THE HISTORY AND EVOLUTION OF THE AVRO TRAINING MACHINE.

Paper read by Mr. R. J. Parrott, A.C G.I. (Hons. Member) before the Institution, at the Engineers' Club, Coventry Street, W., on Friday, 9th January, 1925. Mr. H. B. Molesworth in the Chair.

MR. PARROTT said :—

When I was invited to read a paper before this Institution I had some difficulty in choosing a suitable subject. I decided, however, with the Council's approval, to speak on the History and Evolution of the Avro Training Machine. Having been intimately associated with Mr. Roe in its evolution I feel it is a subject on which I am fully qualified to speak. I realise, of course, that my relationship with A. V. Roe and Co., Limited, places the Council of this Institution in a somewhat invidious position, as it may be criticised for allowing its portals and publications to be used for publicity purposes. Let me assure you, however, that the preparation of this paper was not inspired by any such motive, and my excuse for its reading is that the design of this particular machine formed a milestone in the evolution of the aeroplane, not only in Britain, but all over the world. The design has been defined by eminent aeronautical authorities as constituting "classic" type.

I hope these few remarks will exonerate me from criticism for choosing this subject. I will now proceed.

Before speaking of the actual design of the Avro Training Machine, I must refer to some ealier Avro designs.

Up to 1910, Mr. Roe pioneered the Tractor Triplane, but in 1911, the Company produced a small Tractor Biplane fitted with a 35 h.p. Green Engine. This machine was actually built to end some controversy as to the relative merits of the Tractor Triplane and Tractor Biplane. The Biplane had an exactly similar fuselage to the Triplane and the wings were made of the same total area. The performance of the Biplane was altogether better than the Triplane and we definitely abandoned the latter. Incidentally, it

may be mentioned that this was the first Tractor Biplane to be made in England, if not in the world. It will be observed from the slide that the fuselage was not covered and that the undercarriage was substantially of the type which was then used on the more orthodox machines of the Biplane Box-Kite type. Altogether there was a painful disregard of head resistance (Figs. 1 and 2).

The next step in development took place in 1912 when Mr. Roe designed

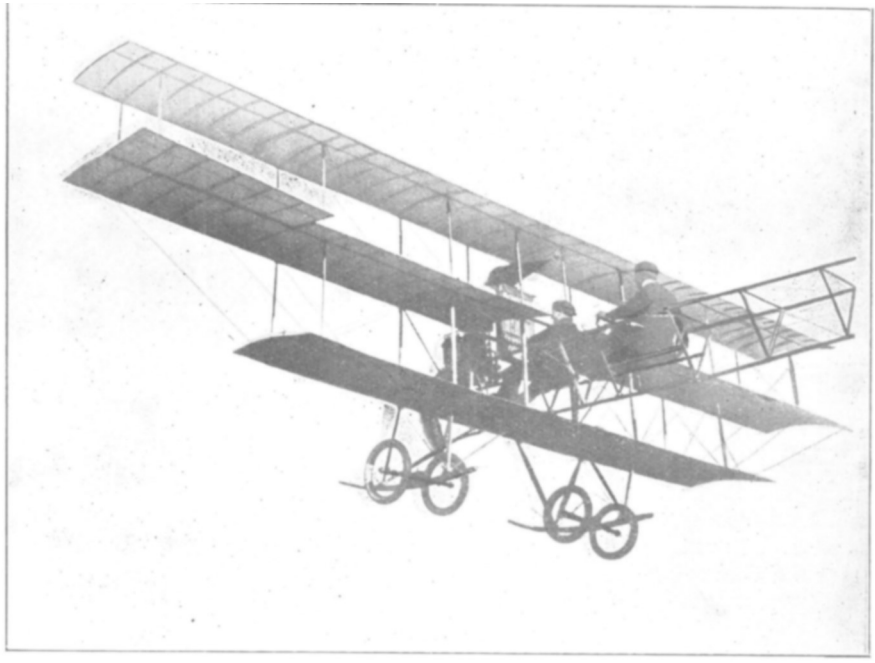

Fig. 1.—Avro Triplane, 1909-1910. Mr. A. V. Roe piloting.

and produced an entirely new type of Tractor Biplane; we called it our Type 500 (Fig. 3). It was fitted with a 50 h.p. Gnôme engine.

It will be seen that a really serious attempt was made to cut down head resistance. The fuselage was covered and of sufficiently large dimensions to completely enhouse the crew and engine, and was of fairly good streamline form. The undercarriage was a distinct departure from the type in use in England at the time and was fairly satisfactory but somewhat heavy. The machine accommodated two persons and was fitted with dual control. The wings were not staggered and lateral control was obtained by warping the outer sections of the main planes. The general design of this machine was un-

doubtedly one of the most advanced in 1912 and it was probably one of the best machines produced that year in England. Its merits secured for it orders for twelve from the War Office and Admiralty. These orders really constituted the inauguration of the Company's manufacturing business. The machines were used in the Central Flying School and gave very good service. From our observations and the reports we received, it was soon obvious that we could do still better and we immediately commenced to consider a new and improved design. About this time we made our first acquaintance with the

Fig. 2.—The original Avro Tractor Biplane, built in 1911. Fitted with 35 h.p. Green Engine. This machine was the first Tractor Biplane ever built.

80 h.p. Gnôme engine, two of which were fitted, for the first time in this country by the Bristol and Colonial Aeroplane Co., in their Coander Monoplanes, which competed in the military trials in July and August of 1912. We were greatly impressed with the power developed by these engines as compared with the 50 h.p. Gnôme and immediately decided to equip our new machine with one. Other business occupied us until April, 1913, when the construction of our new type to supersede Type 500 was commenced. Little did we then realise what a wonderful future it was to have. In the new machine, the principal differences from the Type 500 were, heavy staggering of the wings to give increased wing efficiency and also to improve the downward and forward view; an increase in span and wing chord; a better wing

section; improvement in streamline form of fuselage; the fitting of a unique undercarriage. Many people are under the impression that there have never been displayed in the later machines radical external differences from the original machine of this type. There are one or two differences which are of

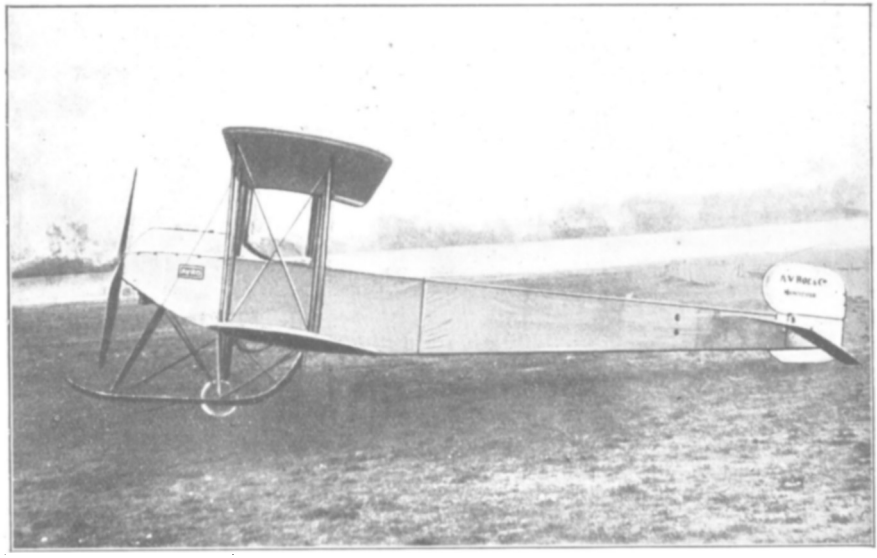

Fig. 3.—Avro Type 500. This type of machine was among the first to be purchased by the Government from a private contractor.

interest. The front bearing plate for the engine had originally a flat rectangular shape quite unlike the more familiar spider of later machines; the lateral flying control was achieved by warping ailerons; the inner ends of the ailerons were secured, and their outer ends, which were of increased chord, were coupled together by a strut and warped by means of a system of wires; and finally, the top longerons were parallel to the longitudinal centre line of the machine (Fig. 4).

The first machine was tested at Brooklands in July, 1913, and a little later took part in some flying events at Hendon.

The machine was well received, but the flat rectangular nose provoked considerable criticism as it spoiled an otherwise very clean and streamline fuselage. The lateral control was also not as effective as was desirable. We withdrew the machine for improvement. A new front bearing support constructed of bent steel tube was devised; this structure was nicknamed the "Spider," a name which stuck to it and eventually became officially adopted. The ailerons were made of the same chord throughout their length and

operated in the orthodox manner. The machine then reappeared and took part in many flying events.

It will be interesting to trace the full career of this particular aeroplane, as surely it may claim to be historical. Early in 1914, the "Daily Mail" purchased it as well as a Blériot Monoplane for the purpose of giving flying demonstrations in different parts of the country. The Avro was piloted by Mr. Raynham and the Blériot by M. Salmet. The " Daily Mail " wished flights to be made not only from the land but also from the sea; we were therefore obliged to design an interchangeable float undercarriage. With the big increase in

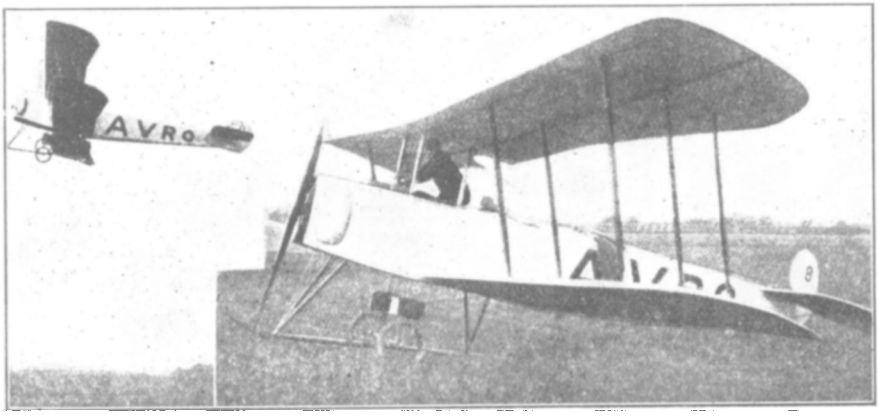

Fig. 4.—A reprint from the " Aeroplane " of the original Type 504 machine.

weight which resulted, we concluded we should have insufficient power and we obtained and fitted an 80 h.p. Monosoupape Engine which was alleged to be considerably more powerful than the ordinary 80 h.p. Gnôme. This engine was a ghastly affair and gave us a great deal of trouble. It was, I believe, the only one of its kind which came to England. The " Daily Mail " made a great deal of use of the aeroplane and it gave successful exhibitions all over England, Wales and Ireland. Mr. Raynham had several quite exciting adventures while on this tour. The people at many places he visited had never seen an aeroplane before and the demonstrations materially contributed to the public education. It was finally crashed near Shoreham. The cause was a forced landing due to engine failure when being flown over land with its float undercarriage (Fig. 5).

About the middle of 1914, that is before the outbreak of war, we received orders for twelve machines of this type for the War Office and one for the Admiralty. A few of the War Office machines were delivered before war was declared.

A point of interest, and one which very clearly showed the lack of co-ordination between the War Office and the Admiralty may be mentioned. Before the construction of these machines commenced the structure had to be approved for strength by the experts of both Services. The War Office agreed to our proposals, but the Admiralty insisted upon larger spars. With a view to avoiding complications in manufacture, we endeavoured to get the War Office to agree to the size demanded by the Admiralty, but they refused.

Fig. 5.—The first flight of the original 504 as a Seaplane, at Paignton, in April, 1914.

The consequence of this was that during the years we were constructing these machines for the Royal Flying Corps and the Royal Naval Air Service, the wings although the same in external appearance, differed in internal dimensions. When these two Services were amalgamated and became the Royal Air Force, the stores must have experienced very great difficulties with repairs and replacements. It is interesting to note that the Avro Standard Training Machine of to-day has the size of spars originally designed by us and adopted by the War Office.

During the early stages of the war the detail design was subjected to a good deal of modification but the main dimensions and characteristics were not altered.

The wing span was 36 ft., and the chord 4.9¾, giving a wing area of 330 sq. ft.

The weight, light, was 950 lbs., and the gross weight, with a crew of two and full tanks, was 1,530 lbs.

This gave a wing loading of 4.63 lbs./sq. ft., and a horse power loading of 24.6 lbs., taking the actual power developed by the 80 Gnôme, as 62 h.p.

In view of the extraordinary good control which has always been an attribute to the Avro 504, we have often been asked how we arrived at our particular control surface proportions, position of centre of gravity, wing section, length of fuselage, etc. It would be idle to state that they were de-

Fig. 6.—A photograph taken at Belfort, immediately before the start of the raid on Friedrichshafen. The machine on the right was flown by Comdr. Briggs.

termined by abstruse stability calculations, because, in 1913, athough theoretical mathematical research into these questions had been made, the findings were not in such form as to be suitable for use by the aeroplane designer. In present times, it is possible, by the use of stability calculations and empirical formulæ, to determine suitable proportions. The principal dimensions of the Avro 504 were arrived at by our previous experience and Mr. Roe's extraordinary instinct in these matters. As our experience has increased, it has become a matter of amazement that these proportions were so good, the more so as we have proved that they were really quite critical. From time to time, we have conducted experiments with the machine, in which tail plane size, length of fuselage, rudder sizes, etc., have been separately altered, and in almost every instance the machine has lost some desirable characteristic. The only alteration in the controls which has been made and which is considered an improvement, is in regard to the shape of the aileron. By clipping the tip it has been found that the control is lighter and more in harmony with the elevator and rudder controls. This is a post-war development which has not yet been adopted by the Royal Air Force.

In the early stages of the war the Avro was used extensively in France, and I think it may be safely described as one of the best, if not the best, machine with which the British Expeditionary Force was originally equipped. It was used for a variety of duties, including reconnaissance, gun-spotting,

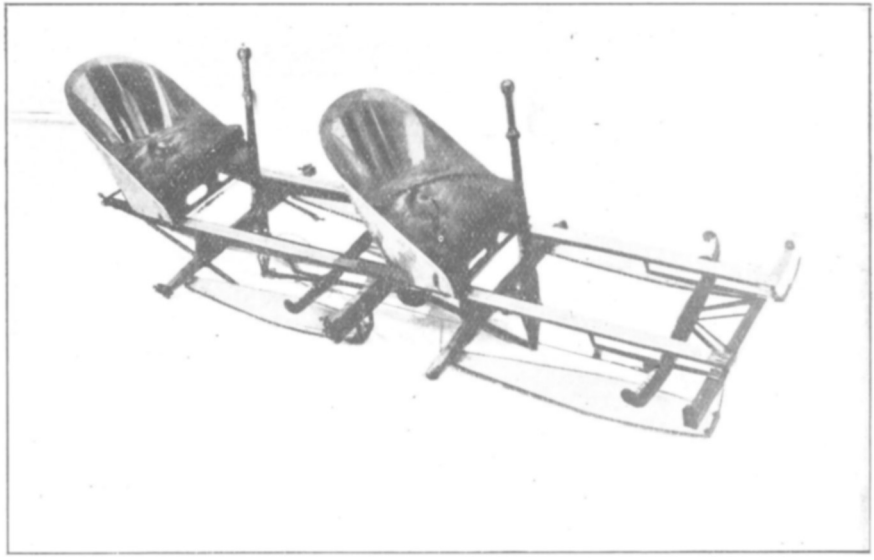

Fig. 7.—The Seating and Control Unit, which could be introduced into the fuselage assembled as shown.

photographic work, and light bombing. The only armament consisted of a pistol carried by the pilot, and, in some cases, a rifle used by the observer. Later on several machines were fitted with a Lewis Gun each.

The machine has some very notable achievements to its credit. The first real bombing raid of the war was carried out with Avro machines, the occasion being the raiding of the Zeppelin sheds at Friedrichshafen, on November 21st, 1914, by the then Engineer-Commander Briggs, Commander Babington and Lieut. Sippe. This achievement was particularly meritorious and was carried out under great difficulties; perhaps some details of the preparations will be interesting and even amusing.

A visit was received from Comdr. Briggs, who had instructions from the Admiralty to obtain from us four machines immediately, and to have them fitted in accordance with his wishes. No information as to their intended purpose was given but it was obvious that they were to be used for some bombing expedition. So well was the secret guarded that we did not know

what enterprise was in hand until the news of the successful achievement of the expedition was published in the daily newspapers. The machines were adapted for their purpose in a very short time and each was packed in a

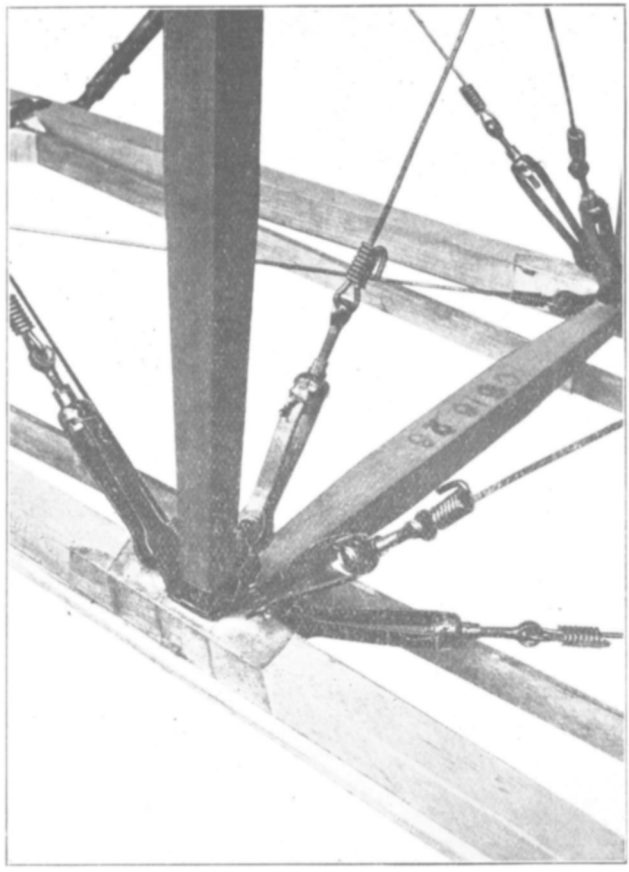

Fig. 8.—Section of fuselage showing fuselage fitting and Avro Turnbuckles.

separate case. At this time no such articles of equipment as bomb-carriers existed, and we had to scheme out our own. Each machine was fitted to carry four 20-lb. T.N.T. bombs and four petrol incendiary bombs. No dummy bombs were available for testing and the carriers were actually tested with live bombs, the bombs being allowed to fall into a suspended piece of sacking.

https://doi.org/10.1017/S2976690700000759 Published online by Cambridge University Press

Not only were the machines despatched from our premises, but also all the equipment, which included bombs, rifles, ammunition, etc. An amusing incident in connection with this happened at London Road Station, Manchester. The bombs had by some means been put into the guard's van of a passenger train and it was not until they were unloaded at Manchester that it was discovered by the railway authorities what they really were. The consternation among the station officials was terrific; that such a contravention of by-laws could have taken place was beyond their comprehension, but having dis-

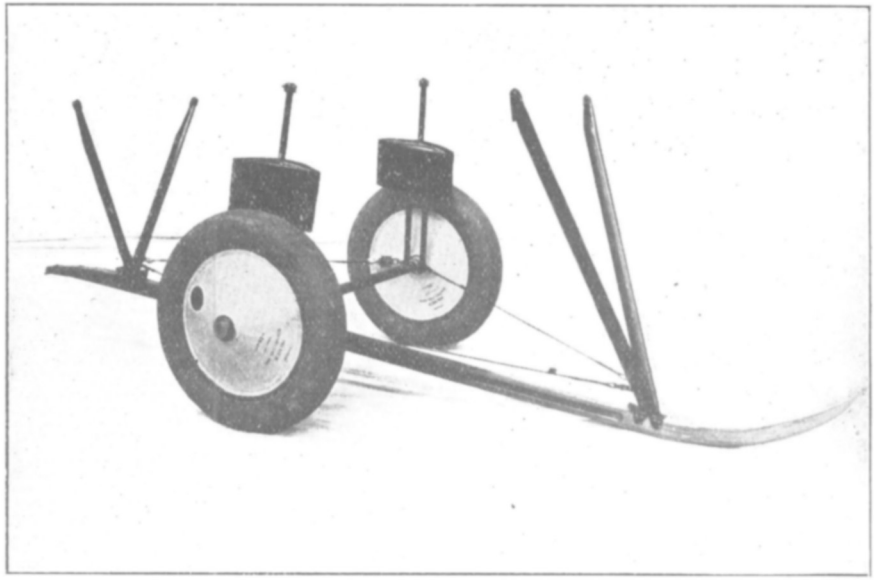

Fig. 9.—The 504 Type Undercarriage.

covered the true nature of this consignment they were in a worse fix than ever. No explosive of any description could remain on a passenger station, and, further, no vehicle, the property of the railway company, could carry it. They flatly refused to let a railway lorry carry the stuff to our works, and it was only by Comdr. Briggs stating that he would commander a vehicle that they finally gave way. Inquiries in regard to this matter went on for long afterwards.

The machines were finally despatched by special trains to the South Coast and by special train from Le Havre to Belfort. Here they were assembled in a balloon shed and the engines run up indoors. Weather delayed the raid about a week. A start was eventually made and the first flight that these machines made was direct to Friedrichshafen. The machine flown by Comdr.

Briggs was shot down, the actual cause of the descent being the carrying away of the petrol pipe by a bullet. The other two machines returned safely (Fig. 6).

Another notable achievement carried out on an Avro 504 machine was the destruction of the first Zeppelin, on May 17th, 1915. This feat is to the credit of Comdr. Bigsworth. He succeeded in climbing above the airship and dropped a bomb onto it. The resistance of the Zepp. structure was not sufficient to cause it to explode and it fell right through the airship. In doing so it seriously damaged the Zeppelin, as it eventually came to the ground and was wrecked. This feat was not quite so spectacular as that of

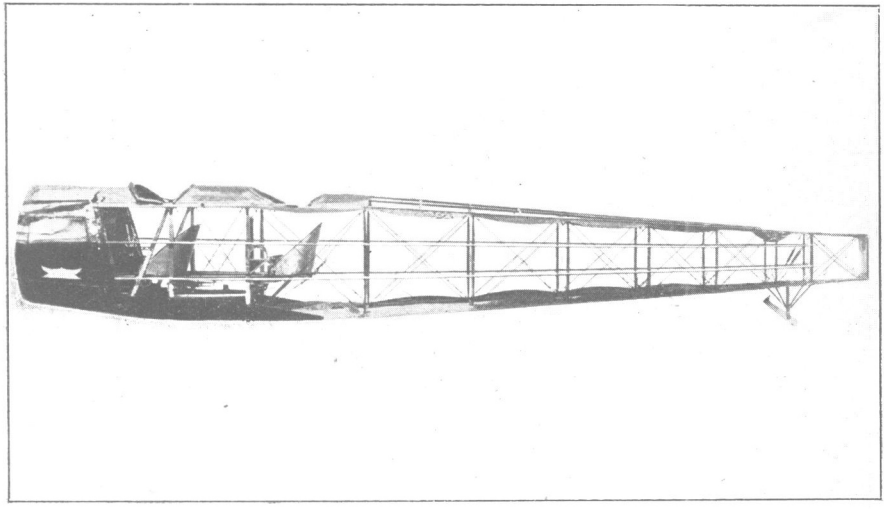

Fig. 10.—The fuselage. Note the use of three-ply to stiffen the longerons between the various points of support.

Lieut. Warnford, who for some time was credited with being the first pilot to engage and destroy a Zepp. Avro 504s were also used in some of the earlier raids on Cuxhaven.

Although, as these few remarks will show, the machine acquitted itself well in active service in the early stages of the war, it soon became evident that it was not fast enough to deal with the new enemy aeroplanes and it was thus withdrawn from France about the end of 1915. It is probable it would have remained considerably longer if a 100 h.p. Mono Gnôme had been fitted. The old 80 h.p. Gnôme was very unreliable and did not develop her rated power.

The subsequent use of the Avro 504 machine was for instructional work only. Although great numbers were constructed, it was not in the earlier

days exclusively adopted for training but was used in conjunction with several other types. The usual training during the earlier period consisted of a course on Maurice Farmans, followed by a course on either Avros, Curtiss, or B.E.s, or all of them. It is somewhat strang to reflect now on the different opinions then expressed about the Avro. At some schools it was regarded as a most dangerous machine, terribly sensitive on controls, and of very weak construction; at other schools the instructors swore by them, and

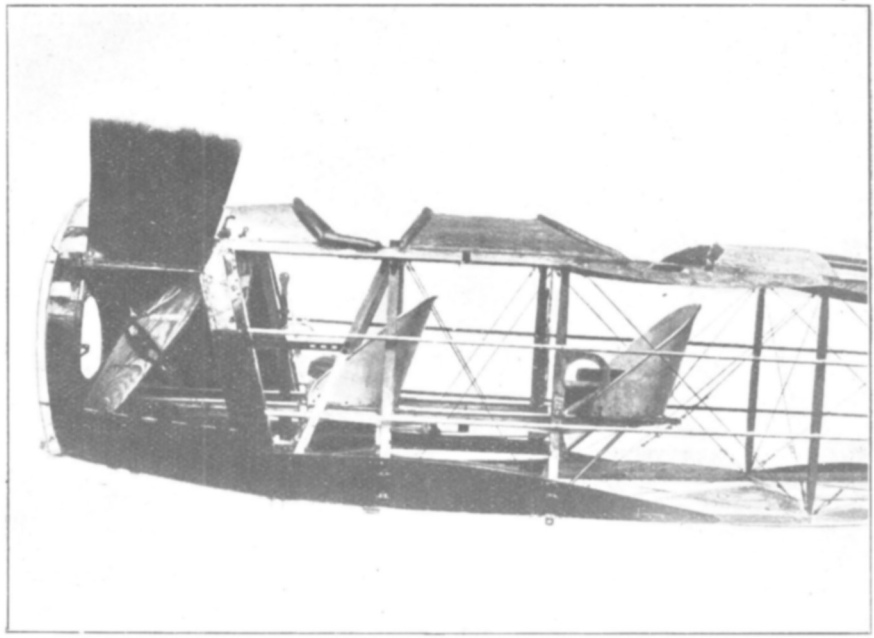

Fig. 11:—The front end of fuselage showing disposition of instructor and pupil.

at one school in particular we carried out a few experimental modifications actually to make the machine more difficult to handle, the view being expressed that its control was too simple.

So matters went on until 1917, when Col. Smith-Barry arose and startled us all by stating that there was no need for a step-up machine to the Avro, and that it was possible to train on the Avro a pupil without any previous experience, to such a state of proficiency, as would enable him to fly any Service type. He succeeded in convincing the Director of Training of the soundness of his proposals, which he demonstrated at Gosport, and, as the outcome, the Avro was adopted as the sole training aeroplane. I think I may candidly admit that although we knew the old Avro was a very good aeroplane, we

were told by Col. Smith-Barry and his disciples of many virtues that the machine possessed which were new to us. In fact, some features which we privately considered were bad were actually extolled as desirable. In this category comes the narrowness of the undercarriage, which caused the machine to swing a good deal on the ground. We were surprised to find that this was considered a desirable feature as it tended to let the machine swing under the torque effect of the rotary engines and, accordingly, gave the pupil a taste of the type of swing he must learn to deal with when handling a Single-Seater Scout fitted with a big rotary engine.

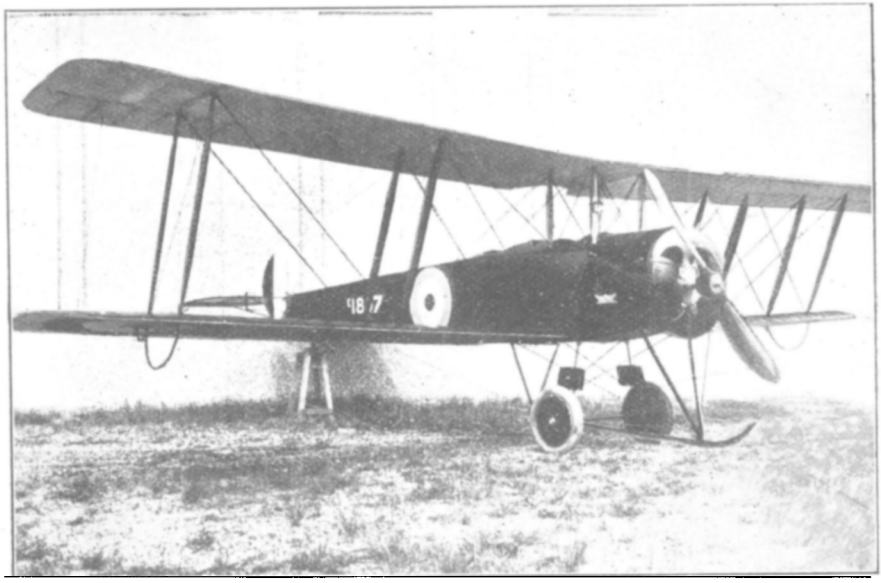

Fig. 12.—The Standard Training Aeroplane, Avro 504 K.

The attention devoted to training in 1917, and the work done at Gosport under the inspiration of Col. Smith-Barry, exercised such a profound influence on the subsequent history of the machine that it is perhaps of some interest to touch on some of the problems involved in training in their relation to the machine, which were tackled at Gosport. In the training of Service pilots it was obviously desirable (in so far as possible) that the finished product should be capable of flying with safety *any* Service type. This meant that he must be able to fly the most difficult type—from a pilot's point of view. The most difficult type appeared to be the fast Single-Seater Scout with a big rotary or radial, due partly to its characteristics, and partly perhaps to the relative impossibility of giving dual instruction on any considerable scale on that type, although, in a few cases, of course, scout machines

were specially fitted as two-seaters for this purpose. On broad lines, the general flying characteristics of the scout type, particularly with large rotary and radial engines, were—exaggerated torque effect, causing swinging on the ground both taking off and landing, especially the former; lightness on controls (of which an outstanding example was the "Camel"), and manœuvrability, and, of course, the manifestations of torque effect on steep turns and in various aerobatic manœuvres.

Some experience of these characteristics had therefore to be given a pupil in the course of his training, and I imagine that it was this (perhaps unex-

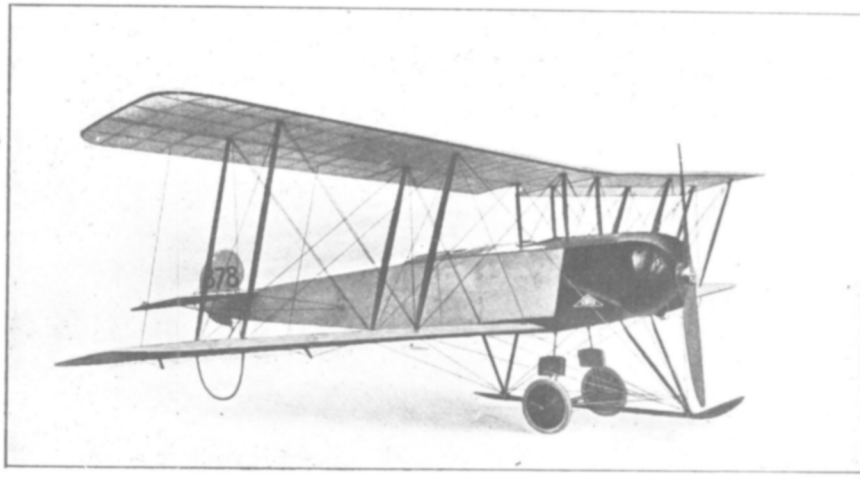

Fig. 13.—Avro Type 504 A. Engine, 80 h.p. Gnôme.

pressed or even unrealised) object that prior to the adopting of Gosport's methods several graduated types were employed for instruction, each one of which possessed *some* of these idiosyncracies, and, taken together, it was perhaps hoped that they collectively filled the bill.

It was apparently discovered at Gosport, and I can assure you that nobody was more surprised than we were, that the 504 J. possessed more of these vices, and to a greater degree, than any other single type available for instruction at the time. We had had some idea of the existence of some of these vices, but we naturally did not talk about them until we woke up (it was a gradual process) to find them virtues.

Obviously, a good deal was due to the rotary engine, but the machine itself cannot be absolved from complicity and it will be convenient at this stage briefly to state the particular characteristics of the machine, which made it so suitable and famous as an instructional aeroplane.

The controls were light and sensitive under all conditions and responded instantly to the slightest movement.

The importance of this quality was that it not only made the Avro highly manœuvrable, but also inculcated in pupils an appreciative sense of touch which was highly valuable and most essential in the handling of high-powered scouts. The lightness and sensitiveness of the controls magnified faults made in flying, and therefore mistakes made by the pupil were quickly and readily noticed by the instructor. Furthermore, the sensitiveness of the controls

Fig. 14.—Avro Type 504 J. Engine, 100 h.p. Monosoupape Gnôme. A machine belonging to the School of Special Flying at Gosport.

made it possible to analyse and demonstrate their smallest as well as their greatest effect, without fatigue to the instructor or discomfort to the pupil.

Although the controls were light and sensitive, they were at the same time exceptionally powerful, and on this account, the machine could be controlled almost to stalling speed. This powerfulness also made it possible to check faults instantly, and to manœuvre the machine with great rapidity.

The machine had a reasonably good rate of climb which made it possible for an instructor in a short space of time to take his pupil to a satisfactory height to commence instruction. This resulted in a considerable saving of

time and cost of instruction. The machine would perform in a normal manner all aerobatics known to flying men.

As mentioned before it had a narrow wheelbase, which, with the rotary engine, made it swing on the ground both taking off and landing. Once a pupil had dominated that tendency he found little difficulty in taking any stationary or radial-engined machine off the ground.

The machine manifested torque effect in the air to a surprising degree, rudder being required to hold the nose up on a right and down on a left steep turn, as also left rudder was required on top of a loop.

The propeller of the rotary 100 h.p. Mono engine would continue to revolve when the machine was on the glide with power completely shut off. The in-

Fig. 15.—An Avro 504 Type, fitted with a 90 h.p. Curtiss Engine.

struction of a pure gliding angle was therefore possible, without the complication of the power developed even by a throttled-down stationary or radial, which was not an unimportant point in the instruction of forced landings.

" It is sometimes forgotten that more accidents occur in training (not necessarily serious accidents, but crashery), when the pupil is flying without engine, on the glide, and approaching a landing forced or otherwise. A machine which permits this practice with a dead engine, and with even some absorption of energy taken up in keeping the prop moving, but which yet has full power at almost immediate disposal in case of necessity during training, possesses distinct advantages."

The narrow wheelbase, curiously enough, was responsible for another training virtue. It allowed a relatively steep inclination of the machine, on the ground, for the instruction of cross-wind landings, and permitted this practice in stronger winds than would otherwise be possible with a wider wheelbase or a lower undercarriage.

The construction is of a robust and straightforward nature and gives confidence to the pupil.

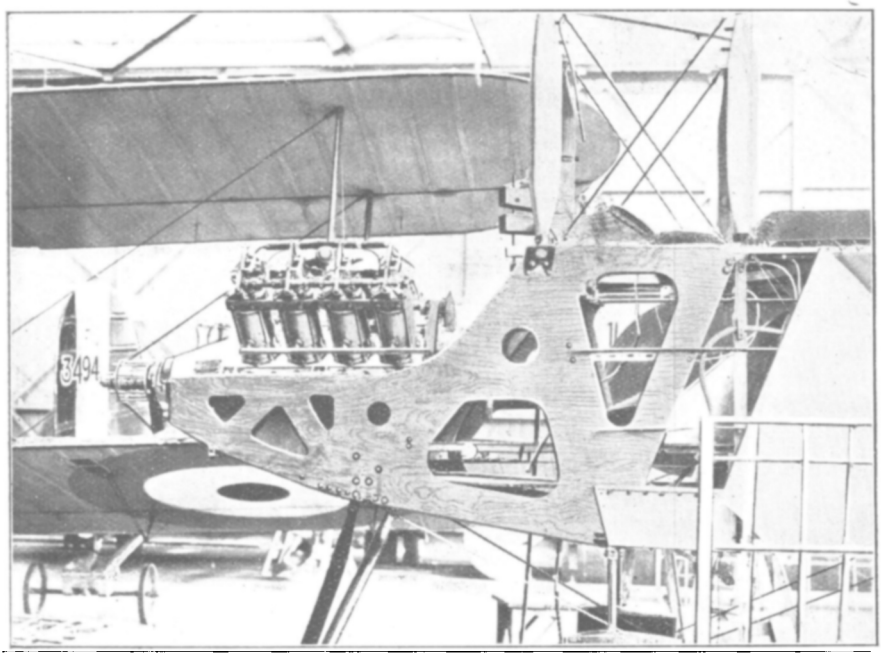

Fig. 16.—Showing the alterations made to the fuselage to fit the 90 h.p. Curtiss Engine.

At any rate these inherent qualities and unsuspected defects (as we had regarded them) enabled Col. Smith-Barry, with his extraordinary development of dual control instruction, to turn out a batch of pilots on this machine exclusively in little more than a month's instruction (some 18 or 19 pilots, I believe), who immediately flew between them almost every existing service type, without any further instruction on any step-up machine, and without bending a wire. From a manufacturing point of view, the design lends itself to rapid production, and most of the fittings have been particularly designed with a view to manufacture by press tool machinery.

There are several constructional features worthy of mention, and a few of the most important will be briefly described. The seating unit, comprising seat-bearers, dual-control shaft, rudder bars, heel rests, etc., was designed in such a manner that it could be assembled apart from the aeroplane and

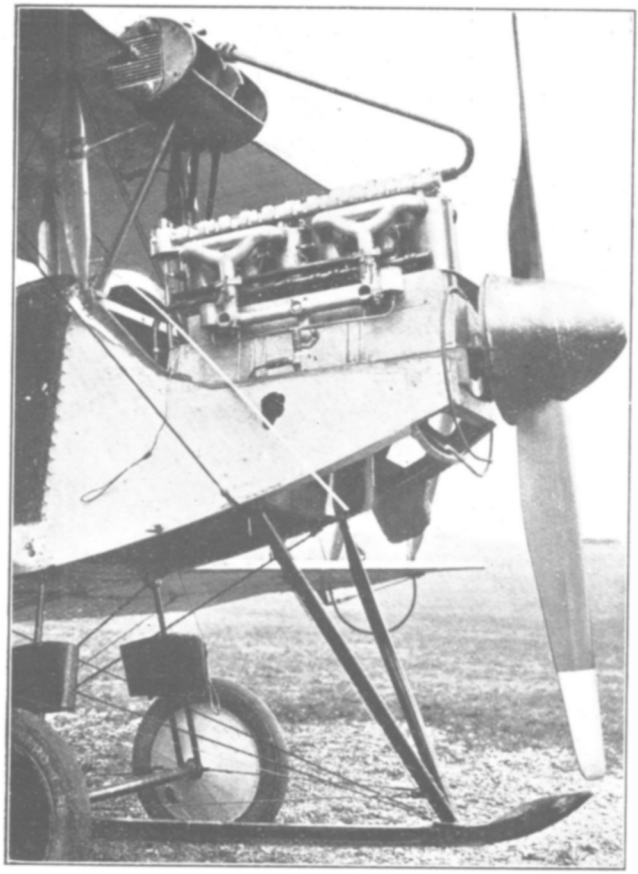

Fig. 17.—Showing the fitting of a 100 h.p. Green Engine.

introduced into the fuselage skeleton as a complete unit (Fig. 7). This feature greatly facilitated erection. Another interesting piece of detail design is found in the fitting used for the attachment of the bracing wires and struts to the longerons in the part of the fuselage behind the cockpits. The same fitting is used throughout, and twenty-six are employed in each machine.

This particular fitting has been the subject of an interesting process of evolution. The original fitting was a composite affair of aluminium and steel; the aluminium forming the socket and the steel being used for the bracing-wire attachments. The next development was to make it entirely of steel, the aluminium sockets being replaced by short pieces of square-section steel tube welded to the base plate. In the final design the welding was eliminated by attaching the sockets, which were now formed from flat plate, to the base plates, by small, bent-over lugs. This fitting has been severely criticised from time to time, but the fact remains that it has been highly satisfactory. The grounds of criticism were twofold, the first, that the longeron was pierced diagonally by the attachment bolt, and the second, that no provision was made for the change of angle between the strut and longerons. We,

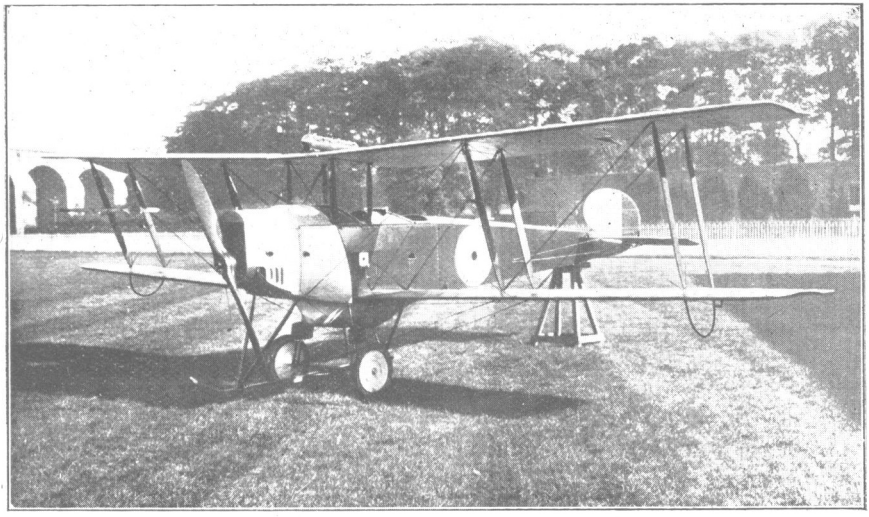

Fig. 18.—An Avro, fitted with a Sunbeam "Dyak" Engine. This installation was carried out by the Sunbeam Co.

however, always considered that these not very serious objections were completely outweighed by its advantages, which were that the same fitting was used throughout, thus avoiding a multiplicity of small components, all practically alike, and, most important of all, the fact that the fitting did not completely embrace the longeron; this feature enabled it to be used on a tapering longeron and also rendered it possible to bodily remove a longeron without pulling the whole fuselage skeleton to pieces (see Fig. 8).

During the early stages of the war, production of aircraft was hampered by the great difficulty which was experienced in obtaining adequate deliveries

of turnbuckles. With a view to surmounting this difficulty, Mr. Roe designed and developed an entirely new style of wire-tightening device; these, later on, became universally styled the Avro Turnbuckle. Their particular merit lay in the fact that the long left- and right-hand tapped barrel was avoided and replaced by a simple nut and pressed-steel yoke piece. I am sure that it is no exaggeration of fact to state that the very heavy production of Avros during the latter stages of the war would not have been possible if it had been essential to use the orthodox A.G.S. Turnbuckle. There are no less than 288 employed in each machine.

Fig. 19.—An Avro fitted with an 80 h.p. Renault Engine.

The wing construction is also simple and ingenious, each wing utilises only five formed ribs, these also constitute the drag struts. Stringers are threaded through these ribs parallel to the spars, and the remaining ribs are formed in position by merely fastening strips of wood on the leading edge, spars, stringers and trailing edge.

There are also several features about the machine which render it easy to maintain in commission. Only one point will be mentioned. The undercarriage, which is the most frequently-damaged part of an instructional machine, is easy to replace, and, furthermore, is pin-jointed to the fuselage in such a manner that an ordinary undercarriage failure does not necessarily damage the lower longerons (see Fig. 9).

The undercarriage shock-absorbing unit utilises rubber cord in tension in a very efficient manner, it is protected from the weather and oil, and needs very little attention. In passing, it may be mentioned that this strut was an original feature in the Avro 504 type. The orthodox method up to the time

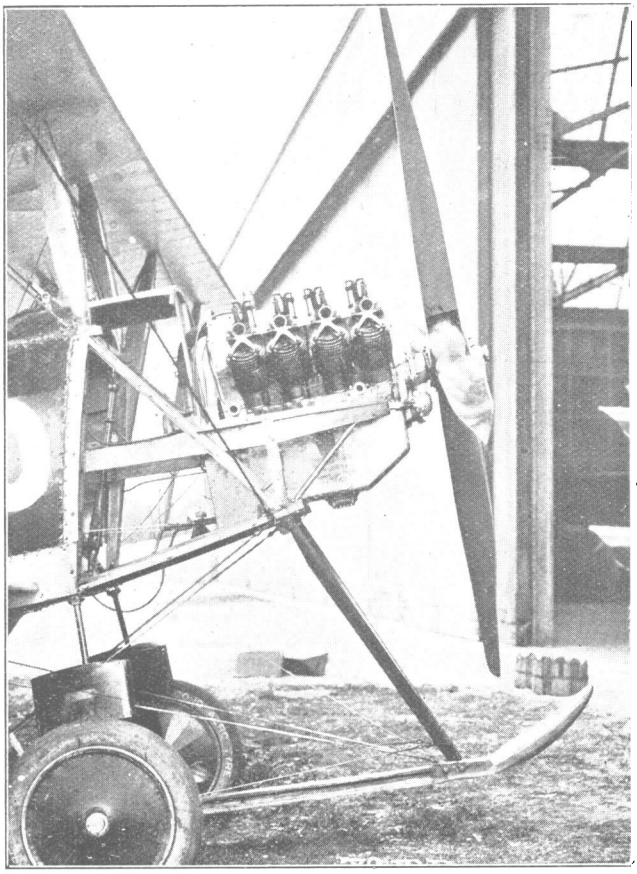

Fig. 20.—Showing the very simple mounting used for the 80 h.p. Renault.

the Avro 504 was designed was the use of rubber cord or solid rubber rings passed directly over the axle and attached to some stationary part of the undercarriage structure. Subsequently similar devices have been utilised on many aeroplanes of all sizes and to-day are almost exclusively used with the addition of some hydraulic energy-absorbing mechanism.

I shall enumerate and explain the different types of 504 later, let it suffice here that the type recommended for adoption as the Standard Training Machine was the 504 J., which was fitted with a 100 h.p. Mono. When this decision was formed our troubles commenced in earnest. A terrific demand was immediately created, and such fantastic figures as an output of 1,200 machines a month were discussed. It was obvious, of course, that this output was far beyond our resources, and large contracts were accordingly let to other firms for their construction. Eventually there were eighteen firms building complete machines, and countless others making spare parts.

Two very great difficulties were encountered immediately, the first was that, although our drawings were perfectly intelligible to our own staff, many

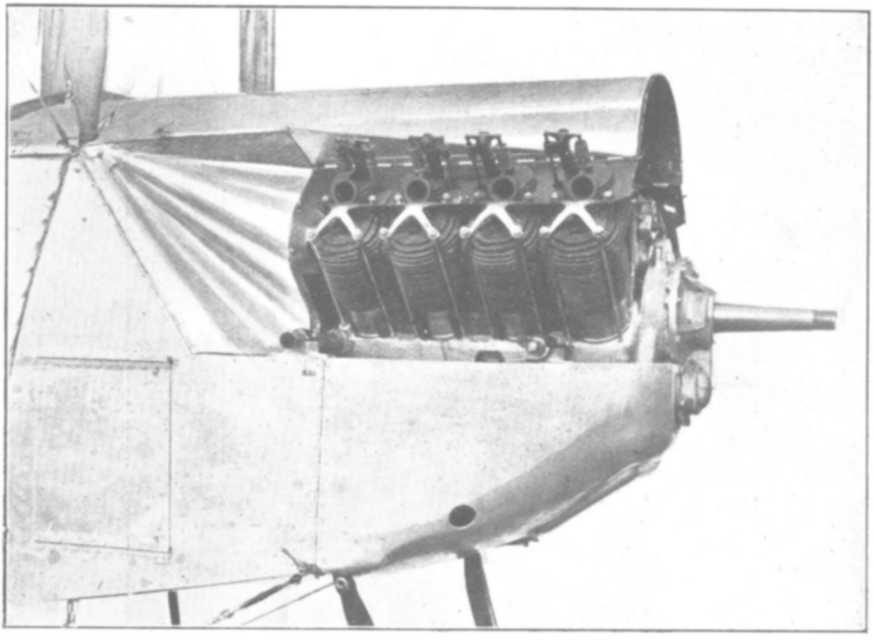

Fig. 21.—Showing the neat cowling of the 80 h.p. Renault as fitted to an Avro 504.

of whom had grown up with the machine, they were far from being so to outsiders. The other difficulty was in regard to the supply of engines. It appears that owing to the obsolescence of the Mono in the " Camel " and other Service types, contracts for Monos had been allowed to drop, and there was nothing like a sufficient number in stock and in production to meet the increased demand for use in Avros. The situation was met by drawing in from every aerodrome, both in France and England, all available rotary

engines, including 130 h.p. Clergets, 110 h.p. Le Rhones, and 80 h.p. Le Rhones. These larger engines would not easily fit the 504 J. and in consequence, the detail of the machine in so far as the fuselage and engine-mounting are concerned, had to be redesigned, and the new type thus created was called the now-famous Type 504 K. (see Fig. 12).

These alterations naturally retarded production and the new machines did not commence to appear until the end of 1917. Production then went

Fig. 22.—An Avro 504 fitted with an 100 h.p. Bristol Lucifer Engine.

ahead at a great rate; our own output rose to over 200 machines per month, and the eighteen other contractors who were building Avros augmented our production to such an extent that more than 5,000 were produced in the twelve months preceding the Armistice. The total war-time production of Avro 504 type machines was 8,340, of which A. V. Roe and Co., Limited, made 3,696, and other contractors made 4,644. Had the war been prolonged the rate of production would have been enormous. Our own new works, nearly completed when the Armistice was arranged, would have enabled us to produce 500 machines a month. These are very remarkable figures and worthy of note. Lord Weir, in an address at Manchester, stated that no other type of aeroplane had been ordered in such huge quantities, and I venture to state that it will be a very long time before any aeroplane is again manufactured on a similar scale. In an address at Newcastle, Lord Weir stated that one-

third of the total available supply of silver spruce was used in the construction of Avro machines.

I now propose to consider the design of the original and its variants in a little more detail. The original type was designated 504, with a few modifications the original machines supplied to the War Office were Type 504 A. and those supplied to the Admiralty, Type 504 B. The only difference between Types A. and B. were that B. was fitted with a fin and had slightly larger section spars than A. (see Fig. 13).

The first orders for these machines were received, and a few were delivered, before the outbreak of war. Very shortly afterwards it was found that for active service the petrol capacity was insufficient, and subsequent orders for Type 504 A. were fitted with additional tankage, bringing the endurance up to $4\frac{1}{2}$ hours. This was still considered insufficient for long-

Fig. 23.—An Avro 504 fitted with 180 h.p. Wolseley " Viper " Engine.

distance reconnaissance, and we received orders for a certain number of machines arranged as single-seaters with still more petrol capacity. A large cylindrical tank was fitted giving a total endurance of eight hours. These types were called 504 C. for Army machines and 504 D. for Naval machines.

The next development took place when both the R.F.C. and the R.N.A.S. were beginning to tire of the unreliability of the 80 h.p. Gnôme, and we received orders from both Services for machines fitted with other types of engines. Thus Type 504 E. came into being. This was an adaptation of

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the Naval type 504 B. and was fitted with a 100 h.p. Monosoupape Gnôme. Very few alterations were necessary; the shape of the spider was altered to accommodate the larger diameter of the engine, and the petrol system was altered from gravity to pressure feed. The R.N.A.S. also encouraged us to try a stationary engine and we fitted into a machine the first Rolls-Royce

Fig. 24.—A close-up view, showing the installation of the " Viper " Engine.

" Hawk," a six-cylinder engine of 75 h.p.; the type was known as the 504 F. The machine was arranged as a single-seater and was reported to be very pleasant to fly. It was, however, much under-powered, and was not proceeded with, although the Admiralty did actually place a contract for 30 of them with another firm. This order was subsequently cancelled, and an

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order for the ordinary 80 h.p. Gnôme Avro substituted. The Rolls-Royce "Hawk" engine was very neatly installed, and I am sorry not to be able to show a slide. Unfortunately, I have not been able to locate a single photograph of this machine. The next variant was Type 504 G. This was an Army machine and was fitted with the then new 130 h.p. Clerget engine. It was fitted with a synchronised Vickers Gun and also a Lewis Gun in the rear cockpit. It was intended for instruction in air fighting. Only ten were constructed, and they did not achieve any great measure of success.

By the date at which these experiments had been carried out the Avro 504 had ceased to take any part in overseas operations, primarily on account of

Fig. 25.—The Avro "Lynx."

its low performance. Recognising this, we made a final effort to resurrect it as a Fighter by fitting a 150 h.p. Sunbeam engine and equipping it with guns. The combination was quite good, and, as far as I can recollect, it had a top speed of about 103 m.p.h., but rather a poor climb. I think the type might have been further developed if it had been pushed. The Services could not be convinced that the machine was adequately strong when fitted with such a large engine and I must confess that we ourselves thought we were very daring. Unfortunately, I have not succeeded in finding a photograph of this machine, either.

Type 504 H. was a special design developed for the Admiralty. It was intended to be catapulted from a ship's deck. Special consideration was given to the very high inertia loads which were set up due to the violent ac-

Fig. 26.—A close-up view of the Avro "Lynx."

celeration. Unfortunately, Commander Dunning, who was responsible for these experiments, was killed in a flying accident before any trials with this type were actually conducted. I understand, however, some valuable experiments were carried out, and that much of the information which exists on this subject to-day was acquired from these experiments.

This brings us to Type 504 J., which was the Army equivalent of Type 504 E. It was fitted with a 100 h.p. Mono Gnôme and was by far the best

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of the 504 series which had been produced up to this time (see Fig. 14). Very great numbers were manufactured by A. V. Roe and Co., Ltd., and several other contractors. It is quite certain that it would have been the Standard R.A.F. Training Machine to-day, but for the shortage of 100 h.p.

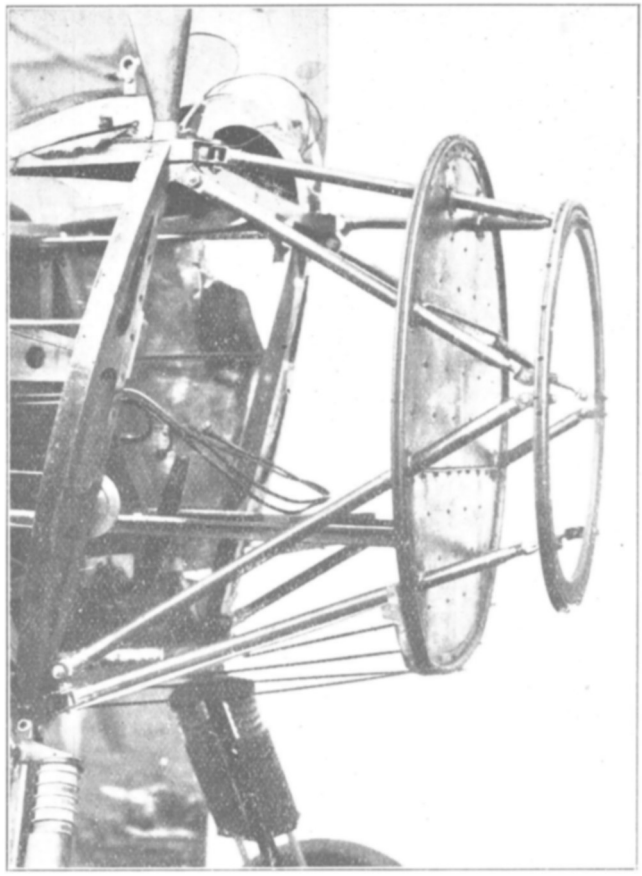

Fig. 27.—A view, showing the "Lynx" Mounting. Note efficient Fireproof Bulkhead.

Mono engines, which led to the introduction of the K. type, previously mentioned. Earlier in my paper, I mentioned that the weight, light, of the original 504 was 950 lbs. The weight of the 504 K. is 1,230 lbs., an increase of 280 lbs. This is not entirely accounted for by the alteration in design

between Types J. and K., but also covers the additional weight due to structure modifications, which had been made from time to time during the development process.

The post-war use of the 504 K. has been quite considerable. It still remains the Standard Training Machine for the R.A.F., of course, but in addition it has been adopted exclusively for similar duty by many foreign countries. Manufacturing rights have been granted to the Japanese Government, and I understand a considerable number of Avros have already been constructed by Japanese labour in Japan. Manufacturing licences have also been granted to private firms in Belgium, Australia and Canada, and they are

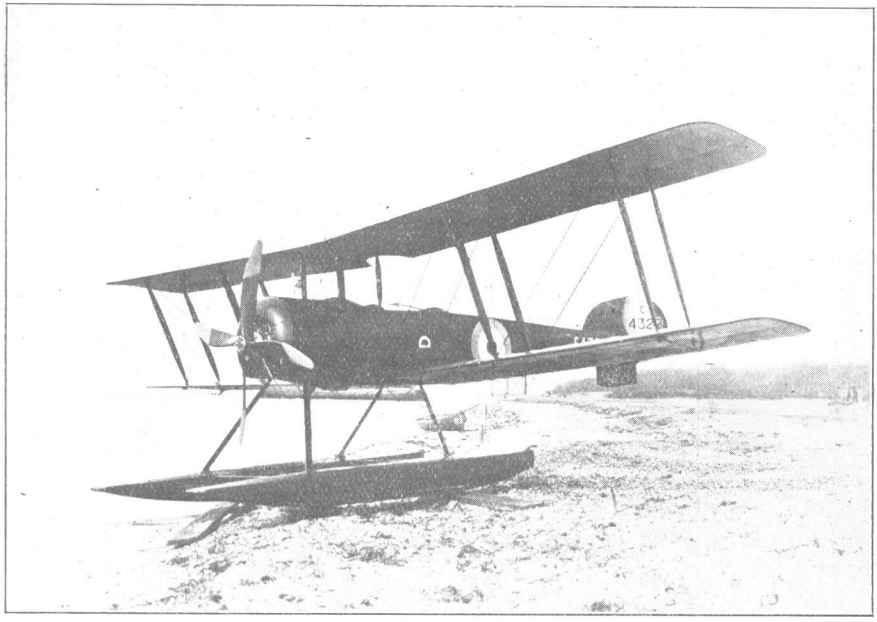

Fig. 28.—A Standard machine fitted with floats.

building machines for their respective Governments. A feature of interest in connection with the machines manufactured in Australia is that they are constructed from timber indigenous to the country. It has also been successfully employed as a Light Commercial Aeroplane for short-distance trips and for aerial survey and photographic work. There are many war-time constructed Avros engaged upon this work to-day. The conditions of service are very severe and the longevity of some of these machines is remarkable, furnishing a demonstration of their wonderful robustness and durability. Shortly after the Armistice we equipped a fleet of them for joy-riding. They

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were stationed in numerous different parts of the country and we carried over 30,000 paying passengers. Although we naturally experienced a few accidents, no passenger was fatally injured.

The late war-time demands upon us were for standardisation of design and rapidity of production to the exclusion of certain lines of development. Relieved of these demands and with more time at our disposal the post-war development of the type has been even greater than during the war. The principal research has been in connection with the engine unit. With a view to meeting a certain prejudice that from time to time appears to exist in regard to the rotary engine, nearly every make of engine between 100 h.p. and 200 h.p. has been fitted. Since the term " prejudice " is perhaps somewhat

Fig. 29.—The " Viper " Avro arranged as a Seaplane.

strong, it is perhaps as well to bear in mind some of the undoubted advantages of the rotary type in training, which are sometimes forgotten when reviewing its disadvantages. Its low weight per h.p., and its gyroscopic effect imparts many desirable qualities to a training machine. It permits a true gliding angle, and, therefore, more efficient instruction in forced landing. It requires a certain amount of aural attention to run it properly (particularly the Mono) which is not without its advantages in cultivating an ear for any engine. And it is a further fact that a pupil who can run a rotary finds no subse-

quent difficulty in running a stationary or a radial, while the converse is far from true. But be that as it may, some of the post-war combinations have proved exceedingly good, and there is no doubt in my mind that the 504 type, with minor modifications to meet particular requirements, will last many years, although it is doubtful whether any combination to-date really comes

Fig. 30.—The latest edition of the Standard Training Machine, showing new Oleo Undercarriage and cut aways at wing-roots and centre section, to improve visibility from front cockpit.

up to the 504 J. with Mono, from the exclusive point of view of land-training requirements, and the subtler niceties of balance and weight proportions which have always distinguished that type. The following engines have been fitted :—75 h.p. Rolls-Royce " Hawk," 150 h.p. Sunbeam, 80 h.p. Renault, 90 h.p. Curtiss, 100 h.p. Green, 120 h.p. Sunbeam " Dyak," 150 h.p. A.B.C. " Wasp," 100 h.p. Bristol " Lucifer," 180 h.p. Wolseley " Viper," 150 h.p. Siddeley " Lynx." Thus six different rotary engines and nine different stationary engines have been fitted to the Avro 504 machine, which must be a record for any particular type of aeroplane (see Figs. 15-27).

The Avro 504 has also been developed as a Seaplane, suitable, inter alia, for instruction purposes, the " Viper " and " Lynx " engines having been successfully employed in this development (Figs. 28 and 29).

In order to be in the fashion, suitable Oleo Compression Rubber Undercarriages have also been designed. One of these is a very simple adaptation of the standard undercarriage, and the other is an entirely new design (see Fig. 30).

In conclusion, I desire to thank you for listening so patiently to me, and I sincerely hope that my paper has been of some interest. If any members of the audience would like to ask any questions I shall be very happy to answer them to the best of my ability.

DISCUSSION.

MR. A. V. ROE:—I think that speaking is one of the most unpleasant things to do. I did, however, jot down one or two points which I wished to mention.

Mr. Parrott did not explain why we adopted the rather unique undercarriage, which was one of the special features of the Avro.

The principal object of the long, single skid was to assist the machine when landing on rough ground, and it also provided an anchorage for the diagonal towing cables to the axle, which prevented long grass from lapping round the axle and tending to turn the machine on its back; a type of accident which was often experienced with the light machines in the early days of flying. These wires acted as a sort of guard or plough and enabled landing to be made in very long grass or standing corn without unpleasant consequences.

It may interest you to know how the number 504 was arrived at. We built twenty-two aeroplanes and seaplanes before commencing to number each different type. When we produced our military two-seater we decided to call this Type 500. The selection of this high number was really a piece of drawing-office "swank." The 504 was the fourth of this series. The machine was not given a name, as is usual in these days, but was merely referred to as the 80 h.p. Avro Biplane, and, later on, when it became necessary to have a more exact identification, the drawing office type number 504 was adopted.

During the time when this machine was being designed and produced, I lived in diggings close to our works at Manchester, and this enabled me to amuse myself in the evenings over the drawing boards. It gave me an opportunity of looking very closely into things, etc.

I was very fortunate in finding Mr. Parrott and Mr. Chadwick, both of whom very materially assisted me in the production and design of the Avro Training Machine. Mr. Parrott came along as the result of an advertisement in "The Engineer," in 1909, for an aeroplane draughtsman, with no salary to commence. About this time my brother joined us and assisted in financing the undertaking, and Mr. Parrott soon had a salary.