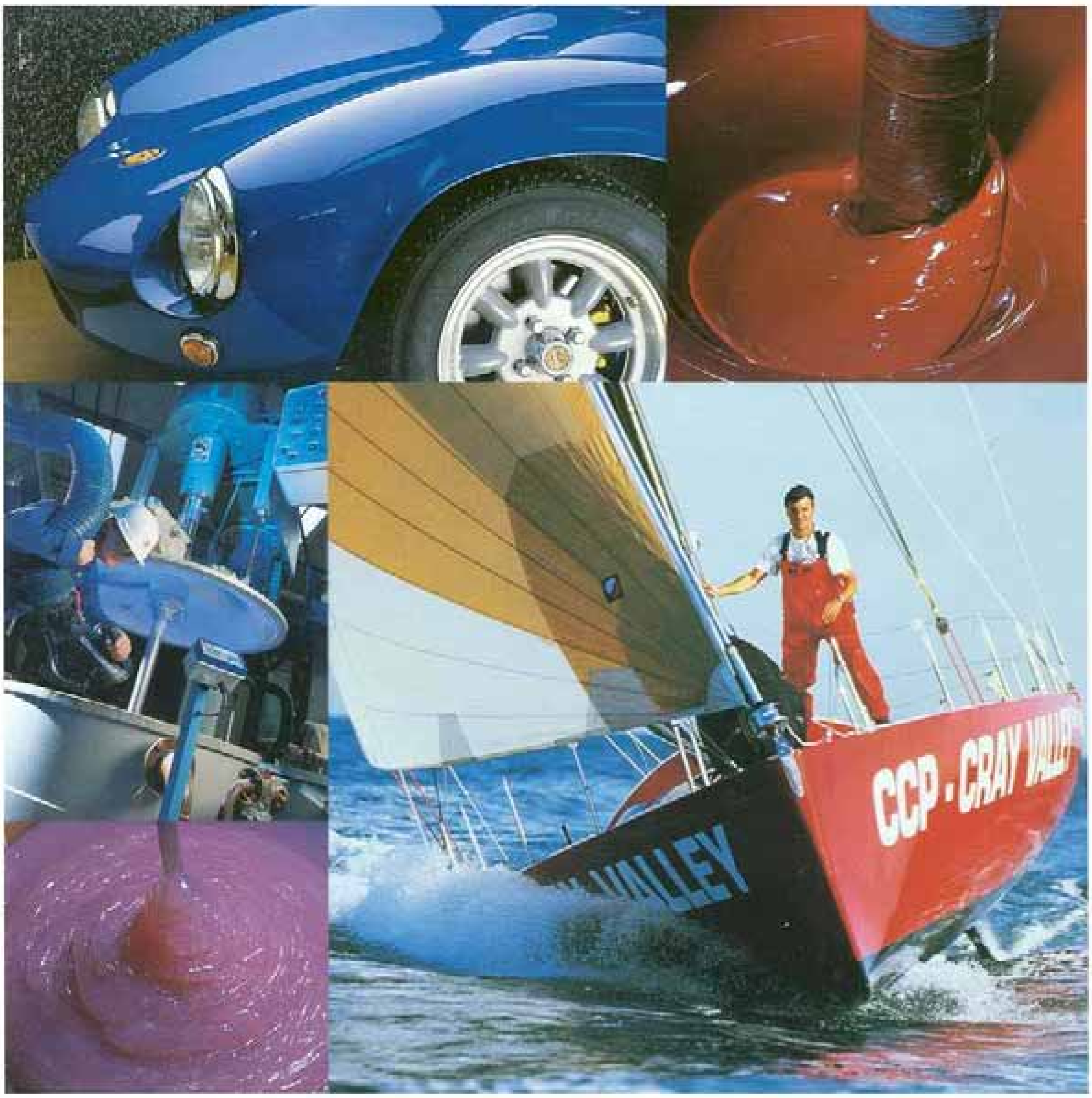
UNSATURATED POLYESTER

APPLICATION GUIDE



CCP

CRAY VALLEY

The unsaturated resins and gel coats from the Structural Resins Department are manufactured within our Resins Division by Cray Valley in Europe and Cook Composites and Polymers in the United States of America.

These two companies form the geographic bases for the international development of our products in the glass reinforced materials industry.

For many years, CCP have published their "Polyester Products Application Manual" and this has become an industry reference for processors in the USA.

Today, we are proud to offer our version to our European customers.

This manual provides a wide range of information on the use of resins and gel coats in manufacturing structural polyester composites.

This guide highlights our commitment to progress, better understanding of processing technologies, safety, and the protection of the environment.

With this guide, we hope to contribute towards the success of our mission.

RESPONSIBLE
CARE

CRAY VALLEY - CCP PRODUCTS AND TRADEMARKS

POLYESTER RESINS

Unsaturated Polyesters
Hybrid Polyesters

ENYDYNE® NORSODYNE® SYNOLAC® STYPOL® PROCORE® ESTRATIL® RESIPOL® STRATYL® ArmorStar® OPTIMOLD®	The unsaturated polyesters developed by CRAY VALLEY and CCP are designed to guarantee highest performance, value for money and improved application, with constant concern for workplace and environmental safety.

GEL COATS

POLYCOR®	As world leaders in gel coats, CRAY VALLEY and CCP possess the technical and human assets to master the problems of surface finish for polyester parts with products that combine application ease with outstanding performances in areas ranging from weather resistance to aging.

BONDING PASTE AND POLYESTER SEALANTS

GRAVICOL	In addition to gel coats and polyester resins, this range of derivative products offers transformers a range of bonding pastes for reinforced plastics.

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1 INTRODUCTION

It is increasingly recognised that health and safety is of paramount importance to an organisation and that every employee shares in this responsibility. It is accepted that any industrial activity incurs risk. The cornerstone of the health and safety management system should be the systematic procedures for the management of these risks. These procedures at a minimum should include risk assessment, organisation & methods, performance measurement, auditing and review. Responsibility for effective performance of the safety management system ultimately lies with the managing director of the organisation. He should define the health and safety policy and the means for enactment.

The manufacture of Fibre-Reinforced Plastics requires the fabricator to handle a number of potentially hazardous chemicals. In the UK, the COSHH regulations 1994 (Control of Substances Hazardous to Health) define the principles of chemical hazard management. The regulations require that the inherent chemical hazards of materials used at any installation are considered in relation to the manner in which they are used. This constitutes the basic risk assessment. Measures must be in place to minimise employee exposure to hazardous substances. The following hierarchy of preventive measures should be employed:

- Elimination of the hazardous substance and/or the associated process.
- Substitution of the same.
- Isolation.
- Procedural measures
- Personal protective equipment

The control measures should employ the best available techniques not entailing excessive cost (BATNEEC).

The information in this section is of a general nature only. The exact compliance required must be determined by the user of the product. Information concerning hazards of material that you use can be found on the Material Safety Data Sheets (MSDS) and labels. You must read these documents.

Information concerning health and safety regulations can be obtained from appropriate governing bodies. At the end of this section are a list of sources and references where more detailed information can be obtained.

Note that this section is not meant to be a comprehensive study or a complete list of all hazards that exist when using polyesters. We cannot predict all possible conditions of use.

2 SAFETY IN GENERAL

Every FRP plant must have a safety programme with at least one person assigned to and directly responsible for safety. It cannot be a sporadic operation. The largest fire losses, and greatest fire frequency and health hazards have occurred where good practice standards were not established or observed.

This person should be responsible for the written safety programme, and training of employees. The Safety supervisor and the employees should be aware of all hazards, the necessary precautions and the accident reporting procedure.

Safety audits should be carried out at regular intervals. You must have a file on Material Safety Data Sheets (MSDS) and other safety data including label precautions for all potentially toxic and hazardous materials found in your work area. Supervisors as well as workers should be aware of what steps should be taken in case of accidental employee contact with these materials. ***DO NOT wait until you have an emergency before you find out what must be done!***

3 FIRE HAZARDS

A fire is destructive and costly. It can start from a simple cause or a complicated one. Knowing how fires start is the surest way of knowing how to prevent one.

There are three elements necessary for any fire - (a) fuel, (b) oxygen and (c) heat or ignition source. If you remove any one of these items, a fire cannot occur.

■ FUEL

You must have fuel in sufficient quantity for a fire. All polyesters in the liquid state are a fuel source. Most are a fuel source when cured or as a dust.

Most clean-up solvents are fuel sources as are catalysts and waxes. Every plant has the usual fuel sources of paper, rags, wood, cardboard boxes, trash, etc.

All fuel sources must be carefully controlled and minimised.

Polyesters are found in four states in a plant: Liquid, vapour, solid, and dust.

Of these, the vapour and dust states are the most dangerous as they put the fuel in its most finely divided form which can burn extremely fast or even explosively. All unnecessary vapours and dusts must be avoided. Keep containers closed or covered as much as possible. Dust should be reduced and not allowed to accumulate.Vapours are created from spraying, heat from curing parts, evaporation, etc.These can spread or collect in almost any area of a plant, not just in working areas. Most vapours from polyesters are heavier than air and may collect in low spots where there is little air movement.Vapours and dust must be removed from a plant.This is normally done by good mechanical ventilation.

Air containing vapours must be diluted to a ratio outside of the explosive range.Vapours of flammable liquids burn or explode when their ratio to air are within certain limits. Limits vary with material, for example the limits for styrene are 1.1% and 6.1% by volume in air.

Most solvents have a lower flash point than polyesters in styrene and should be treated as highly flammable liquids which produce highly flammable vapours. Some local codes limit the amount of high volatility solvents that can be used.

NOTE: The Department of the Environment has regulations on exhausting and/or discharging materials directly into outside air. These must be complied with.

The liquid state is the next most dangerous. It is essential to keep uncatalysed polyesters in closed metal or plastic containers when not in use and stored in a separate area away from the work area until needed. Do not store in direct sunlight or where excess heat build-up can occur. Wipe up or remove all spills or overspray as soon as possible.

Catalysts must be handled according to the manufacturer's recommendations. Organic peroxides can be explosive and are the most dangerous fuel in a plant.They should be kept in their original containers, out of direct sunlight, not exposed to heat, free from contamination, and closed when not in use. Catalysts are oxidising materials which will react (at times explosively) with reducing agents, such as cobalt accelerator, metals and strong acids. Catalysts should never be diluted with acetone. If diluted catalyst is necessary, use only diluents recommended by the catalyst manufacturer. Catalyst must always be kept or used in containers which will not react with the catalyst. Consult your catalyst and spray equipment suppliers for specific recommendations. Overspray and catalyst mist must be minimised.They must be wiped up and removed immediately. See manufacturer's recommendations.

The last condition is the solid state.The most dangerous solids are trimmings, overspray and trash as they are thin ragged sections which can be ignited easily.These should not be allowed to accumulate.All trash should be removed at least once a day, but in high-volume usage it may be necessary to do it hourly, if not continuously. Do not allow waste to come in contact with catalysed polyesters.

The cured parts are relatively safe as they are harder to ignite, but they will burn!

Special care must be taken with catalysed polyesters, e.g. overspray and gun flushings, as these mixtures have the combined hazards of all the individual materials (polyester, catalyst,. Solvent, etc.) plus the chemical reaction between the polyester and catalyst produces heat which can cause ignition of solvents, unmixed catalyst, and other flammable materials. The amount of heat generated will depend on amount of catalyst, degree of mixing, temperature, mass and resin reactivity. Catalysed polyesters must not be allowed to accumulate. Gelled masses should be removed at once or temporarily immersed in large amounts of water until they can be removed.

Waxes and mould release agents are also flammable. Care and caution must be used with this type of material and the materials used in their application and removal. See the manufacturer's instructions for handling, use and storage.

HEALTH, SAFETY & ENVIRONMENTAL REGULATIONS

■ OXYGEN

Oxygen is necessary for any fire. There are two main sources of oxygen - air and chemically combined oxygen in the material itself. All volatile materials must be within certain ratios with air or oxygen to burn or explode. With polyesters, as with most other fuels found in a fibreglass shop (note: peroxides are special cases), good mechanical ventilation can dilute the fuel below its explosive limit.

Peroxides contain chemically combined oxygen which can be very easily liberated for combustion by heat, chemical reaction, decomposition, contamination, etc. Combine this property with the fact that peroxides are also a fuel and all that remains for a fire is heat or a source of ignition. Because of this, peroxides require great care to be used safely. Storage should be in separate containers that are closed when not in use, and spills, gun flushings and overspray should be removed immediately. **See manufacturer's recommendations.**

■ HEAT

Heat or a source of ignition is necessary for a fire. This can be a match, cigarette, flame, hot filament, exotherming polyester, heater, pilot light, spark (metal on hard surface or static), arcing of electric motor or wires, etc. The finer the fuel is broken up (vapour or dust) the smaller the ignition source necessary to start a fire.

To avoid these hazards, all sources of ignition must be removed from spray areas, working, and storage areas.

One source of heat that must not be overlooked is from the chemical reaction of polyesters and/or peroxides. Polyesters produce heat when they gel and cure. The amount of heat produced depends on the amount of catalyst and its degree of mixing, the temperature, the mass, and the reactivity. This is why trimmings, overspray, and flushed material from spray guns must not be allowed to accumulate. They should be removed at once or temporarily dispersed in large amounts of water until they can be removed. The more there is, the greater the probability for an uncontrolled chemical reaction. The heat produced from the exotherming polyester is sufficient to spontaneously ignite liquid catalyst or catalyst vapours.

A good safety programme does not try to reduce or minimise only one of the elements necessary for a fire but works to remove and/or control all three elements.

The «Flash Point Data» table on this page indicates that the use of acetone in a FRP workshop presents a real fire risk. Note also the considerable drop in the flash point of acetone containing materials when determined in a closed cup. The difference is less noticeable in the open cup determination.

FLASH DATA

	Open Cup Flash Point Tag (approx.)	**Closed Cup Flash (approx.)**
Acetone	-10°C (15°F)	-18°C (0°F)
Methyl Ethyl Ketone	-1°C (30°F)	-7°C (20°F)
Ethyl Acetate	4°C (40°F)	-4°C (24°F)
Styrene	37°C (98°F)	31°C (88°F)
Styrene and Polyester	63°C (145°F)	N/A
Polyester Gel Coats and resins	N/A	28°C (33°F)
Gel Coat-3%-Acetone	39°C (112°F)	11°C (52°F)
MEK Peroxide	Varies	82°C (180°F)
3 DAP/1 MEK Peroxide	121°C (250°F)	N/A
Diallyl Phthalate	166°C (330°F)	N/A
Dimethyl Phthalate	149°C (300°F)	N/A

This data definitively shows that there is a much greater hazard in the handling of gel coats with acetone, than gel coat without acetone.The hazard is greater in hot weather. We do not recommend the addition of acetone or any other solvent to gel coats or other unsaturated polyester products.

As with many synthetic materials, the consequences of fire involving polyester resins are exacerbated by the production of dense black, acrid smoke.This is the case whether the resin is liquid or cured. The following extinguishing agents may be used on styrene monomer and/or polyester fires: Dry powder, water fog, foam and carbon dioxide. If electrical equipment is involved, the use of foam or water should be avoided.

NOTE : Direct streams of water may spread a fire involving solvents or monomers due to incompatibilities and density differences (may float on water.) By proper handling of catalysts and accelerators, elimination of fumes and vapours, keeping the shop safe and clean, and some common sense, much can be done to lessen the risk of fire. Keeping these factors constantly in mind, a FRP operation can be made relatively safe.

4 GENERAL HAZARDS OF MATERIALS USED

■ CATALYSTS

You must read the MSDS's on your catalyst products.

In the reinforced plastics industry, several potentially dangerous materials must necessarily be handled.The catalysts required for polyesters are usually organic peroxides, such as MEK peroxide and benzoyl peroxide. By their nature, organic peroxides are usually highly flammable and may decompose with explosive violence under certain conditions.

Catalysts on the market have been tested for heat sensitivity, shock sensitivity, burning rate, flash point, storage stability, and reaction to blasting caps to determine their relative hazards. Obtain manufacturer's data sheets for relevant hazards and how to safely dispose of unwanted or old catalysts.

The catalyst storage building should be isolated from the primary plant, with only enough catalyst brought into the plant for that day's usage.

Catalyst should never be added to or allowed to come in contact with accelerator which has not been mixed well with large, diluting quantities of resin.The best procedure is to mix accelerator in the resin first until a homogeneous mix is obtained, then add the catalyst.

See manufacturer's handling precautions.

The general rule-of-thumb is to have a separate area for catalyst storage and blending and a separate area for accelerator storage and blending - each one on opposite sides of the working area.

The fact that only a very small amount of peroxide initiator can make such drastic changes to the physical properties of polyester resin should emphasise the importance of following the proper procedures in handling the commercial forms of these products. Failure to do so can lead not only to poor performance of the initiator but also, in some instances to violent decomposition.

Do not expose organic peroxides to any form of heat, such as direct sunlight, steam pipes, radiators, open flames or sparks. Heat may cause organic peroxides to decompose violently and they will burn if ignited. Never exceed the peroxide manufacturer's recommended storage temperature or conditions

Contamination is always a potential source of trouble in handling peroxide initiators. A few of these common sources of contamination, that may be found in a FRP facility are described as follows:

- ***Metals***

Do not let organic peroxides come in contact with easily oxidised metals such as copper, brass and mild or galvanised steel. If replacement parts must be installed on peroxide handling equipment, use the same materials of construction as specified by the manufacturer of the equipment.

Metal contamination, such as dust from grinding, can produce serious consequences. For example, installation of a brass relief valve on a «catalyst» pressure pot or a brass connector in a «catalyst» line could cause the peroxide that comes in contact with the brass to decompose. Under such confined conditions, the decomposing peroxide could quickly develop a pressure high enough to burst the pressure pot or to rupture the catalyst line.

Always store an organic peroxide in its original container. If it is necessary to transfer to measure out some peroxide use clean polyethylene, polypropylene, Teflon or stainless steel containers, funnels etc. **Once transferred, never return peroxide to the original container because of the risk of contamination**

- ***Promoters and Accelerators***

Never mix organic peroxides with promoters or accelerators. Such mixtures can be explosive. In addition, never contaminate catalyst with resin or resin overspray because the resin may contain enough promoter to decompose the peroxide.

The peroxide decomposition produces heat; this speeds up the action of the promoter which then produces more heat; and so the cycle can continue until the point is reached where the remaining peroxide decomposes violently.

- ***Solvents or Diluents***

If a solvent is used to clean organic peroxide handling equipment, be sure to dry off the solvent before using the equipment. Some solvents, such as acetone, can react with peroxides to form unstable peroxides of their own. Small amounts of these unstable «solvent peroxides» can cause the explosive decomposition of commercial peroxides.

If it is necessary to dilute an organic peroxide, be sure to consult with the peroxide manufacturer for compatible solvents. Never use contaminated solvents. Never use reclaimed solvents unless they have been tested by the peroxide manufacturer. For greatest safety, use diluted catalyst direct from the manufacturer.

- ***Other***

Contamination of peroxide handling equipment with resin or resin overspray can also be hazardous.A resin contaminated funnel used to charge a «catalyst» pressure pot, for example, could contain enough promoter to start decomposing the peroxide. A small amount of promoter goes a long way. It is not consumed, it just continues decomposing the peroxide. Other types of contaminants to be avoided when working with organic peroxides are dirt, polyester sanding dust, acids, bases and styrene. Further information on the proper handling of peroxides is available on request from catalyst manufacturers.

A few Basic Rules

- Read MSDS's (which should be accessible at material point-of-use)

- Catalyst and promoter, e.g., MEKP and cobalt should never be mixed directly with each other - violent reaction will occur!

- Catalysts should always be stored separately from promoters. Storage should be in an outside fireproof building. Consult your local insurance inspector and fire authorities for guidance.

- Catalysts should not be left haphazardly «sitting around». Only small portions (containers) should be in the work area.The container should be made of a suitable plastic such as Polyethylene.

- Always wear eye protection and rubber gloves. Face shields are also recommended.

- **NO SMOKING** around catalysts (or any polyester or associated materials)

- Catalysts should not be stored in a refrigerator that also contains food or water. They should never be poured into or stored in containers that could ever be mistaken for other materials such as a coke bottle, baby bottle, etc.

- Dilution of catalysts by the end user is not recommended.

Although the flash point of some catalysts is higher than other chemicals usually found in an FRP shop, it is misleading to think that catalysts are «safer» regarding a fire.True, it will take a higher temperature to get them to burn, but they will decompose and auto ignite sooner than other chemicals. Our concern is hot spots such as slop buckets, accumulated catalysed resin disposal, trash piles, exotherming cut-off's, etc., that catalyst is allowed to come into contact with.

The auto-ignition temperature of catalyst is not known, but a reliable catalyst supplier told us the actual decomposition temperature «is probably 63°C to 77°C, (145° - 170F).The auto-ignition temperature of catalysts would certainly be within the range of exotherming polyesters, possibly as low as 93°C (200°F). It would not be uncommon at all to find exotherming polyesters at 149°C (300°F), and above!

- Do not expose catalysts to any form of heat such as direct sunlight, steam pipes, radiators, open flames, or sparks.

- Do not let catalysts come in contact with easily oxidised metals such as copper, brass, and mild or galvanised steel.

- Most catalyst suppliers have safety programmes available (such as slides and films). Contact your supplier and have them give the programme to your work force.

- Always store catalysts at or below the recommended temperature as given by the manufacturer.

- We have been told that dyed catalyst is less stable than clear. Be cautious of inventories of dyed catalyst.

- These safety considerations are not all inclusive, and your catalyst supplier should be contacted for safety recommendations.

■ ACCELERATORS

Read your MSDS's

Some of the accelerators commonly used are extremely hazardous. Diethyl aniline and dimethyl aniline are particularly toxic and even small splashes should not be disregarded since they may be absorbed thorough the skin.

Headaches, nausea, breathing irregularities, or fainting may occur soon after breathing vapours of these materials. If quantities inhaled are excessive, even more severe reactions may occur.

HEALTH, SAFETY & ENVIRONMENTAL REGULATIONS

VOLATILE ORGANIC COMPOUNDS

Read your MSDS's

Some of the solvents and thinners can also have a toxic effect. Due to their volatility and frequent use, they can easily accumulate enough to cause a physiological reaction if inhaled over an extended period. For specific information regarding health hazards of individual products, consult the manufacturer's Material Safety Data Sheets.

The accumulation of styrene and solvent vapours provides one of the conditions for an explosion or flash fire and needs only a static spark or simple ignition to set it off. All foreign fumes and vapours, including those of styrene, which are so predominant around lay-ups, should be immediately removed by a good ventilation system.

STYRENE

We have received numerous phone calls asking how much styrene is emitted from resin and gel coats during the application procedures. These questions are usually prompted by environmental health, national or local regulations. The loss of styrene from polyester is unintended. Styrene is required by the polyester for proper cure. Styrene is the material and cross that links polyester polymer. Styrene, being a liquid, can evaporate. Excessive styrene emissions in the workshop impact on both the occupational health of employees and the subsequent pollution of the environment.

Styrene is lost from gel coats in two ways. When sprayed, gel coat is broken up into fine particles by pressure or air streams. Styrene evaporates as the gel coat travels from the end of the gun to the mould. The loss of styrene at this point depends upon temperature, air velocity, and degree of break up.

The second loss occurs as the gel coat sits on the mould until it is ready to lay up. The main loss is while it remains liquid. During this time period, the loss follows the evaporation rate of styrene. Once the material is gelled, evaporation drops of dramatically. This loss of styrene is influenced by the gel time, temperature, thickness, surface area, mould configuration, and air movement. Our work with a 20 mil(thou) film at 77°F, 25°C, and 15 minutes gel time shows a styrene loss of approximately 14%.

Depending on application equipment, temperature and gel time, you can expect polyester gel coats to lose normally 19-23% styrene into the air.

The loss of styrene from resins follows a similar pattern. Emissions can be divided between the dynamic working phase – spray-up/lay-up and consolidation – and the static curing phase. Our in-house studies have shown that with contact moulding the emissions breakdown to approximately 50/50% between the dynamic and static phases. With a general purpose laminating resin, the total styrene emission constitutes some 15% of the available styrene.

Emissions can be substantially reduced by substituting the open mould process for a closed mould process such as RTM. Where this is not practical, emissions from open moulds in the static phase can be reduced by LSE resins. Emissions can now be reduced further by the use of Low Styrene Content resins and gel coats which function in both the static and dynamic phases. Even when one or other of the above measures is employed, a well designed extraction system will still be required to control workshop styrene levels. The extraction system should be appropriate in size to the workshop area and should be directed to the highest concentrations of styrene. Further information can be found in the CEFIC/GPRMC Resin Handling Guide.

Styrene monomer is flammable and forms explosive mixtures with air.

The lower explosive limit is : 1.1%
The upper limit is : 6.1%
(By volume)

When styrene is present in concentration between these limits, any source of ignition will induce explosion.

The flash point of styrene* is 31°C (87.8°F); the fire point** is 34°C (93.2°F); autoignition*** temperature is 490°C(914°F). Adequate ventilation (especially the use of fume hoods) is to be recommended. Open flames, local hot spots, friction, and static electricity are to be avoided.

• Flash Point is the lowest temperature at which a substance gives off enough vapours to form a flammable or ignitable mixture with air near the surface of the substance being tested .

** Fire point is the lowest temperature at which a liquid in an open container will give off enough vapours to continue to burn once ignited. Fire points are generally slightly above flash points.

*** The auto ignition temperature or kindling temperature is the lowest temperature required to initiate or cause self-sustained combustion in the absence of a spark or flame.

5 COSHH

The Chemical Hazard Information & Packaging regulations 1994 (CHIP) define the requirements for the provision of hazard classification, labelling and hazard data (MSDS) in the supply of chemical substances and preparations. Fifteen hazard classificatins are defined with associated symbols.

- Explosive
- Oxidising
- Extremely flammable
- Highly flammable
- Very toxic
- Toxic
- Harmful
- Corrosive
- Irritant
- Sensitising
- Carcinogenic
- Mutagenic
- Toxic to reproduction
- Dangerous to the environment

For any specific substance or preparation, the hazard classification will be supplemented with standard risk and safety phrases. This information forms the basis of the hazard label and must also be incorporated into the MSDS. It is the responsibility of the supplier to provide a MSDS for each product supplied. It is the responsibility of the user to apply this hazard data in the course of risk and COSHH assessments.

The COSHH regulations are supplemented by the EH40 occupational exposure limits (OEL's) defined by the HSE. The limits state by substance the 8 hour time weighted exposure limit and the short term exposure limit (10 minute reference period) styrene is subject to a maximum exposure limit (MEL) of 100ppm .The higher hazard significance attached to a MEL requires that an employer reduces occupational exposure as far below this limit as is reasonably practicable.

NOTE: also that the UK composites sector is committed to a European voluntary code of practice where it has been pledged that the sector will work below 50ppm OEL. Compliance with OEL's requires that a periodic monitoring exercise is carried out: In the case of styrene, this is best done with reference to a HSE guidance note such as EH44 'Styrene diffusive solvent desorption/GC'.

Styrene is one of the substances to be considered in the first phase of the Existing Substances Regulations (ESR). The objective is to set a common OEL throughout the European Union. The HSE acting as rapporteur has compiled and presented the styrene risk assessment to the European Commission. This risk assessment compiles extensive data on occupational hygiene studies and animal studies. The data presented indicates that styrene is not genotoxic in vivo or carcinogenic, although further animal studies have been commissioned to complete some data gaps. At very high styrene concentrations there is evidence for irritation of the respiratory tract and depression of the central nervous system.

Materials can be hazardous depending on how they enter the body - through inhalation, taken internally or absorbed through the skin.

Some chemicals are dangerous when they enter the body through one rate only; others are dangerous through a combination of entries. Some individuals are more susceptible to toxic materials.

Any contact with toxic materials must be minimised. Liquids - polyester resin, solvent, catalyst, etc., should not be allowed to come in contact with the body. Where contact is unavoidable personal protective equipment (P.P.E.) clothing, gloves etc., must be used and all spills cleaned up at once.

If the possibility of vapour or dust is present, adequate ventilation is necessary and applicators in confined areas must wear «hood type respirators approved by H.S.E.»

NOTE: Air supplied to the hood must be absolutely clean and preferably dedicated for this purpose - no exhaust vapours or oil from compressor. All dust should be removed by adequate ventilation and an adequate face mask should be worn.

Current COSHH (EH 40) regulations require those who use gel coats that contain lead pigments to monitor worker exposure. At Cray Valley, we began a programme sometime ago to eliminate lead pigments.

6 ELECTRICAL HAZARDS

The two main hazards from electrical equipment are sparks and shock. All equipment, power lines, lights and connectors should be explosion-proof and fully earthed.

All sources of possible static should be eliminated. This includes spray guns, holding tanks, transfer lines, etc.

7 EQUIPMENT HAZARDS

A fibreglass shop uses a great many power tools. All tools, which have exposed turning parts, should have guards to prevent hands and clothing from being caught in them. All persons should be properly trained in the use of power tools. Spray guns should be grounded, worn fittings and hoses replaced.

NOTE: Airless spray equipment develops enough pressure to force material through the skin. Safeguards must be taken to prevent this from accidentally happening. Any person who sprays, regardless of equipment type, must be adequately trained and be made aware of how-to-protect himself and others from these hazards. See manufacturer's recommendations.

Before starting repairs on spray equipment or any equipment with moving parts or internal pressure, turn off and disconnect all power sources and bleed off ALL internal pressures. Care must be taken with chopper guns because of the cutting blades and glass roving, which can cut anything with which it comes in contact.

8 ENVIRONMENTAL MANAGEMENT

Care for the environment should go hand-in-hand with active safety management and preferably as part of an integrated system.The most probable source of pollution from FRP workshops are styrene emissions to air. FRP manufacturers must comply with the Environmental Protection Regulations 1991, S 1472 and specifically S 13247 (1995) which defines the processes under the auspice of local authority air pollution control. Guidance notes for FRP processes are detailed in PG4/2 (96).

There is currently a threshold for registration whereby the installation uses 100 tonnes or more styrene per annum corresponding to approximately 250 tonnes resin/gel. Styrene mass emission limits are defined by fabrication process type. For example, for contact moulding the limit is 60kg styrene emission per tonne of resin consumed. The process operator is required to monitor emissions, meet the emission limits, and to introduce measures to reduce emissions. The regulations also state that all emissions should be free from offensive odour outside the site boundary.The means to reduce environmental emissions fundamentally mirror the methods to reduce occupational exposure – closed mould processes, low styrene emission and low styrene content resins, high standards in process detail and housekeeping.

9 SOURCES OF DETAILED INFORMATION

In addition to a well run safety programme, three other programmes must be set up which will greatly reduce fire and health hazards.They are an efficient waste removal system coupled with a clean-up programme and a regular equipment and building maintenance programme. These three programmes, at times, seem costly and non-productive but in reality they save money, promote efficiency and job satisfaction.

The references, sources and equipment listed below is given as a guide only.This is not meant as a recommendation or endorsement of any of these products or services. They are listed as a starting point of the type of information that you should be seeking out in a library.

There are many sources of help in managing safety. The most overlooked and most concerned, outside of your shop are:

- Your insurance agency
- Local Fire Authority
- HSE
- Environmental Health

FURTHER REFERENCES AND SOURCES OF INFORMATION

- *GUIDANCE BOOKLET HS(G) TO THE STORAGE OF LIQUID IN FIXED TANKS (UP TO 10000M3) - HMSO 0-11-885532-8*
- *GUIDANCE BOOKLET HS(G) 51*

The storage of Highly Flammable Liquids in Containers
HMSO ISBN 0 11 885533-6

- *BRITISH STANDARD 2092*

Specification for Industrial Eye Protectors - British Standards Institute.

- *BRITISH STANDARD 4533 Section 2.1 : 1976*

Luminaries with type of protection 'N' - British Standards Institute

- *GUIDANCE NOTE:*

EH9 Spraying of Highly Flammable Liquids
HMSO ISB 0 11 883934 1

- *GUIDANCE NOTE:*

EH16 (Rev) Isocyantes: Toxic Hazards and Precautions
HMSO ISBN 0 11 883565 3

- *GUIDANCE NOTE:*

MS8 Isocyanates: Medical Surveillance
HMSO ISBN 0 11 883565 3

- *GUIDANCE NOTE:*

EH40 Occupational Exposure Limits
This guidance Note is updated annually
HMSO ISBN 0 11 885696-0

- *GUIDANCE NOTE:*

EH42 Monitoring Strategies for Toxic Substances
HMSO ISBN 0 11 885412 7

- *METHODS FOR THE DETERMINATION OF HAZARDOUS SUBSTANCES NO 20 STYRENE IN AIR.*

Laboratory method using charcoal absorbent tubes, solvent desorption and gas chromatography

HEALTH, SAFETY & ENVIRONMENTAL REGULATIONS

- *METHODS FOR THE DETERMINATION OF HAZARDOUS SUBSTANCES NO 43 STYRENE IN AIR.*

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- *METHODS FOR THE DETERMINATION OF HAZARDOUS SUBSTANCES NO 14*

  General methods for the gravimetric determination of respirable and total dust.

  HMSO ISBN 07176 0343-1

- *GRP MOULDING:*

  Control of Styrene Fumes and Dust in GRP Moulding Workshops.

  Report 39 Production Engineering Research Association.

- *BRITISH STANDARD: 4275:1974.*

  Recommendations for the Selection, Use and Maintenance of Respiratory Protective Equipment. British Standards Institute
- *F2486(1975): CERTIFICATE OF APPROVAL FOR RESPIRATORY PROTECTIVE EQUIPMENT.*

  HMSO ISBN 0 11 88 3825 3
- *L5 CONTROL OF SUBSTANCES HAZARDOUS TO HEALTH. REGULATIONS 1994 (COSHH)*

  HMSO ISBN 0 – 7176 1308 - 9

- *STEP BY STEP GUIDE TO COSHH ASSESSMENTS (1994) HS(G)97*

  HMSO ISBN 0 - 11 – 886379 - 7

- *A GUIDE TO HEALTH AND SAFETY IN GRP FABRICATION*

  HMSO ISBN 07176 0294X

- *NOISE AT WORK REGULATIONS 1989*

  NOISE GUIDE 1 & 2

  HMSO ISBN 0 - 11 - 885512 - 3

  NOISE GUIDE 3 to 8

  HMSO ISBN 0 - 11 - 885430 - 5

- *ENVIRONMENTAL PROTECTION ACT. 1990*

  ISBN 0 - 10 - 5443905

- *HEALTH & SAFETY AT WORK ACT 1974*

  ISBN 0 - 10 - 5437743

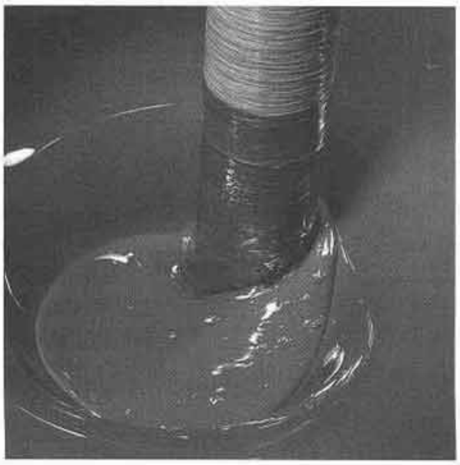
- *HEALTH GUIDE*

  THE APPLICATION OF COSHH TO PLASTIC PROCESSING

  ISBN 0 - 11 - 885556 – 5

- *UP RESIN HANDLING GUIDE*

  GPRMC/CEFIC UP Sector Group.



GENERAL BACKGROUND & CHEMISTRY OF POLYESTERS

REFERENCE: PB-19

This will not be a deeply technical review of the background and chemistry of polyesters, but a general introduction of the terms and polyesters reaction processes. Since the use of polyesters require a chemical reaction to take place, we will have to look at the chemistry involved to understand them.

1 GENERAL BACKGROUND & CHEMISTRY OF POLYESTERS
2 CROSSLINKING
3 CATALYST
4 ACCELERATORS
5 REFERENCE MATERIALS

1 GENERAL BACKGROUND & CHEMISTRY OF POLYESTERS

Polyesters materials have been classified as Plastics. Plastics are various synthetic materials chemically created from organic (carbon based) substances.

Plastics can be broken down into two basic types. Thermoplastics are those which can be formed or shaped by heat. This can be done a number of times (physical change). The other type is thermosetting plastics, which when they are formed or reacted, require or give off heat and cannot be reformed (chemical change). Unsaturated Polyesters are thermosetting.

A slightly better classification for polyesters than plastics is polymers, meaning a chemical chain combining many identical units together.

Polymers usually take their names from either the units used to make them (polyethylene-ethylene) or from how the units are chemically combined or chained together (polyester-ester linkages).

An ester is the final product from reacting an organic acid with an alcohol. In chemistry, this reaction produces a chemical group which is made up of two carbon and two oxygen atoms arranged in a particular order. This particular order is called an ester group or linkage.

Polyesters are polymers chained together by ester linkages. The term organic acid refers to a particular arrangement of one carbon, two oxygen, and one hydrogen atom (carboxyl group). Organic acids may have one or more carboxyl groups in them. To make polyesters, we must use acids and alcohol's which contain more than one carboxyl and alcohol group. Normally, there are two separate carboxyl groups in the acids used to make polyesters and each one can react to an alcohol group.

Because there are two carboxyl groups, they are called difunctional. Compounds with two alcohol groups are normally called glycol's.

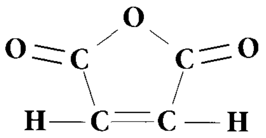
The term polyesters can be broken down into unsaturated and saturated classes. The term unsaturated refers to a chemical state, in which a compound has unsatisfied reactive groups readily available for attachment to other groups. Unsaturated polyesters give off heat (exothermic) and are thermosetting. We will herein deal with only unsaturated polyesters. The saturated polyesters (different chemistry) are represented by alkyds (oil based paints) and polyester fibres (cloth, rayon, nylon...etc.)

The type and ratios of raw materials, which are incorporated into an unsaturated polyester (hereafter polyester refers to unsaturated type), determine the physical properties. While changing the ratios may alter the physical properties and perhaps improve specific properties, others may be sacrificed.

GENERAL BACKGROUND & CHEMISTRY OF POLYESTERS

The more common raw materials are:

■ MALEIC ACID OR MALEIC ANHYDRIDE:



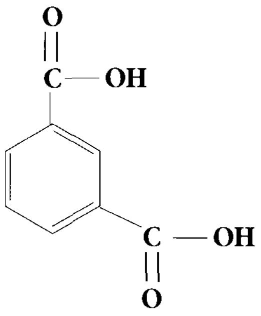
An anhydride is an acid with one unit of water removed. It still reacts like an acid. Maleic acid is used as it contains the unsaturated group. The amount controls the reactivity of the final resin. Additional maleic increases reactivity and the heat exothermed.

■ PHTHALIC ACID OR ANHYDRIDE (CHEMICAL CALLED ORTHOPHTHALIC)

This saturated acid is used to lower the reactivity. (An all-maleic system is usually unsuitable due to heat produced). It also imparts other chemical and physical properties. It is used in most general purpose laminating and casting resins. It was used in the first commercial polyesters. Its chemical name is used to describe one group of polyesters, ORTHO's. The name refers to the arrangement of the two carboxyl groups in the compound.

■ ISOPHTHALIC ACID

This compound has the same amount of carbon, oxygen, and hydrogen as orthophthalic acid. The difference is the arrangement of the carboxyl groups. This different arrangement makes the resin more chemical-resistant and stronger, and has been used to up grade polyesters. It is normally used in gel coats, corrosion-resistant resin, and tooling resins. Its chemical name is used to describe a group of polyesters - ISO's.



■ OTHER ACIDS

Other acid compounds are some times used in small amounts to give special properties, i.e., adipic (flexibility), tetra bromo or tetrachloro phthalic (burning characteristics)...etc.

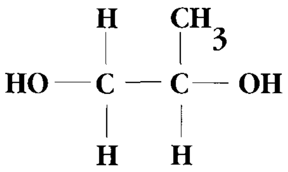
■ GLYCOL'S

There are only a few glycol's used in polyesters... mainly, ethylene, propylene, and neopentyl-glycol. These are used to react the acids together. One of these glycol's has given rise to a generally named group of polyesters. This is neopentyl.

This glycol is used in an isophthalic resin to further upgrade the general performance. The chemical name for these gel coats is ISO/NPG*.

Neopentyl Glycol can be combined with phthalic acid, but we have found the product, ORTHO/NPG*, to not be as good in general performance as a straight ISO.

Cray Valley has referred to our NPG's* as having in excess of 70% NPG*.



$$HO-\underset{H}{\overset{H}{C}}-\underset{H}{\overset{CH_3}{C}}-OH$$

This percent was presumed by people other than chemists to be a weight or volume percent, when in fact it is a mole percent. Chemists use **mole percents** to determine the actual amount of molecules in a substance available for chemical reaction. By using mole percents, a chemist can calculate the ratio of molecules required to achieve the desired reaction.

When gel coat is analysed by typical chemical breakdown techniques, results are reported on a **weight percent** bases, and WILL BE LESS than 70%. This percentage will be even lower when the gel coat is tinted, because the pigments are ground and carried in a grinding resin which is not an ISO/NPG*. Therefore, if analysed, the NPG* content of Cray Valley gel coats will show less than 70%.

The facts are:

- The base resin for Cray valley ISO/NPG* gel coats contain at least 70 mole percent of Neopentyl glycol.
- Performance is what counts and that's where Cray Valley delivers.

We have specially formulated our ISO/NPG* gel coat to optimise performance for flexibility, resistance to pre-release, sprayed porosity resistance, sprayability, weatherability, blister/boil resistance, to name as few. Just having a certain level of NPG* does not ensure a good overall product. Cray Valley has considered many performance aspects and selected a product formula to provide these many needs.

There are a number of other chemicals which may be used

** NPG is a registered trademark of Eastman Kodak Company* to make a polyester resin. They are used to produce particular property. The industry is continually looking at new materials to upgrade polyesters. This continual upgrade doesn't mean the old material is unsuitable, but there might be performance advantages with change.

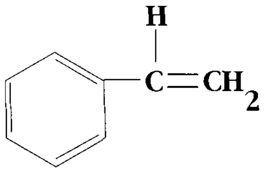
Raw materials are mixed in a definite chemical ratio (moles) and are heated (cooked). When they are cooked, water is produced. This water is taken out of the final product.

NOTE: A trace will always remain.

The cook time is dependent on the raw materials used, cooking temperature, and resin properties desired. Typically cook time can vary from 14-24 hours, and temperature will be around 225°C. (437°F). The progress of the cook is followed by watching the change in viscosity and acid number. An acid number is a chemical counting of how many carboxyl groups have not reacted with alcohol groups. The conditions during cooking are such that the unsaturated group in the maleic does not react, just the carboxyl and alcohol groups react. After these materials are cooked, we have a polyester which is called a base resin and it made of many chains of different lengths.

A base resin at room temperature is usually a solid.

This base resin is then reduced with a monomer (normally styrene) which will thin the polyester and eventually react with it. This monomer has unsaturated group as in maleic. This monomer is chosen because it will react with unsaturation in the base resin very rapidly.



2 CROSSLINKING

The reaction between the base resin and monomer is called a crosslinking reaction. The monomer reacts with base resin because the unsaturated groups will react with each other bridging (crosslinking) the polyester chains together until one solid mass is formed. This reaction, if controlled, is formed. This reaction, if controlled, is what makes polyesters usable.

This crosslinking reaction takes place by what is called a free radical mechanism. This crosslinking can be visualised by nailing wooden boards together. Think of the boards as chains of resin and the nails as styrene. The boards without any nails in them, can be moved and the positions changed as the polyester chains can move in the liquid state. By nailing two boards together, we restrict the movement of the boards. They can be moved, but not separated (gelled state). By hammering in more nails, we can no longer move the boards independently (cured polyester).

To control this spontaneous crosslinking reaction, we must slow it down until we want it to proceed. This is done with chemical additives call inhibitors. These inhibitors seek out free radicals (which can be formed by sunlight, heat, and other sources) and keep them from reacting with the styrene and/or base resin. Since we want this reaction to take place eventually, only enough inhibitor is added to keep the system stable (liquid) for a minimum time (normally three months at 73°F, or 23°C).

Consult data sheet for specific details

The crosslinking reaction (polymerisation) is a chemical process affected by several factors, including:

■ TEMPERATURE

Almost all chemical reactions are directly affected by temperature. Below certain temperatures, a reaction will not work or go to completion. Post cure then occurs at a later date as the temperature increases. The higher the temperature, the faster the reaction (up to a point). Free radical formation is accelerated with higher temperatures.

■ MASS

The quantity of material (Mass) affects the speed of reactivity. A larger mass (casting) will generate more exothermic heat than a thin film, thus a faster cure.

■ CATALYST

Certain chemicals will activate a reaction if they are present in a specific amount. Too much or too little can cause an incomplete REACTION.

■ CONTAMINATES

Certain foreign chemicals will interfere with or keep a reaction from going to completion.

■ ACCELERATORS (PROMOTERS)

Certain chemical additives can speed up a chemical reaction. The crosslinking process can be controlled with the type and amount of accelerator added which increases the activity of the catalyst.

3 CATALYST

A substance added to a polyester in a certain quantity to allow the polyester to cure (harden).

Peroxides are the catalysts used with polyesters. Peroxides are very unstable and will break down or react very easily, but the generation of free radicals is not fast enough at room temperature. Therefore, something is needed to speed up or accelerate the peroxide decomposition. Metal salts (especially cobalt organic salts), as well as heat, will make certain peroxides produce free radicals faster. A metal salt is the reaction product of a metal or metal compound with an organic acid. Peroxides will react vigorously with most metals and give off heat. They will react with skin tissue giving a chemical burn or with metal accelerators (directly and not diluted) possibly causing an explosion and/or a fire. Never allow direct contact of peroxides with metal accelerators. Peroxides must be treated with care and caution.

CAUTION:

Peroxides may cause blindness if in contact with eyes.
Read manufacturer's literature on safety before using.
Always wear safety glasses!

The function of the catalyst is first to overcome the inhibitor and then to cause crosslinking of the polyester resin until it is cured.

THE BASIC STEPS IN THIS CROSSLINKING SYSTEM ARE:

- The free radicals must be generated.
- These free radicals react with an unsaturated group forming a new free radical.
- This new free radical reacts with another unsaturated group making the chain grow. This continues until the free radicals are used up or are immobile.
- Two free radicals can also react with each other to form an unreactive compound.

CURING TEMPERATURES

We will split the review of catalysts into the two major curing situations - elevated temperatures and room temperatures.

- ***Elevated Temperatures***

At elevated temperatures (normally 240°F(115°C) plus), heat is the only accelerator used. The most common application is match metal die moulding. The peroxide that is most commonly used is Benzoyl Peroxide. There are several others used, such as Tertiary Butylperbenzoate, Tertiary Butylperoctoate. Each catalyst has a slightly different useful temperature range which influences the choice. Methyl ethyl ketone peroxide is not used as it breaks down and gasses too quickly at these temperatures.

Benzoyl Peroxide (BPO) has been used in the polyester industry for years. It is extremely efficient. BPO in its pure form is a crystalline powder which is shock sensitive. This pure form is no longer normally used. (It is classified in the same shipping category as TNT).

BPO is available in a number of diluted forms and contains from 85 to 50% BPO in a carrier to reduce its shock and fire sensitivity. The most common form is a 50% BPO paste in tricresyl phosphate. The paste is the easiest form to use as the powdered form is slow to dissolve.

NOTE: Pure styrene will react and produce heat with BPO.

BPO will slowly react with an unaccelerated resin at room temperature. Catalysed resin is usually stable for two to four days at 77°F (25°C). This may vary with the type of resin and should be checked.

All commercial grades of BPO contain the same basic BPO chemical formula, but may very slightly in activity. Their activity should be checked before use versus a standard lot.

- ***Room Temperatures***

Room temperature systems are more frequently used. The peroxide normally used is Methyl Ethyl Ketone Peroxide (MEKP).

Understanding how MEKP works in curing polyester helps to explain why temperature, mass and amount used is critical.

MEKP, added to an accelerated resin, reacts with the accelerator to form free radicals. Once the inhibitor is reacted, then the free radicals attach the unsaturation in the styrene (monomer) and polyester resin. MEKP radicals react with the unsaturated group to form a new free radical. This new free radical then attacks another unsaturated group and forms a larger chained free radical.

NOTE: The MEKP starts the reaction, becomes part of the chain, and reacted unsaturated groups carry it on (self-propagating).

At this point, the system is liquid and it is very easy for the free radicals and unsaturated groups to move around and to come into contact with each other. As the reaction continues, the chains become longer, the viscosity increases, and the mobility of the resin decreases. This continues until the resin gels, whereby the resin is almost immobile. There are still many unreacted unsaturated groups left which migrate until the chains form a network so dense that free radicals have difficulty moving through it. The polyester is not fully cured, but with sufficient mass, the heat of the reaction (exothermic heat) supplies the extra push to move the free radicals to the remaining unsaturated sites left on the resin. This drives the reaction to almost *completion. Once the polyester is almost fully cured (est. 90%), the network is so dense that further migration of any free radicals is extremely slow.*

■ SOME OF THE LIMITING FACTORS GOVERNING CATALYST USAGE ARE:

- Enough catalyst to start the reaction is required.
- Enough free radicals must be generated, once the resin is gelled, to migrate and produce the final cure.

  The normal catalyst range is 1.2% to 3.0% by weight.

See *data sheet on product for exact recommendations.*

- If too much catalyst is added, the catalyst radicals will react with each other rather than the resin and stop chain growth. This catalyst reaction stops right after gelation. The chain network may gel just dense enough to prevent satisfactory cure even if heat is applied much later. This is called permanent undercure.
- We have to have enough heat supplied from:

The polyester Mass: Thin films (above 12 mils/thou) will cure adequately at 77°F (25°C) without development of exothermic (internal) heat. When greater cures are required, i.e., laminates, a larger mass (several layers) will develop the exothermic heat necessary for the faster greater cure.

External source: Working conditions are important. At low shop temperatures, the exothermic heat is dissipated too quickly. Do not use below 60°F (15.5°C~). at higher temperatures quicker gelation will occur.

Methyl Ethyl Ketone Peroxide is an extremely reactive and corrosive liquid. The manufacturer's safety literature should be read before it is used. MEKP is not commercially available in pure form as it is too explosive. MEKP is normally supplied as a 9% active oxygen solution in a non-reactive solvent (normally Dimethylphthalate).

Most manufacturers of MEKP all start out with the same raw materials. They react methyl ethyl ketone with hydrogen peroxide. When these two materials react, we may gel as many as six separate peroxide compounds besides water. The water is normally separated and the remaining group of compounds are called Methyl Ethyl Peroxide.

The ratio of these peroxides will vary from each supplier as they are dependent on the manufacturing procedure. Variance in these ratios will affect the gel and cure of polyester resins. This difference in MEKP is why every lot of each supplier's catalyst should be checked.

If water is left in a batch of catalyst, the gel time and cure will be affected. This may be why some catalysts gas when added to some polyesters.

Improper storage of catalyst can cause the catalyst to change in composition and in reactivity.

See catalyst manufacturer's literature for proper storage.

4 ACCELERATORS

Most room temperature catalyst systems require an accelerator. MEKP does not produce a fast enough gel and cure by itself. A typical unaccelerated resin with 1.2% MEKP will gel in two (2) to eight (8) hours. The useful level of accelerator ranges between 0.05% and 0.5%. More or less can cause incomplete cure.

These accelerators normally used in polyesters are cobalt salts and anilines. Usually, these are added by the polyester manufacturer.

The accelerators will depend on the catalyst used and end-use application.

Cobalt accelerators will shorten storage stability to a minor degree. Anilines and special accelerators can shorten stability considerably.

■ COBALT

Cobalt normally comes as a 12% metal salt solution in mineral spirits. It is the reaction product of the metal with an organic acid. It is the most commonly used accelerator.

Cobalt is reactive with MEKP. It does not act as an accelerator for BPO. Cobalt give a resin a pinkish colour mainly dependent on concentration. Where colour stability and weathering of a product are important, cobalt colour influence can be tolerated while aniline's cannot.

■ DIETHYLANILINE (DEA)

DEA does not react with MEKP by itself, but it will speed up the reaction of cobalt and MEKP. It is used in dual accelerated system. It normally will speed up the gel time only slightly, but will accelerate the cure. The exothermic heat produced will be slightly greater than cobalt only.

It does impart a yellow colour to the resin which is dependent not only on amount, but also on temperature, catalyst level, and mass of material. It also causes the resin to yellow more on weathering. For these reasons it is not normally used in products where colour and weatherability (colour change) are important. DEA is a room temperature accelerator for BPO.

■ DIMETHYL ANILINE (DMA)

Dimethyl aniline also does not react with MEKP, but speeds up the reaction between cobalt and MEKP. DMA will speed up both the gel time and cure time while greatly increasing the exotherm of a system. It affects colour and yellowing like DEA. DMA reacts with BPO.

The accelerator or combination must be paired with the proper catalysts and together are referred to as a curing system.

GENERAL BACKGROUND & CHEMISTRY OF POLYESTERS

The particular system selected for a specific polyester may depend upon one factor or a combination of several factors.

If the polyester used is pre-accelerated, then the choice of catalyst may be predetermined as evidence by the following table:

CURING SYSTEM		
CATALYST	**ACCELERATOR**	**REACTION**
MEK Peroxide	Cobalt	Good, fast gel-slow cure
MEK Peroxide	Cobalt plus DEA	Good gel and cure - if accelerators are in proper ratio
BPO	DMA plus DEA	Good gel and cure - if accelerators are in proper ratio
BPO	DEA	Slow gel - fast cure
BPO	DMA	Fast gel-fast cure
MEK Peroxide	DEA	No apparent reaction
MEK Peroxide	DMA	No apparent reaction
BPO	Cobalt	No apparent reaction

If an unaccelerated resin is used, then the choice of both catalyst and accelerator must be made.

One customer may want slow gel formation and a rapid cure after gel formation, while another customer may want rapid gel formation and rapid cure. In general, the curing system is determined by : gel time, cure time, lay up time, trim time required and process.

5 OTHER SUGGESTED REFERENCES

- *Modern Plastics Encyclopaedia (yearly)*
  Modern Plastics, PO Box 430
  Highstown, New Jersey 08520
- *SPI Handbook of Technology and Engineering of Reinforced Plastics/Compositions 2nd Edition 1973 and SPI Handbook of Reinforced Plastics 1964*
  Van Norstrand Reinhold Company
  450 West 33rd Street
  New York, New York 1001
- *SPI Plastics Engineering Handbook 1954 Reinhold Company*
  (address as above)
- *Organic Chemistry*
  Morrison and Boyd
  Allyn and Bacon Inc.
  150 Freemont Street
  Boston, Massachusetts 02110
- *The roll of organic Peroxides in curing Polyester's resins and their influence on the Physical Properties of Reinforced Plastics*
  Novadel, Ltd
  Lucidol Products Division
  St.Ann's Crescent
  London SW18
- *Papers from Annual Meeting of Reinforced Plastics Division of the Society of the Plastics Industry.*
- *Papers from Compex*
- *Polyesters*
  Brian Parkyn
  London Iliffe Books Ltd
  American Elsevier Publishing Co., Inc.
  52 Vanderbilt Avenue
  New York, New York 10017
- *Polyesters and their applications by Bjorkstein Reinhold Publishing Corporation*
- *Glass Reinforced Plastics*
  Parkyn
  London Iliffe Books
- *Reinforced Plastics Theory and Practice (2nd Edition)*
  M.W. Gaylor
  Cahners Books
  89 Franklin Street
  Boston, Massachusetts 0210

MAGAZINES

- *Modern Plastics*
  PO Box 430
  Hightown, New Jersey 08520
- *Plastics Technology*
  633 Third Avenue
  New York, New York 10164
- *Plastic Design and Processing*
  Lake Publishing Corporation
  P.O. Box 159
  Libertyville, Illinois 60048
- *Plastics World*
  PO Box 5391
  Denver, Colorado 80217
- *Professional Boat Builder Magazine*
  PO Box 78
  Brooklin, Maine 04616
- *Reinforced Plastics*
  Elsevier Services
  Crown House
  Linton Road
  Barking IG11 8JU - England
- *International Reinforced Plastics Industry*
  Channel Publications Ltd
  Loudwater House
  London Road
  High Wycombe HP10 9TL - England

GENERAL PROPERTIES OF FRP

REFERENCE: PB-57

The FRP (GRP) process results in products that are very adaptable materials. Their uses cover a broad range of applications. This section gives you a brief outline of the properties that make FRP products such a useful material.

1 MECHANICAL PROPERTIES
2 PHYSICAL PROPERTIES
3 CHEMICAL PROPERTIES
4 ELECTRICAL PROPERTIES
5 FIRE RESISTANCE
6 OPTICAL PROPERTIES
7 WEATHERING PROPERTIES
8 POLYESTER SHRINKAGE

1 MECHANICAL PROPERTIES

The tensile, compressive and flexural properties depend on the fibreglass material (cloth, roving, woven roving, mat), the glass to resin ratio, and how the glass is orientated in the direction of the stress. The glass fibres can be arranged, during fabrication, in the direction of known stresses so that the strength of the glass is used more economically and so better performance is achieved. For instance, glass roving can be used in areas where direct tension occurs and glass mat where isotropic (random) compression stresses occur. A rod made of parallel roving strands can have a tensile strength of 1,000mpa where a spray-up laminate (made of chopped glass fibres) may have a tensile stress of only 100mpa. A combination mat and woven laminate will have a tensile and flexural strength running from 200mpa to 350mpa.

Impact strength of FRP is high because it has no yield point as do metals. This property eliminates denting, gives the structure dimensional integrity and makes it easy to repair (since it does not get out of shape, even when ruptured).

2 PHYSICAL PROPERTIES

The specific gravity of FRP is low compared with other structural materials (about 1.7 depending on glass-to-resin ratio). An extremely high strength-weight ratio is available (important to the aircraft industry).

The thermal conductivity is very low for a solid material (0.2 W/m°C) which is not only important to insulated structures, but prevents heat build up within the laminate making the surface pleasing to the touch in hot or cold ambient conditions.

A Barcol Impresser is used in measuring hardness of a FRP laminate. A Barcol 934 Impresser should show a reading of 35 to 45 when the laminate has cured. More rigid resins will give a higher Barcol reading while resilient and flexible resins, of course, will give a lower reading.

The heat distortion point of the laminate depends entirely on the type of resin used. General purpose polyesters run about 200°F (93°C), where a high heat distortion polyester rungs up to 275°F (135°C). Continuous operating temperatures should not exceed 250°F (121°C) for general purpose polyester resins.

Thermal co-efficient of expansion is slightly higher than steel and about the same as aluminium, 30°C x 10^{6}.

3 CHEMICAL PROPERTIES

FRP is known for excellent chemical resistance. Although some chemicals attack it rather rapidly, it has excellent resistance to aqueous solutions (salts, acids, etc.). General purpose polyesters have poor resistance to strong alkalis and do not stand up to certain strong acids (such as nitric) or high temperature solutions over 140°F, (60°C). Special polyesters are used in these applications.

GENERAL PROPERTIES OF FRP

This generally high degree of chemical resistance of FRP make it particularly useful for tanks, hoods, covers, pipes, ducts and other structures in the paper, textile, fertiliser sewage disposal and petroleum chemical plants.

Certain solvents such as ketones (acetone) and those having chlorine (Carbon Tetrachloride and Chloroform) attack all polyester resins rapidly.

4 ELECTRICAL PROPERTIES

A unique property of FRP is that it is electrically transparent. This is particularly useful in the manufacture of radomes, doppler systems, etc.The polyester resins generally have a low dielectric constant making them good potting materials for capacitors and other electrical equipment.

FRP is an exceptionally good insulator, having a dielectric strength of 300 to 500 volts/mil (thou) so that it has taken the place of ceramic insulators and has particular use in power transmission equipment.

5 FIRE RESISTANCE

All the resins, being organic, will burn. However, most fire codes call for a certain maximum burning rate or certain characteristics which are available in special halogenated polyester resins or through the addition of chlorinated waxes and antimony trioxide or alumina trihydrate.

6 OPTICAL PROPERTIES

Most general purpose polyester fibreglass laminates are translucent although up to 90% light transmission can be achieved in a 1/16 inch (1.59mm) to 1/8 inch (3.18mm) FRP laminate through the use of special resins and mat. However, an opaque laminate can also be made by incorporating pigments and fillers in the resin. Colour can be moulded into the product so that painting is unnecessary.

7 WEATHERING PROPERTIES

The outdoor weathering properties of FRP are generally very good because of its excellent chemical resistance. However, there is a certain susceptibility to ultra violet rays which require that an ultra violet absorber be specified for translucent laminates. In addition all exposed laminates should either have a gel coat or a glass surfacing mat specified for the exposed surfaces to prevent fibre "blooming" or surface exposure of the fibres.

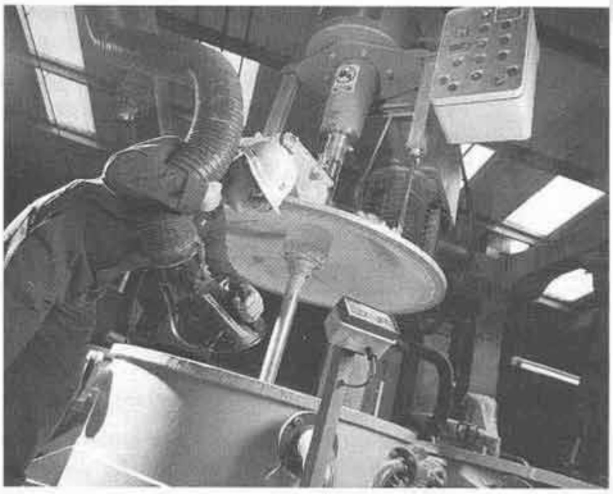
See also "Gel Coat Weathering" in Cray Valley's Applications Manual.

8 POLYESTER SHRINKAGE

Polyesters will shrink approximately 6 to 9% by volume. A rule of thumb to use, when calculating linear shrinkage on a glass laminate, is to figure 0.25% (approx.) shrinkage per running foot.

REFERENCE: PB-55

The fabrication of Fibreglass Reinforced Plastic (FRP) is completely different from the fabrication processes one is normally accustomed to, as with metal for example. When fabricating with metals, the structural part is produced, then the external paint finish is applied. In the fabrication of FRP, the reverse of this procedure is used to manufacture a product. The manufacturer must have a mould. Moulds are of two types; male - the part is moulded onto, and female - the part is moulded into. A pigmented coating, called a gel coat or In Mould Coating is applied to the mould. Then the structural reinforcement is built behind this coating using fibreglass and polymer resin laminates. When the finished part is removed from the mould the gel coat will be the exterior side of the part. Cray Valley is a leader in the industry in the manufacture of gel coats and resins.



1 GEL COATS
2 GEL TIME
3 CURE DATA
4 STORAGE
5 CODE NUMBERS
6 RESIN
7 MIXING
8 CATALYSATION
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1 GEL COATS

A gel coat is a specially formulated polyester resin with thixotropic agents (agents to increase the viscosity and non-sag properties), fillers for flow properties, pigments to give the desired colour, and additives for specific qualities such as gel time and cure.

Gel Coats are used in contact moulding (hand or spray lay-up). The gel coat which is usually pigmented, provides a moulded-in finished surface. It is a weather and wear-resistant coating over the glass reinforcement, that helps in hiding the glass reinforcement pattern which may show through from the inherent resin shrinkage around the glass fibres.

NOTE: The gel coat will not stop fibre print-through caused by poor lamination or post cure of the laminate after demoulding.

The gel coats should be resilient, light stable, and pigmented sufficiently for good hiding.

There are specific gel coat products for either spray or brush applications.

A spray gel coat is applied (by using catalyst injection or a hot pot) with a spray gun having a fairly large orifice and several sets of atomising orifices for positive break-up of the heavy gel coat. Airless or air assist airless equipment is also used. An 18±2 mils (thou) of gel coat is applied to the mould (in three passes) and checked with a thickness gauge (wet mil gauge). A gel coat that is too thin - under 16 mils (thou) - could cause under-cure of the gel coat and too thick a film - over 24 mils(thou) could crack under flexing.

A brush gel coat is (not surprisingly) applied with a brush. These gel coats are formulated to have the correct resistance to drag on the brush, release air, and level correctly. As with spray grades proper thickness should be applied to achieve best results.

POLYCOR gel coats are formulated to be or have:

READY TO APPLY

POLYCOR gel coats do not require further reduction with styrene. The styrene content is controlled for product uniformity from batch-to-batch. Brush grades should not be sprayed and spray grades should not be brushed.

NON-SAGGING

When POLYCOR gel coat is spray applied in multiple passes to a film thickness of 18±2 mils (thou) on vertical surfaces, typically no sagging will result due to its thixotropic properties.

Brush grades should be applied at a covering rate of 0.5 - 0.75 kg/m^{-2} in order to achieve a wet film thickness of 18±2 mils (thou). When properly applied POLYCOR brush grades typically do not sag.

The gel coat will not entrap air (porosity) when applied as per instructions.

■ PROPER GEL AND CURE TIME

POLYCOR gel coats are formulated for the proper gel and cure times to provide quick cure, allowing processing to proceed without much delay.

Rapid cure properties reduce the possibility of "alligatoring" caused by styrene solubility of gel coat (an undesirable and costly feature of slow curing or under-cured gel coats). This also improves the gloss and makes parts pull more easily (see "Cure Data" below).

■ NON-CRAZING AND WATER RESISTANT

POLYCOR gel coats possess resilience and toughness without sacrificing water resistance. They show excellent resistance to blistering, cracking and crazing.

Even though polyesters are known to chalk on outdoor exposure over time, the careful selection of pigments in POLYCOR gel coats result in a slower chalking surface, which is abrasion resistant and can be readily cleaned, waxed and buffed to a high gloss.

■ GOOD HIDING AND PATCHING

POLYCOR gel coats are formulated with optimum pigment concentration to provide complete mould coverage and hiding at 18±2 mils (thou) film thickness. Bright yellows, oranges, reds and dark blues will have slightly less hiding than pastels. The increased pigment load necessary to achieve better hide with these bright colours could cause sprayability and cure problems.

Excellent repairability and colour matching is possible if patching becomes necessary.

TYPICAL PROPERTIES OF POLYCOR GEL COATS	
Viscosity (varies according to colour)	9000 - 22000 cps
Specific Gravity	1.10 - 1.36
Thixotropic Index	5 - 7
Sag at 18 mils (thou)	satisfactory
Hiding at 18 mils (thou)	usually complete
Sprayability	excellent
Shelf Life	3 months at 73°F (23°C)
Coverage	1.5 Metre^2/litre (60 sq. ft/gallon) at 18±2 mils/ thou (inclusive of waste)

2 GEL TIME

Our standard line POLYCOR gel coats are formulated to provide a gel time of 8 - 15 minutes at 77°F(25°C) with 1.8% of 9.0% active oxygen catalyst.

This level of 1.8% is recommended and is ideal.

Gel Coats can be catalysed at a minimum of 1.2% and a maximum of 3.0% as required to compensate for temperature changes. MEKP such as Andonox LCR - S, Interox LA3; Butanox LA; Butanox M50; Peroximon K12, Luperox DHD are recommended.

The manufacturers should check the gel time of the gel coat in the plant because type, brand and concentration of MEKP, age of the gel coat, temperature and humidity will affect the gel time of POLYCOR gel coats. Special gel times are available upon request.

3 CURE DATA

At temperatures above 60°F (15.5°C) POLYCOR gel coat initially sets to a soft gel. After gelation it proceeds to cure to a hard surface. Do not apply below 60°F as the temperature will slow down the chemical reaction to a point where under-cure is possible. Print through and distortion are also more likely at decreased temperatures due to post cure.

Normally POLYCOR spray gel coats are ready for hand lay-up operation 45 - 60 minutes after catalysation. POLYCOR brush gel coats are ready for lay-up in 60 - 80 minutes after application. The time element is dependent upon the temperature, humidity, air movement, catalyst type and concentration.

Fast cure **spray** systems are available upon request.

Gelation and curing are retarded somewhat by either temperatures below 60°F (15.5°C) or high humidity conditions. The part must be cured on the mould to minimise post cure.

A reliable test in determining whether gel coat is cured sufficiently is to touch the film (lowest part of the mould) and if no material transfers to your finger, it is ready to lay-up.

We have discovered a few helpful hints to benefit your polyester usage when cold weather is upon us:

- Polyesters are sensitive to colder temperatures. As the temperature drops, the viscosity increases, the thixotropic index (TI) is lower, and the gel times are extended. High viscosity, low TI and long gel all add up to more sag.
- The catalyst is also sensitive to the colder temperature. In spray gel coat this is important because as it gets colder, the catalyst's viscosity increases which can

make injector readings incorrect.

- You should make sure that the materials are warm before use. With extra cold weather, it may take a longer than normal time to warm up the material. (Depending upon the conditions it can take 3 - 4 days).
- Calibration is very important, especially during cold weather. If the temperature gets below 60°F (15.5°C) in the shop, there will be long delays in gel and cure along with the possibility of under-cure.

The material temperature should be watched very closely. The following are a few steps that can help:

- If the plant has a cement floor, make sure there is a piece of cardboard or a pallet underneath the drum or pail. This procedure will keep the material warmer by preventing the heat from being drawn out by the concrete.
- Bring the materials in earlier and make sure they are up to the proper temperature before use. In spray applications flow rates and atomisation may change due to cold materials. Brush grades will also likely not apply correctly.
- Along with colder weather come icy and foggy roads. Customers should ensure that they have plenty of stock on hand as deliveries could be delayed due to travel conditions.
- Review your inventory very carefully and plan your orders well in advance.

4 STORAGE

Liquid polyesters have a limited shelf or storage life. Over a period of time, they will gel and become solid without the addition of catalyst. The time it takes them to gel without catalyst is dependent on the formulation and storage conditions (temperature and exposure to weather).

Given the above it is wise to check the age of material before use and to use your oldest materials first.

All polyesters should be stored in a cool area below 73°F (23°C) and out of direct sunlight.

NOTE: No liquid (especially water) should be allowed to accumulate around the bung openings of drums or pails because as the temperature changes a vacuum can form in a sealed container drawing in the liquid. If material is stored outside, it should be protected from sun, heat and weather. It is best positioned on its side or tilted with a board or plank/pallet under one edge to help shed water.

If the material gets cold during storage, it should be warmed to at least 60°F (15.5°C) and properly agitated prior to use to assure product consistency. Drums can take 2 to 3 days to warm even inside a shop. A piece of wood or pallet should be placed under the container to help the material warm.

Not completely full and open drums or pails will have shorter stability than full unopened drums or pails. These should always be used up as soon as possible.

Tests show that grinding dust contaminant will adversely affect the stability. It is strongly recommended that all containers, when not in use or being mixed, remain sealed or covered.

CONTAMINATION OF GEL COAT GRINDING DUST
(effects of shelf life (gelation) at 150°F (65.5°C))

Four samples of white "A"	**Control**	**Sample 1**	**Sample 2**	**Sample 3**
Grinding Dust	none	.05%	.25%	.5%
Began to gel after	12 days	7 days	7 days	6 days
Four samples of white "B"	**Control**	**Sample 1**	**Sample 2**	**Sample 3**
Grinding Dust	none	.05%	.25%	.5%
Began to gel after	18 days	10 days	11 days	9 days
Four samples of white "C"	**Control**	**Sample 1**	**Sample 2**	**Sample 3**
Grinding Dust	none	.05%	.25%	.5%
Began to gel after	21 days	8 days	7 days	10 days

Uncatalysed, regular cure formula polyester products have a usage life of three months from date of manufacture when stored at 73°F (23°C) or below, in a closed factory sealed, opaque container and out of direct sunlight. Fast cure products have usage life of 45 days. The usage life is cut in half for every 20°F (7°C) over 73°F (23°C).

FABRICATION WITH POLYESTERS

5 CODE NUMBERS

All European POLYCOR materials are marked as follows:

Trade Name : POLYCOR

Product Description : Emerald Green Iso Spray Gel Coat

Product Code : 4786 - 421

Batch Number : 8561

Net Weight : 20kg

Batch Date (d/m/y) : 18/2/93

6 RESINS

Cray Valley is a leader in the field of resin technology and offers a complete line of resins which should suit your needs. Polyester, phenolic, hybrid and other technologies are available to help industry.

7 MIXING

Do not over mix polyesters. Over mixing will break down the viscosity, increasing the tendency to sag, and cause styrene loss which may contribute to porosity. POLYCOR spray gel coats should be mixed for 10 minutes prior to each shift start up. The polyester should be mixed to the sides of the container, with the least amount of turbulence possible.

8 CATALYSATION

Batch mixing (not catalyst injection) is recommended to achieve the best catalyst mix and cure because even with the equipment properly calibrated, potential problems can arise which can quickly negate all the benefits of calibration. Potential problems such as :

- Poorly atomised catalyst
- Surging problems (polyester or catalyst).
- Poor tip adjustment (catalyst to polyester mix).
- Contamination.
- Poor application procedures.

The equipment and application procedures must be monitored on a routine basis to ensure proper cure and application. Enquire of, and adhere to, all equipment manufacturer's recommendations.

9 AVAILABLE PRODUCTS

For information on POLYCOR gel coats or Cray Valley's range of resins, see your Cray Valley representative or write:

Cray Valley Limited
Laporte Road
Stallingborough
North East Lincs DN41 8DR
ENGLAND

Cray Valley has a wide variety of gel coats and speciality products such as additives, patching materials, speciality resins and other products.

QUALITY CONTROL LAB & TEST METHODS

REFERENCE: PB-18

The fibreglass industry is constantly changing. Parts are made at faster rates, with a demand for higher quality and better durability. There is less latitude for errors that can cause bad products and costly down-time. Everything must work properly and be compatible. Many companies in the fibreglass industry are setting up their own internal quality control labs to monitor incoming materials, to do in-house process monitoring and to assure performance of the final parts.

What the costs of a control lab are is not an easy question to answer. It depends what benefits you want from a QC lab. You can spend a lot of money and get a lot of information but if it is information you do not use then you have spent too much. On the other hand you spend just a little money, but if you get needed and useful information then you have made a good investment.

1 FUNCTION OF A QC LAB

A QC lab or any laboratory has one basic function. It collects and reports information (facts) that should be used to make reasonable decisions.

A QC lab can answer the following type questions.

- Is the material really what the supplier says it is?
- Are you getting what you really paid for?
- Does it meet your in-house requirements for processing and durability?
- Are you getting a consistent material which is necessary for optimum production schedules and requirements?
- Does a new vendor's different material match the presently used product?
- Can production use the product? Is your production consistent?
- How is the material to be used? What amount of material is actually used on each part?
- Are your parts consistent, not only in weight, but in quality?
- Is the process used in making the part cost efficient?
- Does a specific change in production actually bring about a cost or quality benefit?
- Are the products and parts compatible with each other to produce the desired quality?

A QC lab can also perform several other functions:

- Evaluate new products, equipment, or processes.
- Run safety testing.
- Co-ordinate samples to be sent out for testing (Product testing environmental testing or analysis work).
- Assume responsibility for regulatory activities.

The lab can provide:

- Design testing.
- Cost information on parts
- Estimate costs on new parts.

You need to review what you want out of a QC lab before you set it up. Each company's needs are different and they vary from the very critical aerospace applications to other non-critical parts. We cannot give a general lay-out or list of equipment for a lab since what is expected varies.

QUALITY CONTROL LAB & TEST METHODS

2 A GOOD QC TEST

A test method is a set of procedures, where all conditions which affect an end result are held constant providing repeatability.

Some of the characteristics of a good test are :

- The results yield information which is necesssary for determining application performance of the end use of a product.
- It always gives the same result, within a predetermined range when the same exact material is used no matter how many times you run it.
- Different people or group of people using the same conditions and exact material achieve the same answer within a predetermined range.
- The result directly related or tells you something about the property for which you are testing.

3 BASIC LAB REQUIREMENTS AND FUNCTION

A quality control lab begins with a room that is temperature controlled and has good lighting. A sink with hot and cold water, electrical outlets for test apparatus, shelves and a desk are required.

One of the primary functions of the QC lab is record keeping. You must collect data, record it and put it in a form that is usable and accessible for making decisions. The economical way of doing this is by pencil and paper. If large amounts of data must be reviewed than a small computer may be necessary. A spread sheet programme and/or a statistical quality control programme might be necessary.

NOTE: A computer may not save time for simple day-to-day operations, but it does allow handling large volumes of information easily, arranging it and sorting it into a meaningful form.

A QC lab should have a list of all raw materials, with approved suppliers, used in the plants. It should have the 'phone numbers of not only the sales people but the technical people of suppliers. A list of industry organisations, with phone numbers, for answering questions should be included.

It should also have a selection of references. The first of these should be the Yellow Pages for the nearest town or city. Reference books should be set up for each supplier's data sheets, process bulletins and bulletins on how to use their products. The lab should be on the subscription list of as many industry magazines as possible. The subscriptions of many of these magazines are free to industry people.

A binder must be set up that contains all of the test methods that the lab is to use.

The QC lab should have a system for reporting information. Simple forms can be used and should be arranged so that the characteristics and consistency of a batch can be seen at a glance.

When a material comes in there are a number of QC steps that should be done. The details of the actual test depend on what type of part that will be made from it and what you require from the part. Start with the simplest tests then go to the more complicated. You have to do the first steps before you can do the final steps.

3.1. INFORMATION RECORDING

You must record the information on a particular product or raw material when received. This includes:

- The code number, batch number, batch date, date received and a part number if you have such.
- If specifications have been set up for a particular raw material, these should be listed with their tolerances.
- If a specification sheet comes with the material, it should be compared to standard specifications and the typical results of previous batches.

3.2. VISUAL INSPECTION

The simplest inspection is visual and is often overlooked.

This should consist of :

- Look at the containers as they are received. Are any of them damaged or is there any swelling or buckling? Are there any leaks?
- Open the container and look at the material. Does it appear like the previous batch? It is roughly the same colour, cloudy, clear, etc.? Are there any signs of visual contamination, water etc.?

NOTE: The colour of resins may vary greatly from batch-to-batch. If there seems to be a variation, check with the supplier. Results of these visual inspections should be written down.

- Mix the container and visually compare it to the unmixed inspection report to see if any settling has occurred.

NOTE: Some settling may be normal. This means that a plant must be aware that they must mix the material before it is used.

- Pull a sample, put it in a proper container and mark it with the code number, batch date, and date received. Save this, retain for testing or future reference for 90 days.

NOTE: Polyester should be stored in opaque containers at 73°F (23°C) or below.

The following test equipment is required for the above step. Clipboard, paper, paper cups. Containers and a marker. See Yellow Pages under cans and paper and plastic cups.

Before you can start a testing programme you should obtain a list of all the normal tests and procedures the supplier uses to QC the product.

NOTE: If you need an exact correlation, the supplier and you both must use the same test procedures, equipment, etc.

Review the literature for test methods and decide which test procedure you would use. It should be written up and filled in a notebook. Send a copy to your supplier and ask for his comments.

Any time a test is run, the results should be recorded and compared to standard and previous batches.

4 OUTLINE OF BASIC TESTS AND REQUIRED EQUIPMENT

In this section we will list the basic tests one may want to do on FRP laminate materials and also list the required equipment. The final choice of which test run will vary from plant and is up to the manufacturer.

The equipment mentioned here is used for example purposes. There may be other brands that are suitable. More specific guidelines on many of these tests are in the following section. Please consult the index if you require a quick guide to a particular test.

4.1. CATALYST

A very small component but a very important one. There are only two basic tests that can be run with catalyst unless you have a very sophisticated laboratory.

Visual

Check the clarity and see if there are any particles, crystals or cloudiness in this material. If there are you should contact your supplier at once.

Reactivity

You must run comparison tests comparing a new lot of catalyst to an old lot of catalyst in the same resin or gel coat. For this type of QC work to be effective, very tight controls are required for good accuracy.

Gel, cure and peak

You may want to run these tests (also see procedure under 6.1.3).

The equipment necessary is: Paper cups. Insulating cup. Balance (accurate to 0.1 gram). Thermometer (accurate to 0.5°C)

4.2 GEL COATS

4.2.1 Gel time

(see procedure under 6.1)

You can set up to run gel times at a low cost for the necessary equipment, but your accuracy on short gel items will be +/-2 minutes. The accuracy on long gel time systems (20 minutes plus) may only be within +/-5 minutes.

When you spend more money on the equipment your accuracy increases and many times one piece of equipment can be used for a number of tests. Examples area a balance and thermometer.

Equipment needed is : Timer or gel timer. Accurately calibrated thermometer (from chemical supply firm). Paper cups, wide mouthed glass jars. Scales. Graduated paper/plastic cups marked in cc's or ml's. Syringe or ml graduated cylinder (medical supply firm or others). Small school balance. Spatula and stirring stick. Water bath - Fish tank with heat is a cheap alternative (but you must find alternative cooling method.

4.2.2. Viscosity and Thix Index (TI)

Equipment necessary to run this particular test is as follows: Glass jar with wide mouth or similar tin can. Stop watch. Thermometer. Brookfield viscometer and control standard fluid (The best accuracy possible is +/-1 factor for a particular speed and spindle). Water bath.

4.2.3. Specific Gravity

Equipment necessary to run this test is as follows: Specific gravity cup and lid. Balance.

4.2.4 Hide

Equipment necessary to run this test is as follows: Holder. Clipboard. Drawdown plate. Drawdown paper. Drawdown bar.

4.2.5 Colour

If you run a colour test, you must establish a colour standard. Normally a colour standard should be a gel coated panel. The standard may be developed by matching some other item such as vinyl, paint, etc. Once the match is selected, you should have three panels which are marked permanently with the following information on the back; standard, part number, colour and the date. Each panel should be at least 3 by 5 inches (8 by 13 cm) and placed in envelopes. One should go to your supplier, one is working standard that is used day to day. The third is a master which is stored in a cool dark place and only used when the working standard is in question. This third master is the final reference for colour.

If accurate colour consistency is required the master standard and working standard must be kept in a freezer when not in use.

Colour standards will change on ageing unless stored at 0°F +/-5°F (-18°C +/-2°C) therefore a freezer is necessary.

NOTE: This freezer cannot be used to store peroxides or food.

The equipment for running colour is as follows: a mould (fibreglass or glass). Spray gun, 1 quart (1 litre). Pressure pot (stem cut off so a small bottle can be inserted). Light source (below in order of effectiveness): northern light, - fluorescent light with cool day light bulbs, light booth.

4.2.6. *Sag*

To run this test, the following equipment is needed: Glass mould. 3/4 inch (2cm) adhesive tape. Spray gun. Thickness gauge (15-20 mil/thou range)

4.2.7. *Other Tests*

Additional tests that can be run concerning gel coats are:

- Calibration of the spray equipment *(see 4.2.1 for equipment)*

NOTE: a balance and large paper containers (cups) are required.

- Gel Coat Thickness

Gel coat thickness can be checked in the wet film by use of the thickness gauge (mil gauge).

If the gel coat is cured, cut outs can be checked with a pocket comparator.

- Other defects can be checked by use of a 6 - 10 powdered magnifying glass.

4.3 LAMINATING RESINS

The following tests can be run on laminating resins:

4.3.1. *Gel times*

(See necessary equipment under 4.2.1.)

4.3.2. *Viscosity and TI.*

NOTE: You may need a different model of Brookfield as the viscosity is considerably different than gel coat (necessary equipment under 4.2.2)

4.3.3. *Specific Gravity*

(Equipment under 4.2.3.)

4.3.4 *Barcol*

Necessary equipment is: Quart (litre) metal can lid. Balance. Barcol meter 934 model

4.3.5 *Cure and Peak*

(Equipment under 4.1.3)

4.4 FIBREGLASS

4.4.1. *Weight per area*

Equipment needed: Scissors. Ruler or metre stick. Balance.

4.4.2. *Binder content*

Equipment needed: Balance. Muffle oven.

4.5 SOLVENT

The primary test that can be run in shop for solvents is visual. There are other tests available but they require sophisticated and costly equipment (i.e. GPC, refractive index, boiling point etc.). In visual tests, look for colour clarity. Example: styrene should be clear and water white in colour.

NOTE: Record the "grade" of solvent used - reclaimed, industrial, etc.

5 QUALITY CONTROL TESTS

5.1 IN PROCESS

The QC lab can monitor the effect of production changes. These can be process, equipment or raw material changes. These are performed by comparing records before and after the change.

In-Process QC checks can and should include:

5.1.1. *Calibration of the equipment*

(See 4.2.1. for necessary equipment)

5.1.2. *Glass to resin ratio*

- While the components are "wet". Chopper gun glass/resin ratio requires the following equipment: Plastic bags. Balance.
- When the components are cured the glass to resin ratio can be checked with the following equipment: Balance. Muffle Oven

NOTE: If the resin system is filled, the test is much more difficult, fillers such as calcium carbonate and aluminium trihydrate can break down during the heating process.

5.1.3. *Thickness of laminate*

Can be checked in the cured state by using a pocket comparator.

5.2.FINAL PART INSPECTION

5.2.1. *Among the inspection of final parts, before they leave your plant, should be the following tests or procedures:*

- Total Weight - Requires a scale. The size of the scales required will vary based upon the size and weight of the part.
- Surface Quality - is a visual check
- Dimensions
- Correlation studies of the inspection reports to find areas of constant repairs, defects, design errors or process problems.

- ***5.2.2. The QC lab can also check the compatibility and the durability of your parts. Some of these tests are :***

- **Water Resistance** - A 100 hour boil test can be run. This requires either a 8 by 8 inch (20 by 20 cm) cut out of the parts or a mould being run through the production line as parts are made. A corrosion tester is necessary.

- **Weathering** - General weathering tests can be run by taking a cut out 9 by 12 inches (23 by 30.5 cm) and cutting off a strip 3 by 12 inches (8 by 30.5 cm). Both pieces then are marked and coded. The smaller pieces are put in an envelope and kept as the control.

The second piece can be placed outside facing south at about a 45° angle. The panel should be checked every month, noting any changes? If any more precise weathering is required, panels would have to be sent to a testing lab for standard weatherometer or to an exposure site. Most often these exposure sites are in Florida, U.S.A.

- **Physicals** - Normally performed by an outside lab. Look in your Yellow Pages under Testing Labs or contact a local university. Tensile strength and tensile modulus. Flexural strength and flexural modulus. Impact.

- Barcol Hardness.

6 PARTICULAR TESTS

In the above section we listed tests and outlined equipment. In the present section we will take a much closer look at many of these tests to see how they are actually done. This section is organised by the particular tests one would run listed under the polyester products one normally finds in industry.

6.1 UNACCELERATED RESINS (MOULDING)

6.1.1. Non-Volatiles (NV) or Resin Solids

Resin Solids are run only on the resin and monomer or solvent portion of any system.

All pigments or fillers, if present, are separated out before the tests.

This test is used to determine the ratio of base polyester resin to monomer (usually styrene). This is done by boiling off monomers or solvents which boil above 105°C. This ratio of base resin to styrene can affect the cured physical properties of the resin. It will vary according to type of material and application method. It can be as low as 50% resin to as high as 80% resin.

See the data sheet of each material for is proper range.

Solids test procedure

1. Weigh a suitable tin lid approximately 5cm in diameter and record to the nearest 0.001g as W1.
2. Place approximately 1g of resin, weighed to the nearest 0.001g, into the tin lid and record as W2.
3. Place the tin lid and contents into an oven at 150°C for 1 hour.
4. Re-weigh the "dried" resin and tin lid to the nearest 0.001g as W3.
5. Calculate the present solids:

$$\text{Percent solids} = \frac{100 - (W2 - W1) - (W3 - W1) \times 100}{(W2 - W1)}$$

The test should always be done in duplicate.

6.1.2. Viscosity of Non-Thixotropic Polyester Resins

Viscosity is a material's resistance to flow.

- The rate of rise of an air bubble in a sampled centred in an inverted corked glass tube is matched against known lettered standards at the same (77°F or 25°C) temperature. The method has an accuracy of ± 5%.

- Brookfield Viscosity
  Equipment : Brookfield Model LVF viscometer and spindles.

Procedure:

1. Fill eight ounce wide mouth jar to within one inch of jar neck.
2. Adjust temperature 77°F, (25°C) being careful to avoid inclusion of foreign material. Adjust temperature by placing a lid on the jar and placing it in 77°F (25°C) constant temperature water bath until 77°F (25°C) temperature is reached.

3. Choose spindle to be used. Remove lid from container and place spindle into resin being careful to avoid entrapment of air bubbles beneath spindle.
4. Attach spindle to viscometer and lower spindle to level mark indicated on spindle.
5. Start viscometer and set to specified speed for testing. Allow viscometer to run for two minutes. Stop and take reading.
6. Without hesitation, take temperature of resin sample and record
7. Determine viscosity from Brookfield conversion table for above observed temperature.

■ 6.1.3. SPI Gel Time

This test generally is used when a resin will be processed by catalyst plus heat rather than with a promoter. It provides a procedure for determining the relative reactivity between different batches.

SPI Procedure for Running Exotherm Curves

1. Allow samples of uncatalysed polyester resin to reach room temperature, preferably 75 - 79°F (24 - 26°C).
2. Weigh one hundred grams of resin into an eight ounce jar.
3. Weigh two grams of catalyst (50% BPO paste) into resin in eight ounce jar.
4. Stir catalyst into resin well for one minute, being careful to avoid air entrapment.
5. Pour catalysed resin into a 19 x 150 mm. test tube to a depth of 8 cm. (Approximately 20 grams of resin).
6. Allow resin mixture to sit at room temperature approximately 15 minutes (±5 minutes) away from strong light.
7. Submerge test tube into constant temperature 180°F (82°C) water bath.

8. Insert thermocouple (iron-constantan) into centre of resin mixture.
9. Record time required for resin mixture to reach 190°F from 150°F as the gel time; the time from 150°F to peak exotherm as cure time, and the peak exotherm.

■ 6.1.4. Specific Gravity

Tests are run after the samples have sat in a constant temperature bath at 77°F (25°C) for at least one half hour.

The steps are:

1. Weigh the specific gravity cup and lid.
2. Fill the cup with resin.
3. Place the lid on the cup so that resin comes out the small hole in the top. Wipe off the excess resin from the lid.
4. Weight the cup, lid and resin.
5. Subtract the weight of the cup and lid.

Specific Gravity is the weight of the resin in grams divided by 100.

■ 6.1.5. Acid Number

(Similar to ASTM D 465-59)

The acid number is the number of milligrams of potassium hydroxide (KOH) necessary to neutralise the free acid end groups in one gram of sample. This test is used on resins to determine how far the reaction during cooking has proceeded and is used for batch to batch consistency. The acid number will vary from resin to resin; it may be as high as 60 or as low as 5.

NOTE: Acid number can be calculated in two ways : On resin solids only monomer factored out, or on total solution monomer not factored out.

Generally, our acid numbers are based on resin solids only.

Procedure

Tare a titrating flask on torsion balance and weigh into it resin in grams to equal factor if viscosity makes it possible, because this simplifies calculation. The factor is found by multiplying the molecular weight of KOH by the normality of the solution. Factor equals Normality x 56.1. Dissolve in acid number solvent prepared as follows: Solvent one part xylene/two parts toluene/denatured alcohol/small amount phenolphthalein)

- Usually, 20 to 30 ml of this mixture (neutralised to faint pink before dissolving resin) will dissolve a five gram sample of resin. Titrate to a faint pink that will hold 30 seconds.

(This colour with polyesters is often quite fugitive).

- Calculate as follows:

$$\frac{\text{ml of KOH x Factor} \div \text{Percent N.V.}}{\text{Weight of Resin}}$$

Example: Factor 4.4. resin at 50% non volatile.

20 ml of KOH used to neutralise

$$\frac{20 \text{ x } 4.4 \div 50\% \text{ N.V.} = \text{A.N. or } 20}{4.4 \text{ grams}} \qquad \frac{}{0.5} = \text{acid number of } 40$$

6.1.6. *Colour*

Polyester resins have a colour from water clear to a dark amber. This colour varies with resin type and formulation it is normally important when a resin is used to make water clear castings and translucent sheeting. Note additives like cobalt will affect the colour. There are two colour tests:

Gardner Colour ASTM D 1544-74. This is the normal test and basically a test tube of resin is compared to known standards and is ranked 1 (lightest) to 18 (darkest).

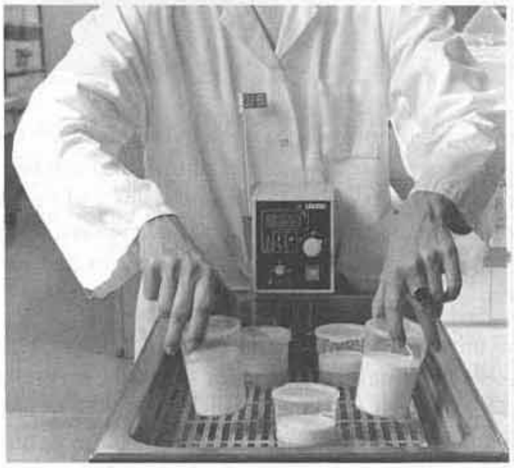
APHA Colour (Hazen). This test is used to rank resin when the Gardner colour is 1 or less. Again, a tube of resin is compared to known standards.

6.2. ACCELERATED CASTING RESIN (marble)

6.2.1. *Pot Life or Gel Time*

Is used to determine how much time you have after catalysation to work with the material at a particular temperature, when the catalyst is mixed in until the resin is no longer liquid.

This test is normally run at 77°F (25°C). Temperature does greatly affect this test.



Procedure

1. Adjust sample to 77°F (25°C) +/- 1°F (0.5°C)
2. Check Gel Meter for proper operation, adjustment of contacts.
3. Set Gel Meter timer to zero.
4. Accurately weigh in required amount of catalyst (normally 1.5% Methyl Ethyl Ketone Peroxide) to 100g of sample otherwise specified.
5. Simultaneously start power and stir catalyst into sample well for one minute. Scrape side of jar while stirring.
6. Place jar in water bath beneath Gel Meter. Centre rod in sample. Adjust meter and rod for vertical alignment.
7. Turn on test switch.
8. When buzzer sounds, timer will stop. Turn power and test switch off.
9. Record result.
10. Clean all equipment and set time back to zero.

- ***Report***

11. Record gel time to nearest 0.1 minute.
12. Report any deviations from standard temperature and conditions.

■ 6.2.2. *Barcol Hardness*

(similar to ASTM 2583)

This test is used normally to determine the relative time when a material reaches its cured state. It also can be used to compare the hardness of different resins and the development of cure. This test is not recommended for production gel coats, but is appropriate for resins and tooling gel coats.

A Barcol impresser measures the resistance to penetration of a needle-like point on a scale of 0 to 100. It requires a mass of material to get an accurate reading. Care must be taken when testing thin films as the needle can penetrate them and give a reading from the substrate below the film instead. For this reason we do not recommend checking Barcol on a gel coat film.

There are two different Barcol meters used in the FRP industry:

- 935 model (softer materials) normally used for initial readings.
- 934 model (hard material) normally used for ultimate cure or when 935 gives readings of 75 or above.

Procedure

Many times, this test is run at the same time as the pot life test. The sample size is increased to either 150 g. Or 200 g. And brought up to 77°F (25°C) and catalysed.

1. Calibrate Barcol impresser versus test disc.
2. Note the time of catalysation.
3. Weigh a specified weight into an aluminium weighing dish and place on a nonheat conductive surface free from drafts. Remainder of sample used for pot life test.
4. After the sample has gelled, test sample every five minutes with a pencil. If the pencil dents the resin, do not use Barcol impresser. Note that the time starts from moment of catalysation and test normally runs one hour or until 70 or 80 is reached on a 935 Barcol.
5. If a pencil will not dent the resin, take a reading with the 935 Barcol Impresser by pressing needle assembly into the resin - note average of at least three readings. Make sure needle assembly is perpendicular to resin surface.
6. Continue this procedure until 935 Barcol reaches 60 to 70. When this happens, then the 934 may also be used.
7. Report time and readings.
8. Wash needle assembly if any resin sticks to it to prevent blocking the needle.

Example : Catalysed gelled

Time (Min.)	935	934
0	-	-
15	-	-
20-25	-	-
30	5	-
35	15	-
40	50 - 60	0
45	70	0.5
50	80	15
55	80	20 - 30
60	80	40

■ 6.2.3. *Viscosity*

Brookfield viscosity is normally run using the same procedure as in unaccelerated resins (see 6.1.2). The Gardner Holdt is normally not used.

■ 6.2.4. *Specific Gravity*

This test is run using the same procedure as in unaccelerated resin (see 6.1.4).

■ 6.2.5. *Other*

The following tests are not normally run on accelerated casting resin. They may have been run on the resins used to make the casting resin: SPI. Solid.Colour.

■ 6.3 LAMINATING RESIN

■ 6.3.1. *Viscosity*

Laminating resins are thixotropic or have a false viscosity. This makes it essential that the model of Brookfield, spindle, speed and time of reading are noted. These must be the same to compare viscosities with other tests or resins.

■ 6.3.2. *Thixotropic Index (TI)*

This test gives an indication of the false body of a resin and directly relates to sag or drain resistance.

Basically, the viscosity is run using a Brookfield and spindle at two different speeds (one is ten times the other) and dividing the slower-speed viscosity by the high speed viscosity, normal range is from 1.2 to 3.0

Procedure

Run the viscosity at RVT, No. 2 spindle at 5 RPM and 50 RPM using the unaccelerated resin procedure except take readings after two minutes.

Divide the 5 RPM viscosity by the 50 RPM viscosity.

■ 6.3.3. Pot Life

Is run the same as casting resins.

■ 6.3.4. Barcol

Is run the same as casting except using an inverted quart (litre) metal container lid in place of aluminium weighing dish. Normally 32 grams.

■ 6.3.5. Specific Gravity

Is run the same as unaccelerated resin *(6.1.4)*.

■ 6.3.6. Sag or Drain

There is no industry standard test for sag. A number of test procedures have been tried, but it is hard to control all the variables involved (temperature, glass type, amount of resin, amount of laminate... etc.).

■ 6.3.7. Wet Out

There is no industry standard, as it is hard to control all the variables (glass type, binder, amount of binder, amount of resin).

■ 6.3.8. Exotherm

There is no industry standard. This can be run by making a laminate of known composition, size and weight at a given temperature and recording the temperature rise and time-to-peak - or by recording the temperature rise and time of a known mass in a particular container.

■ 6.3.9. Other

The following tests are not normally run on laminating resin: SPI. Solids. Colour.

6.4. GEL COATS

■ 6.4.1. Colour

Colour is normally run by eye or machine by comparing a cured sample to a cured standard under a given set of light conditions.

NOTE: Different types of lights will make a colour appear to be a different shade.

Also, the standard must be made out of the same type of materials as the batch. Other materials, paint, vinyl, ceramics, etc., many times use pigments which are not acceptable in polyesters.

This difference of pigments can cause a colour flip, producing different colour in different types of lights. This phenomenon is called metamerism.

It is impossible to achieve an exactly perfect colour match between two batches. This is due to the fact that there are very, very small differences in colour of batches of pigment, and of all the chemicals involved. Usually, the colour is a match within visual limits.

To minimise colour variance, we match to a permanent standard which is kept in a freezer when not in use.

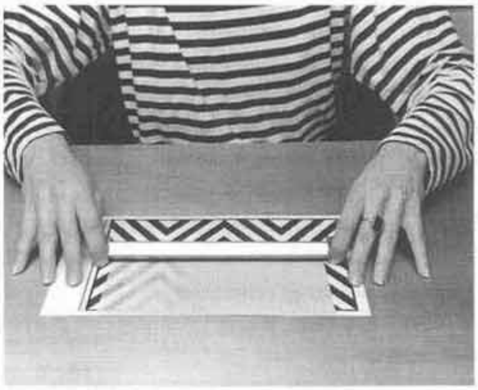
■ 6.4.2. Sag

Sag is normally checked in one of two ways:

- Spraying the gel coat out onto a glass panel 18 to 20 mils thick, then a mil gauge or wire is drawn across leaving gaps. The panel is placed at a 90° angle and checked later to see if the gel coat has sagged and filled the gaps.
- A piece of one inch tape is placed on a glass panel and 18 to 20 mils of gel coat is sprayed over the whole panel. The tape is pulled immediately after spraying and panel placed at a 90° angle. Later, the amount of sag into the one inch area is noted.

■ 6.4.3. Hide

This test determines at what thickness a gel coat will prevent a standard coloured pattern from being visible. The thickness is then measured with a thickness gauge. Note the gap on a drawdown bar will not deposit the same thickness of gel coat due to friction and fluid dynamics, e.g., 10 mil gap may give only 6 to 8 mils gel coat thickness. The paper then is observed to see at what thickness of gel coat the pattern is no longer visible.



■ 6.4.4. Grind

This test may or may not be run on gel coats. It normally is run on the pigment concentrates used to make the gel coat. Basically, a small amount of material is placed on a grind gauge and levelled with a special drawdown knife. Then, it is visually inspected to see at what thickness particles appear on the scale.

A grind gauge (Hegman normally used) is a stainless steel slab in which a variable depth trough is milled. The scale runs from 0 (4 mils deep) to 8 (0 mils deep) in .50 mil increments.

▪ *6.4.5. Porosity*

Porosity is entrapped air. Porosity can be checked on a cured gel coat film by:

Surface - a marking pen is rubbed over an area,, then a rag dampened (not wet) with solvent is wiped over the area to spread and remove excess ink. The area is viewed with or without a magnifier light.

Subsurface - the area is first sanded (600 - 320 grit), then inked, wiped and inspected.

▪ *6.4.6. Pot Life*

Pot life is run using the same procedure as accelerated casting resins except normally 1.8% MEKP is used.

▪ *6.4.7. Viscosity*

Is normally run using the same procedure as laminating resins, but use RVF model, No. 4 spindle at 4 RPM with two minute reading. *NOTE : this material is thixotropic.*

▪ *6.4.8. Thixotropic Index*

TI is normally run using the same procedure as laminate resins, *(see 6.3.2)* but use RVF model and 2 and 20 RPM. Ranges 5 to 8.

▪ *6.4.9. Specific Gravity*

Run the same as for resins (6.1.4.)

▪ *6.4.10. Other*

The following tests are not normally run except as double checks or for a particular reason.

- ***Pigment Solids***

  A weighed gel coat sample is centrifuged. The separate pigment (see Resin Solids) is mixed with solvent and centrifuged. This process is repeated several times until free of resin. The washed pigment is dried and weighed. Pigment solids are determined by :

$$100 \times \frac{\text{weight of dried pigment}}{\text{weight of gel coat}}$$

(NOTE : Subtract weight of container).

▪ *Resin Solids*

Run the same on resin (6.1.1 this section), but use only the resin separated from the pigment and extender by centrifuging.

▪ *6.4.11 Spray.*

Each gel coat is sprayed out at known settings and examined after cured.

We are examining the samples for : Colour. Surface defects e.g. porosity, contamination. Flow, sprayability.

7 TESTS FOR FINAL PROPERTIES

▪ 7.1. GENERAL DISCUSSION

We have reviewed the tests that are run on polyesters before they are used to make a part. Now we will take a brief look at the tests that can be run on a part of which relate to the final physical properties. These tests give a relative guide for comparing one material versus another. They can tell you which material performs better under a certain set of conditions, and the real test of a material comes with actual service. Once a product is taken home and used by the consumer, it no longer matters whether the tensile strength is 90 to 150 MPa. The product succeeds or it fails.

To assure success of a product, the design engineer, who through experience and judgement, balances material characteristics and service requirements against the type and amount of materials needed in a part to give an adequate safety margin. It is in this area of product design and specification that the tests themselves are tested.

In many cases, service requirements may be so complex that suitability of a material for the service can be determined only in actual service.

The material supplier may not have all the information necessary to determine if a material is suitable. The engineer does not know exactly what the manufacturer wants in service life; he has no control over how the material is used and what other materials will also be used. The material supplied can only present the results of tests he has run on how the material performs under a certain set of conditions. In most cases, he will run tests that you feel are important. The manufacturer has the final decision whether a material is suitable for use in his process and for final product.

The tests listed are described briefly - too briefly to be used as a laboratory guide - in order to give interested people a general idea of what the tests are about.

Full detail procedures for all ASTM tests are available from the
American Society of Testing and Materials
1916 Race Street
Philadelphia, Pennsylvania 19111.

Note that in all physical tests, the test sample is preconditioned to assure full cure. If the polyester is not properly cured, the full physical properties cannot be obtained and failure or low readings may result, which may not be due to the material. Also, it is essential that the test samples for comparisons be constructed in an identical manner, variances in thickness, type, substrates, and amounts can change the results.

7.2 *TENSILE, ISO R527 type I*

Specimen

Specimens can be moulded or machined from castings, laminates, or compression moulded plaques. They are given standard conditioning. Typically 1/8 inch (3.18mm) thick, their size can vary; their shape is like a dog bone, e.g., 1/8 inch (3.18mm) thick, 8 ½ inches (21.6cm) long, ¾ inches (2cm) wide at the ends and middle ½ inch (1.3cm) wide.

Procedure

Both ends of the specimen are firmly clamped in the jaws of a testing machine. The jaws are moved apart , pulling the sample from both ends. The stress is automatically plotted against strain on graph paper.

Significance

Tensile properties are usually the most important single indication of strength in a material. The force necessary to pull the specimen apart is determined; also, how much the material stretches before breaking can be determined.

7.3. FLEXURAL PROPERTIES, ISO 178

(Flexural Strength)

Specimen

Usually 1/8 x 1 x 4 inches (3.2mm x 2.5cm x 10cm). Sheet or plaques as thin as 1/16 inch (1.6mm) may be used. The span and width depend upon thickness. Specimens are conditioned.

Procedure

The specimen is placed on two supports spaced two inches (5cm) apart. A load is applied in the centre at a specified rate and the loading at failure is used to calculate the flexural strength (MPa).

Significance

In bending, a beam is subject to both tensile and compressive stresses. (Flexural Modulus). The Flexural Modulus is usually calculated from the data generated during the Flexural Strength tests. Flexural Modulus is the material's ability to hold its shape under flexural loading, or its stiffness.

7.4 IZOD IMPACT, ASTM D 256

Specimen

- Usually 1/8 x ½ x 2 ½ inches (3.2mm x 1.3cm x 6.4cm).
- Specimens of other thickness' can be used (up to ½ inch or 1.3 cm) but 1/8 inch is frequently used for moulding materials because it is representative of average part thickness.

Procedure

A sample is clamped in the base of a pendulum testing machine so that it is cantilevered upward. The pendulum is released, and the force consumed in breaking the sample is calculated from the height the pendulum reaches on the follow-through.

Significance

The Izod value is useful in comparing various types of grades of plastics and constructions. In comparing one plastic with another, however, the Izod impact test should not be considered a reliable indicator of overall throughness or impact strength. Some materials are notch-sensitive and derive greater concentrations of stress from the notching operation. The Izod impact test may indicate the need for avoiding sharp corners in parts made of such materials.

7.5 COMPRESSIVE STRENGTH, ASTM D 695

Specimen

Prisms ½ x ½ x 1 inch (1.3 x 1.3 x 2.5 cm) or cylinders ½ inch diameter x 1 inch (1.3 cm diameter x 2.5 cm).

Procedure

- The specimen is mounted in a compression tool between testing machine heads which exert constant rate of movement. Indicator registers loading.
- Specimens are usually conditioned.
- The compressive strength of a material is calculated as the psi required to rupture the specimen or deform the specimen a given percentage of its height. It can be expressed as psi either at rupture or at a given percentage of deformation.

Significance

The compressive strength of plastics is of limited design value, since plastic products (except foams)seldom fail from compressive loading alone. The compressive strength figures, however, may be useful in specifications for distinguishing between different grades of a material, and also for assessing, along with other property data, the overall strength of different kinds of materials.

7.6 HEAT DISTORTION, ASTM D 648

Specimen

Specimens measure 5 x ½ inch (13 x 1.3 cm) by any thickness from 1/8 to ½ inch (3.2 mm to 1.3 cm) conditioned. (Post Cured-Oven).

Procedure

The specimen is placed on supports four inches (10 cm) apart and a load is placed on the centre. The temperature in the chamber is increased at the rate of 2°C per minute. The temperature is reported at a standard deflection.

Significance

This test shows the temperature at which an arbitrary amount of deflection occurs under established loads. It is not intended to be a direct guide to high temperature limits for specific applications. It may be useful in comparing the relative behaviour of various materials in these test conditions, but it is primarily useful for control and development purposes.

7.7 GLASS CONTENT

Laminate with No Fillers

A small piece is accurately weighed and placed in a tared crucible. The sample is then ignited with a Bunsen burner after which it is placed in a furnace. Sample residue is then weighed and per cent glass calculated.

Laminate with Filler

Many fillers break down under heating (e.g., Calcium Carbonate and Hydrated Aluminium) and leave a partial residue. To determine the percent glass in a filled laminate, digestion and separation methods must be used, and it is not easy to do.

7.8. WATER ABSORPTION, ISO R62, method A

Specimen

For moulding materials, the specimens are discs 2 inches (5 cm) in diameter and 1/8 inch (3.2mm) thick. For sheet materials, the specimens are bars 3 inches x 1 inch (8cm x 2.5 cm) x thickness of the material.

The specimens are dried 24 hours in an oven at 122°F (50°C) cooled in a dessicator and immediately weighted.

Procedure

Water absorption data may be obtained by immersion for 24 hours or longer in water at 73.4°F (23°C). Upon removal, the specimens are dried with a cloth and immediately weighed.

The increase in weight is reported as percentage gained.

Significance

The various plastics absorb varying amounts of water and the presence of absorbed water may affect plastics in different ways.

Electrical properties change most noticeably with water absorption. Materials which absorb relatively larger amounts of water tend to change dimension in the process. When dimensional stability is required in products made of such materials, grades with less tendency to absorb water are chosen.

7.9. OUTDOOR WEATHERING

Specimen

No specified size; specimens for this test may consist of any standard moulded test specimen or cut pieces of sheet or machined samples.

Procedure

Specimens are mounted outdoors on racks slanted at a 45° angle and facing south. It is recommended that concurrent exposure be carried out in many varied climates to obtain the broadest, most representative total body of data.

Sample specimens are kept indoors as controls and for comparison.

Reports of weathering : Describe all changes noted, areas of exposure, and period of time.

Significance

Outdoor testing is the most accurate method of obtaining a true picture of weather resistance. The only drawback of this test is the time required for several years exposure.

A large number of specimens are usually required to allow periodic removal and to run representative laboratory tests after exposure.

7.10 ACCELERATED WEATHERING, ASTM G 23

(Recommended Practice)

Specimen

Any shape; size up to 5 x 7 x 2 inches (13 x 18 x 5cm).

Procedure

Artificial weathering has been defined by ASTM as : "The exposure of plastics to cyclic laboratory conditions involving changes in temperature, relative humidity, and ultraviolet (UV) radiant energy, with or without direct water spray, in an attempt to produce changes in the material similar to those observed after long term continuous outdoor exposure".

Following are the three most commonly used types of light sources for artificial weathering:

Selection of light source involves many conditions and circumstances, such as what material is being tested, the type of information desired, etc.

Source	UV Energy Output. Approx. (X Sunlight)
Enclosed UV Carbon Arc	7.5
Open-flame Sunshine Carbon Arc	3
Water cooled Xenon Arc	1*

*ASTM G 26

Significance

Since weather varies from day-today, year-to-year, and place-to-place, no precise correlation exists between artificial laboratory weathering and natural outdoors weathering. However, standardised laboratory testing produces results with acceptable reproducibility and fairly rapid indications of weatherability are obtainable by comparisons to known materials.Through testing experience over a period of time, these correlation's are established.There is no artificial substitute for precisely predicting outdoor weatherability on materials with no previous weathering history.

We have received many questions on why we do not perform QUV weathering tests on polyesters.The automotive people have made this test popular, but they are now drifting away from it.

The advantage of QUV is that it is fairly quick and easy to run.

Our evaluations have shown it does not correlate to outdoor exposure for unsaturated polyesters and we have stayed with the more reliable standard weatherometer test.

The problem with QUV is the type of light it uses. This particular light source is not the same type as natural sunlight. It appears now that QUV may correlate for aliphatic polymers, but not aromatic. Unsaturated polyesters are aromatic.

There are documents which tell of the problems of using QUV or fluorescent UV lamps for weathering tests.

The following quote is taken directly from paragraph 3.1 of ASTMD 4587-86. Standard Practice for: Conducting Test on Paint and Related Coatings and Materials Using a Fluorescent UV-Condensation Light and Water Exposure Apparatus.

"However, light sources, such as fluorescent UV lamp, that emit a significant amount of radiation at wave lengths shorter than those in natural sunlight, may cause results that lead to unrealistic evaluations of weathering properties"

The following quote is taken from John L Scott's paper "Correlation Between Outdoor Performance and Laboratory Accelerated Testing of Light Stability of RP Panels, "Session 11A, page 3, presented at the 41st Annual Conference of Reinforced Plastic/Composites Institute - January 27 - 31, 1986:

"Judgement of a material based solely on the results provided by this type of unit could lead to the rejection of a formulation which might be quite durable when exposed to natural daylight since the short wave length UV provided by this light source does not exist in the "real world". Conversely, a material sensitive to energy at 350-370 nm could pass a test using this light source only to fail when exposed outdoors. It is evident that one must be very cautious in the use of fluorescent UV-condensation devices when testing materials".

■ 7.11. DIELECTRIC STRENGTH, ASTM D 149

■ *Specimen*

- Specimens are thin sheets or plates having parallel plane surfaces and of a size sufficient to prevent flashing over. Dielectric strength varies with thickness and, and therefore, specimen thickness must be reported.
- Since temperature and humidity affect results, it is necessary to condition each type material as directed in the specification for that material.The test for dielectric strength must be run in the conditioning chamber or immediately after removal of the specimen form the chamber.

■ *Procedure*

- The specimen is placed between heavy cylindrical brass electrodes which carry electrical current during the test. There are two ways of running this test for dielectric strength:

Short-Time Test:

The voltage is increased from zero to breakdown at a uniform rate -0.5 to 1.0kv/sec.

The precise rate of voltage rise is specified in governing material specifications.

Step-By-Step Tests:

The initial voltage applied is 50% of breakdown voltage shown by the short-time test. It is increased at rates specified for each type of material and the breakdown level noted.

- Breakdown by these tests means passage of sudden excessive current through the specimen and can be verified by instruments and visible damage to the specimen.

■ *Significance*

- This test is an indication of the electrical strength of a material as an insulator.The Dielectric strength of an insulating material is the voltage gradient at which electric failure or breakdown occurs as a continuous arc (the electrical property analogous to tensile strength in mechanical properties). The dielectric strength of materials varies greatly with several conditions, such as humidity and geometry, and it is standard test values to field use unless all conditions, including specimen dimension are the same. Because of this, the dielectric strength test results are of relative rather than absolute value as a specification guide.
- The dielectric strength varies inversely with the thickness of the specimen.

■ *Boil Test (ANSI 2124,1 - 1987)*

(American National Standard for Plastic Bathtub Units).

The purpose of this standard is to establish generally acceptable quality standards for plastic bathtub units in the United States. Its purpose is also to serve as a guide for producers, distributors, architects, engineers, contractors, home builders, code authorities, and users; to promote understanding regarding materials, manufacture, and installation; to form a basis for fair competition; and to provide a basis for identifying bathtub units that conform to this standard. This standard and test procedures deal with the acceptability of a plastic bathtub unit as a plumbing fixture. Building codes may have additional requirements.

This standard has a number of tests within it. We will not cover all of them in detail; see the actual standard for details. Basically, the tests which must be run by an independent lab are:

- ***Workmanship and Finish***

This test spells out how many defects and blemishes are allowed after visual inspections, inking and sanding.

- ***Structural Integrity.***

This series states what types of loading and impact the drain fittings, side walls and floor must withstand.

- ***Water Resistance***

This is the 100 hour boil test.
(212°F - 100°C)

NOTE: Type 4 bathtub units, (Thermoplastics) are tested at 180°F (82°C), not in boiling water.

This test requires a certain size panel to be exposed to boiling water, normally for 100 hours. The panel is then visually inspected for colour change, blisters, change in surface profile, cracks and loss of visible gloss. Each item is rated on a scale of 0 to 5 and 0 being no change and 5 being extreme change approaching maximum possible with 1 to 4 being degree of change in between these extremes. The ratings are somewhat subjective and a certain degree of change in each category, (e.g., colour change, blisters, cracks, etc.,) is allowed.

Failure is when any one area is rated above 4 or the total of all five areas is above 9.

NOTE: The applicability of this test to measure product to product field suitability has not been established. It has been used to rank materials under one set of conditions, but passing or failure does not automatically imply that material is or is not suitable for other types of applications. Suitability is determined by the user.

- ***Colour Fastness***

This is a 200 hour weatherometer test.

- ***Stain Resistance***

The stain resistance to a number of chemicals is tested.

- ***Wear and Cleanability***
- ***Ignition Tests***
- ***Cigerette Test***

This test checks if the unit can be ignited or irreversibly damaged by a cigarette.

NOTE: Type 4 units (thermoplastic faced)have a series of other test requirements; see standard itself for details.

7.13 FIRE TESTS

The use, applicability and statements regarding fire test results must be done with great care, as this whole area is in a great state of flux due to regulations.

Different regulatory bodies have different requirements for a material's fire resistance. The major unanswered question is: "Does the fire resistance test predict what happens in an actual fire?" There are no documented tests at this time, outside full-scale tests which absolutely predict what will happen under actual fire conditions.

The present tests tell you only how materials burn under one set of conditions.

8 SOURCE OF EQUIPMENT

Normally you would buy lab supplies and equipment from a company that specilises in laboratory equipment. These are very good sources, but if you are setting up a lab, depending upon what you wish to do, there are other sources of supply. Many items can be purchased at a local drug store or discount store. For example, if you are trying to measure out millilitres of catalyst you can, in many locations, buy syringes that are calibrated in millilitres. You can go the medical supplies for babies for cylinders or eyedroppers that are graduated in millilitres.

For many supplies, the best reference source is the Yellow Pages. You can look under laboratory supplies or if you are looking for a particular item such as paper cups, look under paper cups first. If you do establish a full laboratory, you will want to obtain the catalogues of the laboratory supply companies. For the local ones, check the Yellow Pages under Laboratory Supplies.

The following is a list some of the major ones with their 'phone numbers.

SHEEN INSTRUMENTS
8, Waldegrove Road
Teddington
Middlesex TW11 8LD
081 9770051

GEC AVERY
Smithwick
Warley
West Midlands B66 2LP
021 - 588 1112

PEARSON PARKE
1 - 3 Halegrove Gardens
London NW7 3LR
081 959 3232

METTLER
Kingsmead House
Abbey Barn Road
High Wycombe
Bucks HP11 1QW
0494 450202

GEL COAT SPRAY EQUIPMENT

REFERENCE: PB-3

The application of gel coat is a critical operation. It is dependent on the material, equipment and operator. These are the three factors in determining the quality of your parts. You cannot overlook or take for granted any one of them.

This information is designed to help you in selecting the spray equipment and with determining initial settings. These are general recommendations because each shop is different. The plant, part, production speed and spray person will determine the exact equipment, spray gun and settings.

1. NECESSARY EQUIPMENT FOR THE USE OF A SPRAY GUN
2. GENERAL CONSIDERATIONS FOR SELECTION OF SPRAY EQUIPMENT
3. DESCRIPTION OF TYPES OF SPRAY EQUIPMENT
4. SPRAY SYSTEM SELECTION
5. SPRAY SELECTION AND SETTINGS
6. CALIBRATION
7. CLEAN-UP PROCEDURES
8. MAINTENANCE
9. EQUIPMENT TROUBLE SHOOTING
10. ADDITIONAL INFORMATION ON EQUIPMENT
11. EQUIPMENT SUPPLIERS

1 NECESSARY EQUIPMENT FOR THE USE OF A SPRAY GUN

To use a spray gun efficiently and safely, the following times should be of the proper size and type, and be in proper working condition.

■ VENTILATION

A spray booth is required to spray polyesters. The size and air flow will depend on the size of parts being sprayed.

General rules of thumb.:

- Measurement of the largest part to be sprayed.
  - Height - add a minimum of two feet (61 cm)
  - Width - add a minimum of four feet (1.24m)
  - Length - add a minimum of six feet (1.8m)
- CFM (cubit feet per minute) requirements are figured with the following formula; width x height x 125. The average air velocity, to carry off fumes, is 125 FPM.
- Disposable filters only.
- Contact your Cray Valley representative for recommendations.

■ LIGHTS AND ELECTRICAL SWITCHES

Explosion proof.

■ MANIFOLDS AND REGULATORS

- Manifolds and regulators should have a CFM capacity at least 1 ½ times the sum required by the equipment they supply.
- The atomising air should be on a separate regulator.
- All gauges must be readable and working and should be permanently attached.

■ MOISTURE AND OIL TRAPS

Moisture and oil traps should be installed and drained daily on all air lines at the spray booth. These not only keep contaminants out of gel coats but also protect and lengthen spray equipment life. Do not install within 25 feet of compressor. Traps should be located at the lowest point in the line.

■ QUICK DISCONNECT

If quick disconnects are used, use the largest size possible. Quick disconnects can reduce the volume of air and fluids that pass through them.

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HOSES

Hoses are only for use of delivery of air and fluid from a regulator on a main airline or fluid pump to the gun. The length should not exceed 50 feet (15m) and normally be only 25 feet (8m) long.

Hoses should be large enough to deliver the proper volume of material demanded at the proper pressure when the trigger is pulled at the gun.

You will always get a pressure drop from the pump end of a hose to the gun end.

TABLE OF AIR PRESSUE DROP

Air Pressure Drop at Spray Gun in lbs.

Size of Air Hose Air (Inside Diameter)	20-ft (6m) length	25-ft length (7.5m)	50-ft (15m) length
1/4 inch (6.35mm)	16 ¾	19	31
At 60lbs pressure	19 ½	22 ½	34
At 70lbs pressure	22 ½	25	37
At 80lbs pressure			
5/16 inch (7.93mm)	5 ½	6	11 ½
At 60lbs pressure	6 ¾	7 ½	13
At 70lbs pressure	8	8 ¾	14 ½
At 80lbs pressure			

NOTE: Catalyst and airless hoses are made of special material - consult equipment manufacturer about replacement parts.

MAIN AIR LINES

The main air lines should be of steel pipe and meet the following requirements:

- Be as large as possible.
- Be capable of supplying the pressure and volume of air to run all air-powered equipment used at the same time.
- Be laid out as straight as possible.
- Have minimal fittings
- Have drop lines that come off the top of main air lines.
- Have slant lines to drain any water to one end, with a low end drain.
- Have air lines off drop lines that are not taken off the end but at least 12 inches above. A drain valve should be on the bottom.

Air lines should be pressure tested for leaks yearly.

COMPRESSOR

- Make sure the compressor can supply the volume of air required by all air tools in the plant. (Total draw + 50%)

MINIMUM PIPE SIZE RECOMMENDATIONS

COMPRESSING OUTFIT		MAIN AIR LINE	
Size (H.P.)	Capacity (C.F.M.)	Length	Size
3 to 5	12 to 20	Up to 200 ft (61m) Over 200 ft (61m)	3/4 inch 1 inch
5 - 10	20 - 40	Up to 100 ft Over 100 to 200 ft (61m) Over 200 ft (61m)	3/4 inch 1 inch 1 1/4 inch

CFM Required for various Air Tools

Air motor	4
Polisher	2
Sander	5
Dusting Gun	2.5
Nailers and staplers	6

- If a compressor is being purchased, estimate what will be the future requirements for all air tools in the plant and match the compressor size to the estimate.
- Rule of thumb: one (each) horsepower delivery approximately 4 cubic feet per minute of air.

2 GENERAL CONSIDERATIONS FOR SELECTIONS OF SPRAY EQUIPMENT

Before you can even begin to select a particular spray gun, you must determine the following:

- What type of part is going to be sprayed? Is it a small, large, flat, curved, simple or complicated part?
  - How many parts are going to be sprayed per day (whether all at once, spaced out evenly during the day or at several different times)?
  - How many different colours are going to be sprayed through this gun?
  - What are the future requirements for this spray gun and will it be adaptable to other operations? Is it a temporary or permanent installation?
  - How much physical labour is involved in this spray application (the distance the gun must be moved to spray the part, time to spray one part, dragging of hoses, setting up and cleanup)?
  - What type of maintenance programme do you have or can you set up to protect your investment?
  - What are the safety precautions you must consider?

After answering the above questions, you can determine, in general, what type of gun you need by looking at the characteristics of the spray guns.

3 DESCRIPTION OF TYPES OF SPRAY EQUIPMENT

Spray guns can be classified in a number of ways:

MATERIAL DELIVERY

This refers to how the material is delivered to the gun. This can be done in three ways.

- ***Gravity***

The material is above the gun and flows to the gun - not commonly used for gel coats - sometimes used for clean metal flake gel coats and very heavy, (viscosity) materials.

- ***Siphon***

The material is picked up by passing air over a tube inserted into the material (no direct pressure on the material). Not commonly used for making production parts due to slow delivery rates. Can be used in patching.

- ***Pressure***

The material is forced to the gun by direct air pressure (pressure vessel) or by a pump. If a pump is used, it has a rating usually from 2 to 1 up to 33 to 1. This rating means that if a pump is rated 4 to 1, for every 1 PSI of air pressure put into the air motor the fluid section develops four times that pressure on the material in theory.

For example:

A 4 to 1 pump at 30 PSI is, in theory, delivering material at 120 PSI (4 x 40). In actual practice, the delivery pressure is lower than theoretical. The increase in pressure (4 times) is because the air motor volume is 4 times large than the fluid volume.

Pressure feed systems - mainly pumps - are widely used systems with gel coats.

METHOD OF CATALYSATION

- ***"Hot Pot"***

Catalyst is measured into a container (pressure pot) and mixed in by hand. This is the most accurate method but requires more clean up.

- ***Catalyst Injection***

Catalyst is added and mixed at or in the gun head requiring separate lines and a means of metering catalyst and material flow. This is a common system used in larger shops.

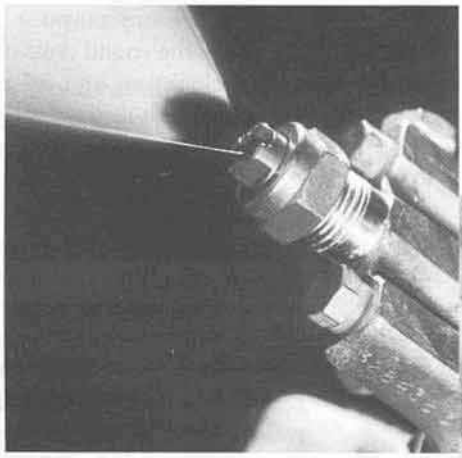
- ***Atomisation***

Conventional Air Atomised.

The material is broken up by direct contact with an air stream (60-90 PSI). This can be done in two ways.

- ***Internal***

Air and gel coat meet inside the gun head and come out a single orifice.



This system is not recommended for gel coats except for one or two special type products as it has a tendency to cause porosity and produce a rougher film. It also requires a solvent flush system.

The internal mix nozzle is often employed in high production applications of materials where fine finish is not required.

The internal mix air nozzle can be used only with pressure feed systems. Only low air and fluid pressures are necessary, and these must be regulated so as to be about equal at the nozzle.

Less air volume is required than with external mix nozzles and this, coupled with the lower air pressure minimises the amount of over-spray and rebound. For this reason, we can refer to internal mix as semi-airless.

Disadvantages of the internal mix air nozzle are few but important. The spray pattern size and shape is controlled by the air cap: a relatively coarse atomisation is produced, not suitable for fine finishes, nozzles are subject to considerable wear (although replacement is easy and low in cost); certain types of materials, such as fast dryers, clog the exit slot of hole and film porosity is worse.

- ***External***

Air and gel coat meet outside of gun head or nozzle. This is a very common spray system.

The gel coat is atomised or broken up in three stages.

- ***First stage atomisation***

  As the fluid being sprayed leaves the orifice of the nozzle, the fluid stream is immediately surrounded by an envelope of pressurised air emitted from the annular ring around the fluid nozzle tip. The resulting turbulence mixes or coarsely atomises the fluid with the air.

- ***Second stage atomisation***

  Immediately past the first stage atomisation, the fluid stream is intersected by jets of air from converging holes on each side of the annular ring. Two straight holes indexed 90° are containment holes and keep the stream from spreading. The turbulence occurring at the intersecting point of the material stream and jets results in a finer atomisation.

- ***Third stage atomisation***

  The angular projections on the nozzle (often called "wings", "ears" or "horns") contain passageways for the air jets. These jets intersect the stream just after second stage atomisation, and at 90° to the two sets of converging holes.

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The primary purpose of these jets are to form or shape the round cross-section of the fluid stream into an elongated one referred to as "fan" shaped. Additional turbulence occurs at this point resulting in additional atomisation.

The spray pattern size is determined by the design of the air nozzle, the fan control, the method of feeding the spray gun, and the cohesive nature of the material being sprayed.

- ***Airless atomisation***

In an airless system, the gel coat does NOT come in direct contact with compressed air nor is it atomised by air. Instead, a high ratio pump (11:1 - 33:1) puts the gel coat under high pressure (1000 - 3000 PSI) and forces it through a small orifice (.015" - .026"). As the material passes through the orifice, the material is atomised, similar to water as it comes out a garden hose with a spray nozzle. Airless systems are used where high volume of gel coat can be handled by the operator on large essentially flat or open parts. It is cleaner and more efficient than conventional air atomised.

Contrary to what might be thought, airless atomisation does not atomise more monomer than conventional air spray.

Tests have shown that a sprayed film will retain more monomer (harmful to yellowing and chalk) under these conditions;

Airless atomisation retains more styrene than conventional air atomised.

Airless atomisation retains more styrene than "properly" atomised air assist airless equipment.

The closer the gun is to the mould, the more styrene is going to be retained.

The fewer the number of spray passes, the greater the amount of styrene retained, typically, a "fine atomisation" (small particles/droplets) will provide a finer orange peel; therefore, better gel coat film/surface/laminate, and better in regard to yellowing/chalking resistance.

- ***Air Assist Airless***

This type of equipment is relatively new to the industry. It is a combination of conventional air atomisation and airless techniques.

Material is supplied to the airless tip at much lower pressure (400 - 1000 PSI), than for standard airless spraying, (1000 - 3000 PSI). At this low pressure though, the spray pattern is coarse and has poor atomisation. Atomising air is now introduced to the spray pattern at low pressure, (3-30 PSI), to refine the spray pattern.

The very nature of the air assist airless concept does not allow for high material delivery rates. As more material is sprayed, more atomising air is needed to refine the spray pattern.

Excess atomisation would then bring you back to the state of conventional air atomisation.

Many of the pumps used are in the 10 to 12:1 ratio range which will do a good job on lower viscosity and weight per gallon (specific gravity) gel coats, but will not do the job when pumping high viscosity, high weight per gallon (specific gravity) white gel coat. In many cases, pumps must be

PERCENT MONOMER IN GEL COAT FILM

Control (material not sprayed)	Conventional Air Spray	Airless	Air Assist Airless	HVLP**
Test 1		(Tip 2140)		
38.3%	32.9%	34.4%	-	-
Test 2		(Tip 1750) (Tip 2640)	(Tip 2640)	-
35.8%	-	20.7% 27.4%	29.9%	-
34.6%	-	- 28,0%	23.1%	-
36.4%	-	22.6% 28.6%	24.7%	-
Test 3				
41.8%	-	(Tip 2140)	-	-
2-3 ft*(6-9m)	-	34.7%	-	-
6 ft* (1.8m)	-	30.8%	-	-
Test 4				
47.0%	-	(Tip 2140")	-	-
1.5 ft* (.5m)	41.4%	43.8%	-	-
3.0 ft* (.9m)	32.5%	41.7%	-	-
4.5 ft* (1.4m)	-	40.0%	-	-
6.0 ft* (1.8m)	-	37.4%	-	-
Test 5	(60 psi) (20psi)			
34.3%	26.6 28.9	-	-	29.0

**Spray distance ** High Volume, Low Pressure* run at line pressure, 100 psi or more and still not enough pressure is developing for adequate break up.

With the low pressure, a very coarse orange peel pattern is developed due to larger than normal droplets of gel coat hitting the mould. This causes a wide range of film thickness' such as 20 mils (thou) at the high point and 11 mils (thou) at the low point.

The wide variance causes problems such as:

- Blister resistance on a 20/11 orange peel type situation would only be as good as the 11 mils (thou) area with much more material actually used.
- Quick sand through in thin areas of orange peel.
- Roll out of skin coat over coarse orange peel is often more difficult and will contribute to a defect customers call shot gunning or buck shot, which is small air bubbles trapped in the low areas of coarse orange peel. These small air bubbles show up on the finish after buffing or after the parts are heated in the sun.

Keep in mind also that coarse orange peel is an effect of low atomisation which means that more monomer is retained in the gel coat film. Excess monomer in the gel coat means that:

- Gel coat sag may be higher due to a higher percent of monomer trapped in the film.
- Because more monomer is trapped, more yellowing and chalking would be expected.
- A higher level of trapped monomer would tend to make the gel coat more brittle and more susceptible to cracking.

■ *High Volume Low Pressure (HVLP)*

This type of equipment is not new to the paint industry but is relatively recent to the gel coat industry. American customers especially are using it in an attempt to cut down on emissions. Intent of the gun is to cut down on emissions (styrene). This method of spraying results in larger droplets, a film with very coarse orange peel (causing roll out to be more difficult), and its wetter, more styrene-rich film is more prone to sag.

A typical HVLP gun is manufactured so that no more than 10 psi of atomising air is at the gun for atomisation. Gel coat is atomised by the higher volume (cfm) of air. Results (application and monomer retention) similar to the HVLP have been obtained by merely turning atomising air way down with the C.A.A. gun (see chart on previous page, Test 5). Note also that airless and air-assist airless retain more styrene in the film than C.A.A. equipment.

Cray Valley anticipates more customers will be using this type of gun to help satisfy emission requirements.

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4 SPRAY SYSTEM SELECTION

There are a number of spray guns that can be used for polyester. Following is a chart of their basic characteristics.

Item	Hot Pot A	Hot Pot B	Hot Pot C	Air Atomised Catalyst Injection	Airless Catalyst Injection	Air Assist Airless
Material Supply	1 quart (.95 litre)	2 quarts (1.9 Litre)	1 or 2 gal. (4-7.6 litre)	1-20 gal. (3.8-76 litre) pressure pot or pump	Pump	Pump
Part Size	Small, up to (20 sq. Ft) (1.86m2)	Small to med. Up to 40 sq. ft (3.72m2)	Medium to large. 150 sq. ft. (13.95m2)	Various	Various	Various
Number of parts	One or two	One or two	One or two	Any number	Any number	Any number
Use	Intermittent	Intermittent	Intermittent	Constant	Constant	Constant
Switching Colours	Easy	Easy	Fair-hose must be cleaned	Fair-separate pressure pots or pumps normally used	Pump and lines must be cleaned	Pump and lines must be cleaned
Future use	Very flexible tooling, prototype small runs	Tooling, small jobs	Tooling, small jobs	Large production	Large production	Medium to large production
Portability	Easy to move	Easy to move	Easy to move	Fixed or cart mounted	Fixed or cart mounted	Fixed or cart mounted
Number of Hoses	One	Two	Two	2 to 4 hoses may be on a boom	2 to 4 hoses may be on a boom	2 to 4 hoses may be on a boom
Catalyst measurement	Weight or volume	Weight or volume	Weight or volume	Metered (requires Calibration)	Metered (requires calibration)	Metered (requires calibration)
Mixed by	Hand	Hand	Hand	By gun	By gun	By gun
Cleaning	After each use	After each use	After each use	Wipe head off intermittently. Clean pots or pump	Wipe head off intermittently. Clean pots or pump	Wipe head off intermittently. Clean pots or pump

GEL COAT SPRAY EQUIPMENT

5 SPRAY SELECTIONS AND SETTINGS

Now that you have selected a particular spray system, you should determine what are the recommended starting pressure settings and spray procedures. These setting may have to be changed slightly to match a particular part and spray operator. Also check with the equipment manufacturer for set-up procedures and handling precautions.

The equipment referred to below is for help and illustration, other systems may be used successfully.

HOT POT				
	DeVILBISS JGA-502		**BINKS 18/20001**	
ITEMS NEEDED	**1 QUART (0.95 LITRE)**	**2 QT. - 20 GALS (1.9 - 76 LITRES)**	**1 QUART (0.95 LITRE)**	**2 QT. - 20 GALS (1.9 - 76 LITRES)**
Container	Attached	Remote	Attached	Remote
Catalyst	Hand mixed	Hand mixed	Hand mixed	Hand mixed
Air atomisation	External	External	External	External
CFM	17 at 70 psi	17 at 70 psi	17 at 70 psi	17 at 70 psi
Air cap	AV-1239-704	AV-1239-704	67PB	67PB
Fluid Nozzle	AV-601-E	AV-601-E	67	67
Needle	JGA-402-E	JGA-402-E	67	67
Pressure				
Air*	60 - 90	60 - 90	60 - 90	60 - 90
Fluid	10 - 25	15 - 45	10 - 25	15 - 45
Delivery lbs./Min.	1-2.5(.45-1.13 kilo)	1-2.5(.45-1.13 kilo)	1-2.5(.45-1.13 kilo)	1-2.5(.45-1.13 kilo)
Spraying Distance	18 -24 in. (46 - 61cm)	18 -24 in. (46 - 61cm)	18 -24 in. (46 - 61cm)	18 -24 in. (46 - 61cm)
Number of passes	3	3	3	3
Mils (thou) per pass	5 - 7	5 - 7	5 - 7	5 - 7

CONVENTIONAL AIR ATOMISED CATALYST INJECTION			
SPRAY GUN	**BINKS 18N CATALYST INJECTION**	**BINKS 18N CATALYST SIDE INJECTION**	**GLAS-CRAFT ISD C-20 GEL COAT NOZZLE KIT**
Air Cap	A63PB	63PB	Stage 2
Fluid Orifice	66SS	66	.078 orifice
Needle	65	65	-
Atomisation	External	External	External
Air-atomisation*	60-90 PSI (carries catalyst)	0 - 90 PSI	60 - 90 PSI
Catalyst	Std MEKP	Std MEKP	Std MEKP
Catalyst Pressure	-	As required	As required
Ball setting (top)	As Required	As Required	As Required
Material Supply Pump (4:1) pressure	25 - 35	25 - 35	25 - 35
Pot Pressure	20 - 45	20 - 45	20 - 45
CFM	17 at 90 psi	17 at 90 psi	17 at 90 psi
Delivery lbs./min	1-2.5 (.45 - 1.3 kilo)	1-2.5 (.45 - 1.3 kilo)	1-2.5 (.45 - 1.3 kilo)
Spraying Distance	18 -24 in. (46 - 61cm)	18 -24 in. (46 - 61cm)	18 -24 in. (46 - 61cm)
Number of passes	3	3	3
Mils (thou) per pass	5 - 7	5 - 7	5 - 7
Calibration (material and catalyst)	Gel times	Flow and gel times	Gel times

*At the gun with the trigger pulled and fan full open

GEL COAT SPRAY EQUIPMENT

AIRLESS CATALYST INJECTION A

		BINKS MAVERICK		
TYPE	**BINKS 43 PL**	**WITH ACI**	**WITH 3400**	**STAR**
Catalyst	*Diluted MEKP	MEKP Std	MEKP Std	MEKP Std
Catalyst atomisation & mix	Air Pressure External	Airless External	Air External	Air External
Catalyst tip	.011 - .013	.052	.015	Fixed
Catalyst injector pressure	25 - 60 PSI	25 - 35 PSI	As required	As required
Catalyst atomising pressure	-	3 to 5 lbs lower	At least 60	15
Gel coat pump	33:1	33:1	33:1	24:1
Pump Pressure	50 - 90	50 - 90	50 - 90	50 - 90
Material tip	.015 - .026	.015 - .026	.015 - .026	.015 - .026
CFM	40 CFM max.	40 CFM max.	40 CFM max.	-
Delivery lbs/minute	2-4 lbs (.9-1.8 kilo)	2-4 lbs (.9-1.8 kilo)	2-4 lbs (.9-1.8 kilo)	2-4 lbs (.9-1.8 kilo)
Passes	3	3	3	3
Mils (thou) per pass	5 - 7	5 - 7	5 - 7	5 - 7
Spray distance	24 - 36 in. (61-91 cm)	24 - 36 in. (61-91 cm)	24 - 36 in. (61-91 cm)	24 - 36 in. (61-91 cm)
Calibration	Flow rate and gel time	Flow rate and gel time	Flow rate and gel time	Flow rate and gel time
Fan pattern	Vertical	Horizontal or vertical	Horizontal or vertical	Vertical

* See catalyst and equipment manufacturers for proper diluents and instructions

AIRLESS CATALYST INJECTION B

TYPE	**GLAS-CRAFT LPA**	**VENUS INTERNAL MIX**	**GS MANUFACTURING**	**POLYCRAFT G555**
Catalyst	Std MEKP	Std MEKP	Std MEKP	Std MEKP
Catalyst atomisation and mix	Air External	- Internal	Airless External	Air External
Catalyst tip	External	-	.011 - 0.13	Fixed
Catalyst injector pressure	35 - 50 psi	Same as material	100 (catalyst regulated by fluid regulator)	30-40 PSI
Catalyst atomising pressure	At least 2 psi below catalyst pressure	-	-	3 - 5 lbs lower
Gel coat pump	33 to 1	11 to 1	20 to 1	30 to 1
Pump pressure	50 - 90	60 - 90	50 - 90	50 - 90
Material tip	.015" - .026"	.015" - .026"	.015" - .026"	.015" - .026"
CFM	-	-	-	-
Delivery lbs/min	2-4 lbs (9-1.8 kilo)	2-4 lbs (9-1.8 kilo)	2-4 lbs (9-1.8 kilo)	2-4 lbs (9-1.8 kilo)
Passes	3	3	3	3
Mils (thou) per pass	5 - 7	5 - 7	5 - 7	5 - 7
Spray distance	24 - 36 in (61-91 cm)	24 - 36 in (61-91 cm)	24 - 36 in (61-91 cm)	24 - 36 in (61-91 cm)
Calibration	Flow rate and gel time	Flow rate and gel time	Flow rate and gel time	Flow rate and gel time
Fan pattern	Horizontal or vertical	Horizontal or vertical	Horizontal or vertical	Horizontal

GEL COAT SPRAY EQUIPMENT

AIR-ASSIST AIRLESS CATALYST INJECTION						
TYPE	**BINKS 118-AC/ VANTAGE 11C**	**MAGNUM AT G 350**	**POLY-CRAFT G-755**	**GS Mfg**	**GLAS-CRAFT LPA 11**	**BINKS 102-2400**
CATALYST	MEKP STD	MEKP STD	MEKP STD	MEKP STD	MEKP STD	MEKP STD
CATALYST ATOMISATION AND MIX	- EXTERNAL	AIR EXTERNAL	AIR EXTERNAL	AIR EXTERNAL	AIR EXTERNAL	- EXTERNAL
CATALYST TIP	.013	FIXED	FIXED	FIXED	FIXED	.013
CATALYST INJECTOR PRESSURE (PSI)	10 - 15 (Plug groove valve at the gun)	60	25 - 45	AS REQUIRED	AS REQUIRED	10 - 15
GEL COAT PRESSURE (PSI) CLEARS	400 - 600	400 - 600	400 - 600	400 - 600	400 - 600	400 - 600
COLOURS	600 - 1000	600 - 1000	600 - 1000	600 - 1000	600 - 1000	600 - 1000
PUMP PRESSIRE (PSI)	Dependent upon size of pump	Dependent upon size of pump	Dependent upon size of pump	Dependent upon size of pump	Dependent upon size of pump	Dependent upon size of pump
MATERIAL TIP	.018 - .026	.018 - .026	.018 - .026	.018 - .026	.018 - .026	.018 - .026
AIR-ASSIST AIR*	5 - 30	5 - 30	5 - 30	FIXED	5 - 45	5 - 30
CFM	-	-	-	-	-	-
DELIVERY (lbs/minute)	2 - 3 lbs	2 - 3 lbs	2 - 3 lbs	2 - 3 lbs	2 - 3 lbs	2 - 3 lbs
PASS	3	3	3	3	3	3
MILS (thou) PER PASS	5 - 7	5 - 7	5 - 7	5 - 7	5 - 7	5 - 7
SPRAYING DISTANCE	24 - 36 inches	24 - 36 inches	24 - 36 inches	24 - 36 inches	24 - 36 inches	24 - 36 inches
CALIBRATION	Flow rate and gel time	Flow rate and gel time	Flow rate and gel time	Flow rate and gel time	Flow rate and gel time	Flow rate and gel time
FAN PATTERN	VERTICAL	VERTICAL	VERTICAL	VERTICAL	VERTICAL	VERTICAL

*As low as possible

AIR-ASSIST AIRLESS SLAVE ARM CATALYST

TYPE	MAGNUM ATG 3500	VENUS PRO GEL COAT	GLASS CRAFT AAC	BINKS 102-2400
CATALYST	MEKP STD	MEKP STD	MEKP STD	MEKP STD
CATALYST ATOMISATION AND MIX	20 - 30 EXTERNAL	INTERNAL MIX*	35+ EXTERNAL	- EXTERNAL
CATALYST TIP	FIXED	INTERNAL	FIXED	.013
CATALYST SLAVE ARM	SET AS DESIRED	SET AS DESIRED	SET AS DESIRED	SET AS DESIRED
GEL COAT PRESSURE (PSI)				
CLEARS	400 - 600	400 - 600	400 - 600	400 - 600
COLOURS	600 - 1000	600 - 1000	600 - 1000	600 - 1000
PUMP PRESSURE	DEPENDENT UPON SIZE OF PUMP	DEPENDENT UPON SIZE OF PUMP	DEPENDENT UPON SIZE OF PUMP	DEPENDENT UPON SIZE OF PUMP
MATERIAL TIP	.018 - .026	.018 - .026	.018 - .026	.018 - .026
AAA (PSI)	5 - 30	5 - 30	10 - 15	5 - 30
CFM	-	-	-	-
DELIVERY lbs/min	2 - 3 lbs	2 - 3 lbs	2 - 3 lbs	2 - 3 lbs
PASSES	3	3	3	3
MILS (thou) PER PASS	5 - 7	5 - 7	5 - 7	5 - 7
SPRAYING DISTANCE	24 - 36 inches	24 - 36 inches	24 - 36 inches	24 - 36 inches
CALIBRATION	FLOW RATE AND GEL TIME	FLOW RATE AND GEL TIME	FLOW RATE AND GEL TIME	FLOW RATE AND GEL TIME
FAN PATTERN	VERTICAL	VERTICAL	VERTICAL	VERTICAL

*Solvent flush requires 20 to 40 psi.

6 CALIBRATION

Since polyesters require the proper amount of catalyst to be added and mixed in to achieve their desired properties it is necessary to calibrate catalyst injection spray equipment.

You cannot use one set of pressure readings day after day because the wear on the equipment, temperature and the differences of flows between materials will change the catalyst ratio.

You will have to calibrate for different colours as flow rates at the same pressure will be different. Calibration is done weekly or for each batch change and really is not that hard or time consuming, once the method becomes familiar. First thing Monday morning is the recommended time for calibrations.

Consult the equipment manufacturer and their literature for their recommended calibration methods and procedures.

6.1 SAFETY CONSIDERATIONS

- Always wear eye protection.
- Do not point a spray gun at yourself or anyone else.
- Always ground spray equipment.
- Depressurise the equipment by pulling the trigger of the spray gun and bleeding the by-pass at the filter.
- Never trust spray equipment even if all gauges say zero pressure. If there is any doubt that the equipment is still pressurised and you have to dismantle it to relieve the pressure, keep protection between you and the equipment such as a piece of cardboard or a rag.
- Airless (high pressure) systems can create enough pressure to force the material through human skin - BEWARE.

GEL COAT SPRAY EQUIPMENT

6.2 GENERAL PROCEDURES FOR DETERMINING FLOW RATES & PERCENT CATALYST OF GEL COAT.

- If you have "x" grams of material collected in 30 seconds and you want the flow rate in pounds per minute:

x grams times 2 = Grams Per minute (GPM)

$\frac{GPM}{454}$ = Pounds Per Minute (PPM)

(1 lb = 454 grams)

Example:

300 grams in 30 seconds

300 x 2 = 600 GPM

$\frac{600}{454}$ = 1.32 PPM

- If you have "x" pounds of material collected in 30 seconds and you want the flow rate in GPM:

x pounds times 2 = Pounds Per Minute (PPM)

PPM x 454 = GPM

Example:

.66 pounds in 30 seconds

1.32 x 454 = 600 GPM

- To determine the amount of catalyst needed for a flow rate:

Example:

Flow rate is 600 GPM.

Percent catalyst desired is 1.8%

600 x 1.8% = 10.8 grams or c.c.'s

6.3 BINKS - 18-N

- Attach fluid hose to gun.
- Check pump filter and lines
- Put pump in gel coat drum.
- Back our regulator and make sure pressure is off.Turn air on to pressure gauge to pump.Then slowly increase pressure until pump starts.
- Adjust pressure to 30 PSI on pump (4 to 1) and check for leaks.
- Run flow rate 30 seconds; adjust to 1 to 2.5 pounds/minute (.45 to 2.8 kg). Catch in a previously weighed container.

NOTE: gel coats must be weighed as volume measurements will not be accurate due to density differences.

- Check catalyst level in tank (5200) and fill if necessary.
- Attach and check catalyst lines.
- Back out regulator to make sure it is off.Turn air on to catalyst pressure gauge.Then slowly turn to 30 PSI. STOP; check for leaks.Then adjust injector pressure to 70 to 90 PSI.A T-gauge must be used (Binks Part 73-125) to check pressure at the gun. If flow rate is at maximum 2.5 pounds (2.8 kg), 60 PSI (with fan full open) is required to properly atomise the gel coat.

NOTE: 100 PSI maximum on Binks Injector
80 PSI maximum on Glascraft Injector.

- Check atomisation and adjust as necessary (either air or Fluid). Note if you adjust downward, relieve pressure on lines as check valve may keep the original pressure until relieved by pulling the trigger.
- Calculate cc of catalyst necessary for the flow rate.

CAUTION:

Do not rely on catalyst charts.
Confirm the flow rate manually.

- Adjust the ball to give this reading.Turn top knob all the way open then 1 1/2 turns in, adjust ball with bottom knob-right side.
- Spray material onto a glass panel and collect by scraping about 100 grams into a paper cup. Note gel time.
- Take gel coat from drum and weigh out 100 grams.Add the same amount of catalyst as No.12 and run the gel time.
- Compare gel times and adjust if necessary.The catalyst ball can be adjusted in 5 unit steps until desired gel time is reached, but stays in the 1.2 to 3.0% range.
- Wipe off gun after each use.

6.4 BINKS - 18-C

- Select and install correct air cap, nozzle and needle in gun.
- Attach fluid hose to gun.
- Check pump filter and lines.
- Put pump in gel coat drum.
- Back out regulator and make sure pressure if off.Turn air on to pressure gauge at pump.Then slowly increase pressure until pump starts.
- Adjust pressure to 30 PSI on pump (4 to 1) and check for leaks.
- Run flow rate 30 seconds; adjust to 1 to 2.5 pounds/minute (.45 to 1.1 kg). Catch in a previously weighed container.

NOTE: Gel coats must be weighed, as volume measurements will not be accurate due to density differences.

- Release pressure on pump and pull trigger. Bleed at bypass.
- Calculate cc of catalyst necessary for the gel coat flow rate.

CAUTION:

Do not rely on catalyst charts.
Confirm the flow rate manually.

- Check catalyst level in tank (5202) and fill if necessary.
- Attach and check catalyst lines.
- Back out regulator to make sure it is off. Turn air on to catalyst pressure gauge.
- Adjust the ball for appropriate reading.
- Collect catalyst for one minute and figure percent.
- Adjust catalyst ball as/if required and run catalyst flow rate again.
- Turn on gel coat pump to previous pressure setting and run gel time comparison *(Refer to: 6.3)*.

6.5 AIRLESS WITH AIRLESS ATOMISED CATALYST SYSTEM (BINKS 43 PL & GS)

- Select fluid material tip and put on gun.
- Check fluid lines and pump filter.
- Put pump in gel coat. (If catalyst slave pump, disconnect. See 6.9)
- Back out regulator and make sure pressure is off. Turn air on to pump gauge. Then slowly turn pressure starts. Check for leaks.
- Turn pressure up to approximately 60 PSI and slowly adjust pressure until tails are eliminated on the mould when spraying with the gun 24 inches (61 cm) from the mould.
- Take flow rate, 2 to 4 pounds/minute (.92 to 1.8 kg/minute). No more than 3 lbs (1.4 kg) for small intricate moulds and no more than 4 lbs (1.8 kg) for large, open moulds.
- Release pressure off pump and pull trigger. Bleed at by-pass.
- Wipe off gun.
- Check catalyst level in tank. Fill if necessary. (If catalyst slave pump, reconnect).

NOTE: May require special viscosity MEKP. Consult catalyst manufacturer.

- Check fitting and lines and install catalyst tip.
  Start with .011".
- Back off regulator and make sure it is off. Turn on air to catalyst gauge. Slowly adjust pressure to catalyst supply. Stop at 15 PSI.
  Check for leaks.
- Adjust catalyst pressure for proper atomisation.
- Run flow on catalyst in graduated cylinder. Calculate percent catalyst and adjust if necessary. Check gel time, adjust as desired but remain in the 1.2 - 3.0% catalyst range. If diluted catalyst is used, the % of dilutent must be taken into consideration.
- Turn on gel coat pump to previous setting and run gel time comparison *(Refer to: 6.3)*.

6.6 AIRLESS WITH INTERNAL AIR ATOMISED CATALYST SYSTEM (BINKS MAVERICK ACI, GLAS-CRAFT, POLYCRAFT, STAR, MAGNUM).

- Select correct tips and put on gun.
- Check pump filter and material lines.
- Put pump in gel coat. (If catalyst slave pump, disconnect. See 6.9).
- Back out regulator and make sure pressure is off. Turn air on to pump gauge; then slowly increase pressure on pump until it starts - check for leaks.
- Turn pressure up to approximately 60 PSI and slowly adjust until tails are eliminated on the mould when spraying with the gun 24 inches (61 cm) from the mould.
- Take flow rate, 2 to 4.0 pounds/minute (.92 to 1.8 kg/minute). No more than 3 lbs (1.4 kg) for small/intricate moulds, no more than 4 lbs (1..8 kg) for large/open moulds.
- Release pressure off pump and pull trigger. Bleed at by-pass.
- Wipe off gun.
- Check catalyst level in tank. Fill if necessary.
- Check catalyst and air line. (Reconnect catalyst slave pump if used).
- Back off regulators.
- Adjust catalyst atomising air and catalyst pressure, and check for leaks.
- Calculate cc of catalyst necessary for the gel coat flow rate.
- Check catalyst atomisation and adjust ball for the required amount of catalyst.
- Run catalyst flow. Compare to gel coat flow. Adjust if necessary. If catalyst pressure is to be decreased, the catalyser pot pressure will need to be bled before calibrating.
- Turn on gel coat pump to previous setting and run gel time comparisons. *(Refer to: 6.3)*.

6.7 AIRLESS WITH ETERNAL AIR ATOMISED CATALYST SYSTEM/EXTERNAL MIX (BINKS MAVERICK)

- Select correct tips and put on gun.
- Check pump filter and material lines.
- Put pump in gel coat.
- Back out regulator and make sure pressure is off. Turn air on to pump gauge, then slowly increase pressure on pump until it starts. Check for leaks.
- Turn pressure up to approximately 60 PSI, and slowly adjust until tails are eliminated on the mould when spraying with the gun 24 inches (61 cm) from the mould.
- Take flow rate, 2 to 4.0 pounds (.92 to 1.8 kg.min). No more than 3lbs (1.4 kg) for small/intricate moulds, no more than 4 lbs, (1.8 kg) for large open moulds.

- Release pressure from pump, bleed at gun and by-pass valve.
- Wipe off gun.
- Check catalyst level, fill if necessary.
- Calculate cc of catalyst necesssary for the gel coat flow rate.
- Turn on catalyst pot or pump slowly - check for leaks
- Run catalyst flow rate and adjust pressures up or down to achieve catalyst desired.
- Adjust catalyst atomising as required for fine atomisation of the catalyst - no catalyst droplets.
- Turn on gel coat pumps to previous setting and run gel time comparisions. *(Refer to: 6.3).*

6.8 AIR ASSIST AIRLESS

(Binks 118-AC/Vantage 11C, Polycraft G755, Magnum ATG3500, GS Manufacturing, Glas-Craft).

- Select correct tip and put on gun.
- Check pump filter and material lines.
- Put pump in gel coat (if catalyst slave pump, disconnect. See 6.9.)
- Back out regulator and make sure pressure is off. Turn air on to pump gauge, then slowly increase pressure on pump until it starts. Check for leaks.
- Turn pressure up to 30 - 50 PSI (largely dependent upon pump ratio). Do not exceed 600 PSI gel coat pressure with clear gel coat, nor more than 1000 PSI with colour gel coat. The pressure will vary according to tip size, gel coat pressure should be as low as possible while still maintaining a good fan and flow rate.

  Do not be concerned with fingers or tails because the air assist will refine them.
- Take flow rate, not to exceed 3lbs a minute (1.4 kg/min).
- Release pressure from pump, bleed at gun and by-pass valve.
- Check catalyst level, fill if necessary (if catalyst slave pump, reconnect).
- Run catalyst flow:

  If 118AC/Vantage 11-C proceed as in 6.4.

  if G-755, ATG-3500, GS or Glas-Craft LPA11, proceed as in 6.6.
- Adjust air assist air. Use only as little pressure as possible so as to minimise the fingers and tails

6.9 DO NOT ASSUME THAT A CATALYST SLAVE PUMP IS DELIVERING THE CORRECT AMOUNT OF CATALYST.

The catalyst delivery can be off due to inaccurate slave pumps, wear, leaks, clogged filters or too high atomising pressure.

Weight / Gallon of Gel Coat	Slave Pump Setting	Actual Weight %
8.8 (Clears)	1.8	1.9
9.8 (Colours)	1.8	1.7
10.8 (Whites)	1.8	1.5
11.8 (Low VOC)	1.8	1.4

If the slave pump is suspected to be inaccurate calibrate the pump per the manufacturer's recommendations. Equipment manufacturers offer calibration kits for checking slave pump calibration.

In addition, slave settings are based on volume percentages. Cray Valley's catalyst specifications are based on weight percentages. There is an inherent error introduced due to the variation of the weight per gallon of the gel coat:

An alternative, but not quite as accurate procedure, to a calibration kit is to use the stroke counting methods. The stroke counting method is to count the pump strokes while checking the flow rate. After the flow rate is determined, disconnect the gel coat supply to the gun. Open the bypass valve on the pump and adjust the valve so the pump is stroking the same number of strokes per minute as when the flow rate was checked. Collect catalyst out of the tip of the gun while allowing the pump to pump gel coat through the bypass at the determined stroke per minute rate. Divide the catalyst flow rate by the gel coat flow rate to get percent of catalyst. Catalyst percent should be approximately ± .10% of the slave pump setting. Confirm by running gel time comparisons.

In addition, the pump must be checked and primed each day because gas pockets can form causing cavitation.

Monitor the filter to ensure it is not plugged or restricted.

7 CLEANUP PROCEDURES

- Relieve all pressure from pump and lines.
- Place pump in can of wash solvent.
- Wipe down outside of pump.
- Remove and clean spray tips.
- Turn up pressure slowly until pump just starts with trigger pulled.
- Run two to three gallons of solvent through pump and lines, then relieve all pressure - spray into a bucket for later disposal. Do not let the pump cycle (both strokes) more than 1 per second.

- Carefully open by-pass at filter.
- Remove and clean filter - replace if necessary.
- Put pump in clean solvent.
- Repeat previous steps.
- Wipe hoses and gun down.
- Grease or lubricate necessary parts.
- Inspect for worn parts and order replacements.
- Make sure pump is stopped in down position to prolong packing life.
- Relieve all pressure and back regulators out to zero.

8 MAINTENANCE

You will have an investment in the spray gun and support equipment. To protect the investment, you should have a planned maintenance programme. It should include the following:

SPARE PARTS

For all spray guns, pumps, hoses, catalyst injector or catalyst slave pump.

- Air cap, nozzle and needle.
- Packing and gaskets.
- Extra hoses - fittings.
- Extra gauges.

Be in constant awareness of the following:

- Catalyst flow.
- Condition of all hoses, gel coat and catalyst. No kinks or frayed hoses,
- Spray pattern and technique
- Check for contamination. If present, remove.
- Wear proper protective equipment.

DAILY CHECKLIST

- Drain water traps morning, noon and afternoon - more if needed.
- Mix gel coat - just enough to keep resin and styrene mixed in.

Do not over mix gel coats. Over mixing breaks down gel coat viscosity, increasing tendencies to sag, and causes styrene loss, which could contribute to porosity. Gel coats should be mixed once a day, for 10 minutes. The gel coat should be mixed to the sides of the container with the least amount of turbulence possible.

- Inventory gel coat for day's use.
- Start pumps with regulator backed all the way out. Open valve and charge air slowly, checking for leaks. Do not let the pump cycle (both strokes) more than 1 per second.
- Shut down.
  Turn off all air pressures and back regulator out.
  Bleed lines
  Store pump shaft down to keep wet.
- Clean up.
- Secure the area.

Remove all solvents and check for hot spots. Remove and properly dispose of any collections of catalysed material or catalyst/materials combinations.

9 EQUIPMENT TROUBLE SHOOTING

(Gel Coat & Chopper)

The majority of polyesters used today are sprayed or pumped through semi-automatic equipment. The care and operation of this equipment will determine whether or not the polyester will achieve its maximum properties and performance.

Gelcoaters (people who spray gel coat) and chopper operators must be trained in how to use and maintain their equipment. This can save or cost you money. Anyone who uses spray equipment should have and read all the literature available from the manufacturer of the equipment. This includes parts diagrams, set-up instructions, operating instructions, maintenance requirements, safety and trouble shooting guides.

If you do not have this information, or have a question, call or write to both the people from whom you purchased the equipment and the manufacturers of the equipment. They will help because they want you to use the equipment efficiently, correctly and safely. Also, they have general literature on spraying, and technical service people to help you.

Always remember you have an investment in your equipment and it was purchased to do an important job. If you do not maintain it and replace worn parts, you will lose your investment and it will not do the job for which you bought it.

A way to determine if a cure related problem is caused by material or equipment is to make a small test part where the catalyst is weighed in. If the part made without the equipment does not have the problem, then the cause is

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more likely in the equipment or operator.

Another way to check is to use a different batch of material through the equipment; however, this could generate bad parts making the first test method preferred.

Listed below are some of the more common problems that can occur with spray equipment. Since there are many different types of equipment is use, we cannot cover each one individually, or list all problems or solutions. You should see the manufacturer's literature for the particular type of equipment you are using or contact the manufacturer.

EQUIPMENT TROUBLESHOOTING - SUGGESTED CAUSES AND REMEDIES

PROBLEM - GEL COAT/SPRAY	SUGGESTED CAUSES AND REMEDIES
Atomisation poor (large droplets)	Check air pressure, length of hose, hose diameter (which may be too small), clogged or worn nozzle or air cap, stuck check valves, too much fluid flow, regulator not working properly.
Balls drop	Bottom needle valve almost closed and vibrates, filter plugged, not enough CFM's.
Balls overshoot	Top valve wide open, turn 1½ turns in - (Binks injector)
Catalyst ball goes out of sight when pressured	Catalyst level too low - insert special gasket with .013 hole over delivery tube (Binks injector), air in flow tube.
Catalyst valve - burst of catalyst	Weak spring due to ageing. If Binks, use Plug Groove valve at the gun. If hose within a hose, check for broken catalyst line.
Cavitating pump - sucks air	Remove siphon tube, put pump directly into resin - if pumps okay - cavitating due to siphon system leak, pump too small, cold or high viscosity.
Check stuck ball	Residue after flushing, vapour lock. Use piece of wood to free ball or tap side of pump.
Chopper will not run or runs slowly	Loss of air, not CFM's; regulator not on; rubber roller adjusted too tight.
Drips (Gun):	
Fluid	Worn, clogged, or bent needle, seating adjustment of needle, over spray on gun, worn packing or seals, loose connection
Catalyst	Worn seat or seals, damaged air valve, trigger out of adjustment, over spray on gun, loose connection, clogged valve or seat, gun head not aligned to gun body, fan control may trap catalyst in dead air apace and drip catalyst out of air horns.
Solvent	Clogged or worn valve, worn seals, sticking needle or button
Gelled hose	Bad fluid nozzle, bad seat.
Glass (chopped) not uniform in length	Worn or damaged blades; worn rubber roller; incorrect roller adjustment.
Glass pattern narrow	Chopper angle wrong; chopper air too low.
Glass off to one side	Chopper out of alignment; fluid nozzle worn or clogged.
Glass to resin ratio varies	Chopper air not regulated; pressure dropping before compressor kicks on - install regulator and set below the compressor's kick-on pressure; pre-wetting and extra wetting not accounted for.
Hot Spots	Catalyst or resin surging, purge catalyst line before starting, catalyst drops.

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PROBLEM - GEL COAT/SPRAY	SUGGESTED CAUSES AND REMEDIES
Housing (chopper) packs with glass	Motor speed too slow; blower air too low; static electricity; overspray in motor; dirty glass.
Material (none on downstroke)	Foot valve, spring, spring retainer, or foot valve ball worn or dirty.
Material (none on upstroke)	Piston cups, piston ball or pump cylinder worn.
Pattern of spray off to one side	Partial clogged air cap, damaged nozzle, worn nozzle or air cap, bent or worn fluid needle.
Plugged filter screen	Seedy or partial gelled batch, trash from material falling off pump when placed in new drum; due to normal build-up, screens and pumps must be cleaned periodically.
Pump cycles when gun is not in use	Worn piston cups, bottom check ball not seating.
Shaft of pump drops an inch or two-shudders.	Starved pump - check filters or worn internal packing. Check for worn packing by stopping pump at top of stroke - if with no material flow shaft creeps down, packing is worn.
Shaft of pump (material coming up around)	Loose or worn seals - clean and tighten, stop pump in down position when system not in use, worn shaft.
Siphon kit jumps	Dirt on check ball in pump.
Slow gel time and/or cure	Check catalyst and material flow, oil or water contamination. Check gun trigger for proper activation. If slave pump, check for air bubbles.
Surging:	
Material	Inconsistent or low air pressure on pump, worn or loose pump packing, out of material, sucking air through loose connection, balls not seating in pump (dives on down stroke - bottom ball; fast upward stroke - top ball; flush pump), filter plugged, siphon line has air leak, screens plugged, too much material flow, cold or high viscosity, plugged surge chamber.
Catalyst	Inconsistent or low air pressure, out of catalyst, check valve sticking in gun or catalyser, loose connection, screen plugged. If Binks equipment install Plug-Groove valve at the gun, keep hoses straight rather than coiled.
Tails (airless)	
Material	Pump pressure too low, worn tip, too large a tip, viscosity too high.
Catalyst	Worn tip, low pressure, wrong tip, viscosity too high, too large a fan.
Tips splitting or trigger will not shut off	Worn seat or worn needle or weak spring, check packing.
Trigger stiff	Bent needle, bent trigger, worn needle guide.
Water in air lines	No extractor, extractor too close to compressor - should be no closer than 25 ft, all take off's from main line should come off the top.
Worn packings	Pump overheating from being undersized, high pressure or pumping without any material, do not let pumps jackhammer - no more than 1 cycle (both strokes) per second - use glass reinforced Teflon™ packings. Keep idle pump shaft in down position to keep dried material from damaging packings.

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10 ADDITIONAL INFORMATION ON EQUIPMENT

■ If pump packing is too tight it will cold flow and there will be strings at the edges of the packing.

■ Always put catalyst tip on bottom so catalyst does not spray on glass.

■ Pre-orifice or insert - softens spray (less force); in some cases requires less pressure for proper break-up.

NOTE: Use same size (or smaller) insert than tip.

To tighten upper packings, relieve pressure, tighten 1/8 turn at a time until no leak under pressure.

■ Catalyst condenses out of atomising air in the hose in 10 to 15 minutes, (system at rest).

■ When ordering gun, specify nozzle and air cap.

■ Transfer pumps go through bung 4:1, 8:1 only.

■ Binks Pump - lower screen: 30 mesh, upper filter 50 mesh. Upper filter is 1/2 the orifice size.

■ Starting pump - open by-pass until flow is steady.

■ To prevent leaks avoid swivel fittings.

■ Compressor electric, one horsepower = 4CFM.

■ Quick disconnect restricts air flow.

■ Catalyst tip angle - same as material - want equal fan pattern.

■ When spraying - pull trigger all the way - it's all or nothing - no partial flow.

■ Lubricant - can use Vaseline.

■ Never insert a sharp object or probe into tip orifices. Blow out with compressed air from the front of the tip to prevent lodged particle from becoming more deeply lodged in orifice.

■ Inquire of the equipment manufacturer about glass filled fluid packings for pumping polyesters.

■ Always install shut-off valves in combination with fluid quick connects.

■ Always flush a filled system (resin/styrene) with unfilled resin, then solvent. Then always clean the filter.

11 EQUIPMENT SUPPLIERS

Following is a partial list of equipment suppliers. They have many detailed booklets on spraying and equipment. Write to (or call) these suppliers and ask for their literature and recommendations.

■ PUMPS ONLY

• The ARO Corporation
One ARO Center
Bryan, OH 43508
Tel: 419-636-4242

• Plastech TT
Gunnislake
Cornwall
PL18 9AR
Tel : 01822 832 621
Fax : 01822 833 999

• GRACO
P.O.Box 1441
Minneapolis, MN 55440
Tel: 612-378-6000

■ COMPLETE SYSTEMS

U.S.A.

• Binks Manufacturing Company
9201 West Belmont Avenue
Franklin Park,
IL 60131
Tel : 847-671-3000
Fax: 847-671-1471

• Glas-Craft Inc.
5845 West 82nd Street., Suite 102
Indianapolis,
IN 46278
Tel: 317-875-5592
Fax: 317-875-5456

• GS Manufacturing
1760 Monrovia, Unit C-1
Costa Mesa, CA 12627
Tel: 714-642-1500
Fax: 714-631-6770

• ITW-DeVilbiss
1724 Indian Wood Circle
Maumee, OH 43537
Tel: 800-338-4448
Fax: 800-338-0131

ITW-Ransburg
P.O. Box 913
Toledo, OH 43697-0913

- *Magnum Industries*
11651 56th Court
Clearwater,
FL 33520
Tel: 813-513-2955
Fax: 813-572-6895

- *Polycraft Systems*
(See Binks Manufacturing)

- *Star Systems*
(See Venus Products)

- *Venus Products-Gusmer, Inc*
1862 Ives Avenue
Kent,
WA98032
Tel: 206-854-2660
Fax: 206-854-1666

U.K.

- *Polycraft (UK)*
Cannock Office
Unit 3
Hollies Business Park
Cannock
Staffs WS11 1DW
Tel: 01543-574-136
Fax: 01543–466-144

- *Glas-Craft Inc.*
Albert Works
Brook Street,
Bury
Lancs BL9 6AH
Tel : 0161-764-2977
Fax : 0161-764-2963

- *Magnum Industries Europe Limited*
Timmis Road
Lye
Stourbridge
West Midlands DY9 7BJ
Tel : 0384 898 589
Fax : 0384 898 394

- *Applicator*
GRP Material Supplies Limited
Alchorne Place
Burrfields
Portsmouth PO3 5QU
Tel : 01705 677 940
Fax : 01705 699 582

- *CT Technical Products*
Jays Close
Viables
Basingstoke
Hampshire RG22 4BS
Tel : 01256 358 258
Fax : 01256 355 015