The Role of Blackburne Engines in Road and Air Propulsion

M W Vincent

Blackburne engines were initially produced for motorcycles from 1912. The fairly simple side valve (SV) design with external flywheel continued into the early 1930s, although overhead valves were adopted on some engines in the early 1920s. V-Twin and three cylinder radial engines were produced for light aircraft following Blackburne's participation in the 1923-1926 Lympne air trials. Motorcycle engine production expanded during the 1920s with a wide model range, and significant commercial and competition activity. V-twin engines were used in Morgan three-wheelers and other light cars. About 1930 the engine range expanded further with the production of a sophisticated engine for the luxury small car market. A 1500cc single overhead camshaft (OHC) six cylinder engine was produced in 1932 for the Invicta car company, while in 1933, a development of this engine led to a twin OHC high performance unit of either 1500 or 1667cc for Frazer Nash sports cars. The larger capacity engine was guaranteed to produce 75bhp. These engines exhibited a number of quite advanced design features for the time. However, relatively few were produced, and in 1937 the company ceased engine production, concentrating on military and aircraft contracts ahead of the impending Second World War.

KEYWORDS: Blackburne, Motorcycle, V-Twin, OHC, Six-Cylinder

The Beginning

The origins of the Blackburne saga can be traced to the wellspring of 'The English Mechanic and World of Science' magazine.[1] The first article in a series which described how to build a motorcycle appeared on 4 January 1901, and from then until mid-April 1901, the construction of every part of its single cylinder engine was described in laborious detail. Figure 1 shows the assembled engine.

All parts of the engine, including the ignition system, carburettor, exhaust system and a combined epicyclic clutch/brake gear reduction unit, were described in enough detail to permit the construction of the engine for use in a motor bicycle, as it was described. The engine was of simple design, and reflected contemporary practice. It featured an automatic inlet valve, opened through suction on the induction stroke, and a mechanically operated exhaust valve, actuated by cam and pushrod. The cast iron cylinder barrel was finned for cooling, four bolts retaining

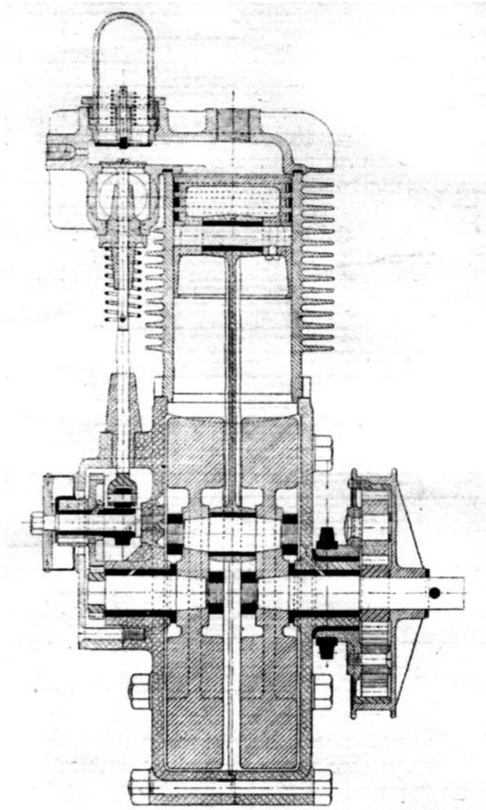

Figure 1. Sectioned assembly drawing of the completed engine, 1901.

both the head and barrel on to the crankcase. The cast iron piston had three plain cast iron rings. The intake pipe and automatic inlet valve on top of the cylinder head, and the pushrod operated side exhaust valve are shown in Figure 1, which also shows the internal flywheels, and the connecting rod. Drive was taken from an externally mounted chain sprocket.

The crankcase, which comprised two light alloy castings bolted together, housed a pair of cast iron flywheels with an offset pin forming the crankshaft. Each flywheel casting featured a balance weight opposite the crankpin, a refinement not universal at this time. The crankshaft/flywheel assembly was of built-up design, allowing the use of a malleable cast iron connecting rod with a plain ring at both little and big ends, into which brass bearing surfaces were fitted. Both bore and stroke were 63.5mm (2½ inches in the design), giving a capacity of about 200cc. The compression ratio was unstated, but a value of about 3.5:1 may be calculated from dimensions in the cylinder head drawings, consistent with the low octane quality of available spark ignition fuels (typically 45-60 octane). The engine was rated at 1.5 horsepower, with speeds of up to 2000rpm mentioned, perhaps optimistic by 1901 standards. With a surface carburettor, atmospheric inlet valve and heavy cast iron piston, maximum engine speed would probably have been about 1200 to 1500rpm, and it seems unlikely that the unit would have produced much more than the rated power.

It is not clear how many *English Mechanic* readers actually produced motorcycles of their own using these detailed instructions, but one who did was Geoffrey de Havilland, famous later as the founder of the de Havilland aircraft company. Geoffrey, later Sir Geoffrey, was a student at the Crystal Palace Engineering School from 1900. In 1902, as a special project forming part of the course, he produced a motorcycle using the *English Mechanic* drawings. After constructing and using the machine, de Havilland decided on a number of improvements, and went on to build a 450cc engine of his own design, claiming several original features. This latter engine was constructed in 1903, after he had started an engineering apprenticeship with Willans and Robinson of Rugby.

The engine de Havilland designed was materially different in a number of important respects, but drew from his experiences with the *English Mechanic* engine. Key differences were the significantly larger cubic capacity, the novel use of a mechanical inlet valve in place of the suction operated device, and an external flywheel of some 12 inches (305mm) diameter. This latter feature allowed the use of a one-piece crankshaft, with split and bolted connecting rod, more typical of passenger car practice. The connecting rod was cast in phosphor bronze. Instead of cooling fins, copper wire was coiled around the outside of the cylinder barrel. On this engine a yoke to retain the valve caps also served to attach the cylinder barrel and head to the crankcase, via two long clamp-bolts. Furthermore, a single-jet spray carburettor with needle valve and butterfly throttle replaced the surface carburettor of the *English Mechanic* design, while ignition was by trembler coil with wipe contact. Compression ratio was 4:1.[3] De Havilland designed and commissioned a frame to complete the motor cycle.[4]

The Burney Brothers

With its relatively large 450cc engine, the motorcycle was judged a success, and in due course passed on to de Havilland's younger brother Hereward. In 1903 two fellow students at Willans and Robinson, brothers Cecil and Alick Burney, were also impressed with de Havilland's motorcycle. When de Havilland was temporarily embarrassed for funds, the Burney brothers bought a set of engine castings and patterns for the proverbial fiver.[5] This was a fair sum at the time, equivalent to roughly a month's wages for a working man. The Burney brothers used de Havilland's design, patterns, and spare castings, to build an engine in the Willans' works, apparently with management consent. The completed engine was then fitted into a locally made cycle frame, for use in sporting trials and other similar events. C.S. Burney was particularly active and successful in trials with his motorcycle[3], establishing quite a reputation.[6]

From about 1904 the engine design inherited from de Havilland was subjected to sustained development and testing by the Burney brothers in competitive motor cycle trials and related events, over a period of about seven or eight years. In 1907 a new design of cylinder head having sloping inlet and exhaust ports was adopted, while a more conventional finned cylinder barrel replaced the copper tube design.[7] Cecil Burney won the Schulte Cup for the best performance in the open class of the Coventry MC 100 mile trial in August 1907 with this engine in his motorcycle. More development followed; by 1909 overhead inlet valve cylinder heads and magneto ignition were in use on both brothers' motorcycles. Success followed at Aston Clinton hill climb and at other similar events.[8]

Harold Blackburn and the Formation of the Company

In 1912, the Burney brothers, then living at Northchurch near Berkhampsted,[9] decided to go into business on their own account as motorcycle manufacturers. The engine they employed had been developed and proven from the original 1903 de Havilland design. A partnership was formed between the Burney brothers and Harold Blackburn, a pioneer aviator whom Alick had met at Hendon.[10] Early in 1911, Harold Blackburn was learning to fly at Hendon, but transferred to Brooklands, where he gained his Royal Aero Club Certificate.[11] Alick was working for Godfrey and Nash in the spring of 1911[12] just as manufacture of the GN cycle car commenced in Hendon.[13] Both Ron Godfrey and Archie Frazer-Nash had also served apprenticeships at Willans and Robinson, starting in about 1906 .[14] Harold Blackburn put up the sum of £200 as capital for the Burney brothers' venture. Initially, production was sufficient to produce three machines, which were built by Charles Southey[15] who was running a cycle business in Berkhamsted,[16] established late in the nineteenth century.[17] The capital provided by Harold Blackburn was used to manufacture three motorcycles with SV engines. The single speed belt-drive machines were assisted by the use of a large external flywheel as on the de Havilland engine.

Contemporary records give a good account of the new Blackburn motorcycle ('Blackburn' at this time was spelled with no 'e'). In January 1913, the engine was rated at 3½ hp[18] and described as being the result of nearly ten years' experiment. Bore and stroke were 85mm x 88mm respectively, with a detachable head and side by side valves. The cylinder head was retained by three long bolts that also secured the barrel to the aluminium crankcase, a departure from the yoke and two bolts employed by de Havilland. The crankshaft was a one-piece forging with balance weights riveted in place. Phosphor bronze main bearings were employed, with white metal big end bearings in a split-connecting rod. The piston, described as light in weight, had two piston rings. It had an oil groove at the bottom of the skirt, which dipped into a trough at its lowest point, flinging oil on to the cylinder walls. Both valves were operated by the same cam, using rocker-type followers, the Bosch magneto being driven from the end of the camshaft.

In September 1913, a Blackburn motorcycle won a gold medal in the Six Days Trial.[19] About this time, the Burney brothers decided to form a company, Burney and Blackburn Ltd, together with the Roberts brothers, Cecil and Arthur. Although the company bore Harold Blackburn's name, he decided about this time to pursue his main interest in aviation. The split was quite amicable, Harold retaining a Blackburn motorcycle and sidecar outfit.[20] About two months later, Burney and Blackburne (now spelled with an 'e') took stand number 41 at the 1913 Motor Cycle show in London,[21] having moved to new and larger premises in Tongham in Surrey. The factory was close to the 'Hog's Back' road, which formed a useful test track for the company's products. In 1914 production of Blackburne motorcycles continued with detail improvements, but essentially the engine remained as developed by the Burney brothers from de Havilland's original design.[22]

World War I and Wartime Development

The outbreak of war in August 1914 had a profound effect on the infant company, as four of the five founder members signed up for the army at the outset. With the departure of Harold Blackburn the previous year, none of the originators remained. The Roberts brothers' father, G.Q. Roberts, took over the management of the company, while veteran TT rider J.S. (Jack) Holroyd took up the post of works manager.[23] Completed motorcycles were commandeered for the war effort, with further commercial production suspended. However, engine development continued for the early war years, with detail improvements.[24] A racing machine was under development,[25] improved valve cooling, steel crankshaft balance weights, and better port design were proposed for the 1916 models.[26] This latter suggestion was probably wishful thinking, given the continuing hostilities. The 500cc SV engine described in 1917, and shown in Figure 2, remained the only model.[27] The 500cc Blackburne engine, with its substantial external flywheel, has a significant visual impact. Figure 3 below shows the cylinder barrel with its three stud fixing, and grooves in the fins to accommodate the studs, which also retained the cylinder head.[28]

Figure 4 shows the crankshaft and connecting rod assembly, plus the cam follower rockers that actuated the valves via push rods. The big end design included an oil scoop for bearing lubrication.[29]

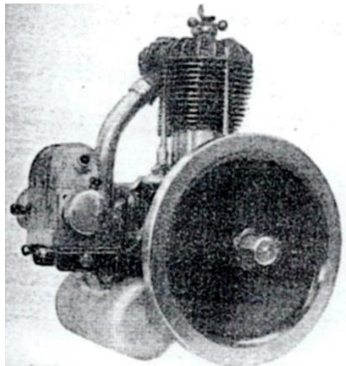

Figure 2. Blackburne 500cc side valve engine 1917.

Figure 3. Cylinder barrel for single and V-twin engines.

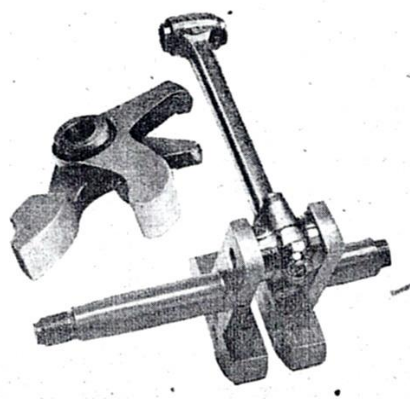

Figure 4. Crankshaft, connecting rod and cam followers.

Despite wartime munitions work, some motorcycle development activity clearly continued. In January 1918 news emerged of a new V-twin engine of one litre nominal capacity designed by Jack Holroyd.[30] The engine employed the single cylinder 85mm bore and 88mm stoke dimensions. A very significant number of parts were common to the older design, which minimised new work during the war years, the cylinder barrel, for example, being unchanged for the V-twin design. The crankshaft also appeared outwardly similar, but was in fact fabricated in two parts. The crank pin and one half of the crank throw, together with one main bearing shaft, were machined from solid and case hardened. The crankpin was bolted through the other half crank throw to complete the assembly. This arrangement allowed assembly of the connecting rods on to the crank pin. Whereas the single cylinder engine employed a split big end bearing design with white metal lining, the V-twin connecting rods were of one piece, with circular big end bearing housings into which hardened 5/16 inch rollers were inserted. One connecting rod was forked, allowing the other rod to fit inside on the common crankpin. Figure 5 shows the new V-twin engine described in January 1918. [31]

This engine was intended to appeal to owners of motorcycle and sidecar units, increasingly popular with the family man. An additional application was the so-called cycle car, production of which began before the war. Demand mushroomed in the immediate post war boom, with pent-up demand for motor transport briefly at an all-time high. Typical of the cycle cars that catered for this demand were the GN and the Morgan three-wheeler. A description of the 1919 Blackburne models gives useful information on the available engines, including their valve timing.[32]

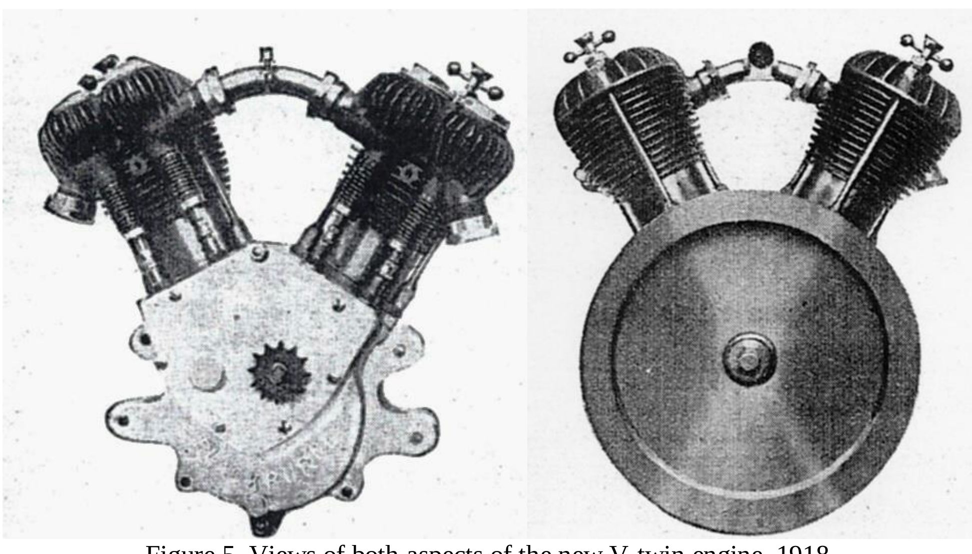

Figure 5. Views of both aspects of the new V-twin engine, 1918.

Both single cylinder and V-twin engines shared the same cam profile and valve actuation method, with both valves operated from a single cam via rocking followers inside the timing chest. Valve timing for Blackburne engines at this time is given in Table 1 below:[33]

Table 1. Blackburne engine valve timing

Inlet valve opens :	12 degrees after top dead centre
Exhaust valve closes :	20 degrees after top dead centre
Exhaust valve opens :	53 degrees before bottom dead centre
Inlet valve closes :	35 degrees after bottom dead centre

The conservative late opening of the inlet valve and minimal valve overlap would have limited both engine speed and power output. However, Blackburne engines had built up an enviable reputation for reliability, ease of maintenance and sustained service. The relatively large capacity lightly stressed design concept had provided similar virtues in Victorian steam engines. The clearly stated Blackburne design policy also makes interesting reading:

> In order to simplify the spare parts problem all Blackburne engines have been designed with the maximum number of parts interchangeable with all types; thus the pistons for the 4hp and 10hp engines either air or water cooled, are made to the same specification and drawing.[34]

Henry Hatch

Whilst this approach did have significant benefits, it may have disguised a reluctance to innovate, possibly due to the loss of the company founders who developed a sound and reliable engine initially. The exodus of design inspiration when the Burney brothers joined the army in 1914 was not made good when they returned to the UK; neither brother rejoined the company. However during 1918, Henry J. (Harry) Hatch joined the company as designer,[35] following which significant design changes were evident. In 1913 Hatch was head of the experimental department with J.A. Prestwich (JAP) in Tottenham.[36] When Hatch joined Blackburne and Burney Ltd. there were just two engines in the company portfolio, the 500cc single and 1000cc twin.[37] Hatch was influential in transforming the engine range through the pursuit of racing and record breaking success, which became a notable feature for Blackburne engines in the 1920s and beyond.

An expanded engine range was evident early in 1919.[38] Single cylinder engines were now available in two different sizes rated at 2¾hp and 4hp, together with 60 degree V-twin engines of 8hp and 10hp. The 2¾hp (348cc) and 4hp (499cc) singles shared a common stroke of 88mm, with bores of 71mm and 85mm respectively, while the 8hp (998cc) and 10hp (1098cc) V-twin engines shared a common bore of 85mm with strokes of 88mm and 96.8mm respectively. The 10hp V-twin engine was available with both air and water-cooling. All engines were of SV design, retaining the famous Blackburne external flywheel across the extended range. These engines were offered to other manufacturers for their machines, in a bid to increase sales. In 1921, manufacture of Blackburne motorcycles was transferred to the Osborn Engineering Company (OEC) of Gosport, Burney and Blackburne concentrating solely on engine manufacture.[39]

Gillett and Stephens

Gillett and Stephens' management, after a merger with Burney and Blackburne in 1921, took a decision to concentrate on engine manufacture. In effect, Gillett and Stephens took control of Burney and Blackburne Ltd, staff transferring to the new organisation including Harry Hatch. The transfer from Tongham near Aldershot to Great Bookham close to Leatherhead represented more than just a geographical relocation. Hatch, who now controlled both experimental and design departments, seems to have enjoyed his new management's confidence.[40]

The policy adopted was one of experimentation, frequently involving racing and other competitive activities, including record breaking at nearby Brooklands track. Successful designs would then form the basis for engines offered commercially. This policy resembled the approach adopted by the Burney brothers during the years from 1904 to 1913. New designs to emerge in 1922 were the 350cc overhead valve engine, and a comprehensively revised fixed head SV engine of 250cc capacity.[41]

The SV engine, capable of almost 5000rpm, broke records at Brooklands in 1922, covering nearly 62 miles in the hour in an OK Junior motorcycle, and sustaining over 56mph for seven hours.[42] The new 350cc OHV engine featured inclined overhead valves operated by pushrods, permitting the classical hemispherical combustion chamber shape featured in many racing engines.[43] This engine is shown in Figure 6.

The OHV 350cc engine borrowed its bore and stroke (71mm x 88mm respectively) from its SV cousin, but employed dramatically different valve timing, combustion chamber shape and port design. To reduce valve train stresses, push rods were angled inwards towards each other at their upper ends. The OHV unit employed the SV single cam design, using two rocker-followers inside the crankcase. The engine was normally fitted with a cast iron piston, and still employed the trademark external flywheel, evolution rather than revolution being apparent at this stage. Valve timing, for the new OHV engines, giving forty degrees of valve overlap, is shown in Table 2.

Table 2. Blackburne OHV engine valve timing

Inlet valve opens :	16 degrees before top dead centre
Exhaust valve closes :	24 degrees after top dead centre
Exhaust valve opens :	52 degrees before bottom dead centre
Inlet valve closes :	58 degrees after bottom dead centre

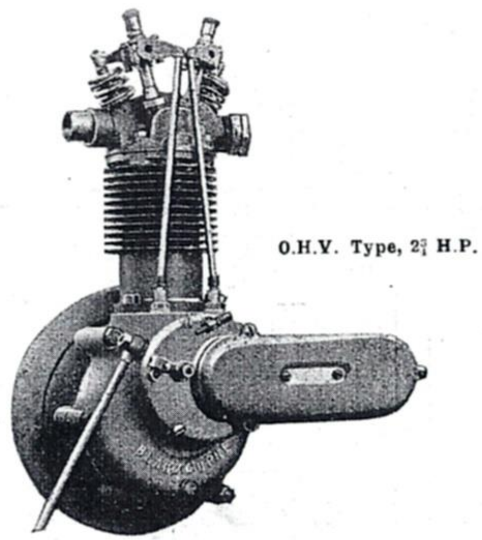

Figure 6. OHV 350 cc engine with external flywheel.

Alive to the benefits of competition success, the company sold a racing version of the 350cc OHV engine, with light alloy piston, higher compression ratio and racing cam. Also emerging in 1922 was an OHV version of the 700cc V-twin engine using the same cylinder dimensions, and probably a lot of common parts from the 350cc single cylinder engine.[44] This engine is shown in Figure 7.

The expanded engine line up for 1923 now ran to eight models, all of which retained the external flywheel. During the 1920s, there was a gradual reduction in demand for the low output SV engine based on the external flywheel De Havilland design, which had given excellent service, but now was increasingly obsolescent. In its place came engines with more advanced features. However, established Blackburne virtues of reliability and high manufacturing standards were not abandoned. A noted feature of Blackburne engines of the period was the degree to which parts from one engine could be swapped with impunity for similar parts from a different engine.

Blackburne engines developed a strong following and were able to provide a serious challenge to the dominant position enjoyed by JAP engines. There was significant enthusiasm amongst Morgan three-wheeler owners for Blackburne

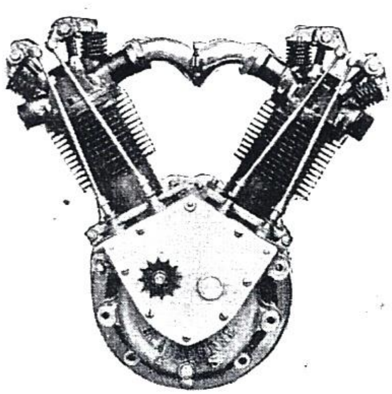

Figure 7. OHV V-Twin engine 1922.

engines. The prototype KM, designed by Harry Hatch, was announced in November 1922 with 1090cc capacity,[45] but production KMA, KMB, (racing) and KMC engines, were all of 1098cc, employing the familiar 85mm by 96.8mm bore and stroke, and were water cooled. The KM engine initially used the traditional three-stud cylinder attachment, but this was changed to four studs for the production KMA engine.[46] The water-cooled OHV twin was specially slanted towards the Morgan, but similar capacity SV engines were also available to Morgan customers.[47] The 1924 line up now numbered eleven different engines, from 250cc single cylinder to 1100cc V-twin units.

The KM engine featured detail differences from earlier twins, the design evolving through progressive improvements. On the OHV version of this engine, the rocker brackets formed part of the cylinder head casting, which, combined with the short rocker shafts, gave a very stiff and rigid structure for satisfactory valve operation. The crankshaft and big ends featured all-roller bearings. A single cam operated both valves for each cylinder as was normal Blackburne practice, but valve timing was now much more ambitious, with 40 degrees of overlap, as shown in Table 2 above. Power output for the touring engine was given as 35bhp (26kW) at 4000 rpm. This can be contrasted with the peak of 16bhp (12kW) at 2600rpm produced by the 1921 SV engine of the same capacity, which was descended from the Edwardian de Havilland design.[48]

During 1923 Norman Norris and Harold Beart used Morgan three-wheelers powered by the V-twin OHV Blackburne engine very successfully, in a range of races, hill climbs and sprints.[49] These engines were prototype racing KMB units with larger diameter gudgeon and crank pins.[50] At Olympia in October 1926, the KMC engine was announced. This was a development of the KMB racing engine, with claimed 40bhp (30kW) at 4000rpm. Stronger connecting rods and larger crankpins were employed compared with the earlier KMA engine, together with improved lubrication and modified valve gear.[51]

Aeroplane Engines

The Gillett and Stephens take-over probably also led to the provision of engines for the developing light aircraft market. The design of motorcycle engines had much in common with the requirements of the light aircraft of the day, namely light, compact air-cooled engines, with good power to weight ratio, of low specific fuel consumption and robust, reliable performance at moderate engine speed. The newer Blackburne engine designs seemed to satisfy these requirements, and to offer the possibility of opening up a new market in light aeroplane applications.

In April 1923 a light aeroplane competition, with engine size limited to 750cc was announced, to be held in the early autumn.[52] The Duke of Sutherland, Under-Secretary of State for Air, publicly supported the competition with a £500 prize, followed shortly afterwards by the Daily Mail, offering a £1000 prize. The competition was organised through the Royal Aero Club, and was intended to encourage the production and uptake of low cost aircraft. Using much lower power engines than those normally employed, the aim was to make flying more widely accessible. The restricted engine size dictated that very small craft would be produced, and the competition entries received were all single-seater aircraft.

Burney and Blackburne provided a modified version of their 60-degree 696cc V-twin OHV engine, with bore and stroke of 71mm by 88mm. The engine was very similar to the 1922 OHV air-cooled road unit shown in Figure 7, altered mainly by removing the normal external flywheel, and extending the crankshaft to drive the propeller. As on the road engine, four bolts attached each finned cylinder barrel to the aluminium crankcase. Power output was given as 16bhp (12kW) at 2400rpm, and 24bhp (18kW) at the maximum engine speed of 3600rpm. Weight complete was 75lb (34kgs).[53] In this guise the engine, known as the 'Tomtit', proved quite popular, being selected for six out of the twenty-eight aircraft entered. There were ten Douglas flat twin engines ranging in size from 500cc to 750cc, and four ABC engines of only 400cc, so the competition really was a battle for micro-aeroplanes.[54] The design of the competing aircraft, which varied considerably, was crucial in the trials with power so limited. In short, competent airframe design and a good pilot greatly affected the outcome.

The ANEC aeroplane powered by a Blackburne Tomtit engine and piloted by James Piercey did extremely well, setting the altitude record, matching the English Electric 'Wren' for best fuel consumption, and achieving the second best speed. This aircraft/pilot combination thus shared some £1500 of prize money with the makers of the Wren.[55] Perhaps not surprisingly, Burney and Blackburne made quite bold claims after the event, writing of their motorcycle engines securing the

Premier awards at Lympne.[56] The specific mention of 'motor cycle' engines is interesting, not only confirming the origin of the design employed, but presumably also reinforcing the quality and reliability of the engine in use in motor cycles and other road vehicles. Company claims included:

> The Reliability Award over 1000 miles
> The Altitude Award: 14,400 feet
> Petrol consumption (joint winner) 87.5mpg [57]

These were significant achievements and should have assisted sales of the Tomtit engine, which was available either in the normal motorcycle orientation, or inverted, as desired. An example survives as a static exhibit in the Shuttleworth Museum at Old Warden in Bedfordshire. A photograph of this exhibit is shown in Figure 8.

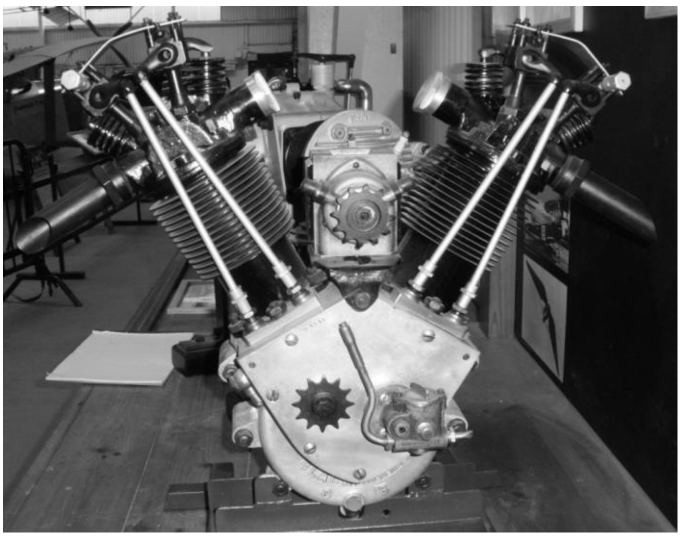

Figure 8. Tomtit V-Twin engine.

A significant number of light aircraft manufacturers of the time fitted the Tomtit engine, but the applications were in the main experimental.[58] In each case, perhaps only one or two aeroplanes of each type were built, and there is little evidence of follow-up production. As in the automotive world, the desire for power and performance prevailed, leading to bigger and faster aeroplanes, even within the sphere of light aircraft. The relatively low power output and small size of the Tomtit engine restricted accommodation to one person, a significant damper on sales of aircraft, and hence engines. However, a number of aeroplanes were in use for a reasonable period, producing some demand for the Tomtit engine.

In the following year, further air trials were again held at Lympne under Royal Aero Club rules, but the challenge was considerably tougher than in 1923. Aircraft had to accommodate two passengers together weighing 340lb (155kg), with engine size limited to 1100cc.[59] To maintain reasonable wing loadings, physical size was significantly greater than the 1923 single seat machines of the type powered by the Tomtit engine. The new competition specification highlighted the scarcity of suitable engines, which ideally needed to produce ample power at relatively low speed, best provided by direct drive from the crankshaft. Burney and Blackburne rose to the challenge, producing a suitable engine in time for the 1924 competition.

The engine was a new design, inevitably less well proven than the 1923 Tomtit unit which performed so well. The new 1098cc ‘Thrush’ three cylinder radial engine, with bore and stoke of 69.4mm by 98.8mm, was described briefly in May 1924.[60] This useful advanced publicity may have influenced six of the nineteen entrants for the 1924 trials to select the Thrush engine.[61] However, 1924 proved disappointing for many entrants in general and in particular for Blackburne, who were forced to witness the debacle of a connecting rod through the crankcase in one trial flight by the Supermarine Sparrow. The aircraft performed well prior to this disaster, but a replacement engine could not be fitted in time, leading to the elimination of the aeroplane.[62]

This was not the sort of publicity desired by Blackburne engines, and suggested poor bottom-end design, inadequate lubrication, or both. About fifteen months later in January 1926 the revised Blackburne Thrush engine passed a formal Air Ministry approval test. This required operation at 90 per cent full power over a 100-hour test duration.[63] The improved Thrush engine had increased to 1500cc nominal capacity, with bore and stroke of 81mm by 98.8mm. Power output was 35bhp (26kW) at the normal rated speed of 2500rpm rising to 38bhp (28kW) at the 2750rpm maximum speed. It could be assumed from the completion of the 100-hour approval test that Burney and Blackburne were working hard to salvage their reputation for reliability. The Thrush three cylinder radial engine, viewed from the propeller side, is depicted in Figure 9.[64]

The engine featured a single throw crankshaft having three separate connecting rods with big end roller bearings running on one crankpin. The rods ran one behind the other, mounted on a cylindrical sleeve. The cylinders were thus not directly in line, but were staggered on the cast aluminium crankcase. The exposed pushrods crossed over to improve alignment with their respective valves, which were inclined to optimise combustion chamber shape. Figure 10 shows the connecting rod and crankshaft assembly.[65] The two-piece built-up crankshaft was drilled to feed oil to the bearings. This aspect of the engine’s design was revised for the 100 hour Air Ministry test. Three camshafts were driven by sun and planet

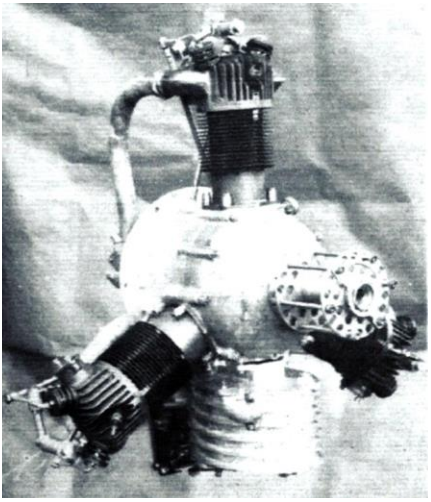

Figure 9. Blackburne Thrush three cylinder radial engine.

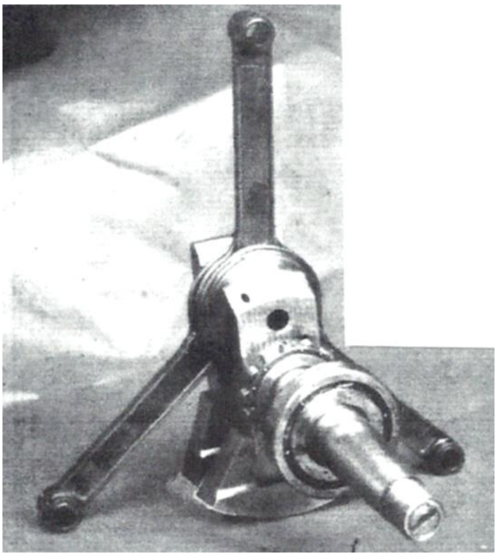

Figure 10. Thrush engine connecting rods on crankshaft.

wheels, from a pinion on the crankshaft. Figure 11 shows the Thrush timing gear drive.[66]

For the 1926 trials, the Blackburne Thrush engine was fitted only to one AVRO and one ANEC aircraft, both designs having performed well in earlier trials.[67] Overall, relatively few Thrush engines were made, and even fewer survive, although there is a 1500cc engine at the Shuttleworth Museum at Old Warden, and

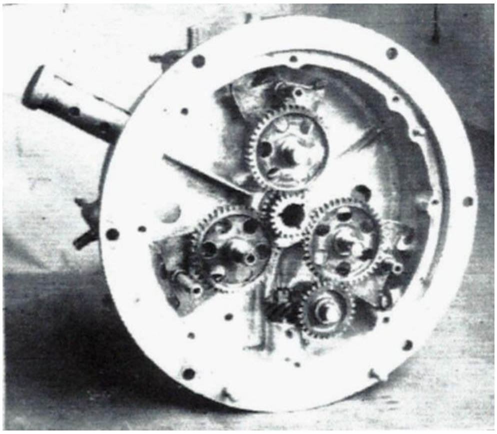

Figure 11. Thrush timing gear drive arrangement.

a very rare early 1100cc version also survives in private hands. Unfortunately commercial sales of Blackburne engines in light aircraft were poor. A fair number of different prototype aircraft trialled both the Tomtit and the Thrush engines, but few if any production orders resulted.[68] Neither engine provided the power output required for commercially viable aircraft, which needed at least 60-70hp to give the performance demanded.

Figure 12 shows a photograph of the 1100cc Thrush engine. This example powers an Austin Seven used for vintage motor sport events. Figure 12 shows the rear view of the engine, depicting pushrods, magneto, carburettor, and induction system.

Record Breaking

Despite the commercial failure of the aero-engine venture, competition and record-breaking activity on two and three wheels painted a happier picture. Harold Beart secured the class H2 British and World flying start kilometre and mile records at Brooklands in 1924, at 94.74 and 93.11mph respectively. These two-way averaged speeds were achieved in a Morgan three-wheeler with water-cooled Blackburne 1100cc V-twin engine.[69] In 1925, Beart improved on his 1924 results, taking records at just over 100mph over distances from 50miles to 100km, again using the Blackburne engine.[70] The engine was a racing development of the KMA production engine, and incorporated a number of features Hatch was keen to test.[71] Blackburne and Burney publicised Beart’s exploits and reported speeds over shorter distances more fully, ie flying start records over kilometre and mile, of 103.37 and 102.65mph respectively.[72] Racing on two wheels produced a significant number of TT wins in the mid-1920s. In the 1925 TT event, Blackburne-powered motorcycles took the first four places in the Ultra-Light-

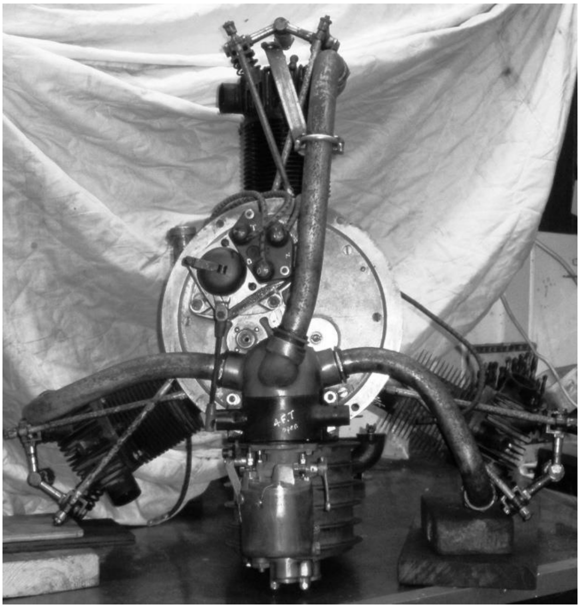

Figure 12. 1924 1100cc Thrush engine.

weight race, with a second place in the Lightweight event.[73] Similar company material documented numerous TT race wins with 250cc and 350cc OHV engines during the 1920s.

Further Developments

By 1928 the much-extended range of engines comprised major differences from the products on offer in 1921 when Gillett and Stephens took over, although the old de Havilland-based SV 500cc engine with external flywheel persisted until 1931.[74] In 1928 a significant development was the revised 175cc SV engine, with novel timing gear, as shown in Figure 13.[75] In this new engine, a skew gear drove a camshaft running at right angles to the axis of the crankshaft. This engine was used mainly for industrial rather than motorcycle applications.[76] Separate cams with circular followers operated the inlet and exhaust valves. An extension to the cam shaft drove the magneto, via a spring coupling, the Blackburne-designed plunger-type oil pump being driven from the other end.

Continuing development and design evolution for competition led in about 1927 to collaboration between Harry Hatch and Robin Jackson, well known in competition circles. A variation of the Blackburne 1098cc V-twin OHV engine was produced, with components manufactured to build three engines.[77] A key feature of this development engine, which was a pure competition unit, included the use of

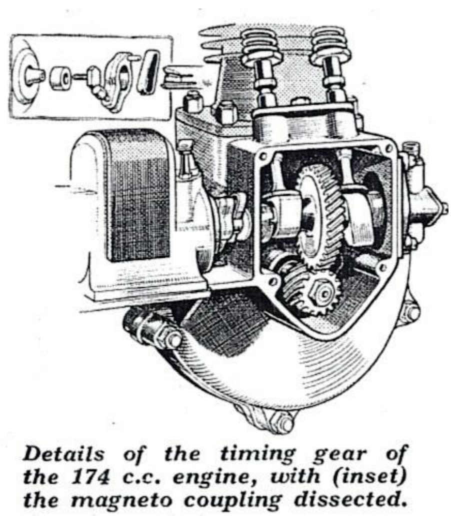

Figure 13. Revised valve gear for 174cc SV engine.

separate cams for inlet and exhaust valve operation, as opposed to previous Blackburne V-twin practice in which a single cam operated both inlet and exhaust valves. This single change, allowing Jackson to incorporate tuning techniques developed over many years of racing at Brooklands, arguably contributed most to the potential of this engine. Photographs of the engine illustrating some of its special design features are shown in Figures 14-16. Figure 14 shows the five-stud fixing for the cylinder barrels, and the staggered holes for the push rods, necessitated by use of a separate cam for each valve. Also visible in the photograph are the forked connecting rod, and internal flywheels.

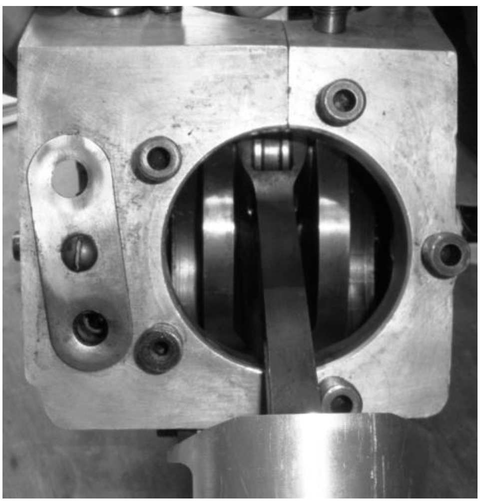

Figure 14. Five-stud crankcase for special Blackburne V-twin engine.

Figure 15 shows the cam-wheels and cams for independent operation of inlet and exhaust valves, while Figure 16 shows the special V-twin Blackburne engine complete. Although the engine used the 85mm bore and 96.8mm stroke of the production 1098cc V-twin unit, compression ratio was much higher at 10.5:1, hence the five stud attachment of cylinder barrels to the aluminium crankcase. The staggered push rods are a visual external difference from the standard parallel design.

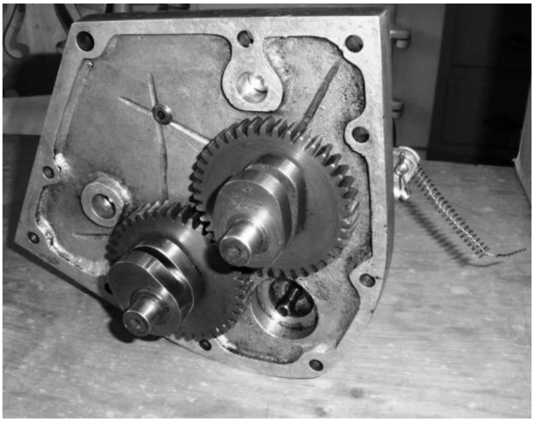

Figure 15. Cams of Blackburne special V-twin engine.

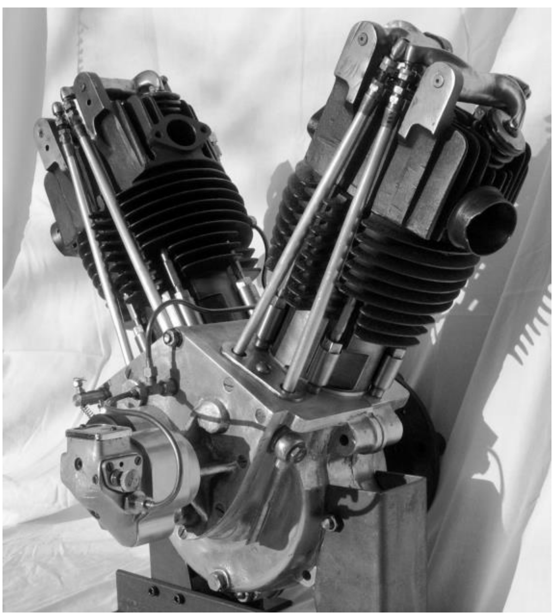

Figure 16. Special V-twin Blackburne engine.

Twin Bowden carburettors were used, and a special (mirror image) cylinder head produced for the left-hand cylinder (viewed from the front). The head for the right-hand cylinder was common to the 500cc single cylinder Blackburne motorcycle engine.

The engine was estimated to give 70bhp (52kW), but it was not dynamometer tested in a naturally aspirated configuration.[78] One engine survived in a reconstruction of the famous pre-war Freikaiserwagen special until it was destroyed in a crash in 1950. After use during the early 1930s in various three-wheeler Morgan cars, this engine was adapted to power the hill-climb and sprint special from 1937 until the car's demise. Initially used in naturally aspirated form, it was later supercharged. The Freikaiserwagen special was one of the most successful ever constructed. In June 1949 the car broke the record at Shelsey Walsh hill-climb, in a time of 37.35 seconds.[79] The previous record, set by Raymond Mays in a two litre ERA, had stood since 1939.

The Carriage Trade

The 1930s saw Harry Hatch embarking on an altogether different project for Blackburne, namely the development of an in-line six-cylinder passenger car engine. Noel Macklin produced Invicta cars, noted for their flexibility and performance, particularly the $4^1/_2$ litre model. However, such cars were extremely expensive, chassis price alone being £750, while a complete car in open two or four seater form was £950.[80] In the early 1930s, recession forced economies, yet customers still wanted the 'big car feel', and a small six-cylinder engine seemed to fit the bill. Responding to these pressures, Macklin looked for a suitable engine for a smaller Invicta. Harry Hatch produced speculatively for Macklin a six-cylinder 1498cc single OHC engine,[81] which was used in the Invicta 12-45 model launched in 1932. However, chassis weight was high, and engine output modest, resulting in an unimpressive performance inconsistent with the reputation of previous models. It is believed that about 200 of these cars were sold.

In designing the small six-cylinder engine for the Invicta, Harry Hatch was breaking new ground for Blackburnes. The first challenge lay in selecting a suitable bore and stroke. Taxation for cars, unlike motorcycles, was based on piston surface area, favouring a small bore to keep annual taxation to a reasonable level. Hatch chose dimensions of 57mm bore and 97.9mm stroke, giving an RAC rating of 12.09 hp, and annual road tax of £12. The cylinder head of the new engine drew from motorcycle experience, providing one port for each cylinder, with inclined overhead valves and a generally hemispherical combustion chamber shape.

As usual with Hatch's designs, the bottom end was rugged and strong. A generously sized oil pump circulated oil through a filter, then via crankshaft drillings to big end and main bearings. The four main bearings were a combination of ball and/or roller at each end and two white metal bearings between cylinders 2-3 and 4-5. Steel connecting rods with white metal bearings were employed, together with domed light-alloy pistons. The overhead camshaft was driven by chain, controlled by a Weller spring-blade tensioner. The valves were operated by rockers with roller followers running directly on the cams. The camshaft and valve gear were lubricated from a crankcase oil feed, via the relief valve mounted on the cylinder block. A light alloy crankcase supported the cast iron cylinder block and head; both sump and cam cover were also of light alloy. Despite efforts to save weight, the complete unit weighed over 150kg (330lb). Figure 17 shows a cross section of the single OHC Blackburne six-cylinder engine.[82]

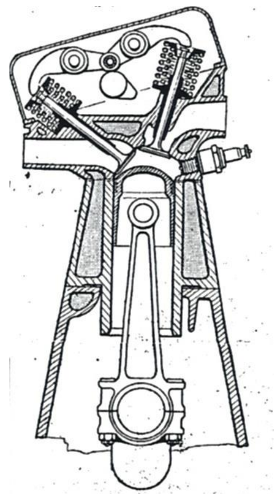

Figure 17. Single OHC Blackburne six cylinder engine section.

The design of the cylinder head was unusual with almost vertical exhaust valves, while inlet ports were horizontal, with steeply inclined inlet valves. This arrangement resulted in a wedge-section head casting, with exhaust ports higher than the inlet ports. The outcome was a sloping top to the cam cover, and the curious illusion of a ‘banana-shaped’ engine. Figure 18 shows the crankshaft and connecting rod assembly from the Blackburne single OHC six-cylinder engine. At least two different crankshaft designs exist for this engine. One featured bolt-on balance weights, while the type depicted shows balance weights integral with selected webs. Figure 19 shows the SOHC engine complete apart from starter motor.

The front engine mounting, crankshaft vibration damper, and the oil filter-housing cast into the crankcase are all visible in this view. This engine was described as the 12-45 by Invicta. A supercharged version described as the 1290 was also available. The vane-type supercharger was driven from the extended nose of the crankshaft, drawing through an SU carburettor, and feeding the inlet ports


Figure 18. SOHC crankshaft and connecting rod assembly


Figure 19. SOHC six cylinder Blackburne engine

through a heavily finned manifold. Compression ratio for the supercharged engine was 4:1 with boost pressure believed to have been 12psig (827mbar).

The Twin OHC Engine

Discussions with AFN, manufacturers of the Frazer Nash sports car, led to production of a twin camshaft variant of the Invicta engine.[83] For the Frazer Nash installation, Hatch reworked the entire design, although many similarities existed and some parts were common to both engines. The crankcase and sump were very similar, if not quite identical, but the crankshaft and connecting rods, cylinder block, head and valve gear were all different. Figure 20 shows the crankshaft from the twin OHC engine.

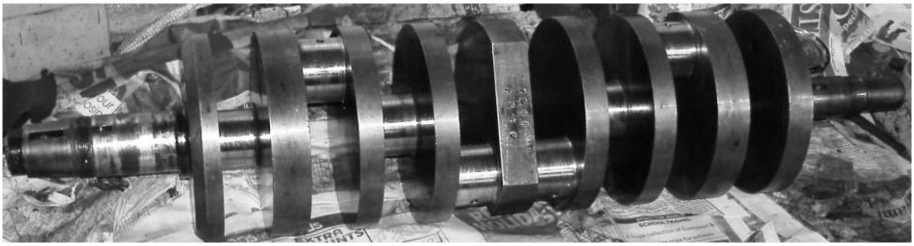

Figure 20. Twin OHC engine crankshaft.

The crankshaft, with mostly circular webs, was very substantial and weighed some 34kg (75lb) without bearings. The camshaft drive arrangements were similar to the SOHC engine, with a duplex chain driving the exhaust camshaft by intermediate sprocket, itself driven from a gear meshing with another keyed on to the crankshaft. The two camshafts were geared together, and thus turned in opposite directions. Lubrication arrangements were also similar for both engine designs. Figure 21 shows the valve train and camshaft drive for the twin cam engine. Cylinder head design was altogether better on this engine than on the SOHC unit, with symmetrical, widely angled valves providing good breathing. The hemispherical combustion chambers employed a central 14mm sparking plug. The rockers operating the valves and roller camshaft followers are also visible in Figur 21. Most twin-cam engines were produced with 60mm bore, giving a capacity of 1667cc. Some owners wanted engines compatible with 1500cc competition limits, resulting in a 57mm bore as for the earlier single OHC engine.

Triple carburettors were initially used, although later engines were fitted with twin carburettors. The cylinder head was fixed to the block with downward facing studs, the nuts accessed via recesses in the block. While this design reduces accessibility, it has the advantage that the head can be removed from the block with camshafts and valves in place, without disturbing the timing or upsetting tappet clearances. The camshaft drive gears are not keyed to the camshafts, but rely on a taper and lock nut design. There is no formal timing as such for this engine; Burney and Blackburne used to adjust the valve timing when the completed engine was on test, to satisfy the claim that each engine would produce 75bhp (56kW).[84] However, it is possible to give a nominal timing, used by many owners over the years, as shown in Table 4 below .[85]

Table 4. Blackburne six cylinder Twin OHC engine valve timing

Inlet valve opens :	16 degrees before top dead centre
Exhaust valve closes :	16 degrees after top dead centre
Exhaust valve opens :	38 degrees before bottom dead centre
Inlet valve closes :	44 degrees after bottom dead centre

Frazer Nash production was never very great, and in total only about 28 cars were fitted with the twin OHC Blackburne engine.[86] A few are believed to have been used in Invicta cars, but even including these, total production is estimated at about thirty units, of which perhaps twenty survive. The engine used light alloy connecting rods, which became brittle with age, leading to failure. This problem accounted for the destruction of a number of engines, but replacement with steel connecting rods removes almost the only significant weakness in the design. As a result, these engines are now valued and sought after. Figure 22 shows the twin OHC Blackburne engine installed in a 1934 Frazer Nash car. The single OHC version of the engine can be seen in the background.

During the years of its production, broadly 1933-1936, Burney and Blackburne appeared to be making almost constant changes to the twin OHC unit, apparently no two surviving engines being exactly alike. Crankcase, sump, cylinder head, cam cover, both intake and exhaust manifolds, crankshaft and water pump all show changes during production. With such low production numbers, these changes perhaps represented optimisation as design stabilised, but this approach was inconsistent with profitable operation.

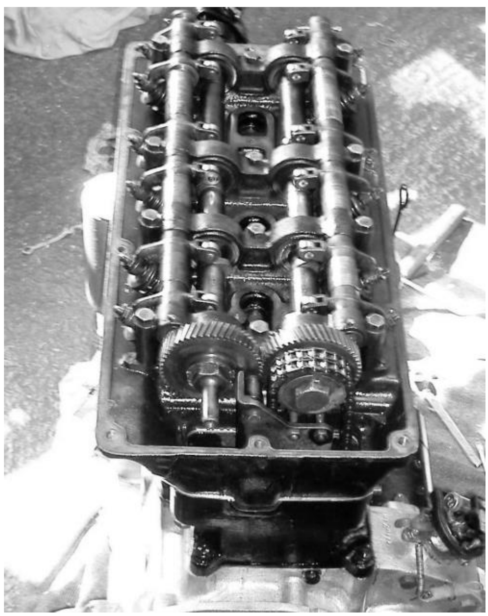

Figure 21. Twin OHC engine showing valve gear

The Mechanical Marvel

In 1933, Harry Hatch collaborated with Eric Walker of Excelsior to produce a 250cc single cylinder Blackburne racing engine for use in Excelsior’s Light-weight TT entry. This interesting design used four valves arranged radially in the cylinder head, giving a part-spherical combustion chamber. Twin carburettors and twin exhaust pipes were employed; their respective valves controlled by inlet and exhaust camshafts each operating one pushrod. On top of each pushrod sat a piston housed in a bronze bush. The upper surface of the piston operated a pair of rockers,

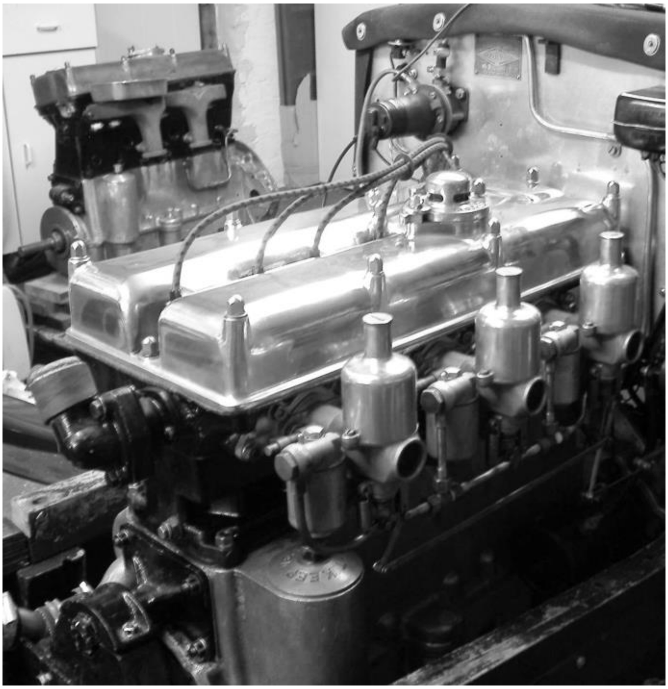

Figure 22. Twin OHC Blackburne engine installed in a Frazer Nash car.

one for each valve.[87] The Hiduminium connecting rod employed a needle roller big end bearing, the crank employing internal flywheels. This sophisticated and complex design was rapidly named the 'mechanical marvel', a title that it has worn ever since. The engine was produced just before the 1933 TT race, and reportedly produced 25hp (18.7 kW) on test resulting in a lap speed of over 90mph at Brooklands.[88] In the TT race itself, the engine enabled Sid Gleave's Excelsior to win the Lightweight race at 71.59mph, with a fastest lap speed of 72.62mph.[89] The engine was a pure racing unit and was not put into production. In fact it did not reproduce its winning form in later events, but it remains a milestone of ingenious design.

Engine Production Ceases

In addition to manufacturing Blackburne engines, Gillett and Stephens had a contract to overhaul and test V-12 Liberty aero engines at the conclusion of WWI.

Through the 1920s this work grew to be a major activity, including the manufacturing of spares.[90] Later, in 1934, the company manufactured aircraft undercarriages and hydraulic equipment, and in 1936, took on a large contract to make incendiary bombs in addition to aircraft work.[91] The revenue from such contracts clearly exceeded that from producing engines for cars, motorcycles and cycle-cars, and by 1937, the management at Gillett and Stephens stopped producing Blackburne engines and turned the company's entire effort over to military contract work.[92]

This change marked the end of an honourable progression from a home-made single cylinder motorcycle engine at the dawn of the century to a sophisticated high performance multi-cylinder sports car engine in the mid 1930s, with light aircraft engines and many record-breaking racing engines en-route. Harry Hatch featured strongly in this process, and not long after production of Blackburne engines ceased, he left the company. After war service in research and development with the Air Ministry, he re-joined the motorcycle industry in the late 1940s, working until his death in 1954.

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