Module -4

Ablative Materials

Classification:

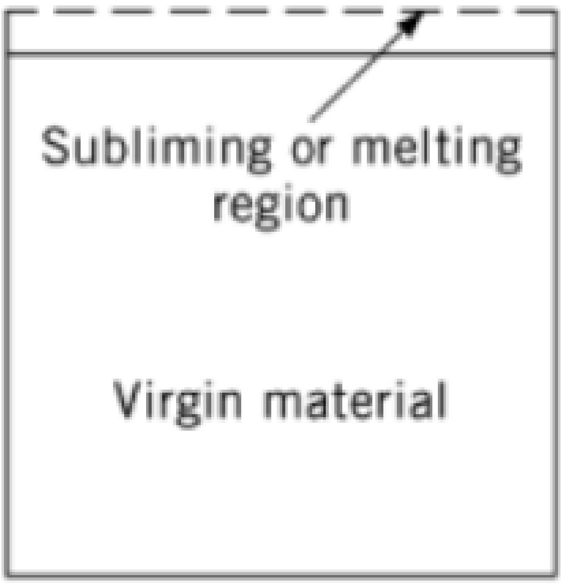
Dominant ablation mechanism

1. Subliming or melting ablators
2. Charring ablators and
3. Intumescent ablators

Ablative Materials

Classification:

Subliming or melting ablators

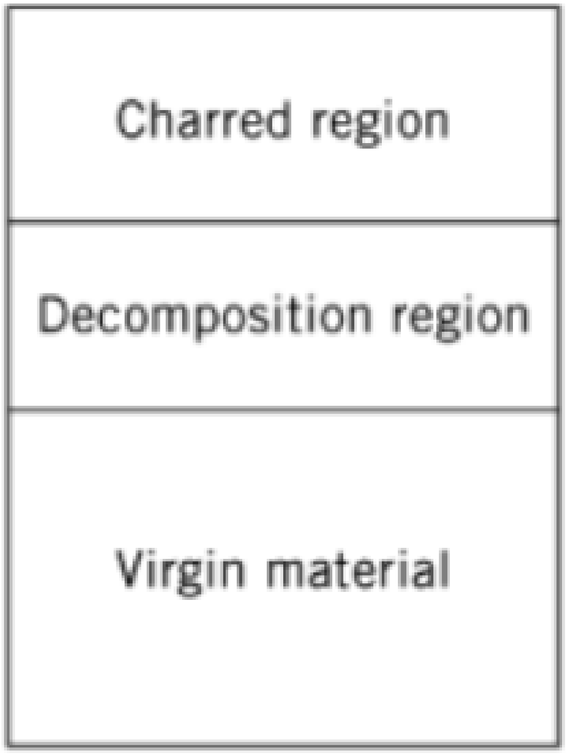


- Heat sinks - heat flux - reaction temperature.
- Removes heat from the insulation material.
- Heat - boundary layer - blocked by the evolving gases.
- Blocking action – reduce heating by more than 50%.
- Copper or beryllium
- Teflon – lightweight and good insulating properties
- Also Teflon will not form conductive char which is very useful for transmitting and receiving radiofrequency signals during re-entry.
- Teflon and quartz fiber – high temperature load.

Ablative Materials

Classification:

Charring Ablators



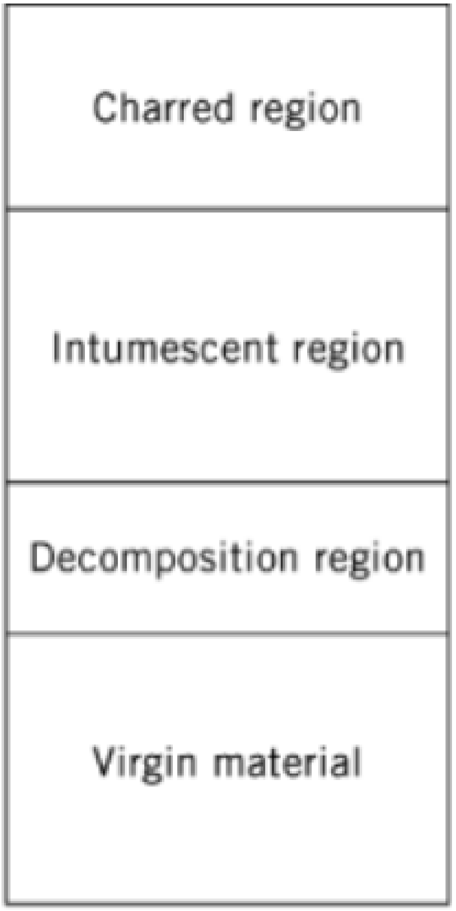
- Charring ablators are most widely used – high heat flux.
- Ablator – heat sink – reaction temperature – decomposes (pyrolizes) - carbonized material and gaseous products.
- Gases – insulation – thickens the boundary layer.
- Continuous – eroded – new surface will form.

- Charring ablators used with subliming or melting ablators.
- Carbon-fiber-reinforced phenolic composites (high density).
- Apollo mission: epoxy–novolac resin with phenolic microballoons and silica fiber reinforcement (low density)

Ablative Materials

Classification:

Intumescent Ablators



- Additives – foam like region on exposure to heat.
- Material thickness - improved insulation.
- Charred ablators
- Used as insulators to protect munitions on naval ships.
- Load-carrying beams for bridges, oil rigs, etc.
- Not generally used - re-entry – high density and drastic shape change.
- Rubberized sheets, tapes, pastes and spray on coating.
- CHARTEK 59, a high performance, lightweight, epoxy-based material.

Ablative Materials

Graphite:

- Carbon - highest heat of ablation.
- Carbon or carbon composites - high heating environments - missile nose tips
- Graphite sublimes at temperatures as high as 3900 K.

Carbon-Carbon Composites:

- Carbon fiber reinforcement with carbon or graphite matrix.
- Nose tip materials 3-directional-reinforced (3D) carbon preforms are used.
- Fibers - rayon, polyacrylonitrile, and pitch precursor carbon fibers.
- Rocket nozzles or exit cones - 3D preforms - Densification

Wood and Glue

Wood:

- Wood – Aluminium alloys and steels
- Construction of small aircrafts – wing spars and ribs
- Wood propellers in some countries
- Interior cabin trim and flooring - relative cheapness and the ease of working
- Wood has excellent elastic properties and ability to resist a greater load for a short period
- Non-homogeneity is main disadvantage.
- Moisture content
- Inspection limits the amount of wood available for aircraft and increases the cost.

Wood and Glue

Classification of Trees and Woods:

- Trees are divided into general groups which are known as:

Conifers

- Softwoods, needleleaf, evergreen;
- Pines, firs , cedars, and spruces
- Coniferous trees cover large areas in parts of Canada and the United States.
- Wood is comparatively light in weight, is easy to work, and is obtainable in large, straight pieces.

Hardwoods

- Ash, birch, mahogany, maple, oak, poplar, and walnut
- Natural forests
- Heavy in weight, difficult to work and obtainable only in relatively small lengths

Wood and Glue

Classification of Trees and Woods:

Monocotyledons:

- This group includes the palm and bamboo trees.
- They have little or no structural value.

Structure of wood:

Composed of four distinct parts

1. Pith – soft central core
2. Hearthwood - concentric rings immediately surrounding the pith
3. Sapwood
4. Bark

Wood and Glue

Structure of wood:

Pith:

- Medulla
- Young tress for which it serves as a food storage place
- In mature trees the pith is nothing but a point or a small cavity

Heartwood:

- Duramen is a modified sapwood.
- It is formed from the adjacent sapwood
- Each year as a new annular ring is added to the sapwood the heartwood also increases.
- Heartwood is heavier, tougher, and darker than sapwood.
- In the living tree the heartwood is subject to attack by fungi, but after cutting it is more resistant to insect attack, decay, stain than sapwood.

Wood and Glue

Structure of wood:

Sapwood:

- It is the younger, lighter coloured, more porous.
- The cells of sapwood are alive and serve for the storage and translocation of food.
- Sapwood is more pliable than heartwood and is preferable when severe bending must be done.

Bark:

- It is the husk or outer cover that protects the tree.
- It does not serve any useful structural purpose.

Wood and Glue

Strength of wood:

- Strength of wood depends upon a great many factors. The absence or limitation of defects is a primary consideration.
- Different factors which controls the strength of wood are
    1. Density of the wood (specific gravity)
    2. Locality of Growth
    3. Rate of Growth
    4. Moisture Content
    5. Defects

Wood and Glue

Specific gravity:

- Strength of wood - directly proportional to its specific gravity.
- Increase in the specific gravity by 10% - compression parallel to the grain and modulus of elasticity in static bending.
- At the same time the shock resistance will be increased over 20%.
- Specific gravity of wood must be determined for an oven-dry condition.

Locality of Growth:

- Woods have equal strength - specific gravities - irrespective of their locality.
- Rocky Mountains has considerably less weight and strength than the same species grown on the Pacific Coast.

Wood and Glue

Rate of Growth:

- Hardwoods of very rapid growth are usually above the average in strength properties.
- The conifers or softwoods are below the average in strength when rapidly grown.
- For aircraft requirement a minimum of six annual rings to each inch through the zone of the maximum grow.

Moisture Content:

- The strength of wood is very dependent upon its moisture content.
- Moisture is present in wood as free water in the cell cavities and as hygroscopic moisture in the cell walls.
- Moisture decreased - wood shrinks and increases in strength.

Wood and Glue

Defects:

- Defects in wood are very common and have a very bad effect on the strength.
- **Sloping grain** is the most common defect. This constitutes spiral, diagonal, wavy, curly, interlocked, or other distorted grain.
- **Knots** reduce the strength of wood largely because the grain is distorted in their vicinity. Knots should not be permitted along the edge of a piece of wood or in the flange of a wing spar.
- **Pitch pockets** are lens-shaped openings between annual rings which contain resin. They vary from under one inch to several inches in length.
- **Mineral streaks** are dark brown streaks containing mineral matter and are found in such woods as maple, hickory, basswood, and yellow poplar. They extend for several inches to a foot along the grain. Decay – toughness – shock resisting properties.
- **Checks, shakes, and splits** in wood are causes for rejection. All of these defects weaken the wood, cause internal stress, and are generally unreliable.

Wood and Glue

Aircraft woods:

White Ash :

- White ash - aircraft construction.

White ash	Green ash
Blue ash	Biltmore ash

- Fairly heavy but is also hard, strong, and elastic.
- Oak - lighter, easier to work, tougher, and more elastic.
- 16 annual rings per inch.
- Second growth ash.

Wood and Glue

Basswood:

- Lime, linden, teil, bee, and bass.
- Light, soft, easily worked, and tough, but not strong or durable when exposed to the weather.
- It receives nails without splitting better than most other woods.

Beech:

- Fagus grandifolia.
- Heavy, hard, strong, and tough, but not durable when exposed.
- Beech is frequently used for facing plywood when hardness is desired.
- It will take a very fine polish.

Wood and Glue

Birch:

- Sweet birch and Yellow birch are commonly used in aircraft work.
- Heavy, hard, strong, tough, and fine grained. Excellent finish.
- Due to its hardness and resistance to wear it is often used to protect other woods.
- Birch is the best propeller wood and also the best wood for facing plywood when a high-density wood is desired.

Black Cherry :

- Moderately heavy, hard, strong, easily worked, and fairly straight-grained.
- It is an excellent base for enamel paints.
- Black cherry is sometimes used in manufacturing aircraft propellers.

Wood and Glue

Cork Elm:

- Rock elm.
- Heavy, hard, very -strong, tough, elastic, and difficult to split. It will take a beautiful polish.
- Low in stiffness but very resistant to shock, because of its tough qualities.

Hickory:

Shagbark hickory	Bigleaf shagbark hickory
Mockernut hickory	Cow oak

- Heaviest and hardest wood. Extremely tough.
- Hickory is seldom used in aircraft construction because of its weight.

Wood and Glue

African Mahogany:

- African mahogany differs from-true mahogany because it does not have well-defined annual rings.
- Mahogany works and glues well and is very durable.
- It shrinks and distorts very little after it is in place.
- African mahogany is used for semi hard plywood faces.

True Mahogany:

- Strong and durable, but brittle.
- It glues and works well.
- True mahogany is used in the manufacture of aircraft propellers and for the semi hard faces of plywood.

Wood and Glue

Sugar Mapie:

- Hard maple. Heavy, hard, and stiff, and very difficult to cut across the grain.
- This wood has a very uniform texture and takes a fine finish.
- It wears evenly and is used as a protection against abrasion.
- Occasionally for aircraft propellers.

Oak:

- Propeller construction or for bent parts in aircraft.

  White oak   Bur oak   Post oak   Cow oak

- Red oaks - occasionally but they are more subject to defects and decay.
- Heavy, hard, strong, and tough.
- Oak propellers are used for seaplanes, particularly because of their resistance to the abrasive action of water spray.

Wood and Glue

Black Walnut:

- Heavy, hard, strong, easily worked, and durable.
- It is difficult to season but holds its shape very well in service.
- Black walnut is used in the manufacture of propellers and is next to birch.

Port Orford Cedar:

- Port Orford cedar is one of a group known as white cedars.
- Its wood is light, strong, durable, and easily worked.
- As a substitute for spruce it can be used in aircraft construction.
- It is also used for semi hard faces of plywood.

Wood and Glue

Seasoning of wood:

- Wood shrinks considerably as the moisture content is reduced.
- When wooden parts are manufactured, it is essential to determine the moisture content which they will attain in service.
- Moisture content - humidity and temperature of the surrounding air.
- Natural drying - **air seasoning**. It is seldom used for aircraft wood, because it takes more time (one to two years) and cannot be controlled.
- Artificial seasoning - **kiln drying,** desired moisture content - in less than one month.

Wood and Glue

Air Seasoning of Wood:

- Air seasoning is performed by carefully piling the green lumber under a shed that will protect it from rain and snow, but will permit air to circulate through it.
- The foundation for the pile of lumber must be at least 18 inches high and have a slope of one inch per foot from front to rear.
- In piling the wood, good-sized air spaces must be provided to insure ventilation of all wood in the pile.
- To avoid checking of the ends of the lumber, caused by premature drying, the ends must be painted with a hardened gloss oil, paraffin, or pitch.

Wood and Glue

Kiln Drying of Wood:

- Kiln drying of wood is based on external air humidity and temperature and the moisture content of the wood.
- Temperature and humidity are closely regulated by means of heating coils and sprays.
- There is also a natural or forced system of ventilation through the carefully piled lumber.
- The temperature is gradually increased and the humidity lowered in the compartment as the moisture content of the lumber decreases.
- The exact procedure varies for different species of wood.
- Careful adjustment of temperature and humidity is necessary as the drying progresses, to insure a steady, even drying and freedom from internal strains.
- In order to ascertain the moisture content at any point in the drying process, samples are inserted in the pile of lumber.

Wood and Glue

Glues and Gluing (Joining of wood):

- Glue plays a very prominent role in wooden aircraft construction.
- Many wood joints depend wholly upon the joining power of glue for their strength.
- It is necessary for aircraft glue to be absolutely reliable. It must retain its strength under adverse conditions (as when wet, hot, or attacked by fungus) and must not deteriorate rapidly with age.
- There are six types of glue commonly used in aircraft assembly operations

1. Urea Formaldehyde Resin Glues
2. Resorcinol Phenolic Glues
3. Alkaline Phenolic Glues
4. Casein Glues
5. Blood Albumin Glues and
6. Animal glues.

Wood and Glue

Urea Formaldehyde Resin Glues:

- This glue is an excellent all-purpose glue for aircraft shop work.
- Water and fungus resistant.
- It will cure at room temperature but is superior when cured at 140°F under pressure for 4 to 8 hours.
- 3 hour life time.
- Deteriorate if heated in water above 145°F but is water resistant at normal temperatures.
- Dried powder - powder is dissolved in cold water the resulting glue is ready for use.

Wood and Glue

Resorcinol Phenolic Glues:

- It is derived from resorcinol and formaldehyde and has the durability characteristics of the phenolic resin glue used in waterproof plywood combined with the working characteristics of the urea glues.
- A resorcinol type glue consists of two parts
    1. a water-soluble liquid resin and
    2. a separate powder
- Working life, characteristics, and setting time are same as urea glues.

Alkaline Phenolic Glues:

- It uses alkaline catalysts to insure curing of the glue in a reasonable time.
- It is necessary to cure at an elevated temperature of between 150° and 180°F.
- This exhibits excellent durability characteristics, and possesses much better resistance to adverse conditions of heat and moisture than urea & casein glues.

Wood and Glue

Casein Glues:

- Casein glue was the all-purpose glue in aircraft construction prior to the development of urea formaldehyde resin glue.
- Casein is obtained from curdled milk and is combined with other materials to form a glue.
- Powdered form. Generally, one part of casein glue powder is mixed with two parts of water by weight to form a liquid glue.
- Casein glue should be used only within four hours of its preparation.
- When casein glue is applied to wood, it should be clamped for at least five hours, preferably overnight, to permit thorough setting

Wood and Glue

Blood Albumin Glues:

- It is used in gluing standard plywood.
- They are very water resistant, exceeding even the best casein glue in this respect.
- These glues are made from an albuminous base from the blood of slaughtered animals, combined with chemicals, such as lime, caustic soda, or sodium silicate.
- The blood albumin is obtainable as powder, and the mixture is added to about twice as much water, more or less, depending upon the consistency desired.
- In the manufacture of plywood the water-resistant properties of the blood albumin glue are improved by pressing the plywood between two hot plates while glue is setting.

Wood and Glue

Animal Glues:

- Animal glues were used extensively in gluing propellers.
- Urea resin or casein glue has replaced them somewhat because of better all around qualities.
- Animal glues are manufactured from the skin, bones, or sinews of animals.
- These materials are boiled in water, and the extract concentrated and jellied by cooling.
- Dry glue is thoroughly soaked in cold water for several hours and then heated in a closed retort.
- The glue is kept at this temperature while being used. Glue which has been heated for over four hours must be discarded.
- One pound of dry glue should be mixed with 214 pounds of water in order to obtain the normal consistency.

Wood and Glue

Gluing Wood (Joining Process):

- Seasoned.
- Finely smoothened.
- Glue is uniformly applied.
- Starved joint
- Dried joint
- Clamped or Pressed - 100 to 200 p.s.i. for 5 hours or more
- Machining or finishing – after two or more days.

Wood and Glue

Plywood:

- Thin layers of wood
- Veneer
- Grains - at right angles to each other
- Centre ply - softwood and are considerably thicker
- Hardwood - face plies - resist abrasion and take a better finish.
- Box spars for wings, webs of ribs, wing and fuselage covering, flooring and interior cabin panelling.
- A plywood with a metal sheet cemented to one face to take excessive wear is often used for flooring.
- Birch and mahogany
- Basswood

Wood and Glue

Types of Plywood:

1. Waterproof Plywood
2. Superpressed Resin Plywood
3. Molded Airplane Parts.

Wood and Glue

Waterproof Plywood:

- Resistant to water and fungus.
- Bend - steamed or soaked in boiling water.
- Hot-pressed - synthetic resin adhesive.
- Phenol formaldehyde.
- Heat and pressure are then applied to cure the glue.
- Temperature - 300°F and pressure – wood type.
- Paint - moisture absorption by the wood.
- Moisture content – 7 - 12%.

Wood and Glue

Superpressed Resin Plywood:

- Same as waterproof plywood – pressure (500 to 1500 p.s.i)
- High-density plywood
- Increasing density by more than 2 times – shear strength increases by 7 times.

Molded Airplane Parts:

- Molds – desired shape.
- Soaking in hot water is avoided.
- Fuselage
- Limitation – cost of jigs and dies
- Large scale production

Aircraft Fabrics and Dope

Aircraft Fabric:

- Term – material and the process – open structures – wings, fuselage and tail.
- Reinforcing – plywood and composite structures
- Earlier – Cotton and Linen
- Smooth surface

Purpose or Requirement of fabrics:

1. To provide a light airproof skin for lifting and control surfaces.
2. To provide structural strength to weak structures.
3. To cover other non-lifting parts of an aircraft to reduce drag.
4. To protect the structure from the harmful elements or environments.

Aircraft Fabrics and Dope

Application of fabrics:

Wing covering:

- Envelope, blanket, or combination method.

Envelope Method:

- Sewing several widths of fabric to form an envelope / sleeve.
- Sleeve – pulled over the wings from open end.
- Open end – hand-sewed or tacked.
- Machine sewing – lots of labour

Aircraft Fabrics and Dope

Application of fabrics:

Blanket Method:

- Machine sewing fabrics - placed on wing - hand sewing along the trailing edge.
- Care must be taken to apply equal tension over the whole surface.

Combination method:

- Envelope method to maximum extent and remainder is covered using blanket method.
- Obstructions or recesses.

Aircraft Fabrics and Dope

Fuselage Covering:

- Sleeve or blanket method.
- Sleeve method – machine sewed – drawn over fuselage will fit snugly.
- Sleeve - all seams - parallel - longitudinal members of the fuselage.
- Blanket method - machine sewed – except one final longitudinal seam along the bottom centre of the fuselage.

Dopes and Doping:

- Tighten fabric covering, air and water tight: brushed or sprayed.
- Deterioration by weather or sunlight.
- Reduces skin friction – finely polished.
- Clean, fresh, dry atmosphere: above 70°F and below 60% , good ventilation.
- Consistency applied over the entire surface.
- Deteriorate – warm conditions.
- Storage temp. - 60 °F.
- Precautions against fire – inflammable nature.
- Dope rooms – isolated ; Metal partitions and fireproof doors – within factory.

Dopes and Doping:

Cellulose-Nitrate Dope:

- Nitrocellulose and a plasticizer
- Nitrocellulose – cotton with nitric acid
- Glycol sebacate, ethyl acetate, butyl alcohol, and toluene – Plasticizeter
- Flexible film
- Consistency –thinners; Ex. benzol or ethyl alcohol
- Pigmented dopes – to protect fabric from sunlight

Dopes and Doping:

Cellulose-Acetate-Butyrate Dope:

- Cellulose-acetate-butyrate - Base
- Triphenyl phosphate – Plasticizer
- Ethyl acetate, butyl acetate, diacetone alcohol and methyl-ethyl-ketone
- Pigment
- More fire resistant than nitrocellulose dope

Aircraft Paints:

- Final finish operation
- Painting - Priming coat followed by finishing coats of varnish, enamel, or lacquer.
- Paint: Vehicle + Pigment
- Vehicle: Liquid - cements the pigment together and strengthens it after drying
- Pigment: Solidity, colour, and hardness to the paint.
- Pigment: Corrosion resistance and inert
- Examples: Iron oxide, zinc chromate, titanium oxide, iron blue, lead chromate, carbon black, and chrome green.

Aircraft Paints:

Desirable properties of paint:

- Resistant to corrosive medium
- Abrasion resistant
- Elastic to prevent cracking
- Good adhesive qualities
- Smooth finish and good appearance.
- Corrosion resistant

Aircraft Paints:

Types of vehicles:

1. Solidifying oils
2. Volatile oils or spirits

Solidifying oils

- Exposed: dry and become tough, leathery solids.
- China wood oil
- Dries quickly, tough, durable, and free from cracks.
- Linseed oil – raw state – several days.

Aircraft Paints:

Volatile oils:

- Exposed – evaporates
- Dilute paint and dissolve varnish resins
- Examples: Alcohol, turpentine, benzine, benzole, toluene, ethyl acetate, and butyl acetate.

Primer:

- Corrosion resistant - direct contact with the surface of the metal.
- Good adherence and good base for the top coats of paint.
- Tough, abrasion resistance and scratch resistance.
- Red iron oxide primer and zinc chromate primer.

Aircraft Paints:

Red iron oxide primer:

- Brownish-red colour
- Pigment - iron oxide and a small amount of zinc chromate
- Non-volatile vehicle: China wood oil and some linseed oil

Zinc chromate primer:

- Universal choice for aircraft work
- Greenish-yellow
- Pigment - zinc chromate with some magnesium silicate.
- Spraying - toluene
- Aluminum powder – interior surfaces

Aircraft Paints:

Lacquer:

- Applied as finishing coats on airplanes.
- Cellulose nitrate, glycol sebacate, glyceryl phthalate resin, volatile spirits such as toluene, butyl acetate, butyl alcohol, and ethyl acetate.
- Pigment – required colour.
- Light in weight, used readily in service.
- Lacquer dries almost instantly when applied.
- Fabric or metal surfaces.

Aircraft Paints:

Varnish:

- Solution - Resins dissolved in oil or mineral spirits.
- Oil varnishes are those in which the oil dries and becomes part of the film after application.

Aircraft spar varnish

- Outside exposed surfaces of wood, metal, and doped fabric.
- Clear, transparent, protective coating.
- Vehicle for aluminum pigment, aircraft enamels, and primers.
- Phenol formaldehyde, China wood oil, some linseed oil, driers, mineral spirits, turpentine, and dipentine.
- Brushed or Sprayed
- Salt water as in sea plane hulls.

Aircraft Paints:

Enamel:

- Mixture - Pigment and Varnish.
- Enamels are harder and more durable than paints.
- Frequently used for the top coats in finishing airplanes.
- All aircraft enamels - Pigment with spar varnish

Aircraft Paints:

Acid-resistant Paint:

- Interior surfaces - battery boxes and materials in the vicinity of such boxes.
- Asphalt varnish - Jet black in colour and has good brushing qualities.
- Dries to touch in 5 hours and completely in 24 hours.
- Resistant to sulfuric acid, nitric acid, or hydrochloric acid.

Bituminous Paint.

- Coal-tar derivative and suitable solvents.
- For aircraft purposes it is usually pigmented with aluminum powder.
- Unexposed parts of hulls, floats, wings, and tail surfaces on seaplanes.

Aircraft Paints:

Methods of Applying :

1. Dipping
2. Brushing and
3. Spraying

Dipping

- Factories or large repair stations
- Process - dipping the part to be finished in a tank filled with the finishing material.
- Primer coats are frequently applied in this manner.

Aircraft Paints:

Brushing:

- Satisfactory method of applying finishes to all types of surfaces.
- Small repair work and on surfaces where spraying paint is not practicable.
- Material - thinned to the proper consistency for brushing.
- Too thick - tendency to pull under the brush.
- Too thin - they are likely to run or not cover the surface adequately.
- Proper thinning and substrate temperature allows the finish to flow-out and eliminates the brush marks.

Aircraft Paints:

Spraying:

- Quality finish
- Large surfaces with a uniform layer of material - most cost effective method of application.
- Compressed air; Reservoir or feed tank; controlling device.
- Spray cans – small areas.
- Spray gun with an integral paint container – small areas
- Large areas – pressure feed equipment is more desirable.
- Air supplied - free of water or oil
- Water traps and filters
- Filters and traps must be serviced on a regular basis.

Aircraft Paints:

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Aircraft Paints:

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Aircraft Paints:

Soya-bean-oil Compound:

- Non-volatile raw soya-bean oil, ester gum, and China wood oil combined turpentine.
- Used as a seam compound for making metal hulls.

Marine Glue:

- Rosin, pine tar, denatured alcohol, and a drying oil such as China wood oil, rosin oil, or linseed oil .
- Used as a seam compound on either wood or metal hulls for water tightness.