ATP2152

AIRCRAFT MATERIAL 2

(MATERIAL PESAWAT TERBANG 2)

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Aircraft Material 2

CHAPTER 1

PLASTICS AND ELASTOMERS

Week 2
Semester 2 – 2020/2021

Special Engineering Plastics:

Kevlar

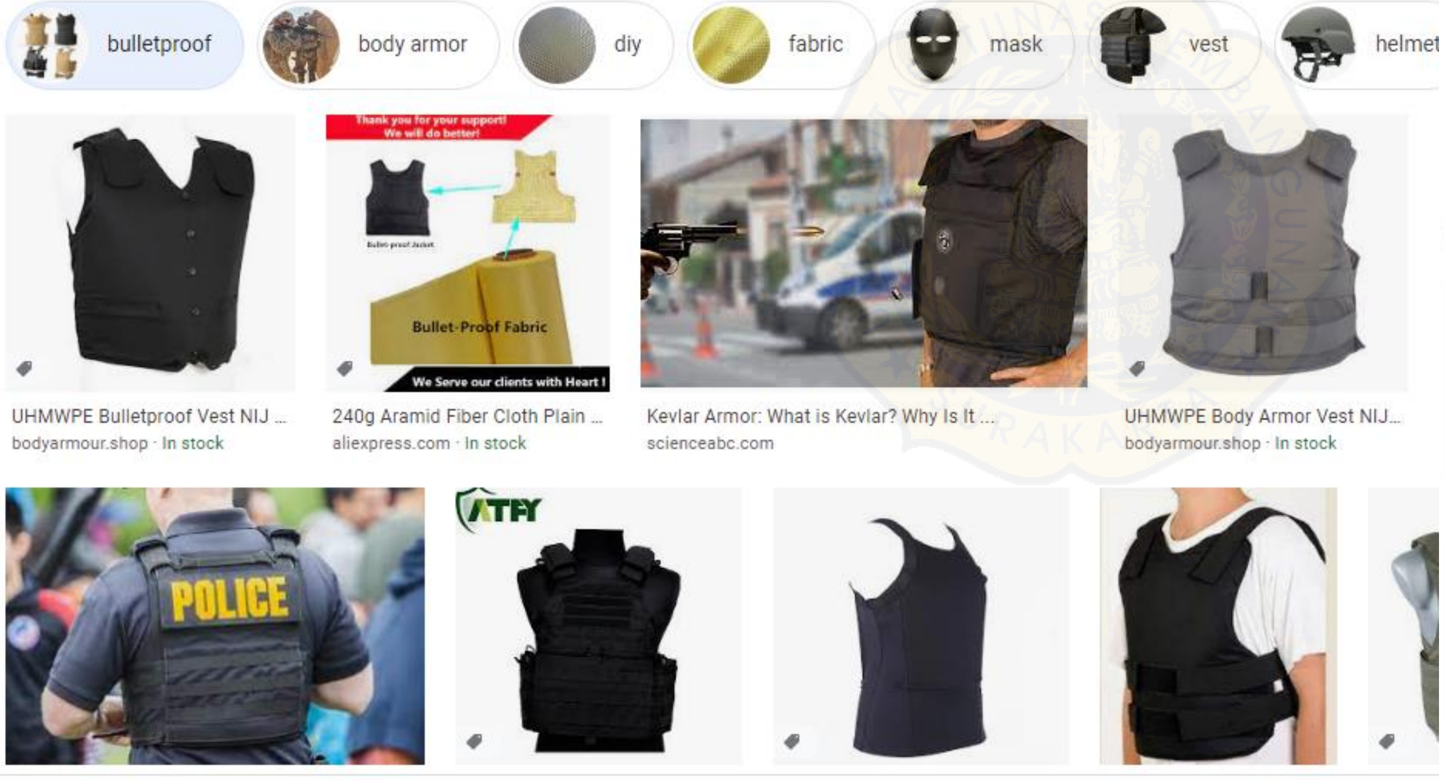
Super-strong plastic, able to stop bullets and knive!

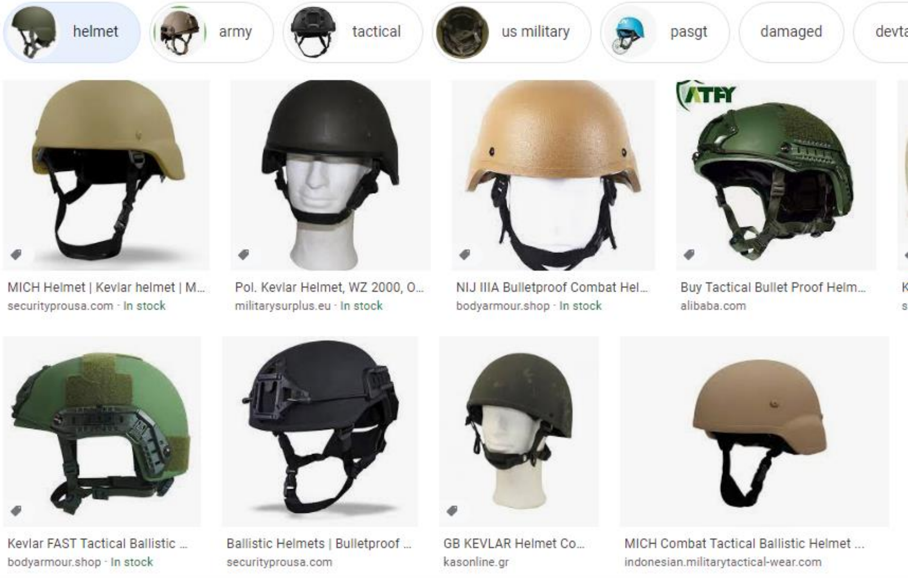
Pic. Source: composite envisions and easycomposite.co.uk

PLASTICS AND ELASTOMERS
Kevlar

Special Engineering Plastics:

1. Kevlar



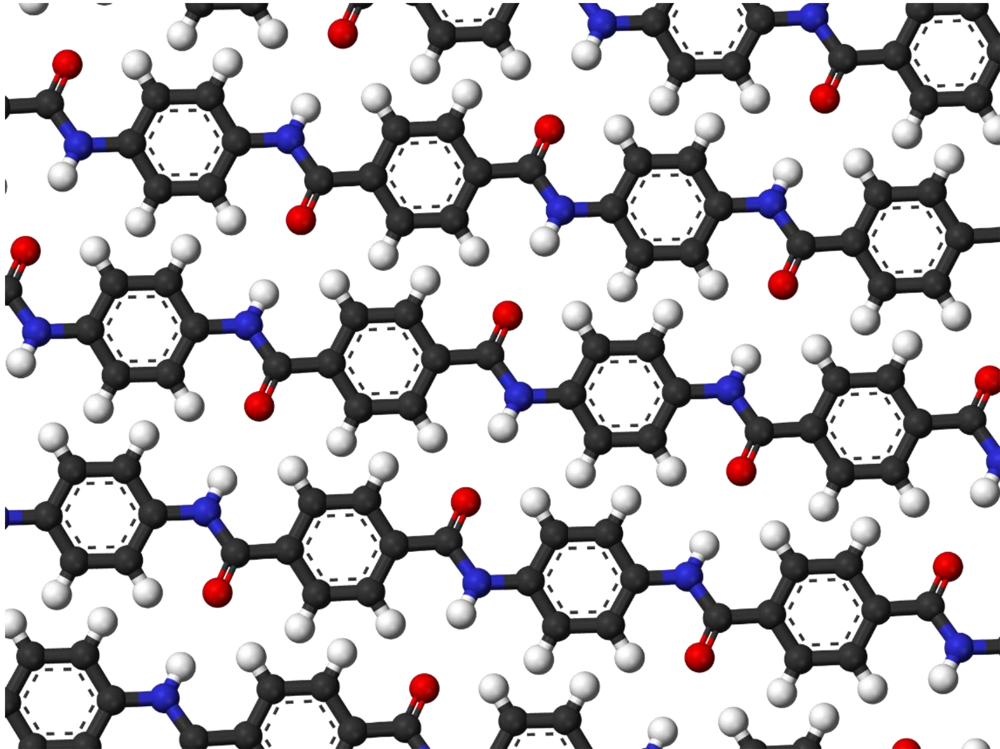


Pic. Source: Google

Special Engineering Plastics

1. Kevlar

- was introduced by DuPont in the 1970s.
- is the first organic fiber with sufficient tensile strength and modulus to be used in advanced composites. Originally developed as a replacement for steel in radial tires, Kevlar is now used in a wide range of applications.
- How can Kevlar be so strong?
  Kevlar is made from aramid (aromatic polyamide). The aramid ring gives Kevlar thermal stability, while the para structure gives it high strength and modulus.
- Three grades of Kevlar: Kevlar 29, Kevlar 49, and Kevlar 149.



Pic. Source: wikipedia

1. Kevlar:

Grade	Density (g/cm3)	Tensile Modulus (Gpa)	Tensile Strength (Gpa)	Tensile Elongation (%)
29	1.44	83	3.6	4.0
49	1.44	131	3.6--4.1	2.8
149	1.47	186	3.4	2.0

Additional properties of Kevlar:

- Kevlar has a slightly negative axial coefficient of thermal expansion, which means Kevlar laminates can be made thermally stable.
- Kevlar is very resistant to impact and abrasion damage.
- Kevlar can be mixed with graphite in hybrid fabrics to provide damage resistance, increased ultimate strains, and to prevent catastrophic failure modes.

- **Kevlar Disadvantages:**

  - The fibers themselves absorb moisture, so Kevlar composites are more sensitive to the environment than glass or graphite composites.
  - Although tensile strength and modulus are high, compressive properties are relatively poor.
  - Kevlar is very difficult to cut. You will need special scissors for cutting dry fabric or pre-preg, and special drill bits for drilling cured laminates. Cutting of cured laminates without fraying is very difficult.

PLASTICS AND ELASTOMERS
Nomex

Special Engineering Plastics

2. Nomex

Pic. Source: Google

Special Engineering Plastics

2. Nomex

- In both fiber and sheet forms, NOMEX® helps (people and materials) to perform, even in highly aggressive environments.
- NOMEX® fiber provides outstanding heat and flame resistance and offers excellent textile properties. Applications include filters, industrial coated fabrics.
- NOMEX® is also used for electrical insulation in both paper and pressboard forms, where its inherent dielectric strength, mechanical toughness and thermal stability provide high reliability in the most demanding applications.

Aviation Applications for Core Structures of NOMEX®-:

- NOMEX® offers not only thermal protection, but also light weight, necessities for the aviation industry.
- Honeycombs of NOMEX® substantially improve the performance of most current commercial aircraft.
- A structure with a NOMEX® core can increase strength by 37 times while increasing weight by only 6%. Used in flaps, wing-to-body fairings, nacelles, radomes, doors, floors, ceilings, stow bins and walls.
- NOMEX® helps aircraft manufacturers save weight and helps keep passengers safe.

Pic. Source: Quora

Electric Applications of NOMEX®-:

For electrical insulation, in various forms - primarily papers and pressboards:

- has the right balance of properties for use in transformers, motors, generators and other electrical equipment.
- NOMEX® provides high levels of electrical, chemical and mechanical integrity when converted into its various sheet forms.
- If used properly, NOMEX® paper products can extend the life of electrical equipment, reduce premature failures and repairs, and act as a safeguard in unforeseen electrical stress situations.

Elastomers:

- Materials that have considerable elastic properties.
- Included in the category of plastics. Elastomers will tolerate repeated elongation and return to their original size and shape, in a similar way to natural rubber

Pic. Source: Craftech Industries

Elastomers:

Some of the more common elastomers, used in the aerospace industry include:

Buna 'N'

- Known as Nitrile.
- A synthetic rubber, made (initially in Germany) by the polymerization of butadeine and sodium (hence BuNa).
- It has excellent resistance to fuels and oils, and is used for oil and fuel hoses, gaskets, and seals.
- This material also has low 'stiction' properties, when in contact with metal, and is, therefore, particularly suited to 'moving-sear applications.

Elastomers:

Some of the more common elastomers, used in the aerospace industry include:

Buna 'S'

- a relatively cheap material, also with a performance similar to natural rubber.
- It is often used for tyres and tubes, but its poor resistance to fuels/oils/cleaning fluids makes it unsuitable for seals.

Fluoro-Elastomers

- These have exceptional high-temperature properties and can be used at 250^{o}C.
- They are also solvent-resistant and are mainly used for high-temperature seals. A common name for these materials is Viton. These materials are expensive.

Common elastomers, used in the aerospace industry (cont'd):

- **Neoprene** - has very good tensile properties and excellent elastic recovery qualities. It is also solvent-resistant and, therefore, has a wide range of applications as fuel and hydraulic seals and gaskets. However, because of its special elastic recovery properties, it is also ideally suited to diaphragms and hydraulic seals.
- **Poly-Sulphide Rubber** - although it possesses relatively poor physical properties, it has exceptionally high resistance to fuels and oils and is widely used for lining or sealing fuel tanks. It is also used for lightly stressed seals and hoses, which come into contact with fuels or oils. This compound is commonly known under the trade names of PRC or Thiokol.
- **Silicone Rubber** - has very good high- and low-temperature properties ($-80^{o}C$ to $+ 200^{o}C$). It is often used for seals, but is also used for the potting of electrical circuits, because of its ability to retain its rubbery state, even at low temperatures.

Plastic Manufacturing Processes:

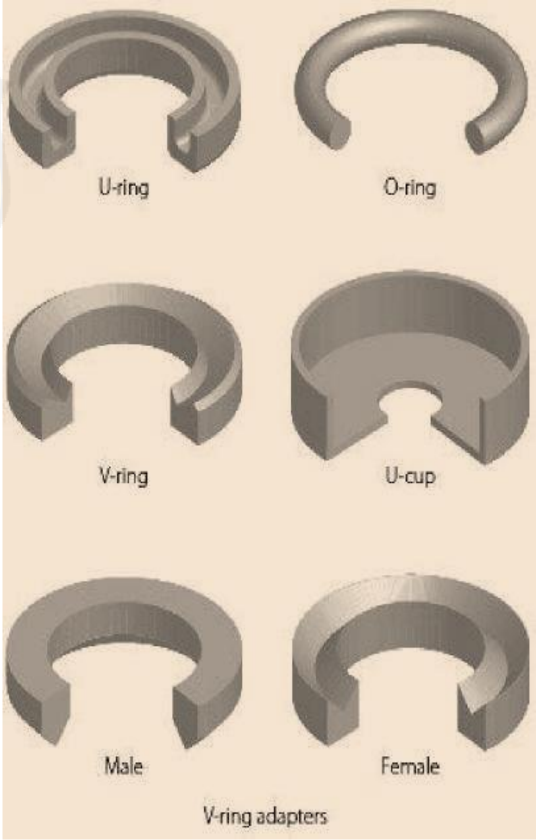
Most common manufacturing methods are:

- **Casting** - the molten material is simply poured into a mold and allowed to set.
- **Molding** - powder, liquid or paste is forced into a set of shaped dies.
- **Extrusion** - plastic is forced through a suitably shaped die. Rod, sheet, tube, angle sections etc. are produced this way.
- **Lay-up** - load-carrying plastic fibers and an adhesive are layered in a mold or around a former.
- **Sandwich-Construction** - plastic facings have, sandwiched between them, a honeycomb or foam core. Very stiff, but light, structures are achieved by this method.
- **Compression Molding** - the material is put into a heated, hardened, polished steel container (the die) and forced into shape, by a plunger.

Note: Vacuum Forming uses a similar tooling but, in this instance, the plastic is sucked into contact with the shaped die (a method often used to manufacture aircraft interior trim).

Non-Metallic Components:

- **Seals**:
  - Seals or packing rings (see figure) serve to retain fluids and gases, within their respective systems, as well as to exclude air, moisture and contaminants.
  - have to withstand a wide range of temperatures and pressures and, because of this, they have to be manufactured in a variety of shapes and materials.
  - The most common materials are: natural rubber, synthetic rubber and Teflon (trade name for polytetrafluoroethane or PTFE).
  - O-ring seals effectively seal in both directions of movement. They are used to prevent both internal and external leakage, and are the most commonly used seals in aviation.



- **Other seals**:
  - V-ring and U-ring seals. The V-ring has an open 'V' facing the pressure and is located by the use of a male and female adapter. The U-ring seals will, usually, be found in brake unit assemblies and master cylinders, where pressures below 89 x 10^3 kN/m^2 (1000 PSI) are encountered.

Adhesives and Sealants:

Adhesive bonding has been used on the aerospace industry. Adhesives are used for constructional tasks varying from aircraft fuselages, flight control surfaces, to propellers and helicopter rotor blades.

- **The Mechanics of Bonding:**

  The actual adhesive bond may be achieved in two ways:

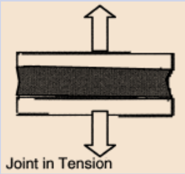
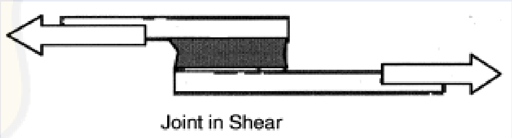
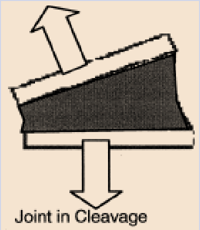
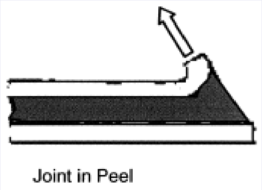
  - **Mechanical**: - here the adhesive penetrates into the surface and forms a mechanical lock, by keying into the surface. It also forms re-entrants, where the adhesive penetrates behind parts of the structure, and becomes an integral part of the component to be joined.
  - **Chemical (Specific):** - in this method of bonding, the adhesive is spread over the surfaces to be joined and forms a chemical bond with the surface

- In practice, most adhesives use both ways of bonding to form a joint.

Stresses on a Bonded Joint:

- Adhesive joints are liable to experience four main types of stress
- Joint stress is at a maximum when the adhesive is in shear (refer to figure). Adhesives should not be used if significant stresses will be carried in tension or peel. Lap joints are the types more, generally favored, as the strength of the adhesive bond is proportional to the area bonded:
  - **Tensile**,
  - **Shear**,
  - **Cleavage**,
  - **Peel**.

- **Stresses on Bonded Joints:**

	Condition	Ilustrasion
Tensile	Where the two surfaces are pulled directly apart.	
Shear	Where the two surfaces tend to slide across each other.	
Cleavage	Where two edges are pulled apart.	
Peel	Where one surface is stripped back from the other	

Advantages of Adhesives

The major reasons for the widespread use of adhesives are as follows:

- No weakening of the component due to the presence of holes. Also providing a smooth finish due to lack of rivet heads.
- No local stress raisers, which are present with widely-pitched conventional fasteners (Bolts, rivets etc.).
- Can be used to join dissimilar materials and materials of awkward shapes and of different thickness, as riveting and welding are not always possible on very thin (or very thick) materials.
- Although the strength per unit area, may be inferior to a mechanical or welded joint, adhesive bonding takes place over a greater continuous area and, therefore, gives comparable or increased strength, coupled with improved stiffness.
- Adhesive and sealants provide electrical insulation and prevent dissimilar- metal corrosion between different materials.
- Leak-proof (fuel and gas) joints can be achieved.
- The elastic properties of some adhesives, gives flexibility to the joint and may help to damp out vibrations.
- Heat-sensitive materials can be joined.

Disadvantages of Adhesives

The major disadvantages associated with adhesive bonding are:

- Limited heat resistance. This restricts the process to applications where environmental temperatures will not, generally, be above 200^{o}C.
- Poor electrical and thermal conductivity.
- High thermal expansion.
- Limited resistance to certain chemicals (i.e. some paint strippers).
- Integrity difficult to check with non-destructive testing procedures.

Strength of Adhesives

The three most important considerations are:

- Fail Stress: - fail load within the glued area
- Creep behavior
- Durability: - its long-life capability without serious deterioration.

Groups and Forms of Adhesives

When using adhesives, great care must be taken that only the correct type is used, otherwise, a catastrophic failure may well occur, should an unsuitable adhesive be used on a critical structure.

The two major groups of adhesives are:

- Flexible
- Structural

Flexible Adhesives:

- Flexible adhesives are used when some flexing, or slight relative movement of the joint, is essential and where high load-carrying properties are not paramount.
- In general, flexible adhesives are based on flexible plastics or elastomers, whereas structural adhesives are based on resins, (the most common ones being epoxy or polyester)

Structural Adhesives:

- Structural adhesives are primarily aimed at applications where high loads must be carried without excessive creep. They are, therefore, relatively rigid, but without being excessively hard or brittle

Note: Another group of adhesives is the two-polymer type, which has a reasonably even balance of resin and elastomer, which results in a flexible, yet fairly strong, adhesive.

Adhesive Forms:

- Adhesives can be obtained in a variety of forms, the most common being liquid, paste or film. Also available, are those such as the special foaming types, which are used to splice honeycomb sections together.

Adhesives in Use:

To achieve optimum bonding, performance, and life in service, follow carefully planned processes and procedures and pay attention to quality at every stage. The major criticisms, levelled against the use of adhesives, are:

- Absolute cleanliness at all stages is essential. Surface preparation of the component is also crucial. To ensure consistent results on structural components, a purpose-built 'clean room' is required, in order to reduce contamination to a minimum.
- Pressure and heat may be required. Sophisticated equipment is required to produce pressure over the components in areas where adhesives are applied. This will often entail vacuum bags, purpose-built ovens, or pressurized curing ovens (autoclaves).
- Inspection of the bonded joint is difficult. Special inspection techniques and test pieces are necessary to check the integrity of the bond. Prior to preparing the mating surfaces for 'gluing', it is necessary to carry out a 'dry' lay-up i.e. a trial assembly of all related parts to check and adjust the fit if necessary. This procedure is essential, to enable the final assembly 'wef lay-up to proceed without delay, and without the risk of generating swarf or of contaminating specially prepared surfaces.

Surface Preparation:

- Grease, oil, or other contaminants, must be removed by suitable solvents.
- An optimum surface roughness must be produced.
- Once pre-treated, a surface must be protected from harmful contamination until the bonding process is complete.
- Surfaces to be bonded are normally thoroughly cleaned / degreased in a suitable solvent. This may be followed by a chemical etch or light blasting treatment, followed by a water wash and subsequent drying.

Final Assembly:

- The adhesive is applied (usually within a specified time, otherwise re-processing may be necessary), and the assembly suitably clamped, or put in a nylon vacuum bag, and heated in an autoclave. The curing process then takes place under carefully controlled temperature and pressure conditions.
- When cool, the component is inspected, visually for positioning and for a satisfactory spew line. The glue-line thickness is also checked, with a calibrated electronic probe, and specimen test pieces are tested for shear and peel properties.
- Following a satisfactory inspection, the component is finally given appropriate corrosion protection (usually over-painting).

Note: After commencing the final (wet) lay-up, curing of the adhesive must be carried out within a specified time (usually 12 hours). If this period is exceeded by a few hours it is necessary to increase the temperature and pressure levels during curing (and to obtain an official 'concession' cover for this discrepancy).

If the permissible time between wet lay-up and curing is greatly exceeded (e.g. a full shift or day), it will be necessary to dismantle and not only re-commence the wet lay-up, but also to, possibly, repeat some of the preliminary surface preparation treatments (such as etching).

Typical (Abbreviated) Process:

- Dry lay-up (i.e. 'dummy run')
- Prepare faces to be bonded (alumina blast, etch (pickle) anodize, etc).
- Water wash and dry.
- Apply adhesive in clean room and clamp or apply vacuum bag.
- Cure in press/oven or autoclave (typically 120°C – 170°C)
- Release autoclave pressure when cool.
- Inspect:
  - Positioning, uniform, continuous glue-line etc.
  - Glue-line thickness (electronic probe).
  - Specimen test-piece results (shear and peel).
- Carry out final post-cure surface treatments, (e.g. over-painting of primer, sealant or top coat of solvent-resistant paint)

Sealing Compounds:

- Certain areas of all aircraft are sealed to withstand pressurization, prevent fuel or fume leakage and to delay the onset of corrosion, by sealing against the weather.
- Most sealant compounds, consist of two or more ingredients that are compounded to produce a desired combination of strength, flexibility and adherence. Some materials are ready-for-use, straight from their packaging, whilst others require mixing before application.

One-Part Sealants:

- are prepared by the manufacturer and are ready for application straight from their packaging. Thinner (recommended by the sealant manufacturer), may be used, is mixed with the sealant.

Two-Part Sealants:

- are identified as the base sealing compound and the accelerator,
- are generally mixed, by combining equal portions (by weight), of the base and accelerator compounds,
- manufacturer’s instructions must be followed, but, in general, require the addition of the accelerator to the base compound, followed by thorough mixing before application.

Sealant Curing

- The curing rate, of mixed sealants, varies with temperature and humidity. For example, at temperatures below 15°C, curing is extremely slow. At temperatures above 21°C, curing times are usually faster. For best results, a temperature of around 25°C, and relative humidity of 50%, is ideal for curing most sealants.
- If the temperature of curing must not exceed 50°C at any time during the curing cycle. The heat can be applied, by using infrared lamps, or heated air, providing the air is dry and filtered.
- A practical test, to see if curing has been completed, can be done by laying a sheet of cellophane on the work, and checking whether the sheet adheres to it (lack of adhesion indicates full curing).