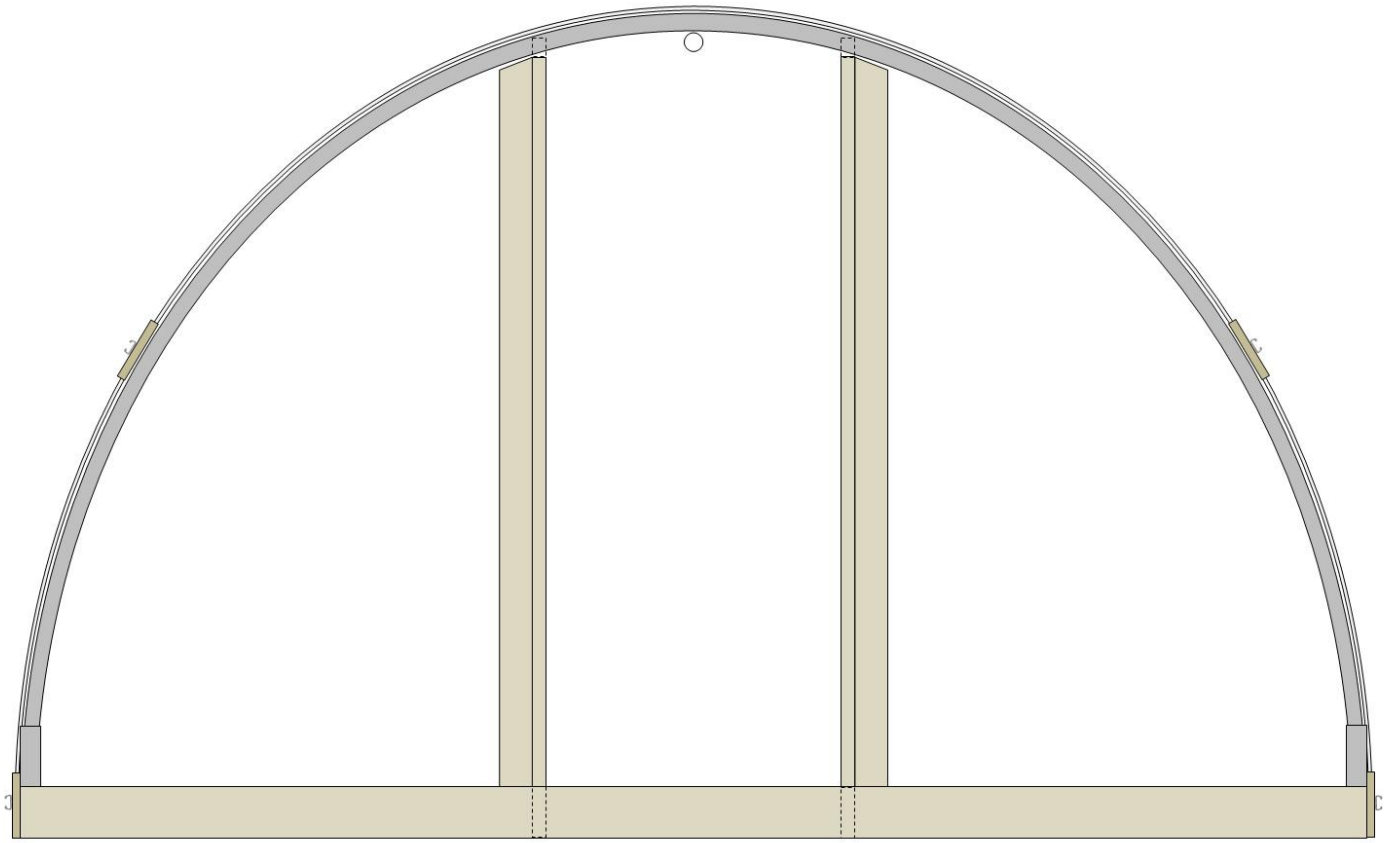




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c. **Outer door frame boards:** Stand another 2X4 vertically on end against the outside of one of the door frame boards installed in 5.b. above so that it is resting on the inside edge of the baseboard and against the inside of the end bow. Position it such that its widest side is facing you. Using the end bow as a guide, make a mark on the 2X4 just under the bow.

Cut the 2X4 to length at that angle. Secure to the door frame board it was measured against with 2½-inch wood screws. “Toe nail” an extra screw diagonally through the bottom outside of the board into the baseboard to keep it from swiveling. Repeat for the opposite side.





Outside Top



Outside Bottom



Inside Bottom

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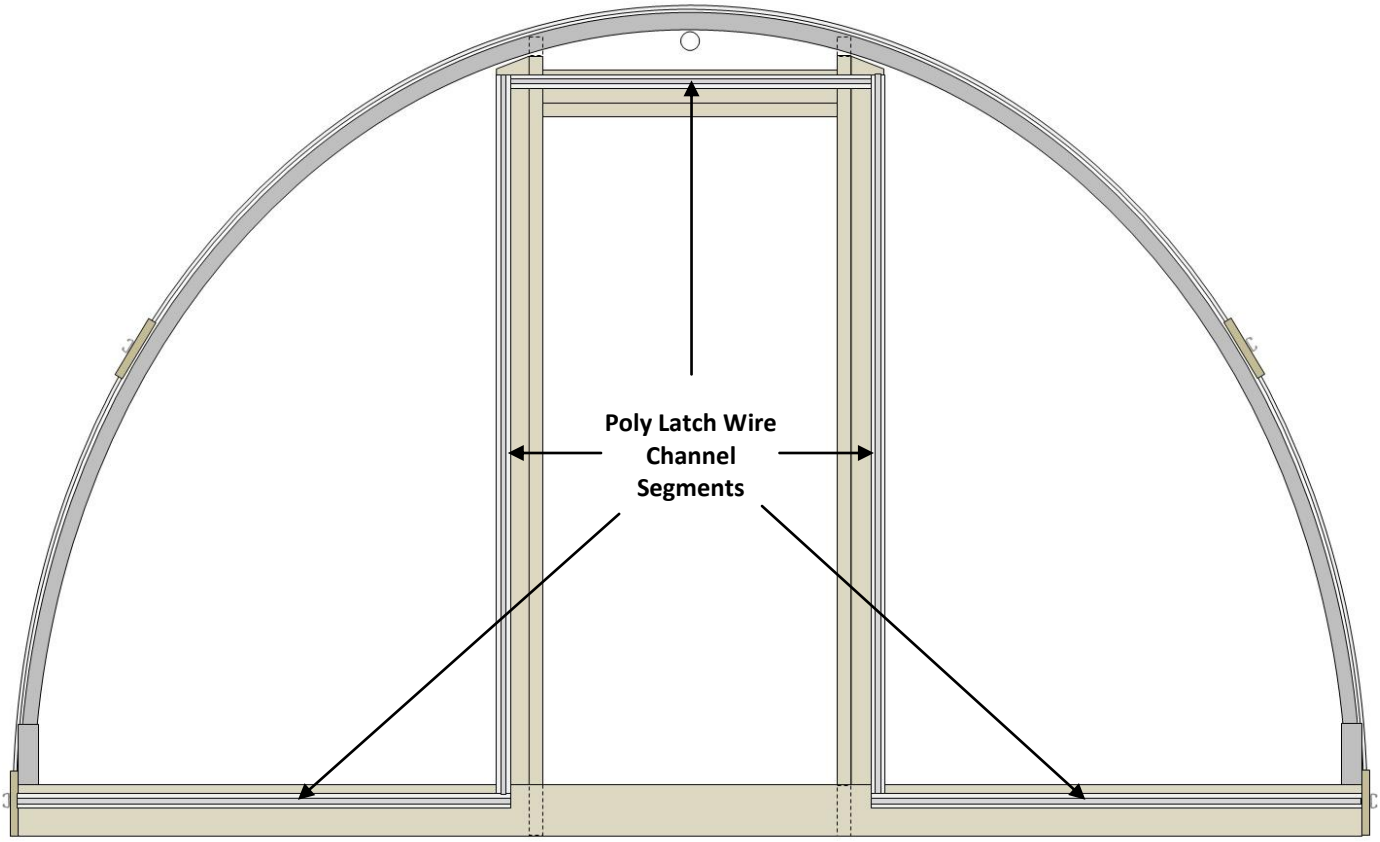
d. **Doorway header:** We want at least 1½ inch of overlap at the top and bottom of the door as well. Measure the height of your door. Ours was 64½ inches. Subtract 3 inches. Measure up from the baseboard along one of the inner door frame boards to that measurement *(61½ inch for us) and make a mark. Repeat for the opposite side as well.



Hold a 2X4 horizontally across the inside of the top of the doorway. Place one edge of it against the left inner door frame board and behind the right door frame boards. Using the right door frame board as a guide, make a mark on the 2X4 on the inside edge of the frame. Cut 2 pieces of 2X4 to this length.

Hold both header boards in place as shown below and level. The cross-connector on the end bow may be a limiting factor s it was for us, since this tunnel was built on shorter ground posts. Clamps are very useful to hold them in place. Ensure that the bottom of the bottom board is below both marks made above. If you are installing on a tunnel with taller ground posts, position the lower header board at the lower of the two marks when the header board is level. Secure the header boards in place with 2½-inch wood screws.

e. **Poly Latch Wire Channel:** Outline the doorway with poly latch wire channel as shown. Make sure you leave enough room for a 2X3 board (see step 5.h.). Then add a strip at the top edge of the end wall baseboard on either side of the door frame as shown. Attach by the same method previously described using Phillips tech screws and cut to length as necessary.
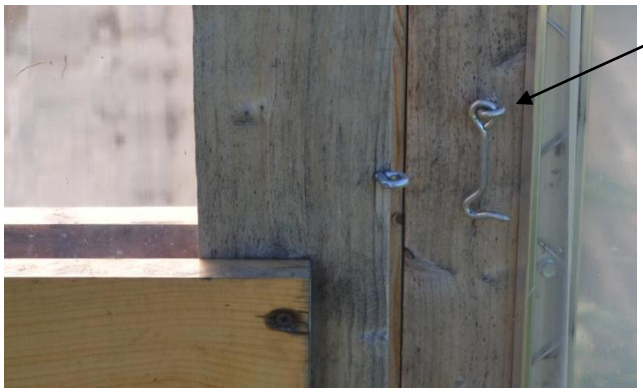


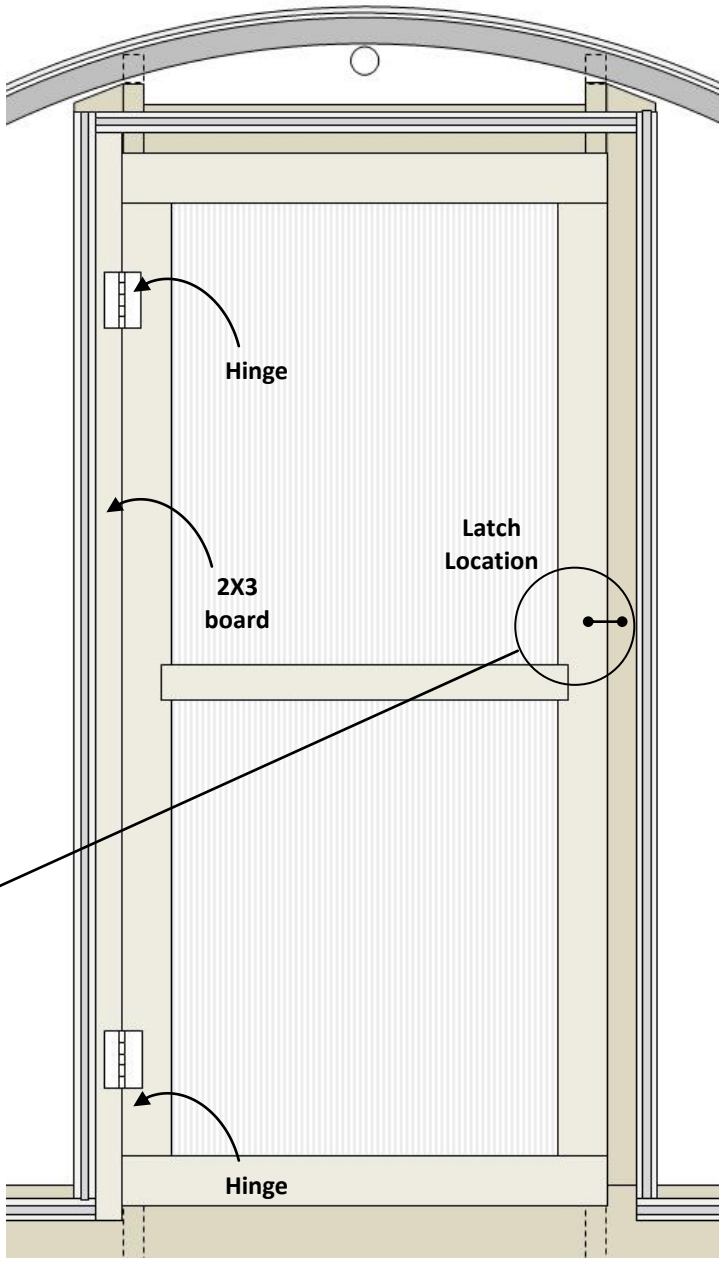
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f. **Hanging the door:** Horizontally position the door over the doorway such that the edge that will have a hinge is in line with the point where the inner and outer door frame boards meet on that side of the doorway; confirm you have the same overlap on the opposite side (this should be 1½ inch or the width of the inner 2X4s.

Adjust vertical position such that you have even overlap at the top and bottom. When you are satisfied with its position, ensure it is level, and clamp it in place. Attach a 2X3 to the outside of the door frame along the edge of the side of the door that will have hinges. Secure very well with several 2½-inch wood screws, because it will be supporting the weight of the door.

Attach 2–3 evenly spaced hinges along the 2X3, positioning them such that the hinge itself is aligned with the seam between the door and the 2X3. Attach some kind of latch on the opposite side.





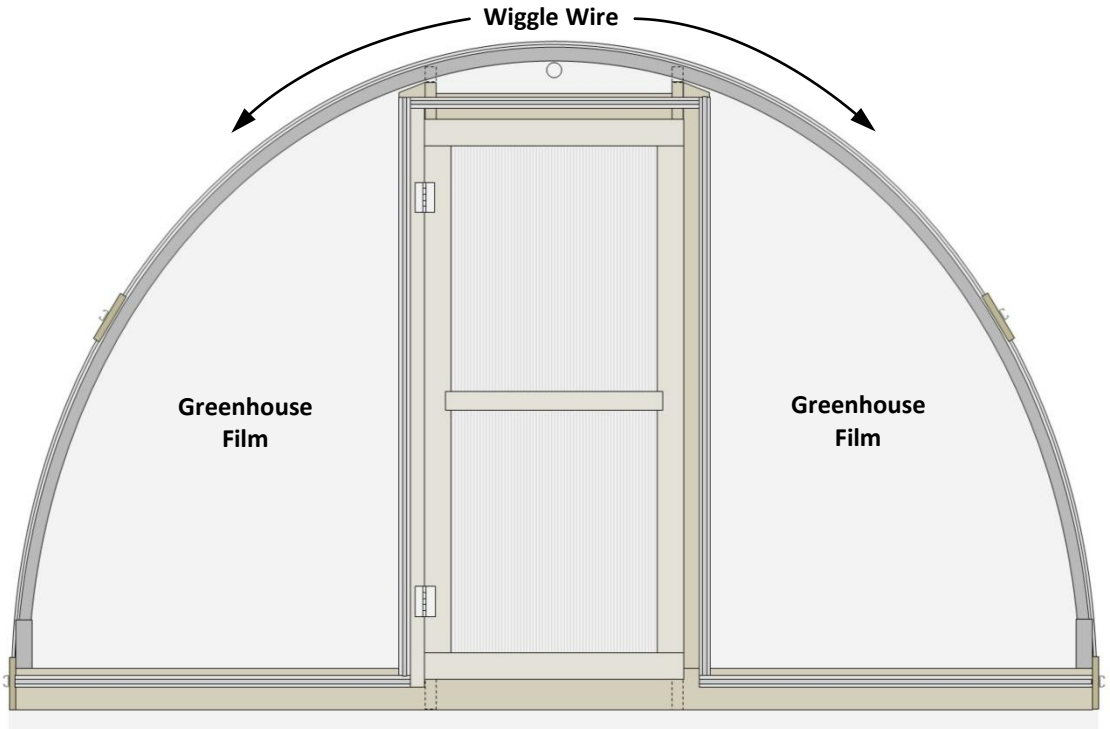
g. **Skinning the End Wall:** You should be using 24-foot wide greenhouse film if you have short ground posts or 28-foot wide film if you have longer ground posts. Place the roll on piece of top rail and hang it on a pair of D-handled digging forks or spades. Pull off about 8 feet for shorter tunnels, 9 feet for taller and cut somewhat straight across with a razor knife. This is best accomplished against the ground.





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Drape the plastic over the end wall bow so that the cut portion is horizontal and even with the bottom of the baseboard. Starting at the peak, insert poly latch wire down both sides of the end wall bow at the same time, pulling the plastic tight as you go. By the nature of the way poly latch wire works, it will take up some plastic as it is inserted. Doing it concurrently on opposite sides has a desirable stretching and tightening effect on the plastic. This will make the tunnel more wind resistant than one with loose plastic. Doing one side, then the other will also result in tightening, but may move and/or misalign the plastic more than you may want it to and make it crooked or even short-sheeted on one side.







On the side of the tunnel, pull the bottom end of the plastic tight and poly latch wire a 2-foot section into the end of the hipboard and the small section of poly latch wire channel on the side baseboard below it.

Next, poly latch wire around the door. If you find the plastic is too tight and is starting to tear, cut a slit up the plastic over the center of the door to give it some slack and pull tight by hand as needed as you wiggle wire the door in. Do the top first, then each side. Finally, poly latch wire the strips on each side of the end wall hipboard. When you are done, the plastic should be taught like a drum and wrinkle free.

Repeat steps 5.a. through g. for the opposite end of the tunnel.



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6. **Skinning the Main Portion of the Tunnel:** This process is best done with little or no wind. If possible, postpone this portion of the procedure if the weather is not cooperative.

   a. The correct width for plastic for this tunnel is 24 feet if you have short ground posts or 28 feet if you have long ground posts. the source supplier has included several lengths of 24- and 28-feet wide Tufflite® IV Greenhouse Film to our inventory specifically to support construction of these tunnels. Depending on the length and ground posts size of the tunnel you decide to build, our Excel spreadsheet calculator tell you which length, width, and part number is appropriate for your project.

   b. Position the plastic at one end of the tunnel and offset, so that it faces down the side of the tunnel.

   c. Pull film off the roll and walk with it down the side of the tunnel until you reach the opposite end. For longer and/or taller tunnels, you may want to have extra people on hand and use ropes with tennis balls tied into the plastic (see page 32) to help with the next step.

   d. Raise the plastic up and over the tunnel and align it evenly on both sides.

   e. Install a section of poly latch wire (maybe 2 feet) at the peak of one end of the tunnel. Go to the opposite end, pull the film tight lengthwise down the top of the tunnel and install a small section on that end. Then, working together and at opposite ends of the tunnel, wiggle wire the plastic downward from the peak to the hipboard on one side of the tunnel, pulling the plastic taught lengthwise evenly as you go. Be careful not to pull so hard as to tear the plastic. Then, repeat for the opposite side.



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7. **Roll-up Sides**: There are a couple options here. You can choose low cost manual roll-ups that require manually rolling up each side of the tunnel and inserting a kick-stand to hold them in place, or you can choose hand crank roll-ups that allow you to roll up the side of the tunnel and stop it at any point you like.

   a. **Low Cost Manual Roll-ups:** This design uses ½-inch EMT conduit, ½-inch EMT compression fittings, Snap Clamps, #8 x ¾-inch Phillips-head self-drilling tech screws, and ½-inch cast iron water pipe T-fittings. This is a good cost-saving option for shorter tunnels, but is not recommended for tunnels over 30 feet long. This can also easily be used in place of a door on one of the end walls to further shave costs and maximize venting capability.

      i. Lay out 10-foot sections of ½-inch EMT along the side of the tunnel. Connect them together using ½-inch EMT compression fittings. Tighten both sides of each fitting against each other and install a tech screw in each side of the fitting through the EMT to prevent it from slipping. Predrilling may be necessary. Cut the last piece of EMT so that you have at least 6 inches extending beyond each end of the tunnel. Lay this assembled piece down along the side of the tunnel.

      ii. Attach a T-fitting to one end of the EMT. Fully insert the EMT into it. You may need to thread it on somewhat. Predrill and drive a tech screw through it and into the EMT inside it to prevent slipping.

      iii. Lay the assembled EMT on the loose plastic at the bottom of one side of the tunnel. Wrap it around the EMT evenly and secure in place with Snap Clamps every foot or so. Adjust the Snap Clamps as necessary, removing any wrinkles in the plastic and ensuring that the EMT is parallel to the baseboards.

      iv. Install Phillips self-drilling tech screws through the Snap Clamps.

      v. Trim the plastic as necessary.

      vi. Grasp the T-fitting and rotate it to roll the plastic up and insert a leftover 3–5 foot piece of EMT into one side of the T-fitting. This will serve as a kickstand for it, keeping it at any level you leave off as well as serve to keep the plastic pinned against the side of the tunnel module to some degree.

      vii. Repeat steps 7.a.i. through vi. above for the opposite side of the tunnel.









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b. **Sidewall Hand Crank Roll-ups:** This design uses ¾-inch EMT conduit, ¾-inch EMT compression fittings, Snap Clamps, #8 x ¾-inch Phillips-head self-drilling tek screws, and Sidewall Hand Crank.

i. Lay out 10-foot sections of ¾-inch EMT along the side of the tunnel. Connect them together using ¾-inch EMT compression fittings. Tighten both sides of each fitting against each other and install a tech screw in each side of the fitting through the EMT to prevent it from slipping. Predrilling may be necessary. Cut the last piece of EMT so that you have at least 6 inches extending beyond each end of the tunnel.



ii. Lay the assembled EMT on the loose plastic at the bottom of one side of the tunnel. Wrap it around the EMT evenly and secure in place with Snap Clamps every foot or so. Adjust the Snap Clamps as necessary, removing any wrinkles in the plastic and ensuring that the EMT is parallel to the baseboards.

iii. Install Phillips self-drilling tech screws through the Snap Clamps.

iv. Trim the plastic as necessary.



v. **Guide Rail:** Make a mark in the center of a 10-foot piece of ¾-inch EMT. Drive one end a couple inches into the ground at the base of the corner of the end bow where you have chosen to locate the hand crank, right below the poly latch wire channel. Using the poly latch wire channel installed on the end bow as a jig, bend the EMT around the bow to the mark you made in the center. Pull the EMT out of the ground, flip it over and repeat for the opposite end. Cut the EMT at the mark you made before bending it. This will give you 2 prebent guide rails with a slight curve so that the Hand Crank will follow the contour of the of the bow — this will be more important for tunnels with short ground posts.

vi. **Handcrank:** Some adapters come with the Hand Crank for other sizes of pipe; you will not need them for this installation. Slide the Sidewall Hand Crank over the end of the long EMT assembly and tighten the set screw against the EMT. Attach the handle to the spindle on the end of the Hand Crank.



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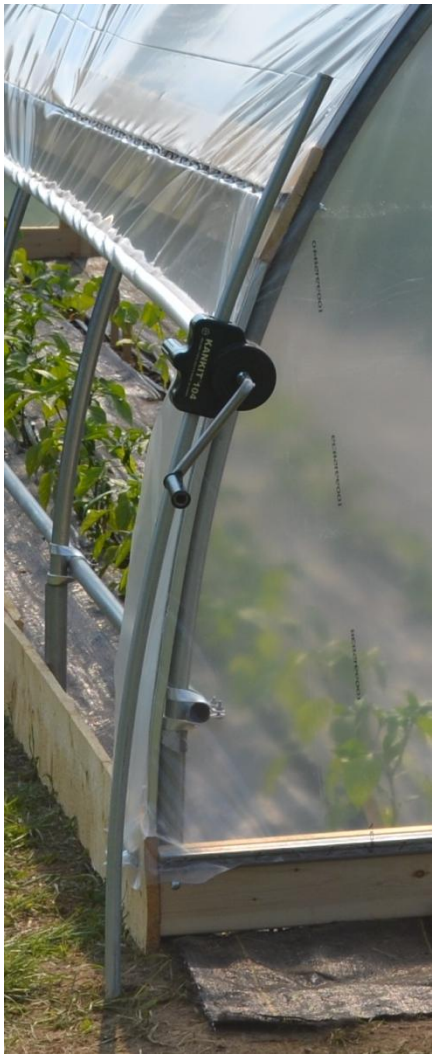
vii. Holding the casing of the Hand Crank in one hand, turn the handle to take up any slack there is in the plastic until the rolled up plastic and EMT is up against the very bottom of the tunnel.

viii. Insert the guide rail through the rollers in the guide channel and drive it about a foot into the ground. Rotate it so that the curve of the guide rail is parallel with the curve of the end bow. **Note***: In order to ensure full venting, the guide rail must not be driven in so far that the top of the guide rail is below the height of the poly latch wire channel.*

ix. Turn the handle of the Hand Crank to roll up the sidewall plastic. **A built in brake will automatically hold the plastic roll at any point that you stop turning.**

x. Roll all the way up to check alignment. At this point, the rolled up plastic should be parallel with the horizontal wiggle wire channel. This is important for uniform venting. If not, roll back down and adjust Snap Clamps as necessary.

xi. Repeat steps 7.b.i. through x. above for the opposite side of the tunnel.



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8. Hipboards:

a. Roll both sides up about 1 foot off the ground so the EMT and other hardware is weighing down the plastic.

b. Starting at one end of the tunnel, poly latch wire the channel on the hipboard. No additional tension should be necessary.

c. Repeat for the opposite side. The top covering of the tunnel should tighten up and be free of wrinkles as you do so.

d. Cut away any excess plastic.









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9. **Lacing:** This consists of line, rope, twine, or even webbing that is applied over the roll-up sides to keep them tight against the tunnel and prevent wind from catching (and damaging) them when they are partially open or closed. We generally prefer parachute cord because it has 550-pound breaking strength and is UV resistant. There are many sources online.

   a. Roll the sides up about half way.



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b. Fasteners: Along the bottom of the tunnel you should have J-bolts installed. You could also use eye bolts. Along the hipboards, the lacing may be attached to eye screws or laced through the poly latch wire.

c. Arrange your spool of lacing at one end of the side of the tunnel as shown.

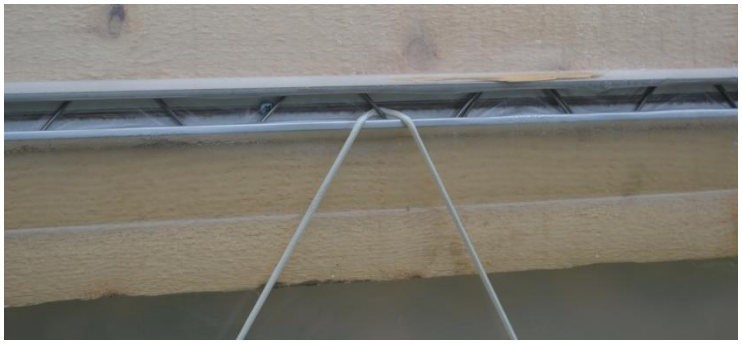
d. Lace in a zig-zag pattern from hipboard to baseboard the entire length of the tunnel. At each end you should also have a vertical run that is parallel to the end wall bow.

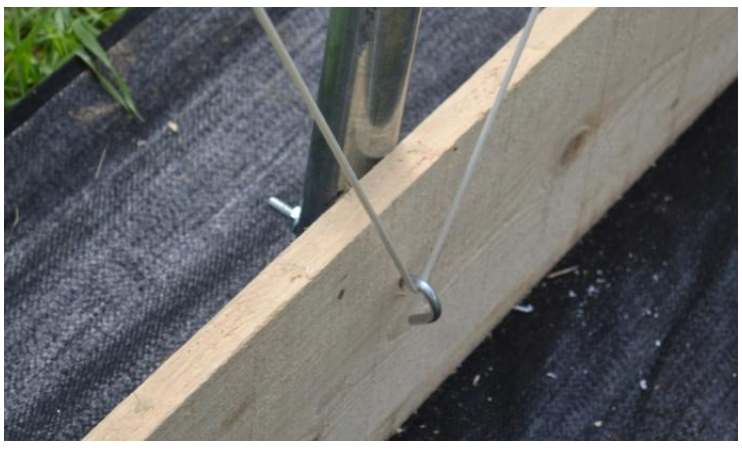
e. Tie off on one end with a bowline or similar knot. Starting at that end pull the lacing tight down the length of the tunnel. Tighten and tie off on the opposite end using a trucker's hitch, illustrated on page 21.

f. Repeat steps 9.a. through e. for the other side of the tunnel.









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Other Tunnel Options:
As we mentioned, there are any number of ways to put together your high tunnel. Please refer to our additional instruction manuals for directions.

- **Purlins for Trellising**: These tunnels, since they are made of steel, are strong enough to support the weight of vine crops such as tomatoes and cucumbers. After some extensive trialing, we have come up with a way to construct these purlins that does not cause the structure to catch water or snow.



- **Seedling Benches:** We have also designed some convenient fold-away seedling benches that can mount on the inside of the tunnel. These benches are very useful as they can be used to grow seed-lings, support trays of microgreens, and also be used to cure fall storage crops such as alliums and squashes.



- **Scissor Doors:** A low-cost alternative for end walls. Scissor doors allow one or both end walls of your tunnel to open to their fullest extent, making entry with larger equipment easy.

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