TECHNICAL BULLETIN 142

Acrylic FRP Products

Modular Showers & Tub-Showers

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 continuous cast products are un-limited in the areas of design, configuration, colors, fabrica-tion, and superior surface appearance. Let your imagina-tion run wild—specify Aristech Surfaces acrylic sheet, the leader, for all of your plumbingware products.

Introduction

This Technical Bulletin describes how modular showers and tub/showers (Figure 1) are produced from Aristech Surfaces acrylic sheet reinforced with polyester resin, selected fillers and chopped fiberglass. 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 95 to 100 units per 8-hour shift or one unit approximately every 4-1/2 minutes.

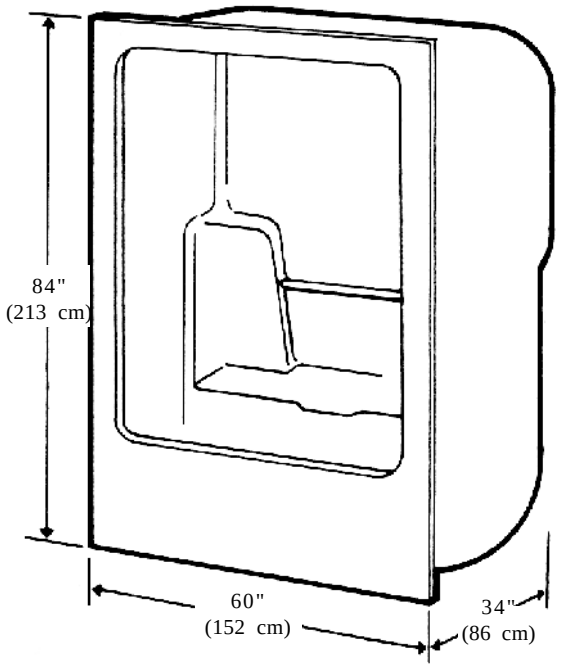

Figure 1. Modular Showers and Tub-Showers.

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 ft.^{2} (1,400 to 1,900 m^2).

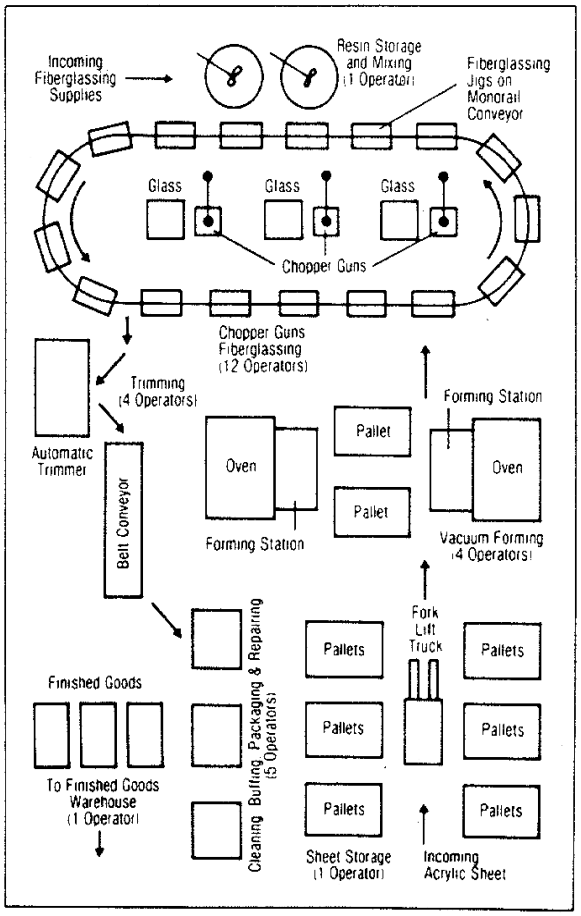

Figure 2. Typical Plant Flow Diagram

Acrylic Sheet Handling and Storage Area

A typical sheet size for this process is 0.150" - 0.187" (3.8 to 4.8 mm) thick x 63" (160 cm) wide x 87" (221 cm) long for 60" (152 cm) modular tub-showers. Modular showers usually require the same thickness and length but vary in width depending on the dimensions of the finished product. The length of the sheet can also vary if a non-standard finished height (length) is used. Put in more specific terms, the sheet width should be 3" (7.6 cm) greater than the finished product width and the sheet length should be 3" (7.6 cm) greater than the finished product height. The sheets are supplied on wood pallets in quantities of about 50 sheets weighing about 2000 lbs.(900 kg). The material is stored as received, horizontally stacked on pallets. Pallets are generally stacked

no more than four (4) high. Usually five (5) to eight (8) colors are inventoried. Each stack of pallets should contain only one color and adequate space should be left between and around stacks to allow for easy movement of a forklift truck so that pallets can be moved to the vacuum forming machines with a minimum of effort. The storage should be arranged with the product mix in mind. It is highly recommended that a first-in first-out sheet inventory procedure be utilized. This involves always using the oldest sheet available and putting new pallets on the bottom of the stack. Each pallet should be plainly marked with color and pallet identification number so that the forklift 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 pallet numbers. No special equipment is needed in the sheet storage area other than a forklift truck capable of lifting at least 2500 lbs.(1,200 kg).

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 pallet is being delivered to the vacuum forming machine. The exit to the fiberglassing area will have to be open, therefore this area should be under positive pressure to minimize dirt from the fiberglassing area.

Sheet Cleaning Devices

As sheets are individually removed from the pallet and prior to loading that sheet into the clamping frame of the vacuum forming machine, or immediately after clamping the sheet into the vacuum forming machine frame, it should he 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/inch^2 (2.1 kg/cm^2) 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.

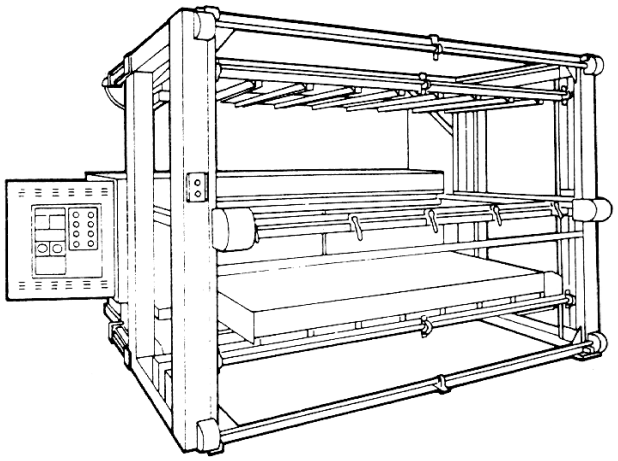

Figure 3. Vacuum Forming Machine

Vacuum Forming Machines

The vacuum forming machine (see Figure 3) should be an automatic type that has 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" (25 cm) from the sheet and the bottom heaters 20" (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 4.5 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 6' x 8' (1.8 x 2.4 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 modular units 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 many experenced manufacturers of this type tooling. Prices vary widely for this type tooling, ranging from about $18,000 to $40,000 per tool. The steps involved in producing these tools are:

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

The aluminum casting is hand-finished to a 600 grit sandpaper texture. Vacuum holes, if not precast, are drilled every 1" (2.5 cm) 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" (0.5 mm) diameter holes, or smaller if possible, should be drilled on 1" (2.5 cm) 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 vcacuum 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 modular units. 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. The Ren Manufacturing Company will render assistance in producing the first epoxy mold if the manufacturer wishes to make his own molds. If the manufacturer wishes to have epoxy molds made, McNeils Pattern Works in Argonia, Kansas, can produce such tooling.

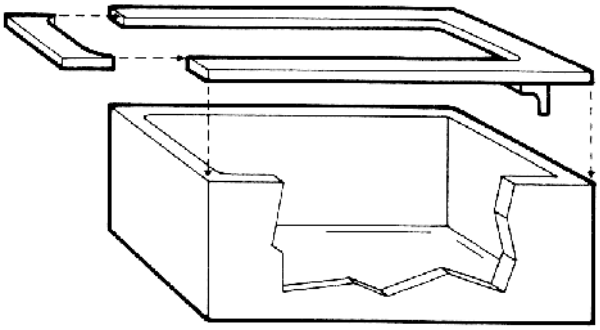

Figure 4. Cast Aluminum Mold

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 and 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 tans 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 only fiberglassing process currently being used successfully is the chopper spray gun technique.

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” (2.5 cm) 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

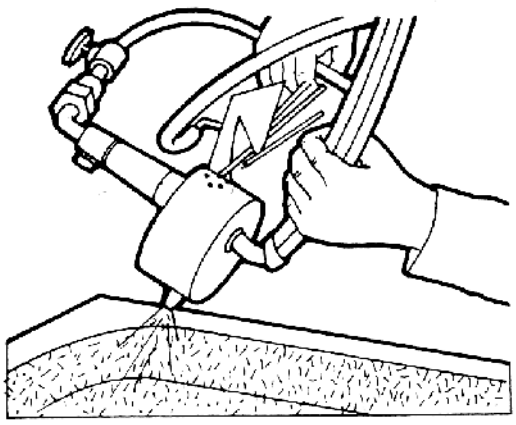

Figure 5. Chopper Gun.

of polyester resin and tri-hydrated alumina which is necessary today to meet fire code requirements for the finished product. Tri-hydrated alumina 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. 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 mm) 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 typical configurations. These rollers are supplied by the chopper gun manufacturers.

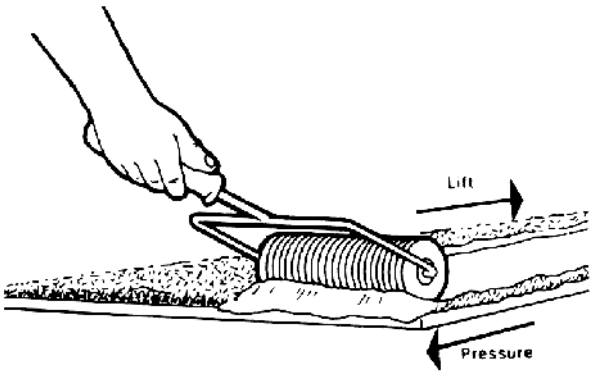

Figure 6. Rollers

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 tank is usually in use while mixing is occurring in the others. One thousand gallon capacities are desirable. One tank, approximately12,000 lbs. (5,400 kg), will supply enough mix to glass 80 to 100 bathtubs. 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 support in the tube sump or in other areas. Very seldom is full support in all areas required.

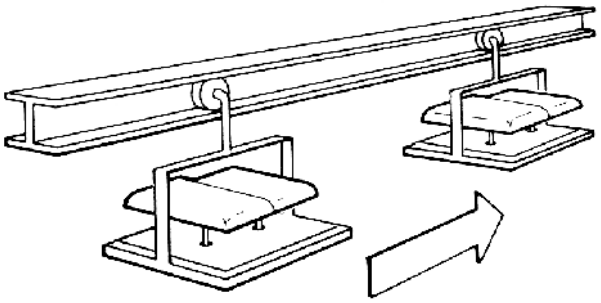

Figure 7. Jigs on Conveyor

Conveyor System
The movement of product from the vacuum forming area through the fiberglassing area to the trimming area is best accomplished by an overhead monorail conveyor system. This conveyor speed will be approximately 3' (1 m) per minute. There are several suppliers of overhead monorail systems that will supply technical assistance in setting up the overall system.

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 bev required for the personnel who work in this area. The fiberglassed unit must be trimmed on all four sides along the outside flange. These are four simple vertical cuts when the unit is lying on its back. Also the drain and overflow holes will be cut out of the unit in this area.

Automatic Trimming Equipment
The automatic equipment consists of a holding fixture and a series of traveling saws (drills) equipped with diamond-tipped saw blades.

Manual Trimming Equipment
It is possible to manually trim the modular units. A holding fixture is designed so that an edge guide is available all along the outside perimeter of the four edges. An air driven saw or router equipped with diamond-tipped cutters is manually moved around the unit to cut off the excess flash.

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 fiberglassing 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. This area can also be used to repair damaged units.

Materials and Quantities Used

A. Acrylic Sheet
Size 0.187"(4.8 mm) thick by 63" (160 cm) wide by 87" (221 cm) long supplied 50 sheets per pallet. Each sheet contains 38.06 $ft.^2$ (3.5 m^2) and weighs 44.07 lbs. (20 kg) The completed modular tub-shower after trimming, will contain about 40.53 lbs.(18.4 kg) of acrylic.

B. Polyester Resin
General purpose type polyesters designed for bonding to continuous cast acrylic sheet are recommended. These resins should be designed to accept 45 to 50% tri-hydrated alumina (by weight) and for use with chopper spray guns. Usually the polyester resin suppliers will have specific recommendations as to the type of tri-hydrated alumina and catalyst required. (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 supplied in wound balls containing 33 lbs.(15 kg) each. However, larger balls are now available from some suppliers.

D. Particle Board
A piece of 1/2" to 5/8" (13 to 16 mm) thick particle board is usually fiberglassed into place on the bottom of the bathtub for extra support and rigidity. This board is about 24" (61 cm) wide x 48" (122 cm) long and spans the area between the apron and the bathtub bottom. This board will weigh about 10 lbs.(4.5 kg). Other stiffeners used on the sides or back are usually cardboard or gypsum board.

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 are applied to the bathtub. After trimming, about 120 lbs.(55 kg) will remain.

F. Weight
Based on weights given above, the finished modular tub-shower will weigh approximately 185 lbs.(84 kg).

G. Raw Material Costs
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
.187" (4.8 mm) Acrylic Sheet	38.06 $ft.^2$ (3.5 m^2)
Polyester Resin	55.35 lbs. (25.1 kg)
Catalyst	0.55 lbs. (.25 kg)
Tri-hydrated Alumina	55.35 lbs. (25.1 kg)
Fiberglass Roving	24.30 lbs. (11.0 kg)
Particle Board	8 $ft.^2$ (.74 m^2)
Carton	1 each

Process Operation and Direct Labor Consumed

A. Vacuum Forming

Based on a production schedule, pallets of acrylic sheet are placed by both forming stations and the carton covers removed. The operators will record the pallet 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 4.5 minutes to a temperature of about 380° F (193.3 F) . 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 station, the same sequence is being performed. Four machine operators will be required in this area. Pallets of acrylic sheet will be placed at the vacuum forming machine and the old pallets removed by the forklift driver from the acrylic sheet handling and storage area. The formed parts will be placed on the fiberglassing 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 fiberglassing. This operation will consume about 18 man-minutes per bathtub produced.

B. Fiberglassing

Three teams of fiberglassing 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 operators will place the particle boards and other stiffeners on the tub-shower. Each team will spray and roll approximately 1/3 of the required amount of polyester resin glass mix or 45 lbs. (20 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 apron cavity and the tub bottom and position the particle board and other stiffeners. The third team will apply their resin uniformly over entire area. An alternate method is for each team to work in an individual spray booth and start and finish each bathtub. This operation will consume about 54 man-minutes per bathtub produced. (See Appendix 1 for tips on good fiberglassing techniques supplied by one of the chopper gun manufacturers.)

C. Trimming

The fiberglassed bathtub 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. 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 18 man-minutes per modular unit produced.

D. Finishing and Packaging

The trimmed modular units will be inspected and any minor marks or scratches buffed out. Tubs with more serious defects will be set aside for repair. The modular units 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 22-1/2 man-minutes per unit produced.

E. Auxiliary Operations

Approximately 8 man-hours per 8-hour shift will be required to mix the resin. The forklift 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

Operation	Direct Labor (Man Minutes)	Number Of Personnel
Vacuum Forming	18	4
Fiberglassing	54	12
Trimming	18	4
Finishing & Packaging	22.5	5
Auxiliary Operations	13.5	3
Total	126	28

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

Appendix

Chopper Gun Techniques

(Data 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/cm^2). 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 promotors 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, takes 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

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