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Handbook of Lay-Up and Bagging

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NASCO

PREFACE

This booklet is provided as an aid to those involved in the technology of structural composites fabricated parts and assemblies. Its purpose is to accumulate the most commonly used characteristic processing methods of materials used in manufacturing aircraft and aerospace structures.

The information herein has been obtained from material specifications, process specifications and related documents and was valid at the date of publication.

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NOTE:
Information contained in this booklet should be regarded as a guideline only. Lay-up and bagging procedures can vary widely within companies, due to their individual requirements. Company procedures and specifications take precedence over any information in this manual.

PURPOSE

To illustrate techniques for the preparation of bagging assemblies to be fabricated using temperature and pressure. To help each employee maintain the highest level of manufacturing expertise.

INTRODUCTION

Molding a reinforced plastic or adhesive bonded structure with no defects requires a coordinated effort, from the design to the completed part.

Designers, material and process engineers, tooling engineers, quality control engineers and manufacturing personnel must work together to produce quality parts.

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MATERIALS

The following materials are required for bagging operations:

- Bagging Films
- Release Films
- Breathers and Bleeders
- Sealant Tapes
- Peel Plies and Release Fabrics
- Pressure Sensitive Tapes
- TFE coated Release Fabrics
- Valves and Hoses
- Miscellaneous

  Impression film (may be required for honeycomb prefit)

  Shrink tapes (bondable and non-bondable)

  Non-silicone tooling rubber.

National Aerospace Supply Company (NASCO)
can provide you with all of the above materials.
Please refer to our product list in the
Appendix Section.

Call NASCO at (949) 240-6353 or Fax (949) 248-5655.

STEP-BY-STEP LAY-UP PROCEDURE

Lay-up for a typical bagging operation should be as follows:

1. Add release medium between tool and part.
2. Place lay-up on tool.
3. Cover lay-up with perforated parting film or peel ply.
4. Next lay down a layer or layers of bleeder material. This combination should insure adequate bleeding (escape of air and excess resin from the part) so the cured part will have the desired resin content.
5. Add thermocouple wires, (minimum of two, depending on size of part).
6. Place valve base on breather just beyond the edge of the lay-up. Add bag sealing compound, approximately 4 inches beyond the edge of the lay-up. Cover entire lay-up with a flexible nylon film and seal to the tool with sealing compound.
7. Install vacuum valves (minimum of two, depending on size of part) and and connect vacuum hoses, then slowly apply vacuum pressure while working the wrinkles and excess air out of the lay-up bleeder material and vacuum bag, to eliminate all bridging of bag in corners.
8. Check system for vacuum leaks by turning off the vacuum and watching the gage. A drop of one inch of mercury per minute is acceptable. If the drop is greater, check for leaks or pinholes in the bag material, or a poor seal to the tool or mold.
9. Keep the part under vacuum while it is waiting to be cured in the oven or autoclave to prevent movement of detail parts or bridging of bag.

SCHEMATICS OF TYPICAL LAY-UPS FOR VACUUM BAGGING

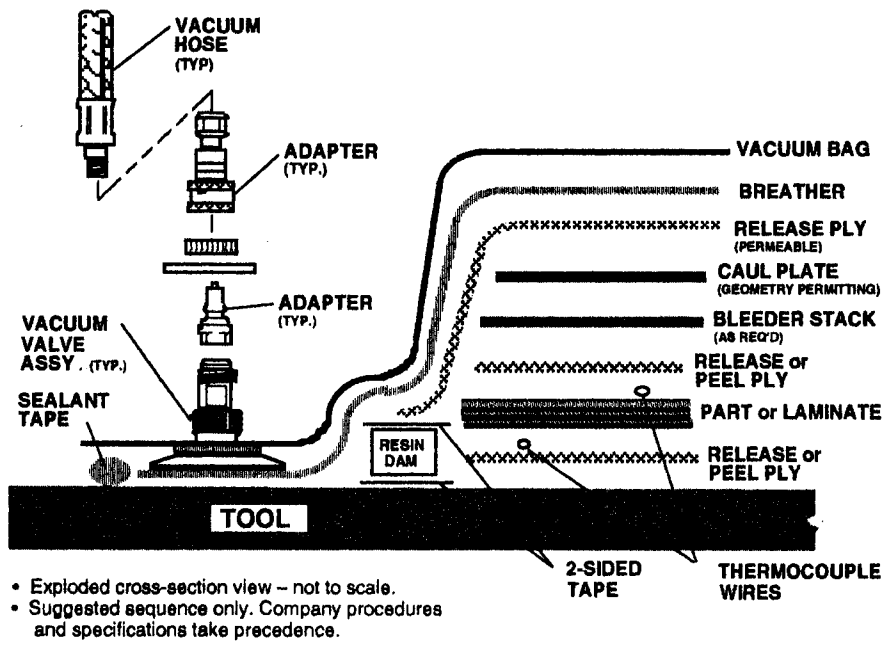


Fig. 1. Typical lay-up for vacuum-bagging a laminate.

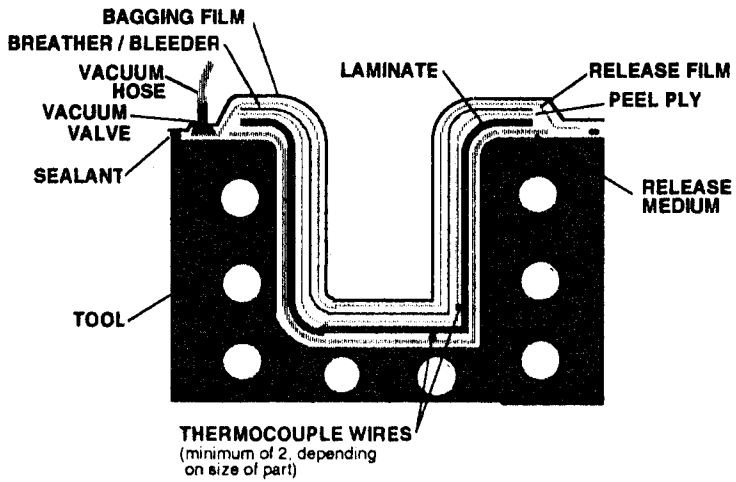


Fig. 2. Typical lay-up procedure for curved laminates.

SCHEMATICS OF TYPICAL LAY-UPS FOR VACUUM BAGGING

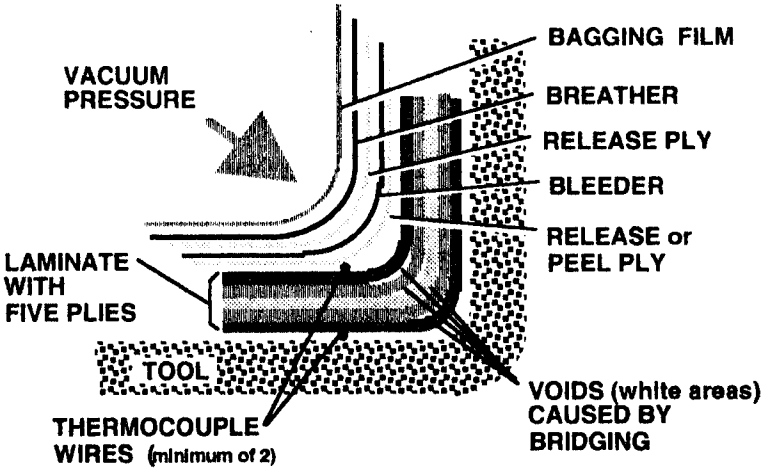
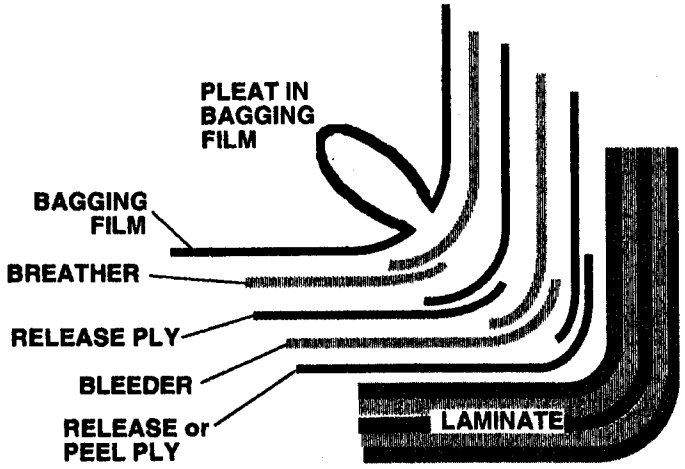


Fig. 3. Areas in white show voids which can be prevented by pleating the bagging film at the radius of the corner, as shown in the figure below.



NOTE: Stagger laps at each radius to provide a smooth transition during cure cycle. Using a flat piece of molded nylon or rigid polyurethane, remove wrinkles from the radius to prevent voids or bridging in the part.

Fig. 4. Staggered laps at radius to prevent voids.

TIPS & TECHNIQUES FOR QUALITY PARTS

CLEANLINESS

Cleanliness is necessary in the fabrication of plastic and bonded structures.

- Gloves of lint-free white cotton are a must for every production worker. Some types of latex gloves are acceptable, while some other types of rubber can not be used, as they adhere to most components and also leave fingerprints which will causeundesirablevoids.
- Cotton gloves should be discarded as soon as they become soiled.
- Workers should not use hand creams.
- Frequent washing of hands will reduce the problem of sore, cracked skin or dermatitis.

REDUCING FIRE HAZARDS

Fire hazards are greatly increased by elevated temperatures and high pressure. The use of fire-retardant processing materials and CO_2 or LN_2 as the pressure medium can greatly reduce the danger of autoclave fires. Fire retardant bagging materials include silicone rubber, nylon or TFE.

FINAL STEPS BEFORE CURING

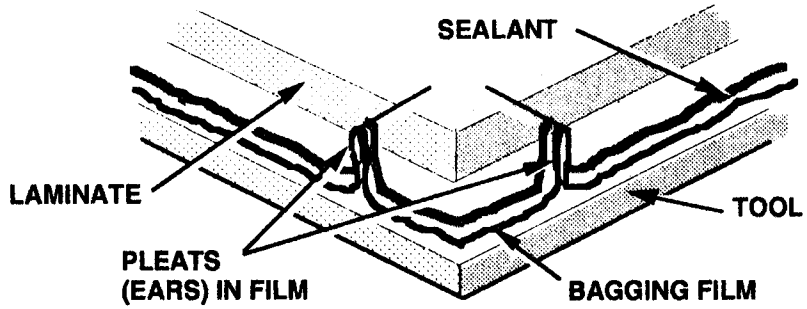
The autoclave or oven should be vacuumed during clean-up and then purged of all enclosed air before the cure cycle is begun. After the normal cure is completed, the autoclave and parts are cooled before releasing the autoclave pressure.

Before bagging and close-up of the part, technicians should check to make sure all hand tools such as Exacto knives, blades, Stanley knives, or scissors are returned to tool boxes. All too often, excess blades are molded into finished parts.

Thermocouple wires (minimum of two, depending on size of the part) should be embedded in the sealer around the periphery of the part.

Then place additional sealant over the area where the TC wire is located to prevent vacuum leaks around the wire. This area is a common cause of leaks.

In placing the vacuum bag over the part, "pleats" in the bagging film are used to provide excess material over the part. The pleats can be approximately three inches in height, two to three feet apart, or larger or smaller as required for the shape of the assembly, but should be at least two inches higher than the part. These pleats allow room for unusual shapes or protrusions in the lay-up without danger of puncturing the bag. This will also eliminate bridging and possible voids in the laminate. Be sure to gather excess bag material around protrusions prior to applying the vacuum. (See drawing.)



Before attaching lines or hoses, the vacuum fittings should be checked for any sign of wear on "O" rings and for any blockage from resin contamination.

After the bag is in place, a partial vacuum should be applied and the whole assembly checked for leaks. A leak detector can be used.

Too much emphasis cannot be placed on checkout of the part before placing it in an oven or pressure vessel for cure. The name of the game is: **"Time and money". Loss of a part means loss of dollars.**

SAFETY PRECAUTIONS

Some of the solvents used in the plastics shop—either as cleaning solvents or as ingredients in the composition of resins or adhesives—are inflammable. Solvents and resins/adhesives should be stored in approved fire-safe areas, and appropriate fire-fighting equipment should be kept on hand at all times.

Some solvents and adhesives contain chemicals which, in addition to being flammable, may prove harmful to the human body if contact is prolonged. The vapors of these materials may cause headaches or irritation of the eyes, nose, and throat—and prolonged contact with epoxy adhesives may affect sensitive skin adversely. Therefore, adequate ventilation and appropriate protective equipment *must* be provided for certain operations.

A basic knowledge of the hazards to be avoided is the first requirement for safety in the shop. All shop personnel should be familiar with Safety Handling Control Bulletins concerning all approved materials: Reference EPA and AQMD safety literature.

Following is a partial list of the materials that need to be handled with great care:

- Methyl Ethyl Ketone
- Petroleum Napthas
- Toluene
- Benzine
- Methyl Alcohol
- Carbon Tetrachloride

WARNING:

DO NOT USE UNFAMILIAR MATERIALS WHICH MAY BE HARMFUL WITHOUT ASKING YOUR SUPERVISOR OR SAFETY ENGINEER.

TROUBLESHOOTING CHECKLIST

First define the problem. Second, locate the cause. A list of possible causes follows:

Bonding Tool - Possible leak through the tool if there is an integrated vacuum system or at tooling pin/hole location and between plies on non-wet tooling.

Breather Material - Check that no resin flow or adhesive bleedout can come into contact with breather.

Bridging of the Material - Caused by inadequate "ears" or pleats at corners. Causes void areas in the part.

Gages - Ensure all instruments & gages have been certified.

Hoses - Can be damaged if improperly handled or stored.

Material Compatibility - Incompatible materials (adhesives, resins, sealants, breathers, bag films, tapes, etc.) can cause major problems.

Pinholes - Punctures in film can be caused by improper handling.

Quick Disconnects - Check O-rings for any sign of wear or deterioration, or any blockage from resin contamination and replace if necessary.

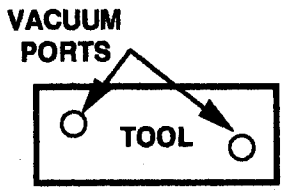
Sealant Tape - Check for improperly applied sealant tape.

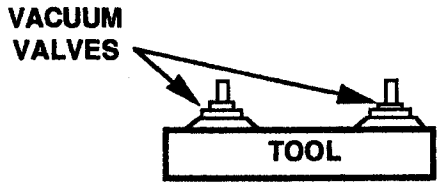
Thermocouple Wires - Make sure TC wires are in excess trim area only, and not in bondline or finished molded part. Check also to be sure no TC wires are between plies of layup. Locate only on surface in excess trim areas. Check for bent or kinked TC wires. Be sure wires in TC plugs are correctly connected with respect to polarity. **Caution:** TC wires with glass insulation should be avoided whenever possible.

Tooling Pins - Cover or pad all tooling pins and locating pins to prevent rupture of the bag.

Vacuum Lines - should be checked for obstruction in the lines, such as cured resin, etc.

Vacuum Ports - Make sure there is no tape or sealant over vacuum or probe ports on tool surface. (See drawing below.)





GLOSSARY

A

absorption. Penetration of one substance into the mass of another.

accelerator. Accelerators are added to an epoxy resin-curing agent mixture to speed up a sluggish reaction.

aging. Effect on materials of exposure to an environment for an interval of time.

air-bubble void. Entrapment of air between plies or in a bond line.

ambient. Surrounding environmental conditions, such as pressure, temperature or relative humidity.

angle-ply laminate. A laminate with fibers of adjacent plies oriented at alternating angles.

anti-static agents. Agents that, when added to a molding material or applied to a surface make the material less conducting, hindering the attraction of dust or build-up of electrical charge.

areal weight. Weight of fiber per unit area (width x length) of tape or fabric.

autoclave. Pressure vessel in which assemblies are placed for curing when even pressure and temperature is required.

B

bag molding. Technique for producing molded parts by fluid pressure through a flexible membrane.

bagging. Applying an impermeable layer of film over an uncured part and sealing edges so a vacuum can be drawn.

barrier film. Layer of film used to permit removal of air and volatiles from a composite lay-up during cure while minimizing resin loss.

batch (or lot). A quantity of material formed during the same process and having identical characteristics.

binder. Bonding resin used to hold strands together in a mat or preform during manufacture of a molded object.

blanket. Material plies that have been laid up in a complete assembly and placed on or in the mold all at one time. Also the form of bag in which the edges are sealed against the mold.

bleeder cloth. Woven or nonwoven layer of material used in manufacturing composite structures to allow the escape of excess volatiles and resin during the cure cycle. The bleeder cloth is removed after the curing process and is not part of the final part.

bleeding. Removal of excess resin from a laminate during cure.

blow-by. Flow or leakage of internal air pressure through the part and out through the vacuum vent lines that exhaust to the atmosphere.

bond. Adhesion of one surface to another, with or without the use of an adhesive as a bonding agent.

breather cloth. Loosely woven material that serves as a continuous vacuum path over a part, but is not in contact with the resin.

breathing. Opening and closing of a mold to allow gas to escape early in the molding cycle. Also known as degassing.

bridging. Condition where one or more plies of prepreg,bag film, breather, release film, tape, fabric, etc., span a radius, stop or chamfered edge or core without full contact. See Fig. 3, page 4.

bundle. General term for a collection of parallel filaments or fibers.

C

carbon fibers. Fibers made from a precursor by oxidation and carbonization and not having a graphitic structure.

caul plate. Smooth metal plate free of surface defects, the same size and shape as a composite lay-up, used in immediate contact with the lay-up during the curing process to transmit normal pressure and temperature and to provide a smooth surface to the finished part.

cavity. Depression in a mold; the space inside a mold where resin is poured; the female portion of a mold. Molds are designated as Single Cavity or Multiple Cavity, depending on the number of depressions.

clamping plate. Mold plate fitted to the mold and used to fasten the mold to the machine.

clamping pressure. In injection molding and in transfer molding, the pressure which is applied to the mold to keep it closed; in opposition to the fluid pressure of the compressed molding material.

cocuring. The act of curing a composite laminate and simultaneously bonding it to some other prepared surface during the same cure cycle.

coefficient of thermal expansion. The change in volume per unit volume produced by a one-degree rise in temperature.

compaction. The application of a temporary vacuum bag and vacuum to remove trapped air and compact the layup.

composite. A material containing two or more distinctive materials (fillers, reinforcing materials and compatible plastic resin) designed to develop specific performance properties.

contact pressure resins. Liquid resins that thicken on heating, and when used for bonding laminates, require little or no pressure.

continuous filament. A yarn or strand in which the individual filaments are the same length as the strand.

coupon. Specimen for a specific test, such as tensile coupon.

crazing. Apparent fine cracks at or under the surface of an organic matrix.

crossply. Any filamentary laminate in which the laminae are at right angles to one another.

cure. To change the properties of a resin by chemical reaction, which may be condensation or addition; usually by either heat or catalyst, or both, with or without pressure.

cure cycle. The cycle of time/temperature/pressure used to cure a thermosetting resin system or prepreg.

curing agent. Catalytic or reactive agent which, when added to a resin, causes polymerization. Also called "hardener."

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

curing time. Length of time a part is subjected to heat, pressure, or both, to cure the resin.

cycle. Complete, repeating sequence of operations. In molding, the cycle is the period, between a certain point in one cycle and the same point in the next.

D

debond. A deliberate separation of a bonded joint or interface, usually for repair or rework purposes.

debulking. Compacting of a prepreg stack under moderate heat, pressure and/or vacuum to remove most of the air, to ensure seating on the tool and to prevent wrinkles.

deformation. Change in shape of a specimen caused by the application of a load or force.

delamination. Separation of layers of material in a laminate.

denier. A numbering system for expressing linear density, equal to the mass in grams per 9000 meters of yarn, filament, fiber, or other textile strand.

density. The mass per unit volume.

deviation. Variation from a specified dimension or requirement.

disbond. Area within a bonded interface between two adherends in which an adhesion failure or separation has occurred.

dry fiber area. Area of fiber not totally encapsulated by resin.

dry lay-up. Construction of a laminate by layering pre-impregnated reinforcement (partly cured resin) in a mold, usually followed by bag-molding or autoclave molding.

ductility. The ability of a material to deform plastically before fracturing.

dwell. A pause in the application of pressure to a mold, made just before the mold is completely closed, to allow the escape of gas from the molding material. Also can be used for staging temperature for gel point control.

E

end. A single fiber, strand, roving or yarn being or already incorporated into a product.

elongation. Deformation caused by stretching.

extensometer. A device for measuring linear strain.

F

fabric. A material constructed of interlaced yarns, fibers, or filaments. Nonwovens are sometimes included in this classification.

fabric fill face. Side of the woven fabric where the greatest number of the yarns are perpendicular to the selvage.

fabricating, fabrication. Manufacture of plastic products from molded parts, rods, tubes, sheeting, or extrusions, by punching, cutting, drilling and tapping. Fabrication includes fastening plastic parts together or to other parts by mechanical devices, adhesives, heat sealing or other means.

felt. A fibrous material made up of interlocked fibers by mechanical or chemical action, moisture or heat; made from asbestos, cotton, glass, etc.

fiber. Term used for filament materials.

fiber content. The amount of fiber present in a composite.

fiber direction. Orientation or alignment of the longitudinal axis of the fiber.

fiber-reinforced plastic (FRP). Term for composite that is reinforced with cloth, mat, strands, or any other fiber form.

filament. The smallest unit of a fibrous material. Filaments are usually of extreme length and very small diameter.

filament winding (continuous). An automated process in which continuous filament strands are resin-treated and wound on a removable mandrel in a pattern.

fill. Yarn running from selvage to selvage at right angles to the warp in a woven fabric.

filler. Inert material added to a resin mixture to reduce cost, modify mechanical properties, add color, or improve surface texture.

filling yarn. Transverse threads or fibers in woven fabrics, running perpendicular to warp. Also known as weft.

fish-eye. Small globular mass which has not blended completely into the surrounding material and which shows particularly in a transparent or translucent material.

flash. Extra plastic which has flowed out of the mold cavity during molding, along the parting line which must be removed. Also adhesive flash and resin flash in vacuum/autoclave bonding.

G

gel. The initial jelly-like solid phase that develops during the formation of a resin from a liquid. A semi-solid system consisting of solid aggregates in which liquid is held.

gel coat. A resin applied to the surface of a mold and gelled prior to lay-up. The gel coat becomes an integral part of the finished laminate, and is usually used to improve surface appearance and bonding.

gel point. The stage at which a liquid begins to exhibit pseudoelastic properties. Also known as "gel time."

graphite fibers. Fibers made from a precursor by oxidation, carbonization, or graphitization process (which provides a graphitic structure.)

greige. Fabric that has received no finish.

H

hand lay-up. The process of placing successive plies of reinforcing material or resin-impregnated reinforcement in position on a mold by hand.

hardness. Resistance to deformation; usually measured by indention. Types of standard tests include Brinell, Rockwell, Knoop and Vickers.

heat cleaned. Glass or other fibers which have been exposed to elevated temperatures to remove preliminary sizings or binders which are not compatible with the resin system to be applied.

heat sealing. Method of joining plastic films by applying heat and pressure simultaneously.

heterogeneous. Term for a material consisting of dissimilar materials.

homogeneous. Term for a material of uniform composition throughout.

hot wet lay-up. A method of fabricating a reinforced product by applying a hot resin system as a liquid when the reinforcement is in place. Hot setting adhesive/resin requires a temperature at or above 100°C (212°F) to set.

humidity, relative. The ratio of the pressure of water vapor present to the pressure of saturated water vapor at the same temperature.

hybrid. A composite laminate comprised of laminae or fibers of two or more composite material systems.

hydraulic press. Press in which molding force is created by the pressure exerted by a fluid.

hydroclave. A pressure vessel that uses water as the pressure medium. A hydroclave can be pressurized to 3000 psi. The risk of explosion or fire is considerably less in a hydroclave.

hydrophobic. Capable of repelling water.

hygroscopic. Capable of adsorbing and retaining atmospheric moisture.

I

impregnate. In reinforced plastics, the saturation of the reinforcement with a resin.

impregnated fabric. A fabric impregnated with a synthetic resin. (See pre-preg.)

inclusion. A physical and mechanical discontinuity occurring within a material or part, usually consisting of solid, encapsulated foreign material.

insulator. Material which conducts minimal electric current or heat.

integrally heated. Tooling which is self-heating, through electrical heaters such as cal rods. Most hydroclaves are heated integrally.

interlaminar. Term pertaining to the area existing between two or more layers of a laminate.

K

Kevlar. Organic polymer composed of aromatic polyamides.

knitted fabrics. Fabrics produced by interlooping chains of yarn.

L

laminate. To unite sheets of material by a bonding material, usually with pressure and heat, commonly referring to flat sheets. A product made so by bonding.

lay-up. As used in reinforced plastics, the reinforcing material placed in position in the mold; the process of placing reinforcing material in position in the mold. A description of the component materials of a laminate.

M

mandrel. A fixture or male mold used for the base in the production of a part by layup or filament winding.

mat. A fibrous material consisting of randomly oriented chopped filaments or swirled filaments with a binder; available in blankets of various widths, weights, and lengths.

mat binder. Resin applied to the fiber and cured during the manufacture of mat, to hold the fibers in place and maintain the shape of the mat.

matrix. The essentially homogeneous material in which the fiber system of a composite is embedded.

moisture absorption. The pick-up of water vapor from air by a material. It relates only to vapor withdrawn from the air by a material and must be distinguished from water absorption, which is the gain in weight because of the take-up of water by immersion.

mold. Cavity into which the plastic composition is placed, and from which it takes form; to shape plastic parts by heat and pressure.

mold-release agent. A liquid, powder or wax used to prevent sticking of molded articles in the cavity. (See parting agent.)

mold surface. Side of laminate that faced the tool.

molding. Shaping of a plastic composition in or on a mold, usually under heat and pressure.

molding cycle. Period of time for the complete sequence of operations to take place on a molding press.

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

monomer. A relatively simple compound which can react to form a polymer.

N

nesting. Placing of plies of fabric so that yarns of one ply lie in the valleys between the yarns of the adjacent ply (nested cloth).

nonwoven fabric. Material produced by compressing together yarns, fibers, rovings, with or without a scrim carrier.

nylon. Generic name for all synthetic polyamides.

O

out-time. The time a prepreg is exposed to ambient temperature, i.e., the total amount of time the prepreg is out of the freezer. The primary effects of out time are to decrease the drape and tack of the prepreg while also allowing it to absorb moisture from the air.

overcuring. The beginning of thermal decomposition because of too high a temperature or too long a molding time.

oven dry. The condition of a material that has been heated under prescribed conditions of temperature and humidity until there is no further significant change in its mass.

overlay-sheet. A non-woven fibrous mat (in glass, synthetic fiber, etc.) used as the top layer in a cloth or mat lay-up to give a smoother finish, or minimize the appearance of the fibrous pattern.

P

PAN fibers. Polyacrylonitrile spun and stabilized fibers.

parting agent. Lubricant or release agent used to coat a mold or cavity to prevent the molded piece from sticking to it, making it easier to remove.

peel ply. Outside layer of a laminate which is removed to achieve improved bonding of additional plies. The peel ply can be left on for greater protection during handling.

peel strength. Adhesive bond strength, as in pounds per inch of width, tested by stress applied in a peeling mode.

pH. A measure of acidity or alkalinity of a solution, with the value of 7 representing neutrality, and increasing acidity corresponding to lower values, and increasing alkalinity corresponding to higher values.

pick. An individual filling yarn or roving in a fabric.

pick count. The number of filling yarns per inch of woven fabric.

pin holes. Small cavities penetrating the surface of a cured part, or holes in bag film.

pitch fiber. Fibers derived from a special petroleum pitch.

plasticizer. A material of lower molecular weight added to a polymer to separate the molecular chains.

pleats. In placing the vacuum bag over the part, pleats in the bag provide extra material over the part to eliminate bridging and possible voids in the laminate. Pleats are at least two to three inches in height, every two to three feet, as necessary, to allow room for unusual shapes or for protrusions in the lay-up without danger of puncturing the bag. (See drawing on page 6.)

polymer. An organic material composed of molecules characterized by the repetition of one or more types of monomeric units.

polymerization. A chemical reaction in which the molecules of monomers are linked together to form polymers.

porosity. A condition of trapped pockets of air, gas, or vacuum within a solid material.

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

post-cure. Additional elevated temperature cure, usually without pressure, to complete the cure. In certain resins, complete cure is attained only by exposing the cured resin to higher temperatures after the original cure cycle.

pot-life. The length of time that a catalyzed resin system retains a viscosity low enough to be used in processing.

precursor. Either the PAN or pitch fibers from which carbon and graphite fibers are derived.

prefit. Method for checking the fit of mating parts before bonding.

preimpregnation. See *prepreg.*

prepreg. Ready-to-mold material in sheet form which may be cloth, mat, or paper impregnated with resin and stored for use. The resin is partially cured to a "B" stage and supplied to the fabricator who lays up the finished shape and completes the cure with heat and pressure.

pressure. There are various kinds of pressure: dead weight, vacuum, super-heated steam, fluid water pressure, compressed air, and inert pressure. Dead-weight pressure is preferred for room temperature curing of parts. Vacuum pressure requires bagging to evacuate the air in a part. Vacuum produces 14.5 psi pressure. Super-heated steam pressure has become obsolete because of plumbing corrosion, and the expense of replacing valves, pipes, etc. Fluid or water pressure, (hydraulic pressure) is common in hydroclave operations. The main requirement is to have sufficient pressure on the part in all directions to obtain a void-free assembly.

pressure bag molding. A process for molding reinforced plastics, in which a tailored flexible bag is placed over the contact lay-up in the mold, sealed and clamped in place. Fluid pressure, usually compressed air, is placed against the bag, and the part is cured.

R

reinforced plastic. A plastic with relatively high stiffness or very high strength fibers imbedded in the composition.

release agent. A material applied in a thin film to the surface of a mold to keep the resin from sticking to the mold.

resin. Organic material which flows when subjected to stress. Most resins are polymers.

resin content. The amount of matrix present in a composite either by percent weight or percent volume.

resin-starved area. Area of composite part where the resin has a non-continuous smooth coverage of the fiber.

rupture. Cleavage or break from physical stress.

S

sample. A small portion of a material or product intended to be representative of the whole.

scrim. A low cost, nonwoven open-weave reinforcing fabric made from continuous filament yarn in an open mesh.

sealant. Material in paste or liquid form that hardens or cures in place, forming a seal.

selvage. Outer woven-edge of a fabric parallel to the warp or length.

shelf life. Length of time a material can be stored and retain all its original characteristics.

shrinkage. Relative change in dimension between the length measured on the tool when it is cold and the length measured 24 hours after it has been removed.

solute. The dissolved material.

specific gravity. The density or mass per unit volume of a material divided by the density of water.

splice. Joining of two ends of glass fiber yarn or strands usually by means of an air-drying adhesive.

spray-up. Techniques of using a spray gun as the processing tool. In reinforced plastics, fibrous glass and resin can be simultaneously deposited in a mold.

staging. An intermediate stage of a thermosetting resin that is between monomer stage and complete cure.

starved area. An area in a plastic part which has too little resin to wet out the reinforcement completely. This may be caused by improper wetting or excessive molding pressure.

starved joint. An adhesive joint which does not have enough film thickness of adhesive due to insufficient adhesive spreading or because of excessive pressure during lamination.

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 called *shelf life.*)

stress crack. External or internal crack caused by mechanical stresses

surfacing mat. A very thin mat, usually 7 to 20 mils thick, of highly filamentized fiber glass used to produce a smooth surface on a reinforced plastic laminate.

T

tack. Degree of stickiness when referring to a resin prepreg material.

tape. Unidirectional prepreg material.

thermocouple. Thermocouples are used to measure and record temperature differential in the part being cured. Thermocouple wires are usually placed in the flash or trim area. These wires can be iron constantine, type J, or equivalent and chrome alumel Type K. The chrome alumel TC wires are usually used where the cure temperature is very high, such as 800°F+. Wires must not be bent or crimped, as they will become inoperable.

thermoplastic. A plastic material that is capable of being repeatedly softened by application of heat and repeatedly hardened by cooling.

thermoset. Plastic material that changes, during cure, into an infusible and insoluble material.

time. The interval between events, i.e., start and completion of a cure cycle.

tow. Untwisted bundle of continuous filaments or fibers.

tracer. A fiber added to a prepreg to verify fiber alignment.

U

unbond. An area within a bonded interface between two adherends in which the intended bonding action failed to take place. (See debond.)

unidirectional laminate. A laminate with nonwoven reinforcements and all layers layed up in the same direction.

V

vacuum. A state of being sealed off from external/environmental influences; state of emptiness. A near-perfect vacuum is 14.5 psi or 29.5 Hg. NOTE: Two inches of mercury (Hg) is comparable to one psi pressure. (See Pressure Conversion Table in Appendix A.)

vacuum bag molding. A process in which a sheet of flexible material, plus a bleeder cloth and release film are placed over the lay-up, sealed at the edges of the mold, and a vacuum is applied between the bag and the lay-up. The entrapped air is removed by vacuum and the part is cured with temperature, pressure, and time. The part is bagged to remove excess air and volatiles, and also to apply an even distribution of pressure during the cure cycle.

vent cloth. Layer or layers of open-weave cloth to provide a path for vacuum to reach the area over a laminate being cured.

venting. In curing a part in an autoclave, turning off vacuum source and venting vacuum bag to the atmosphere.

voids. Air or gas that has been trapped and cured into a laminate.

volatiles. Materials in a resin formulation that are driven off as vapor during cure cycle.

W

warp. Yarn running lengthwise in a woven fabric. (See "fabric fill face").

water absorption. Ratio of the weight of water absorbed by a material to the weight of the dry materials.

weave. Particular manner in which the fabric is formed by interweaving yarns.

wet lay-up. A method of making a reinforced product by applying the resin system as a liquid while the reinforcement is put into place.

whisker. A short single crystal fiber or filament. Whisker diameters range from 1 to 25 microns, with aspect ratios between 100 and 15,000.

working life The period of time during which a liquid resin or adhesive, after mixing with catalyst, solvent, or other compounding ingredients, remains workable. (see also **pot life**)

wrinkle. A surface imperfection in laminated plastics in one or more outer sheets of paper, fabric or other base which has been pressed in or out.

X

X-axis. In composite laminates, an axis in the plane of the laminate which is used as the 0 degree reference for designating the angle of a lamina.

Y

yarn. A generic term for strands or bundles of continuous filaments or fibers usually twisted and suitable for making textile fabric.

yarn, plied. Yarns made by collecting two or more single yarns together. Normally the yarns are twisted together, though sometimes they are collected without twist.

Z

zero bleed. A laminate fabrication procedure that does not allow loss of resin during cure. Also called "net resin systems".

APPENDICES

APPENDIX A
TABLES

Table I - PRESSURE CONVERSION TABLE

INCHES Hg VACUUM	PSI
1	0.491
2	0.982
3	1.473
4	1.964
5	2.455
6	2.946
7	3.437
8	3.928
9	4.419
10	4.912
11	5.401
12	5.892
13	6.383
14	6.874
15	7.365
16	7.856
17	8.347
18	8.838
19	9.329
20	9.820
21	10.311
22	10.802
23	11.293
24	11.784
25	12.275
26	12.766
27	13.257
28	13.748
29	14.239
30	14.730

Table II - TEMPERATURE CONVERSION TABLE

To convert temperatures to Fahrenheit: Degrees Centigrade X 1.8 + 32
To convert temperatures to Centigrade: Degrees Fahrenheit –32 ÷ 1.8

C° to F°	C° to F°	C° to F°	C° to F°	C° to F°	C° to F°
50 122	96 204	138 280	181 357	224 435	335 635
51 123	97 206	139 282	182 359	225 437	340 644
52 125	98 208	140 284	183 361	226 438	345 653
53 127	99 210	141 285	184 363	227 440	350 662
54 129	100 212	142 287	185 365	228 442	355 671
55 131	101 213	143 289	186 366	229 444	360 680
56 132	102 215	144 291	187 368	230 446	365 689
57 134	103 217	145 293	188 370	231 447	370 698
58 136	104 219	146 294	189 372	232 449	375 707
59 138	105 221	147 296	190 374	233 451	380 716
60 140	106 222	148 298	191 375	234 453	385 725
61 141	107 224	149 300	192 377	235 455	390 734
62 143	108 226	150 302	193 379	236 457	395 743
63 145	109 228	151 303	194 381	237 458	400 752
64 147	110 230	152 305	195 383	238 460	405 761
65 149	111 231	153 307	196 384	239 462	410 770
66 150	112 233	154 309	197 386	240 464	415 779
67 152	113 235	155 311	198 388	241 465	420 788
68 154	114 237	156 312	199 390	242 467	425 797
69 156	115 239	157 314	200 392	243 469	430 806
70 158	115 239	158 316	201 394	244 471	435 815
71 159	116 240	159 318	202 396	245 473	440 824
72 161	117 242	160 320	203 397	246 474	445 833
73 163	118 244	161 321	204 399	247 476	450 842
74 165	119 246	162 323	205 401	248 478	455 851
78 172	120 248	163 325	206 402	249 480	460 860
79 174	121 249	164 327	207 404	250 482	465 869
80 176	122 251	165 329	208 406	255 491	470 878
81 177	123 253	166 330	209 408	260 500	475 887
82 179	124 255	167 332	210 410	265 509	480 896
83 188	125 257	168 334	211 411	270 518	485 906
84 183	126 258	169 336	212 413	275 527	490 914
85 185	127 260	170 338	213 415	280 536	495 923
86 186	128 262	171 339	214 417	285 545	500 932
87 188	129 264	172 341	215 419	290 554	505 941
88 190	130 266	173 343	216 420	295 563	510 950
89 192	131 267	174 345	217 422	300 572	515 959
90 194	132 269	175 347	218 424	305 581	520 968
91 195	133 271	176 348	219 426	310 590	525 977
92 197	134 273	177 350	220 428	315 599	530 986
93 199	135 275	178 352	221 429	320 608	535 995
94 209	136 276	179 354	222 431	325 617	
95 203	137 278	180 356	223 433	330 626	

APPENDIX B
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