EVERYTHING YOU EVER WANTED TO KNOW ABOUT FIBERGLASS

A COMPLETE GUIDE TO FIBERGLASS PRODUCTS AND USES. WRITTEN IN EASY TO UNDERSTAND TERMS.

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CONTENTS

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INTRODUCTION

The main purpose of this book, is to de- mystify the world of fiberglass for the first time user, explain the materials and processes, and to show how to complete the most common and simple projects.

There is nothing more satisfying then a job well done. Those of us who love to "do it yourself" will find that fiberglass is one of the strongest and most versatile materials to work with.

Fiberglass, and the FRP (fiberglass reinforced plastic) process are a mystery to most people, and many people are afraid to start a project using FRP. However, once you know what you are doing, you will find yourself completing projects with ease, and getting results that are better than you had imagined.

This book sets out to de-mystify the FRP process for the average layman. By explaining products and processes in easy to understand terms, and clear illustrations. We hope to give every do it.yourselfer the confidence to take on any FRP project with confidence.

Properly constructed, FRP products can be lighter and stronger than metal. We have found that the first FRP project is where you will learn the most about the process. Unless you are only doing a simple repair, you will probably make some small mistakes in your first effort. Learning from mistake is often the best way to learn, so don't be discouraged!

What is FRP?

FRP stands for FIBERGLASS REINFORCED PLASTICS. An

FRP is made by combining two elements: The reinforcement (fiberglass cloths) and the resin. By combining these two materials that are both very strong, but not very useful without each other, we end up with a finished product that is very strong and useful.

When we think of fiberglass, the first thing we think of is boats, and boat making probably is the most common use of FRP. But if you take a look around, you will find that very many products are made with fiberglass, including, motor homes, canoes, kayaks, car bodies, children's toys, sporting equipment, surfboards, spas, shower enclosures, water tanks, the list could literally go on and on.

It is by combining the two products that we come up with the stronger end result.

This of course is a very simplistic explanation, but in the following chapters, we hope to make you understand the two components of FRP, and the best way to choose and combine the two to complete the project at hand.

If there are any terms you do not understand in this book, or any other reference material you are using, please refer to the glossary of terms at the end of the book. You will find it most helpful.

HOW MUCH RESIN DO I NEED ???

CHOPPED STRAND MAT

- THE GENERAL RULE FOR CHOPPED STRAND MAT IS YOU WILL NEED 1.5 TO 2 TIMES THE WEIGH IN RESIN AS YOU HAVE IN CLOTH . SO 1 POUND OF CLOTH WILL NEED 1.5 TO 2 LBS OF RESIN.

HERE IS A MORE HELPFUL TABLE

1 GALLON OF RESIN WETS OUT;

MATERIAL	Sq Yds.
.75 OZ MAT	7
1.5 OZ MAT	3.5
2.0 OZ MAT	2.62
4 OZ CLOTH	15
6 OZ CLOTH	10
10 OZ CLOTH	6.5
18 OZ WOVEN ROVING	4.5
24 OZ WOVEN ROVING	3.5

Chapter 1

Types of Reinforcements, and Their Uses

Most fiberglass cloths are made from two different types of fibers, E-glass, and C-glass. The most commonly used , and the one we will be discussing, is E-glass. Almost every cloth sold in the USA is E-glass.

E-GLASS

E-glass is made by melting down glass marbles in a furnace, and then forming them into fine fibers by forcing them through very tiny holes. The fibers are stretched, and then wound onto spools . The strands will vary in size from .0001 inches to .0005 inches in diameter. They are then combined to make yarns. The strands are treated with a chemical to make them able to accept resin more easily. The most common type of treatment is called silane sizing and it allows the cloth to accept both polyester, and epoxy resins. More about this later.

There are literally hundreds of types of fiberglass cloths. The three main types that you will be using in most projects are: woven cloth, chopped strand mat, and woven roving, and some combinations woven roving and chopped strand mat.

S-2 GLASS

S-2 glass is a registered trademark of the Owens Corning Corporation. S glass is 20% stronger than e-glass, and usually costs twice as much. It is used when extra strength is needed , and extra weight is not desired.

TYPES OF REINFORCEMENTS

Woven cloth

Fiberglass cloth is made much as any other cloth is . It is woven on textile weaving machinery. It can be woven several different ways, plain weave, long shaft satin weave, and unidirectional weave. (fig 2-1). There are also other more complicated weaves, such as twill weave, but we will stick to these three types for our purposes.

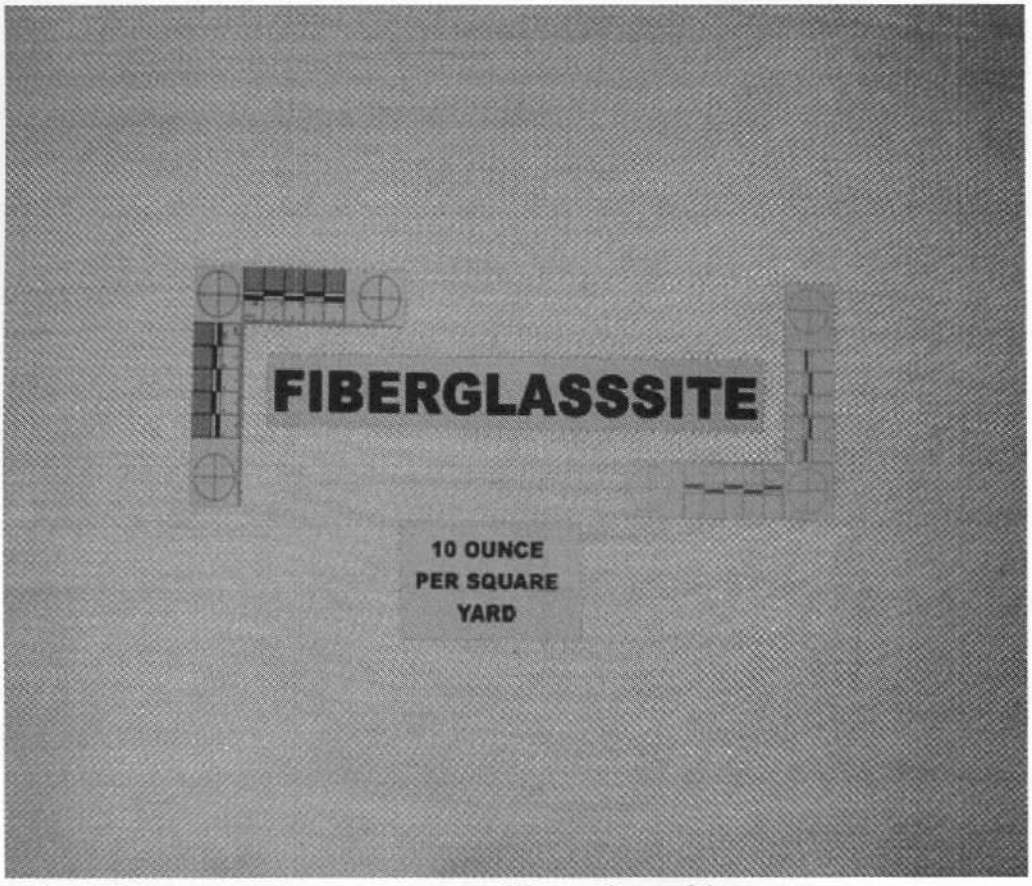
Fiberglass cloth is measured by ounces per yard in the USA, and grams per square yard in Europe. Cloth sold in the USA can vary from one half ounce per square yard, up to over 50 ounces per square yard. The most commonly used weights for most projects are four, six, and ten ounces per square yard.

Most cloths that you will find yourself using are plain weave. Plain weave cloth usually has the same number of strands running it's length and width(warp and weft). Plain weave produces a stiffer end product than most other weaves, and because it has the same number of strands running in each direction it is easier to keep the laminate strength balanced.

Plain weave cloth is ideal for large and simples molds, and flat, or nearly flat surfaces.

For each kind of cloth we will explain it's benefits and it's limitations.

Woven cloth gives the most strength, but is the least thick. Cloth requires the least amount of resin, this makes the cloth very strong, but it lacks stiffness. Also, it does not give good waterproof ness because of the small amount of resin. It is the resin, not the cloth that gives you the waterproof ness. To solve this problem, cloth is usually layered with chopped strand mat. More about mat later.



Fiberglass cloth www.fiberglassSite.com

CHOPPED STRAND MAT

Chopped strand mat is made by laying down chopped strands of glass fibers in a random pattern on a flat surface. Each stand is about two inches long. A bonding agent (usually a powder) is used to hold the strands together. The result is a mat of even thickness , made up of fibers going in every possible direction. This will give you strength in every possible direction.

CSM as we will call it, is sold in ounces per square foot. All other reinforcements are sold in ounces per square yard. It can be purchased in weights ranging from ¾ ounces per square foot, up to 4 ounces per square foot. In the USA the two most used weights are 1.5 ounce, and 2.0 ounce per square foot.

The CSM that you find in stores, in plastic packages is 1.5 ounces per square yard, and it is overpriced. Compare the

prices to the prices on www.FiberglassSite.com.

CSM usually comes in widths from 38 to 50 inches. In can be purchased by the yard or in large rolls.

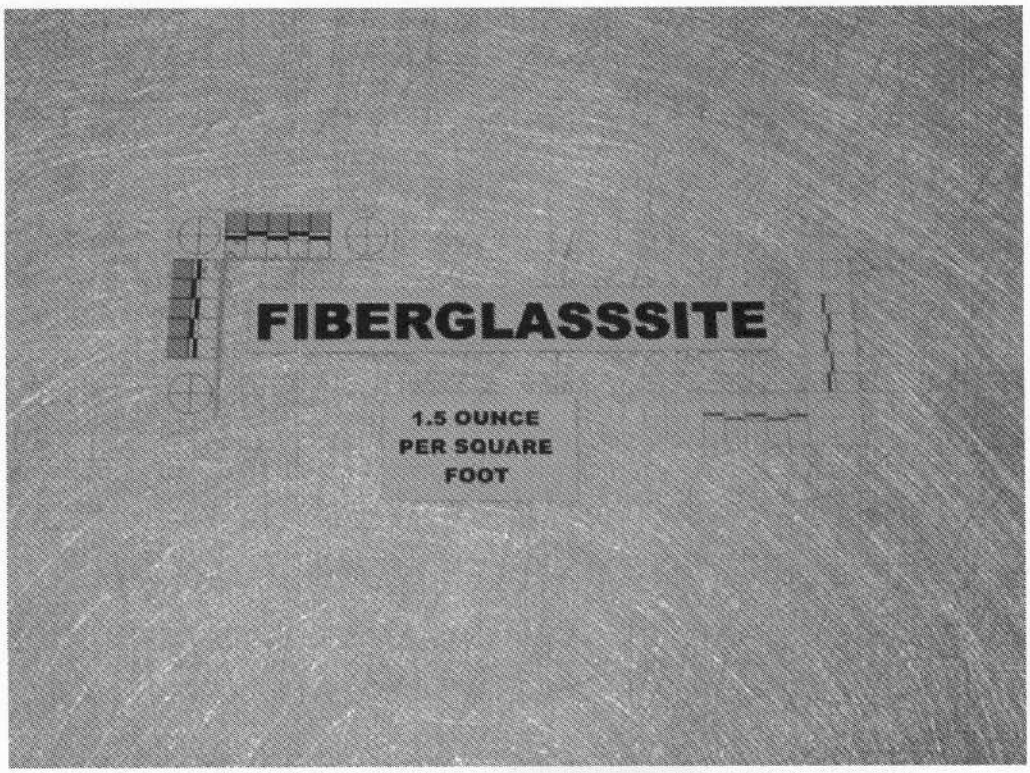
CSM Is the least expensive of all reinforcements, and it is very versatile.

CSM soaks up more resin than any other reinforcement. The advantage of this is that is gives more waterproof ness than any other type of reinforcement. CSM produces the stiffest laminate, and because the strands are in a random pattern, it gives strength in every direction.

For repairs jobs , CSM is the easiest material to use. It is easy to wet out, or saturate with resin. In it's dry state it is fairly stiff and will not easily go into tight curves, but when saturated with resin, the binder holding the individual strand together breaks down, and this allows the mat to be shaped into any configuration.

When using mat on curved surfaces, 1.5 ounce per square foot is recommended. 2.0 ounce is better suited for flat surfaces, and for buildup, because it is stiff.

It takes about 20 layers of 1.5 ounce CSM to make a laminate 1 inch thick. In most repairs , two layers of CSM will be sufficient; but you can make it as thick as you wish to get the desired strength.



CHOPPED STRAND MAT www.FiberglassSite.com

Woven Roving

Fiberglass woven roving (see picture below) is different from fiberglass cloth.

Fiberglass cloth is made from glass fiber thread that is twisted like yarn, woven roving is made from continuous strands of glass fibers that are grouped together. Woven roving is a thick cloth like reinforcing material. In the 18 and 24 ounce weights, it is as thick as a blanket.

The two most common weights for woven roving, are 18, and 24 ounces per square yard.

Woven roving is mostly used for buildup when thickness is needed. It is alternated with layers of chopped strand mat to fill in the heavy weave pattern of the woven roving.

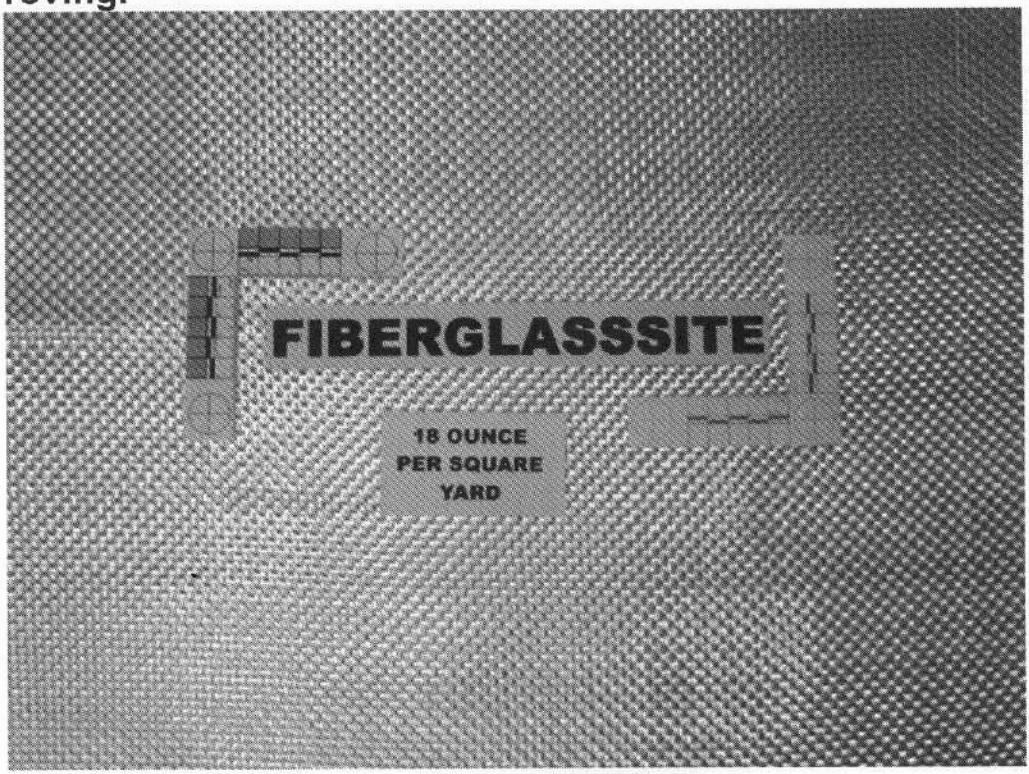
The combination gives good thickness and strength.

On a weight basis, woven roving is cheaper than cloth, and more expensive than chopped strand mat..

The advantage of using woven roving, is that is gives a quicker buildup of thickness , compared to using cloth.

Because of the heavy thick weave, you are not going to get the nice smooth finish of cloth when you use woven roving. , that is why it is generally used for buildup, after you use cloth for your first layer , to get the smooth finish.

Like cloth. Woven roving uses less resin then chopped strand mat. That is why in situations that require waterproof ness, chopped strand mat is used in combination with woven roving.



WOVEN ROVING www.fiberglassSite.com

WOVEN ROVING 24 OUNCE PER Sq YARD

COMBINATION MAT.

There is a product available called "combination mat" . it is a "combination" of woven roving , and chopped strand mat. They are sewn together. It is sold in various weights.

This is used to save time when very heavy buildup is needed. It is difficult to saturate because it is so thick. It is best left to the professionals.

BIAXIAL CLOTH

In biaxial cloth two layers of unidirectional fibers (the same used in woven roving) are connected, with the fibers running at a 45 degree angle. The glass fibers are stitched together. Generally, un the USA biaxial cloth is sold in combination with chopped strand mat, and called biaxial mat.

The purpose of this is to give strength in different directions. It is often used in curved or round molds, such as water tanks or light poles.

CARBON FIBER

Carbon fiber looks much like woven roving, except that it is usually black in color. Each strand of carbon fiber is made up of 3,000 or more individual strands of carbon fiber thread. The resulting product is so many times stronger than E, or S glass . Carbon fiber is used when great strength is needed, but light weight is desired. One layer of Carbon Fiber is equal to many layers of Fiberglass cloth.

It is used and applied in the same manner as any other reinforcement.

The big drawback is the price. It is very expensive.

It is used in race cars, speed boats, wind turbines, airplanes, any place where you need superior strength, and light weight.

RESINS

Resin side bar.

Here is a quick rule of thumb that will save you a lot of headaches.

When you apply resin to your fiberglass, the fiberglass is properly saturated when it becomes completely clear.

"If the cloth is clear, there is nothing to fear"

With apologies to the late great Johnny Cochran.

There are many types of resins that can be used to saturate fiberglass reinforcement material. But for our purposes , we will only be discussing polyester and epoxy.. Why, because these are the two kinds of resin sold to the general public.

Polyester resin is a thermosetting plastic. Thermosetting means that it is set or cured by heat, which can either be applied chemically from the inside, or from the outside.

An accelerator or catalyst, commonly know as the curing

agent is added to create the internal heat. Polyester resin is used at room temperature. When the curing agent is evenly mixed in, this causes an internal heat, which in turn causes the resin to cure, or harden.

You can control the working time of the resin by the amount of catalyst you use. However, if you use too little, it will not cure at all. Most of the time you will be buying the resin in quarts, or gallons. It will come with a clear liquid (usually MEK) in a small plastic container . The resin will come with a chart that will tell you how much of the catalyst to use to get the desired working time .

Working time can range from 5 minutes to one hour. Caution: all resins have a shelf life. Usually about one year. After that they are no good. Fiberglass reinforcement can last for years and years in dry storage, and will still be good, but old resin is useless. This is why we recommend that you buy your resin locally. Polyester resin is available at Home depot Lowe's, and boat supply stores. And epoxy resin is available at boating supply stores.

The Polyester resin you will most commonly buy is called a "general purpose resin." this means that it is good to use for most any job that you re going to do.

LAMINATING AND FINISHING RESINS

Many types of polyester resin have been developed for specific purposes. The two basic types are laminating, and finishing (also called surface) resin.

The laminating, or lay up resin is air inhibited, which means that in the presence of air it will not cure fully. This will leave the surface tacky. This condition is actually desirable when additional layers of fiberglass are to be added to the laminate, as there is no waxy surface to prevent the next layer to adhere properly.

Finishing, or surface resin, is non-air inhibited, which means that it will fully cure in the presence of air. This is desirable for the final layer of a laminate.

Non air inhibited resin has a wax or similar ingredient added. When the catalyst is added, the wax rises to the surface, sealing off the air, and allowing a complete cure. The surface then can be sanded.

Laminating, or lay up polyester resin can be made tack free by adding a special wax to the resin , prior to application. Another method of achieving a cure when laminating or lay up resin is used is to seal the surface from the air. This can be achieved with a layer of cellophane or plastic. All possible areas where air could come in must be taped off.

When finishing surface resin is used, it cures with a waxy surface. If you intend to add another layer to this, the wax must be removed. You can either sand it off, or wipe it off with acetone .

The general purpose resin we spoke of earlier gets around all of these problems. Some pros look down on general purpose resin, but most people who use it find that it is satisfactory for most types of fiberglass repair work, and small jobs.

For large jobs, study up on the laminating and finishing resins, rather than a general purpose resin.

EPOXY RESIN

Epoxy resin is usually twice as expensive as poly. Instead of resin and hardener, epoxy comes in a two part system. You can not control the working time of epoxy resin, so start with small quantities until you get your experience.

You use epoxy resin just like poly. Saturate the cloth until it becomes clear, work out the bubbles, and wait for it to set..

West Systems two part epoxy resin is sold in most boat stores. People in the know say West System is the best, although we are sure there are others that are good.

Epoxy two part systems come with clear instructions, read them, that stuff is expensive and you don't want to waste it!

GEL COAT

Gel coat is a type of polyester resin. It's main use it to form the protective color coat on the outer surface of a fiberglass mold. If you have ever seen a fiberglass boat, you have seen the shiny gel coat surface.

Gel coat comes in clear, or colored, or you can add your own pigment.

Gel coat is applied over the mold release agent that is first applied to the mold. Then the various layers of reinforcement are added.

Gel coat touch up kits are available at most boating stores, just follow directions.

MOLD RELEASE AGENTS.

Whatever type of mold you are using, wood, metal, plastic etc. , you must first apply a mold release agent to the entire surface of the mold. If you do not, you will not be able to remove the finished product from the mold.
(you do not use mold release agent when you are applying fiberglass to a surface that you want it to stick to forever, like a surfboard, or the deck of your boat)

Most mold release agents have to be applied in several layers, but there is a one part mold release agent on the market. See what your local boat supply store has , or look at a boat supply internet store, which is more likely to have the latest thing.

All of the release agents come with full directions. After applying the release agent, be careful when applying your first layer of reinforcement. If you scratch of the mold release agent,

the mold will stick in that area.

TOOLS EQUIPMENT AND SUPPLIES.

Mixing containers are used for mixing your resins, for holding solvent agents for cleaning brushes and tools, etc.

Disposable mixing containers are sold very cheaply at boating supply stores, and Lowe's and Home Depot.

Do not use paper containers , because they usually have a wax coating that will contaminate your mix.

Disposable plastic containers are most desirable. Most of them come with ounces and cups measured on the side.

Always buy more than you need. You will want to mix your resins in amounts you can use before they cure up. You can pour the mixed resin directly onto your project, and then work it around with a plastic squeegee.

MIXING STICKS

Here is another no- brainier . Wooden mixing sticks are either very cheap or free at most paint stores. Get more than you think you will need, and dispose of them after each use.

PAINT BRUSHES

Paint brushes can be used to apply resin to small areas, or to hard to reach areas. We recommend cheap throw away brushes. You can clean up a brush with acetone, but it will be more time and trouble than it is worth.

SQUEEGEES

Here is another cheapee that you must buy more of than you think you will need. Plastic squeegees cost about 69 cents, but they are worth their weigh in gold when it comes to spreading resin. On a flat mold, you can pour on some resin, spread it with the squeegee, then lay on your cloth, pour on more resin, and spread it evenly with the squeegee.

Each time a squeegee gets fouled up, set it aside and start a new one. Sometimes when the resin dries, you can bend the squeegee, and the resin will break off evenly and you can use it again.

Get a few different size Squeegees for different size areas.

SCISSORS

A good pair of cloth cutting scissors will cut any reinforcement that you are using. Eclectic scissors are available for big jobs.

MASKING TAPE.

Keep a good supply of masking tape handy to mask of areas you don't want to ruin, and to tape off plastic barriers if you choose to use the,

RAGS.

Rags are a mans best friend when working with resins. Buy a bag of cheap disposable rags. Always use white rags only because resin will dissolve the dyes in colored rags, and make a mess!

PUTTY KNIVES

Flexible putty knives come in various sizes. They are useful for applying putty and fillers.

CELLOPHANE

As we discussed before, there are times when you have to seal off a project from air. Cellophane is good for small areas, plastic is better for large areas.

UTILITY KNIVES

Keep a good supply of blades on hand. You can cut cloth on a hard surface with a utility knife, and you will find yourself needing the knife for many other uses.

SAND PAPER

There are many different kinds of sand paper, and all kinds can be used on fiberglass.

Sanding is usually done by starting with the heavy grits, and working down to the finer grits. 80 grit is extremely coarse, 150 is medium, and 600 grit is for very fine sanding.

FIBERGLASS RUBBING AND POLISHING COMPOUND.

This is used for making gel coat repairs, and for the maintenance of gel coats. Read and follow directions.

LAMINATING LAY UP ROLLERS.

These are used to remove air bubbles from your project as you lay on the resin.

After laying on the fiberglass , and using the Squeegee to evenly apply the resin, use the roller to work out any air bubbles.

Work from the center, and push the bubbles out to the sides, and then away. These rollers are available wherever resin is sold.

PAINT ROLLERS AND TRAYS.

Paint rollers are very useful for applying resin to large areas. As always, buy cheap throw away roller covers, and plastic disposable tray liners.

Paint rollers can also be used for another neat trick that will save sanding time. While the resin is still wet, lay clear plastic film over the wet surface. Gently use the roller to smooth the plastic over the surface. Then slowly remove it before the resin dries. This will save sanding time in the end.

CUTTING WHEEL

Every home store sells a cutting wheel attachment for your drill. You will find this very useful in cutting away the parts of the finished product you do not need. Wear your respirator.

PROTECTIVE CLOTHING

We can not stress enough the importance of protecting your eyes, skin, and lungs from the fiberglass, and the resins. Always cover your skin completely, wear gloves, respirator, and eye protection.

Chapter 12
Glossary of terms

- A -

Accelerator: An additive to polyester resin that reacts with catalyst to speed up polymerization. This additive is required in room temperature cured resins. See Promoter.

Acetone: A ketone group solvent that is used to dissolve polyester resins. Used to a large extent for clean up of tools in fiberglass operations.

Additive: Any number of materials used to modify the properties of polymer resins. Categories of additives include reagents, fillers, viscosity modifiers, pigments and others.

Adhesion: The state in which two surfaces are held together at an interface by forces or interlocking action or both.

Aging: The effect, on materials, of exposure to an environment for an interval of time; the process of exposing materials to an environment for an interval of time.

Air-bubble Void: Air entrapment within and between the plies of reinforcement; non interconnected, spherical in shape.

Air Vent: Small outlet, to prevent entrapment of gases.

Alkyd Plastics: Plastics based on resins composed principally of polymeric esters, in which the recurring ester groups are an integral part of the main polymer chain, and in which ester groups occur in most cross links that may be present between chains.

Alligatoring: A visible cosmetic defect in the exposed gel coat which looks like wrinkled or alligator skin.

Ambient: The surrounding environmental conditions such as pressure or temperature.

Amine Resins: A synthetic resin derived from the reaction of

urea,
thiourea, melamine or allied compounds with aldehydes, particularly
formaldehyde.

Anisotropy of Laminates: The difference of the properties along the
directions parallel to the length or width into the lamination planes; or
parallel to the thickness into the planes perpendicular to the lamination.

Antimony Trioxide: Fire retardant additive for use with resins.

Anti-static Agents: Agents which, when added to the molding material or
applied on the surface of the molded object, make it less conducting (thus
hindering the fixation of dust).

Ash Content: The solid residue remaining after a reinforcing substance has
been incinerated (or strongly heated).

Aspect Ratio: The ratio of length to diameter of a fiber.

- B -

B-stage: An intermediate stage in the reaction of certain thermosetting
resins in which the material swells when in contact with certain liquids
and softens when heated, but may not entirely dissolve or fuse; sometimes
referred to as resistol. The resin is an uncured prepreg or premix is

usually in this stage.

Bag Molding: An airtight film used to apply atmospheric force to a laminate. See Vacuum and Pressure.

Barcol Hardness: A measure of surface hardness made with a Barcol Impressor instrument in accordance with ASTM D-2583. The hardness value can be used as an indication of the degree of cure of FRP laminates.

Bare Glass: Glass (yarns, rovings, fabrics) from which the sizing or finish has been removed; also, such glass before the application of sizing or finish.

Barrier Cream: A cream used to protect the skin from contact with resins.

Benzoyl Peroxide (BPO): An initiator for curing polyester resin. BPO is used with aniline accelerators or where heat is used to cure the resin.

Biaxial Winding: In filament winding, a type of winding in which the helical band is laid in sequence, side by side, with the crossover of the fibers eliminated.

Bi-directional: Reinforcing fibers that are arranged in two directions, usually at right angles to each other.

Binder: A resin soluble adhesive that secures the random fibers in chopped

strand mat or continuous strand roving.

Bisphenol A: A condensation product formed by reaction of two (bis)
molecules of phenol with acetone (A). This polyhydric phenol is a standard
resin intermediate along with epichlorohydrin in the production of epoxy
resins.

Blister: A flaw either between layers of laminate or between the gel coat
film and laminate.

Bond Strength: The amount of adhesion between bonded surfaces; a measure
of the stress required to separate a layer of material from the base to
which it is bonded.

Burst Strength: (1) Hydraulic pressure required to burst a vessel of given
thickness. Commonly used in testing filament-wound composite structures.
(2) Pressure required to break a fabric by expanding a flexible diaphragm
or pushing a smooth spherical surface against a securely held circular
area of fabric. The Mullen expanding diaphragm and Scott ball burst
machine are examples of equipment used for this purpose.

- C -

Casting: The process of pouring a mixture of resin, fillers and/or fibers
into a mold as opposed to building up layers through

lamination. This technique produces different physical properties from laminating.

Catalyst: Technically considered an initiator, catalyst is the colloquial name given to the substance added to the resin or gel coat to initiate the cure.

Catastrophic Failures: Failures of a mechanical and unpredictable nature.

Catenary: A measure of the difference in length of the strands in a specified length of roving as a result of unequal tension; the tendency of some strands in a taut horizontal roving to sag lower than the others.

Caulk: An elastic material used to protect joints or connections from external elements, particularly moisture.

Cavity: The space between a male and female mold set in which the part is formed. Sometimes used to refer to a female mold.

Centipoise: A unit of measure used to describe the viscosity of a liquid. Viscosity is measured with a Brookfield Viscometer for most polyester resin applications.

Chalking: A surface phenomenon indicating degradation of a cosmetic surface. Chalking is a powdery film which appears lighter than the original color.

Chopped Strand Mat: A fiberglass reinforcement consisting of short strands of fiber arranged in a random pattern and held together with a binder. Mat is generally used in rolls consisting of ¾ oz/ft2 material to 2 oz/ft2 material.

Cloth: A fiberglass reinforcement made by weaving strands of glass fiber yarns. Cloth is available in various weights measured in ounces per square yard or kg/m2.

Color Stability: The ability of a surface coating or pigment to resist degradation due to environmental exposure.

Composite: A reinforcing fiber in a resin matrix whose cumulative properties are superior to the individual materials.

Compression Mold: A closed mold, usually of steel, used to form a composite under heat and pressure.

Compressive Modulus: A mechanical property description which measures the compression of a sample at a specified load. Described in ASTM D-695.

Compressive Strength: The stress a given material can withstand when compressed. Described in ASTM D-695.

Conductivity: Reciprocal of volume resistivity; the conductance of a unit cube of any material.

Connection: Where two panels are attached to each other or a panel is attached to the building.

Contact Molding: Refers to the use of a single or open mold onto which resin and reinforcement materials can be applied. Contact molding is characterized by one finished cosmetic side.

Continuous Filament Strand: A fiber bundle composed of many glass filaments. Also when referring to gun roving; a collection of string like glass fiber or yarn, which is fed through a chopper gun in the spray up process.

Continuous Strand Roving: A bundle of glass filaments which are fed through a chopper gun in the spray up process.

Continuous Laminating: An automated process for forming panels and sheeting in which fabric or mat is passed through a resin bath, brought together between covering sheets, and passed through a heating zone for cure. Squeeze rolls control thickness and resin content as the various plies are brought together.

Core: A low density material used between two FRP skins. Examples of core materials are end-grain balsa wood, urethane foam, PVC foam and various honeycomb materials.

Coupling Agent: Any chemical substance designed to react with both the reinforcement and matrix phases of a composite material to form or promote a stronger bond at the interface; a bonding link.

Crazing: Cracking of gel coat or resin due to stress.

Creel: A device for holding the required number of roving balls or supply packages in desired position for unwinding onto the next processing step.

Creep: The change in dimension of a plastic under load over a period of time, not including the initial instantaneous elastic deformation. (Creep at room temperature is called 'cold flow.')

Cross-linking: The chemical bonding of molecules which in polymers occurs in the curing transition from a liquid to a solid.

Cure: The completion of the cross-linking process during which a composite develops its full strength.

Cure Temperature: Temperature at which a cast, molded, or extruded product, a resin-impregnated reinforcement, an adhesive, etc., is subjected to curing.

Cure Time: Time between introduction of catalyst or initiator to a polymer and final cure.

Curing Agent: A catalytic or reactive agent which when added to a resin causes polymerization; synonymous with hardener.

Cycle: The complete, repeating sequence of operations in a process or part of a process. In molding, the cycle time is the period (or elapsed time) between a certain point in one cycle and the same point in the next.

- D -

Delamination: The separation of composite layers from each other.

Density: A comparison of weight per volume, measured in pounds per cubic foot.

Dielectric Strength: The value of a material as an electrical insulator or the resistance to the flow of electric current.

Dimensional Stability: A description of the change in size of an object during the molding process or in varying temperature conditions or under various loads.

Distortion: A change in shape form that which is intended.

Draft: The angle of the vertical components of a mold which allow removal of the part.

Drape: The ability of pre impregnated broad goods to conform to an irregular shape; textile conformity.

Dry Spot: Area of incomplete surface film on laminated

plastics; in
laminated glass, an area over which the interlayer and the glass have not
become bonded.

E-glass: Originally formulated for use in electric circuitry, E-glass is
the most common glass formulation used in fiberglass reinforcements.

Ejection/Demolding: The process of removing a molding from the molding
impression; by mechanical means, by hand, or by the use of compressed air.

Ejection Plate: A metal plate used to operate ejector pins; designed to
apply a uniform pressure to them in the process of ejection.

Elastic Limit: The greatest stress which a material is capable of
sustaining without permanent strain remaining upon the complete release of
the stress. A material is said to have passed its elastic limit when the
load is sufficient to initiate plastic, or non recoverable, deformation.

Elongation: Standard measure for the amount a sample can stretch as a
percentage of original length before it fails or breaks.

Encapsulating: Completely surrounding an object with resin or a fiber
resin composite.

End: A strand of roving consisting of a given number of filaments gathered together.

End Count: An exact number of ends supplied on a ball or roving.

Epoxy Plastics: Plastics based on resins made by the reaction of epoxides or oxiranes with other materials such as amines, alcohols, phenols, carboxylic acids, acid anhydrides and unsaturated compounds.

Epoxy Resin: A polymer resin characterized by epoxide molecule groups.

Exothermic Heat: Internally developed heat accompanying a chemical reaction, such as might be created when curing a thermosetting resin.

Extenders: Low cost materials used to dilute or extend high cost resins without much lessening of properties.

Fabricator: Manufacturer of reinforced plastic products.

Fatigue: The failure or decay of mechanical properties after repeated applications of stress.

Fatigue Life: The number of cycles of deformation required to bring about failure of the test specimen under a given set of oscillating conditions.

Fatigue Limit: The stress below which a material can be stressed cyclically for an infinite number of times without failure.

Fatigue Strength: The maximum cyclic stress a material can withstand for a given number of cycles before failure occurs; the residual strength after being subjected to fatigue.

Female Mold: A concave mold used to precisely define the convex surface of a molded part.

Fiber: Reinforcement material which is a major component in a composite matrix.

Fiber Diameter: The measurement (expressed in hundred-thousandths) of the diameter of individual filaments.

Fiberglass: Glass which has been extruded into extremely fine filaments. These filaments vary in diameter, and are measured in microns. Glass filaments are treated with special binders and processed similar to textile fibers. These fibers come in many forms such as roving, woven roving, mat and continuous strands.

Fiber Orientation: Fiber alignment in a non-woven or a mat laminate where the majority of fibers are in the same direction, resulting in a higher strength in that direction.

Fiber Pattern: Visible fibers on the surface of laminates or moldings; the thread size and weave of glass cloth.

Filament: A single thread-like fiber of extruded glass. Typically microns in diameter.

Filament Winding: A process which involves winding a resin-saturated strand of glass filament around a rotating mandrel.

Fill: yarn running from selvage to selvage at right angles to the warp in a woven fabric.

Fillers: Usually inert organic or inorganic materials which are added to plastics, resins or gel coats to vary the properties, extend volume, or lower the cost of the article being produced.

Fillet: A rounded filing of the internal angle between two surfaces of a plastic molding.

Fire Retardants: Compounds mixed with the resin to reduce flammability.

Fish Eye: The effect of surface contamination which causes a circular separation of a paint or gel coat.

Flame Retardant Resin: A polyester resin which has been specifically formulated to reduce the flame spread and/or smoke generation characteristics.

Flammability: A measure of how fast a material will burn under controlled conditions. ASTM D-635/UL E-84 tests.

Flange: An extension around the perimeter of a mold or part for the purpose of demolding, stiffening or connecting two components.

Flash Point: The lowest temperature at which a substance gives off enough vapors to form a flammable mixture.

Flexural Modulus: An engineering measurement which determines how much a sample will bend when a given load is applied. Described in ASTM D-790.

Flexural Strength: The resistance of a material to being broken by bending stresses; the strength of a material in bending, expressed as the tensile stress of the outermost fibers of a bent test sample at the instant of failure. (With plastics, this value is usually higher than the straight tensile strength.)

Flow: The movement of resin under pressure, allowing it to fill all parts of a mold; flow or creep - the gradual but continuous distortion of a material under continued load, usually at high temperature.

Flow Line: A mark on a molded piece made by the meeting of two flow fronts during molding. (Also, 'striae', or 'weld-mark,' or 'weld-line.')

Foam: A lightweight, cellular plastic material containing gas-

filled
voids. Typical foams include urethane, PVC and polyester.

Foam-in-place: The process of creating a foam by the combination of two
liquid polymers. See In-Situ.

FRP: Fiber Reinforced Plastics, also known as GFRP (Glass Fiber Reinforced
Plastic), GRP (Glass Reinforced Plastic), FRP (Reinforced Plastic) and
Composites.

Gel: The irreversible point at which a polymer changes from a liquid to a
semi-solid. Sometimes called the "B" stage.
Gel Coat: A surface coat of a specialized polyester resin, either colored
or clear, providing a cosmetic enhancement and weatherability to a
fiberglass laminate.

Gel Time: The length of time from catalyzation to gel or "B" stage.
Gelation: The formation of a gel.

Glint: A visual defect in a fiber glass reinforced cured organic (usually
corrosion resistant resin) panel. The defect appears as many small visible
unwet or foreign substances - a salt and pepper effect. The defect is not
visible before cure but appears at exotherm of the panel.

Good Side: The side of a molding in contact with a mold surface.

"Green": Resin which has not completely cured and is still rather soft and rubbery.

GRP: Glass reinforced plastics. Generally based on polyester resin. See Fiberglass, FRP.

Guide Pin: A pin which guides mold halves into alignment on closing.

Hand Lay Up: The process of manually building up layers of fiberglass and resin using hand rollers, brushes and spray equipment.

Hardener: A substance or mixture added to a plastic composition to promote or control the curing action by taking part in it. Also, a substance added to control the degree of hardness of the cured film.

Heat Distortion Point: The temperature at which the strength of a material begins to degrade.

HET-Acid Resin: Polyester resin with exceptional fire qualities.

Honeycomb Core: Strips of paper, plastic, metal, etc., joined together to form a honeycomb pattern. Used as a lightweight core in sandwich moldings.

Hydraulic Press: A press in which the molding force is created by the pressure exerted on a fluid.

Hygroscopic: Capable of absorbing and retaining atmospheric moisture.

Ignition Loss: The difference in weight before and after burning; as with glass, the burning off of the binder or size.

Impact Strength: The ability of a material to withstand shock loading; the work done in fracturing a test specimen in a specified manner under shock loading.

Impregnate: To saturate with resin. The most common application is saturating fiberglass with a catalyzed resin.

Inhibitor: An additive to polyester resin or styrene used to slow the chemical reaction which leads to curing.

Insert: A piece of material put into a laminate during or before molding to serve a definite purpose.

Instron: An instrument utilized to determine the tensile and compressive properties of materials.

Interface: The junction point or surface between two different media; on glass fibers, the contact area between glass and sizing or finish; in a laminate, the contact area between the reinforcement and the laminating resin.

Interlaminar Shear Strength: The maximum shear stress existing between layers of a laminated material.

Intumescent: A fire-retardant technology which causes an otherwise flammable material to foam, forming an insulating barrier when exposed to heat.

In-situ: In the position which it will finally occupy, e.g. molding or forming foam.

Isophthalic: A polyester resin based on isophthalic acid, generally higher in properties than a general purpose or orthothalic polyester resin.

Isotropic: The description of equal strength properties in all orientation. Isotropic composites are usually achieved by random fiber orientation.

IZOD Impact Test: A destructive test designed to determine the resistance of a plastic to the impact of a suddenly applied force.

Jackstrawing: A visual effect of glass fiber turning white in a cured laminate. This usually does not effect the strength of a laminate, but could be an indication of materials incompatibility.

Jig: Any fixture for holding parts in position, while joining them together or to maintain their shape.

Joint: A line or distinction formed when two panels are connected. Also

referred to as a seam.

Laminant: The product of lamination. A composite consisting of a layer or layers of thermoset polymer and fiber reinforcement.

Laminate: To place into a mold a series of layers of polymer and reinforcement. The process of applying FRP materials to a mold. To lay up.

Lamination: Applying layers of glass and resin to a mold. Also used to describe a single ply of laminate.

Lay: In glass fiber, the spacing of the roving bands on the roving package expressed in the number of bands per inch; in filament winding, the orientation of the ribbon with some reference, usually the axis of rotation.

Layer: A single ply of lay up or laminate.

Lay Up: The act of building up successive layers of polymer and reinforcement. Layers of catalyzed resin and fiberglass or other reinforcements are applied to a mold in order to make a part.

L/D Ratio: A term used to define an extrusion screw, which denotes the ratio of the screw length to the screw diameter.

Load-Deflection Curve: A curve in which the increasing flexural loads are

plotted on the ordinate axis and the deflections caused by those loads are
plotted on the abscissa axis.

Loss on Ignition: Weight loss, usually expressed as percent of total,
after burning off an organic sizing from glass fibers, or an organic resin
from a glass fiber laminate.

Low-pressure Laminates: Laminated, molded and cured using pressures from
400 psi down to and including the pressure obtained by the mere contact of
the plies.

Low-pressure Molding: The distribution of relatively uniform low pressure
(200 psi or less) over a resin-bearing fibrous assembly of cellulose,
glass, asbestos, or other material, with or without application of heat
from external source, to form a structure possessing definite physical
properties.

Male Mold: A convex mold where the concave surface of the part is
precisely defined by the mold surface.

Mandrel: The core around which paper-, fabric-, or resin-impregnated glass
is wound to form pipes, tubes, or vessels; in extrusion, the central
finger of a pipe or tubing die.

Master (plug): A full scale representation of the intended part, usually retained as a reference and the part from which production molds are made.

Mat: See Chopped Strand Mat.

Mat Binder: Resin applied to glass fiber and cured during the manufacture of mat, to hold the fibers in place and maintain the shape of the mat.

Matched Die Molding: Technique for producing long runs of identical parts with two finished sides.

Matched Molds: Two or more tools arranged in a set as a male and female mold. Normally used in a press.

Matrix: The liquid component of a composite or laminate.

MEK Peroxide (MEKP): An initiator often referred to as catalyst and used to initiate polymerization of a resin. Methyl Ethyl Ketone Peroxide.

MEK Solvent: Methyl Ethyl Ketone; a colorless, flammable liquid sometimes used in clean up procedures.

Microballoons: Microscopic bubbles of glass, ceramic or phenolic, used as a filler or to create syntactic foam or putty mixtures.

Micron: One micron = .001 millimeter = .00003937 inch.

Mil (Mil Thickness): The unit used in measuring film thickness. One mil

equals one thousandth of an inch. (I mil = .001 ").

Milled Fibers: Glass fiber processed by a hammer mill into lengths of
1/32" to 1/8". Commonly used as a reinforcement in polyester putty.

Modulus of Elasticity: An engineering term used to describe a material's
ability to bend without losing its ability to return to its original
physical properties.

Mold: The tool used to fabricate the desired part shape. Also used to
describe the process of making a part in a mold.

Molding: The process of using a mold to form a part.

Mold Release: A wax or polymer compound that is applied to the mold
surface which acts as a barrier between the mold and the part, thus
preventing the part from bonding to the mold.

Mold Shrinkage: The immediate shrinkage which a molded part undergoes when
it is removed from a mold and cooled to room temperature; the difference
in dimensions, expressed in inches per inch between a molding and the mold
cavity in which it was molded (at normal temperature measurement); the
incremental difference between the dimensions of the molding and the mold
from which it was made, expressed as a percentage of the dimensions of the
mold.

Molding Compounds: Plastics in a wide range of forms to meet specific processing requirements. Granules or pellets are popular forms.

Molding Cycle: The period of time occupied by the complete sequence of operations on a molding press requisite for the production of one set of moldings; the operations necessary to produce a set of moldings without reference to the time taken.

Molding Pressure: The pressure applied to the ram of an injection machine or press to force the softened plastic completely to fill the mold cavities.

Monomer: One of the constituents of polyester resin.

Multiple-cavity Mold: A mold with two or more mold impressions; that is, a mold which produces more than one molding per molding cycle.

NOL Ring: A parallel filament wound test specimen used for measuring various mechanical strength properties of the material by testing the entire ring, or segments of it.

NPG Gel Coat: Neopentyl glycol gel coat has enhanced weatherability compared to non-NPG gel coat.

Nesting: In reinforced plastics, the placing of plies of fabric so that the yarns of one ply lie in the valleys between the yarns of the adjacent ply (nested cloth).

Notch Sensitivity: The extent to which the sensitivity of a material to fracture is increased by the presence of a surface inhomogeneity such as a notch, a sudden change in section, a crack or a scratch. Low notch sensitivity is usually associated with ductile materials and high notch sensitivity with brittle materials.

Orange Peel: A gel coated or painted finish which is not smooth and is patterned similar to an orange's skin.

Orthophthalic or Ortho Resin: A polyester resin based on orthophthalic acid, also known as a general purpose resin (GP).

Parting Agent: See Mold Release and PVA.

Parting Line: The location on a molded product between different segments of the mold used to produce the product.

Pattern: The initial model for making fiberglass molds. See Plug.

Pigment: A colorant added to gel coat or resin.

Pigment Separation: Occurs when the pigment is not thoroughly mixed into the gel coat during formulation or the gel coat is improperly mixed prior to use. It is characterized by a non-homogeneous surface color.

Pinholes: Small holes on the exposed gel coated surface. They are about the diameter of common pins and may be easily counted.

Pit: Small regular or irregular crater in the surface of a plastic, usually with width approximately of the same order of magnitude as its depth.

Plastics: Organic chemical compounds called polymers which can be formulated to produce a wide range of properties.

Plastic Deformation: Change in dimensions of an object under load that is not recovered when the load is removed; opposed to elastic deformation.

Plastic Tooling: Tools (mostly for the metal forming trades) constructed of plastics, generally laminates or casting materials.

Plug: A composite industry term for a pattern or model.

Polyamide: A polymer in which the structural units are linked by amide or

thioamide groupings. Many polyamides are fiber-forming.

Polyester Resin (Unsaturated): The product of an acid-glycol reaction commonly blended with a monomer to create a polymer resin. In its thermosetting form it is the most common resin used in the FRP industry.

Polymer: A chain molecule composed of many identical groups, commonly found in plastics.

Polymerization: The chemical bonding of polymer molecules during the curing reaction.

Polyvinyl Alcohol (PVA): A parting film applied to a mold for part releasing.

Porosity: Entrapped gas bubbles or voids in a gel coat film.

Positive Mold: A mold designed to apply pressure to a piece being molded with no escape of material.

Post-cure: To cure by application of heat after the chemical exothermic reaction has subsided.

Pot Life: The time during which the catalyzed resin remains liquid or "workable." See Gel Time.

Pregel: An unintentional extra layer of cured resin on part of the surface of a reinforced plastic. (Not relating to 'gel coat.')

Premix: Reinforcing material mixed with resin, and usually with pigment, filler and catalyst, before placing in the mold.

Prepreg: Reinforcing material impregnated with resin prior to the molding process and cured by the application of heat.

Pressure Bag: A membrane which conforms to the inside of a laminate laid up on a mold. The membrane or bag is then inflated applying pressure which consolidates and densifies the laminate.

Print Through: A distortion in the surface of a part which allows the pattern of the core or fiberglass reinforcement to be visible through the surface. Also known as print out, telegraphing or read through.

Promoter: A reagent which speeds resin cure. See Accelerator.

Pultrusion: Reversed "extrusion" of resin-impregnated roving in the manufacture of rods, tubes and structural shapes of a permanent cross-section. The roving, after passing through the resin dip tank, is drawn through a die to form the desired cross-section.

Putty: A thickened mixture of resin made by adding fillers, thixotrophs and reinforcing fibers.

PVA: See Polyvinyl Alcohol.

Reinforced Molding Compound: Compound consisting of a polymer and a reinforcement fiber or filler supplied by raw material producer in the form of ready-to-use materials.

Reinforcement: A fiber which when encapsulated in a polymer resin matrix forms a composite or fiberglass laminate. Also refers to a structural member designed to stiffen a molded part.

Release Agent: A compound used to reduce surface tension or adhesion between a mold and a part.

Resin: A liquid polymer which when catalyzed cures to a solid state.

Resin Content: The amount of resin in a laminate expressed as either a percent of total weight or total volume.

Resin-Rich Area: Space which is filled with resin and lacking reinforcing material.

Resin-Starved Area: Areas of insufficient resin, usually identified by low gloss, dry spots or fiber show.

Resin Tearing: Separation of pigments in a gel coat affecting cosmetic appearance.

Rib: A reinforcing member of a fabricated or molded part.

Room Temperature Curing Adhesives: Adhesives that set (to handling strength) within an hour at temperatures from 68 to 86 F, and later reach full strength without heating.

Roving: A collection of bundles of continuous filaments in untwisted strands. Used in the spray-up (chopping) process.

Sandwich Construction: A laminate with two composite skins separated by, but bonded to, a structural core material. Used to create stiff, lightweight structures.

Scrim: A low cost, non woven open-weave reinforcing fabric made from continuous filament yarn in an open mesh construction.

Seam: See Joint.

Self Extinguishing: Ceases to burn when the source of flame is removed.

Self-tapping Screws: Hardened screws which cut their own thread as they are set.

Set-up: To harden, as in curing.

Shear: An engineering term referring to forces applied normal to the surface of a given material. The movement between plies of a laminate is referred to as interlaminate shear.

Shear Edge: The cut-off edge of the mold.

Shelf Life: The allowable storage time before a product must

be used.

Ship Lap: Method of joining two panels together by means of one panel having a recessed shelf to receive the other panel on top of it leaving a flush surface.

Shrinkage: The relative change in dimension between the length measured on the mold when it is cold and the length on the molded object 24 hours after it has been taken out of the mold.

Sink Mark: A shallow depression or dimple on the surface of an injection molded part due to collapsing of the surface following local internal shrinkage after the gate seals; an incipient short shot.

Skein: A continuous filament, strand, yarn, roving, etc., wound up to some measurable length, and usually used to measure various physical properties.

Skin Coat: The first layer of laminate next to the gel coat, generally, one ply of chopped strand mat.

Solvent Resistance: The non swelling of a material and, of course, the impossibility for it to be dissolved by the solvent in question.

Specific Gravity: The ratio between the density of a given substance and the density of water.

Specimen: An individual piece or portion of a sample used to make a

specific test; of specific shape and dimensions.

Splice: The joining of two ends of glass fiber yarn or strand, usually by means of an air drying glue.

Split Mold: An open mold made in two or more pieces.

Spray Up: The process of spraying glass fibers, resin and catalyst simultaneously into a mold using a chopper gun.

Stiffness: The relationship of load and deformation; a term often used when the relationship of stress to strain does not conform to the definition of Young's modulus.

Storage Life: The period of time during which a liquid resin or packaged adhesive can be stored under specified temperature conditions and remain suitable for use. Also Shelf Life.

Strands: A primary bundle of continuous filaments (or slivers) combined in a single compact unit without twist. These filaments (usually 51, 102 or 204) are gathered together in the forming operations.

Strand Count: The number of strands in a plied yarn; the number of strands in a roving.

Strand Integrity: The degree to which the individual filaments making up the strand or end are held together by the sizing applied.

Stress-Strain Curve: Simultaneous readings of load and deformation,

converted to stress and strain, are plotted as ordinates and abscissas,
respectively, to obtain a stress-strain diagram.

Styrene Monomer: A component of polyester resin that provides crosslinking
sites and reduces the polyester to a workable viscosity.

Surfacing Mat: A lightweight tissue (10-30 mils thick) of glass or
synthetic fiber used to provide a resin-rich surface. See Veil.

Surfactant: Chemicals used to modify or change the surface of a layer of
resin or polymer. Usually used to form a film on a curing resin, producing
a tack-free surface.

Syntatic Foam: A foam made by mixing microspheres with a resin.

Tack: Surface stickiness.

Tack Free: A surface which is not sticky after cure.

Tangent Modulus: The slope of the line at any point on a static

stress-strain curve expressed in psi per unit strain. This is the tangent
modulus at that point in shear, extension, or compression as the case may
be.

Tape: A narrow width reinforcing fabric or mat.

Tenacity: The term generally used in yarn manufacture and

textile
engineering to denote the strength of a yarn or of a filament of a given
size. Numerically it is the grams of breaking force per denier unit of
yarn or filament size; grams per denier, gpd. The yarn is usually pulled
at the rate of 12 inches per minute. Tenacity equals breaking strength
(grams) divided by denier.

Tensile Load: A dulling load applied to opposite ends of a given sample.

Tensile Elongation: An engineering term referring to the amount of stretch
a sample experiences during tensile strain. ASTM D-638.

Tensile Strength: A measurement of the tensile load a sample can
withstand. ASTM D-638.

Thermal Coefficient of Expansion: Measures dimensional change of a
material when heated or cooled. Measured in inches per inch per degree.

Thermal Conductivity: Measures the transfer of heat through a material.

Thermoplastics: A group of plastic materials that become elastic or melt
when heated, and return to their rigid state at room temperature. Examples
are PVC, ABS, polystyrene, polycarbonates, nylon, etc.

Thermosets: Materials that undergo a chemical crosslinking reaction going
from liquid to solid or semi-solid. This reaction is

irreversible. Typical
thermosets are polyesters, acrylics, epoxies, and phenolics.

Thixotropic: A term describing the rehology (or flow characteristics) of a
liquid that resists flowing or drainage during application.

Thixotropic Index (T.I.): A measure of thixotropy using a Brookfield
Viscometer. The low speed viscosity divided by the high speed viscosity.

Tooling Get Coat: A gel coat formulated for mold surfaces.

Translucent: Permits a percentage of light to pass but not optically clear
like window glass.

Ultimate Tensile Strength: The ultimate or final stress sustained by a
specimen in a tension test; the stress at moment of rupture.

Under Cut: An area of a part or mold that has an acute angle between two
surfaces. If a part has an undercut a split mold is necessary.

Unidirectional: Strength lying mainly in one direction. A glass
reinforcement in which the fiber is oriented in one direction.

UV Stabilizer: A chemical compound which improves resistance to
degradation from ultraviolet radiation.

Vacuum Bag Molding: Process for eliminating voids and forcing out entrapped air and excess resin from lay ups by drawing a vacuum from a plastic film which blankets a laminate.

Veil: An ultra thin mat similar to a surface mat, often composed of organic fibers as well as glass fibers.

Viscosity: The liquid properties of a material. Resistance to flow.

Void Content: The percentage of voids in a laminate.

Void Free: A molding containing no entrapped air cavities, blisters, or voids.

Water Absorption: The amount of water which a laminate will absorb.

Wax: A compound used as a release agent. See Release Agent.

Weave: The particular manner in which a fabric is formed by interlacing yarns, and usually assigned a style number.

Wet Lay-up: The reinforced plastic which has liquid resin applied at the reinforcement is laid up. The opposite of "dry lay-up",

"prepreg".

"Wet-out": The action of saturating a glass fabric with resin. Also a measure of the speed with which a fabric soaks up resin.

Wet-out Rate: The time required for a plastic to fill the interstices of a reinforcement material and wet the surface of the reinforcement fibers; usually determined by optical or light transmission means.

Wet Strength: The strength of paper when saturated with water, especially used in discussions of processes whereby the strength of paper is increased by the addition, in manufacture, or plastic resins; the strength of an adhesive joint determined immediately after removal from a liquid in which it has been immersed under specified conditions of time, temperature and pressure.

Woven Roving Fabric: Heavy fabrics woven from continuous filament in roving form. Usually in weights between 18-30 oz. per square yard.

Yarn: Twisted strands of roving, used to weave textile reinforcements.

Yield Strength: The stress at which a material exhibits a specified limiting deviation from the proportionality of stress to strain;

the
lowest stress at which a material undergoes plastic deformation. Below
this stress, the material is elastic; above it, viscous.

Young's Modulus: The ratio of tensile stress to tensile strain below the
proportional limit.