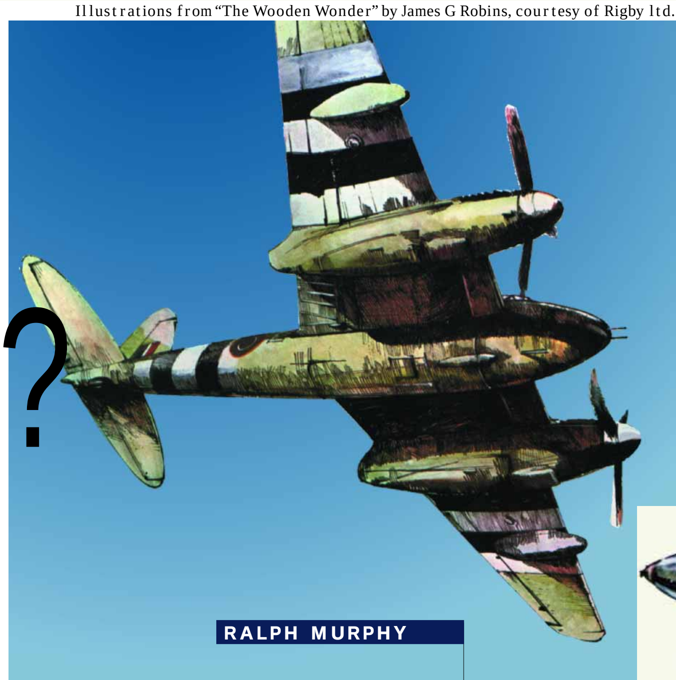
WHY NOT WOOD?

Illustrations from "The Wooden Wonder" by James G Robins, courtesy of Rigby ltd.



Above: Howard Hughes's "Spruce Goose", which was designed to carry 1,000 fully equipped troops, was for many years the largest aircraft ever built.

Left: The famous "wooden wonder", the de Havilland Mosquito was one of the fastest aircraft of WWII.

Below: The unique German rocket fighter, Messerschmidt 163 "Comet", had 8mm thick plywood wing skins.

An overview of the knowledge, techniques and skills of using wood, plywood and adhesives to build and maintain aircraft.

RALPH MURPHY

WOODEN AIRCRAFT HAVE BEEN around since the dawn of aviation. And many well-known aircraft use wood for such major components as wing spars and wing ribs.

Wood is is still used because it is a very efficient material. It is pleasant and easy to work with minimum tools and equipment. Wooden aircraft structures can be very long lasting if cared for properly.

Wood also has no fatigue life, although the metal attaching parts may have fatigue lives. Wood is a non-strategic renewable resource, which is why many famous wartime aircraft were built from wood, such as the de Havilland Mosquito. Howard Hughes's Spruce Goose, and the wings of the Messerschmidt 163 Komet rocket fighter were also made from wood.

Classes of wood: Wood is divided into two classes: softwoods or non-porous types and hardwood or porous types. The difference is in the nature of the cellulose cells and how they are bound by a substance called lignin. Essentially, hardwood has long fibres and softwoods short closed cells joined end-to-end.

More detail about classes of wood can be found in the CSIRO publication Trade Circular no. 3, *The growth and structure of wood*, available from: CSIRO Forestry and Forest Products Division library, Private Bag 10, Clayton South, MDC 3169.

Certain softwoods have the right combination of strength, density and quality to be useful for aircraft construction. Timbers such as sitka spruce and Douglas fir have traditionally been used, but Australian and New Guinea timbers such as hoop pine, bollywood and klinki and some others are increasingly being used.

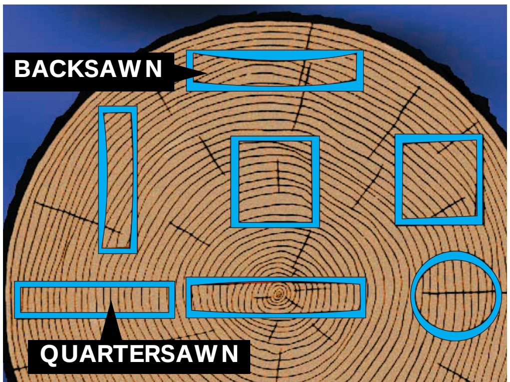
Some hardwoods such as alpine ash and mountain ash are useful for applications where a hard surface and strength are required, for example, for bearing blocks and for attaching highly loaded parts.

Aircraft plywood has traditionally been made from birch, mahogany, spruce and gaboon. However, some Australian timbers have proved useful, including hoop pine, and coachwood.

Logs can be sawn in several ways. Slices cut across the log, called lily-pads, are used for preparing end-grain material such as end-grain balsa for sandwich construction. Pieces sawn along the length of the log can be "backsawn" or "quartersawn" (also known as "vertical grain"). Some pieces are inevitably somewhere between (*see diagram below*).

Once sawn, the timber must be air or kiln dried. Timber shrinks in the drying process, mostly in the tangential direction along the annual rings, less in the radial direction across the rings, and almost nil in the length of the wood.

The designer will always specify the way the timber is to be used. In general, quar-



Effects of shrinkage on the shape of sections drying from the green condition. Quartersawn is preferred.

tersawn timber is preferred, as it is less likely to twist, warp and develop cracks, especially in the drying process. All timber and plywood must conform to a recognised aeronautical specification. These specifications often set parameters for:

- Species of wood, minimum number of rings per inch, slope of the grain.
- Permitted density range at a certain moisture content.
- Defects not permissible.
- Minimum strength and stiffness.
- Lack of brittleness, and so on.

Common specifications for spruce are the American MIL-S-6073 and the British 2V37. There are specifications for native Australian timbers as spruce substitutes which were issued as emergency wartime specification (E)2D-811 for hoop pine, bunya pine, Queensland maple, bollywood, silver quandong and silver silkwood.

Common specifications for birch plywood are British 6V3 and German GL1. There are specifications for native Australian species plywood issued as emergency wartime specification, for example (E)D812-1943 for coachwood and hoop pine plywood.

The properties and specifications of a range of timbers and plywood are listed in the American publication, ANC-18 Bulletin *Design of Wood Aircraft Structures* (available from the US Government Printing Office).

While there are many suppliers of wood and plywood, you won't find aircraft quality timber at the local timber yard; you will have to order it, and wait for delivery.

So plan well ahead. Any worthwhile timber or plywood may be qualified – refer to the CASA document Airworthiness Advisory Circular AAC 196-3.

Moisture content: You need to understand the importance of the moisture content. Moisture content (MC) in a piece of wood is the weight of water in a piece of wood divided by weight of the dry wood. The result is expressed as a percentage.

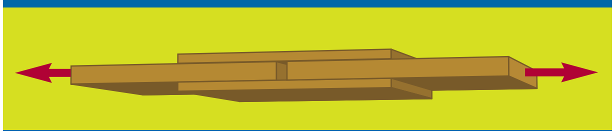
Timber is quite wet when harvested, and must be kiln or air dried down to about 15 per cent MC. This is crucial to the longevity of the wood, as below 20 per cent MC, the wood will generally not be attacked by fungi or parasites. Also, the strength of wood decreases markedly with increasing moisture content.

Moisture content can be measured by the oven dry method or by an electronic moisture meter. In practical terms, the builder or repairer has little control over the moisture content, as the wood will adjust its moisture content to the environment. Yet MC is very important not only to longevity and strength, but also when glueing wood. The adhesive manufacturer's instructions should be followed.

Working wood: Joint details – the traditional dowel, mortise, dovetail joints and nails – are useless for aircraft structures. Properly designed glued shear joints (*see diagram*) and bolted joints are required.

The Sport Aircraft Association of Australia (SAAA) has an excellent network of inspectors and competent builders. The SAAA can be contacted at PO Box 169, Clifton Hill, Vic 3068.

Above: Typical fabric covered wooden wing under construction.



Above: Old fashioned furniture joints are unsatisfactory; aircraft require properly designed joints which put the glue in shear.

An excellent practical publication is the EAA *Aircraft Building Techniques - Wood*, available from the Experimental Aircraft Association, PO Box 3086, Oshkosh, WI 54903-3086 USA.

Glues: You need a good knowledge of the types of glues permitted, and the techniques to achieve good glueing integrity.

Unfortunately most adhesive manufacturers no longer provide release notes for aircraft wood glue. Therefore you must ensure that the adhesive is recommended for aircraft wood glueing and is used strictly in accordance with the manufacturer's instructions.

The user should also ensure that break samples are prepared at each glueing session to be sure that the glueing process was satisfactory. There should always be a 100 per cent wood break.

It is a good idea to put some wood break samples in the aircraft to be broken in later years for an indication of glue integrity.

You should obtain the manufacturer's data sheet on the adhesive, and abide by the requirements, particularly for temperature and relative humidity.

Always do a dummy run to check that the joint can be glued within the time limits specified by the adhesive manufacturer for pot life, the joint open life and the time before clamping is required.

The most common adhesives today are epoxies and resorcinol formaldehyde. Casein has been widely used, but can be subject to fungal attack.

Some adhesives are not permitted, such as acid catalysed phenolics, which attack the wood fibres over time, and urea formaldehyde which may not provide long -term integrity.

Urea formaldehyde has been permitted for use in gliders on the basis that they are stored and cared for well. Glues which stretch – such as PVA and contact adhesive – are not permitted. FAA Advisory Circular AC 43.13-1A "Aircraft Inspection and Repair" gives useful information about adhesives and glueing technique.

Types of repair: Successful repair of wooden structures can be achieved. Publications such as AC 43.13.1A (readily available from technical suppliers), ANC 19 Bulletin, "Wood Aircraft Inspection and Repair" and the British Civil Aircraft Airworthiness Information and Procedures CAP 562 give general information on techniques and types of repairs, if no manufacturer's approved data are available and applicable to the aircraft.

Wooden aircraft are very durable if properly cared for. The MC will change with conditions, but provision of adequate drainage and ventilation holes will prevent excessive humidity build-up, protecting against rot, decay and glue deterioration.

Wood will swell and shrink with changes in moisture content. This can lead to loose bolted joints – particularly propeller flange bolts.

Propeller torque is transmitted by friction against the crankshaft flanges, and the loss of friction due to loose bolts will severely damage the propeller. Propellers have been known to catch fire as a result!

Wooden aircraft are best stored protected from the weather, and are not recommended for use in the hot and wet conditions of tropical environments.

The exterior should be painted, preferably with fabric covering over the plywood to give added durability. Interior wood surfaces should be given several coats of good spar varnish.

Access for thorough inspection should be provided. Australian airworthiness directive AD/GEN/29 gives useful information.

Ralph Murphy is a senior airworthiness engineer for CASA.