Production manufacturing sounds pretty serious, and it very well can be. Consider the small studio that lands a contract from a door manufacturer to deliver eighty identical window inserts weekly. The studio operator better be quick to learn that there are techniques to speeding production, reducing waste and keeping costs to a minimum—and a job doesn’t have to be big or complicated to benefit from them. Essentially, any time a glass enterprise is faced with making multiple repeats of the same item, production manufacturing methods can save time and money. In a way, producing multiples of the same item is easier than making just one. Using the proper techniques for multiples, a routine is established, and it gets smoother and more efficient with each repeat. The time necessary to produce four identical panels will be much lower (per panel) than for making only one. In glasswork, anything that reduces time will lower costs.

**Planning:** Proper Pre-Planning Prevents Poor Performance. You may be excited about a production project and eager to get started, but don’t let impatience get the best of you. Pry that glass cutter out of your hand and replace it with a pencil for the time being. Planning is imperative to efficient production. You must take the time to mentally go through each phase of production and the transitions between them, thinking about where and how you can save time and effort. The payoffs can be tremendous.

The physical arrangement of space in your work area is an important factor to consider. Art glass production takes place in definite stages, each following another in planned sequence and each requiring different tools and materials. Your space and supplies should be arranged to support the needs of each stage, not frustrate them. For example, if the grinder is located fifteen feet away from the cutting table, you’re going to do a lot of unnecessary walking back and forth. If that arrangement can’t be changed, you might plan to stack your glass pieces on a board as you cut them, enabling you to move them to the grinder in a single trip. Every situation will be different—the amount and shape of the space available, the number of workers involved, the type of product under production, and so on. But, whether you’re twenty people in two thousand square feet or an individual in a small garage, there will always be a most efficient way of arranging and operating. Plan as carefully as possible for a natural flow of process and movement in the work area.

Another critical component of the planning stage is your materials inventory. Make sure that you have everything you need before beginning production. Interrupting the flow of your process for trips to the supplier is not only frustrating, it is terribly time consuming. Halting production disrupts an established routine. There is time involved in shutting down your procedure and time involved in starting up again. If there are other workers involved, it may mean leaving them idle for a period. Remember, time is the most important element of your costs.

The condition of materials is just as crucial as their availability. Inspect everything thoroughly—before leaving the supplier if you can, but certainly before beginning the production run. Inspect bevels for scratches and trueness, glass for uniformity of color and mix, lead for fit and consistency, and hardware for quantity and size. Take every step necessary to assure “no surprises” once production begins. It’s a principal factor in keeping costs down.

**Design:** The design of your product should facilitate production efficiency. Obviously, the less complex a design, the faster and more efficiently it can be produced. The object, however is not to sacrifice design integrity in favor
of production speed, but to take efficiency into consideration when you design. The complexity of a design can be “toned down” without affecting the desirability of the end product. Take the time to address every complicated piece and consider how it might be simplified or streamlined to make multiple cutting easier. Make small pieces larger, or eliminate them altogether. Round off extreme points. Widen very narrow pieces. Soften inside curves. Consider adding a straight-line inner border if it will eliminate some curves. Consider using paint, wire or foil for small details if it will eliminate some glass cutting. Within reason, and without affecting its overall appeal, do everything you can to design production efficiency into your product.

The materials you choose are also part of your product’s design. Select them carefully, for production efficiency as well as aesthetic appeal. Think “yield” when you pick glass. If it cuts easily and has a uniform distribution of color mix, you’ll get more pieces from each sheet, reducing materials costs. Glass that cuts well will also decrease your grinding time—a very desirable way to cut production costs. If you’ll need to use the same glass in future runs of the product, choose it from a manufacturer with a reputation for consistency. You can avoid glass matching problems in the future by choosing carefully in the beginning. When selecting foil or lead, make sure they are sized to fit the glass you’ll use—again, keeping both ease of assembly and good looks in mind.

**Pattern Preparation:** Patterns present special problems in production manufacturing, primarily because you’re using each pattern piece over and over again. Don’t use standard patter paper. It absorbs cutting oil and ink, leading to rapid destruction. A light, flexible plastic is a good alternative.

You’ll need a least three complete patterns—a cutting pattern (for transferring the design to glass), a construction pattern (on which cut glass pieces will be assembled) and a backup pattern. The backup is important insurance against loss of or damage to your other patterns.

The accuracy of your pattern pieces and how you handle them in process are more critical in production manufacturing than in single project construction. The reason is simple. If you have a faulty pattern piece and use it to cut one piece of glass, correcting the error is relatively easy. But in production, you may cut ten, twenty or one hundred inaccurate glass pieces before realizing the mistake. Blunders multiply in multiples production! So, be absolutely sure your pattern pieces are accurate before beginning production.

To the degree that you can safely cut glass without pattern pieces, do so. But don’t sacrifice cutting accuracy to save time on pattern pieces! If, by using a light box, strip cutter or other method, you can accurately cut glass pieces—great: you’ve saved some time. But if those methods lead to less precise cutting, forget them. Poorly cut pieces will cost you increased time and frustration in many phases of production to come.

**Glass Cutting:** Some simple rules of thumb will save lots of time when you begin cutting glass for multiples production. The first is this: cut all you need of one piece, from one color, at the same time. For example, you are making twenty jewelry boxes with a floral-design top. The flower has three leaves of different shapes. Cut all twenty pieces of leaf-1 without interrupting the routine to cut other pieces. By doing so, you establish speed and efficiency through repetition. Where it might take you a full minute to score and break-out the first leaf-1, by the time you get to the tenth you’ll be rolling along at fifteen seconds each. With each repeat of the same cut, you’ll spot the most efficient place to start and end your scores, discover the “just right” breaking points and pressures, and find little short-cuts that make cutting that particular piece easier.

Next, cut any other pieces that are the same glass color you have been using. If leaf-2 and/or leaf-3 are to come from the same glass, for instance, you would cut them next, rather than move on to another glass. This way, you have a head start because you are immediately familiar with the cutting characteristics of that glass, like how much scoring pressure is most effective and how it responds to breaking.

Let your awareness and “feel” for the glass work in you favor. In addition, by executing all your cuts of one color at once, you will increase the yield from that glass by consciously getting as many pieces as possible from each sheet, with little waste.

As you cut a set of pieces, stack each part atop the last in its appropriate place on the construction pattern. The symmetry of the stack will help you gauge the uniformity and accuracy of your cutting, and the height of finished stacks will serve as a double-check to your piece count. It’s a real waste of time to find yourself one piece short during another stage of the production process.

Because you’ve got a lot of cutting to do and want to do it as fast as possible, you risk sacrificing accuracy for speed. Don’t let that happen. The techniques of multiples production, combined over all the stages, will add up to a very efficient process without rushing anything. If you get in a hurry, especially in the cutting stage, you’re likely to cause yourself losses instead of gains. Inaccurate cutting means increased grinding—a process you’d rather skip altogether.
It can also cause major setbacks in assembly, if not caught and corrected earlier. So, choose cautious, conscientious cutting. It will always pay off later.

Here’s a special tip that will be useful when your products are flat and assembled with lead. If you cut your glass pieces slightly smaller than you might for the “perfect fit” in a single project, you can speed up assembly time dramatically. With the added “play” you eliminate much of the struggle to get glass pieces to fit the lead comfortably. Cementing will take up the slack without requiring increased time at that stage. It might go against your sense of perfection, but it you can let go of it, do so, as long as it will save time without sacrificing the quality of the end result.

Glass Grinding: Most will agree that grinding is a proverbial pain in the glass—something to be kept to an absolute minimum. This is definitely true in production manufacturing. The less grinding, the better. In production, consider the grinding stage as “just taking the burrs off”, not grinding to fit. You should only need to use a grinder to smooth the edges of glass pieces to facilitate foiling or fit into lead. If you find yourself grinding to size or to shape the glass pieces, it indicates a problem in the cutting stage and you should concentrate on correcting it there.

If the glass has been cut with acceptable accuracy, grinding should literally take only seconds per piece—just a quick pass to smooth each edge. The process will go quickest if you grind all identical pieces in sequence.

If the product will be assembled with foil, the glass pieces will have to be cleaned and dried after grinding in order to assure that the foil sticks. If they will be assembled with lead, cleaning after grinding is unnecessary.

Leading vs. Foiling in Production: Whether your product will be leaded or cooper-foiled is a decision you’ll make in the design stage. Most glassworkers have their personal preferences, but don’t let prejudice outweigh efficiency and productivity. Remember, efficient production should be designed into a product from the very start. Here are some of the pros and cons of lead came and copper foil in the production process.

**Efficient production should be designed into a product from the very start.**

In most products, leading is substantially faster and usually less expensive than foiling. The difference is speed is due to the painstaking process of wrapping each glass piece with copper foil. Add to that the increased time it takes to solder the complete seams of a foiled project versus the intersections of a leaded one. In addition, foiled products require two extra cleaning stages that are unnecessary with lead. Leading is usually less expensive because it is faster, and because it uses much less of solder. The one distinct advantage to copper foil is that it does not require cementing.

Generally speaking, lead is usually easier and more forgiving than foil. A crafter can move fairly quickly with lead and get a cleaner, more consistent appearance in the finished product. With foil, creating smooth, even lines can be slow and frustrating, so uniformly form one item to the next is more difficult.

Many items, especially tiny ones with very few pieces, can only be made effectively with foil. The same is true for Tiffany reproductions or other designs requiring fine detail. The nature of your product will ultimately dictate your choice of foil or lead, but again, don’t disregard the importance of production efficiency.

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**Save time and effort by pre-stretching all the lead you think you’ll need for a production run.**

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**MULTIPLES PRODUCTION WITH LEAD CAME**

Assembly: Lead assembly for multiple copies of the same item requires a little advance thought. The challenge is to make sure that all lines are duplicated in each piece, in order to assure uniformity of appearance from one product to the next. Imagine you are working with a window design that consists of a grid of simple rectangles—a patchwork of vertical and horizontal lines which intersect each other. If, in one window, you use long lead strips vertically and short pieces horizontally, you need to do the same in each copy of the same window. Failure to do so will result in “identical” windows which look substantially different! The analogy can be carried to leaded projects of any design. Before you begin assembly, decide where and how lead strips will run and intersections will occur, and be careful to repeat the same routine in each product.

It is useful to pre-stretch all the lead you think you’ll need for a production run. Doing it all at once will save the time and effort it takes to interrupt your assembly routine later on.

Pre-cutting lead for multiple projects is difficult and usually not worthwhile. To effectively pre-cut all lead to size requires completely assembling one project, then disassembling that project and using the cut lead strips as measuring units for further lead cutting. There’s also the problem of marking each strip and keeping them separate from one another until ready for use. Unless the product is an extremely simple one or your production numbers are very high, you’re better off to cut lead as you proceed through assembly. Consider the complexity of your product and how many you are making, then decide whether the pre-cutting process will increase or decrease efficiency.

To simplify the assembly stage, try to design your product to use lead came that is sized 3/16 inch or larger. Lead that is narrower than 3/16 is more difficult to work with because it is taller than it is wide and won’t stand steady on
edge. You can ease assembly and save time by avoiding the constant balancing act necessary with very narrow lead came.

Assemble one complete project at a time, then proceed to soldering it. There is rarely a payoff to assembling a number of projects before soldering them, and you risk a mishap in the meantime. If there is more than one worker involved, however, this is a good spot to split duties.

**Flux and Fluxing:** Yes, there is such a thing as efficiency in fluxing! Like the other stages of production, you gain time by doing as much of one thing as possible at one time.

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### You will gain time by doing as much of one thing as possible at one time.

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In fluxing joints, you are limited only by how fast your flux dries after applying it to a joint. Solder won’t flow well or adhere well to dry flux. So, the idea is to flux as many joints as you can solder before the flux starts to dry. This might vary from run to run depending on air temperature and the type of lead, solder and flux you are using. Generally speaking, if you can flux ten joints and solder them successfully, you’re doing pretty good. Stop to think how many more times you would lay down one tool and pick up the other if you fluxed and soldered each joint one at a time.

For lead came, oil-based flux will usually achieve the best results, since it is a slower drying solvent. Paste flux is a good material and it solders great, but it will also cost you more time in the clean-up stage. Read the flux contents to be sure what you’re getting. Remember, too, that flux is harmful. Follow the manufacturer’s instructions carefully and always use a small fan to suck fumes away from the operator.

**Soldering:** The right soldering iron is critical to efficient production soldering. Use a powerful iron (overpowered is better than under powered) that has a temperature control which offers a total operating range. Your supplier can help you. It must be powerful and controllable enough to maintain the right temperature - not too hot, not too cool - for the time it takes to solder an entire project. Time is wasted when an iron cools off and sits idle to reheat. An iron that’s too cool is slow and inefficient, producing a faulty joint, both structurally and visually. Without continuous and proper heat, solder will appear grainy and fail to effectively penetrate the lead joint. An iron that’s too hot can be inefficient as well - spitting flux and burning the lead it touches. With a good temperature control on a powerful iron, you can adjust as needed to work most efficiently with almost any set of materials.

When you begin soldering, do the stabilizing joints first. These are the critical intersections that will keep your assembled project from changing shape or size as you continue work. In a flat project, the stabilizing joints are usually the outside corners.

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For speed and uniformity in soldering, take care to use the flattest part of the iron tip, and in it’s flattest position, joint after joint, product after product. As in every stage, you’ll develop a smooth routine that will speed the process and aid uniformity and continuity. If one joint gives you problems, don’t fight it; you may make it worse. Leave it for the time being while you go on to others. When you come back, it will be cool and more likely to accept hot solder.

After soldering is complete on all sides, take time to inspect the product thoroughly. Look for glass cracks, faulty joints, construction errors, line trueness, and so on. Ask the question, “Is this product ready for the next step?” This is the time to address and correct any perceivable faults. Don’t wait until after cementing and cleaning to discover a problem that needs to be fixed.

**Cementing and Cleaning:** If you cut your glass pieces intentionally small to speed assembly, the project will be a little loose, so mix your cement a little loose (wetter) as well. This will assure complete penetration into all joints and channels. Use mineral spirits to thin the cement; it’s cleaner than turpentine or paint thinner.

Brush the cement across and parallel to all lead pieces, using enough to penetrate the opposite side. When cement seeps through, you’ve used enough. As a matter of fact, it’s perfectly possible to cement both sides of a flat panel at once if enough oozes through. If you can make this technique work for you, fine, but don’t sacrifice quality.

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### It’s perfectly possible to cement both sides of a flat panel at once, if enough oozes through.

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Before turning the project, use a mixture of whiting and sawdust to clean the side you just cemented. The mixture, brushed on, cleans the glass and also acts as a drying agent, keeping cement from seeping back through when applied to the opposite side. If you’ve used a heavily textured glass, take great care not to get cement onto the textured side. It is very hard to remove from cracks and crevices and requires unjustified time. The best way to avoid the headache is to avoid heavy textures altogether.

When cementing is complete the projects need to dry. If necessary, speed up the drying process by placing the finished items near a heat source and/or stacking them separately to allow air exposure. After drying, point each project with a sharp wooden tool, taking care not to dig any cement from the lead channels.

**MULTIPLES PRODUCTION WITH COPPER FOIL**

**Foil Application:** When you’re faced with a thousand pieces of glass to foil, things can seem pretty bleak. But it goes quicker than you might think with a few simple tricks of the trade. Number one, make sure the glass pieces are squeaky clean. Here’s how: buy or make a tub or bucket
with a bottom made of screen, so you can put glass in the bucket and run water through it, much like you’d wash berries in a colander. Don’t use soap, it will only slow you down. All you’re doing is removing dust and cutting oil from the glass pieces, and this can be accomplished by rinsing them thoroughly in very hot water. After rinsing, dry the glass with a terry cloth towel. This won’t take long, since the glass pieces will still be hot from the rinse water. Try to keep like pieces together as you wash and dry, since you’ll want to foil them concurrently.

Although narrow copper foil is a little more difficult to apply than the wider sizes, it has some benefits in production. Narrow foil solders faster and most crafters find it easier to create a consistently smooth and attractive seam. It also uses less solder and looks cleaner and sharper in the finished product. Wider foil is sometimes necessary for structural purposes, however, depending on the nature of your product. Keep these things in mind when you choose foil for production purposes.

For the same reasons you cut like pieces together in the cutting stage, you want to foil them together in the foiling stage.

For the same reasons you cut like pieces together in the cutting stage, you want to foil them together in the foiling stage. After the first couple of repeats, you’ll know just how to handle the particular piece, how much foil is necessary, the most efficient place to start the tape, and so on. Following the simple “rule of routine” is a very effective time saver.

Be careful to touch the sticky side of the foil as little as possible. Apply foil to the glass piece and then simply fold the foil edges down. Don’t burnish the edges of each piece as you might in single-project construction. Instead, lay the foiled piece on a flat surface and press on it, lightly but firmly, to stick the foil edges to the glass. Then flip the piece to it’s opposite side and press again. When all like pieces are complete, lay them flat beside each other and use a standard wallpaper roller to press them firmly down, burnishing the foil edges. Then flip the pieces and repeat the rolling process again.

You can see how this foiling process is much quicker than treating each glass piece separately, as you might in single project construction. When there’s a ton of foiling to do, these little tricks add up to tremendous time savers.

Assembly, Fluxing and Soldering: Copper foil projects are usually best assembled one complete project at a time. Working in sections can cause more confusion than the time saved is worth. A notable exception is three-dimensional products, like boxes with pattern designed lids, or panel lamps with pattern designed skirts. It might very well be more efficient to complete all the more intricate sections first, saving the 3-D construction for a separate sequence.

After placing the foiled pieces in their spots on your construction pattern, inspect them for position, paying attention to the gaps between them. Assuming your cuts are reasonably accurate, the best procedure is to center the pieces within their pattern lines, and be satisfied. This simple rule will keep you from spending too much time trying to compensate for irregular gaps. It will also foster uniformity from one product to the next, even when cuts aren’t identical.

Just as in lead came production, flux as much area as you can solder before the flux starts to dry. Solder all stabilizing areas first to maintain project size and shape through the remainder of the process. Try to get away from tack-soldering for the sake of stability; if you’re soldering, solder something. You can accomplish tacking and finished soldering in the same step by choosing initial soldering points that will provide the stability you need.

Try to establish a routine in the first projects that you can repeat in subsequent ones. For example, you might first solder short, straight lengths at random (for added stability), then complete all short, straight lengths in the project. Next, do the longer, more difficult seams. A repeatable routine that makes sense will speed up your soldering as you move from one copy to the next.

Whenever possible, do your finished soldering in a single pass over a seam. It can be done and could very well cut your soldering time in half. With the right combination of iron temperature, solder and flux, you should be able to create a smooth, consistent, finished line without first tinning and then returning to build a rounded seam. Invest a little time to experiment with iron temperature and application speed in the first project or two, then use what you’ve learned in the remaining projects to make soldering a “one pass” process. The right soldering iron can make all the difference in the world.

After you turn a project, you can avoid the problem of hot solder penetrating through to the finished side by placing a damp, terry cloth towel underneath. It will chill the bottom side, giving you more time to solder the top side carefully without fear of melting through.

Cleaning and Patina Application: Have your patina and a clean application brush ready to use. With a soft scrub-brush, wash your soldered project in a warm, soapy solution to remove all oils, fingerprints and flux residue. Then rinse it in very hot water, dry it quickly and immediately apply patina. The solder will accept patina better when it is still hot from the rinse water. Wash the project once more to remove any patina from the glass, and then isolate the finished item from your work area to prevent oxidation from soldering fumes.