

Acrylic FRP Products

Large Round or Rectangular Spas

Aristech Surfaces has been the leader in acrylic/fiberglass reinforced product ideas for over 30 years. Many O.E.M./fabricators have discovered new possibilities in the use of Aristech Surfaces acrylic sheet. The advantages of Aristech Surfaces acrylic continuous cast products are unlimited in the areas of design, configuration, colors, fabrication and superior surface appearance. Let your imagination run wild. Specify Aristech Surfaces acrylic sheet, the leader, for all of your plumbingware products.

Introduction

This Technical Bulletin describes how large spas are produced from Aristech Surfaces acrylic sheet reinforced with polyester resin, selected fibers and chopped fiberglass. See *Figure 1*. A general procedure is given with enough detail to enable a potential manufacturer to start in the business provided he utilizes the technical support that is available from selected raw material and equipment manufacturers. The operation described is capable of producing 120 to 130 units per 8-hour shift or one unit approximately every 3-1/2 minutes.

The sheet length and width are usually 3 to 4 inches (8 to 10 cm) greater than the finished product dimension to provide for sheet clamping during forming. The sheets are supplied in wooden cradles in quantities of about 50 sheets weighing about 2,500 lbs. (1,134 kg). The material is stored as received. Usually 5-8 colors are inventoried. Packages should contain only one color and adequate space should be left between and around stacks to allow for easy movement of a fork lift truck so that packages can be moved to the vacuum forming machines with a minimum of effort. Storage should be arranged with the product mix in mind. It is highly recommended that a first-in first-out sheet inventory procedure be utilize. This involves always using the oldest sheet available. Each package should be plainly marked with color and identification number so that the fork lift operator can easily select the proper material and so that the vacuum forming machine operators can easily record any problems in their log by color and package numbers. No special equipment is needed in the sheet storage area other than a fork lift truck capable of lifting the oversized cradles.

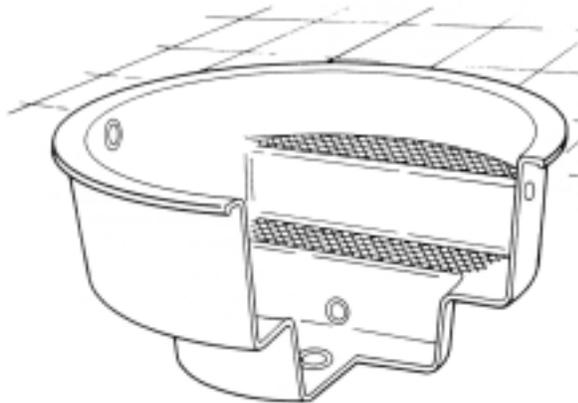


Figure 1. Typical Large Spa Shape.

Plant Layout

A typical plant flow diagram is shown in *Figure 2*. Many plant layout variations are possible. Perhaps the most important feature is to keep the material or product moving in a continuous or assembly line fashion. Each operation will be discussed in process sequence starting with acrylic sheet handling and storage and ending with packaging and storage of finished goods. The total plant, excluding finished goods warehousing, will require 15,000 to 20,000 ft² (1,400 to 1,900 m²).

Acrylic Sheet Handling and Storage Area

A typical sheet size for this process is 0.125" - 0.187" (3.2 to 4.7 mm) thick x 100" (254 cm) wide x 100" (254 cm) long for large spas. Sizes and thicknesses will vary depending on product design and depth of vacuum forming draws.

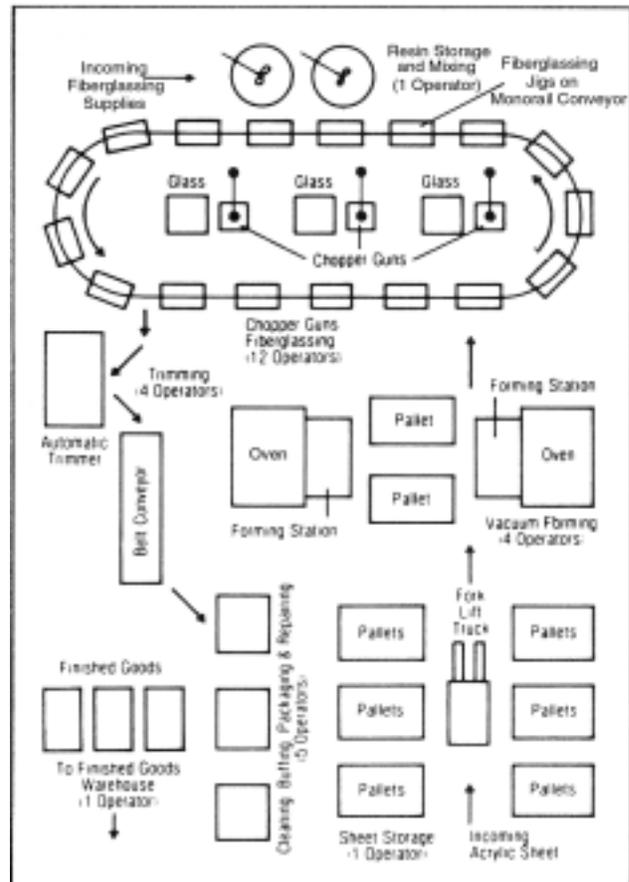


Figure 2. Typical Plant Flow Diagram.

Vacuum Forming Area

The vacuum forming area should be enclosed and relatively free of drafts and airborne dirt. The area should be kept clean at all times. The entrances from the sheet storage area can be an overhead garage-type door that is only open when a new cradle is being delivered to the vacuum forming machine. The exit to the fibreglassing area will be open. Positive pressure will be needed in this area to minimize dirt from the fibreglassing area.

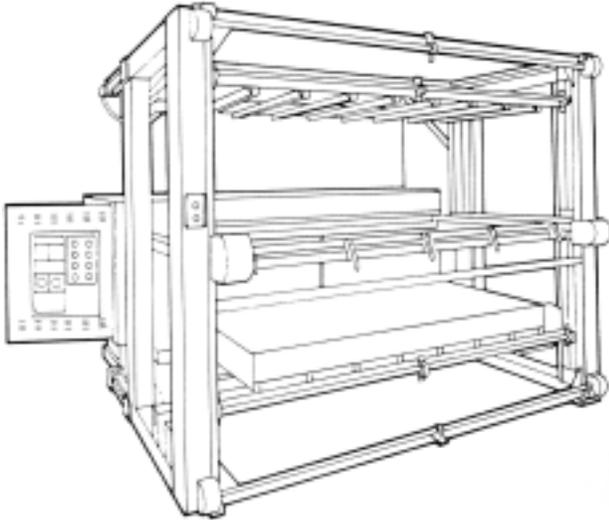


Figure 3. Vacuum Forming Machine.

Sheet Cleaning Devices

As sheets are individually removed from the packaging and prior to loading that sheet into the clamping frame of the vacuum forming machine, it should be cleaned to remove any dust, dirt or particles that might adhere to it. The sheet usually contains some static electricity, especially if the relative humidity is less than 50%. Cleaning is best accomplished by using an antistatic device attached to an air hose. These devices can be obtained from either the 3M Company or Simco Company. (See sources of supply in technical bulletin #159 for complete address, etc.) The device is attached to a standard air hose operated at 30 lbs/inch² (2.1 kg/cm²) and is activated by a push button on the air nozzle. One simply blows air across both sides of the sheet to remove the adhered particles and static electricity. It is important to remove the static electricity to prevent the particles from "jumping" immediately back on the sheet. If a sheet is extremely dirty it should be wiped with a tack cloth such as those supplied by the Detron Manufacturing Company.

Vacuum Forming Machines

The vacuum forming machines (see Figure 3) should be automatic single station types that have top and bottom vertically moving platens. The sheet clamping frame should be activated with air cylinders and move horizontally into an electric infrared-type oven with heaters on both top and bottom. The top heaters are usually 10 inches (25 cm) from the sheet and the bottom heaters 20 inches (50 cm) from the sheet and are controlled with 15-second percentage timers. Two vacuum forming machines will be capable of producing a unit every 3-1/2 minutes. If more production is required, more machines can be added.

The automatic vacuum forming machines used in this process could be designed to clamp the exact sheet size used or be off-the-shelf items which would probably have a 10' x 12' (3 x 7 m) maximum clamping area. If the off-the-shelf size is used, the clamp frames would be adjusted inward to clamp the smaller sheets. The clamping frames should be designed to move out from the machine horizontally for easy loading of the sheet and unloading of the formed part. The clamp frame should load from the bottom which will allow a sheet to be automatically loaded into the frame with a simple air operated vertically moving platform. The formed part can be unloaded with the same equipment used in reverse. Many other types of equipment are successfully used to produce large spas ranging from a simple infrared electric heater only on the top side to convection air ovens where multiple sheets clamped in frames can be heated simultaneously. Manufacturers of vacuum forming equipment are generally prepared to offer considerable technical advice and assistance. They will usually have machines set up for a potential customer to observe in actual operation. Some of the manufacturers will vacuum form the potential customer's part to demonstrate the procedure prior to purchase.

Tooling or Molds

The recommended tooling for this type operation is cast aluminum with cast-in or externally attached cooling coils. A typical mold is illustrated in Figure 4. There are several experienced manufacturers of this type tooling. Prices vary widely for this type tooling, ranging from about \$18,000 to \$60,000 per tool. The steps involved in producing these tools are:

- The Spa is designed and depicted through designers renditions and engineering drawings.
- The drawings are used to produce a wood pattern.
- The wood pattern is used to produce an aluminum casting.

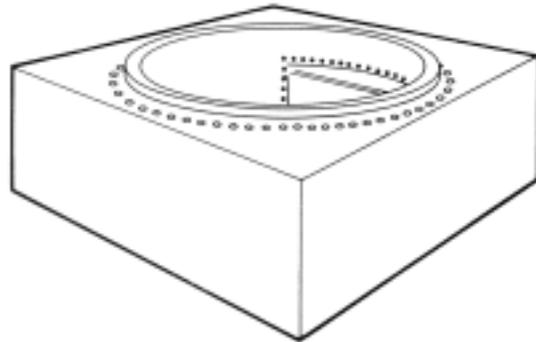


Figure 4. Mold for Spa.

The aluminum casting is hand finished to a 600 grit sand paper texture. Vacuum holes, if not precast, are drilled every one inch in the heart of the recessed radii. These holes can be as large as 1/16" (1.6 mm) in diameter. In the flat parts of the tool, 0.020" (.5 mm) diameter holes, or smaller if possible, should be drilled on one-inch (25.4 mm) centers. These holes prevent air entrapment which can cause an objectionable texture (pimples) in the flat portions of the formed part. If a formed-in texture is used in these areas, then these vacuum holes are not necessary. Several large holes, 1/4" (6.4 mm) in diameter, should be placed in the drain hole and overflow cavities to allow for rapid evacuation of the air during the vacuum forming step.

Two other types of mold construction are successfully used to produce large spas. The first is a simple box shaped plywood or metal mold where the part is allowed to free form in the radii. The second type is made from epoxy resins and is similar to the aluminum molds except for no cooling coils. Epoxy manufacturers will render assistance in producing the first epoxy mold.

Fiberglassing Area

The fiberglassing area should be separated from the other areas because of the nature of this process. Polyester resins contain styrene monomer which is flammable and must be handled in such a way to limit worker exposure to its vapors. The exact procedures or precautions vary geographically depending on building codes and specific company internal safety regulations. When setting up a fiberglassing operation, your local building code agency, OSHA and EPA, should be contacted. The area must have adequate exhaust fans and/or spray booths. The total area can be a huge "spray booth" provided adequate exhaust fans and ventilation are utilized. Styrene vapors are heavier than air. Therefore, floor exhausts will be necessary. Respirators and eye protection will be required for the personnel working in this area. The most popular fiberglassing process currently being used for this process is the chopper spray gun technique. However, some small producers still use a hand lay-up process.

Chopper Guns

There are several manufacturers of chopper gun equipment. The equipment costs from \$3,500 to \$10,000, and as the saying goes, "You get what you pay for", especially applies in this case. The more expensive equipment (see Figure 5) uses an airless dual spray polyester stream that has an external catalyst mix. The fiberglass is chopped separately, usually in 1" (25 mm) lengths, and blown into the spray pattern about 3" to 5" (7 to 13 cm) in front of the dual spray nozzles. The dual spray does the best job of wetting the glass fibers. This equipment is also designed to spray a 50-50 mixture of polyester resin and tri-hydrated alumina. The alumina imparts fire resistance and reduces costs. It is a solid, sold as a powder, which is, in turn, mixed with the polyester resin. This mixture is more viscous and more difficult to pump. However, the more expensive equipment has pumps and auxiliary equipment that can manage this mixture.

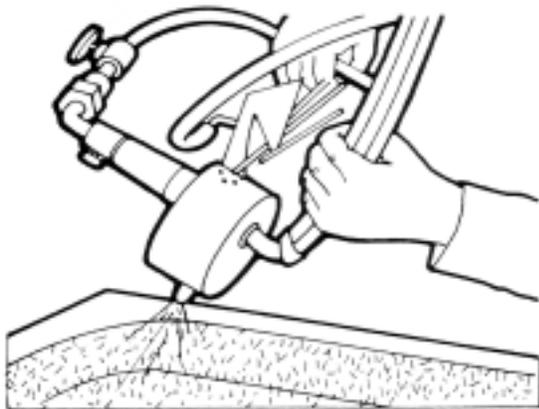


Figure 5. Chopper Gun.

No recommendations can be made as to specific manufacturers. Most have comparable equipment ranging from economy models to the more deluxe models. As a group, the chopper gun manufacturers are usually very cooperative with potential customers. They have application labs where the equipment can be demonstrated and/or they will bring their equipment to your plant for a demonstration. They usually offer excellent technical service.

Rollers

There is not too much to say about the rollers, although this operation is as important as the chopper-gun spray application. The rollers are aluminum consisting of a series of small discs about 3/8" (9.5 mm) wide. These discs are arranged in various configurations ranging from 7" to 9" (18 to 23 cm) rollers, that look like the rollers used to paint walls in your home, to small 1/2" to 1" (12 to 25 mm) wide rollers for rolling out tight inside radii. See Figure 6 for a typical configuration. These rollers are supplied by the chopper gun manufacturers.

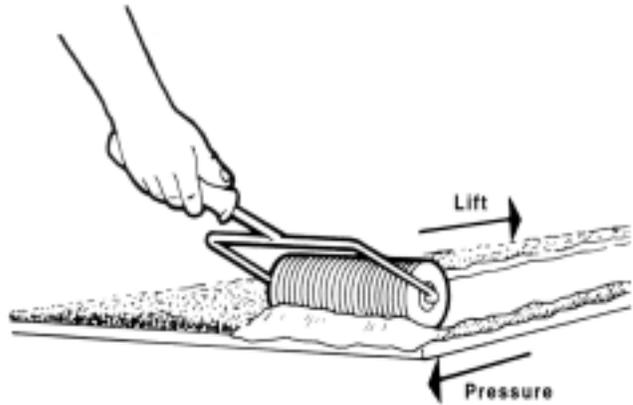


Figure 6. Roller

Resin Tank Mixing and Central Resin Supply

It is desirable to set up a central resin supply system for the chopper guns. This operation usually consists of a series of central supply tanks where the polyester resin, and tri-hydrated alumina are mixed and kept under constant agitation. One thousand gallon (3,785 liter) capacities are desirable. One tank is usually in use while mixing is occurring in the others. One tank, approximately 12,000 lbs. (5,400 kg), will supply enough mix to glass 80 to 100 spas. Suppliers of polyester resins offer excellent technical assistance in setting up resin supply systems.

Fiberglassing Support Jigs

It is necessary to build jigs to support the acrylic shell during the fiberglassing operation. Once the part is fiberglassed, it, of course, becomes self-supporting. The jigs are constructed in many ways depending on the exact shape of the formed unit. Some units are very nearly self-supporting and require only a simple support in back and along the flanges (see Figure 7), while others may require additional support in other areas. Very seldom is full support in all areas required.

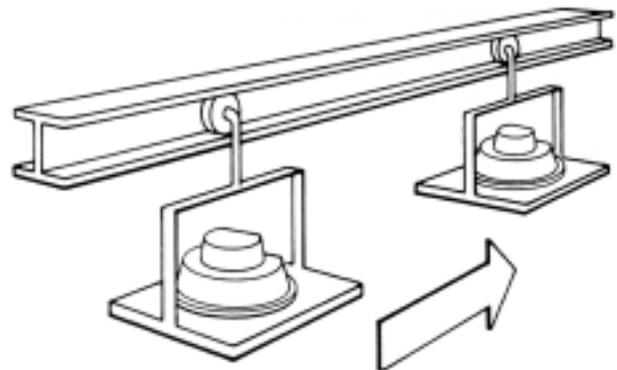


Figure 7. Fiberglassing Support Jigs

Conveyor System

The movement of product from the vacuum forming area through the fibreglassing area to the trimming area is best accomplished by an overhead monorail conveyor system. The conveyor speed will be approximately 3 ft. (90 cm) per minute. There are several suppliers of overhead monorail systems that will supply technical assistance in setting up the overall system. See sources of supply in technical bulletin #159.

Trimming Area

The trimming area must be enclosed to contain the sawdust and debris. Adequate dust collecting equipment is required to keep airborne dust to a minimum. Eye protection and respirators will be required for the personnel who work in this area. The fibreglassed unit must be trimmed along the outside flange. This is usually a horizontal cut.

Automatic Trimming Equipment

The automatic equipment consists of a holding fixture and a series of traveling saws or routers equipped with diamond-tipped saw blades or bits.

Manual Trimming Equipment

It is possible to manually trim the large spas. A holding fixture is designed so that an edge guide is available all along the outside perimeter. An air driven saw or router equipped with diamond-tipped cutters is manually moved around the unit to cut off the excess flash. Manufacturers of such equipment are listed in technical bulletin #159.

Conveyors

It is desirable to place the parts that move from this area on a horizontal belt conveyor. This conveyor will move through the area from the fibreglassing area to the finishing and packaging area.

Finishing and Packaging Area

This area can be combined with the acrylic sheet handling and storage area or be a separate area. The loading dock would be immediately outside this area. No special equipment is required here. The trimmed units are cleaned and a corrugated cardboard cover placed on the face of the unit. Sometimes a full carton may be required; if so, there are many suppliers of cartons. They will offer excellent assistance in designing the carton, and supplying prototypes for evaluation.

Materials and Quantities Used (Large Spas)

A. Acrylic Sheet

Typically, the sheet is 0.125" (3.2 mm) thick by 100" (254 cm) wide by 100" (254 cm) long supplied in cradles. Each sheet contains 69.44 ft² (6.45 m²) and weighs 53.73 lbs. (24.4 kg) The completed spa after trimming will contain about 45 lbs. (20 kg) of acrylic, depending on shape.

B. Polyester Resin

Special acrylic bonding polyesters are recommended. These resins are designed to accept 45 to 50% tri-hydrated alumina (by weight) and for use with chopper spray guns. Usually the polyester resin supplier will have specific recommendations as to the type of tri-hydrated alumina and catalyst required. However, a list of manufacturers of these two materials is given in technical bulletin #159. (1% catalyst by weight based on resin usage will be consumed.)

C. Glass Roving

Sixty (60) strand (no tracer) continuous clear, silane coated fiberglass is recommended. This material is usually sup

plied in wound balls containing 33 lbs. (15 kg) each. However, larger balls are now available from some suppliers. Several suppliers of glass roving are listed in technical bulletin #159.

D. Reinforcement Members

Various types of "stiffeners" are used ranging from corrugated cardboard shapes to wood slats. Generally, these are applied prior to the second application of FRP. Cardboard in an equilateral triangular shape with 2" (5 cm) "legs" makes effective "stiffeners."

E. The Resin Mix

The resin mix is usually 41% polyester resin, 41% tri-hydrated alumina and 18% chopped glass. About 135 lbs. (61 kg) of this mix is applied to the Spa. After trimming, about 120 lbs. (54 kg) will remain.

F. Weight

Based on weights given above, the finished spa will weigh approximately 160 to 170 lbs. (72 to 77 kg).

G. Raw Material Cost

With the information given above and current prices of the various raw materials, raw material costs can be very easily calculated (see Table 1). Of course, raw material costs must be increased based on material usage efficiencies and scrap rates. A well run operation will have a material usage efficiency of 90 to 95% and finished goods scrap rate under 5%.

Table 1.

Material	Quantity Used
.125" (3.2 mm) Acrylic Sheet	69.44 ft. ² (6.45 m ²)
Polyester Resin	55.35 lbs. (25.1 kg)
Catalyst	0.55 lbs. (249.5 g)
Tri-hydrated Alumina	55.35 lbs. (25.1 kg)
Fiberglass Roving	24.30 lbs. (11.0 kg)
Reinforcements	20 lin. ft. (6.1 lin. m)
Carton	1 each

Process Operation and Direct Labor Consumed

A. Vacuum Forming

Based on a production schedule, the acrylic sheet is placed near both forming stations and the carton covers removed. The operators will record the package numbers, color and number of parts to be run in the log or daily work sheet. The ovens are preheated and percentage timers set. An acrylic sheet is loaded in the clamp frame (20 seconds) and the automatic vacuum forming machine started. The sheet will be heated for 2.5-3.0 minutes to a temperature of about 380 °F (193.3 °C). Percentage timers must be adjusted to arrive at these conditions. After the sheet is heated, it will automatically exit the oven, vacuum form (35 sec.) and cool (3 min.). The part is removed (35 sec.) and the sequence repeated. At the other forming machine, the same sequence is being performed. The formed parts will be placed on the fibreglassing jigs by the vacuum forming machine operators. It is usually desirable to keep 10 to 15 formed parts as a buffer between vacuum forming and fibreglassing. Four machine operators will be required in this area. This operation will consume about 14 man-minutes per spa produced.

B. Fibreglassing

Three teams of fibreglassing operators will be used in this area. Each team will consist of a chopper gun operator and three roll-out operators. The second team of roll-out opera

tors will place the reinforcement members on the spa. Each team will spray and roll approximately 1/3 of the required amount of polyester resin glass mix or 45 lbs.(20.4 kg) each. The first team will apply about 1/16" (1.6 mm) over the entire back surface and one side as uniformly as possible. The second team will apply additional resin to the recessed areas and the bottom and position the stiffeners. The third team will apply their resin uniformly over the entire area. An alternate method is for each team to work in an individual spray booth and start and finish each spa. This operation will consume about 42 man-minutes per spa produced. (See appendix 1 for tips on good fiberglassing techniques supplied by one of the chopper gun manufacturers.)

C. Trimming

The fiberglassed spa will be removed from the overhead conveyor and placed on the automatic trimming machine. A button is pushed to activate the trimming machine. It will take the machine about one minute to trim the part. After trimming, the drain hole and any other openings may be cut out manually. The part is blown off with antistatic air, and placed on a belt conveyor for movement to the finishing and packaging area. Four (4) operators will be required in this area. The operators will have time to load and unload the conveyors and machines. This operation will consume about 14 man-minutes per modular unit produced.

D. Finishing and Packaging

The trimmed spas will be inspected and any minor marks or scratches buffed out. Spas with more serious defects will be set aside for repair. The large spas will be face covered or placed in cartons and stacked for shipment or removal to a finished goods warehousing area. This operation will use 5 operators and consume about 17-1/2 man-minutes per unit produced.

E. Auxiliary Operations

Approximately 8 man-hours per 8-hour shift will be required to mix the resin. The fork lift driver will spend about 8 man-hours moving pallets of acrylic sheet, particle board and other raw materials during an 8-hour shift. Movement of finished product will consume another 8 man-hours. Table 2 summarizes direct labor requirements.

Table 2

Operation	Direct Labor (Man Minutes)	Number Of Personnel
Vacuum Forming	14	4
Fiberglassing	42	12
Trimming	14	4
Finishing & Packaging	17.5	5
Auxiliary Operations	10	3
Total	97.5	28

(Direct labor efficiency is estimated to be 85 to 95%)

Appendix

Chopper Gun Techniques

(Courtesy Of Venus Products Inc.)

The gun should be held with one hand and the end of the boom with the other. This overcomes the boom drag and whip and allows the gun hand rapid and flexible movements. The best sequence is to use horizontal sweeps like spray painting. Do not build up too much with each pass as the more overlaps, the more likely an even deposit can be made. Hold the gun 24" to 40" (61 to 102 cm) from

the mold. The operator of the gun should keep his hands clean, a pan of clean acetone at the base of the boom is desirable. Other personnel should serve the gun, such as moving the molds, positioning parts and other possible messy operations. Since the laminators will be working close by, this is the best way to keep the gun operating a higher percentage of the time. If the chopper is operated below 70 psi (4.9 kg/cm²), it may have a tendency for impulse stalling. The operator should insert his finger in the front of the cover and roll back the rubber roll. To start the roving, it can be folded and inserted in the guide, then with a slight turn of the rubber roll it should engage, ready for operation, without removing the cover. The fiber is slightly oriented in a vertical position or parallel to the resin fans. This is true with any gun. This can be used to advantage with the SPRAY MOLDER pattern, sweeps up to the flange of a mold will make a deposit on the edge with very little overshoot. The fibers will also be oriented to minimize fractures or tears in the edge. A "swipe" can be made, to build up edges, by making a fast swipe along the edge, laying the pattern down in the narrow direction (vertical rather than normal horizontal). To eliminate practically all overshoot and waste, make the usual pass up to the edge of the mold, not past it, then make the necessary swipes for reinforcement of the edge. When the first rolling is made with the impregnating rollers, use enough pressure to drag the laminate toward the edge. The laminate can be forced to slide sufficiently on the first roll to obtain full thickness at the edge. A little practice will permit a lay-up with practically no overshoot and about a 3/4" (19 mm) excess for trimming. Tensile tests will generally show a difference of about 15% to 25% due to orientation; this is true for any gun and chopper. Design considerations may use this orientation to advantage by increasing the strength in a desired direction without increasing the weight. This one-handed gun can be indexed 90° for cross-lapping to overcome orientation. Faster impregnation can be obtained by spraying a coat of resin before depositing the glass. This is particularly desirable when working next to gelcoat to avoid air bubbles next to the gelcoat. As a central source for catalyzed resin, the operator can hold the nozzles against the side of a lilly pail and squirt resin into the pail for miscellaneous jobs in the shop that require catalyzed resin. Excessive pressure or failure to hold against the side will cause blow-back. Laminators should have one roller in each hand when impregnating with small rollers, a 2" x 3" (5.1 x 7.6 cm) to compact and wet-out the fibers and another roller to remove remaining air and finish the laminate. With a little practice, both can be used simultaneously. The larger rollers, 2" x 7" (5.1 x 17.8 cm) and 2" x 9" (5.1 x 22.9 cm), should be used with an extension handle, and with both hands and more pressure for fast, efficient laminating.

Quality Control

The glass-resin ratio can be determined by separate timed tests or with burn-out tests. Once the right ratio and the amount of glass-per-part is determined by management, the gun operator should approach within 2% of the nominal weight after making 5 parts. Before making a part, set the red pointer on the scale to the amount of glass required per part to be sprayed. The scale will show at any time how much more glass should be applied and gives the operator an immediate measure and reduces the training period. Diligent use of the scale will maintain quality of parts with very close control on weights, hence reduce costs. The value of this simple device is seldom fully appreciated. Personnel may get overconfident and fail to use it, and as a consequence lose control. It may be desirable at the initial operation of the gun to have a leadman or supervisor assist the operator in learning the operation of the gun. The supervisor can watch the glass weight and

coach the operator until he gets the "feel of it". Also he can observe the pattern and make adjustments for desirable characteristics. It is well worthwhile for personnel to familiarize themselves with material and equipment variations. Experimentation will prove valuable in maintaining control on quality. The SPRAY MOLDER is merely a tool, what you get out of it depends, to a great degree, on how well it is operated.

The temperature of the resin and the laminating room temperature should be controlled. This will prevent run-out and inadequate cure, production will be faster and quality better. The characteristics of the SPRAY MOLDER require the use of softer treatment roving than other gun systems. The airless system does not have a lot of high pressure air to blow the fibers all over, instead they are trapped between the resin fans and carried forward, thoroughly wetted. Softer fibers wet-out faster and will give a wider and better pattern for uniform layups with less orientation of fiber.

Soft spots may occur if a nozzle plugs and just one part of the resin is sprayed, or if the operator does not hold the gun at the proper distance for convergence of the two resins on impact. Unbalanced fans can also contribute to this. Resin and catalyst or promoters should be mixed before inserting pumps in containers, otherwise a noncuring resin will be picked up by the pumps. Some study and analysis of the parts manufactured may be desirable to use the possible orientation of fiber to advantage in various areas of the product. Management should be careful to select the best man available for the gun operation. If he is well coordinated, will take reasonable care of the equipment and is conscientious about quality, a smooth economical operation will prevail. Excellent quality control will minimize costs and contribute to a healthy, profitable, competitive organization with a reputation that will bring future growth and expansion.

For cautions and other information relating to handling of an exposure to this product, please see the applicable material safety data sheet published by Aristech Surfaces.

These instructions are based upon experience with Aristech Surfaces products only. Experience with products of other manufacturers is specifically disclaimed. For most uses, check for local code approval and test for application suitability. These procedures, techniques and suggested materials should only be used by personnel who are properly trained in the safe handling of the chemicals and the equipment with which they are working. Avoid aromatic solvents, clean with mild soap and water, avoid abrasives. These suggestions are based on information believed to be reliable, however, Aristech Surfaces makes no warranty, guarantee, or representation and assumes no obligations or liability as to the absolute correctness or sufficiency of any of the foregoing, or that additional or other measures may not be required under particular conditions or circumstances.



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