

## **Building the 1912 F Replica and Triplane at MOSI**

### **Peter Teagle, Chairman, Roe Heritage Group**

In 2001 the volunteers who worked with the aviation collections at the Museum of Science & Industry were looking for a project more challenging than basic collections care such as dusting aeroplanes. One of them, ex-Avro design draughtsman Dennis Stead, suggested that building an Avro Type F might be the ideal project. The Type F was a unique Manchester product of 1912 and was identified as the first enclosed monoplane to fly. So it would make an interesting addition to the collections. Building the airframe seemed to be within the capabilities of the volunteers. The most difficult item to replicate, the engine, was not perceived as a problem as the original survived. This was a 35 h.p. Viale radial, owned by the Royal Aeronautical Society and on exhibition at the Science Museum, in London.

The initial idea was for the project to be funded by the Friends of MOSI, but discussion of the project at an executive meeting secured an offer of £5,000 by the MOSI Director. This was thought to be adequate to build the airframe with the probability of later funds to replicate the Viale, if required. Although there was a clear interest from the outset that the original engine should be secured and fitted, there was interest also in having an engine that worked. There was some consideration of registering the project with the Light Aircraft Association as a potential flyer if only to ensure build quality and some thought also of the advantages of an airworthy aircraft in terms of promotional value, if nothing else. These ideas were quickly revised but, ultimately, scotched. A working engine-build project was beyond the skills of the volunteers while the cost was prohibitive if suitable partners or external contractors were involved. The final decision not to make a 'flyer' was taken by the MOSI Curator, Nick Forder, when a former Avro Chief Test Pilot informed him that, "No one will want to fly an aeroplane fitted with an engine made by someone they have never heard of."

Meanwhile, a data search failed to reveal any AVRO drawings surviving despite assertions that the first task given to Roy Chadwick on joining the company was to produce a General Arrangement drawing of this aircraft. Nevertheless vital information came from contemporary 'Flight' and 'Aeroplane' magazine articles. A total of thirteen different photographs of the original Type F were located, including some original glass plate negatives in the 'Flight' archive. These could be greatly enlarged to reveal interior details, particularly for the cockpit area.

Although General Arrangement drawings in the magazine varied in some dimensions such as wingspan, they gave sufficient base-line information for dimensional analysis of the photographs to give accurate shaping. The 'WW1 Aeroplanes' articles on deducing measurements from photographs were studied closely, and a considerable amount of maths was applied, but the definition of even the best of the photographs made precise calculations impossible. The desire to achieve an aeroplane which was as true to the original as possible slowed the development process significantly as precise information

was simply not available and postulations based on known Avro design practices and likely external influences produced a wide range of alternatives. Eventually, the design of the wings was prioritized, leading to much study of the only known photograph of the aircraft flying with lively discussions between the 'historians' and the 'aero-engineers'. The former did not believe that the wings had internal wire bracing, while the latter's experience led them to conclude that it should have! No internal bracing was fitted. By this time the volunteer group had lost two key members who would have undertaken the majority of the woodworking. Although the facilities of the local education college had been secured to cut down the baulk of aircraft grade spruce into useable pieces, this 'grace and favour' approach brought further delays.

In 2004 a team of retired British Aerospace employees who were part of the Avro Heritage Group at BAe Woodford, became involved in the project. They had rebuilt an Avro XIX (Anson) to fly and were then attempting to build a flight-worthy replica of the Avro Type G Military Trials biplane of 1912, but were short of funds. Agreement was reached for this group to build the wings for the Type F as a paid contract, though the payment would be in the form of a range of aircraft grade fittings suitable for the proposed Type G.

Once the design features of the wings were agreed, the wing manufacturing job was straight-forward. The wing was 6 feet chord, a constant profile, with 95% of the structure in spruce and only the tips and trailing edge of aluminium tubing. These were completed, less covering and fittings, and delivered to MOSI in August 2005. At this point the British Aerospace team was asked to build a working replica of Alliott Verdon Roe's Triplane No 1, with the enthusiastic support financially of the pioneer's grandson, Eric. This removed the team from the Type F project for four years. During this period the team relocated to MOSI and changed their title to the Roe Heritage Group (RHG).

With the first flight trials of the replica Triplane not achieving lift-off and the prospect of a long-term programme to solve this problem, RHG was invited to resurrect the Type F project as main contractor. One of MOSI's five historic buildings was to be redeveloped to include a new gallery entitled 'Revolution Manchester'. This was to look at some of the Manchester innovations that had helped shape the world. The Avro F, as the world's first cabin monoplane design, was identified as the centre-piece exhibit for the transport section of the new gallery. This necessitated a change in the parameters of the project, not least of which was a completion deadline in 12 months' time. RHG accepted the challenge, acknowledging the very generous help it had received from MOSI in the Triplane years.

The aim to fly the Type F was now removed, but a new requirement was to hang the whole machine from the gallery ceiling as in the act of take-off. It was essential that the aeroplane should not fall on visitors' heads during the next fifty years while the means of suspension should not be obtrusive. To ensure this the designers - recollecting their experience of stressing the attachment of the Blue Steel nuclear missile to Avro Vulcan bombers fifty years previously - adopted a *Board of Trade* type factor of six on the deadweight which was estimated at 800 lbs. This, of course, led to the strengthening of

the internal structure to dissipate the effect of this large factor on the rest of the airframe.

To speed construction, a twenty foot table was made. The fuselage geometry was drawn on the white painted surface to be signed-off by the designers who had pored over the photographs with their magnifying glasses for so long. The left and right hand sides were made in model aeroplane fashion with plywood gussets to attach the vertical members. Inherited with the project by RHG were a set of steam-bent ash forward fuselage longerons. These were replaced by longerons which were kept to their curved shape by strategically placed jig blocks, having been reduced slightly in section to promote flexibility. To everyone's surprise, when the frame was removed from the table it kept its overall shape. On completion the two frames were quickly erected on the table with simple temporary bulkheads to keep them squared off and vertical. The horizontal cross members of the centre section carry-through structure were put in after the frame top and bottom members, making the task of pulling in the front and back sections straightforward.

The original aircraft was designed to be easily transported by road and rail. This was done because the Avro workshop was in Manchester but the flying was conducted from Brooklands, the dismantled aircraft being taken to the station on horse-drawn carts. The Type F featured a fuselage that could be split vertically so that it would fit inside a covered theatre pantechicon railway wagon. Alliott Roe had previously lost two uninsured aircraft when the sparks from the locomotive set fire to the tarpaulin covering them and so was anxious not to move any of his aircraft by rail without adequate protection. Due to the intended method of display, a lack of precise information about attachment fittings and the constraints of the build-timetable, it was decided not to incorporate this join. Instead, the fuselage structure was built to both simulate the joint and allow the fuselage to be separated at a later date, should this prove necessary. Although folded metal sockets had been manufactured previously by RHG, these were not used in favour of a system expected to be both quicker and stronger. In any case, research was unclear as to whether the sockets used on the original were of folded '504-type' or cast aluminium as used on early Roe designs.

To produce a strong corner joint, sixteen gauge circular steel plates were folded in half through ninety degrees to be screwed with epoxy glued to the ply gusset and cross member, creating at the same time a sound attachment for the diagonal bracing of the four external sides. Any frame diagonals required were attached to eye bolts through these plates. Bracing of the original was by wire, but rod, screwed at each end, was used on the replica. A 4mm diameter rod was specified, but in the end 5 mm was used throughout as it was much easier to obtain. Manufacture of the end fittings, a derivative of Alliott Roe's bicycle spoke system, was sub-contracted out while the whole system was plated to resist corrosion. The corner plates were painted with black Hammerite.

The gradual embodiment of the fuselage bracing required constant monitoring to avoid twisting or otherwise distorting the structure but in relatively short order a stiff and strong box girder evolved. To fit out the fuselage with landing gear, flying controls, ground

adjustable tailplane and balance rudder, the Triplane-approach of individual team members taking responsibility for a sub assembly was followed. John designed and, with George built, the landing gear with its transverse leaf spring incorporating Alliot's patent hub system to mount the wheels. The latter were Honda motorcycle rim, spoked to the patent hubs. The spoke work was sub-contracted to a motorcycle wheel-builder who advised, too late, that more suitable rims, without stamped markings, were available. The hubs were also contracted out, using the original patent documentation as reference. John constructed jigs for welding the two V struts and made up the complex bracing system. A work experience 'apprentice', Paul, was taken on by MOSI specifically to work on the project and was supervised closely by RHG members. His first job was to work with Mike on modifying an existing replica Type G tailplane to Type F form which was a rib bay smaller.

Aided by a demonstration rig previously constructed by volunteers at MOSI, Geoff designed the control system based on the diagram in the 12 October, 1912, issue of *Flight*. The article showed the under-seat system which operated the large warping lever/king-post behind the pilot. Geoff had to design a lay-shaft system in the rear fuselage to achieve the operative alignment for the two part elevators as no contemporary information existed for this. David made most of the metal fittings in his home workshop, his masterpiece being the double channel joystick unknown in any other aircraft. Details for this were obtained from an enlargement of one of the photographs sourced through *Flight* and enlarged to show the view through the cabin lower windows. This differed from details of the sketch of the flying controls in *Flight*.

The same enlarged view gave Paul information about the pilot's seat which was combined with a drawing for an Avro 504 seat. As the 504 flew a year later than the Type F, this was felt to be a reasonable indicator that the seat would have had a plywood box base with a beaded-edge alloy back. The multiple holes in the back of the seat must have saved several ounces! Mike and I made the internal W bracing which backed up the landing gear and attached to the strong wing pick-up frames. This involved flattening the one inch diameter steel tube ends to give the angled seating at each end. It was strenuous work with a heavy duty machine vice with an eighteen inch extension to its handle to give enough purchase to squash the tube ends. The tubing itself was recycled from the electrical conduit taken from the intended display building during initial strip-out. The tubes were protected by Hammerite paint after under-coating against corrosion. Roy, the RHG inspector, built up the laminated long mono-skid with the assistance of Paul, using the straight grained ash readily available from a local timber merchant.

There was considerable discussion as to the tube sizes to be used on the rudder until it was agreed that Bill should use 5/8th tubing pinned to the wooden ribs and spar structure with aluminium strips. The rudder hinge line is inclined at 2 degrees to the main spar and provides a pivoting pick up for the tailskid at the bottom. Most of the rest of 2010 was spent in fitting out the fuselage. By the end of that year, it was confirmed that it must be on display in the new gallery by November.

Tom started the covering process with the wings, originally built by the nascent RHG six years previously. Research revealed that the original was covered in 'Pegamoid' fabric, though it was unclear whether this was cotton or linen based. The 'Aviator's Storehouse' catalogue, which was produced by A V Roe to retail components to aspiring aviators, listed a range of different materials with no indication of company preference. It was decided to use Seconite as a covering for both practical reasons and durability. Paul produced a two-rib wing section as a test piece and then, under supervision, covered the tailplane. Previously the tailplane had been trail-fitted to the fuselage to enable the control gearing to be set.

HMG Paints Ltd mixed a coloured dope to give an antique finish which was applied by hand-brushing. It was decided that the aluminium-clad forward fuselage was not painted, as commonly depicted, and so this work was deferred. It was assumed that the 'AVRO' lettering on the under surfaces of the wings and the fuselage was black. Both red and blue were suggested as possible alternatives but, in the absence of evidence to the contrary, black was chosen as being the most likely colour. A professional sign-writer was employed to complete the lettering which took most of two days to complete.

Pressure was now increasing as the completion deadline loomed, although it was extended when the contractors working on the building and installing the new exhibition were delayed. At this point, it was decided to prioritize outstanding work to ensure that a reasonably complete aircraft was available for the opening.

From the project's inception it had been intended for the original Viale engine to be fitted to the replica. This engine remains the property of the Royal Aeronautical Society and is on display in the Science Museum in London. Despite lobbying successive RAeS presidents and securing their verbal support, formal applications to the RAeS to borrow the engine were unsuccessful. The construction of a full size model seemed the only alternative but, again, time was an issue and securing a loan of the original engine to come to Manchester for temporary installation in the airframe and/or replication was fraught with procedural issues. So, late in the day, it was decided to construct a 'cartoon engine' based on information gleaned during several visits to London during the course of the project.

The engine build was taken on by the MOSI volunteers who spent the following week searching through builders' skip, DIY and hobby shops for potentially useful parts. Bob, who had undertaken the bulk of the project's research, scaled up photographs to full size, while Terry managed the engine build and selected components as close as possible to the correct shape and size. The Air & Space Curator was provided with lists of likely requirements and then allocated responsibility to produce a number of rubber O rings to simulate the cylinder cooling fins. Norman dressed the crankcase and Harold sprayed the components.

Meanwhile the dismantled machine was lowered from its mezzanine workshop space in the Air & Space Hall and moved across the road to the new gallery. The new building doors were too narrow to allow the fuselage to be moved on its undercarriage, so this

and the crash pylon were removed and the fuselage turned on its side to avoid the need to remove the tailplane. Assembly could then proceed and the suspension system be evolved. After re-rigging the landing gear, the wings were set up to the correct incidence of dihedral, and the lengths of the many bracing wires were finalized. The warping system was connected and could produce a good simulation of the wing twist as shown in one of the contemporary photographs.

The top and bottom of the fuselage had been left uncovered to permit interior installation work. This included an LED strip lighting system which would allow the interior to be illuminated remotely by visitors to show the structure. Quite late on, it was found necessary to give spring assistance to the elevator circuit to offset the static hinge moment and permit the surfaces to sit in flying attitude. The big remaining job was to cover the cockpit area with the aluminium skinned glazing panels. This was carried out by Dennis and Geoff. Cardboard patterns were made directly from the fuselage and the aluminium and transparent plastic were bench cut to suit from these. The window shapes were then cut from the aluminium and the plastic sheet bonded to the aluminium with double sided tape. The window edges were then dressed, inside with doped cotton tapes and outside with black tape, to simulate the presumed original type fixing. The assembly could then be attached by small screws to the wooden structure. Each side required four individual panels, each of which can be removed to allow internal access without the removal of main components.

MOSI Technical Services fastened a hand-operated winch and pulley system to the gallery massive roof beam for the main suspension cable. A substantial steel angle section, with a range of pick up holes, was bolted to the strong points aft of the pilot's roof trap door, permitting a range of bank angle settings. This slightly inelegant method was necessitated by the lack of clear information from the gallery designers about suspension and attitude during the aircraft's design and construction. Two sets of potential suspension points had been incorporated into the build due to the unknown mass of the Viale engine and issues of its availability. With a lighter representative engine now to be fitted, the rear suspension points were selected. Hoisting the aircraft for the first time both confirmed the desirability of a powered winch and left the aircraft in a nose down attitude. This was corrected by fitting a tail tie down wire to a floor eye bolt, giving good lateral stability.

The MOSI Director was then consulted and he approved the proposed attitude. A V wire was added to the main undercarriage gear, again fastened to the floor, which on being tensioned by adjusting the winch lift prevented sway and preserved bank angle without the need for additional wing tip wires. The cartoon engine was fitted by the MOSI volunteers one evening, and just needed the propeller to be fitted. Bill, the RHG propeller expert, produced an ash laminate 7 feet 6 inches diameter propeller. Details for this had been scaled up from the range of contemporary photographs, mindful that the original Type F had been fitted with more than one propeller. This seems to have been normal for Avro aircraft of this date in an attempt to maximize engine performance by empirical means. It was quite difficult to achieve the plan form shape while preserving a helical twist. The ash was stained to a darker hue to give the appearance

of mahogany. The propeller was not finished in time for the first of a series of launch events on 20 January, 2011, so a propeller was borrowed from Doncaster Aeroventure's Bleriot XI reproduction as a temporary measure. The weight of the propeller was a problem when attached to the engine, and so an additional stay wire was fitted to the back of the engine. This linked to an internal cross member and prevented the engine from twisting and overstraining the seating attachments to the engine bearers.

The propeller was fitted as soon as it was ready as were dummy fuel and oil tanks in the forward fuselage. Although it is known what sort of instrumentation was carried, the exact type and location are not known and are not visible in any of the photographs. For these reasons they were left out with the intention of fitting later should additional information become available.

Once the exhibition designers were satisfied with the internal lighting system, the top and bottom of the fuselage was fabric covered. The original Type F features dark edging along the fuselage which the Curator believed was black tape protecting stitching, as seen commonly on Moranes and Nieuports. Close study of the photographs revealed this to be moulded battening, presumably to prevent fabric pillowing. Like contemporary Bleriotics, the flying surfaces of the Type F had pinned battens on the upper flying surfaces, running chord wise along the tops of the ribs, to prevent fabric billowing in the prop wash. The external lacing on the fuselage joint was simulated.

As the Type F is displayed in flying attitude, it really should have a representation of Wilfred Parke in the cockpit. This has been considered but Parke's habit of wearing a Warren-type safety helmet has made it slightly more difficult to achieve. Building the replica did, however, allow us to comment on the degree of visibility from the cockpit. This was doubted by most contemporary reports, except those by Avro employees! Malcolm was volunteered to sit in the cockpit and take a photograph of the never before seen view through the windscreen of the world's first enclosed monoplane.

The building of the Roe Triplane replica was covered by Mike Taylor's paper at Stopping the Rot in 2008. Since then abortive flights trials were carried out at RAF Woodvale and the Triplane was displayed at various venues, including Duxford, Southport and at Lea Marshes near the railway arch in which the original was prepared for flight. The Triplane later moved to the former Avro factory airfield at Woodford to be housed in the Fire Station, courtesy of the current site owners. The present plan is to change the belt drive to a chain drive, fit a more efficient propeller and attempt a flight hop on the 1¼ mile main runway. A range of sprockets and a chain drive were provided by Renold, the Manchester company which is believed to have supplied the chain to AV Roe for his original Triplane. These allowed a test programme to be followed to ascertain the most efficient drive ratios.

The first proposal to improve the aerodynamics of the old propeller was to embody a thicker profile and enclose the root tube completely. This was to be done by using a

balsa core covered with plywood facings and a circular section ash spar bonded into the steel root tube. In the event, this idea was developed further into a plastic foam and GRP form, still with the ash spar. A test piece was made for vibration testing before proceeding with production of the revised design. The production blades were first cut out using a hot-wire, and then sanded to remove surplus material. The blade core was then ready for the glass laminating process to start. It is hoped to have the Triplane reassembled and ready for testing at Woodford in Spring 2013.