DE HAVILLAND DH86 EXPRESS
by Ivan Pettigrew
Construction Notes

As a five year old, growing up in New Zealand, the only aeroplanes I had ever seen were single engine biplanes. When they flew low over our town, there was a distinctive noise, and I could see two heads sticking out from the cockpits. Then suddenly one day a different noise came from the sky, and soon I could see a huge monster plane approaching, yes a biplane, and flying very low, but this one with four, yes four engines and propellers. Being alone on the road while walking home from kindergarten, I was scared out of my wits, and wanted to run into the nearest house to find somewhere to hide. It was 1935, and the DH Express had arrived to start the first scheduled air service in the country that would link the major cities. Three of these machines were imported and maintained a reliable air service until 1939 when WW II started and they were impressed into service in the air force.

De Havilland built four multi engine biplanes in the nineteen thirties. The first was the DH84 Dragon which used the four cylinder 130 HP Gypsy Major inline inverted engine. The Gypsy Major engine was built by a division of the De Havilland Company, and was used in many of the "Moth" series of single engine planes built by De Havilland in that era. The non tapered wings of the Gypsy Moth were used for the outboard wing panels of the Dragon. They even folded in the same manner as on the Gypsy Moth, so that the Dragon could be stored in a small hangar. But with those non tapered wings, the cruise speed was very low. The Dragon did not have any electrical system, so after passengers were loaded, the engines had to be hand propped so that flight could get underway.

In the early thirties there was a need in certain countries, and especially Australia, for a safe passenger plane that could carry a larger passenger load than existing planes on long flights. De Havilland entered the race to build a plane that met the requirements, and the Express came to life. It was designed and built in four months, and that included the manufacture of a new engine, the 200 HP Gypsy Six. This engine used the same cylinders and pistons as the four cylinder Gypsy Major, but a longer crankcase was built to accommodate six cylinders. This engine was later used in the DH 89 Rapide which was built in much larger numbers than either the DH 84 Dragon, or DH 86 Express. The Gypsy Six engine, later called the Gypsy Queen, was also used in a number of single engine planes like the Percival Vega Gull and Proctor.

It was a major achievement to design and build the Express in four months. It might have won the race to get a contract to build the plane for the airlines, and it may have met the performance requirements, but it fell short in the area of safety. The dismal track record of it in the first few years of operation showed up many flaws in the design and construction. The first fault to show up was in the attachment of the fin. A jack screw provided for moving the leading edge of the fin from side to side to compensate for yaw in the case of an engine failure. Several of the early production planes lost their fin and rudder in flight, most of them in Australia, and the results were of course always fatal. Then the construction of the wings and fuselage was very light and resulted in a lot of flexing when flying in turbulence. It was so bad that it often affected the control of the aircraft. The plane was very difficult to keep straight on take off, the fuel system was a nightmare, and the list goes on. By the time De Havilland built the Rapide, they seem to have been able to get everything right.

It has not been the same story with my experience in building two of these designs. In 1994 I built a model of the DH 89 Rapide. With nicad batteries and heavy Speed 600 brush motors, it was on the heavy side and not the most pleasant model to fly. A few changes were necessary to get the airframe and flying characteristics right. Fourteen years and about thirty models later, I designed this model of the DH 86 Express. Something seems to have improved along the way. This model is a delight to fly and does not seem to have any of the misgivings of the full scale plane. I have to admit that part of my motivation in building this model was to use a set of four Jamara 480 brushed motors with MP Jet gearboxes that a friend gave me. They seem to have been made for this model. Four years ago I installed a pair of these motors and gearboxes in the model of the Sealand 480, and I don't think the cowlings have been off either of these motors since the day I finished the model. They are very reasonable to buy, sound great in flight, and seem to last for ever. With series parallel wiring for the four motors in the Express, only one speed control is needed, and current draw from a 6S Li-Po battery is reasonably light at 26 amps.

Construction of the model is not without its challenges. The undercarriage is a tight fit in the fairings. However the fairings add to the streamlining of the model, and the torsion bar suspension used on the main gear gives very good operation on rough fields. The wings have a very high aspect ratio. Efficiency in a biplane comes from using a thin airfoil. In this model, the Selig 3021 is used. As in sailplanes, a high aspect ratio wing, combined with a thin wing section, demands accurate construction. The wing as rather long for most modelers to handle in one piece, so wing joiners have been shown so that the outer panels can be removed from the point where the ailerons start. The wing joiners require good workmanship because of the thin airfoil section. In the prototype, the upper wing was actually built with just one of the outer panels being removable. Wing joiners are a certain amount of work, add weight, and can be a weak point if not built well. Think twice before deciding to join the wings at the center section. There is much more stress and possibility of wing failure in such an arrangement than having the joiners outboard as shown. Notice that the centre section of the bottom wing is different from the top one, but the design of the outer panels is similar, except that the lower ones can be built without ailerons. The full scale Express had ailerons on both top and bottom wings, but on the prototype model it is has been found sufficient to have them just on the top wing. Be careful about putting outboard aileron servos on the lower wing. They would require long servo extensions, and these have been know to be the cause of radio interference when running parallel to the motor wiring in multi engine models.

FUSELAGE

In most construction, regular carpenter glue has been found to be the most satisfactory adhesive to use. It gives time to set the parts in the correct position, and when building a box structure as used in a fuselage like this, carpenter glue is much stronger than CA glues for attaching crosspieces where the end grain is being glued. The fuselage of the Express is of traditional “box” construction. The two sides of the primary structure are built over the shaded sticks shown on the plan, and then joined together. Notice that the nose section including the cockpit is detachable to give access to the motor batteries. It is best built later on when the primary side panels have been joined. Also note that the two sides are not joined right together at the aft end of the fuselage, but are separated by a small rectangle of 3/16” sheet that is wide enough so that the rear end of the fuselage is the same width as the fin spar that is used for mounting the rudder. Stringers along the sides, top are bottom, are added to enhance appearance. Additional details on these are shown in the two cross sections shown of the fuselage. Other additions are doublers that add strength inside the wing saddles, and the stringers inside the fuselage that support the cross pieces which form the servo mounts. There are various kinds of latches that can be used to keep the nose section in place, but a simple way is to use rare earth magnets inserted into the adjoining bulkheads. The platform for the motor battery is shown. This is longer than required, but provides for movement of the battery in order to achieve the correct C of G location. The exact location of the battery will depend on several factors, the main ones being the weight of the battery, the weight of the motors used, and the weight of the tail. Be careful not to overbuild the tail surfaces. With a long moment arm, weight of the tail surfaces is critical.

TAIL SECTION

Notice that the spars for the stabilizer and elevators are tapered, being quite wide at the root in order to give added strength. Having a relatively thick cross section like this means that the construction can be lighter, and it is easier to control warps in the flying surfaces. Start construction by making the spars first, and fitting the hinges. Build the surfaces over the plan in the conventional manner. Although the stabilizer spar is built in one piece, it is necessary to build just half of the stab at a time. After building the first half, prop the tip up a little so that the bottom surface of the spar on the other half is flat on the building board. There is one thing to watch however. Because the spars and ribs are tapered, if the tail units are built with the lower surfaces pinned right down to the building board, they will end up with a warp in them. Check this during assembly because it may be necessary to slide some of the parts up the pins slightly so that there is no warp built into the surface. The part that has to be slid up the pin slightly is the outer end of the leading or trailing edge where is joins the last rib. Tail surfaces built in this manner with a deep chord are resistant to twisting. Do not rely on the shrinkage of the covering to reset the surface if it has been build with a warp in it. If a tail surface has a warp in it, dampen the structure and weight it down while drying overnight. A couple of attempts at getting it straight might be necessary.

WING CONSTRUCTION

Upper wing The top wing is easier to build because the spar is straight all the way from the centre of the wing to the tip. In the lower wing, sweep back and dihedral start at rib #4 where the inner engine nacelle is located. Cut the main spar for the top wing from 3/32 inch sheet balsa. and join together over the plan so that the sweep back and dihedral angles are correct. This joint is very important both for accuracy and strength. The spar must be held perpendicular to the building board while measuring the dihedral angle or it will not be correct. Support the overlapping join of the spars with a tapered balsa doubler. Glue hardwood strips to the top and bottom edges of the wing spar as shown in the plan. Tapered spruce or basswood doublers should overlap the joins. If the outer panels of the wing are to be detachable, the spar should be cut now at the correct place and the wing boxes built to receive the tongues of the plug in wing extensions. Before gluing the last piece of ply to the rear surface of the spar strips to form the box, make the tongues that are attached to the spar of the outboard wing panel so as to get a good fit. There is a slight taper on the tongues so that they fit quite tightly when fully inserted. Attach these tongues to the spar of the outer wing panel so that the outboard spar is in perfect alignment with the inner section. Builders with experiences in using carbon fibre rods for joining wing panels may prefer to use that method. The areas of greatest stress in the wing are the join in the spar at the centre of the wing, and the wing boxes. It is recommended that a good quality carpenter glue be used for these joins. CA glue is fast for tacking things together, but sometimes the quality of the join is compromised. Carpenter glue gives a more dependable join.

Before cutting out the ribs, notice that they are of different thicknesses, depending on the stress they are subject to. Some ribs support wing struts etc, while the ones that hold the aileron bell crank have a lot of side thrust on them when full aileron is applied. It is good to cut ribs first to the outside line shown on the plan, then nest them together to check accuracy and sand off high spots. Cut all the ribs into two pieces at the point where they join the spar. Trim 1/16” off the nose ribs to allow for the sheet covering from the main spar to the leading edge. A balsa stripper set to 1/16” makes this very easy to do. Where inset sheeting is applied to the wing aft of the main spar, such as at the centre section, and in the area of the engine nacelles in the bottom wing, the main part of the ribs in these areas must also be also be trimmed 1/16 inch to allow for the thickness of the balsa sheeting

Assuming that the outer panels are going to be removable, proceed as follows. Assemble half of the main upper wing section (e.g. left half) flat on the workbench with the other half of the spar raised a little to the dihedral angle. Start by pinning the spar in place on the plan. Attach the rear part of the ribs to the rear face of the main spar. Next glue the trailing edge in place. Now attach the nose ribs to the front surface of the spar, and the first (inner) leading edge strip cut from 1/8 inch sheet. Notice that the leading edge consists of two strips of balsa. Only the first strip should be applied at this time. When this half of the wing panel is complete, raise the outer rib so that the spar of the other half is flat on the workbench and assemble the second half of the wing. Sheeting is now applied from the leading edge to the main spar, but ONLY to the lower surface of the wing. It will be noted that the wing at this point is still not torsionally strong, meaning that it can easily be twisted. After the sheeting is applied to the upper surface of the area already sheeted, the wing will be very rigid and difficult to twist. Hence it is very important to weight each wing panel down on a surface that is perfectly flat while applying the sheeting to the top surface. There is no washout in this section of the wing. It only starts from the point where the ailerons start. After applying the sheeting to the top surface from the spar to the leading edge, the remaining leading edge strip is cut from 3/16" or ¼" sheet balsa as indicated and glued to the one already in place. It is then contoured to shape. Notice that this outer strip does not pass through the area of the center section where the wing joins the fuselage. Check that there is no twist in the wings, and that each side has the same angle of incidence. If there is any twist in the wing, it is important to correct it at this stage before it is covered. Dampen the sheeting between the spar and leading edge, and weight the wing down overnight so that it sets without any twist.

The outer panels are now built directly over the plan is a similar manner to the inner sections. Notice that the spruce strips glued to the spar do not need to go all the way to the tip. The ribs must be notched for the 1/8 x ¼ inch secondary spars. Then cut off the rear section on an angled line between the rear corners of the upper and lower secondary spars. The part of the rib removed will be used for building the ailerons. Assemble each panel over the plan, and sheet the lower surface from the leading edge to the main spar. There is washout in this section of the wing, so before applying the sheeting to the upper surface, weight this panel down with a 1/8 inch block at the point shown near the trailing edge at the end of the aileron. This will provide for the washout necessary. Next apply a 1/16 inch sheet strip between the upper and lower secondary spars in the area of the aileron cut out.

AILERONS

The 1/8 inch sheet spar of the aileron is now cut out and attached with hinges to the upper secondary spar. Then the aileron is built in place on the plan. It is necessary to trim the front edge of the aileron ribs to get a good fit to the aileron spar. Notice that the trailing edge is slightly tapered from rib #11 to the tip. When this strip is cut off, it leaves a tapered flat on the rear edge of the aileron. The bottom surface of the aileron should be trimmed in this area so that the trailing edge is reflexed and comes to a sharp point where it meets the upper surface. It adds a little washout effect and makes the tip less prone to tip stall. Look carefully at the diagram of the tip rib and notice how the lower surface of the trailing edge slopes slightly upwards. Try to duplicate the design of the Frise ailerons with top hinging. It makes for good control balance at slow speed and helps avoid the adverse drag that is often a problem in slow flying models with a long wingspan. If built correctly, the forward point at the lower edge of the aileron spar should protrude downwards into the airstream to give some drag when the aileron is raised such as when entering a turn.. This drag on the inner wing helps the aircraft turn in the desired direction.

If the wood is on the flimsy side where the aileron hinges are inserted, add a small doubler. Be sure to pin the aileron hinges with toothpicks. After the tongue of the hinge is inserted in the balsa slot, drill a 1/16" hole in the middle of the tongue area, and push a toothpick through. Apply a drop of glue and cut off the ends of the tooth pick. Pinning the hinges this way will ensure that they don't come loose. "Hinge gap" covering on the top surface of the wing will further ensure that hinges do not come out.

Aileron differential is the other thing that helps to counter adverse drag, so it is important to make the arm of the aileron servo as shown on the plan. It can be cut out from one of the disks that usually come with new servos. The distance the aileron horn is back from the leading edge of the aileron is another factor in aileron differential, so watch that the aileron horns are mounted where shown on the plan. Placing the aileron horn slightly further back will increase the differential.

BOTTOM WING

Spar: First build the spar for the main part of the wing which goes out to the joiner at rib #8. The bottom wing in perfectly flat from the centre line to rib #4. At rib #4, another of the compound joints in the spar has to be built where it is necessary to get both the dihedral and sweep back angles correct. Next build the box and tongue for the wing joiner, then the spar for the removable outer panel of the wing.

The main section of the wing is built in one unit as far out as the wing join at rib #8, but has to be done in three stages. First build the central section which goes out to rib #4. This part is perfectly flat and is built directly over the plan on the building board. If the left hand panel from rib #4 to rib #8 is to be built next, block up the right hand end of the completed section so that the spar of the left hand panel is flat on the building board while it is being built.. When this left hand section is completed, the end is blocked up so that the spar on the right hand side is flat on the building board while that part is built. It is best to build all three sections before sheeting is started. Proceed with the sheeting as for the top wing, but before applying the sheeting to the top surface from the spar to the leading edge, it is wise to install the wiring for the motors. This should be #11 gauge and twisted so as to reduce the possibility of producing electrical interference. Notice that extra sheeting is applied to the area where the engine nacelles are located and should be inset. This sheeting is necessary to support the nacelles and also the covering material. The outer wing panels are built as for the top wing, but are much simpler to construct if ailerons are not used. Washout is the same for the bottom wing as the top one. There is no twist as far out as rib #8, but a gradual twist throughout the outer panel to give 1/8" washout at the tip, this being measured at the front of the trailing edge at the last rib location.

ENGINE NACELLES, MOTOR MOUNTS AND UNDERCARRIAGE

The engine nacelles are built by first gluing the hardwood motor mounts in place, securing them firmly to the leading edge of the wing and the main spar. Then the strips of hardwood that locate the undercarriage and brace the motor mounts should be attached. These pieces are numbered on the plan according to the sequence in which they are attached. The undercarriage components in particular need to be glued very well with epoxy glue since they are subject to more stress than any other part of the airframe. The undercarriage is designed so that the lateral section of the U/C leg that passes through the two nylon mounting clamps serves as a torsion bar. The swept back nature of the U/C leg means that the wheel arcs both backwards and upwards when a bump is hit. This results in very good absorption of bumps when operating from a rough surface. Complete the construction and mounting of the undercarriage legs. The outer motor mounts are simpler than the inner ones which incorporate the undercarriage.

Next the nacelle bulkheads are glued in place. Notice that a cross piece is first attached to the main motor mounts, and then the N-1 and N-6 bulkheads are attached to these cross pieces. Glue N-2, N-3 and N-7 bulkheads in place. After this, N-5 is attached to the bottom of N-1 and N-3 on the inner nacelles, while a curved strip of 1/8 sheet balsa is attached between the bottom of N-6 and the trailing edge which serves as a keel for the lower outer nacelle. The nacelles are now planked with strips of 1/16" sheet balsa. Notice that bulkheads N-1 and N-6 at the front of the engine nacelles are cut from ¼" balsa, but the planking of the nacelle just comes to the mid point of that bulkhead. This leaves a 1/8 inch shoulder at the front of this bulkhead which serves for holding the cowling in place. When the planking is completed the motors should be installed. If using MP Jet gearboxes, notice that there are no screws holding the motors in place in the sleeve which the front of the motor fits into. It is important that the hose clamp holding the motors in place is over this sleeve, and not just over the mid point of the motor. After fitting the motors, check that they are all perfectly aligned. Use shims to make any fine adjustments that may be necessary.

The engine cowlings are built in place with the motors installed. Before starting the construction of the cowling, four small pieces of hardwood are glued to the front surface of N-1 and N-6 in the locations shown. These are for locating the #2 wood screws that hold the cowlings in place.

Next the nose blocks are made, but the hole for the propeller shaft should at this point be made just large enough for the nose block to be a snug fit over the prop adaptor. If the motors are mounted a little back from their correct location, the prop adaptor will hold the nose block in place while the cowlings are built. Afterwards the hole for the propeller shaft can be enlarged and the motors moved forward to their correct location. With the nose block thus held in place by the propeller shaft, start making the cowls by cutting out the side panels of each cowling. These are attached to the hardwood blocks on N-1 and N-6 with screws, and glued at the front to the nose block. Next apply the top curved sections of the cowling, gluing these to the nose block and adjacent side panel sections, but not of course to N-1. The curved sheet forming the top of the cowling is easily shaped if the outer surface is moistened. Attach it to the upper edge of the side panels by having a strip of 1/16 x 1/8 balsa along the join on the inside as a doubler. The bottom of the side panels on the inboard cowlings are glued to C-1, while the bottom edges of the outboard cowlings are joined with a sheet of 1/16" balsa which is curved around the bottom of N-6 and the nose block. When the glue is dry, take out the screws and remove the cowlings. Now the hole in the nose block for the propeller shaft can be enlarged to give adequate clearance. Before covering the cowlings, small washers should be made from 1/64 ply and placed under the heads of the #2 screws that hold the cowlings in place. These ply washers are glued to the sheet covering.

The wheel fairings can be made in place so as to ensure a good fit, and provide clearance for the undercarriage legs. Be sure to allow clearance for the rearward movement of the U/C leg so that the wheel does not hit F-2 or F-1 when the model hits a bump. The nose piece of the wheel fairing, F-4, is first made with a single thickness of 1/16 balsa. Then laminate with a second layer glued to the inside in order to increase strength.

The wing struts are constructed as shown on the plan. Where necessary, tabs are glued to the wing ribs to hold the ends of the centre and outer struts. Small rare earth magnets inserted into these tabs as shown will keep the wire at the end of the strut from coming out. The struts are not functional, so can be built from balsa. Two methods are used to attach the wire ends. Where the wire end is straight, such as at the bottom end of the inner and centre struts, a hole is drilled in the bottom end of the strut and a straight piece of wire is inserted. If a drop of CA glue is put in the hole first, the wire sets up firmly and is not likely to come out. For the other fittings, the wire is fitted into a shallow slot cut in the side of the strut. Strength is improved if the end of the wire is bent to a right angle and inserted into a hole drilled through the strut where the end of the wire is to be located. After the wire is glued in place, and it can be held with a few turns of thread binding. The struts are covered with film covering, using the same film as used for covering the entire airframe. The exact location of the bottom ends of the inner and centre struts where they attach to the engine nacelles is not shown on the plan. This is determined by starting with the outboard strut, and lining up the inner struts parallel so that the location can be marked for drilling the hole in the nacelles where the wire at the lower end of the strut plugs in. When assembling the model, attach the lower wing first, then be sure to fit the inner (angled) struts in place before attaching the top wing.

Covering is conventional with Solar film, Monokote or other films of a similar nature. Clear transparent MonoKote is great for covering all the windows. It is best to do these first, before applying the rest of the covering on the fuselage.

Very little needs to be said about flying. If the wings are built as indicated, and have the correct washout, there should be no danger of tip stall. Unlike the full scale aircraft, the model is easy to keep straight on take off, and beautiful slow three point landings are easy to do. But wheel landings are also possible, depending on the pilot's preference.

Good Luck with your Express.

SUMMARY

DH 86 EXPRESS. August 2008. Scale 1/7.9 Span, 98 inches. Wing area 1,507 square inches. Airfoil Selig 3021 modified towards the tips. Length 71 inches, Weight with 6S 2800 Li-Poly battery, 114 ounces. Wing loading is 13.5 ounces / square foot (allowing for 80% efficiency of biplane wings.) Four Jamara 480 HS BB motors are used, wired series-parallel, driving 10 x 7 APC-E props through 4.1:1 ratio gearboxes. Static Thrust is 76 ounces at 6,200 RPM drawing 26 amps from the battery. (13 amps each motor.) The wings have a very high aspect ratio. Efficiency comes from using the thin Selig 3021 airfoil, but as in sailplanes, it makes for a challenge in accurate construction. Removable outer wing panels are optional, but demand good workmanship because of the thin airfoil used. Likewise, the undercarriage is a tight fit in the fairings, but they add to the streamlining of the model. The torsion bar suspension used on the main gear gives very good operation on rough fields. Flight characteristics are excellent. A safe, easy to fly model.