# A Method for Displaying Art



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# Notice

This monograph includes information on tool use, painting, etc., which you may already know; my hope is that people with little or no experience with hand tools can make hangings by following these directions. I *don't* include extensive information on using power tools because you should learn to use them under supervision. If you're not familiar with any of the power tools mentioned here, you should get someone who knows them to teach you, as hands-on demonstrations are a lot more effective than a manual.

I have not put in a lot of legal boilerplate about my not being responsible if you're careless or inexperienced with tools; most of the people who will wade through this are quite capable of being adult about their own capabilities. This should be sufficient warning:

> **If you don't know how to use a power tool mentioned in here, *get help from someone who does*.**
>
> **If you're doing lighting and aren't familiar with wiring 120– or 240–volt circuits** (this is very different from wiring low–voltage electronics), ***get help from someone with experience.***

There are lots of people in fandom with the knowledge and experience to build this hangings safely, and often there are mundanes who are willing to help. Don't try to do these yourself if you haven't done this kind of work before.

I also don't promise (again without legal boilerplate) that you'll be satisfied with the products of any of the companies named. With a couple of noted exceptions, I have tested and found usable everything in this monograph. If you're unsure, call the company and ask for a sample; most reputable companies will provide them. If you find something better, write or email me and I'll mention it, with thanks, whenever I produce the next edition.

# Introduction

This is an explanation of the design, construction, and assembly of the pipe-and-clamp Art Show hangings commonly called “tinkertoy[1]”.

These hangings were originally developed by LASFS in 1982 from the slotted-angle[2]—plus—cloth hangings created by Marsha Elkin [Jones] in the early 1970’s. They were subsequently reworked by NESFA and are now used by NESFA, PSFS, the Lunarians, and Arisia. Compared to the other types of hangings I know of, they offer an assortment of advantages:

- *Ease/speed of assembly*: These hangings have been assembled by one slightly-experienced crew chief working with an entirely inexperienced crew; such a crew has put up over 1000 square feet of display space per hour, and a green crew with two experienced leaders has put up over 1500 sf/hr. (It doesn’t hurt that many fans are tinkerers with good spatial sense, but these do go up faster even with people who haven’t worked with them before.)
- *Sturdiness*: Since the supports are all metal (pipes and clamps), the structure is relatively rigid and self-bracing, unlike (e.g.) the widely-used P2D hangings[3].
- *Durability*. The supports are metal, so they last virtually forever and don’t warp; the surfaces are pegboard, but since the pegboard doesn’t hold the frames together it lasts longer.
- *Support for lighting*. It’s easy to build lighting into or on top of the hangings in both high- and low-ceilinged rooms, and to build in wiring (making “electric trees”) so the lighting can be hooked up more easily.

Against this there are some disadvantages:

- *Weight*: These hangings weigh ~105 pounds per hundred square feet of display space. (By contrast, P2D hangings weigh ~40 #/csf.) Much of the greater weight of these hangings is pegboard, which is used on both sides of the hangings (rather than a single thickness as in P2D). It’s possible to use cloth instead of pegboard, but the consensus of artists now seems to be that cloth doesn’t hold the art solidly enough to make up for the nice background; also, cloth that is sturdy, looks good, and meets local fire codes is much more expensive than pegboard in many cities.

1. Tinkertoy is a trademark of Playskool Inc., a subsidiary of Hasbro Inc.

2. most of the slotted angle came under the trade name Dexion, which is the name NESFA has used whenever discussing this material in print.

3. Pegboard—2x2—drywall-screw. These hangings, originally using screw eyes instead of drywall screws, were described by Joe Mayhew several years ago in the ASFA newsletter. There are several variations on this type; most notable are Martin Deutsch’s Balticon hangings, which are held together with bolts and wire struts and are precision-drilled for uniform assembly. These are sturdy and go up easily but are very difficult to make.

- *Startup cost:* At the prices I paid in the summer of 1992, these hangings cost ~$70 per hundred square feet of display space without lights; a good-sized regional show can cost $1500-3000 or more.[4] Note that almost half of this is the clamps that hold the pipe together; these are small enough that groups who are too far apart to share hangings should consider sharing clamps (shipping them is relatively cheap).

The following factors may be either better or worse than what you're currently using or looking at:

- *Bulk.* These hangings take about 1½ cubic feet of storage space per hundred square feet of display space, which compares unfavorably with NESFA's previous slotted-angle—plus—cloth hangings and with P2D hangings (about 1cf per 100sf) but is likely to be better than most of the pre-framed hangings (edged pegboard, pegboard on doors, etc.) that I've seen.
- *Advance construction time*. Cutting and assembling the pipe in the sizes required, and rigging the pegboard for hanging, takes some time; 4-6 people can build 40-100 panels in a weekend (depending on how much of the weekend they're around for). This is more time than for P2D hangings (where most of the work is done by the lumber yard) but less than several other types require. In any case, the work is an investment of capital: spend some time in the slack between conventions and you'll need less time to set up at-con (when time is always short). Note that most of this is not precision work and a lot of it doesn't need serious muscle, so you can tell potential volunteers there's work for everyone.
- *Shadows.* These hangings are somewhat less open than a simple zigzag (the way P2D hangings are usually set up) and can cast shadows on themselves more than a zigzag would. It's *possible* that there's a room in which zigzags would be adequately lit and these hangings would require additional lighting, but I haven't seen one; in many rooms even a zigzag layout would be substantially helped by added lighting. Note also that the layout of these hangings allows one light to cover more than twice as much display space as a light on the standard 4′ zigzag.

The current form of these hangings has been evolving over the last nine Boskones, with additional experience at other East Coast regionals (Lunacon, Philcon, Arisia) and at Noreascon Three and Magicon. It's still not a completely satisfactory design—in particular, there may still be a better way to hang pegboard—but it works well enough that several groups have expressed interest. The information here is current as of the date at the foot of each page; anyone who sees this and gets any bright ideas is encouraged to contact me (see info on the title page) and/or come to a setup session at one of these regionals to see how the hangings work.

## Alternatives

There are a huge number of ways fans have devised to display art; I'm not going to go into most of them here, but enough people have asked questions that I'll say a few words about using PVC pipe and joints.

I'll admit to a personal bias against PVC, coming initially from the wretched hangings used at Suncon in 1977; these hangings were probably fairly cheap, but they were very weak because they used ~1½″ pipe. 2½″ pipe will work for short spans (not over 4 feet), which gives you some of the same problems as P2D hangings; the hangings recently built in Minneapolis look elegant, but the panels they offered were 4 feet wide and 6 feet high, which surprised and/or confused some artists. 3½″ pipe might be strong enough for longer spans, but will take huge amounts of storage space and cost about as much as the metal hangings I describe here—possibly more depending on how complicated

4. Sample show sizes: Arisia 1792 sf (1993ff), Boskone ~2800 (1988–1992; >3800 in 1986–87), Lunarians 3168 (1992ff), Philcon 4224 (1992ff), Magicon 8880 (Main show) / 1408 (Retrospective) / 528 (print shop).

a structure you want to build. Another disadvantage of PVC is that there is a very limited selection of joints; building 3–sided bays instead of zigzags would be complicated because there's no joint with as many connections as the clamp used in all the centerline joints of the metal hangings. Finally, rigging PVC for lights does not look like it would be easy; there are electrical boxes which fit small sizes of PVC, so you'd probably need hybrid joints to connect the PVC for lights with the larger PVC needed to support the art.

This being said, I should note that the PVC zigzags built in Minneapolis looked like they went together very easily; and in their space they were able to hang lots of lights on the ceiling, plugged into lighting tracks, so they avoided the lighting problems most shows have. Perhaps somebody there will do writeup similar to this one for PVC hangings?

## Organization

The rest of this monograph is divided into five sections:

- **Design** (page 9) covers choosing between the two known styles of these hangings (or developing your own) and deciding whether to use lighting, with or without the built-in wiring these hangings support.
- **Specifications** (page 18) tells how to break down your layout into a shopping list, and where to start looking for the items on the list.
- **Making the Parts** (page 38) describes the work you'll need to do well before the show (preferably during warm weather, as it takes enough space that you'll find it easier to work outside).
- **Setup & Teardown** (page 60) tells what to do once you have this mass of metal and pegboard in the room that is going to be an art show.
- **Nomenclature** (page 69) is a brief reference for terms defined in one place and used in many others. (Specialized items that are only referred to once or twice are described under Materials: Miscellaneous, at the end of Specifications.)

I'll apologize here for a somewhat formal tone. It's probably easier to build the hangings than to wade through my description; ***don't*** be intimidated by the language.

***Note:*** this monograph has some unavoidable national biases. The measurements are "English" rather than metric because that's the way most of the hardware in the U.S. is still made; if your country works entirely in metric sizes, please send me your best translation (as opposed to conversion) of the measurements herein and I'll include it, with thanks, in the next edition. Note also that the wiring I describe fits the U.S. codes; rules may be different in other countries and are certain to be different (along with parts lists) in countries where the standard for electric power is ∼240 volts rather than ∼120. I would also like to know what are the non-U.S equivalents of Yellow Pages and TomCat, which are extremely useful resources for anyone building these hangings.

## Acknowledgments

The information in this monograph represents my summary of the work of large numbers of people over the last 20+ years. Some of the most notable contributors (in roughly chronological order) include:

- Marsha Elkin, who created the hangings these are based on.

- Al Kent, who prepared sufficiently detailed mechanical drawings of the Elkin hangings that LASFS could (a) understand how to build them, and (b) conclude that there had to be a simpler way to get the same effect.
- Members of LASFS who discovered and developed the pipe-and-clamp system that makes assembling the hangings so quick.
- Mark Olson, who persuaded NESFA to try these hangings some years after I'd first seen them and mistakenly decided they weren't flexible enough[5] for our use.
- Monty Wells, who built the first of these hangings and lighting in Boston and who has been a font of ingenuity, technical information, and tools; his encyclopedic knowledge and workroom turned many wild ideas into hardware.
- Stuart Hellinger, who was the first art show manager outside of Boston to see the possibilities of the NESFA version of these hangings; he and Mark Richards repeatedly came up from New York to make the hangings and the built-in wiring, and his badgering produced the first tolerable method for hanging pegboard from pipe.
- Karl West, who designed the first good template for painting pipe, and who gave me a number of ideas on the way to devising a method for hanging pegboard from pipe.
- Kurt Siegel, who took home my there's-gotta-be-a-better-way-to-wire-this-mess grumble and showed up at the next convention with the first electric tree, and who first suggested threading a pegboard hook to hang pegboard from pipe.
- Kevin Fallon, who had the initial ideas for hanging pegboard in sandwiches and for the box lighting sockets.
- Joe Mayhew, who persuaded me that assembling on tables is easier than assembling on the floor.
- Chris Cooper, the first person to build hangings based on these designs without my hanging over him.
- Ted Atwood, who stood in as assembly/disassembly crew chief when I had too many responsibilities, and who reworked the box lights to make them safe and durable.
- George Flynn, Porforadear and grammarian extraordinary, who made the convoluted syntax of this monograph more understandable (it's not great now, but it was wretched before).
- Steve Gold, who pointed out that this monograph had gotten big enough that a ToC would making it easier to read.
- The many members of NESFA who helped build and rebuild several hundred panels worth of these hangings (for NESFA and for other clubs) as the concepts evolved and I learned about efficient construction methods.
- Last but far from least, all of the helpers who showed up before the conventions were scheduled to open and stayed after everything else had closed, many of them specifically to help with the art show hangings. I particularly commend their patience as I developed on-site most of the assembly techniques and many of the improvements mentioned here, while repeatedly forgetting most of their names even as I was working with them. Armies may still march on their stomachs, but conventions are carried by blood, sweat, and volunteers (thanks to Orycon for the slogan).

5. The hangings aren't as easy to reconfigure as Dexion, which can be lapped at either 1″ or ¾″ intervals (depending on type) to make a huge variety of sizes from a few basic pieces. I used this capacity fully on my first layout, which had panels 6′1″ wide, 6′2″, 6′4″, 6′5″, . . . . in a room that was *barely* large enough for the show we wanted to do. But these hangings are quite flexible enough for any *reasonable* layout.

# Design

## Panel Layout

This design uses 3-sided bays of panels laid out in straight lines (“spines”) as shown from above in figure 1. (The dotted lines represent a single piece of pipe; the solid lines represent two pieces of pipe, 3′3″ and 7′ off the floor, supporting sheets of pegboard.) Figure 2 shows one set of hangings in perspective. It is possible in theory to put up these hangings in a zigzag (similar to P2D hangings),

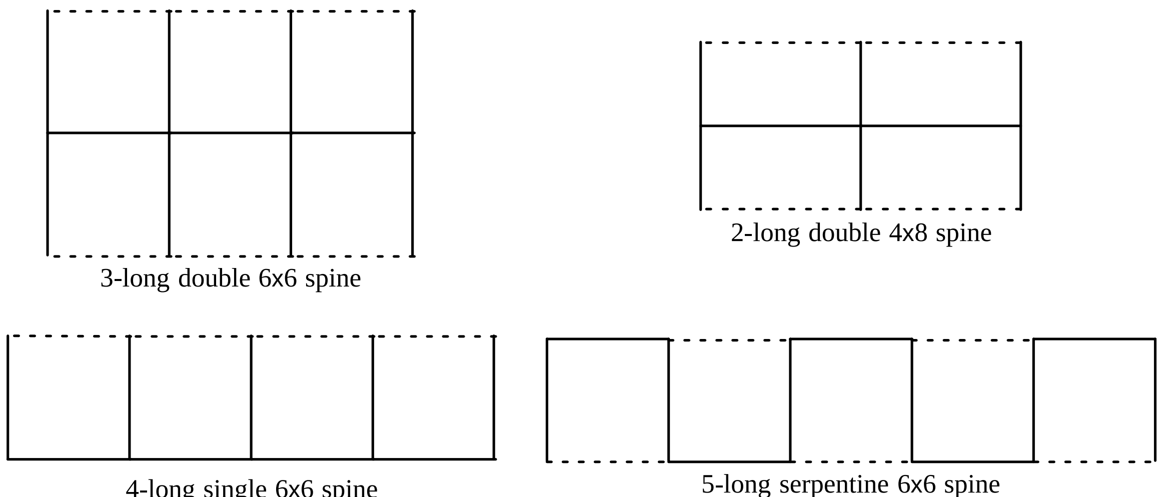


Figure 1

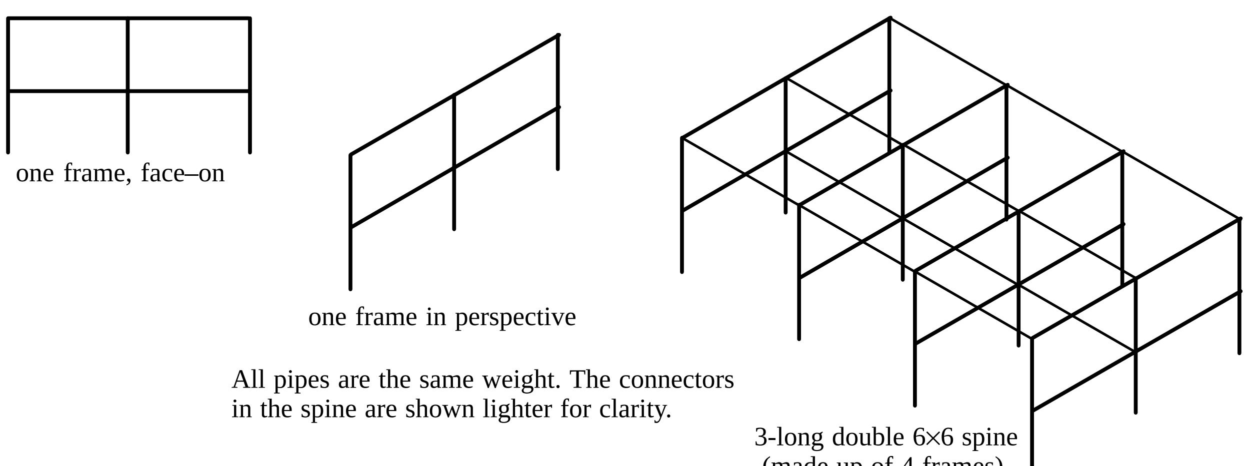


Figure 2

but I’ve never seen it done. (A design I can picture would not be quite as stable and would take up ∼30% more room for a given number of panels[6]; it would also take somewhat more equipment to light.) It’s possible to do an assortment of odd-shaped hybrid blocks (Boskone did for some years due to being in a room in the shape of a semi–regular octagon), but usually you’ll be better off building up a layout out of the straight spines illustrated in figure 1.

These hangings have been built in two different layouts, with bays nominally 6′ x 6′ (gives three panels 4′ high and 6′ wide per bay) or 4′ x 8′ (gives 4 4′ x 4′ panels, two of them in line). It’s also possible to build other sizes, but in my experience 8′ x 8′ is a difficult size to light effectively and odd sizes could be a pain to administer (most artists are used to 4′x4′ or 4′x6′ panels). Which you choose to build is a personal judgment that you can get into theological arguments about; points to consider include:

- I built 6x6’s for NESFA because it mimicked the Dexion hangings (which we were replacing gradually, so we wanted to match them) and for Lunarians and PSFS because it worked well for them and it was generally useful to have lots of interchangeable hangings in this part of the U.S.
- Arisia built 4x8’s because they were committed to 4′–wide panel units.
- Some artists like 8′–wide panels but prefer 6′–wide to 4′–wide (which will make up almost half your space if you build 4x8’s); a few have expressed preference for the 4′–8′–4′ (wide) arrangement of panels.
- The 6x6 allows a little more room for people to stand back from the back panel without standing in the aisle, but some people find looking at the side panels more cramped.
- 6x6 panels require fewer lights than 4x8’s for the same amount of display space (see discussion of lighting strategies below). 4x8’s use smaller bulbs, so the price for power (which you pay every year) will be similar but the capital costs will be significantly higher.
- 6x6’s can be stretched to 6x7’s, at a very small cost in pipe and couplings, when you have a little extra space; this gives you some of the advantages of both types. If you have a very little extra space you can stretch them to something in between 6′ and 7′.
- In an infinitely large room the 6x6’s are 14% more space-efficient; in an average room, which layout lets you cram in more panels will depend on the exact dimensions of the room and on how big your aisles have to be. Since conventions seem to change hotels every few years (or more often if they haven’t expected to), your choice shouldn’t be affected by the number of panels a layout lets you cram into a particular space.

You should make this decision very early, and stick with it; hybrid setups are a pain. I prefer 6x6’s but will cover both layouts in this monograph.

You also may want to argue the question of double versus single or serpentine spines. Most layouts use only double spines unless the space dictates setting a spine against a wall (for which you need a single spine). Some issues to consider:

- Double spines cost ∼10% more than single spines per square foot of display space for 6x6 layouts, and ∼20% more for 4x8 layouts.
- In an infinitely large room, using 8-foot aisles, double 6x6 spines are 4% more space-efficient than singles/serpentines (double 4x8’s are actually slightly *less* space-efficient than singles). As above, this may not be a major factor since actual results will vary from room to room.

6. Space use would be roughly the same in cities/states which don’t define an aisle as a *straight* clear space (allowing the hangings to stand closer together); it’s not likely you’re in one of these.

- For most rooms, bays seem to work better than panels directly facing aisles. This is a subjective decision; clearly traffic flow is better when most people studying the art are in bays rather than standing in the aisles, but you might have enough space that the difference is slight or you might not care about traffic (e.g., if the fire codes in your area aren't very strict).
- A layout of double spines will be substantially cheaper (both initially and in year-to-year expenses) to light than the same amount of display space in single spines, since each of the lights covers more panels.

# Lighting

Almost all SF-convention art shows that don't currently use supplementary lighting can be improved by adding it.

Lighting in hotel function space is designed to be adequate when the floor is clear or set up with chairs and tables, which are $\sim 2\frac{1}{2}'$ high (and nobody cares about lighting underneath them). Art show hangings, by contrast, are $6\frac{1}{2}'$ to $7'$ high. Hotel lighting usually consists of a mix of recessed spotlights and chandeliers; the spotlights are usually so tightly focused that they don't give smooth light even at floor level, and the chandeliers usually light only the middle of the room—this can be especially fun if your artshow space is several small rooms knocked together, giving rivers of darkness in the middle of your show. Lighting in exhibit halls is ***sometimes*** acceptable; however, in most halls either the ceiling is so low or the lights are so widely spaced ($30'$ apart is standard in high-ceiling halls) as to give lighting as bad as in hotel function space. (As an example: lighting at the Philcon '92 and '93 art shows was adequate—not great, but adequate—and they have fluorescent fixtures $2'$ square on $8'$ centers on a ceiling $\sim 20'$ high. Point–source lights instead of clusters, or lights more widely spaced, would have made the lighting inadequate at best.)

It's theoretically possible to place your hangings to avoid some of the worst shadows, but you can lose a lot of floor space trying to make most of the hangings work with the available lighting. A common mistake is to put a panel directly under a single light (spotlight or fluorescent tube) and figure that the light will cover both sides; in practice the light won't do anything for either side of the panel, because you want it to bounce off the panel at a shallow angle instead of running parallel to the panel.

***Note:*** added lighting is likely to cost you some money each year; hotels usually don't fuss about artists plugging in miniature clip lights here and there, but you will be drawing enough power that your hotel is likely to need to bring in extra from the main or a large tap, and if it does this it will want to charge for it. The total cost should be in the low–to–medium hundreds of dollars for the large-average regional art show (2400-3600 display square feet), but this varies widely across the U.S.

***Note:*** the added lighting will also require a small amount of storage space and some work to set up; how much depends on the size of the show and whether you go with built-in lighting.

## Testing a space for lighting

If you're unsure about the lighting in a given space, try walking across the room in both directions (front to back and side to side) in several places, holding a piece of light-colored cardboard vertically; note how the light on the cardboard changes. Next, estimate the effects of lots of panels breaking up the light, e.g., try making a bay out of stiff(ened) cardboard (3 $4'$[high]x$6'$ pieces or one $4'$x$8'$ between two $4'$x$4'$s, assembled in a squared U) and having a couple of people hold this at the right height (top $7'$ off the floor) in several places around the room. You will probably find that in many places the shadows the panels throw on each other are unacceptable. (You will certainly find some places where the lighting is acceptable—but the odds are very poor that you will be able to fit enough panels into the room using only the places where the lighting is acceptable.)

## Lighting layout: low ceilings

If you are doing a small show, you may be working in a function room on an office or sleeping floor; such a room typically has an eight-foot-high ceiling. Older hotels also have small-to-medium rooms with ceilings eight to ten feet high. Lighting art shows in these rooms is relatively easy; the lights are mounted on the outside connector pipes (shown as dashed lines in figure 1) of the hangings, and pointed up and slightly towards the back of the bay, so the light reflects off the ceiling.

This method works well only for the most common layouts, namely double spines in the middle of the room and single spines against the walls, but with this kind of room and layout it's very convenient; you can do all your work standing on a chair or stool (tall people may be able to work standing on the floor) instead of dragging around a ladder and hoping you won't knock into anything. (It may be possible to redesign the frames to have extended horizontal pieces, or slightly taller outside uprights, and mount sidearms on these, to make this work for single spines in the middle of a room and serpentines, but I don't think it's worth the hassle.)

If you use this method of lighting you will probably want to build box sockets (see description of socket types on page 33) with single outlets, so they can chain together; otherwise you'll need *lots* of cube taps and short cords.

## Lighting Layout: high ceilings

Most art show rooms will have ceilings higher than ten feet, as smaller rooms are often sections of a large ballroom with a uniformly high ceiling. In such rooms, lighting for these hangings is mounted on "trees": uprights 8′-10′ tall with side extensions to put the lights above the art. In the drawings below, double pipe that supports pegboard is shown by heavier lines and single pipes with lights by lighter lines

For 6x6 hangings there is a tree every other frame; each tree holds up four horizontal supports with one four-arm clamp (a "helicopter"[7]). Where two supports would finish lighting a spine, a tree holds

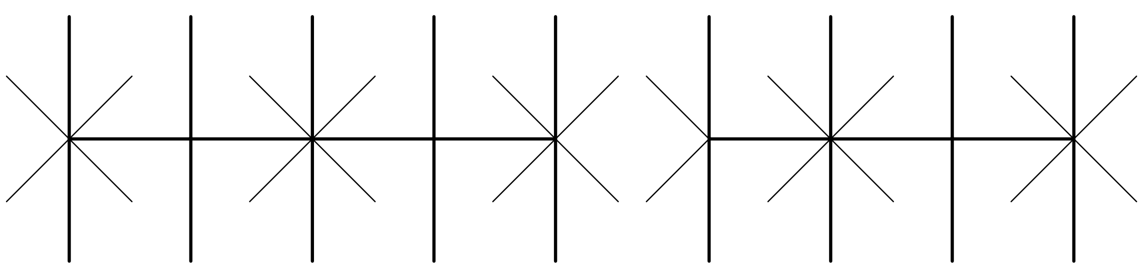


Figure 3

up a half helicopter (a "vee"). This gives one lighting position above the middle of each bay and one facing each end panel (figure 3). In general, you need separate lights for facing end panels unless you're allowed to have aisles less than 7′ wide (figure 4). In theory, you could omit the half tree even with the wide aisle of figure 3 and put two lights on each of the helicopter arms over the aisle; in practice this makes pointing the lights more difficult (since two of them must be close together), lighting less ideal (since one of each pair must point more horizontally) and setup more complicated

7. I don't know who first used this term, but it's apt and everyone who works on the hangings understands it.

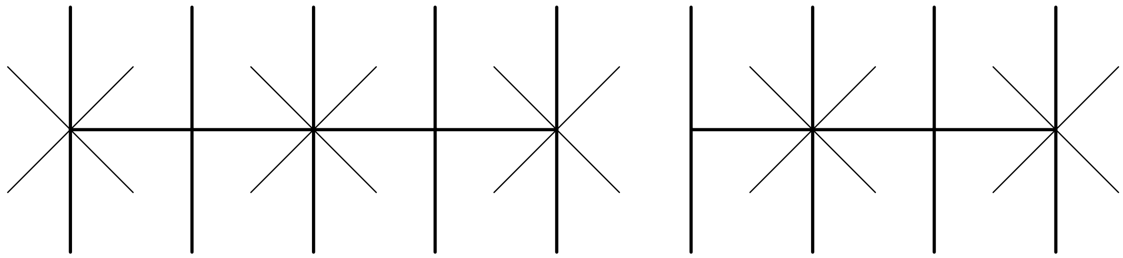


Figure 4

(since the helicopters don't all have the same number of lights). You may be able to reduce the num-

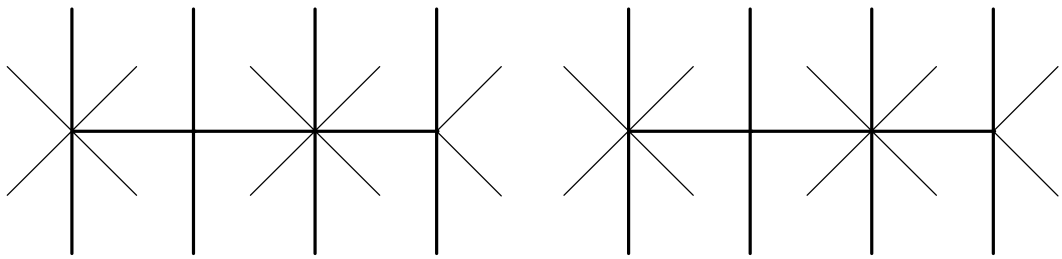


Figure 5

ber of trees (but not the number of lights), even if you don't have narrow aisles, by shifting panels from one spine to another, e.g. the rearrangement shown between figure 5 and figure 6; however,

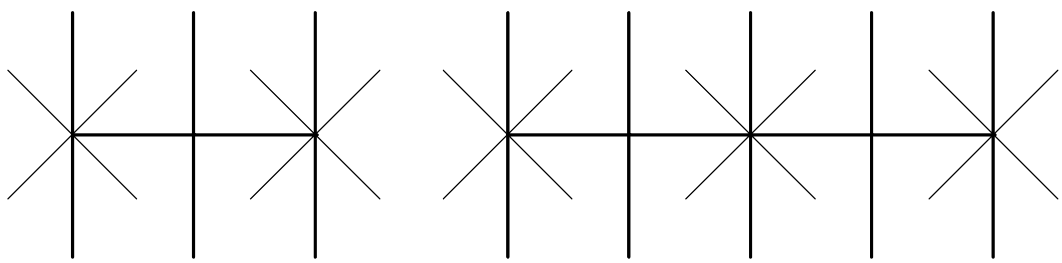


Figure 6

you may prefer to have the more balanced layout of figure 5 since the savings in labor and material of figure 6 are not large.

Single and serpentine spines can also be lit with trees using other shapes of supports. A single spine may use the same lighting if it's in the middle of the floor; if it's against a wall or placed so the flat

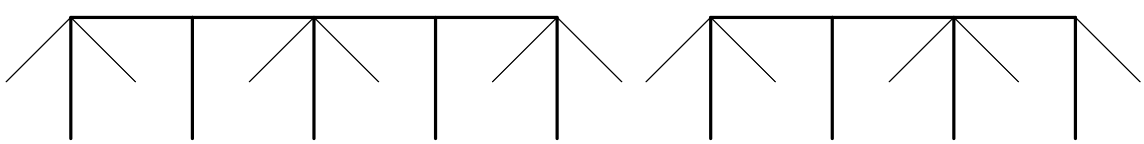


Figure 7

side gets enough light from the room's fixtures, the helicopters become vee's and the vee's become sidearms (figure 7). To light a serpentine, leave off opposing pairs of supports, making helicopters into tee's (figure 8) except for a vee at one end; the supports are the same whether you have an even or an odd number of frames. It's also possible to save one upright at the cost of some complication and a more expensive clamp, by making the first two supports three-quarter helicopters (figure 9).

Getting even lighting on 4x8 hangings is somewhat harder. A single floodlight or bulb-plus-reflector will not cover an 8′ span sufficiently evenly, so double lights on each support are generally needed.

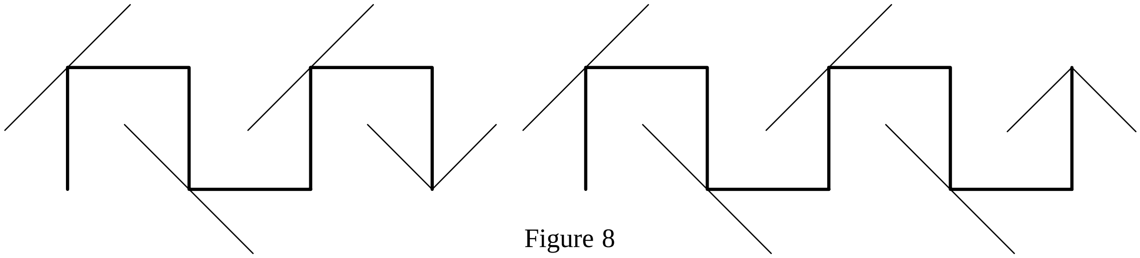


Figure 8

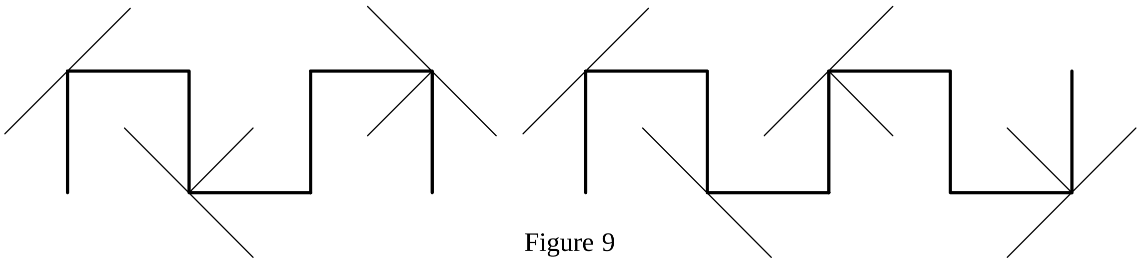


Figure 9

(The best way to avoid the difficulty of hanging and aiming two lights on one support is to build your own box sockets from scratch as described on page 33.) I've thought of several possibilities, including a simple analog to lighting on the 6x6 hangings (using supports to the centers of the edges of the bays, which is too long to be convenient or sturdy) and helicopters in which the arms aren't at right angles (these would be a pain to build) There are two alternatives which seem satisfactory to me; each of them has its advantages and disadvantages.

You can put a smaller helicopter on every upright (figure 10); this will require more pieces and take

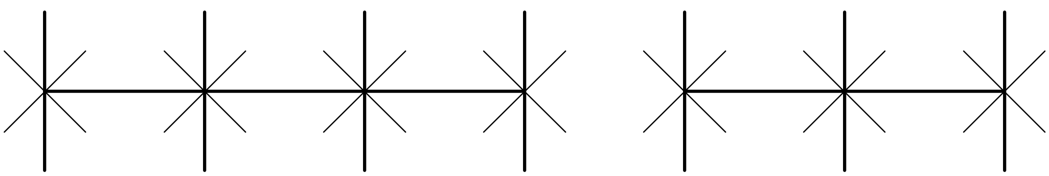


Figure 10
"small"

more time to set up, but it will give a slightly better lighting angle and put less strain on the clamps holding up the lighting supports.

Or you can put supports on the outside uprights (figure 11), parallel to the spine, making tees instead

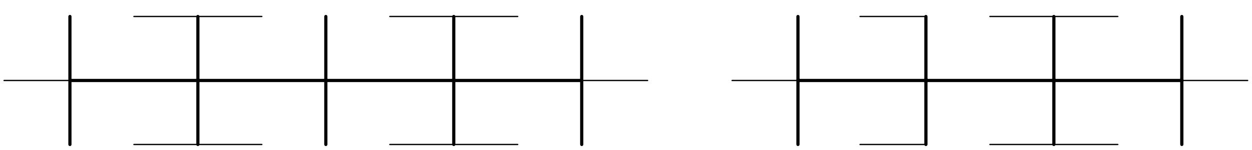


Figure 11
"outside"

helicopters. ***This is the only method I've actually used for lighting 4x8 hangings;*** I did this to adapt Arisia's hangings for Magicon, partly to allow for the fact that their lights were already wired together in strings (one double socket every $\sim 18'$ of cord, $\sim 6$ double sockets in a set)[8]. This is not as convenient or as clean-looking as internal wiring, but it may serve; internal wiring with this tree lay-

8. I don't recommend building lighting in long strings, since it means you have to substantially rewire your lighting if you change your layout; instead, these supports work better if each lighting fixture has an added electrical outlet, or there are at most two fixtures chained together. Arisia has started shortening its chains.

out would be substantially more complicated compared to figure 10 (since the trees don't form a single line). ***Note:*** figure 11 does not work for serpentines or for single spines in the middle of the room; you could probably use single arms at odd angles to hang lights where they would cover the panels on the aisles.

Arisia's original lighting design for these hangings involved making all the uprights taller and putting a double socket directly on top of each outside upright, with each light pointing at the diagonally opposite corner of the bay. (The ends were lit by sidearms as shown above.) I strongly recommend against this; normally-available lights are either too wide-angle or too tight to light well at this distance, and in either case the lights will point almost horizontally, so attendees will throw shadows on the art they're looking at.

Arrangements of supports for 4x8 single and serpentine hangings are analogous to those for 6x6 hangings.

***Note:*** As of February/March 1993, Kurt Siegel et al. were considering ways to improve the placement of lights. Putting in more lights per bay, angled so they fill each other's shadows, is an attractive idea, but this will increase the cost (and perhaps the setup time). Some of these ideas were tried on a few of the hangings at ConFrancisco; I didn't get to ConFrancisco so I can't rate the ideas.

## Wiring/Electrification

The simplest way to get power to the lights is to run power cords from tree to tree, being careful not to overload the cords. This can be made easier by making all of the uprights along the path of the cord the same height as the trees and hanging the cord from the tops of the uprights using duct tape, or stiff wire bent into a useful shape (e.g., a Y or coil), or a sidearm made of an extra clamp and a scrap piece of pipe. You could also drop a cord from each tree and connect them at waist or floor level, but this requires more power cords and multi-outlet connectors.

NESFA and the Lunarians use "electric trees" developed by Kurt Siegel. The lighting trees have built-in wiring; as previously, the lighting support is assembled on the ground and set on the tree before it's stood up, but the lights are plugged directly into outlets on the tops of the trees instead of being ganged together before the support is set on the tree. Power is fed to the trees at waist level, so nobody has to go up on a ladder to make connections (which used to take at least as long as setting up the hangings themselves). Electric trees can be built by amateurs, with care and testing; the specifications given below meet the U.S. rules for temporary wiring. These trees cost $15-25 each plus $75-100 for a wheeled traveling case (a "roadcase", necessary to protect the connections); we've found the cost and advance work well worthwhile in work saved during the convention.

## Lights

There are several ways to alter lights or make your own so they will sit securely on the structures described above. Look at the descriptions on page 33 and compare them with what you can find in your area in order to decide whether to alter old- or new-style spring-clamp lights or to build your own "box sockets" from scratch. If you decide to build from scratch, you also need to decide whether you will connect the lights to a power source running down the center of the spine as described above, or build each light with an outlet included so the lights can be chained together directly. (Chaining lights together works well only with the outside lighting supports shown in figure 11 or for rooms low enough that you mount the lights on the outside connector pipes and reflect off the ceiling, which you can't be sure of doing if the art show expands or the convention moves.)

# Other issues

## Hanging pegboard

Independently from the 6x6 vs 4x8 vs . . . choice, you need to choose which of two methods to use to hang the pegboard (or devise a better one of your own—if you do, let me know). These are the best current choices:

- the hook method uses upside-down pegboard hooks to hang single pieces of pegboard from the pipes;
- the sandwich method uses loosely-tied-together pairs of pieces of pegboard (like an old-fashioned sandwich-board advertisement), hanging the sandwiches from the ties that hold them together.

The hook method is developed from a suggestion from Kurt Siegel; the sandwich method is extended from an invention of Kevin Fallon. You should read the sections discussing making (page 44) and setting up (page 65) these two types, and consider the following:

- The hook method allows the pegboard to store absolutely flat and in single pieces; some assembly is required at-con, but the pieces are hung one at a time, so none of the work requires tall or strong people. The hooks can also be loaned out for use with local pegboard (which is uneconomical to ship long distances); however, you do have to be careful not to lose them, as they take time to make.
- The sandwich method tends to make the pegboard bend up at the ends in storage (this can be minimized with careful stacking). No assembly is required at-con, but you have to work with two pieces at once and feed one of them over the top of the hangings, which can be difficult for short people.
- Both of these methods are quite new; until recently, all tinkertoy hangings had cloth surfaces instead of pegboard. Both work reasonably well so far, and both have partisans; I don't know which will prove better in the long run.

Ideally you should see both systems in action before making your decision, but that means (as of this writing) visiting either Philcon (which has a small number of hooks, mostly sandwiches) or both Arisia and either Lunacon or Boskone at Magicon. I have an emotional attachment to the hooks, which I did most of the development on, but they're a fair amount of work to make and the sandwich pegboard may go up faster (it certainly takes fewer steps) if you have a typical mix of fans helping you set up.

For your possible interest, I will note two other methods which have been used and discarded:

- sandwiching pairs of pieces of pegboard around the pipes with 1″ threaded standoffs and machine screws.
- Reinforcing designated hanging holes on each piece of pegboard with grommets (grommeting kits are available at most large hardware stores et al.) and using bolts through the grommets to sandwich pairs of pieces of pegboard over the pipes.

Both of these methods have a serious disadvantage: the fact that you must connect two pieces of pegboard while holding them up against the pipe. (The standoff method reduces the distance over which you need to make the end of a screw fit into a hole, but it requires inconveniently small screws.) You can put $\sim 2/3$ of the pegboard on frames on the floor, which is somewhat easier, but this makes it harder to assemble the frames into spines and you'll still have to screw together the rest of the pegboard in mid-air.

It’s possible that you could make or find U–shaped hooks with curls on both ends such that you could simply put the hooks over the pipes and hang the pegboard from them one piece at a time, but I suspect this would turn out to be difficult—the weight on one side of the hook is likely to pull it away from the other side, making the second piece of pegboard on a hook difficult to hang. If you decide to try this, please let me know the results (see address on the title page), with samples and pictures if possible.

## Painting pegboard

Arisia reports that most artists prefer light backgrounds; Stuart Hellinger (frequent Art Show director for Lunacon) says that dark backgrounds are preferred. (The few artists I’ve seen covering the pegboard use black or dark blue cloth.) The NESFA cloth hangings, now retired, were pale beige with some texture, but no artist has told us of disliking either standard (medium brown) or Duron (dark brown) pegboard. Painting the pegboard is a fair amount of work, and the paint can get ratty-looking fairly quickly since the surface it’s on isn’t very hard; light-painted pegboard *may* make the hangings less imposing, but it’s not clear there’s much difference since most of the surface is usually covered with artwork or bidsheets. My current take is that it’s not worth the effort, so I don’t talk about it under Making the Pieces; you should think about this one and let me know the answers (see address on title page) to any surveys you do.

## Miscellaneous

Note that the hangings as designed by LASFS have bays 3′ deep and 6′ wide; our experience using these hangings (at the Austin NASFiC, 1985) is that having lots of panels only 3′ wide is a pain. If you really want this layout, you can figure out the specifications and material requirements from the information below (start from the information for 4x8 hangings).

For the two Worldcons where these hangings were used, we made the bays 7′ wide (but still 6′3″ deep) by adding short pieces to all of the connector pipes. We had the floorspace, and the additional room for people looking at the art is a good idea at a Worldcon; for the regionals I’ve seen (including Boskone), the added room is less necessary, since the show usually gets crowded only in the few minutes just before it closes. If you want to be able to do this, you will need access to a pipe threader and should save all the couplings that come with the pipe. (Details on what to do to keep this option open appear on pages 40ff.)

# Specifications

This section may be duller than the legal and genealogical sections of the book of Numbers, but it's intended to make the arithmetic of hangings clear enough that anyone can work it out by stepping down through the sections. I still do something like this any time I create a new layout; the layout for Magicon took several pages of tables because I wanted to be sure I had enough pieces for everything I wanted to do. To use this section, work through "Dimensions and Counts":

1. start with "Size when Assembled" and work out a floor plan;
2. confirm that you have the right amount of display space using "Panel Count" (page 19);
3. break down the layout (spines to frames, frames to pieces) using the "Piece Count" sections (pages 19–21);
4. work out how much pipe you will need by multiplying your counts of the various pipe by the sizes of those pieces in "Pipe Dimensions" (pages 24ff).

After you have a piece list, go through "Tools" (pages 25ff) to pick out what you'll need for the kind of hangings (unlit/lit/wired, sandwich/hook pegboard hanging) you're going to build. Then read through "Materials" (page 28) to find out what to buy to make up the pieces you've counted up. To keep "Dimensions and Counts" simpler, most descriptions of terms have been moved into "Materials"; major terms have their own sections, while minor terms (marked in "Piece Count" and "Tools" sections with a †) are defined in alphabetical order under "Miscellaneous" (pages 34ff).

Specifications that pertain solely to hangings with lighting are in this font.

*Specifications that pertain solely to lighted hangings with built-in wiring are in this font.*

## Dimensions and Counts

### Size when Assembled

All hangings are 7 feet high.

For lighting, allow 9.5-10 feet height for 6×6's and 8.5-9 feet for 4×8's.

Note that you can usually adjust the hangings to fit around chandeliers, leaving out individual lights that would run into them (a chandelier will usually light the area directly below it well enough). If the ceiling is lower than this overall, you can generally mount lights directly on the hangings and bounce the light off the ceiling.

An N-long 6×6 spine is N times 6′4″ long, + 1″.

A 6×6 double spine is 12′9″ wide.

A 6×6 single or serpentine spine is 6′5″ wide.

An N-long 4×8 spine is N times 8′4″ long, + 1″.

A 4×8 double spine is 8′9″ wide.

A 4×8 single or serpentine spine is 4′5″ wide.

With 8′ aisles (a common fire requirement) and 6×6 hangings you should be able to get almost one square foot of panel space for each square foot of floor space in the panel area (including aisles around spines but not including space for 3-D tables, control desk, etc.).

## Panel Count

An N-long 6×6 double spine has 6N + 4 4′×6′ panels.

An N-long 6×6 single or serpentine spine with aisles on all sides has 4N + 2 4′×6′ panels.

An N-long 6×6 single spine with its long side against a wall has 3N + 2 4′×6′ panels.

An N-long 4×8 double spine has 8N + 4 4′x4′ panels.

An N-long 4×8 single or serpentine spine with aisles on all sides has 6N + 2 4′×4′ panels.

An N-long 4×8 single spine with its long side against a wall has 4N + 2 4′×4′ panels.

(Yes, 4x8 spines have some 4′×8′ panels, but planning is a lot easier if you do everything in 4′×4′ units. Which artists get the 8′ panels is the administrator's problem, not the designer's—but it may also be a reason for choosing to use 6×6 hangings.)

## Piece Count: spines to frames and connector sets and trees

An N-long spine consists of N+1 frames connected by N sets of connectors.

All the information below assumes that your ceiling is high enough for direct lighting. If the ceiling is too low (10′ for 6×6 hangings or 8.5′ for 4×8), skip the trees and mount lights on the side connector pipes aimed toward the ceiling, as described in "Lighting layout: low ceilings" (page 12).

An N-long 6×6 double spine requires 1 + N/2 (round down) lighting trees.
All trees are full trees unless N is odd, in which case one tree is a vee-half tree.

An N-long 4×8 double spine using small helicopters (figure 10, page 14) requires N +1 full lighting trees.

An N-long single spine against a wall requires 1 + N/2 (round down) lighting trees.
All trees are vee-half trees unless N is odd, in which case one tree is an angle quarter tree.

An N-long single spine in the middle of a room requires
the same number and type of trees as the same size of double spine
***or***
the same number and type of trees as if it were against a wall if it is placed so that it doesn't need any light on the flat side.

An N-long serpentine requires N tee-half angle trees and one vee-half angle tree.

An N-long 4×8 double spine with lights on the outside (see figure 11, page 14) requires N tee-half square trees and 2 quarter square trees if N is even, or N–2 tee-half square trees and 4 quarter square trees if N is odd.

In most cases you can leave out half of the type of tree you're using on the end if you have small aisles (see figure 4, page 13), i.e.:
on a double spine
- a full tree becomes a half tree
- a half tree is omitted;

on a single or serpentine spine
- a half tree becomes a quarter tree
- a quarter tree is omitted.

## Piece Count: frames and connector sets and trees to single pieces

A set of connectors for a double spine consists of 4 connectors.

A set of connectors for a single or serpentine spine consists of 3 connectors.

If you are doing 6×6 hangings and want to be able to expand them to 6×7, add one 9″ piece of pipe, threaded on one end, for each connector, and note that all connectors must be threaded on one end.

A double frame consists of

3 uprights;
4 horizontals;
2 one-arm clamps;
2 three-arm clamps;
2 four-arm clamps.

A single frame consists of

2 uprights;
2 horizontals;
1 one-arm clamp;
1 three-arm clamp;
2 four-arm clamps.

For single frames, you could use cheaper clamps (three-arms in place of the four-arms), but this would require you to replace about a quarter of the clamps if you need to build double spines later.

A serpentine frame consists of

2 uprights;
2 horizontals;
2 three-arm clamps;
2 four–arm clamps.
**except** on the end frames, which have 1 four–arm, 2 three–arm, and 1 one–arm.

This can also be done with 4 three-arm clamps, or 2 three's and 2 angle two's, but above re using smaller clamps still applies. (The smaller clamps also very slightly reduce the chance of somebody snagging on a unused, protruding arm of a clamp.)

Each upright requires a foot (see page 31).

A full tree consists of 1 lighting upright and 1 helicopter.

A vee-half tree consists of 1 lighting upright and 1 vee.

A tee-half tree consists of 1 lighting upright and 1 tee.

A quarter tree consists of 1 lighting upright and 1 sidearm.

**Note:** each lighting upright *or electric tree* ***replaces*** a standard frame upright; adjust totals from the above accordingly.

A helicopter consists of

4 lighting supports and 1 four-arm clamp
***or***
2 long lighting supports and one double–tee clamp.

The latter is sturdier for all layouts, and preferred if you're using box lights instead of clamp lights; see discussion of types of lights on page 33.

A vee consists of 2 lighting supports and one 1 three-arm clamp.

A tee consists of 1 long lighting support and 1 one-arm clamp.

A side arm consists of 1 lighting support and 1 one-arm clamp.

*Each electric tree consists of base, trunk, and top pipes.*

**variation**: Eastercon wanted to avoid pipes over 6′3″, so they made each upright out of two pieces, using three–arm solid clamps in place of one–arms (on the side uprights) and an inline (on the center uprights, in addition to the three– or four–arm). They *really* wanted to be able to carry the hangings in personal cars instead of a truck; I wouldn't expect this to be worthwhile under normal conditions because the hangings weigh enough that carrying a typical show will take several sturdy cars (most conventions need to rent a truck for other movein tasks anyway).

## Piece Count: pegboard

Pegboard should be used in 2′×4′ pieces; larger ones are a pain to store, move, and work with.
A 4′×6′ panel takes 3 pieces of pegboard. (I did say this was covering every detail . . . . )
A 4′×4′ panel takes 2 pieces of pegboard.
For each piece of pegboard you need

If using the hook method:

- 2 hooks;
- 2 10-24 nuts.

If using the sandwich method:

- 1.5′ of rope;
- 2 short tie wraps (cable ties);
- 6-12” of lath† (net; individual pieces are 2′ long).

1 long tie wrap or pipe cleaner for every *two* pieces of pegboard that will be in away from a wall (i.e., backed up with another piece of pegboard).
1 long tie wrap or pipe cleaner for every piece of pegboard that will be against a wall

## Piece count: lighting

- Lots of power strips and cube taps *unless you are building electric trees.*
- Lots of power cords *(not quite as many if you are building electric trees*).

No, this isn’t very helpful—but it’s not easy to give clear quantitative rules. You should make a drawing of your planned layout, with lighting, and work out what connections go where and what cords go between them. Points to consider:

- When figuring connections for non-electric trees with full helicopters, you should find out whether local codes allow you to put two cube taps in series; if not, you will have to use power strips. These are more expensive and annoyingly bulky, and the breakers on them trip unexpectedly, usually unnecessarily.
- For power cords for either kind of tree:
  - Collect trees into circuits. A circuit is 1800 watts if you’re using 12-gauge cords. (The ratings printed on the boxes the cords come in are higher, but they don’t allow for running 10-12 hours straight at that load.) NESFA owns mostly 14–gauge cords (which carry 1200 watts) for historical reasons; I don’t recommend that you buy this size since it’s likely to cost at least as much and to need more work at setup.
  - You’ll need short cords, most of which can be 14-gauge, to connect trees within a circuit *unless you are building electric trees*. 15-footers are ideal for 6×6 hangings since they’re just long enough to connect adjacent trees without much slack even if you extend the bays to 7′ wide.
  - You will also need however many long cords it takes to get all your circuits out to where the power comes from. If you don’t know where the hotel can provide a feed, plan for it to be on the back wall of the room near a corner.
  - You may want to try to buy a smaller number of types of cords to make planning and setup easier, e.g. only 12/3, only a few lengths (15′, 25′ to connect circuits that cross an aisle, 50′ for connecting circuits to power).
  - Note that complete power cords usually cost less at builders’ supply stores than the parts you’d need to make them cost anywhere.
- You will need over-the-floor rubber duct† to protect the cords where they cross aisles at floor level; the duct isn’t cheap, but making the cords cross aisles above people’s heads takes time you may not have at setup.

See discussion of lights on page 33 to determine which type of lights you have. Depending on which type of light you can find to modify, you will need:

- For old-style spring-clamp lights:
  - 1 spring-clamp light.
  - 1 piece of stiff thin plastic (epoxy (e.g., from pc board), plexiglass, etc.) ~ 3″×3″.
  - 1 U-bolt to fit ¾″ pipe (~1⅛″ wide, ~2″ long).
- For new-style spring-clamp lights:
  - 1 spring-clamp light.
  - 1 piece of aluminum ~3″×3″, ~.14″ thick (see construction info, page 47).
  - 1 U-bolt to fit ¾″ pipe (~1⅛″ wide, ~2″ long).
- For box lights with no outlets:
  - 1 indoor utility box†.
  - 1 outdoor cover plate† with enough ½″ sockets for the number of lamp heads.
  - 1 clamp–type strain relief† (size to fit the knockouts on the utility box).
  - 1 #10×½" machine screw.
  - 1 #10 nut.
  - 2 #10 lock washers (internally-starred type).
  - 2 wire nuts† sized to take 1 16–gauge stranded wire and 1–3 (matching number of lamp heads) 20–gauge stranded wires
  - 1 6–9′ 16/3 "replacement cord" (molded male plug on one end, bare wires on other)
    ***or***
    6–9′ of 16/3–SJ electrical cord and a male 15–amp 3–wire plug
    ***or***
    1 6–9′ 16/3–SJ extension cord.
    Choose among these according to what's cheapest.
    ***Warning***: you must use a grounded (3–wire) cord (in order to ground the box) even though the lamp heads come without a grounding wire.
  - 1 spade lug to fit 16–gauge stranded wire.
  - 1 ¾″ conduit hanger†.
  - 1 ¼″ Nut–Sert™ or equivalent† (this will make adjusting the hanger much easier).
    ***or***
    1 ¼″ nut and 2 ¼″ lock washers (split type).
  - 1 ¼″×¾″ round-head stove bolt (or machine screw).
- For box lights with one outlet:
  - 1 indoor utility box†.
  - 1 outdoor cover plate† with enough ½″ sockets for the number of lamp heads.
  - 2 clamp–type strain reliefs† (size to fit the knockouts on the utility box).
  - a few inches of 12–gauge solid wire and 1 wire nut† sized to take 2 12–gauge stranded wires and 1 12–gauge solid wire.
    ***or***
    2 spade lugs sized to take 1 12–gauge stranded wire.
  - 2 wire nuts† sized to take 2 12–gauge stranded wires and 1–3 (matching number of lamp heads) 20–gauge stranded wires.
  - ~1 foot of electrical tape (black plastic, ¾″).
  - 1 #10×½″ machine screw.
  - 1 #10 nut.
  - 2 #10 lock washers (internally-starred type).
  - 1 1″ or ¾″ conduit hanger†.
  - 1 ¼″ nut and 2 ¼″ lock washers (split type)
    ***or***
  - 1 ¼″ Nut–Sert™ or equivalent†(this will make adjusting the hanger much easier).
  - 1 ¼″×¾" round-head stove bolt (or machine screw).
  - 1 safety cap†.

- 1 12/3 SJ† or flat extension cord (for length, see discussion below).
  ***or***
  1 piece 12/3 SJ or flat cord, and one each male and female 15–amp 3–prong plugs.
- For box lights with two outlets:
  - 1 outdoor box† with 3 ¾″ holes.
  - 1 ¾″–to–½″ reduction bushing.
  - 1 clamp–type strain relief†.
  - 1 standard duplex outlet.
  - 1 standard (indoor) metal cover plate for a duplex outlet.
  - 1 12/3 SJ† or flat extension cord (for length, see discussion below).
    ***or***
    1 piece 12/3 SJ or flat cord, and one each male and female 15–amp 3–prong plugs.
  - Parts for internal wiring:
    ***either***
    - 2 wire nuts† sized to take 2 12–gauge stranded wires, 1 12–gauge solid wire, and 1–3 (matching number of lamp heads) 20–gauge stranded wires.
    - 1 wire nut† sized to take 2 12–gauge stranded wires and 1 12–gauge solid wire.
    - 1 foot of 12–gauge solid wire.
    - 1 foot of black plastic electrical tape.

    ***or***
    - 6 spade lugs sized to take 1 12–gauge stranded wire.
    - 2 spade lugs sized to take 1–2 (matching number of lamp heads) 20–gauge stranded wires.
  - 2 safety caps†

  If putting more than one light on the box, you will need for **each additional light**:
  - 1 ½″ tee.
  - 1 ½″–by–close nipple.

The cord length for box lights with outlets depends on how the lights will be laid out; you want to make sure you don't need extension cords between lights. For instance, if you use outside supports (as in figure 11, page 14) you can either use 9–foot cords and run the cord directly across the gap between supports, or make every other cord 35 feet long and run these to the next box on top of the panels (this looks slightly neater but I don't think it's worth the effort). You can also use one long cord (in place of two shorter ones) with two boxes on it (this is the way all of the Arisia lights are rigged) for half or more of the one–outlet box lights; a mix of singles and doubles may give you enough flexibility and save some money on cord.

All box lights require
- 1–3 lamp heads† according to your design: usually, 1 for 6×6 hangings and 2 for 4×8 hangings. (I haven't tried 3 lights in a cluster but you might find a use for this.)
- 1 defrictioner† for each lamp head

*each electric tree uses the following pieces:*
- *3 single-gang outdoor/rainproof boxes† with three ¾″ holes.*
- *3 15-amp duplex outlets.*
- *2 safety caps†.*
- *3 standard (indoor) metal cover plates for duplex outlets in single-gang boxes.*
- *2 ¾"-by-close nipples (if you're in a builder's supply store these will be in the plumbing section); black iron and galvanized are both fine, brass is unnecessarily expensive.*
- *8′ 12-gauge solid wire in each of three colors (black, white, and green preferred). Be sure to get solid wire rather than stranded, which would require you to do more work to meet U.S. electric codes.*
- *1 strain relief† to fit a ¾"–threaded hole*
  ***or*** *(if above not available)*
  *1 strain relief† to fit a ½"–threaded hole and a ¾″–to–½″ reduction bushing.*

- *1 25′ 12/3 SJ† or flat extension cord*
  **or** *(depending on relative cost)*
  *1 15-amp three-prong (grounded) plug and 15–17′ of 12/3 SJ† or flat electric cord (shorter for 6×6 hangings, longer for 4×8)*

## Pipe Dimensions

Uprights for all frames are 7′ long.

Connectors for 6×6 hangings are 6′3″ long.

Connectors for 4×8 hangings are 8′3″ long.

Horizontals for 6×6 hangings are 6′3″ long.

Horizontals for 4×8 hangings are 4′3″ long.

(All connectors and horizontals are longer than nominal length; the additional length fits into the clamps, leaving the nominal length clear for hanging pegboard.)

All of the measurements for lighting supports and uprights are approximate because the lights can be adjusted to cope with small variations (and will usually have to be adjusted after they're put up anyway); picking the right lengths can also let you waste less pipe.

Lighting supports for 6×6 hangings (for old–style helicopters, vees, angle sidearms) are 4.5-5′ long.

Long lighting supports for 6×6 hangings (for new–style helicopters, tees) are 9.5-10′ long; if transporting pipe this long is a problem, choose a total length and make the supports out of two slightly dissimilar pieces (e.g. a 10′ support is made of pieces 5′1″ and 4′11″), each threaded on one end, and a coupling. You can get this easily by cutting the standard 10′ pipe in unequal halves and putting the threaded ends together.

Long lighting supports for 4×8 hangings for square tees are ∼8′3″ long.

Lighting supports for 4×8 hangings with small helicopters are ∼3′ long.

Lighting supports for 4×8 hangings (for square sidearms) are ∼2′ long.

A stub pipe is 3-4″ long.

Lighting uprights for 6×6 hangings are 9.5-10′ tall (use 10′ if you might extend 6×6 bays to 6×7).

Lighting uprights for 4×8 hangings are ∼8.5′ tall.

*Electric trees are the same net height as standard lighting uprights, made up of the following:*
*base: 3′6″, threaded one end.*
*trunk: total height less 4′10″, threaded both ends.*
*top: 3″, threaded one end. (If you aren't doing new–style helicopters (with long lighting supports), cut the threaded ends off pipe that will become lighting supports, which don't need threads.)*

If you are using the standard lighting and not making electric trees, you may want to make every center upright a lighting upright; see discussion under "Wiring/Electrification", page 15, and note that this also makes setup easier since you will only need to make half as many types of frames.

## Example

A four–long 6×6 double spine will provide 28 panels (page 19) and measure 25′5″ long (page 18).

The spine will be made up of 5 double frames and 4 connector sets (page 19).

This will require 10 each of one–arm, three–arm, and four–arm clamps; 20 horizontal/connector pipes; 15 uprights (page 20). The horizontal/connector pipes (interchangeable for this size of panel) will be 6′3″ long and the uprights will be 7′ long (page 24)

If you are lighting the hangings you will need 3 full trees (page 19). This means you will need 12 standard uprights and 3 tree uprights in place of the 15 uprights listed above. You will also need

12 lights and either 3 double tees and 6 long (9.5–10′) lighting supports, or 3 four–arm clamps and 12 short lighting supports (page 20).

# Tools etc.

## For making the hangings

- **either**
  a powered pipe cutter with a reamer attachment, and a threader (and cutting oil)—this is necessary if your plans require threading much pipe
  **or**
  at least one manual pipe cutter **and** (strongly desirable for smoothing cut ends of pipe):
  - 1 1″ 60°-included-angle countersink.
  - 1 heavy-duty low-speed drill. The average home drill is **not** sufficient, but such a drill may be rentable.
  - a few ounces of light oil (motor oil, ThreadLube, 3-in-1).
- 2 ∼12″ pipe wrenches (3 if using a manual pipe cutter).
- some spray paint (black and a color, as discussed under Markings (page 39)).
- a quart or more of paint thinner (the cheapest you can find) or safety degreasing solvent (“Stoddard solvent”).
- some 1″ EMT. This normally comes in 10′ lengths; you need:
  - ∼4′ for basic hangings.
  - ∼3′ for unwired lighting trees on 6×6 hangings.
  - ∼2′ for unwired lighting trees on 4×8 hangings.
  - ∼5′ for tees.
- a few nails. 6d finish is a good type, but almost anything >1.5″ long (preferably lightweight) will do
- a drill bit slightly smaller than the above nails.
- a drill.
- a hammer.
- a few ounces of (thread–locking) anaerobic adhesive† if you are making up some of the pieces of pipe from what’s left after cutting full–length pieces *(and a few more ounces if doing electric trees)*.
- at least two pairs of sawhorses (or a useful equivalent); more will speed up the work, especially if you’re using a manual pipe cutter and/or are cutting pegboard from 4′×8′ to 2′×4′.
- Something to store clamps in†
- If you’re going to be putting exposed threads on the pipe in order to be able to lengthen them, a pint or so of corrosion inhibitor†
- If you’re using the hook method of hanging pegboard:
  - a hexagonal 10-24 threading die.
  - a socket to hold the above die; a 1″ 6-point will frequently work.
  - a speed wrench to fit the above socket (probably ½″).
  - Groove–joint pliers, also known as water-pump pliers, or ChannelLocks™. These are a type of slip-joint pliers with tracks or notches that can hold the jaws at several different widths, and angled jaws that can be parallel at all the widths. You will need:
    - 1 ∼12″.
    - 1 16–18″.
  - a ¾″ by 3–4″ [pipe] nipple.
  - a ½″ by 5–6″ [pipe] nipple.
  - a double–end bench grinder (this can probably be rented).

- a vise, preferably two:
  - 1 large enough for the forming anvil (see page 44).
  - 1 to hold the 1″ half–round pegboard hooks; this can be a small one with a clamp to hold it to a convenient table.

The first three items can be bought at Sears, and possibly a big hardware store; the others are likely to be found at any good hardware store.

- If you're using the sandwich method of hanging pegboard:
  - a small pair of diagonal cutters.
  - a soldering pencil, iron, or gun.
  - a 2½″ hole saw.
  - a drill press (or a very steady hand with a drill).
  - a few doublehead nails (∼12d).
  - a hacksaw or a small set of bolt cutters.
- If you are cutting pegboard down from 4′×8′, you'll need a table saw (preferred) or a skilsaw (hand-held rotary); you should get a carbide–tipped blade for this, as pegboard is very hard on standard steel saw blades. If you're stuck with using a skilsaw, you'll also need:
  - 4–5 8′ 2×4's and 2 cheap 4′ 1×4's.
  - 4-5′ of good-quality 1×4.
  - 2-3 ∼6d nails.
  - 6 large nails (16d or so).
- a 3⁄32″ drill bit.
- a 5⁄16″ drill bit (unless you are using NutSerts or similar, in which case get the size bit called for by the manufacturer).
- If you are building box lights:
  - at least one roll of electrical tape.
  - a crimping tool (if building two–outlet box lights).
- A circuit/continuity tester for 120-volt circuits (this will look like a 3–prong plug with 3 lights on the back, and have a diagram indicating which sets of lights mean what), if you are building box lights with outlets *or electric trees*.
- *Tools and supplies for a roadcase:*
  - *a table saw (necessary; some parts **must** be cut precisely) or a cutting fence for a skilsaw.*
  - *a skilsaw (depending on accessibility of table saw, which may able to do everything).*
  - *a pint of wood or carpenter's glue. Elmer's carpenter's glue—**not** the standard white glue—is OK and cheap.*
  - *∼160 1″ drywall screws.*
  - *∼40 1½″ drywall screws.*
  - *∼60 2″ or 2¼″ drywall screws.*
  - *∼8 3½″ drywall screws.*
  - *16 ¼″×3″ bolts ("hex-head cap screws" or similar—with a flat hexagonal head rather than a slotted domed head, and threaded only on the last ∼1″ is OK).*
  - *16 ¼″ nuts.*
  - *16 ¼″ washers (these may look too large; the ¼″ spec is the size of a bolt that will pass through the center hole with lots of room to spare).*
  - *1 variable-speed drill.*
  - *1 Phillips screwdriver bit to fit the drill.*
  - *a 3⁄32″ drill bit.*
  - *a 5⁄16″ drill bit.*
  - *2 6″ or 8″ tee hinges. This is a hybrid type: one side is a very elongated triangle as on a strap hinge, the other a conventional leaf. If you absolutely can't find these use strap hinges.*

- *If the hinges don't come with screws, 1 ¾" flat-head wood screw (**not** drywall screws) for each hole in each hinge; pick a screw size that matches the holes in the hinges (typically #6 or #8).*
- *a hasp and padlock if you think it's necessary (we didn't).*

- *Lumber for a roadcase:* ***approximately*** *20′ of 1×2, 86′ of 1×4, 14′of 1×8, 24′ of 2×8, 5 sheets of ¼" plywood. These numbers are estimates for costing a show of 100–150 panels; for the exact figures, take the number of trees you will build to the dimensions specs and cutting list on pages 54–56. All of this can be very cheap lumber.*
- *Casters for a roadcase: two straight and two swivel, 2-3″ wheel size (rated for at least 50 pounds); the distance lengthwise between the inside edges of the holes on the long side of the base plates should be at least 1¾″. Casters with brakes are useful but may only be available in much more expensive brands.*

## For assembly

The clamp setscrews take a ¼″ hex drive; you'll want a lot of some sort of tool with this kind of business end to tighten the clamps. Possibilities include:

- "ball drivers" (really, that's what they're called). These can dull easily when you bear down on them, and they're awkward or weak to use on the side arms of multi-arm clamps when there's a pipe in the center socket.
- an official tool from Kee. this has a ratchet but is outrageously priced; you can get a similar tool at a better price from a number of places (e.g., Sears).
- a socket with ¼″ hex bit, mounted on a ¼″ or ⅜″ socket driver (whichever size the socket fits). We found this to be convenient, and it's a fairly standard item—it won't be in every hardware store but Sears will stock it, as will many auto–parts stores; the latter are likely to charge less, which isn't bad since the tools are likely to walk or be lost before they break. Glue bit and socket together before using, as they like to fall apart.

There are tools you can throw together for somewhat less, but probably none of these will save you enough to be worth the trouble.

Whatever you get, figure at least one of these for every 25-35 panels, and maybe get a few ball drivers for use in starting frames and building helicopters. You should also have a ¼″ hex key wrench (often called an Allen wrench) to work on setscrews stuck hard enough to damage a ratchet.

**Note:** ***don't*** get power tools for assembling the pipe; the cheap ones run at high speeds without enough torque to tighten the fittings properly, and the expensive ones can ruin clamps, setscrews, pipes, or all three. The setscrews tighten in just a couple of turns, so there's no advantage to using something that looks faster.

You will also need:

- at least one set of small, spring-loaded diagonal cutters to clip cable ties with. (You'll have bought these to make the hangings if you use the sandwich method of hanging pegboard.)
- ~6″ of ¾″ strapping tape, or ~3″ of duct tape, *each show* for each piece of pipe in the hangings, in order to bundle the pipes for transport and storage. Duct tape may net cheaper but leaves more of a messy residue on the pipe and tears more easily.
- If you're hanging pegboard by the hook method, a few ⅜″ nut drivers. Battery–powered screwdrivers with ⅜″ stopped sockets (so the socket is just deep enough to hold one nut) can also be useful here, but you should have the nut drivers in case the power screwdrivers break down.

- Optional, but a good idea: carts to move the pegboard on. If you get heavy-duty 2′×4′ flatbeds they won't be cheap ($115-150 each) but they will make it much easier to move the pegboard in storage, around the art show, and even into and out of a truck (fully loaded if you have a level loading dock or rent a truck with a lift gate instead of a ramp, but in any case in much larger piles than you can carry).
- If you are using trees to hold up the lights, a lightweight six–foot stepladder and a pair of work gloves to allow you to adjust the lights after the hangings are up and the power is turned on. You can't aim the lights perfectly before the hangings go up; aside from the problems of getting the aim generically correct, you'll often have bays which look better if the light is tipped a bit toward the darker artwork.
- If you're mounting lights on the outside connectors of the spine, a kickstool (rolls on casters which retract when you stand on the stool) is very convenient. (This won't be tall enough to help with lights on most trees. There are also taller rolling stepstool platforms; they're nice if you have room to carry and store them, but they take up much more room in your truck than a folder ladder and they're not cheap.)
- If using spring–clamp lights: 1-2 nut drivers to match the nuts on the U-bolts. This will probably be ⅜″ or $^{7}/_{16}$″; take a sample nut with you to be sure.
- If using no– or one–outlet lights:
  - 1–2 large screwdrivers to fit the slot in the bolt that tightens the conduit hanger.
  - 1–2 box or adjustable wrenches to fit the nut on the bolt that tightens the conduit hanger. This nut is usually square, which means that you may have to get adjustable wrenches because of the nut's not fitting any standard fixed wrench.

# Materials

## Pipe

The official name for the pipe used in these hangings is Intermediate Metallic Conduit (IMC). This is neither EMT (tubing, frequently also called "conduit") nor true pipe; it is much lighter and less expensive than pipe, but it is thick enough to be threaded and cannot be bent by reasonable means (unlike EMT). We use the ¾″ size, which has proven strong enough for all flat work that I've seen—I don't know what would happen if the artist who used to send in scribed slate started working with pieces several feet on a side, but anything lighter shouldn't be a problem.

IMC is most commonly found at large electrical supply houses; I had no luck with smaller stores or home/builders' supply stores. Look in the Yellow Pages under Electric Supplies (or the closest equivalent) and don't call just the places with big ads, as many of the best/largest places have just a one–line listing. It's definitely worth shopping for this; I got quotes ranging from $.38 to $.81 per foot. Tell them how much you're buying and they may give you a little off for quantity; they may also have to order such a quantity.

IMC usually comes in bundles of 5 "10-foot" pieces; each piece is actually about 9′11″, is threaded at both ends, and has a threaded coupling on one end. You'll use some of the couplings to assemble scraps, and should keep the rest (e.g., in case you want get in a space where you can build larger bays, as described on page 17).

You can estimate the pipe you will need by adding up (by type) the pieces in your layout using the Piece Count sections, then use the following rules:

For 6×6 hangings you can get 3 horizontals/connectors, or 2 and 1 upright, from 2 pieces of IMC.
For 6×6 hangings you can get 2 lighting supports or 1 lighting upright from 1 piece of IMC.
For 4×8 hangings, you can get 1 connector or lighting upright or 2 horizontals from 1 piece of IMC.

Note that all of these imply some waste, averaging 3% of nominal length for 6×6 hangings and somewhat more for 4×8. It's possible to cut until you have too short a piece to work with, attach another full piece, and continue cutting, but this takes more tools and time to prepare; also, having couplings in most pieces and in many different places on those pieces will get in the way when you're setting up.

*Alternatives*

- The LASFS hangings use some sort of lightweight (aluminum?) tubing. We found that even 6′ lengths of this would sag under heavy artwork; also, aluminum tubing is likely to be expensive outside of areas with lots of aerospace manufacturing.
- In theory the lighting supports can be made of EMT, since they are guaranteed to have relatively little weight on them. In practice this doesn't work well; 3⁄4″ EMT is small enough that the clamps have a hard time gripping it, and 1″ doesn't fit. (7⁄8″ would be ideal, but it doesn't exist.) If you were really desperate to save money and didn't care about construction time or appearance, you might hammer and epoxy stubs of IMC inside 1″ EMT for the clamps to grip on, but I wouldn't advise it—it would be a lot of trouble and the results would probably not be straight. A short piece of IMC can be slit and forced over EMT, but the result doesn't fit the clamps.

Note that if you use lightweight tubing instead of IMC your assembly crew will have to be very careful; the right torque for IMC will crush EMT.

- Eastercon (British national convention) and Intersection (1995 Worldcon, in Glasgow), used standard pipe since IMC is unavailable in Britain (where most wiring is run in PVC pipe). Standard pipe (as used in plumbing) is much heavier and more expensive than IMC, but has the advantage that the clamps are sized for it, so the joints are somewhat sturdier. Chris Cooper reports that the net cost for metal was about the same because Kee clamps are made in Britain (so they were much cheaper than in the U.S.) and the cost of the pipe included cutting to the specified lengths.

## Clamps

The clamps discovered by LASFS, and used in their hangings and all four sets I've made, are available from Kee, in Buffalo NY. You can phone Kee directly (716-896-4900) and ask for local outlets, or try the Materials Handling Equipment listings in the Yellow Pages.

These are the clamps mentioned in this writeup:

| manufacturer's name | mfr's part # | name used here |
|---|---|---|
| single-socket tee | 10-5 | one-arm |
| side-outlet tee | 35-5 | three-arm |
| four-socket cross | 40-5 | four-arm |
| combination socket tee and crossover | 46-5 | double tee |
| 90° side-outlet tee | 21-5 | angle two-arm |
| 90° three–socket tee | 25–5 | three–arm solid |
| straight coupling | 14–5 | inline |

The first three are the types used by all the existing hangings; I now recommend using double tees instead of four–arms for lighting helicopters. You will need right-angle two-arm clamps only if you are building cheap serpentines, and inlines and three–arm solids only if you're doing the Eastercon variant (see page 20). The clamps are available to fit several different sizes of pipe; the "–5" at the ends of these part numbers means the clamps fit 3⁄4″ pipe. The one–arm, three–arm, four–arm, and angle/straight two–arm each have a hole for one pipe to pass *through* the clamp, and the named arrangement of arms allowing pipes to butt up against the pipe passing through. For a while I was calling the standard clamps 2-way, 3-way, and 4-way, but these names aren't particularly clear to somebody looking at the clamps for the first time; you may want to call them 2-way, 4-way, and 5-way for the maximum number of pipes they can connect. There is a setscrew in each arm, plus 1-2 in the pass-through socket, to lock the pieces of pipe in place.

There are a number of other manufacturers of somewhat similar clamps (e.g., SpeedRail), but I don't know whether they carry clamps with the specific arrangements of arms needed for these hangings; also, several brands have bolts with protruding heads (instead of recessed setscrews), which you don't want in an art show (people could brush against them and get hung up).

Whatever you decide to buy, you will want to shop around; you won't get much of a discount anywhere, but if you're doing a good-size layout (100 panels or more) all at once you should be able to get 5-10% off, which may amount to more than the vendor will charge you for shipping if/when he has to order the clamps. (Nobody in Boston keeps any stock of this brand; I expect this is also true elsewhere.) I don't know how the other brands of clamps compare for price with Kee.

In 1992 these clamps cost $3.95/6.95/11.25 for one/three/four-arm after a discount of ~8%; shipping added ~3% of the cost. I'm told the price goes up at the end of each calendar year.

You may want to buy some spare setscrews, as they do die occasionally; unfortunately they cost $30 for a bag of 100, Kee doesn't sell them in smaller quantities, and no vendor I found was willing to buy and break a bag. (There doesn't seem to be an alternate source, which isn't surprising given the setscrews' miscegenation; the socket is English measurement and the thread is metric.) You might buy a few from one or another of the groups that currently have this type of hangings, just to have them on hand.

## Pegboard

There are two kinds of pegboard: 1⁄8″ and 1⁄4″. The 1⁄8″ is the right type for hangings; the 1⁄4″ is more expensive and heavier and requires larger, more expensive hooks (the hooks intended for 1⁄8″ pegboard will easily fall out of 1⁄4″). Shop around for the best price, trying the largest builders'-supply company in your area first; you may be able to get 2′×4′ pieces at a reasonable price, or it may be a lot cheaper to get 4′×8′ and cut it down.[9] Cutting is messy and time-consuming, so think about the tradeoff if your club's purse will support it.

The Lunarians' monster sandwich hangings used Duron™ pegboard, which is quite durable and has a smoother (but darker) finish than normal pegboard. When they were converting to tinkertoy, they and NESFA got lucky—Stuart Hellinger found an overstock that the manager was willing to cut and deliver for about the price of regular pegboard. If you can get a bargain like this, fine; otherwise it's probably not worth the extra cost ($12-15 per 4′×8′ sheet in Boston in 1992).

9. In Orlando, 4×8's were $5 and 2×4's were $1.45. In Boston the best price was $2.35 for 2×4 and $5.50 for 4×8. It's possible a bulk order for 2×4's would have gotten a better price, since it looked like the store was charging a premium for an odd product; 2×4's are available from the mill but are sometimes cut down by the store.

## Pegboard Hanging

If you're using the hook method, the best hooks I've found (requiring the least reshaping) come from National Steel; you want the 1″–diameter half-rounds for ⅛″ pegboard (part #180-356). You should be able to find these wholesale in boxes of 200 for ~$13; call National (800–346–9445) for the name of the local salesman, or, if you know a local store that carries this brand, see if they will order and give you a break on price. You will also need lots of 10-24 nuts; try a wholesaler ("Fasteners" in the Yellow Pages, or check TomCat) or a builders' supply—you'll pay through the nose at a typical hardware store and they won't have enough anyway.

If you're using the sandwich method, the best rope I've found is a lightweight braided nylon, available at boat stores as "lanyard line", which is ⅛″ or 7⁄64″ braided nylon. The same thing may be findable in cordage bins at builders' supply stores or even general department stores, but you'll probably have to special-order it to get enough. You will also need lots of small tie wraps; very thin by 3-4″ long is fine and should be available at an electronics store for $10-13 per thousand.

The tie wraps for securing the pegboard should be 8″ long and thin enough to fit through the holes in ⅛″ pegboard (e.g., Waldom #65008), which means you'll probably have to special-order them; they should cost ~$35-45 per thousand at an electronics store. Pipe cleaners are often cheaper; you may or may not find them easier to work with.

## Hanging Art

You should talk to National Steel and other vendors about hooks to hang the art from; we bought National's ½″-diameter half-round hooks part #180-364. It's useful to standardize and we were told artists preferred this type; the hook is small enough that it doesn't get in the way and the end is turned over enough that it doesn't gouge the back of the art as some other types do.

You will also need bulldog and/or binder clips—not quite as many as the pegboard hooks since these are needed to hang art that has been matted but not framed. Try a stationery superstore (Staples, Office Max, . . . ); if you get any information from artists about what type and size are preferred, let me know for a future edition.

## Feet

Unless you are absolutely sure you are never going to use these hangings in a room with a carpeted floor (in which case I pity your feet), you will need something to prevent the ends of the pipes from cutting into the carpet. Here are a couple of traditional choices:

- pieces of plywood ~3″ square, ½″ or more thick (thinner will break under the weight of the hangings); if you don't sand the edges, they'll do almost as much damage as the pipe. These are much bulkier to store than the solutions below, but they're cheap. For carrying convenience you can drill a hole through each and string them on a rope.
- *Caster feet* are small square pieces of plastic, usually with a bit of a rim (like tiny ashtrays), that go under small casters (e.g., on couches) specifically to prevent them from cutting into carpet. Also known as furniture cups, etc.; try a large home-supply or hardware store, or a furniture store.

Both of these protections have to be put under the pipes during setup and collected afterwards; this isn't a dreadful task but it's a nuisance (and one more piece to lose).

What I now recommend is the "1-inch round standard spring cap" from Midwest Fastener Corp. in Kalamazoo MI, or whatever equivalent you can find in your hardware store—a **large** hardware store may have something like this in its collection of cardboard–drawers–with–nuts–bolts–etc. Try calling the manufacturer. if you can't find these or some equivalent in your area. This cap has two advantages:

- Unlike chair feet (also known as furniture tips) and crutch tips, it fits **into** the end of the pipe, allowing you to slide a clamp over it during assembly;
- Unlike knockout covers (which are designed to fill holes in sheet metal) it has elongated spring fingers designed to hold firmly when stuck into the end of a piece of pipe.

This type of cap isn't cheap, but you don't need a lot of them and they work better than anything else I've found. Note that Kee also makes pipe feet in plastic (part #77-5) and "malleable iron" (part #84-5), but these were more expensive than anything else I looked at.

Note that your choices interact with how/whether you make additional upright pipes out of leftovers from cutting the 10′ pieces to size; a foot that a clamp won't fit over isn't less of a problem if the clamp can slide down from the other end, which doesn't work with pieced–together pipe. You may want to work out your cutting list *before* making a final decision on feet, or change the cutting/piecing list if you decide that caps that don't interfere with clamps are too expensive; see discussion of cutting/piecing on page 40. Note also that the small caps don't interfere with bundling the pipe.

If you go looking for any permanently–attached type of foot, take a clamp and a piece of pipe with you to test what you find.

## Lightbulbs

Bulbs for trees on 6×6 hangings (in single lights) are 150-watt flood–focus R40's (indoor type). ("R" specifies the reflector shape of the bulb; "40" is the bulb's width (greatest extent in a plane perpendicular to the base) in eighths of inches.) 100-watt R40 bulbs slightly reduce the wiring needed and what you have to pay the hotel for electricity **if they light adequately;** many of the ones I've tested didn't cover as much area or as smoothly as the 150-watt bulbs.

Bulbs for trees on 4×8 hangings (in double lights) are 75-watt flood–focus R30's (indoor type).

Bulbs that will be sitting on outside connector pipes and bouncing light off a low ceiling may be either spot- or flood-focus; you should make a sample bay (see "Testing a space for lighting", page 11) and see what kind of light you get with each type. I found that flood-focus lights worked with an eight-foot-high ceiling, and spot-focus lights with one ~9′ high; your bulbs, ceiling, etc. may vary.

Usually the box the bulb comes in says "spotlight" or "floodlight", but many inexperienced helpers (especially in the large stores where you'll get the best prices) use "spotlight" and "floodlight" interchangeably for any reflector bulb, so be sure what you're getting, Frequently "spot" or "flood" will be printed on the center of the face of each bulb, and most spot bulbs have clear faces while most floods have frosted faces. If you're not sure what you're getting, insist on a test: at a distance of 2 feet a flood-focus bulb will cast an even light over a 3′-5′–diameter circle while a spot-focus bulb will cast two concentric circles, one very large and faint and the other much brighter and smaller (less than one foot diameter).

You want the indoor grade of bulb for trees because the outdoor is much heavier, which is a concern when your lights will be hanging from one end of an arm that's only supported at the other end; also, I've never seen an outdoor flood-focus bulb. Outdoor bulbs **may** do for lights sitting on outside connector pipes; they're certainly cheaper, but I've never tested how good a light they give.

## Light sockets

I have not been able to find the kind of lights we started with for the NESFA hangings (which we began lighting before we shifted from Dexion hangings to tinkertoy) since the summer of 1989. If you can find a spring-clamp light (sometimes called a clip-on light) in which there is a fitting consisting of two knurled balls, $\sim 3/8''$ diameter, connected by $\sim 1/8''$ of $\sim 1/8''$ rod, in between the clamp and the socket, these can be readily converted into lightweight lights (see "Old-style spring-clamp sockets", page 47).

It's more likely that you will find the newer style of spring-clamp light; in these the fitting between the socket and the spring clamp has a knurled ball at one end, and a shoulder and conical point at the other; the point is forced in between coils of the spring, so that taking out the fitting requires forcing open the spring, while the double-ball fitting described above can be taken out by loosening two screws. This can also be converted into a lightweight light suitable for using on tinkertoy hangings, but you will need a milling machine or a numerically controlled punch to make the mounting plates. (NESFA got very lucky: Ted Atwood had access to such a machine at work. You *might* be equally lucky.) See "New-style spring-clamp lights", page 47.

You can also hang either type of spring-clamp light unmodified, by twisting one of the faces of the business end of the spring clamp so it goes through the other face, then pushing the end of the support arm through the twisted face. This is a simple solution but it doesn't work very well. Setting up these lights requires some force and the lights are harder to aim, since they tend to try to hang straight down from the support instead of staying where you put them; also the trees must be 6–9$''$ taller.

Both of the above solutions are lightweight and relatively inconspicuous, and will cost $6-10 per light. You can also buy these lights with shields; the shields aren't actually required under the U.S. electrical code since the lights will be more than 7 feet off the floor, but some localities may require the shields anyway. **Check your local codes;** such a regulation appeared in Boston shortly before Noreascon 3 and caused us a lot of grief because I didn't find out about it until the Art show was mostly up. You may be able to find old-style clamp lights with integral shields; these will be heavier, and bulky to store, but they may be your best choice if you must have shields.

You can also build mountable lights around electrical boxes. These are somewhat heavier (so you'll have to be careful about supports) and a little more conspicuous. Their big advantage is that they can be built with parts you can get at any good electrical supply store. These lights can be built with none, one, or two outlets in the same box as the light; lights with outlets are useful if you are building 4×8 hangings with outside trees (see figure 11, page 14), or either shape of hanging with lights mounted on the outside connector pipes (reflecting off the ceiling), as you can chain the lights together without additional hardware, making hooking up the lights significantly easier even without electric trees. (You can even hardwire chains of two or more boxes, but I don't recommend this; you'll save a little money but lose flexibility.) See "Box lights" on page 48 to consider how difficult each type is to make.
***Note: of the three variations of box lights described, only the one–outlet variety has been made in quantity.*** You may need to do some samples of your own to find the best way of building no–outlet and two–outlet box lights. In any case, be sure to get help from someone who has experience working with 120– or 240–volt wiring.
**Note:** the two–outlet box lights screw onto the threaded end of a support; no– and one–outlet lights have a clamp that fits around the end of any support. You can get multiple outlets in a (one–outlet) clamp–on box light by adding a cube tap, but this may push the weight and total cost beyond that of a two–outlet. (The two–outlet lights can similarly be promoted to six–outlet, but it's not likely you'll need this.)

## Miscellaneous

(Thread–locking) **anaerobic adhesive/sealant** is an opaque goop, frequently brightly colored, that is preferred to epoxy for making threaded joints stay together. Common trade names include Thread-Lok and LokTite. The adhesive comes in several strengths, with names varying by manufacturer; get this-joint's-never-coming-apart rather than this-joint-will-hold-if-you-don't-look-at-it-cross-eyed. You should use just a few drops on each joint, so a small tube will do a lot of joints (I haven't counted just how many); see if the store you deal with will let you return any unopened packages. This stuff is easy to find in automotive supply stores, although they may not understand if you ask for anaerobic adhesive instead of ThreadLok (they may not sell that brand but they'll understand what you're looking for).

**Clamp storage:**. the clamps usually come in a burlap bag in a woven-plastic bag in a cardboard box (sometimes with just one layer of bag). This packaging won't die immediately but it's awkward to carry and use, and sheds fibers on the clamps. 'zanne Labonville discovered that tall 5-gallon plastic buckets with handles and tight-sealing lids are sold in large builders'–supply stores; you may be able to salvage some that had (for instance) spackling compound or food in them, but usually these aren't worth the trouble to clean. Some places also have a 3-gallon size; a 5-gallon bucket full of clamps may be too heavy to carry (try this for yourself), while a 3-gallon may hold as much as you can carry and/or be just right for some of the smaller clamps or some of the clamps you don't have very many of (e.g., double tees for long–arm helicopters). Note that these buckets seal tightly and are difficult to open; special opening tools are available, but a claw hammer and a large screwdriver (or a very small pry bar) will do about as well and should probably be in your toolkit anyway.

**Corrosion inhibitor** is a thick, opaque solution of waxes in a volatile liquid. IMC is usually galvanized (or coated in some other fashion so it won't rust easily), but if you cut threads in the pipe you'll expose the raw metal. There are a variety of corrosion inhibitors available at various stores (hardware, builders' supply, . . .); we used one called LPS-3. You should plan to renew the coating every few years.

**Conduit hangers** come in a number of varieties; you're looking for a metallic type which has separate screws to hold the hanger to the wall and to tighten the hanger around the conduit. The type I've seen looks rather like an outline of Green Lantern's insignia (to those of us who misspent some of our youth with comic books). The size can specified for EMT or for IMC, or just as a dimensionaless number; take along a piece of your IMC to make sure it will both fit properly in the hanger.

The **defrictioner** and **machine screw** (and **wing nut**) are used to make the lamp-head joint swivel more controllable.

On all the lamp heads I've seen there are sharp and prominent teeth on both faces of the swivel joint, almost like gear teeth; the joint is clearly designed to hold a position very firmly rather than to be easily adjustable. The joint is hollow to make room for the wires; the teeth are on the outermost part of the faces, and one face has a thin rim just inside the teeth to keep the pieces of the joint aligned. The defrictioner will go between the two toothed faces and around the rim. Possible defrictioners include:

- an external retaining ring. These are used to hold rotating shafts in place; they're very narrow and have a small gap with tabs on either side outside the main ring. (Internal retaining rings also exist; the tabs on these would make it harder to keep the two parts of the joint aligned.) A *large* hardware store will have these in with the drawers of assorted sizes of individual bolts, nuts, washers, etc.

- a “wave washer”. These are narrow washers made of spring steel that lies flat only when under pressure. They work very well (since they put a bit of tension in the joint) but may be hard to find; try the Yellow Pages under “Washers” (or maybe “Fasteners”), or call the nearest company listed under “Washers: Wave” in TomCat.

Nylon washers might also work, but they’re not as sturdy and aren’t easy to find in the sizes needed for most of the types of lamp head I’ve tested. Rubber grommets, O-rings, and felt disks (lamp insulators) are Right Out, as the teeth will tear them up very quickly.

Take a sample lamp head with you when you go shopping as different brands of lamp head come with different-sized joints.

If you can find them, you should also put a smaller “dish” or “belleville” washer under the head of the screw that holds the swivel connection together, so there’s a little more tension; with the wave washers in place you should be able to adjust the screw so it won’t loosen when you bend the joint.

Once you’ve found enough of some kind of defrictioner, see what length of machine screw is needed to hold the joint together. You should replace the original screw with one of the same diameter but enough longer to allow room for the “dish” or “belleville” washer (or split lock washers on both ends) and a wing nut, so you can aim the light easily and make sure the joint is tight afterwards. A good hardware store will have a wide variety of screw sizes so you can find exactly what you need.

**Indoor/utility boxes** come in a number of variations. You should look for a relatively large/sturdy single gang box (almost as wide as the cover plate, and almost as deep as wide). **Do not get plastic utility boxes!** These come under a variety of names like quick-box, ready-box, etc., and are cheap but not legal; to be legal, the lights must be in a metal box so the box can act as a ground. (Just to make matters confusing, the right type of box is often called a handy–box.) ***Note:*** I’ve been assuming rectangular boxes because that’s what I’ve seen in use; for lights, a round box might work as well and could give more room for wiring.

**Lamp heads** are designed to attach to rainproof boxes for outdoor lighting; tell your supplier this if he looks blank when you say “lamp head”. (If he still looks blank, find a larger supplier.) A good builders’ supply house will have these right next to the outdoor boxes & cover plates.
**Note:** the U.S. electrical code says that bare bulbs don’t have to be shielded in temporary setups if they are more than 7’ off the floor; Noreascon III was screwed by a local extension of the code. Before committing to lamp heads, be sure that you will be able to use them in your area, since they can’t be refitted to use shields/reflectors.

**Lath** (or lattice) is typically $1/4''$ x $1\,3/8''$ or $5/16''$ x $1\,3/4''$ softwood, commonly used on trellises and used here as filler to keep the stacks of pegboard flat. (Without these pieces the ends may bow higher than the middles, possibly warping the pegboard permanently.) You may want to make the sandwiches first, then see just how much filler is needed; also, if you have a table saw you will find it cheaper to cut $\sim 2''$ strips of hardboard (same material as pegboard, without the holes) than to buy lath (which is knot-free and hence expensive, e.g., $.10-.40 per foot).

**Machine screw** (optional)**:** see defrictioner.

**Nut–Serts**™ are fasteners shaped rather like a standard nut with an additional flange; the flange fits through a hole slightly large than the bolt the Nut–Sert is designed to hold, and flattens to hold the Nut–Sert in place when you put a bolt through from the flange side and tighten it. They do about the same for sheet metal as Tee–Nuts do for blocks of wood, giving a sturdy thread in a piece that won’t hold a cut thread under the stress you want to put on it. These devices may be available under other names (the patent has probably expired); call around to hardware and builder’s–supply stores.

**Outdoor cover plates** for lamp heads come on a number of styles: round or rectangular, 1 or 3 threaded sockets (I haven't seen 2). You want a shape to match your indoor utility boxes (q.v.) with enough holes for the number of lamp heads you'll put on it. If it has more holes you will need threaded fillers to fit the holes—these *should* come with the cover plate, but check to see. Some stores sell packages of 1–2 lamp heads and a suitable cover plate for less than the pieces would cost separately. Note that the designs in this monograph call for outdoor cover plates only with indoor boxes!

**Outdoor/rainproof/exterior electrical boxes** are heavier than ordinary utility boxes (usually cast rather than crimped or spotwelded from sheets). Any electrical supply house will carry them*, although they may have to order in enough for a lot of trees, which use a less-common type*; they can also be found at large builders' supply stores. You want the type with **one** threaded socket on each of the top, bottom, and back; a box with two sockets at either end will make an unbalanced light socket *or tree*. **Do not** get the outdoor/waterproof outlet cover plates that normally go with these boxes; since you'll be using the lights *and trees* indoors, waterproof covers are an unnecessary expense. Be sure to get real outdoor boxes; "zip" boxes, "Handi–Boxes", etc. won't work.
*The instructions for electric trees say to use two single–gang boxes, connected with a nipple and with a duplex outlet in each, rather than 1 double–gang box with two duplex outlets. The latter is bulkier, which would require a bigger roadcase than described in "Making the Parts", and may also be hard to find in a one–socket–per–side variety; it's not likely to be cheaper.*

**Over-the-floor rubber duct** is a rubber or plastic strip, triangular in cross-section, with a slot in the widest side that allows it to fit over power cords and protect them if they will be walked on. It's not cheap ($1-2/foot), but it is strongly recommended if there is any place where you need to run the power cords across the floor. (E.g., between the power source and the nearest tree; you may be able to run cords from the tops of the trees over to the wall and down, but don't plan on this.) Flexiduct™ is a well-known brand name (sometimes used as a generic) made by Winders & Geist, Lincoln NE. It comes in rolls of 25-50 feet depending on size; the #1 can cover 1 14/3 SJ cord; the #25 can cover 2-3 cords. Unlike many manufacturers, W&G will sell to you directly, although you might get a discount on a large order from a local supplier. There are other brands available; to find them, ask around or look in TomCat.
Whichever brand you get, order it in bright yellow rather than grey or black; it's a trip hazard even when properly taped down (use, at least, duct tape the entire length of both edges and a few strips across), and the bright color may discourage people from walking on it, further protecting your power cords.

**Safety caps** are used to fill unused sockets in the outlets of box sockets and in the middles of the electric trees, since duplex outlets are much cheaper than singles (having the spare sockets is also useful if an artist wants a few watts). These are small plastic rectangles with two prongs shaped and spaced like the ones on a standard electrical plug. They go by various names; you can find them at electric supply, builders' supply, and hardware stores, and even large department stores.

**SJ** is a standard of construction for electric cord; it's the commonest type of flexible cord I've seen (most round orange extension cords are this type). However, you can also get 12/3 flat cord, in bright yellow or even more vivid colors (one of which Kurt refers to as "bubble gum"). SJ is OK for making light sockets, but the flat cord is better for wiring the rest of the show together; it's easier to bundle where two or more cords are running parallel (e.g., close to the power source.)
SJ is available in rolls; the flat cord may also come this way depending on where you look. However, entropic as it may seem, it's often cheaper to buy complete extension cords and cut them up in the lengths you need for box sockets *or electric trees* rather than buying a roll of cord and the plugs to go on it, even if you waste some cord.

A **strain reliever** holds onto an electrical cord where it goes into an electrical box, so the connections inside a box won't pull loose if you pull on the cord.

- The inexpensive type is usually marked something like "clamp connector for non-metallic sheathed and service entrance cable". Most are designed so they can either screw into an outdoor/rainproof box or clamp into a hole in an indoor/utility box with a lock nut (supplied), then clamp down on a cord using two small screws that drive a flat piece of metal toward the opposite side of the strain relief. A variation of this type has a built–in bend so it holds the cord flat against the box instead of protruding at right angles; this can useful for some homemade lights (think about which direction the cord will run from the light) *and particularly good for electric trees, where a protruding mounting could snag passersby, provided that there is enough thread on the strain relief that it will set firmly in the back socket of the outdoor utility box when turned to point downward—you should test this before buying this type.*
- More expensive (and larger) types are made of two pieces of concentric plastic or metal that pinch the cord when they're twisted together. I haven't seen these made in a right–angle type, and the straight ones are bulky enough to be convenient, *especially for electric trees*.

Strain reliefs come in various sizes; you need to be sure the size you get fits the holes in the boxes you will be working with. ( I've seen some of the inexpensive type labeled $^3\!/_8''$ when they actually had $^1\!/_2''$ pipe threads, so carefully compare what you find with your boxes to make sure you get the right size.) You may have trouble finding a size that fits the $^3\!/_4''$ socket on the oudoor boxes (for two–outlet lights *and electric trees*), in which case you can often use a smaller size fitted into a $^3\!/_4''$-to–whatever reduction bushing (usually found in the plumbing department). Make sure that the size you get will securely hold the cord size you'll be using; some of the $^3\!/_4''$ types I've seen won't hold a small cord or a flat cord securely.

**Wire nuts** come in several sizes; you should look at the specs on the boxes and get the sizes appropriate for the wires you're putting together, as shown in the parts list.

Wire nuts come with several almost–parallel ridges running the length of the nut; some types come with "wings" or "ears"—two ridges on opposite sides of the nut that are much larger than the rest of the ridges. Wings/ears are very useful if you can find nuts with them because they make it easier to get the nuts very tight.

Note that in some states in the U.S. wire nuts are the only approved method of connecting several wires in a box, or connecting stranded wires (via a solid wire) to the screw on a duplex outlet; soldering is Right Out in all states. Spade lugs are somewhat easier to get right than wire nuts, but your state may not allow them for 120–volt connections.

## Final Notes

When you're adding up your order, allow at least 10% extra of clamps and 5% of everything else over what you absolutely need for your planned layout; it will give you some flexibility in the layout and a little leeway in case parts get lost, which they certainly will if you can't afford to lose anything. (Parts can also be defective on delivery; replacing these may take time you don't have.) You need to allow more margin for the clamps because they are more fragile than most of your other parts; also, they usually have to be ordered from the factory (taking weeks for delivery), while most of the other pieces can be bought anywhere (albeit at outrageous prices) in an emergency.

Do price comparisons on *everything*; you're buying enough pieces that you will save significant money on almost anything. Look at both builders' and electrical supply stores (more than one of each) for the electrical parts; the big builders'–supply stores sell enough pieces that they sometimes underprice electrical supply stores. A hardware stores may be convenient, but is likely to be much more expensive for most of the parts you want and won't carry many of them.

# Making the Parts

## Pipe

Cutting and assembling the pipe will take time and space; make sure you have these, as well as the tools mentioned in the previous chapter. If you're painting on identification/clamp marks (which makes assembly much easier), you'll need a well-ventilated space or somewhere outdoors for at least one day.

### Using a pipe wrench

A pipe wrench is *not* a monkey wrench, although they look very much alike. A pipe wrench has sharp-toothed jaws that will catch hold of even a round surface if the metal isn't too hard. It also has a spring that makes the jaws act like a ratchet when properly adjusted; if you put the wrench on a piece of pipe with the jaws facing away from you, they will bite when you push on the handle and release when you pull.

Because a pipe wrench is designed to bite into the work, you can't adjust it simply by putting it on the pipe and turning the knurled adjusting nut until the jaws are tight; after you do this, take the wrench off and tighten an additional half-turn or so. Lightly slam the wrench onto the pipe instead of laying it on; if the wrench is adjusted correctly, the pipe will not touch the back of the jaws.

### Using a manual pipe cutter

A manual pipe cutter can be worked by one person but is easier with two, one to turn the cutter and one to hold the pipe with a pipe wrench. (Monty Wells, our tools guru, says a pipe vise on a solid, immobile bench is a big plus, but that's hard to get in an area where several people can do construction work simultaneously; if you don't have a vise, you can put the pipe on sawhorses with blocks or notches to prevent it from skidding sideways while the pipe wrench prevents the pipe from turning.)

1. Turn the cutter handle to open the jaws so they will fit over the pipe.
2. Hold the jaws closed on the mark with one hand and turn the handle to tighten with the other until the cutter wheel just bites into the pipe.
3. Bring the cutter once around plus a bit (you'll feel it become easier to turn when you complete a circuit), then tighten a bit (about $^1/_8$–turn of the handle) and repeat until the pipe separates.

- ***Don't*** overtighten the cutter; this makes cutting harder and wears out the blade and the rollers.

- ***Do*** support the free end of the pipe when you feel the cutter start to go through; otherwise you can get a messy break that is a pain to clean up.

In theory you can balance the wrench on the pipe with one hand and turn the pipe cutter with the other: in practice, cutting pipe goes much faster with one person for each tool. If the people doing this are working in sync, the one with the wrench can sometimes make the work easier by turning the pipe a bit in the opposite direction each time the cutter goes around; this way the cutter handle is pointed in the same direction when it should be tightened, instead of needing to be further and further around the pipe.

An electric pipe cutter/threader can speed up your work substantially, smooth the cut ends of pipes, and make your hangings somewhat more adaptable—***if*** you (a) have somebody who knows (or can show you) how to use one, (b) can borrow one or are willing to spend the money for rental ($75-100 per day), and (c) have a workspace where the substantial noise it makes isn't a problem. You will need a threader if you want to make the parts to allow you to enlarge 6x6 hangings to 6x7. *A threader is also necessary for making electric trees, but if that's all the threading you need done you may be able to get a plumber or large hardware store to do this for you.* NESFA's clubhouse is adjacent to a plumber, but we ended up cutting most of the pipe by hand because it was not easy to get bundles of 10-foot-long pipe to the plumber's pipe cutter (it was in the back of the basement). We did do a lot of threading (while hand-cutting was going on). Renting another power cutter probably would have saved us enough time to make the cost worthwhile; a question for some clubs (besides whether anyone knows how to use one) is whether they can be sure to have enough people on hand to keep a power cutter busy (ideally this is 4-5 people: one operating; one feeding pipe to the operator, catching the scraps, and cleaning the worst of the oil off threaded pieces; two assembling scraps for second cuts; and possibly another to measure pipe and generally assist).

***Note:*** some of the pipe I've used was cut with a PortaBand (sp?), a portable band saw with a twisted blade that is used for cutting pipe *in situ*; hacksaws and saber saws were also used. I wouldn't recommend any of these even if you can borrow the saw. Unlike a pipe cutter, the saw doesn't automatically make square cuts; also, it leaves a very rough edge that takes a lot of work to smooth (you **don't** want your setup crew to get metal splinters in their hands).

## Markings

Assembly is a lot easier if the pieces are marked to show which type they are and where the clamps go; this saves time measuring and avoids confusion of similar-length pieces during assembly. It's also useful to have the owner marked in case you loan hangings, or combine the hangings for a large show. I've worked out a simple code involving combinations of black and colored bands, where black commonly marks where a clamp goes and the color does other marking:

- uprights: black at the top end and near the middle where clamps go, one colored.
- horizontals: two colored.
- connectors for 6x6: two colored (same size as horizontals)
- connectors for 4x8: mark with three colored bands or as for trees.
- trees: two blacks where the clamps go, one colored.
- lighting supports: one black where clamp goes (end or middle), one colored.
- *electric tree bases: one black where clamp goes, one colored, one red.*
- *electric tree trunks: one black where clamp goes, one colored. (The wired sections of electric trees aren't likely to be confused with anything else, but marking ownership and where the clamp goes is a Good Thing.)*

The following owner colors have been used so far:

- blue (NESFA)
- green (Lunarians)
- brown (PSFS)
- international yellow (Arisia)

We've also used red as a warning marker on specialized pieces (tree bases, small pieces to make a packable dealers' display); you may want to use it to mark couplings so solid pieces of pipe can easily be distinguished from compound pieces during setup and teardown.

Try to pick a color that won't conflict with these, unless you can't find one and are far enough away that you're sure your hangings will never be mixed with any of the above (don't bet on this).

## Preparation

- Work out in advance how you're going to cut and piece together the pipe to get what you need with the least waste.
  ***Note:*** all past 6x6 designs have basically cut one upright (7′) and one horizontal/connector pipe (6′3″) from two 10′ pieces, then put the scraps together and cut another horizontal/connector. This may have been the wrong thing to do, because (a) the uprights don't need threads on either end, (b) it's useful to have a thread on one end of each horizontal/connector so you can expand to 6x7 or 7x7 if you have the room and the inclination, and (c) a joint doesn't weaken an upright piece as much as it weakens a horizontal piece (although we've never had a problem with properly-assembled joints in horizontal pieces). If the uprights are pieced together, you have to pay just a little more attention when making them (to make sure the couplings won't get in the way of the clamps), but this isn't likely to be a problem. ***However***, if the uprights have couplings you must either use detachable feet under the pipes or find some sort of insertable end cap (a good idea anyway; see discussion under "Feet", p. 31) instead of chair feet, since the coupling will be right in the middle; one of the clamps will have to go between the coupling and the foot and it won't fit over the foot.
- Set up a chart to keep track of your progress, so you won't cut too many of one size and run out of pipe you need for other sizes.
- Make painting templates from the EMT. Cut a piece a little longer than you need to mark, measure the distance you will mark from the smoother end of the tubing, drill at this point, drive a nail through the holes, and bend it over so it won't come out. You will need:
  - one template for 3′2½″;
  - one template for the length of a tree less 7′ *unless all trees will have built-in wiring*;
  - if you are making tees for 6x6 serpentine spines (figure 8, page 14), one template for half the length of the tee support (i.e., 4′6″–5′);
  - if you are making tees for outside lighting for 4x8 hangings (figure 11, page 14), one template for 4′2″

## Cutting

1. Break apart the bundles of pipe and take off all the couplings (and thread protectors if the other ends of the pipe come with them).
2. Set up at least one measuring crew and one cutting crew. Cutting will probably be the rate-limiting step; the measuring crew can fill in other tasks as below. I've found that with 6x6 hangings cut with a manual pipe cutter, the measuring crew can assemble and measure scraps (if you have three wrenches, or two wrenches and a power cutter), and do some de–burring or painting, in between measuring alternating sets of horizontals and uprights.

3. The pipe cutter leaves a sharp ridge inside the cut ends; you'll want to get rid of this so it doesn't bite the setup crew.
   - If you're working with a power pipe cutter, use the reamer to smooth the end remaining in the drive after each cut, and bring back the cut-off pieces (singly as you work or all together afterward) to be reamed.
   - If you're cutting the pipe manually, use the countersink and heavy drill whenever the cut pipe piles up high enough; this is a very quick step, but it takes one person to hold the pipe and one to hold the drill. Drip a little light oil on the countersink every 2-3 pipes; carefully collect the slivers produced (e.g., put a box under where you're working), as they're sharp.
4. If you're cutting threads in any of the pieces of pipe, rinse off the cutting oil after threading by dipping the new threads in paint thinner or degreasing solvent; when the liquid has evaporated, dip the threads in a corrosion inhibitor.
   - Don't bother applying corrosion inhibitor to the threads on leftover pieces which you're going to assemble to make more full–length pieces; just clean off the oil so the anaerobic sealant will stick.
   - If you have a power cutter/threader, it's a good idea to make sure *every* horizontal/connector pipe is threaded on one end. This will be helpful if you ever want to stretch 6x6 hangings to 6x7 because you won't have to sort you 6' pipes into those which can stretch to 7' and those which can't; it also makes expanding to 7x7 possible.
5. For pieces that are being assembled from leftover pieces, use a couple of drops of anaerobic adhesive on both sets of threads, thread both pieces into one of the couplings you took off in step 1, and tighten with two pipe wrenches.
   - If you cut threads in these pieces to reuse them (usually not necessary for 6x6 hangings), rinse the cutting oil off the threads (with paint thinner or degreasing solvent) and let dry.
   - Assemble and tighten the pieces first, *then* measure and cut; you can't be sure how deep the ends of the pipe will go into the coupling.
   - Support the work, apply the wrenches close to the joint, and don't overtighten—two adults putting their full weight on two wrenches, especially if the wrenches aren't next to the joint, can bend the joint if they don't stop when it's tight enough. Have your wrench crew(s) test how much they can tighten the joint without bending it.
   - If you are making very short (typically 9″) pieces so you can expand 6x6 hangings to 6x7, put adhesive and a coupling on the threads (since the short pieces won't be any use without couplings) and tighten.
6. *If you're making electric trees, the trunks will have to be threaded on both ends and the bases and tops will have to be threaded on one end. This will not be very many pieces; if you don't have access to a cutter/threader, try a large hardware store or the place you bought the pipe. The very short top pieces can be gotten by cutting the threaded ends off pieces that will become lighting supports (for which precise length isn't critical).*

## Finishing

1. The easiest way I've found to spraypaint the pipe smoothly in bands is to put several pieces across two slightly tilted sawhorses (work on slanted ground or prop up one end of each sawhorse); one worker holds the pieces and lets one at a time roll down the slope, while another sprays, following the pipe with the nozzle and moving the nozzle a bit side-to-side. This lays on several thin coats which are less likely to run.
2. To use the painting templates, put the piece of pipe as far into the appropriate template tubing as it will go, then roll this assembly down the sawhorses as above while spraying

right at the end of the tubing. This will give you a band with one sharp edge (where the clamp aligns) and one vague edge. For uprights, paint the uncovered end of the pipe (so the setup crew can be sure which end is up), then take off the template. For trees, take off the template and repeat at the other end with the other template (or put templates on both ends if you have enough people to handle all the pieces). Mop the painted end of the template after each piece (if you don't get *some* paint on the template every time you're not using it correctly).

3. If you're using permanent feet on the uprights, put them on now.
4. When everything is dry, bundle the pipe in fives (this takes at least two people, one or two to hold and one to tape); in theory sixes and sevens are stable but in practice they seem to be less so. Besides, (a) fives are a bit easier to count, and (b) you don't want to add having your pipes at sixes and sevens to all the other confusion of the art show.
5. Pipe can be stored more-or-less upright, or flat; don't stack it on a slant, or flat without even support (i.e., don't tempt fate).

## Clamps

The clamps will have a light coating of oil when delivered and will have all the setscrews run way out.

1. Rinse off the clamps in paint thinner or degreasing solvent and let dry.
2. Run all of the setscrews all the way into the clamps to make sure the threads and the set-screw sockets are good.
3. Back the setscrews out, then use a piece of pipe to measure how deep the setscrews will go without biting into the pipe; back the setscrews a couple of turns out from this point; this will protect the threads, and save time the first time you assemble the hangings.
4. String each type of clamp on short pieces (up to 3 feet or so) of pipe; pack them as close as possible, leaving a few inches of pipe free at each end. Make sure the clamps are all facing the same way (e.g., setscrews on the four-arm clamps lined up). Tighten a few set-screws (i.e., not on every clamp) enough so the clamps won't rotate around the pipe.
5. Spraypaint the clamps with your owner color (see page 40) on surfaces without setscrews (so the threads don't clog). The pipes will sit on sawhorses and can be turned and held by hand (if you've left enough pipe free at one end) to expose a surface with no setscrews in it; run a wide stripe (in multiple passes) down these surfaces. Make two stripes on the three- and four-arm clamps, since the only clear space is a little hard-to-see bit in two of the angles between arms.
6. Pack the clamps away securely when you're done.

***Note:*** In LASFS's original design, each set of parts (pipe, clamps, and cloth hanging surfaces) for one 2-long double spine was packed in an individual canvas "body bag", and the clamps were left on the uprights permanently. This seems like a neat idea but it has problems: there's no advantage in presorting if you want some other layout (e.g., if you move to a new room) and the body bags are quite bulky to store. If the uprights are properly marked, the time to put the clamps on the pipes at each setup will probably be no worse than the additional time to move awkward bundles.

# Pegboard

## Cutting

If you bought pegboard in 2x4 pieces you're home free; otherwise you'll have to cut it down to size. You can do this with a table saw if you have (a) someone who knows how and (b) a table saw with a fence that can be set for 2′ width (or someone who is a wizard at freehanding on a table saw), and (c) room to maneuver 4x8 sheets around the saw. Otherwise you'll need a skilsaw and someone who knows how to use it. Given such a person, here's what to do:

**setup:**

1. Set up two sawhorses about six feet apart. Lay the 8′ 2x4's on edge at right angles to the sawhorses, and nail the cheap 1x4 across the ends so the pieces stay on edge.
2. Make a cutting template:
   a. Do test cuts in a piece of pegboard until you see just where the edge of the skilsaw plate sits when the blade cuts exactly between two rows of holes; mark this point.
   b. Put the good 1x4 against this edge and mark (go up through the pegboard from underneath) where two holes near opposite edges of the pegboard hit the wood; record how many holes these nails are away from the holes between which the saw cut.
   c. Drive 6d nails through these marks until ~½″ protrudes from the other side of the wood; drive the nails as straight as possible.
3. Set the skilsaw to a cutting depth ~¼″ deeper than the stack of pegboard you're cutting.

You'll be cutting *across* the pegboard, making 4 2′ slices out of each piece.

**cutting:**

1. Square up ~4 pieces of pegboard (test scraps to see if your saw can cut this many) on top of the 1x4's; use at least 3 large nails through holes in each long edge (at the corners and near the middle) to keep the pieces lined up.
2. Drop the template onto the stack of pegboard with the nails through pegboard holes (however many holes away from a point 2′ from a short edge you noted in setup step 2b) and run the skilsaw through the pegboard with its plate lightly touching the cutting template. (The saw will go right through the top edge of the 1x4's holding up the pegboard; that's OK.) Move the template for each of the other two cuts.
3. Bang the cut sheets against a hard surface, then brush or vacuum them thoroughly; otherwise the sawdust will be all over your art show for years to come.

If you have enough sawhorses and 1x4 to make two cutting benches, two people can be setting up one bench and clearing away the cut pieces while a third saws steadily.

***Warning:*** the sawyer (and possibly the helpers) will need ear and eye protection, which should be available where you bought the pegboard. Eye protection means goggles, not just glasses; left–handed sawyers will be facing the saw exhaust and may want a full face shield and an apron.

## Marking

As you finish cutting and cleaning the pegboard, stack it on newspaper (or a surface you don't care about); keep the stack square as you pile it up. When you've got as high a stack as you trust (2-3 feet), spray a couple of stripes of your owner color (see page 40) on each short edge—make them wide and thick enough that they can be seen clearly on single sheets.

## Assembly

Note that both methods involve several steps which can be done in parallel, depending on the number of people you have working.

### For the hook method:

**setup:**

1. Put the ½″ nipple inside the ¾″ nipple. Open the vise wide enough to take the ¾″ nipple but not the ½″; put the two nipples crosswise in the vise (with the ½″ one sitting on top of the jaws) and tighten the vise so it holds the ¾″ nipple firmly. This will give you a very sturdy forming anvil, although you can probably make a tolerable one by seating the ¾″ nipple in some scrap lumber (drill 1″ holes in a couple of 1x4's and build a frame around them).
2. Cut a *short* piece of pipe (IMC) (¼–½″ long) and jam it onto the lower jaw of the smaller groove-joint pliers; use anything handy (paper towels, rubber gloves, epoxy, . . .) to make it stay in place. Shift the jaws on the larger groove-joint pliers so they are ~1¼″ apart when parallel.
3. Stack enough washers inside the 1″ 6-point socket to support the 10-24 threading die flush with the lip of the socket. If at all possible, drill and tap one side of the socket for a small setscrew to hold the die in place; otherwise just shim the die with a piece of tape so it doesn't fall out readily—you *want* to be able to take it out when necessary but not to have it fall out. Put the socket on the speed wrench.

**making the hooks:**

1. Hang each hook over the forming anvil; it will probably not go all the way against the pipe. Hit it *sharply* with a hammer (standard carpenter's hammer, not a lightweight tack or ballpeen hammer, or a heavy mallet) in the middle of the half-round; this will smooth out defects caused by the manufacturer's forming process but open up the curve to a little less than 180 degrees. Hitting the hook should force it to sit down flush against the anvil, but it should come up easily; if you have to hit the hook from underneath to free it, the first blow was too light.
2. Hang the hook over the piece of pipe in the smaller groove–joint pliers with the middle of the half-round facing the upper jaw. Hold the hook firmly with this pliers and use the large pliers to squeeze the hook into a true 180 degrees around the pipe (put one jaw against the tip of the hook and the other just below the safety stub). This can be done by one person but you *may* find it easier with two.
3. Use the bench grinder to grind the outside of the tip of the hook to a point of 30-45 degrees. It doesn't have to be sharp; it just has to lose most of the flat end.
4. Lay out as many of the hooks as you have room for on a piece of scrap wood and spray them with your color (see page 40); after they're dry, lay another piece of wood on top of the first, flip the sandwich (have a second person help hold if necessary), and spray the other side. This both identifies the hooks as yours and marks them as not for hanging art. ***Note:*** You may be able to paint the hooks adequately by dipping in paint instead of spraying, but don't ask me how to get them to dry (hang them on a clothesline?).
5. Clamp the hook in the small vise with the safety stub protruding. Cut a thread on the stub with the threading wrench you assembled in setup step 3.
   - Every 2-3 hooks, drip some cutting oil (3-in-1 will do) on the stub to prevent the threads from seizing.

- Be very careful getting used to this setup. The stub will only take 3-5 threads; it will break off in the die if you turn too hard, or if you move the back end of the speed drive lined up with the stub while cutting the thread and while backing off. Practice on the ends of some hooks before starting work on the stubs.
- When you do break a stub, take the die out of the socket, put it in the vise, and drill out the broken piece from the back with a $\sim 1/8''$ drill (that way the drill will drive it out and you won't have to cut it up completely in place). A screw extractor may also be useful for this.

### For the sandwich method:

These instructions describe cutting half–round notches in the pieces of pegboard, opposite where the ties will go, so that the pegboard will lie mostly flat when stacked (see figure 12). This is not absolutely necessary, but doing this work in advance means you need to do less work (inserting fillers) each time you stack the pegboard to prevent it from warping.

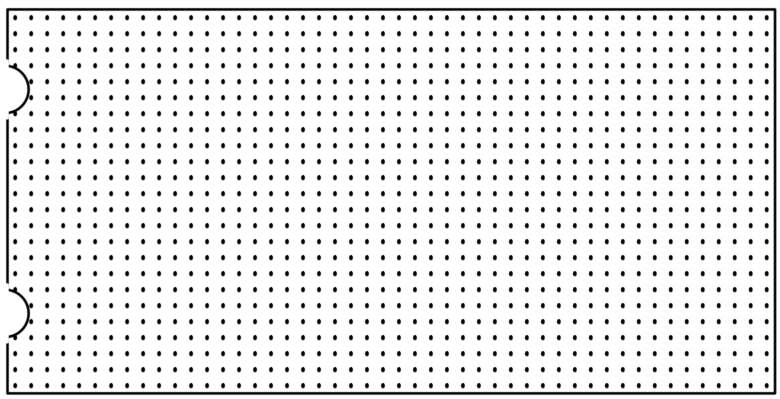


Figure 12

**setup:**

1. Create a template for the hole saw on the drill press. The template should hold a piece of pegboard so the center drill of the saw should touches the edge of the pegboard at a point midway between the 5th and 6th holes from each corner, so it will cut a notch as shown in figure 12.
2. With the soldering/woodburning pencil, cut $\sim 16''$ lengths of cord (one per piece of pegboard). (This is a bit smelly and you'll have to mop off the end of the pencil occasionally with a wet sponge or paper towel, but the ends of the cord will fray if they're not melted in some way.)
3. Cut the top heads off the doublehead nails with a bolt cutter or hacksaw. If you have a file or grinder, smooth any sharp point on the cut ends.

**making the sandwiches:**

1. Use the drill press and template to put two half-circle notches in each piece of pegboard. You may be able to stack 2-4 sheets of pegboard (with large nails through the holes to keep them in line) and cut them simultaneously; the depth of the hole saw is usually the controlling factor because the cut pieces will pile up in the saw.
2. Tie together pairs of pieces of pegboard; leave a consistent amount of slack in each tie so that the two pieces will lie flat when hung over a piece of IMC.

a. Stack two pieces of pegboard on a convenient surface. Turn them so the un–notched short edge of each piece is towards you. If the two sides of the pegboard are conspicuously different, put the uglier sides together.

b. Push the top piece down to expose the second row of holes on the piece underneath.

c. Drop 3 of the cut–off doublehead nails through the lower piece of pegboard; the nails go through the second row of holes from the short edge, near the corners and the middle. This will keep the top piece $\sim 1''$ offset from the bottom piece when you tighten the cords in step e.

d. Count 5 holes over from one corner along the short edge of the bottom piece of pegboard. Put one end of a piece of cord up from underneath the piece through this hole; put the other end up from underneath through the next hole over (#6). Put the two ends of the cord through the top piece in the same way. Repeat at the other corner near you (see figure 13).

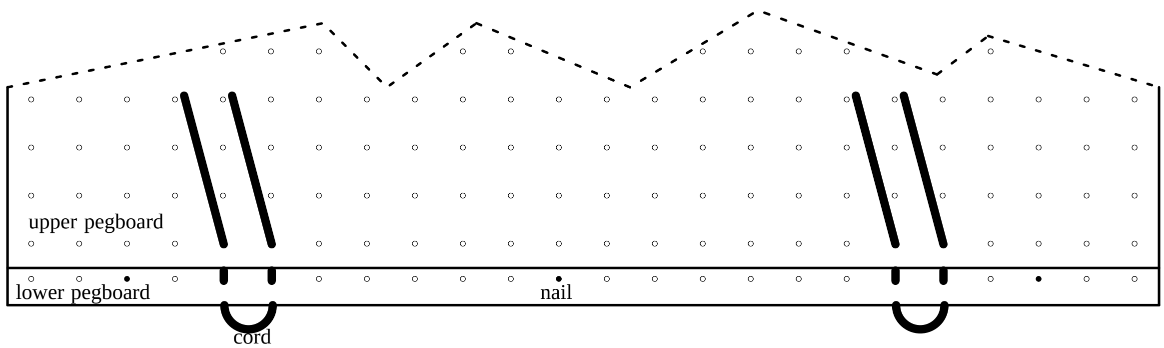



Figure 13

e. Pull on both ends of one of the pieces of cord while bracing the lower piece so the upper piece snugs up against the nails/screws, and tie a hard square knot in the cord. (This shortens the parts of the cord between the pieces of pegboard to $\sim 1''$.) Repeat with the other piece of cord.

f. Lift the upper piece of pegboard so it comes away from the nails, and take out the nails.

g. Pull on the knot assembly so all the cord comes out from between the pieces of pegboard and the pieces lie aligned with each other.

h. Put small tie wraps around both pieces of cord (free end and loop) right where they come out of each side of the knot, and pull very tight; this will prevent the knot from slipping or coming undone. (*note*: we also tried putting heat–shrink tubing over the cord before tieing, then sliding it over the knot and shrinking, but tubing large enough to fit over the knot won't shrink small enough to be secure.)

i. Trim the tie wraps as short as possible with diagonal cutters, and trim the cord close to the tie wraps with the soldering pencil. (This will melt the trimmed ends so they don't unravel.)

3. Stack the sandwiches with the ties in alternating directions, so some of the cord fits into the notches and the rest hangs out from the edge of the stack. As the stack rises, fill with lath or strips of hardboard as necessary (2-3 strips crosswise, spread between the ends, every *N* sandwiches) to keep the middle of the stack roughly the same height as the ends. (This prevents the pegboard from bending when it's stored; bent pegboard will *mostly* flatten out, but you're better off not making it bend.

# Lights

Skip the rest of this chapter (through page 59) if you are not doing supplemental lighting attached to the hangings.

## Spring-clamp lights

These lights are signficantly lighter than box lights, putting less load on helicopters. However, I haven't been able to find old–style spring–clamp lights in almost five years, and rigging the newer style of light is not easy. (The set NESFA made used plates generated after hours on numerically–controlled stamping equipment.)

### Old–style spring–clamp lights

1. Cut the plastic into a roughly equilateral triangle $\sim 3''$ on a side.
2. Make holes for the U–bolt:
   a. Using a U–bolt as a reference, mark two points $\sim 3/8''$ in from one of the edges of the plastic triangle and as far apart as the centers of the ends of the U–bolt.
   b. Drill $5/16''$ holes at these points.
   c. Put a U–bolt through these holes; put the flat plate that came with the U–bolt over the ends of the U–bolt, and add the nuts that came with the U–bolt to keep the pieces together.
3. Drill a $3/32''$ hole $\sim 1/8''$ from the corner opposite the two U–bolt holes.
4. Separate the screw and nut that hold together the clips holding the spring clamp to the knurled dumbbell between the clamp and the light socket. ***Do not*** loosen the screw that holds the dumbbell to the socket. Put the plastic triangle between the clips and run the screw through the holes in the clips and in the plastic. Put the nut loosely on the end of the screw.
5. Turn the clips so the ends which fit over the spring clamp are over the plate. Put the dumbbell between the other ends of the clips and tighten the screw. The screw should be tight enough that nothing rattles and loose enough that the dumbbell can move in its socket.

### New–style spring–clamp lights

Before you start work on all the lights, do step 4 on one. Measurement C is the clearance between the two surfaces between which the spring fitted; S is the average diameter of the shaft holding the two surfaces together (the shaft is curved to fit around the spring so it will be wider at the ends than at the middle). Both of these dimensions were around $0.14''$ for the pieces NESFA worked with.

1. Cut aluminum stock of thickness C into a roughly equilateral triangle $\sim 3''$ on a side.

2. Mill a slot 0.8″ long and S wide into one of the corners of the triangle, perpendicular to the opposite side. (You may need to cut off some of the point so the mill can get started straight; if you do, reduce the length of the slot by what you cut off, up to 0.2″).
3. Make holes for the U–bolt:
   a. Using a U–bolt as a reference, mark two points ~3⁄8″ in from one of the edges of the plastic triangle and as far apart as the centers of the ends of the U–bolt.
   b. Drill 5⁄16″ holes at these points.
   c. Put a U–bolt through these holes; put the flat plate that came with the U–bolt over the ends of the U–bolt, and add the nuts that came with the U–bolt.
4. Pry open the coils of a spring clamp to release the pointed end of the fitting that connects the clamp to the light socket. Loosen the screw in the clips that hold this fitting to the socket, and take out the fitting.
5. Fit the slotted corner of the plate into the gap between point and shoulder of the fitting. Hammer the fitting as far into the slot as it will go, using a nail set or a large blunt nail to drive the fitting down to the end of the slot. (You may want to add a drop of epoxy.)
6. Put the knurled ball of the fitting back into the clips that held it to the socket. The screw should be tight enough that nothing rattles, and loose enough that the dumbbell can move in its socket.

## Box lights

***Note: of the three types of lights described here, only the one–outlet lights have been made in quantity.*** You may need to do some samples of your own to find the best way of building no–outlet and two–outlet box lights. In any case, be sure to get help from someone who has experience working with 120– or 240–volt wiring.

If you are making box lights, you should already have decided (in “Design”) how many lamp heads (one, two, or three) and outlets (none, one or two) to have in each light. Setting up the lamp heads is the same for all types:

1. If the lamp head wire ends don’t come pre-stripped, take ~3⁄8″ of insulation off the ends of the wires.
2. The lamp head consists of a socket and a threaded end held together by a screw through a toothed friction joint. Take this joint apart and rebuild with longer screw, dish/belleville/ lock washers, defrictioner, and wing nut (see discussion under “defrictioner”, page 34). If the defrictioner is a solid piece (e.g., a wave washer instead of a retaining ring), you’ll have to pull the lamp head wires out of the threaded end of the joint and run them through the defrictioner and back through the joint.
   ***Warning:*** these lights are sold for outdoor use; this modification will make them unsuitable for outdoor use. This won’t matter for art shows, but you should know in case you end up reusing these lights for something else.
3. Lamp heads come with a lock nut (on the threaded end of the head) to help hold them in place. The nut has one smooth side and one toothed side; the smooth side of the lock nut should face toward the light socket. Lamp heads are usually shipped this way; if yours weren’t take the nut off the threaded end of the lamp head, turn it over, and put it back on. In either case run the nut all the way toward the socket on the threads..

**no–outlet box lights**

1. Take lamp heads for one box and run the wires of each lamphead through one of the sockets in a cover plate. Screw each lamp head most of the way into its socket and secure by turning the lock nut so it fits hard against the cover plate. If there are any unused sockets in the cover plate, put a bit of anaerobic adhesive on the threads of a threaded knockout filler and screw it tightly into the cover plate.
2. Attach the conduit hanger to the box:
   - If you are using NutSerts or equivalent:
     a. drill a hole in the back of a utility box (hole size per directions that came with the NutSerts); put the hole as close to the center of the back as you can, but be sure it goes through the body of the box and not through a knockout.
     b. Fit the NutSert into this hole on the inside of the box; run a $\frac{1}{4}''$ bolt into the NutSert from the outside of the box and tighten until the NutSert is secure (use a wrench), then remove the bolt.
     c. Put a $\frac{1}{4}''\times\frac{3}{4}''$ stove bolt through the mounting hole of a conduit hanger and into the NutSert
   - If you are not using NutSerts:
     a. drill a $\frac{5}{16}''$ hole in the back of a utility box; put the hole as close to the center of the back as you can, but be sure it goes through the body of the box and not through a knockout.
     b. Put a $\frac{1}{4}''\times\frac{3}{4}''$ stove bolt through the mounting hole of a conduit hanger; add a lock washer, put the bolt through the hole into the utility box, and add anaerobic adhesive, another lock washer, and a nut.
   - In either case, face the conduit hanger in the direction you want (you will probably have to model this—be careful to get it right if not using a NutSert, because changing it will be a pain); when you have the hanger in the right position, tighten the bolt firmly.
3. Push out one of the knockouts in one end of the utility box. (This will probably require a screwdriver to start, and repeated bending to break it loose.) Take the nut off a strain relief, put the threaded end through the hole you've just opened, put a bit of anaerobic adhesive on the threads, add the nut, and tighten very hard.
4. Prepare the power cord:
   - If you are starting with an extension cord, cut off the socket (female) end, take off about an inch of the outer insulation, and strip $\sim\frac{3}{8}''$ of insulation off the ends of the wires.
   - If you are starting with bulk electrical cord, take about an inch of outer insulation off both ends, strip $\sim\frac{3}{8}''$ of insulation off the ends of the wires (this length may vary for one end according to the directions on the male plug) and attach the male plug to one end.
   - If you are starting with a replacement cord, do nothing.
5. Run the free end of the cord several inches through the strain relief into the utility box. Put the cover plate with the lamp head(s) next to the box. Twist together all the black wires (from the cords and the lamp heads); twist on a wire nut until it stops, then wrap the nut and wires with electrical tape to keep them together. Repeat with the white wires. Put a spade lug on the green wire of the cord.
6. There will be several small holes scattered around the utility box; use the #10 machine screw, nut, and lock washers (and anaerobic adhesive) to attach the spade lug solidly to the inside of the box.

7. Pull ***most*** of the slack cord back through the strain relief (leave a couple of inches loose for safety) and tighten the strain relief.
8. Screw the cover plate onto the open face of the box.

### one–outlet box lights

This is quite similar to no–outlet box sockets; instructions are given complete for clarity.

1. Take lamp heads for one box and run the wires of each lamphead through one of the sockets in a cover plate. Screw each lamp head most of the way into its socket and secure by turning the lock nut so it fits hard against the cover plate. If there are any unused sockets in the cover plate, put a bit of anaerobic adhesive on the threads of a threaded knockout filler and screw it tightly into the cover plate.
2. Attach the conduit hanger to the box:
   - If you are using NutSerts or equivalent:
     a. drill a hole in the back of a utility box (hole size per directions that came with the NutSerts); put the hole as close to the center of the back as you can, but be sure it goes through the body of the box and not through a knockout.
     b. Fit the NutSert into this hole on the inside of the box; run a $\frac{1}{4}''$ bolt into the NutSert from the outside of the box and tighten until the NutSert is secure (use a wrench), then remove the bolt.
     c. Put a $\frac{1}{4}''\times\frac{3}{4}''$ stove bolt through the mounting hole of a conduit hanger and into the NutSert
   - If you are not using NutSerts:
     a. drill a $\frac{5}{16}''$ hole in the back of a utility box; put the hole as close to the center of the back as you can, but be sure it goes through the body of the box and not through a knockout.
     b. Put a $\frac{1}{4}''\times\frac{3}{4}''$ stove bolt through the mounting hole of a conduit hanger; add a lock washer, put the bolt through the hole into the utility box, and add anaerobic adhesive, another lock washer, and a nut.
   - In either case, face the conduit hanger in the direction you want (you will probably have to model this—be careful to get it right if not using a NutSert, because changing it will be a pain); when you have the hanger in the right position, tighten the bolt firmly.
3. Push out one of the knockouts in one end of the utility box. (This will probably require a screwdriver to start, and repeated bending to break it loose.) Take the nut off a strain relief, put the threaded end through the hole you've just opened, put a bit of anaerobic adhesive on the threads, add the nut, and tighten very hard.
4. Cut the extension cord about a foot from the socket (female) end; if the cord is longer than you need, cut off the excess from the piece with the plug. Take off about an inch of the outer insulation on both the cut ends and strip $\sim\frac{3}{8}''$ of insulation off the ends of all of the wires. Cut a few inches of 12–gauge solid wire and strip similarly.
5. Run the cut ends of both pieces of cord several inches through the strain relief into the utility box. Put the cover plate with the lamp head(s) next to the box. Twist together all the black wires (from the cords and the lamp heads); twist on a wire nut until it stops, then wrap the nut and wires with electrical tape to keep them together. Repeat with the white wires. Twist together the two green wires from the cords with the solid wire and add wire nut and tape.

6. There will be several small holes scattered around the utility box; use the #10 machine screw, nut, and lock washers (and anaerobic adhesive) to solidly attach the other end of the solid wire to the inside of the box.
7. Pull ***most*** of the slack cords back through the strain reliefs (leave a couple of inches loose for safety) and tighten the strain reliefs.
8. Plug the circuit/continuity tester into the socket; without touching the box, plug the cord into an outlet. Fix any problems the tester shows (e.g. white and black cross–connected, white or black not insulated from the box).
9. Screw the cover plate onto the open face of the box.

These instructions assume that you're putting a single box on each cord. If you're putting two boxes on each cord:

a. make an additional cut in step 4, making male, female, and center pieces of cord.
b. wire one box with the female piece and one end of the center piece, and the other box with the male piece and the other end of the center piece.
c. follow all other directions as given.

### two–outlet box lights

1. If you are making two–light boxes, thread the wires of each light through one of the crosspieces of the tee and down the upright. Screw the lamp heads into the tee without anaerobic adhesive. Run the wires through a nipple and a reduction bushing. Put anaerobic adhesive on both threads of the nipple. Screw together bushing, nipple, and tee, and tighten this assembly with large wrenches.
   If you are making one–light boxes, thread the wires of the light through a reduction bushing and screw the lamp head into the reduction bushing.
2. Screw the reduction bushing (with anaerobic adhesive) into the back hole of the box and tighten.
3. Prepare the power cord:
   - If you are starting with an extension cord, cut off and discard the socket (female) end, take off about an inch of the outer insulation, and strip $\sim 3/8''$ of insulation off the ends of the wires.
   - If you are starting with bulk electrical cord, take about an inch of outer insulation off both ends, strip $\sim 3/8''$ of insulation off the ends of the wires (this length may vary for one end according to the directions on the male plug) and attach the male plug to one end.
4. Take the nut off a strain relief and discard. Screw the strain relief (with anaerobic adhesive) into one end hole in the box. Push the free end of the cord several inches into the box through the strain relief.
5. Connect the wires:
   - If using spade lugs*:*
     a. Put lugs on all the wires; if making multiple–light boxes, twist together the same–color wires from the all the lamp heads and use a single spade lug.
     b. Connect the spade lugs to the corresponding screws on a duplex outlet (black wires to brass screws, white to silver, and green to green), distributing the lugs between the two screws of a color.
   - If using wire nuts*:*

a. cut two 3–4″ pieces of 12–gauge solid wire and strip ⅜–½″ off both ends (according to the directions on the wire nuts and the duplex outlet).
b. Twist together all the black wires (from lights and cords) with one solid wire; add a wire nut, twisting on until it stops, and wrap electrical tape around nut and wires where they meet; attach the other end of the wire to one of the brass screws on the outlet. Repeat with white wires and silver screw.
***Warning:*** Some duplex outlets have wire–size holes next to the screws for an alternate way of making a connection. ***Do not use these holes***, as this violates many electrical codes; wrap the bare end of the wire around the shaft of the screw instead.
c. Put a spade lug on the green wire from the cord and attach to the green screw on the outlet.

6. Put the outlet near the open face of the box. Pull ***most*** of the slack cord out of the box; leave a couple of inches. Tighten the strain relief on the cord.
7. Screw the outlet to the box using the screws provided with the outlet. The outlets are often sold with the screws in position, so you may have to back them out before you can drive them in.
8. Plug the circuit/continuity tester into the outlet; if you attached a plug to bulk cord, connect a cord known to be good to the cord from the box. Plug the cord into an outlet. Fix any problems the tester shows (e.g. white and black cross–connected, white or black not insulated from the box).
9. Screw the outlet cover plate onto the outlet.

## Electric Trees

Skip the rest of this chapter (through page 59) if you are not doing built-in wiring.

***Note:*** The trees described here are slightly different from the ones built for NESFA and Lunarians. They have a pigtail to connect power instead of a "flanged inlet" (a recessed male connector); this saves almost a third of the cost per tree and a significant amount of work, and is a better design.

***Note:*** the instructions below assume you got black, white, and green (the standard colors) 12–gauge solid wire for the trees. If you got some other color(s), write out which color is replacing which standard color and post this several places around your work area so everyone who is doing wiring makes the same substitution(s).

1. Cut two pieces of wire, one 15″ long and the other 1′ longer than the trunk pipe, in each of the three colors of wire. Strip ¼″–⅜″ of insulation off each end of each wire (according to instructions on the duplex outlets), then lightly tape together each set with masking tape (i.e., one piece for short wires, two pieces for long wires—this is just to keep the wires in sets).
2. The outdoor boxes will have threaded holes in the back. Fill these holes on two boxes with the spare threaded fillers (flat, slotted as if to take a coin instead of a screwdriver) that come with the boxes.

3. Assemble the following in order: trunk pipe, a box, nipple, another box, top pipe; put anaerobic adhesive on all threads before you screw the pieces together, using the holes in the ends of the boxes. When all five pieces are together, tighten the whole assemblage with two pipe wrenches applied to the two pieces of pipe just where they enter the boxes; be careful not to bend any of the joints. Don't worry about getting the boxes to line up, as they'll be 8-10 feet in the air and hard to see; just get all the joints tight.
4. Connect each wire in the short set to the corresponding screw on a duplex outlet (black to brass, white to silver, green to green). Push the other ends of these wires through the nipple from the top box (the one that has the top pipe at one end) to the lower box. ***Warning:*** some duplex outlets have wire–size holes next to the screws for an alternate way of making a connection; ***do not use these holes***, as this violates many electrical codes. Wrap the bare end of the wire around the shaft of the screw instead.
5. Screw the duplex outlet to the top box, using the screws that came with the outlet; they will fit holes in lips at both ends of the open face of the box.
6. Connect the other ends of the black and white wires to the corresponding screws on another duplex outlet.
7. Each box should come with a green screw that fits into sockets in the inside back corners of the box. (If not, find a self–tapping or sheet–metal screw to fit.) Put the screw into the lower box at the end next to the top box; wrap the other end of the green wire around the screw and tighten.
8. Push one end of the long set of wires down the trunk pipe, working from the box. Connect the other ends of the wires to the other set of corresponding screws and the unoccupied green screw on the duplex outlet of step 6.
9. Screw outlet to box as in step 5.
10. Put a 4-arm clamp on the trunk pipe with the setscrews on the arms facing ***away*** from the boxes; slide it down from the free end of the pipe and tighten one setscrew just enough to keep it from moving.
11. Finish the pipe assembly:
    a. Put the ends of the wires through an end hole in another box; put anaerobic adhesive on the threads at this end of the pipe and screw on the box.
    b. Screw a nipple into the hole at the opposite end of the box and a coupling onto the nipple, using anaerobic adhesive
    c. tighten this assembly by gripping the trunk pipe and the coupling.

    Since the box is softer metal, repeatedly screwing a pipe into and out of it could damage the threads; the extra nipple and coupling give you a sturdier socket for connecting the base to the trunk.
12. Connect the black and white wires to another duplex outlet as in step 6.
13. Connect the green wire to the box as in step 7.
14. Take the nut off a strain relief and discard. Put some epoxy or anaerobic adhesive on the threads of the strain relief and thread it into the threaded socket in the back of the box until it won't go in any further (use pliers if necessary to seat it solidly).

15. Prepare the power cord:
   - If you are starting with an extension cord, cut off the socket (female) end
   - If you are starting with bulk electrical cord, cut the cord to the appropriate length: 14½′ or more for 6×6 hangings, 9′ or 35′ long for 4×8 hangings depending on whether your design uses small helicopters (figure 10, page 14) or outside supports (figure 11, page 14). Take ~1″ of outer insulation off one end of the cord. Strip ¼″ or so of insulation off the ends of the wires and attach the male plug to this end according to the directions that came with it.
16. Take ~2″ of outer insulation off the bare end of the cord and strip ~¼″ of insulation off the ends of the wires. Put spade lugs on the wires. Put this end of the cord through the strain relief into the box at the bottom of the tree, pushing it in a few inches beyond the stripped section.
17. Connect the black and white wires of the cord to the corresponding screws on the other side of the duplex outlet in this box; connect the green wire of the cord to the one green screw on the outlet.
18. Put the duplex outlet next to the box; feed most of the cord back through the strain relief, leaving a little slack, and tighten the strain relief.
19. Screw outlet to box as in step 5. Put a safety cap in at least one of the sockets of the outlet.
20. Double-check all the wiring to make sure everything is connected correctly (black to brass screws, white to silver screws, green to green screws or boxes) in all three boxes and the male plug.
21. Put the continuity tester into the duplex outlet in the bottom box. Connect an extension cord to the cord coming out of the tree and walk away from the pipe. Plug the extension cord into a wall outlet. ***Do not touch any parts you've wired while the cord is plugged in!***—you don't know yet that it's safe. If the continuity tester does not show the correct lights, unplug the cord, take out all the outlets, and recheck to see where the tree is miswired. Repeat with both of the upper boxes.
22. Screw on cover plates using the screws provided. Screw the shell of the male plug onto the body of the plug and tighten the strain relief.
23. Attach a tree base to the bottom box. Measure 7′ up the tree from the end foot and wrap a piece of masking tape around the tree at this point.
24. Detach the tree base and spray over/next–to the tape with black paint, so you can put the clamp back if it ever gets moved. Put a band of your identifying color somewhere on the trunk.
25. Move the four-arm clamp on top of the black band. Align the arms with the faces of the bottom box and tighten the setscrews.

## Roadcase

This is mostly standard construction for theatrical roadcases; the sides are 1/4″ plywood framed **on the outside** with 1x4. However, standard roadcases have a clear inside and a caster at each corner; this case will have racks inside to support the trees and casters underneath the racks—in effect, the rest of the case is there just to keep the racks in place.

Your roadcase will be built to hold Y layers of X trees each; choose X and Y such that (a) they are roughly the same, and (b) X times Y is at least the number of trees you'll have plus some margin for expansion, e.g., for 17 or even 16 trees X=4, Y=5. X should probably not be larger than 4, because X=5 gives a case too wide to fit through many doors. Note that 24 trees is enough for about 190 panels; if you're building more trees than this, consider building two cases.

The inside dimensions of the roadcase are
w = X times 6″
h = Y times 6″
l = length of **completed** tree trunk + 1–2″. (If you haven't built any trees, do a test assembly of all the trunk pieces (as described above), without tightening, to estimate this.)

These dimensions are significantly greater than those of the NESFA and Lunarians roadcases; this means that the trees don't have to be built as painfully precisely as ours were, and gives you room for storing other art show supplies (bases of trees, pegboard hooks, . . . ; just don't put in so much that the plywood bends or you can't lift the case when you're going over steps, into your truck, etc.).

Outside dimensions L, H, W are 2″ greater than l, h, w respectively.

hb, Hb, wb, Wb, and Lb are h, H, w, W, and L (respectively) less twice the width of your 1×4. (This width is typically 3½″ but you should check your wood.)

In the table below, "width" applies only to those pieces that must be cut in two directions.

**cutting list**:

| piece ID | material | count | length | width | notes |
|---|---|---|---|---|---|
| top | ¼″ plywood | 1 | L | W | 1 |
| bottom | ¼″ plywood | 1 | L | W | 1 |
| sides | ¼″ plywood | 2 | L | h | 1 |
| ends | ¼″ plywood | 2 | w | h | 1 |
| A | 1×2 | 8 | h | | |
| B | 1×4 | 8 | L | | |
| C | 1×4 | 6 | Wb | | 2 |
| D | 1×4 | 4 | w | | |
| E | 1×4 | 8 | hb | | |
| F | 1×8 | 4 | hb | | |
| G | 1×8 | 2 | wb | | |
| J | 2×8 | 2 | w | | |
| K | 2×8 | 2Y – 2 | w–1⁄16″ | 6″ | 3 |
| M | 2×8 | 2 | w | 3¾″ | 3,4 |
| N | 2×8 | 2 | w–1⁄16″ | 2¼″ | 3,4,5 |
| O | 1×4 | 2 | Hb or wb | | 6 |
| P | 1×4 | 1 | Ll | | 7 |

**notes:**

1. Cut these parts very carefully, as they control the way the case fits together; use a table saw, or at least a fence, if at all possible.
2. Omit one of these pieces if making the top from two pieces of plywood.
3. 2×8 that is cut to narrower widths should be ripped on *both* sides so the edges are smooth and even; you don't want the rounded edges most 2×N stock comes with.
4. M and N could be cut from smaller 2× stock (e.g., 2×6), but if you use 2×8 you can cut both widths from one length, reducing the amount (and number of types) of lumber you have to buy.
5. It's worthwhile to cut the width of this piece *after* the case is completely assembled; that way you can eat any net error in your other measurements, since the lid is supposed to close snugly on these pieces.
6. Optional pieces if you decide to make ends from two pieces of plywood (see below).Length will be Hb or wb depending on whether the seam between the two pieces of plywood runs vertically or horizontally.
7. Optional piece if you decide to make top from two pieces of plywood (see below).

**comments:**

For a case that will hold more than 16 trees, you could need 5 sheets of plywood in order to do each surface as a single solid piece. If you want save a little money at the cost of somewhat more assembly work, you can make the top and ends out of two pieces, with an extra piece of 1x4 to cover the seam; if you're feeling really adventurous and are sure the trees will fit in a smaller space (test this before starting to cut!) you can shrink the dimensions, e.g., multiply X and Y by 5¾″ or 5½″ or less instead of 6″, and refigure the rack spacing accordingly (make sample racks to test the spacing before you cut all the wood). Have fun, and write if you get work. . . .

Use cheap wood (e.g., "sanded" plywood) for the plywood and 1×N; the case doesn't have to look pretty, and you'll glue 1×N and plywood well enough to hold everything together. The 2×N is structural, so you'll want decent wood for it.

Cut and label ***all*** pieces before beginning construction; (a) the letters are not exactly in the order used, and (b) if you get all the pieces cut, several people can work on different parts of the case (different faces, marking supports, . . . ) simultaneously.

**assembly—surfaces:**

Frame plywood with 1×4:

sides get pieces B on long edges, then E on short edges;
top and bottom get B on long edges, then C on short edges and across the middle;
ends get D on horizontal edges, E on vertical edges.

On each piece of plywood, set the first framing pieces flush with edges and ends of plywood and attach them, then fit the second pieces between them (shaving the ends of these pieces if necessary).

Attach each piece of 1×4 to the plywood with glue spread evenly over the entire piece (squeeze out a thick line, then spread it using a piece of scrap wood as a squeegee), followed by 1″ drywall screws every ∼9″ (mostly these are just to hold the pieces together until the glue sets). Put the plywood on top and screw through it into the 1×4.

Add O and/or P if necessary (on top of seam in plywood) after the other 1×4 pieces are in place.

**racks—making pieces:**

For each piece K and M:

1. Mark one edge at 1½″ from one end and every 3″ thereafter to the other end.
2. Draw a line down the length of each piece 1½″ from this edge.
3. Mark this line at 3″ from one end and every 6″ thereafter to the other end.
4. Draw a line from each of these marks to the two nearest marks on the edge of the wood. Shade the resulting triangle so the cutter will know what to get rid of.

Steps 1–4 for a piece M for 4 trees (24″ long) should give you figure 14.

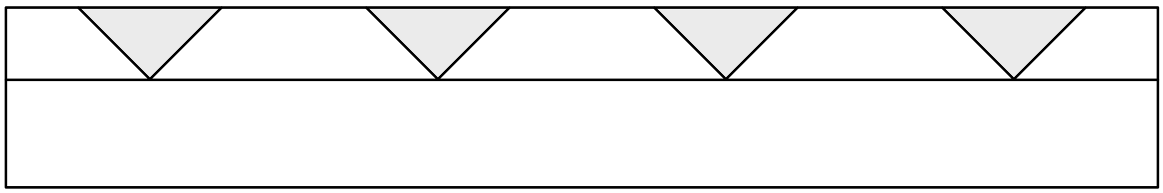


Figure 14

5. Cut out the triangles you've marked (shaded sections of figure 14):
   Use a bandsaw, or a saber saw with a long and sturdy blade, if you have it
   ***or***
   cut just to where the lines meet with the skilsaw, and finish with a hand or saber saw
   ***or***
   a. draw a lengthwise line ~½″ beyond the existing line (2″ from the marked edge);
   b. set your skilsaw to maximum depth;
   c. cut each angled line through to the second lengthwise line;
   d. turn the piece over and finish the cuts on the other side.

- In any case, cut far enough that the piece of wood drops without having to be knocked out; you want the sides and bottom of the notch to be fairly smooth.
- After you cut the first notch in the first piece, lay the piece notch–down on a flat surface and make sure that a piece of pipe slides freely through the notch. If it doesn't, recut this notch and cut all the others a little larger (e.g., outside the lines instead of inside); the notches don't have to be precise but they must be deep enough that the rack pieces sit solidly on one another and not on the pipe.

**rack supports:**

The trees will sit with their boxes a few inches outside the racks. You should think about where to put the racks:

- If you put one rack nearer the end of the roadcase than the other, you may have enough space to put the tree bases in the case (keeping trees and bases together is a win so this is worth measuring), but the trees will only fit into the case in one direction.
- If the racks are the same distance from the end of the roadcase, the trees will fit in the case pointing in either direction, but you may not be able to get the tree bases into the case.

Mark where the centers of the racks will go on the insides and outsides of the side and bottom pieces of plywood. Draw lines all the way across both faces of all three pieces.

bottom piece:

1. The casters will sit centered on the lines on the bottom piece, near the side edges. Put the casters in position and mark roughly where the bolts will go.

2. Attach pieces G centered on the marks on the outside of the bottom sheet; use glue and 1″ drywall screws, driving the screws through the plywood into the pieces G. Avoid putting screws where the caster bolts will go.
3. Attach pieces J on top of G's; use glue, and drive 2″ or 2¼″ drywall screws into each J from the inside of the bottom piece. Again, don't put the screws where the caster bolts will go.
4. Drill ³⁄₃₂″ holes in the bottom center of each notch in the pieces M.
5. Put glue on pieces M on the edge opposite the notches. Center these pieces in both directions on the marks on the inside of the bottom; there should be just over 1″ of plywood beyond each end of each M. Run 3½″ drywall screws through the holes in the notches in the M's into the G's and J's.
6. Turn the bottom outside-up, drill one ⁵⁄₁₆″ bolt hole for each caster, put each caster over its hole, and drop a ¼″×3″ bolt through caster and hole. Square up the casters with the bottom and drill a second bolt hole through another hole in the caster base plate and drop in another bolt. Drill the final two holes and add bolts. (Doing the holes and bolts in this order makes sure the holes in the bottom line up with the holes in the caster base plates.) Put a few drops of anaerobic adhesive on the threads of each bolt, add washers and nuts, and tighten all around.

side pieces:

1. On each side of each of the lines you drew on the insides of these pieces, draw another line ⅞″ away. Turn the bottom piece right–side–up and set each side piece on top of a long edge of the bottom piece. The lines should fall ~⅛″ outside the pieces M; adjust them if they don't, but make sure the lines stay perpendicular to the long edges of the side pieces. If you move these lines substantially, also move the lines on the outsides of the side pieces.
2. Put glue on pieces F and center on the marks on the outside; use 1-2 screws to hold if it doesn't fit solidly.
3. Fit pieces A flush with the new lines on the inside so there is a 1¾″ gap between them. Test this spacing with the end of a piece K, which should slide freely; it does ***not*** need to be snug, as the pieces A are only to keep the pieces K stacked more–or–less on top of each other and the pieces M.
4. Drive 1½″ drywall screws through this sandwich in both directions (~2 in each A and ~4 in each F), so the pieces inside and outside are pulled solidly against the plywood between them.

**final assembly:**

This is easiest to start with 2-3 people to hold the pieces together while another puts in the first screws.

1. Turn the bottom casters-up and set it on top of one of the side pieces.
2. Put glue on one long edge of the other side piece; line up the side piece underneath the bottom flush with its ends, with the face of the side against the M's. Screw 2″ or 2¼″ drywall screws every 6-9″ through the bottom into the edge of the side; drive the screws into the 1×4 on the outside of the side piece, not into the plywood. Drive another 2″ or 2¼″ screw through the sides into the end of each M.

3. Put glue on two adjacent edges of each end piece; line them up with the edges of the bottom and side pieces (end piece goes **inside** both other pieces) and screw in as above. Repeat with other end piece.
4. Put glue on the edge of the other side piece and on the matching edges of the end piece; fit together and screw as in step 2.
5. Turn the case over, block the casters (or lock them if they have brakes) so the case doesn't run away from you, and lay the top in place. Open the tee hinges as far as they will go and lay the leaf side on the top so the strap side hangs over the pieces F. Screw the hinges to the top and the side using wood screws (drywall screws won't be as sturdy).
   - At least one hole in the strap side (maybe two) will be on top of the edge of the top rather than the face of the side; ***don't*** put a screw in this hole! The holes at the middle and end of the strap should be enough to hold; if you want more security, drill a matching hole in the strap between the occupied holes and the pivot and put in another screw.
   - If you got strap hinges instead of tee's, the end of the upper strap will hang over the frame of the top and a screw in the last hole won't have anything to go into; if this annoys you dreadfully, glue/screw a piece of 1×4 under the end of the strap.
   - Mounting the hinges this way will make their pivots stand out a little, but recessing them is a pain, and this way (a) the lid can come all the way open without tearing off the hinges (the hinges will close as the lid opens, and vice versa), and (b) the screws go into the correct side of the hinges.
6. If you bought a latch, add the pieces on the opposite side from the hinges.
7. Stack half the K's on top of each M; the K's should slide freely between the A's (if not, you can sand the ends down a bit). If you didn't previously cut the N's, measure the remaining height and cut to fit. Put the N's on top of the last K's and try closing the case. The lid should still close fully but rest lightly on the N's as well as the sides; if necessary, recut the N's to fit.
8. Take out all the K's and lay a row of trees in the notches in the M's. Add one K on top of the row at each end, notches up. Add layers of trees and K's until done, then add any spare K's (if you allowed a lot for expansion), followed by the N's.

It's not necessary to paint the case; theatrical roadcases are usually painted black so they don't reflect light backstage, and paint is unlikely to do much to help preserve the wood. (***Don't*** leave the case out in the rain—it's likely to be harder on the trees than on the wood.)

# Setup & Teardown

After all that work (and detail) designing and constructing the hangings, this should be easy (which is the point).

Instructions that pertain solely to hangings with lighting are in this font.

*Instructions that pertain solely to lighted hangings with built-in wiring are in this font.*

## Preparation

### Some time before the show

If you can possibly get time and people, do a small test assembly (e.g., a 2-long typical spine); this will make it easier for other people to figure out how the hangings go together if you get run over by a bus (Don't laugh; it happened to Aussiecon II's masquerade director just before the con.) Make sure your marking system is well-documented.

If you've been handed just this section and didn't help with designing or making the pieces for the hangings, get the people who were in charge to give you a hand, or at least get hold of the rest of this monograph. The hangings can be pieced together by people who've previously only seen them assembled, but setup will go a lot faster if *somebody* is familiar with the parts, their markings, and how they go together.

Be sure you have all your tools packed.

Work out exactly how many double, single, and serpentine frames and lighting supports (helicopters, vees, tees, sidearms) you will be building, break this down to the number of uprights of each type (double-frame center/side, single-frame back/front, serpentine) you will need. Also work out which frames will have standard *or electric* trees.

Break down the above list to individual pieces and check against what you have in storage just to make sure the Metal-Munching Moon Mice (or any other mysterious visitors) haven't pigged out on your equipment.

Work out which trees will be wired together (see principles on page 21).

If you have worked with these hangings before, you should have a fair idea how tight the screws should be. If you haven't, or are unsure, borrow a torque wrench that fits your drive sockets and tighten several screws using 12 foot-pounds, then test what they feel like when you try to tighten them further with your tools. (Buying the torque wrench isn't a bad idea; you can get one with a pointer readout from Sears for $20-30, which means you can probably find a tolerable equivalent elsewhere for less, and having it to make samples at setup can help.)

Work out where on the floor everything temporary will go, especially work places (e.g., tables to assemble uprights) and anything heavy (e.g., pipe, pegboard if it's not on carts). If you can, plan to mark the floor before the pieces are unloaded, so the pieces don't have to be moved to make way for hangings but are not off in a corner.

Make sure everything, particularly tools, is packed to go. (Yes, check again; the tools are just specialized enough that if you need them you won't be able to find them in a local store—the more desperately you need them, the farther away they'll be.)

### Before starting to set up the show

If you've previously marked the pipe and bundled it by type, sorting it into stacks by type as it comes off the truck is easy. In any case, look over the pipe before it leaves storage and figure out which pieces are which. (The markings may vary from what's listed here; if so they should be documented somewhere.)

- uprights are usually $7'$ and should be marked with one colored band, and two black bands for clamps. One of the black bands will generally be at the end of the pipe; uprights for 4×8 hangings *may* be taller, in which case they will be marked as for trees.
- horizontals for 6×6 hangings are $\sim 6'$ long and marked with 2 colored bands.
- horizontals for 4×8 hangings are $\sim 4'$ long and marked with 1-2 colored bands.
- connectors for 6×6 hangings are $\sim 6'$ long and marked with 2 colored bands.
- connectors for 4×8 hangings are $\sim 8'$ long and marked either with 2-3 colored bands or as uprights/trees.
- Lighting supports can be anything from $3'$ to $10'$ long (check the designer's plans), marked with one black band for a clamp and one colored band; the long ones may come in two pieces.
- non-electric lighting trees are 9-$10'$ tall for 6×6 hangings or 8-$9'$ tall for 4×8 hangings, with two black bands (neither at an end) for clamps plus one colored band.
- *electric tree bases are short, threaded on one end, and marked (one black band near the threaded end) for a clamp, plus two colored bands, one of which should be red to mark that these are special pieces.*

If making 6×6 spines, remember that connectors and horizontals are the same length. (If you're using extended connectors for a large show, they're assembled from short pieces and standard connectors.)

Mark the floor to show where the corners of the spines go; if you can get into the space early, do this even before the pieces arrive. (This takes 2-3 people and makes erection much easier). If you have time, you might mark where each frame will stand, so that each one can be stood up in the right place instead of being juggled to meet the connecting/horizontal pipes.

## Setup

### Making frames

The steps below may seem too complicated, but if you spend a bit of time planning your work order and setting up your work area, you will find they make the setup fast and easy. In particular, making uprights on tables and laying out the frames almost-in-place is a new way of setting up, but the first time we tried it

- we were done an hour before the scheduled start of check–in and two hours before most artists started showing up (they'd gotten used to finding this show's setup running late and being drafted to help set up P2D hangings).
- we didn't take any additional space for setup and didn't run out of workspace despite filling our space with hangings.
- we didn't have to move any assembled frames more than a few feet.

and we did all of this despite two chiefs working with an almost completely-inexperienced crew.

***Note:*** the instructions below will produce hangings with empty clamp sockets protruding at the ends of each spine. This is not a problem, since they'll only be in places people shouldn't brush up against anyway (in the middle of the end panels, or seven feet in the air) and will only protrude an inch or so; you really don't want the additional complication of trying to make the ends come out flat, and may not have enough of the right parts to do so.

1. If the pipe wasn't piled according to type when it was brought in, sort the bundles by type.
2. Cut the tape on all the bundles of pipe. Clear off and throw away the pieces of tape; otherwise you'll be stepping in it until you leave the space—you can never find all the loose pieces when you're picking up before the show opens.
3. Put a few clamps on a pipe and tighten the setscrews appropriately; if you have a torque wrench, set it to 150 inch–pounds before tightening. (If you have enough torque wrenches for everyone, set them all and skip the rest of this step.) Everyone on the crew should use these samples to calibrate how hard they themselves should tighten the setscrews.
   - People who aren't very strong will still be able to tighten the setscrews adequately, but will probably have to push harder than they might expect (maybe by leaning on the wrench); be careful about this, because an undertightened joint can let go and hurt someone and/or some art. (You **will** check all the joints again after setup and before art is hung, won't you?)
   - very strong people may overtighten the setscrews and strip the sockets if they don't calibrate themselves.
4. Put a couple of tables somewhere that will be an aisle near the middle of your space. (You'll be done with these part way through setup, so you can take them from 3-D or the control desk if your facility doesn't have enough.) If you're making mostly double spines (or bought four-arm clamps for single/serpentine spines as suggested on page 20) use one table for center(back) posts and one for side(front) posts.
   - After you set up the tables, count out the right number of uprights (including non–electric trees) for each one to add clamps to; it's much easier to do this now rather than trying to keep count as the pieces are assembled.
5. For each upright, take the appropriate clamps:
   - double-spine centers: 2 four-arm.
   - double-spine sides: 1 three-arm, 1 one-arm.
   - single-spine backs: 1 four-arm (three-arm if the buyer was cheap), 1 three-arm.
   - single-spine fronts: 1 three-arm, 1 one-arm.
   - serpentines, except end-most uprights: 1 four arm, 1 three-arm (or 1 three–arm and 1 angle two-arm if the buyer was cheap).
   - serpentine end-most uprights: 1 three–arm, 1 one–arm.

   Lay an upright on the table and slide the clamps into position (on top of the black bands, flush with the sharp edges of the bands):

a. Put the clamps on the pipe so the setscrews on the arms of multi–arm clamps face toward the other clamp on the pipe; this makes it easier for the erection crew to get to the setscrews.

b. Line up the arms of the two clamps as follows:

- double–spine side uprights: the center arm of the three–arm clamp with the sole arm of the one–arm clamp.
- single–spine front uprights: the center arm of the three–arm clamp with the sole arm of the one–arm clamp.
- single–spine back uprights made with two three–arm clamps: all three arms of the two clamps.
- serpentine uprights made with one three–arm clamp and one angle two, both arms of the angle two with arms of the three–arm.
- serpentine end uprights: the center arm of the three–arm clamp with the sole arm of the one–arm clamp.

As you align the clamps, turn them so that one arm of each clamp sits upright on the table; this makes sure the arms are parallel.

- For double spines, make pairs of side uprights in which the arm setscrews on the one-arm clamps face each other, so the two uprights are mirror images.
- For serpentines made with angle two–arm clamps, make uprights in sets of four, two identical followed by two mirror–image.

Tighten the setscrews using a $\frac{1}{4}''$ hex driver.

6. *Unpack the electric trees and attach bases to trunks.*
7. *The upper clamp on electric trees should already be in place; make sure its arms are parallel with the faces of the lower box, then add the lower clamp to the base, aligning its arms with those of the upper clamp.*
8. Find a large clear space to assemble the lighting supports (helicopters, vees, tees, or sidearms).
   - For helicopters with short supports, vees, and sidearms, put the clamp flat on the floor with the pass-through socket vertical and the setscrews on the arms facing up (except for sidearms—the setscrew on a one-arm clamp will face sideways). The pass-through socket will be filled last (by the tree); put a scrap of pipe in the socket, and leave a tiny bit of space between the pieces you put in the arms of the clamps and the scrap, so the erection crew won't have too much trouble mounting this assemblage on the tree.
   - For tee's, slide the pass-through socket of a one-arm clamp to the middle of a long support and tighten (the arm will sit on top of an upright).
   - If you are building full helicopters with long supports, the tree will fit into the arm of the double–tee clamp; run a support through each of the pass–through sockets, centering it on the clamp. If the supports are stored in two pieces, it may be easier to assemble them after putting the longer piece through a pass–through socket.
9. Screw lamps into lamp sockets and test them. (Every so often a bulb will die.)
10. Put together sockets and lighting supports:
    a. Attach the assembled lights to the ends of the supports.
    b. Bring the cords to the clamp, wrapping them 2-3 times around the pipe on the way.
    c. At the clamp, connect the cords with cube taps if you aren't using electric trees.
11. If you are using extended connector pipes (i.e., to make 6×6 hangings into 6×7), set someone to adding the extensions to the connector/horizontal pipes.

As the uprights are finished, lay out parts for the frames in reverse order of use for each spine, starting near the point where you will **finish** a spine:

12. Take a set of uprights for one frame (center and pair of sides for a double, back and front for a single, pair for a serpentine).
13. Lay the uprights on the floor at about the right spacing.
    - Make sure the setscrews on the arms of any one-arm clamps are facing up; swap side uprights of a double frame, or back and front uprights of a single frame, if necessary to make this come out (otherwise somebody will have to pick up the frame to tighten these joints).
    - Alternate trees and standard uprights in the centers of double frames and the backs of single frames so that each frame is the correct type for where it is on the floor.
    - *Turn electric trees so the pigtail coming out of the bottom box is facing the ceiling if the foot of the tree is towards the power source, or facing the floor if the top of the tree is towards the power source; this way the connection will face toward the power source when the frame is stood up.*
14. Lay horizontal frame pipes roughly in position between the uprights: four pipes for a double frame, or two for a single or serpentine frame.
    - If you have enough horizontals consisting of a single piece of pipe, put them at the top of the uprights, as the pegboard will be easier to hang; use the compound horizontals at the middle of the uprights.

**Steps 12–14 are a good thing for the crew chief to do *instead* of specific assembly tasks.**

15. Fit the horizontals into the sidearms of the clamps and tighten the setscrews.
16. As the frames are finished, pile them so they overlap just a little in order to leave room to start the spine. This will give you enough working room even in cramped quarters (although you may have to eat aisle space for the lighting supports).
17. Lay out the appropriate number of connector pipes: four for a double spine, three for a single or serpentine. Put the connectors where they will be needed **after** the frames in that area have been assembled so they won't be confused with frame parts. If possible, include one solid pipe in each set of connectors; this will be the one the pegboard hangs from.

## Erecting Frames

This takes, by preference, 8 people to start a double spine or 6 for a single/serpentine spine. You can do it with fewer (especially if you're doing a 4×8 layout instead of a 6×6), but you're better off getting a full crew; borrow people from somewhere else if necessary, because you'll only need them for a few minutes.

1. Using one person per upright, bring the first frame to where the end of a spine will be and stand it up in place. The people carrying the frame should watch each other so all uprights go up at the same rate, to avoid straining the clamps.
2. If this frame supports lights, pause at ~30 degrees from horizontal and put the lighting structure on the top of the tree; make sure all setscrews are tightened. *Plug ends of light cords into boxes at tops of electric trees*.
3. *Make sure the tree's pigtail (at torso height) faces **toward** the power source. If it's facing the wrong way on a double frame, the person holding the tree should lift it just off the floor, then turn in place while the people holding the other two uprights walk the frame around hem; if it's facing the wrong way on a single frame, rebuild the frame correctly and check all the others to make sure they're correct.*

4. Using the same procedures as in step[s] 1–3, stand up the next frame at the appropriate distance; use a connector pipe to estimate if you don't have calibrated eyeballs.
5. Give your two tallest people tools and connector pipes and have them connect the two frames by putting *one connector at a time* into place, tightening the setscrews on it, then moving to the next piece.
   - There will be one connector at around stomach height (middle in a double spine, back in a single spine, panel face in a serpentine) and three (double spine) or two (single or serpentine spine) 7′ off the floor. It may be easier to attach the low connector first.
   - If you have a connector without couplings, it goes above the low connector pipe.

If you're really short of people you can start the spine (steps 1–5) by standing one frame against the wall, then carry it into place before finishing (step 6). A one–bay double spine, can be carried by five people (one on each of the corner uprights, one on the low connector), although six (one per upright) is better.

6. The spine is now stable; repeat steps 4–5 for every frame including step*[s] 2–3* for every frame supporting lights until the spine is done. As each frame is added, check the floor markings and move the frame as necessary to make sure the spine stays in line.

If you have a large enough crew you can start two spines, then split the crew into two and have each finish a separate spine.

7. If you are using (unattached) caster feet instead of (attached) caps feet under the uprights, put them under each upright of a frame after the frame is entirely attached to the spine and confirmed to be in the right position. This will probably take two people, one to lift each upright and one to stuff a foot underneath (or one to put the feet on the floor next to the uprights and another to lift each upright and kick the foot under it), but it's a lot easier than trying to set the uprights into the feet while you're erecting and connecting frames.
8. Connect the trees in sets according to your plan. Double-check to make sure that you aren't overloading (maximum of 1200 watts on 14-gauge cords, 1800 watts on 12-gauge cords *and pigtails of electric trees*).
   - *Connect electric trees with cords running along the lower connector pipes of the spines.* Cords for non-electric trees can be run from tree to tree at the top of the trees, or you can bring the cord from each tree down to the lower connectors and connect as for electric trees.
   - If you are running the cords along the lower connector pipers, this must be done **before** pegboard is added to the back panels in the bays, so have someone start this work as soon as two adjacent trees are up. Be sure to lash the cords in place on top of the connectors; use anything in preference to tape, which is a pain to clean off.

## Pegboard

1. Distribute pegboard to where pieces will be hung and lean the pieces against the lower connectors and horizontals, sandwiches on one side of each frame and center section, or single pieces (if you're using the hook method) on both sides. (This is where carts are a real help.)
2. If you're using the hook method:
   a. put the hooks upside down into the top rows of holes in the pegboard (usually in the 5th hole from each edge, but look where the board will hang and move the hook if necessary to avoid a coupling);

b. add and tighten the nuts (if you're a low-dexterity type like me, it may be easiest to put 2-3 nuts in driver and twist on the top one). ***Don't overtighten the nuts!***—there's no load in their direction and very few threads for them to fit onto. If you have them, electric screwdrivers can be helpful here.

3. Hanging the pegboard:
   - If using hooks, just hang each piece from the top pipe.
   - If using sandwiches, open the sandwich and lift one piece over the top pipe; some people can control one piece of a sandwich with the other, but it's easier to having a person on the other side to catch the far piece.
4. Tie bottoms of pegboard together with pipe cleaners or long, thin tie wraps, as in figure 15; if you are using hooks, the idea is both to prevent the pegboard from being knocked upwards (e.g., when a piece of art is take off), which could let the hooks come off the pipe.
   a. Square up two facing pieces of pegboard so their edges are even with each other.
   b. Run the flat end of a tie wrap, or either end of a pipe cleaner, through matching holes in both pieces of pegboard immediately *above* the lower horizontal pipe.
   c. Bring this end of the tie wrap back through a hole directly below the first hole and immediately *below* the pipe (usually, two holes down).

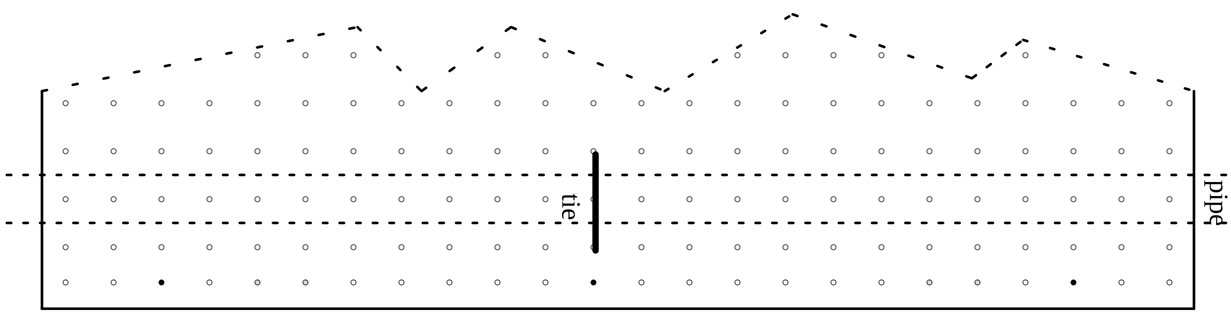



Figure 15

   d. To finish:
   - If using tie wraps, push the flat end through the fitted end, pull tight, and cut off the excess with diagonal cutters. ***Don't*** tuck the end of the tie into the pegboard, as this makes the rest of the tie bulge.
   - If using pipe cleaners, twist the two ends together and press flat.

We used to put the ties through holes near the horizontal centers of the pegboard, but it turns out that putting the ties near the edge is much easier and almost as effective; to make this easiest, hang one sandwich or pair of pieces , then tie them before hanging the next pieces.

Viola! (and any other instruments you may happen to have . . . ).

# Disassembly

Once the art and the hooks it hangs from have all been taken away, disassembly should be almost the exact reverse of assembly:

1. Cut the ties at the bottoms of the pegboard with diagonal cutters. Use cutters even if you tied the pegboard with pipe cleaners; it's faster than trying to figure out which way each cleaner was twisted so you can untwist it.

2. Take pegboard down off upper pipes and lean against lower pipes; this will take two people if the pegboard was hung by the sandwich method.
3. If pegboard was hung by the hook method, take off nuts and hooks; one person with a nut driver can loosen the nuts while others with pocketed work aprons collect the pieces.
4. Stack pegboard on carts. If pegboard was hung by the sandwich method and is going to stay on the carts, stack it carefully:
   a. Pull the knots of the hanging cords all the way out so the two pieces lie against each other.
   b. Stack the sandwiches in strict alternation, so the hanging cords in a sandwich fit into the notches in the sandwiches above and below it.
   c. If the sandwiches still bow, insert laths every few sandwiches as necessary to make the stack level out.

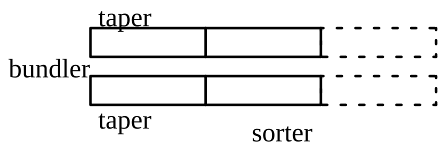
   If the pegboard will be restacked soon (e.g., in storage), it doesn't need to be stacked as carefully at teardown, but the above steps should be followed when it's stacked to stay.
5. Clear away extension cords. One person should use clippers to cut the ties and unplug the cords; if you didn't use electric trees you may need another person with a ladder to unplug the cords at the lights. Another person should take extension cords to where they can be coiled. Set someone to coiling the cords in some place out of the way of teardown.
6. Have one person take hold of each leg of a frame at the end of a spine, standing beside the spine for outside legs and outside the end for the center leg (for double spines)
7. Take off connector pipes ***one at a time***.

- ***Don't*** let anybody loosen a setscrew and walk away from the pipe thus released unless somebody else is supporting the end. If possible, give tools to exactly two tall people (or four if you have plenty of help) and have them work in pairs, loosening both ends of one connector at the same time and putting it on the floor before going to the next one.
- Loosen ***only*** the setscrews holding the connectors—you don't want the frame to collapse in your hands.
- Take off ***only*** the connectors (pipes running parallel to length of spine); it's much easier and safer to take apart the frames on the floor unless you're dreadfully short of people.

8. Lower frames to floor, stopping partway down to *unplug lights,* unscrew bulbs from sockets and take the lighting support **as a unit** off the tree.
9. Repeat steps 6–8 until you have a one–bay spine; at this point make sure there's somebody for every leg on both frames before taking off the connectors, then proceed as above. At this stage you'll need ~8 people, which you should be able to get for a short time; holding uprights is easy work and fans are often entranced by teardown.
10. Take apart the frames and lighting supports; depending on how many tools and people you have, you may want to have 1-2 people with tools just loosen the setscrews on the clamps, then have the rest of the crew take clamps off pipes after all the frames are down. Take all the clamps off every piece of pipe *except the trunks of electric trees, but not excepting the bases*. If you used extenders on the connectors to make 6×7 bays, take them off after the clamps are off.

11. As soon as all the frames are down, clear a space near the middle of the floor for a taping bench. This can be just a couple of chairs, but we've found it goes faster with two rows of two or more tables (narrrow "schoolroom"s if possible) end to end with a small gap between the rows, and four people as in figure 16; the rest of the crew dumps pipe across the

Figure 16




tables in front of the sorter, who sorts the pipe into sets of five of a type and rolls them down to the bundler, who holds them in a bundle for the tapers. However you set this up, square up the pipes before taping, as otherwise the tape can break if the bundles are stored on end.

12. Pack up clamps in buckets and everything else (except pipe and pegboard) in whatever you have for storage.

# Nomenclature

*Bay:* an alcove of panels forming three sides of a square or rectangle.

*Builders' supply:* a large store that carries lumber, wire, plumbing, cabinets, and everything else (including the kitchen sink) needed to build a house. Examples in the U.S. include Home Depot and Home Quarters (all over the east coast) and a lot of smaller chains in particular areas. Check your yellow pages.

*Clamps* are described according to the number of arms that butt pipes into the one pipe that passes through the clamp (see table on page 29).

*Frame*: a flat assembly of pipes and clamps. These hangings are built up from frames.

*double frame, serpentine frame, single frame:* used for *double, serpentine,* and *single* spines respectively.

*P2D hangings:* a widely–used hanging design built from pegboard, 2×2, and drywall screws.

*Pipe* unless explicitly noted otherwise means IMC (see page 28).

*Spine:* any number of panels connected into a single block. Spines can be

- *double:* bays on both sides; the commonest layout
- *single:* bays on one side, flat on the other; usually used against a wall
- *serpentine*: a single spine with bays on alternating sides; used where there's not enough room for a double spine, but the flat wall of a single spine would be too imposing.

*N–long spine:* a double spine with N bays on each side, or a single spine with N bays on one side, or a serpentine the same size as an N–long single spine.

*Skilsaw*: common term for a hand–held electrically–powered rotary saw. This was a brand name at one point, but now it's used for everybody's brand.

*TomCat*: the *Thomas Register of American Manufacturers* (yes, that's the official abbreviation; their mascot looks like a rakish, potbellied Sylvester in overalls). Most companies of any size have one, as do main libraries in many larger cities. Massively useful, as it lists both makers and large–scale suppliers of anything manufactured.

Text that applies to all hangings appears in this type face.

Text that applies only to hangings with attached lighting appears in this type face in "Specifications" and "Assembly".

*Text that applies to lighted hangings with built–in wiring appears in this type face in "Specifications" and "Assembly".*