CHAPTER ELEVEN

MODELMAKING

In a sense, models are the most eloquent presentation form available to designers. No matter how good their drawings, they are illusions. (By that I mean the illusion of three dimensions attempted in two.) Models are simulations and as such often convey a better idea of a design than drawings alone can. Of course, designers may have time to make only one model—or none—and their presentations will therefore always include drawings, which are still the quickest and cheapest way to provide multiple views of an intended space or object. They are also the most accurate way to describe a design. A well-scaled, adequately detailed model, however, is without peer for presenting a design.

There are really only two categories of models that are generally recognized: study models and presentation models. General agreement ends here, and it is sometimes hard to know where a study model starts becoming a presentation model. Usually, study models are cruder in their fabrication, may lack all surface detail, and frequently aim at exploring only one quality of a design—often the massing.

Presentation models, on the other hand, are usually larger, are made of more different materials, and may reproduce considerable detail in a rather complex effort to present the look and "feel" of a building or space. A still more elaborate form of modeling is the full-size mockup of a piece of a building (or of an entire object, in the case of industrial designers) in the effort to study some particular fact or facts.

We can only begin to explore model making here, so we will concentrate on the ones that are most useful to students. This will also put a limit on the materials and tools we will look at; few students have the time, tools, and skills to work on machined, "hard" models.

SOME VERY IMPORTANT CAUTIONS

It is important to recognize the dangers of modelmaking: extensive use of cutting tools is required. Students tend to work late at night, when their reflexes are slowed by fatigue. This is the worst possible time to construct a model—the cardboards are heavy, the knife drags, a slip can sever a tendon. Remember: *Don't work late or when you are tired.*

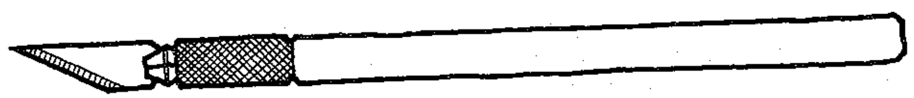
A further caution: dull knives (and other blades) are a greater danger than sharp ones, because they present wider surfaces (being blunt) to the material grain or texture and hence can deflect more easily. Note: *Use sharp blades and change them often.* Don't "make do" here—the cost of the doctor and of the healing time will far outweigh any minor economies you may make. Keep a whetstone (even the free ones sports shops give away with a new pair of ice skates will do) on hand so that if you run out of new blades, you can sharpen the dulled edges frequently.

On heavy materials *do not attempt to cut through with one pass* of your knife—make several light passes. When you bear down hard to cut through with one pass, your muscles cramp and stiffen, and you lose some control of the knife. This will ultimately mean that the knife will wander from the line you want it to follow. At the least this will ruin some material and slow the job. A light touch will enable you to control the knife almost as you do a pencil. The job will, in the end, go faster if you follow the seemingly slowest route.

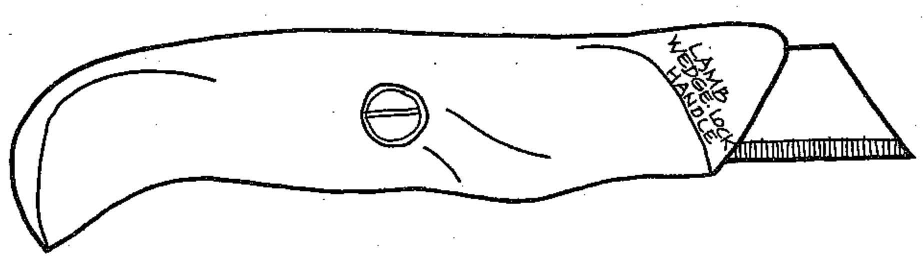
TOOLS

To make models you will need some tools that you may not already own, so I will describe them here. They include cutting tools, straightedges to cut against, glues, and clamps.

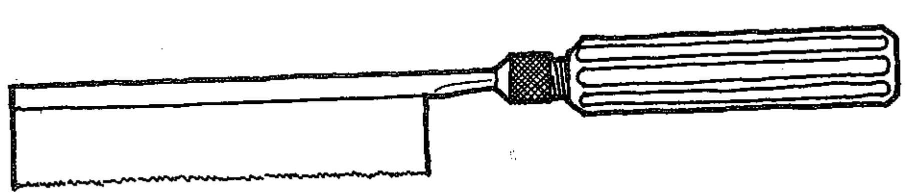
No. 1 Modeling Knife Handle. X-acto and other makers supply a small handle that holds blades of several different shapes. It is universally referred to as a "no. 1 handle." Generally, only one blade shape is useful, the no. 11. I buy them in quantities of ten. They are used to make detail cuts and small openings, since they are acutely pointed, and are well-suited to making inside corners, as at window openings.



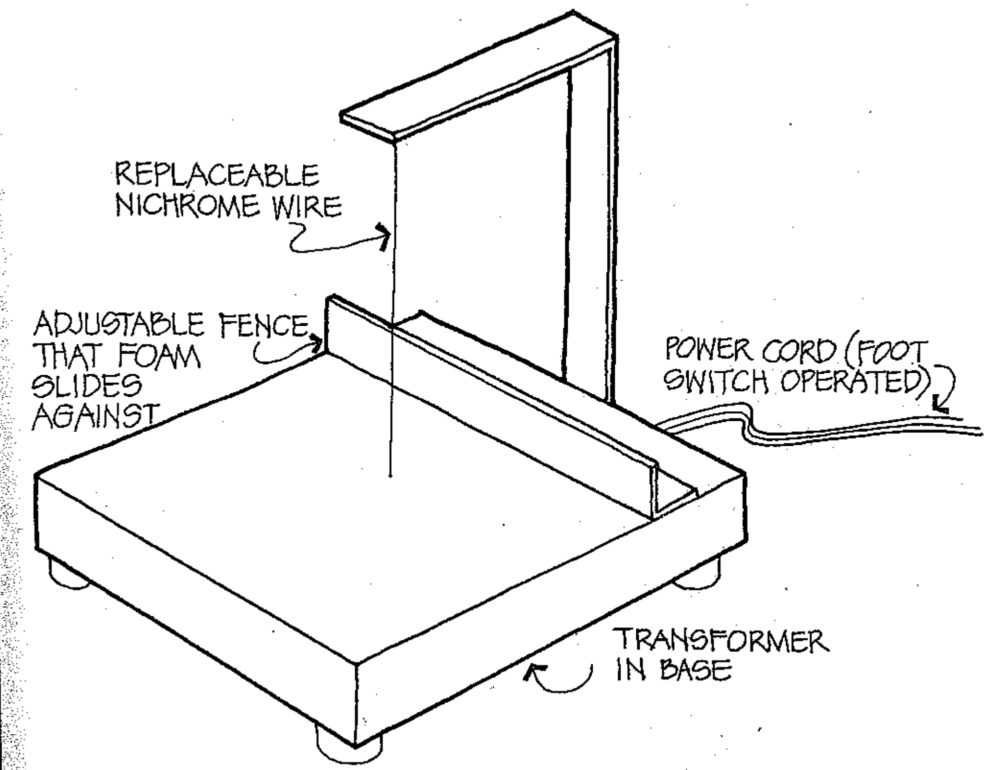
Mat Knife. A bigger handle that holds regular mat-cutting blades is made by many manufacturers. The ones I like best are by Stanley or by Lamb (illustrated). The blades they hold are of standard shape and are widely available. They are used for long cuts in heavy materials.



Zona Saw. For cutting small pieces of wood you will need a model-maker's saw, usually called a "Zona" saw. Several manufacturers offer this type of saw; look for one with a stiffened back and a very thin blade with exceptionally fine teeth (approximately 40 to the inch).



Hot-Wire Cutting Tool. If you will be making study models of building masses, you may well decide to make them of Styrofoam (polystyrene foam) blocks, cut quickly with a hot wire. These tools can be homemade or bought ready-made. The former are much cheaper than the latter, though they require some small skill in electrical assembly. Avoid the fumes of the heated Styrofoam—they are apparently very toxic!



Aluminum T-Square. You will need a metal t-square. The aluminum kind is cheaper than the stainless steel kind. They both look just like a t-square, only made of metal. They are used for making long cuts and for laying out the model.

Stainless Steel Ruler. You will find a metal ruler very useful for shorter cuts. Mine is a stainless steel model 18″ long, made by Pickett. It has a cork composition backing that keeps it from slipping around. This is a most important feature.

Aluminum Triangle. To cut small pieces, you will need an aluminum triangle. Since it is lightweight, you can use a relatively large one to cut small pieces. Mine is 12″ on its long side.

Cutting Board. For years I used scrap pieces of cardboard to protect my drawing surface when I made models. The cardboard needed to be replaced fairly frequently since otherwise it became scarred and pulled the knife away from the line I wanted to cut. In recent years cutting boards of high-density polyethylene have been available, and I have taken to using one. They are easy to store and self-healing (somewhat), so that previous cuts don't draw your blade (the problem all cutting surfaces have at some time or other). They are expensive, so you may need to resort to the "scrap" cardboard cover.

Mitre Box. A modelmakers' mitre box can be very useful, though it is not absolutely essential. Joints depend largely on the area joined for their strength. If two surfaces can be mitred, they present a greater area to each other and hence sustain a stronger bond. With small pieces that will be stressed in any way, it is always a good idea to mitre the joining surfaces.

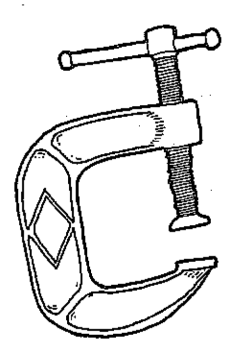
Glues. Most of our work can be held together with white (polyvinyl acetate) glue. This is available from many makers, including Borden and Uhu. It is water soluble when wet, and transparent and fairly waterproof when dry. Since its medium is water, it will make lighter materials stretch. Be careful when working with large pieces of paper or cardboard and white glue, since once wet with the glue the weight and softening effect of the water can cause the paper or boards to stretch. The more permanent companion of white glue is aliphatic resin glue, which is yellow, dries cloudy, and is stronger and more durable than the whites.

Rubber cement is also frequently used in modelmaking, although it is a very unsatisfactory product in the long run. Its major deficiencies are that it is highly flammable and that its bond is fugitive, lasting only a few weeks. However, it is workable, which means that you can stick something down with rubber cement and work it into position. (This is only true if you put the cement on one of the two pieces to be joined and bring them together while the glue is still wet.)

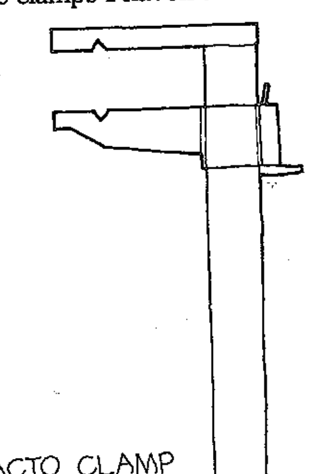
Cyanoacrylate glues ("magic" glues) are very useful. They will glue most nonporous materials but don't work on many plastics, and they are—magic. Observe all manufacturers' cautions—it is painful to unglue yourself from your model. Lately, cyanoacrylate glues have been available for porous materials (though I haven't had a chance to try them yet).

Spray adhesives are offered by several manufacturers and are very handy for mounting drawings or prints on cardboard or for cardboard to cardboard—in fact, for laminating any relatively smooth, porous sheet materials. Their bond is not durable in my experience, however, and the adhesives in some cases "blush" through paper materials. They are also expensive. I think of the spray adhesives as a lazy person's rubber cement.

Clamps. A clamp can be anything that holds materials together while their glues set. For us that can mean pins, rubber bands, drafting tapes, clothes pins, books, or actual metal clamps. It is a good idea for you to have all the above. The metal clamps I recommend have a jaw opening of about 1½". X-Acto makes some plastic clamps I haven't used that look as though they could do the job.

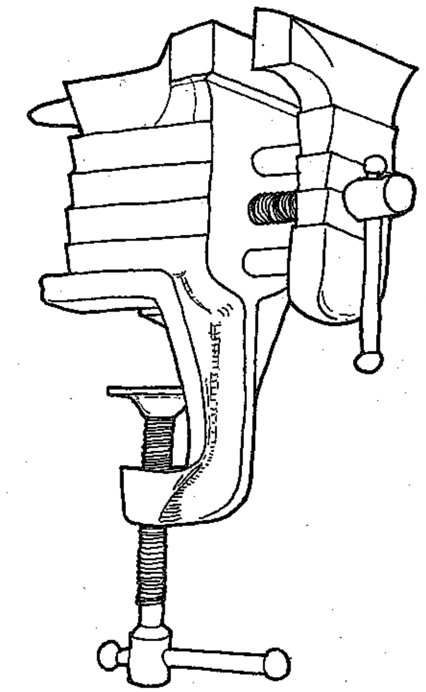


C CLAMP



X-ACTO CLAMP

Vise. A small vise is frequently useful in assembling parts that are later applied to the larger model. Several types are available, including one with a vacuum base, which only works on a smooth surface such as Formica. (I can't imagine what you would be doing working on Formica as you make a model, since the knives we employ are sharp enough to scar and ruin even melamine plastics.) My vise has a screw clamp on its base that allows me to attach it to a work top as thick as 2½".



Tack Hammer. A small hammer is useful for driving pins into dense layers of chipboard or for attaching the model to a wooden base. A tack hammer such as upholsterers use is ideal for this and has the added benefit of a magnetized head to hold those little steel nails and pins your fingers are too big to manage.

Pliers. A pair of pliers is almost indispensable. I regularly use two kinds: a lever-locking plier (now available with a long nose from Petersen Vise-Grip) and a conventional needle-nose plier. Of course, there are other tools you may need at one time or another. Most of them are conventional (in the sense that they can be found in a home tool box), and you may well own them already.

MATERIALS

The variety of materials useful in the construction of models is endless. What I will describe here is the core group that seems to have won general acceptance over the years. Be on the lookout for ordinary materials to use in novel ways that may make your production job easier.

Clay. Plasticine is used by some people to make initial massing study models. It is the least architectural of materials, though, in its inherent softness and plasticity. Its main virtue is that it is relatively quick to use. Many people are allergic to it, however, so be aware of this potential drawback.

Styrofoam Blocks. Because of the problems inherent in clay mentioned above, many people prefer to make their study massing models out of white Styrofoam (polystyrene foam) blocks. These create a cream cheese universe, but at least they are hard-surfaced (relative to the clay) and sharp-cornered. You can use scrap packaging material for this purpose (if you can find it in big enough pieces), but the blocks purchased from artists' suppliers are denser and more uniform. They are best cut with a hot-wire tool, described above.

Chipboard. Chipboard is a dense, gray cardboard, prized for study models because of its uniform, anonymous nature as a material. It doesn't look like anything except chipboard. A more polished (and somewhat denser) version is known as "bookbinders' board." The only place I've ever found to buy it is a bookbindery.

Chipboard comes in a variety of thicknesses, which ultimately means that you can find an appropriate thickness of board so that even small-scale study models (usually made out of a single layer of board) can nonetheless have a realistic wall thickness.

The problem with these materials is that their density and grain or texture resist the knife, so considerable effort is involved in cutting them. Though we will talk again about cutting in general, the key to using these boards is to cut through them with multiple passes of the knife, as described previously, and *not* to attempt to cut them with a single pass and great effort.

Foamcore. Foamcore is the now-generic name of two products of interest to modelmakers. Both are boards made of a sandwich of two paper faces laminated to a polystyrene foam inner layer of various thicknesses. One of the boards is a kraft-paper-faced foam board, the other a plate-bristol-board-faced foam board. The kraft-faced board is brown like butcher's paper, with a white core. The plate-bristol-faced board has a smooth, hard, white face and a white core. They are both paramount materials to amateur modelmakers (all of us who don't make our livings at it) in that they are easy to work, are well-suited to modelmaking, and are usefully sized. We'll go into more about them later.

Illustration Board. A white cardboard of great usefulness, available from several makers though usually referred to as "Strathmore board," is a fine presentation model medium. Be sure to specify "illustration board—Strathmore drawing board," made up of several layers of rag-based drawing paper. It is very expensive and also well-suited to modelmaking. The illustration board is made of two layers of Strathmore paper bonded to a white cardboard substrate of several thicknesses. It provides a cream cheese alternative to the chipboard models we will discuss. Since its surface is the same as that of Strathmore drawing paper, it is possible to intermix the two and achieve a great range of thicknesses. This fact has led to a whole new style of model in the last ten or fifteen years or so that is as abstract as the designs it represents. The models have more in common with the paper the architecture is drawn on than with the reality of building they both show.

Plastic and Wood Structural Shapes. Several makers supply shaped sticks that are useful in the construction of architectural and design models. Those shapes are usually made for railroad or other hobby models and are frequently found at hobby shops. Some artists' supply shops sell them, and some have a large enough clientele to have shapes made for architects alone. In any case, no matter where you live, look in a drafting supply catalog, a hobby store, or the ads in model railroad or airplane magazines for shapes that can represent beams, columns, and other linear elements.

The Human Figure and Other Scale-Giving Factors. Just as human figures are essential in sections and other drawings to give scale, so are they useful in models. The simplest way to show them is to use figures cast to scale in lead or gun metal that are now generally available. They can be bought at most artists' and architects' suppliers and provide a reasonable expression of scale. An alternative (and the only way to show the figure in large-scale models) is to find appropriately sized figures in magazine illustrations, laminate them to cardboard, and prop them up in your models.

Model cars, trucks, buses, boats, airplanes, park benches, street lights, furniture, and so forth can all be purchased in cast metal. They can be used as is, with their dull metallic sheen reinforcing their abstraction, or they can be painted with nonglossy modelmaker's paints.

Trees also help provide scale and context and are an eternal problem to modelmakers. Lichen is packaged and sold for use in model railroads, and it makes a good shurb for architectural models, but a terrible tree. Its scale and texture are not right for trees and look too chunky and dense. The best, and most believable, material for trees is something I know only as "graveyard weed." Ask around for it; some drafting supply stores carry it.

DECISION-MAKING CHECKLIST

More than anything else, the production of a model takes planning. By planning I mean thinking through all the steps from choosing the type of model to make, to buying your supplies (for instance, most artists' supply stores are closed on Sundays), to the actual manufacture of the model. Decide on the materials that are appropriate for your situation. Evaluate the amount of time available to you. Think about production—how will you *make* it? That includes the step-by-step procedures for manufacturing the pieces themselves. Decide in advance how you will account for the thickness of the materials. What sorts of joints will you use? What kind of glue? Make an inventory of materials on hand. Will they really be enough?

After this period of planning, I return to the beginning and ask myself whether the initial decision as to model type is still realistic. How long will it really take to make this model? Do I have that much time, and if I do, is that how I want to spend it? Once I have answered these questions and settled on the type of model I both want to and can make, I go through an actual written inventory to make sure I have every essential. A series of questions follows that will assist you in making an exhaustive checklist.

1. Do I have the necessary amount of board stock, whether chipboard, illustration board (and/or illustration paper), or foamcore?

2. Do I have the basswood or plastic beams and other premade parts my mental image calls for (such as cast figures)?

3. Do I have the appropriate glue or glues, and are they fresh and useful? (Glues dry, even in closed containers, and lose their workability over time.)

4. Do I have the tools I will need? (These include the ones described above and any special ones you may know you will need.)

5. Do I have an adequate cutting and assembly surface?

6. Do I have an adequate nearby reference surface on which to rest my drawings as I build the model?

7. Do I have a plan of action for the manufacture and assembly of the model that presently exists only in my mind?

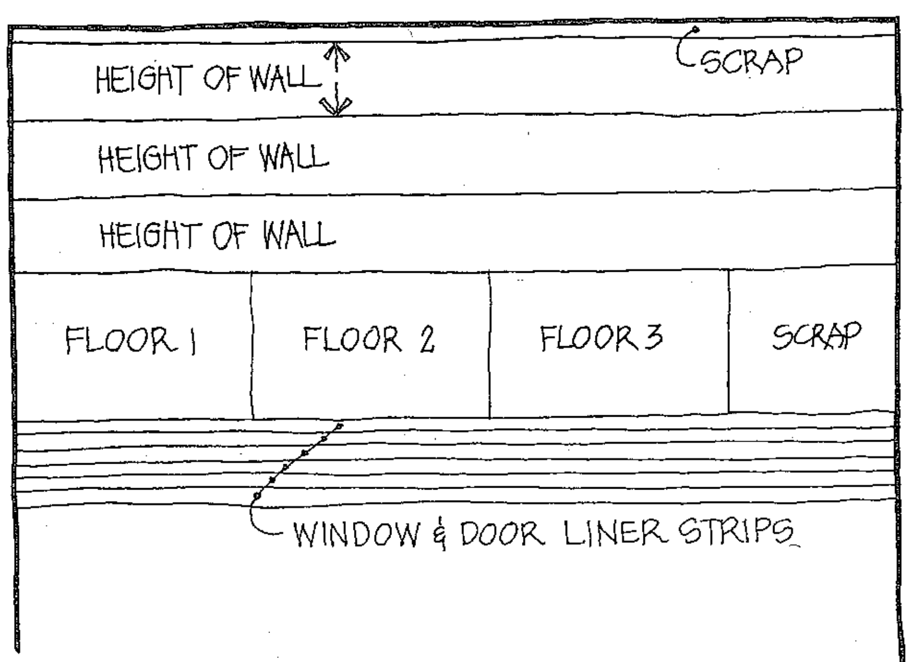
THE PLAN OF ACTION

The planning of a model is a separate and distinct procedure from the planning of a building. Like cabinetmakers, modelmakers need to prepare lists of materials that show each piece to size, taking into account the materials' thicknesses. Fortunately for us, the lists of materials can be laid out directly on the board stock we will eventually cut up to make the model.

What I do is lay a sheet of the board stock I am using on my drawing table and square it up to the t-square. Then, having calculated from my design drawing the approximate linear length of "wall" I will need, I convert that dimension to actual (full-size) inches. If that length is within the width of my board, I simply draw a single line parallel to an edge of the board and the height (to scale) of my model's walls. The height you use is a factor of how you have visualized and are constructing the model. In general, it is a poor idea to have the floors come through to the outer wall of a model, so the walls should run the full height of the building or object you are modeling. In this case, the walls need to be laid out first, and the floors and roof fitted to them.

You may find that the edges of the board have been damaged in transit from the factory to your workplace. If so, you will want to draw a line to guide you in cutting off the damaged selvage. Use that line as the point of origin for laying out later lines. If I will need more than one stock wall strip, I draw another line below the first. Be sure to lay out plenty of wall strips; there is always a certain amount of waste when you come to the end of the strip.

Now lay out the floor or floors on your board. You must remember to subtract the wall thickness all around from the overall dimensions of your building. Since the materials we use almost never are precisely the right thickness, it is a good idea to lay out your model pieces working from outside dimensions in. To conserve material, try to nestle the shapes together. Lay out any other pieces you will need.



CUTTING

At the risk of being repetitious, let me again urge caution and respect for the cutting implements. I have known several people who have hurt themselves badly while modelmaking, and the damage can be permanent.

In cutting sheet materials, always run your knife along a metal straightedge. On occasions I have fooled myself into thinking I was exempt from this rule. Every time I have done so I have ruined a perfectly useful plastic straightedge. The metal edge should be thick—at least 1/8"—if you will be making long cuts. The straightedge functions in two ways: to guide the cut and to protect your fingers. The thicker edges are harder for the knife blade to leap over—a safety factor—and they are more likely to keep your knife vertical—an important consideration when you later measure to that cut or glue something to the edge. Whenever possible, place the metal straightedge on the part of the material you will use, and let the scrap, or the part not yet allocated, stick out on the far side. In this way, if your knife wanders, it will ruin material you haven't yet invested time in.

Stand in such a position that your stroke can be made smoothly, with nothing hindering its completion. Now, using the mat knife for long cuts (over about 18") and the no. 1 knife handle and a no. 11 blade for shorter cuts, make the cut. Draw the knife toward you, along the opposite side of the straightedge from the one your holding arm is on. Start the cut at the farthest point from you on that line, preferably at an edge. If you are working in chipboard or other resistant material, make several light passes along the straightedge, one after the other without moving it. On lighter (less resistant) boards and on shorter cuts, you may find a thin-gauge aluminum triangle an adequate guide. In these cases, where the long muscles of the arm can control the cut fairly easily, the reassurance of a thick straightedge isn't necessary.

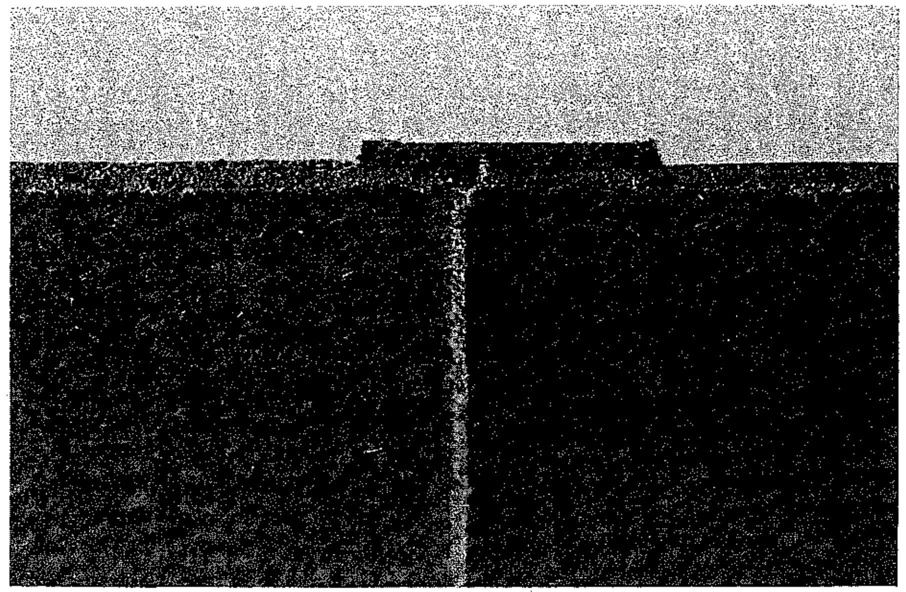
JOINTS

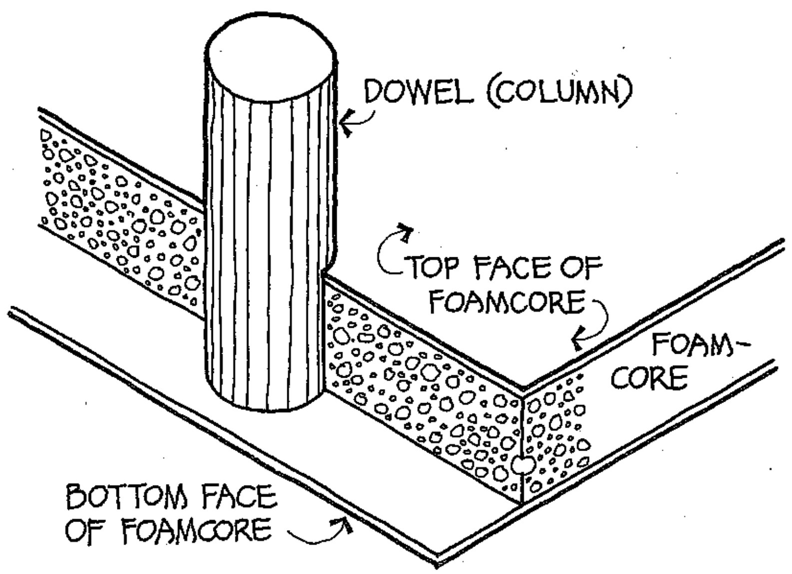
The biggest problem when planning and making models is joints. They must be designed for adequate strength, which is a factor of surface area in the joint. The greater the area the greater the strength. Joints must be allowed for when laying out the panels before cutting.

There are three fundamental conditions that concern us: right-angled joints, edge-to-edge joints, and point-to-plane joints. The joints most frequently used (because they solve the problems we encounter with the least effort) are called: butt, lap, and rabbeted.

Butt Joints. Butt joints occur where edges abut edges in the same plane. They are least commonly used in modelmaking because the panels we use are so thin that their edges do not provide enough surface area to glue adequately, and the joint they make is therefore not strong enough. It may happen, however, that you need to join two panels together either because the stock you are using is not big enough for the project at hand or because you are running out of material. In either situation, I recommend that you use a scrap strip running the full length of the joint to back it up and that you glue it along its entire surface (however, this is technically no longer a butt joint).

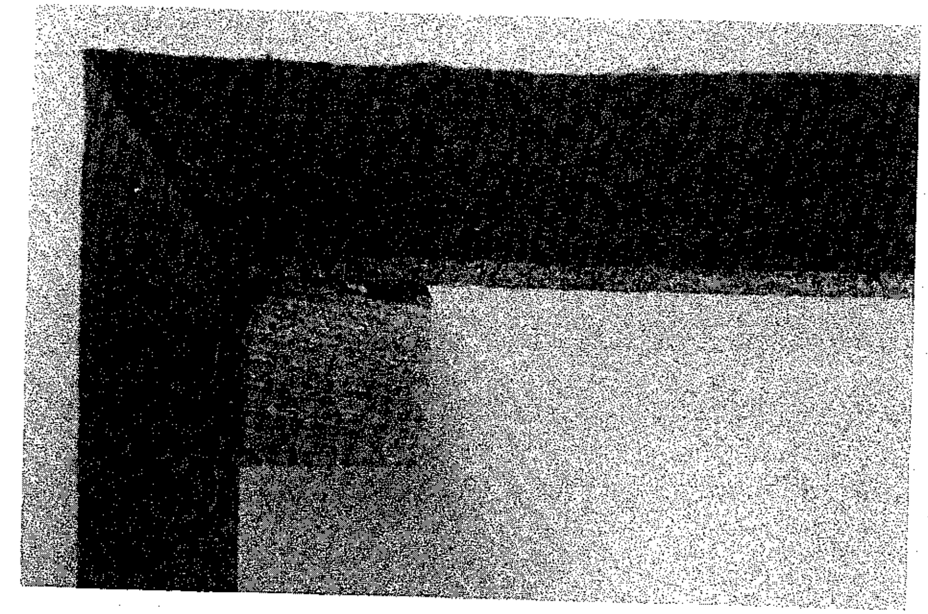
Where a column or beam meets a plane is also strictly a butt joint, and such points of contact are also hard to make strong. You can do so when you are working with a thick material or with a built-up wall model (described below) by allowing the column or beam to penetrate the top skin of the foamcore or built-up material and by gluing it to the foam or both layers of the chipboard.



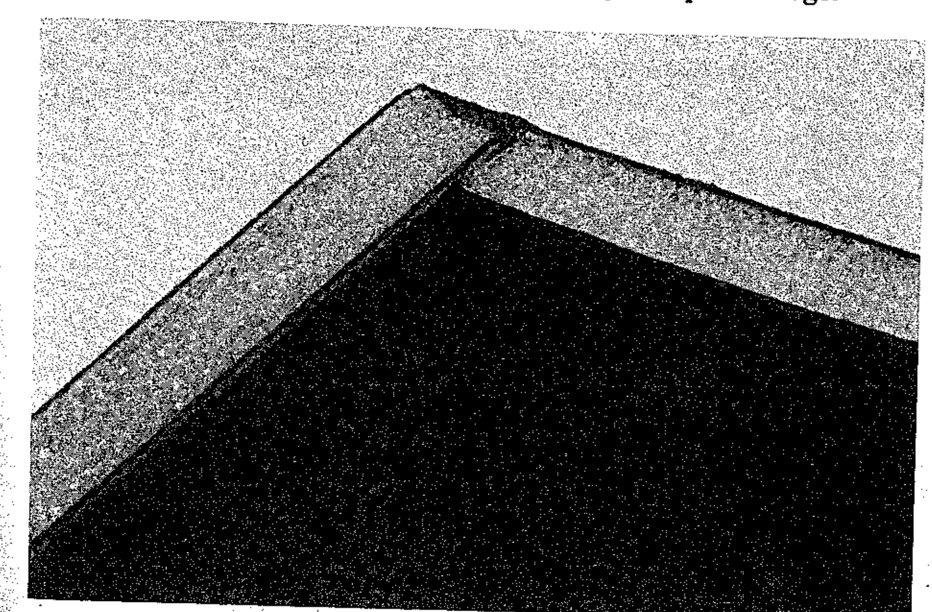


Lap Joints. Lap joints are used in the construction of chipboard and foamcore study models. They are simple, right-angled edge-to-edge joints that depend for their integrity on the strength of the glue. (Lap joints, in the sense of two panels being overlapped, are almost never encountered in modelmaking.) Since there is relatively little surface-to-surface contact in these joints, it is best to back them too. The simplest way to do that is to use a 1/8″ × 1/8″ (or 1/4″ × 1/4″ if the model's size allows) balsa wood stick along the length of the joint. The wood should be glued securely to both panels it abuts.

The only other lap joints commonly used occur in relatively large-scale models made of such material as foamcore, the thickness of which will allow you to make a simple joint that will have enough internal area to survive for a while. But it probably won't withstand a trip from your home to school if it gets jostled around. The next type of joint solves this problem and is also useful in making presentation models.



Rabbeted Joints. A rabbet (spelled "rebate" in British English, but pronounced "rabbet" in both languages) is a right-angled cut along a corner edge of a panel by which enough material is removed so that the corner can accommodate the fitting in of the adjacent panel's edge.

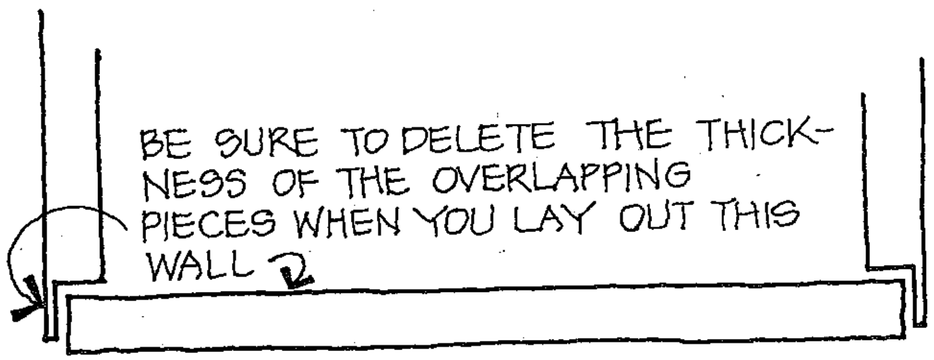


Rabbetted joints are the strongest generally used in making board-stock models. They typically present about twice the surface area for a joint than a simple lap-jointed corner would and therefore make very strong joints.

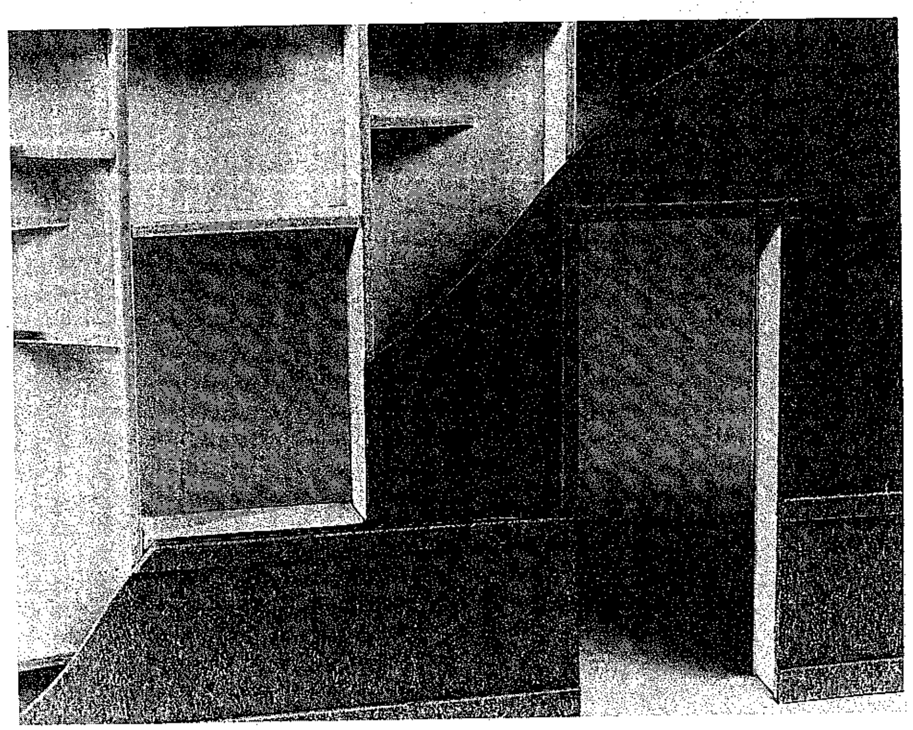
In a model that has walls built up of several layers of board stock (or built up as a hollow panel as described below), rabbeted joints are extremely useful. Their construction in chipboard will be described in the section on built-up models.

Model Types Useful to the Student

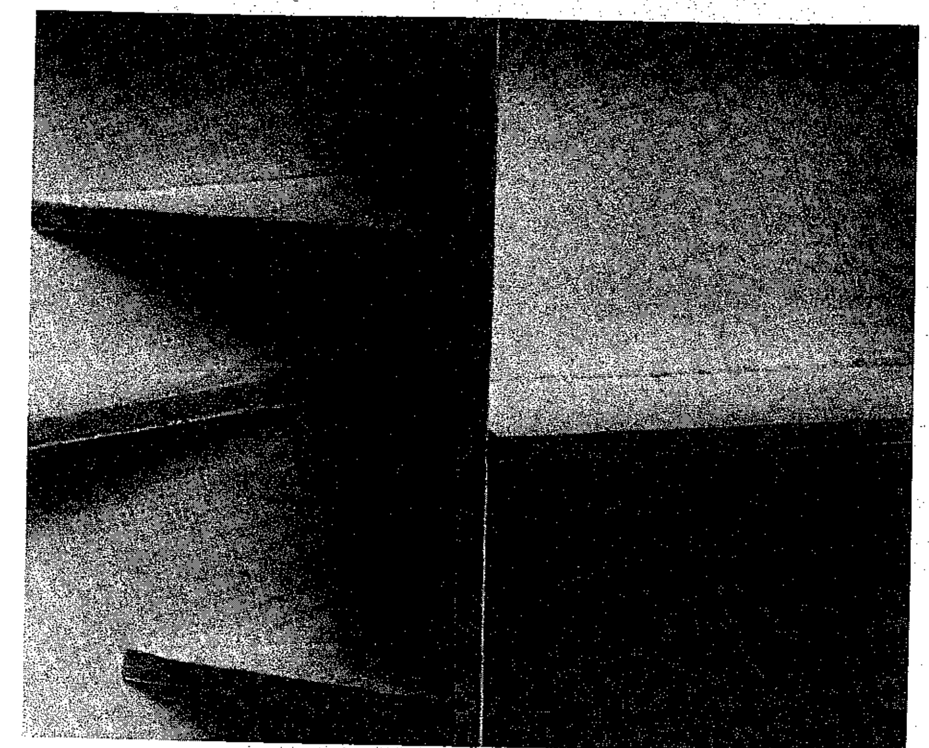
As mentioned earlier, there is no general agreement on nomenclature in the field of modelmaking. Realistically, there are really only three types of models that students are likely to make. They are solid mass models, The only really difficult part of manufacturing this type of model is keeping track of where you need to subtract the stock thickness and where you don't. It is easy to forget, when you are dimensioning panels, that you must subtract the designed wall thickness *twice* from the inner panels—once for the left-hand wall and once for the right.



Once you have figured out the dimensions of the various panels, cut the stock to height out of the full width of your material. This gives you long pieces to cut the walls from and ensures that the various panels will be the same height. If you need two or more "wall" lengths, cut them to height with great care so that they will be of uniform dimension. Next, cut a lot of strips that are the thickness of your model's walls, minus the thickness of two layers of your stock. These are the pieces that you will use to close up the wall's edges and to separate the two wall panels. They will also serve to line all openings for windows, doors, and so on.

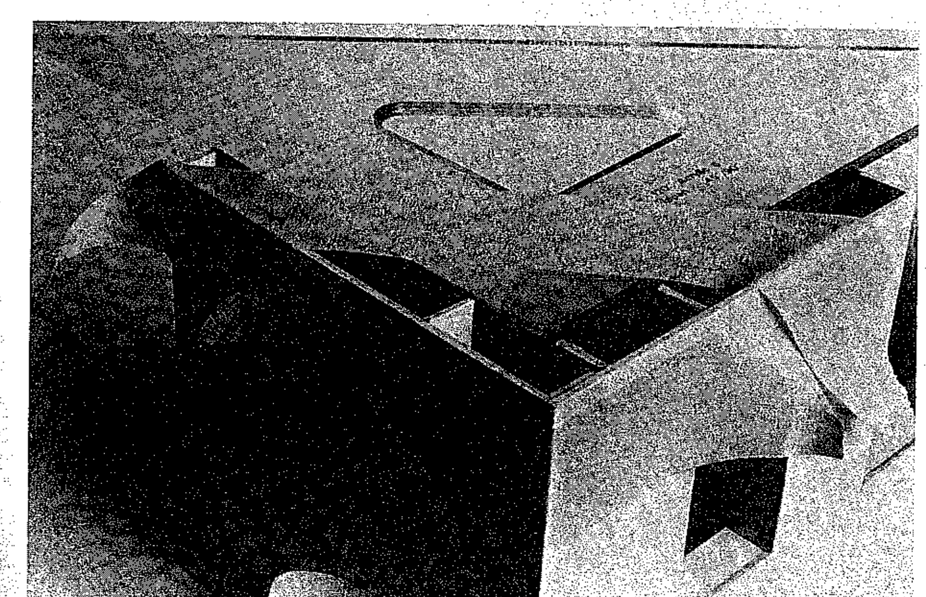


It is a good idea to brace the liners and edges as you assemble your panels. I like to do so with the corners of scrap pieces of the stock I am using. I simply hack off corners on the diagonal, ending up with a triangular gusset piece I dip in the glue and shove into position beside the strip I need to brace. These pieces add significantly to the strength of the total assembly and should not be neglected.



Weight the panels with books while the glue dries. A layer of ordinary waxed paper between the books and the panels will ensure that the glue doesn't seep out and ruin both.

When you have completed the panels of your model, you must assemble them so that the corners are square. This is relatively simple if you are gluing the walls to an accurately cut floor, but that is not always the sequence of events. When I am assembling walls with rabbeted corner joints but no reference angle to assure their trueness, I use a small, old acrylic triangle no longer useful for drawing to check the inside angle. A clean carpenter's square will do the job as well.



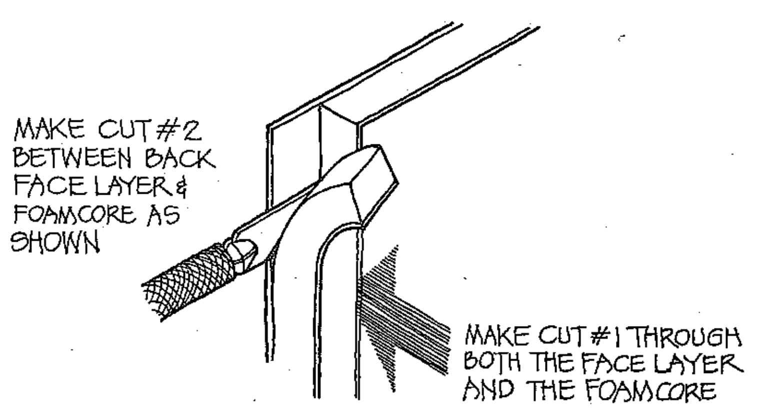
like clay or balsa block models; skin or sheet models that utilize one layer of cardboard or thin plastic stock; and built-up wall models that also use card or plastic stock. Solid mass models are useful as study models; they are almost never appropriate for presentations. Single-skin models are useful as both study and presentation models, and built-up wall models are almost always of presentation quality if only because of the time invested in them.

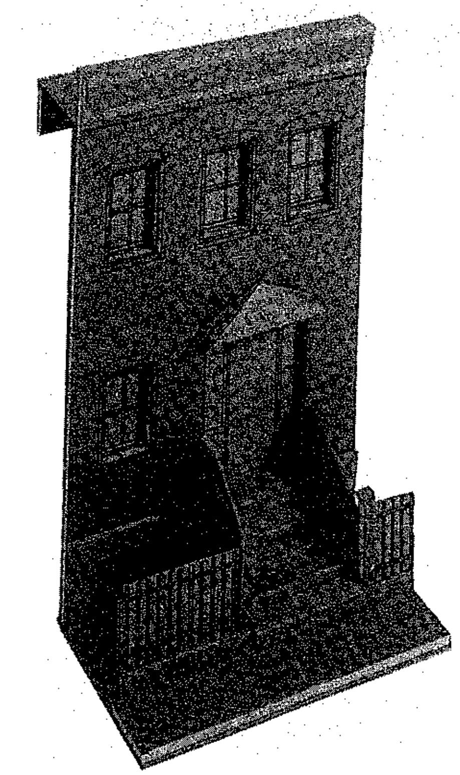
Massing Models. Massing models are useful for studying the bulk, volume, or shape of a building or object in its context. They are always study models. As a general rule they do not include the building's openings (doors and windows). These models show mass in the dictionary sense of expanse or bulk. The appropriate materials to use in making a massing model are clay, Styrofoam blocks, and wood blocks (only balsa wood is easy to work and therefore truly appropriate for a do-it-yourself model).

Single-Skin Models. Other study models are used by designers to study form and proportion. They are made of (relatively) easily cut and manipulated sheet materials such as gray chipboard or foamcore. A single layer is used, since only the envelope and mass need be suggested, not wall openings and surface thickness. Workmanship is often crude; the panels of the model are frequently cut and recut as the design is developed and refined. The lap joint is most appropriate for this type of model.

Single-skin construction can also be used to make presentation models. This is especially true where the model is of small scale, and the sheet stock used for its construction approximates (to scale) the design thickness of the walls. In these models the fabrication should be more careful than in study models, and openings and some surface detail will usually be shown.

Foamcore is eminently well suited to the fabrication of single-skin presentation models since it is of substantial thickness and can be readily worked to create the strong, rabbeted joints described above. They are relatively easy to make. You make a cut on the inside face of a wall panel that is parallel to the edge to be joined and one material thickness in from that edge. You must be careful to only cut through the top layer of bristol board or paper and the foam's middle layer. Do not cut or score the outer layer of board or paper. You now need to run your no. 11 blade down the joint pointing into the foam layer and immediately adjacent to the outer layer of board or foam. This second cut will detach the foam and inner piece of paper or board you no longer need. You are left with a rabbeted edge, ready to receive the adjacent panel. The whole process is easier to do than to describe and is illustrated here:

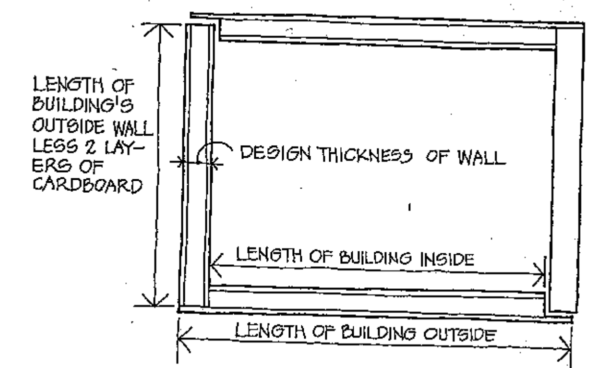




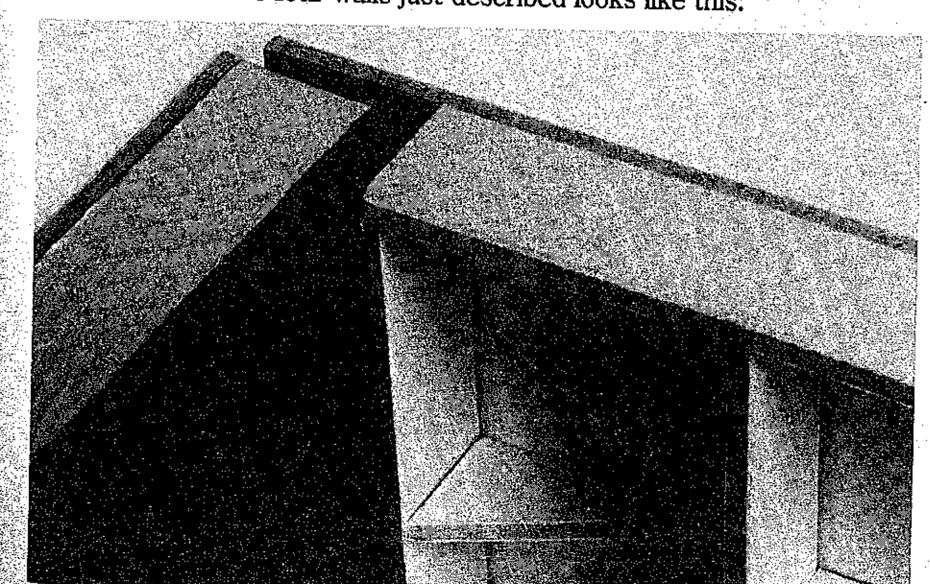
The other great attribute of foamcore is that its surface can be drawn on to suggest surface detail that is otherwise too shallow to show in the model. The bristol-board-surfaced material is ideal for this, although the brown butcher paper surface will also withstand being drawn on. I find that the best medium for such drawing is ink, which because of its bold contrast with the board surface is well adapted to abstract detail.

Built-up Wall Models. Where the scale of your model is too large for single thickness materials to satisfactorily simulate a wall, you will need to build up panels. This is somewhat more time consuming than the simpler methods previously described, which is why this form of modelmaking is appropriate to presentation models. In brief, what is involved is the creation of hollow wall assemblies constructed of inner and outer layers of sheet stock held apart by edge and spacer strips. The inner and outer layers need to be of different lengths so as to create the rabbeted corner connections previously described.

The procedure involves a plan of attack, as always. First, decide which set of walls will be fit inside the other. They should be made up as a simple pair of panels, with both the outer wall surface and the inner of the same length. That length equals the *outside* dimension of your building minus the thickness of two layers of the stock you are using.



The manufacture of the other two walls is somewhat more elaborate, since they include the corner joints. In this pair of walls the inner panels are the length of the building's outside dimension *less* the thickness of the walls. The outer panels are the length of the building's outside dimension. The fit of the four walls just described looks like this:



Making Curves

Sooner or later you'll design something that requires a curved wall or portion, and you will confront the problem faced by all curve-makers in a rectilinear world. Our materials are flat!

To make a curved plane out of a lightweight cardboard you need to make many small score marks on its backside. The marks can be made with a knife, in which you run the risk of cutting through the board, or they can be made with a fine ballpoint pen, which must be born down on. Think of making a model of a drum. If the cardboard represents the sides of the drum, then the score lines should run up and down those sides.

Once the cardboard is scored you should gently roll it over the edge of the table so the board can fold a little at the score marks. Hold the card so the score marks are parallel to the edge you are rolling the board over and are on the underside of the board. Now glue the curved plane to several cardboard disks you have prepared that are two-cardboard thicknesses smaller in diameter than the finished drum. The disks help the curved plane maintain its shape and keep it from bellying.

If you are working with thicker boards you will need to take chunks out of their backs instead of simply scoring them. In foamcore boards I do this by laying out locations for surgery with my drafting tools and then making two cuts at 45° to the surface and removing a triangular strip.

Curved planes made with foamcore need to be supported just as those of cardboard do.