SMALL RACING CARS.*

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Introduction.

It is undeniable that everybody with a normal sense of values enjoys a clean sporting contest of any kind between adversaries who are fairly and evenly matched. To make the contest a real test of merit it must take place in public, and must be in accordance with the accepted rules.

The above requirements are met by motor racing, since thousands of people witness the great long-distance motor races of the present day. The rules usually are also comparatively strict, and fine sportsmanship frequently exists in addition, in connexion with honouring the unwritten rules of the motor racing game.

It has been the author's good fortune during the last few years to be entrusted with the designing of a number of types of what, for the want of a better term, may be briefly described as "small racing cars." The work, as it happens, has been entirely carried out for one Company, whose drawing office and experimental department are combined under his care. Having previously been in daily contact at different times with motor-cycle engines, airship engines, both rotary and stationary aeroplane engines, and a variety of accessories connected with the various types, it was at first somewhat difficult to go back to the beginning and start with small engines all over again, but there is a great fascination about these small units, because they provide an almost ideal ground for experiment, the cost of which is greatly reduced by the small size of the parts involved.

To prevent any misunderstanding it is as well to make clear at the outset the main considerations governing the matter from a commercial angle, although there is no intention to do this in any detail, as it has already been done by the Managing Director of the same company in his paper "Making Modest Production Pay," which was read before the Institution a year ago.‡

It has never been possible for the firm to consider the construction

* The author read this paper before the Institution at the invitation of the Council.

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‡ See Proc. I.A.E., Vol. XXVIII, p. 439.

of racing cars which, in a mechanical sense, could be regarded as epoch-making types, such as the Grand Prix Peugeots of before the War, the straight-eight 1½ litre Delages, or the Alfa Romeos and Auto Unions of the present day. The cost of constructing such cars would be out of all proportion to the prices which could be obtained from the sale of them, and unless the market for such products alters considerably, it is unlikely that the firm will ever construct such high-powered and ultra-specialised machines.

Victory or a fine performance in a big race brings with it the following advantages to the firm concerned :—

(*a*) The Publicity Department have at their disposal very valuable material for advertisement.

(*b*) A great deal is learnt about the type of car used in the race, especially in regard to any weaknesses it may possess, even of the most trivial description.

(*c*) A fine spirit is created amongst all those responsible for the effort, and all concerned come away from the contest more capable and self-reliant because of what they have seen and done.

These advantages have, in reason, an upper limit of financial value, and the cost of the cars must not exceed that figure in the worst event, allowing, of course, for the price at which they can be, or have been, sold.

To meet these requirements in many races, over a period of years, it is essential that the cars raced should bear a strong family resemblance to the production types, and in the case of the cars considered in this paper, it will be seen that all of them are, in fact, made up from variations of standard production units, the amount of variation being only just sufficient to meet the purpose intended, or to comply with the rules of the race or record attempt involved. This proceeding is, of course, somewhat facilitated by the fact that the production units had originally racing prototypes to start with.

On account of the wide ground covered by the title of the paper, it is hardly possible for the author to do more than touch upon the main points involved. In general, small racing cars may be considered to be those having engines not exceeding 1,500 c.c. engine capacity, with or without superchargers, and cars of this type are built for three main classes of racing ;

(i) Road races, with bodies in accordance with the international regulations.

(ii) Track races, in which any type of body and any kind of fuel are allowed.

(iii) Record attempts, in the International class concerned.

Description of Certain Small Racing Cars.

Between 1930 and 1934, a number of types of small racing cars have been built in the Works referred to for these three classes of races, and a short description of each type is now given in the form of a historical summary, outstanding racing successes by any one type being mentioned to the credit of the type concerned.

Series M. Midget, 1930, "*Double Twelve*" (Fig. 1, Plate XXIX).

These cars were produced for the 1930 double-12-hours' race run at Brooklands in two series of 12 hours. The race was run on the track, but classed as a road race as the cars had to be stock models with full equipment subject to a list of alterations permitted by the rules, no other alterations from standard being allowed.

These cars had 4-cylinder engines, 57 mm. × 83 mm. bore and stroke, with overhead camshafts and two-bearing crankshafts. The wheelbase was 6 ft. 6 in. and the track 3 ft. 6 in. Two-seater racing bodies conforming comfortably with the regulations were used complete with hoods, gauze screens, wings, lamps, full equipment, and an outside exhaust. A data car was built in advance of the others, and very thoroughly tested out at Brooklands. The maximum speed of these cars for a lap at Brooklands was approximately 68 m.p.h. The data car of this type, the first M.G. to be built as a racing car, and nicknamed "Shinio" on account of the amount of polishing devoted to the engine, is still in existence and is used daily by the author as a runabout. The cars proved reliable and won the team prize, the only casualty amongst five cars being a broken petrol pipe.

Ex. 120, *Record-breaking Car*, 1930.

Experience with the previous cars had brought to light serious shortcomings in some directions, particularly in regard to maximum speed. Since International records are all in classes, the engine size had to be reduced to just under 750 c.c., which would not help the power output as things then stood, and the original M. type chassis would not stand up to really high speeds for any length of time if fitted with a power unit giving a very much increased output.

With an eye to the future, an entirely new chassis was designed having a 3-point engine mounting, semi-flexible frame with tubular cross-members, and the radiator mounted on the engine nosepiece, so that it did not move with the frame, the track being 3 ft. 6 in. and the wheelbase 6 ft. 9 in. Capt. G. E. T. Eyston, who has since driven these small racing cars in so many races, co-operated in designing this car.

The power unit was reduced to 743 c.c. by shortening the stroke to 81 mm. and the bore was reduced to 54 mm. As the job developed on the drawing board the author felt that the foundations of a future type were being laid, which has indeed proved to be the case, since the firm have used this type of general construction ever since for all subsequent racing and production cars. The car as finally turned out had the equivalent of a two-seater racing body so far as frontal area is concerned, but what would normally be the passengers' cockpit was covered by a fairing.

This car was the first car to get a record for the firm and the first small car (750 c.c. class) in the world to attain 100 m.p.h. Unsupercharged it lapped Montlhery at about 94 m.p.h., and later, when a supercharger was installed, it attained 100 m.p.h. and then 100 miles in the hour from a standing start. The latter run nearly ended in disaster, as the engine broke up at the end of the run, and started a bad fire. A photograph of this car at Montlhery is given in Fig. 2, Plate XXIX.

C. Type Midget, Road Racing Car, 1931 (Fig. 3, Plate XXIX).

These cars were built for the 1931 Double-12-hour Race at Brooklands, in which the M. type Midget won the team prize the year before. The cars were run with wings, lamps, gauze screens, hoods and full equipment generally.

In this design the chassis frame design of Ex. 120 was retained in its entirety with semi-flexible frame, 3-point engine mounting and radiator mounted on the engine nosepiece. The engine was a 4-cylinder un-supercharged 2-bearing job fitted with a " heavy " crankshaft and a light flywheel, but as the result of development work attained the firm's present-day standard stroke/bore for engines of this capacity, 57 mm. bore by 73 mm. stroke, giving a capacity of 746 c.c. A somewhat large and strong four-speed gear-box was developed for this car, together with a 2-plate clutch. Down-draught carburation was also adopted.

The car represented a great advance in detail work and was the first small car in the series to be equipped with a large petrol tank, a feature now considered to be indispensable for small racing cars. That there was ultimately a good deal of trouble with these petrol tanks almost goes without saying, since anyone who has taken part in long-distance races knows how difficult such troubles are to avoid; in fact, it is only this year that the author has succeeded in producing designs of light tanks (24 gauge) which give little or no trouble during a season's racing and may last longer than that without repair.

The type of car of this series had a lap speed of 74·6 m.p.h. at Brooklands with full equipment, and the cars were 1st, 2nd, 3rd, 4th and 5th in the race, thus again winning the team prize. In the next big race, the Dublin Grand Prix, a C. type Midget also won the race.

By this time the development work on superchargers had advanced far enough that it was possible to put forward a conversion set, by means of which the cars could be fitted up in supercharged form. This was all got ready in time for the Tourist Trophy Race at Ulster, the cars being also fitted with much lighter bodies, since the original coachbuilt bodies were on the heavy side. The increased torque had already been taken care of in the clutch and transmission when the car was first designed, so that the fitting of the supercharger was not likely to cause transmission failures. The lap speed of these cars with full equipment was 84·5 m.p.h. at Brooklands and 96 m.p.h. with wings and headlamps removed. The result was another win for the C. type which came home first in the Ulster T.T.

This type of car, and variations of it with a modified cylinder-head and different sizes of supercharger (Chassis Series J.4), has now competed in so many races that its points are well known to many racing men. It must be credited with having produced some of the most alarming alterations in handicap allowances which have yet occurred in the racing game, the handicaps in the 750 c.c. class having to be most drastically revised in consequence of its appearance in the field.

Ex. 127, *Single Seater,* 1932 *Record Breaker* (Fig. 4, Plate XXX).

Following upon the destruction by fire of the old record-breaker Ex. 120, it was decided to put in hand designs for a new one. A conference was held between officials of the Company and Capt. George Eyston and members of his racing syndicate, as the result of which it was decided to produce an angular offset drive single-seater. The resulting car has been such a success that it probably represents the greatest contribution the author has been able to make towards improving the science of designing and the art of building racing cars. It was built three years ago, and at the time of writing is still the fastest small car in the world. It has been re-engined several times to keep abreast of our engine development, and has been fitted with a new body of reduced size, but the rest of the car remains very much as originally designed. The car was not a success at the first attempt, as it was fitted with a chain-driven supercharger and sent to Montlhery before its own supercharger was ready. The chain-driven supercharger obstructed the air flow to the radiator to such an extent that nothing effective could be done about it, and the car had eventually to be fitted with the supercharger equipment provided for in the first design. In this design a chassis frame on the lines of the C. type was used, the track being 3 ft. 6 in. and the wheelbase 6 ft. 9 in.

The nearside side-member is cranked at the rear end to miss the rear axle, which has its centre banjo offset. The engine is mounted at an angle of 7 deg. to the fore and aft centre-line, and the transmission designed to suit, the rear-axle gears being cut at an angle so that the pinion shaft is at an angle of 7 deg. and lines up with the propeller shaft. The driver sits beside the propeller shaft, his theoretical position being also at an angle of 7 deg. parallel with the shaft. The radiator is mounted on the engine, but is square with the fore and aft centre-line. The supercharger is between the front dumb-irons at an angle of 7 deg., in line with the crankshaft, and is geared down to run below engine speed in the ratio of 21 : 27.

While the drawing office was engaged in preparing this scheme and its details, the final form of the body was produced by Mr. R. Jackson, of the Competition Department, whose model so exactly suited the conditions, that the body finally built as a duralumin structure with aluminium panels, is indistinguishable from the model except in respect of size.

Ex. 127 was named the "Magic Midget," and holds all class records in International Class H. (750 c.c.) from one kilometre flying start to 12 hours. Its fastest official lap at Montlhery is 128·6 m.p.h., but up to the present time it has never been fully extended with a modern engine. It was the first small car to attain a speed of 120 m.p.h.

J. 3. *Midget,* 1933.

This type of car was not built for racing, but was adapted from the current production J. type chassis by fitting a short-stroke crankshaft and a direct-driven eccentric-vane supercharger. A number of them were sold as sports models, but one car was allotted for record-breaking and took the International Class H records from 12 to 24 hours.

J. 4. Midget, 1933, Road Racing Car (Photo of car with full equipment, Fig. 5, Plate XXX).

This car was an improved version of the C. type Midget, being fitted with a number of refinements, including a very much lighter body, as standard, and a new design of cylinder-head. The head was generally similar to our previous type, but the inlet ports were turned round so as to be on the opposite side to the exhaust, and 14 mm. plugs were fitted. These alterations were designed to give a better flow of inlet gases and to improve the heat-flow through the head into the cooling water. The head was successful in both respects, and laid the foundation for the increased power output now obtained from the later series engines, in addition to becoming the present standard cylinder-head for production. A number of cars of this type were built and supplied to various racing drivers, the first one turned out driven by the late Mr. H. C. Hamilton winning the small car race in the German Grand Prix. The type has appeared in many races and has a number of successes to its credit.

Series K. 3, Magnette, 1933, Road Racing Car (Fig. 6, Plate XXX).

These cars were first produced for the Mille Miglia Race in Italy, and are somewhat larger than any of the types previously described, being 4 ft. track, 7 ft. 10 in. wheelbase, and fitted with 6-cylinder engines, 57 mm. bore × 71 mm. stroke, having a capacity of 1087 c.c. The general construction of the chassis followed the Midget lines, the engine being mounted on a 3-point suspension, but the radiator in this case was mounted on the frame. A preselector gear-box of the Wilson type was fitted instead of the ordinary sliding gear-box, and the cars were turned out complete with full equipment. In putting forward this design the author had considerable doubts about the possibility of scale effect making it unwise to continue to use a 3-point engine mounting on a larger heavier car. The weather was very bad when the first car was built and ready to go to Italy for an extended road test, and Brooklands was closed for the winter, but testing on the main roads at the highest speeds practicable in the circumstances little was revealed except a somewhat increased tendency to high-speed tramp induced by the brakes. This afterwards necessitated the fitting of torque stay cables, not primarily to take the torque, as the springs carried this easily at a very moderate stress figure, but to prevent the combined rotating and rocking movement of the axle, which is apparent when it tramps. It appears from trials that by preventing the rotating movement of the axle, the periodic rocking movement is reduced to a very large extent, but the cure may not even then be complete at the highest speeds unless the shock-absorbers are adjusted to the best advantage. The new K.3. series won its class in the Mille Miglia and also the team prize, the drivers being The Earl Howe and members of his team. A car of the same series also won the Ulster T.T., the driver being T. Nuvolari, who was chased home by the late Mr. H. C. Hamilton on a J.4. Midget.

Another chassis of the same series fitted with a single-seater body, and driven by Mr. E. R. Hall, won the 500-mile race at an average speed of 106·32 m.p.h.

Ex. 135, *Single-seater* 1934 *Track Racing Car* (Fig. 7, Plate XXXI).

This car, which is in a sense a larger edition of Ex. 120 Midget, was designed specially for record-breaking. The car has also been used for road-racing, and has a spare body of road-racing type. The chief alteration from our previous practice in this design was the use of a box-section frame. The power unit is a 6-cylinder, 57 mm. bore × 71 mm. stroke, giving a capacity of 1086 c.c., the car being thus in International Class G. Although the chassis was originally intended for track work, the car, with its road-racing body, ran second in the Mannin Beg race in the Isle of Man, and then first in the British Empire Trophy at Brooklands, the latter race being round artificial sandbanks. It has since been successfully used for record breaking.

*K.*3. *Magnette, Series* 1934 (Fig. 8, Plate XXXI).

With the opening of the 1934 racing season, it became plain that, with the exception of the Ulster T.T. race for standard cars with normal fuel, all the principal races at home would be for unrestricted racing cars, alcohol-base fuel (or any other fuel) being permitted. To meet these conditions the K.3. cars were altered to suit, a new series being produced with light shell bodies and large petrol tanks forming the rear end of the body-work. Roots type superchargers were also specified, this type being selected to reduce oil consumption. A number of other minor alterations were made to increase the power output of the engines and decrease weight. It was also found necessary greatly to improve the brakes to meet the severe requirements of "round the sandbanks" racing, and this was successfully done in time for the new season's batch of cars. These cars have run well, and one of them, driven by Mr. Norman Black, won the Mannin Beg race. The lap speed at Brooklands for this type of car is 108–110 m.p.h., with a maximum of about 116 m.p.h. under favourable conditions.

Q. Type Midget, 1934, *General Purpose Racing Car* (Fig. 9, Plate XXXI).

This model was designed to meet the requirements of the private owner who wants a small racing car for track work and general racing, being intended to be particularly nice to drive. It is fitted with a 746 c.c., 4-cylinder engine, 57 mm. bore × 73 mm. stroke, with a 3-bearing crankshaft without counterbalances. The body is a light two-seater of regulation dimensions, so that a mechanic may be carried if desired, or if required by the rules of the race. The track is 3 ft. 9 in., and the wheelbase 7 ft. 10 in., the dimensions being large for a car in Class H.; it will, however, comfortably accommodate a 6 ft. 3 in. driver, which seems to be necessary, as for some reason very tall men often seem to want to race in Midget cars. As an offset against the increased size of the car, the engine has been increased in performance to meet the demand for power, and gives 105 h.p. at 7,000 r.p.m. The car is only sold stripped without equipment, but has dynamo, starting motor, a duplex electric fuel pump, and the usual instruments. It is fitted with a special model Zoller supercharger giving an inlet-pipe pressure of 27–28 lb. per sq. in. at 7,000 r.p.m. engine speed; the supercharger runs at 69 per cent of engine speed. The normal lap speed of this type is 108–110 m.p.h., with a maximum of 115 m.p.h., although these figures have, in fact, been exceeded at Brooklands meetings. At full speed the car is quite comfortable and the instruments can easily be read. This type holds the mountain lap record at Brooklands in the 750 c.c. class, and also the International Class H records for the standing mile and kilometre.

N. Type Magnette, Series N.E., 1934.

These cars were produced from standard N. type chassis to meet the requirements of the Ulster T.T. Race. For 1934 superchargers were banned by the R.A.C. and the cars were heavily scrutineered to make sure that no alterations from standard were introduced other than those allowed by the rules. Fuel was also limited to 50 per cent benzol as a maximum. The dimensions of the N. chassis are track 3 ft. 9 in., wheelbase 7 ft. 10 in., and the engine is a 6-cylinder 57 mm. bore by 83 mm. stroke, 1271 c.c. Probably no restriction hit the competitors so hard as one requiring them to use their standard inlet pipes. The cars were designed with light bodies and large petrol tanks, and a full equipment of lamps and accessories. At the last moment it was announced that no lamps were necessary. The drawing-office had great difficulty in designing the tail contours so as to contain all the equipment and the petrol tank, especially as the scrutineer who saw the jobs through from start to finish insisted on the rear body supports being left in just like the standard chassis; however, after an anxious moment when the first body was fitted on, everything went in as planned. The Magnette driven by Mr. Dodson won the race at an average speed of 74·65 m.p.h.

Engine Development.

The racing engine has always been a somewhat frail and fickle power unit by comparison with the normal-duty engines of the same day and generation, but, nevertheless, each discovery which makes a racing engine stronger, or more powerful for a given size and weight, usually finds a repercussion sooner or later in standard practice. This is specially true in the case of the engines under review, as the firm's normal production engines of to-day contain all the best points of the racing engines of a year or so ago, and the difference between the racing engines and the production sports types seems to get less and less every year.

The starting point for the range of cars already referred to in this paper was the 1930 Midget engine. This engine was a 4-cylinder

2-bearing design, having a bore and stroke of 57 mm. by 83 mm., giving a capacity of 847 c.c.

A typical power curve of this engine, taken from a good sample of the type a year or two ago, is given in Fig. 12, Curve No. 1. To develop the engine for racing stronger pistons were fitted, the compression-ratio raised to about 6·5 : 1, and a number of minor modi-

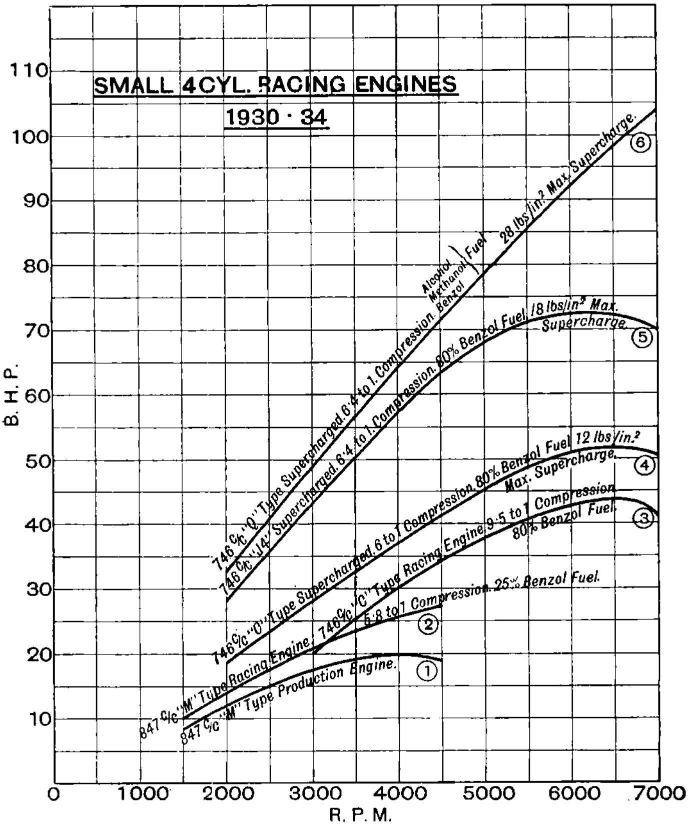

Fig. 12.

fications made, including an improved exhaust system, larger carburettor and a large cast sump to keep down the oil temperature to a reasonable figure when using full throttle continuously. The result is shown in Fig. 12, Curve No. 2, all power curves shown being corrected to normal barometer and temperature, to make them comparative with one another. The m.e.p. of these engines was very low, as may be seen from the power curves, but this does not mean that they were not good engines, as they were extremely reliable and provided the foundation for the development which quickly followed.

For the 1931 season the engines were finally reduced to 73 mm. stroke, leaving the bore 57 mm. This was partly to reduce them to under the 750 c.c. displacement limit and partly to make room for $1\frac{5}{8}$ in. big-end bearings instead of $1\frac{1}{2}$ in. as formerly used. The engines might have been reduced to 750 c.c. by using a smaller bore and much the same stroke as before, but it was felt that, even apart from the question of big-end bearings, 57 mm. dia. was the right size of piston to fit the existing cylinder head, as the volume of raised top piston crown which could then project into the head would be a maximum, thereby making it possible to obtain the highest possible compression-ratio. If the 83 mm. stroke had been retained with reduced bore and the same swept volume, the highest attainable compression-ratio would have been very much decreased.

The crankshaft was designed to be machined from a heavy forging with counterbalances aggregating about 60 per cent counterbalance, including the rotating weight of the big-end bearing. Since the oil was fed into the crankshaft through the rear main bearing, an approximately " circular " oil feed was used from rear to front, to minimize centrifugal effects which might otherwise limit the arrival of oil at No. 1 big-end bearing at the front end of the engine.

The camshaft was re-designed to give a timing more in accordance with current ideas—exhaust opens 50 deg. before dead centre, closes 20 deg. after, inlet opens 15 deg. before, closes 55 deg. after, the same valve timing being in use to-day on all these engines, including the supercharged types.

To cope with surging troubles when cornering and braking, a float-chamber oil feed was fitted to the side of the sump and supplied with fresh oil from a dash tank, thus maintaining the sump at a constant full level. This arrangement is the best possible, as it also maintains the maximum volume of oil in circulation in the engine, which is highly desirable from a cooling point of view, and also complies with the rules in some road races which allow reserve oil to be carried in a tank, provided it is not " included in the oil circulation of the engine." A typical power curve of this engine at 9 : 1 compression-ratio using 80 per cent Benzol fuel is given in Fig. 12, Curve No. 3. With these alterations the power unit really came into its own, and in readiness for supercharging which was to follow, a 2-plate clutch was designed, and a stronger gear-box was provided, the latter being a proprietary unit of excellent make. In this unit also the engine mounting evolved was the type the firm use to-day, except for the addition of rubber cushions between the gear-box and the cross-tube on the later models. A tube of suitable size is passed right through the clutch housing, and extends with suitable fittings right into the channel of the frame, there being no overhung support to twist the side-members. The engine nosepiece, which forms the third point of suspension, was mounted in a rubber bush and carried a suitable bracket for supporting the bottom-mounted radiator.

Later in the season the first supercharged types were prepared, an eccentric vane supercharger being used running at twenty-one twenty-sevenths of the engine speed, and giving 12 lb. inlet pipe pressure at full speed. The fitting of this supercharger raised many problems, the first being where to install it so that there would be reasonable room to expand at a later date. The position finally adopted was between the front dumb-irons, the supercharger being in this case mounted on two cross-tubes by means of four clips, two of which have rubber bushes in them. Some difficulty was experienced in designing a suitable universally-jointed coupling shaft, owing to the limited space available ; a full universal was required to allow for relative movement between the engine and the supercharger and also some end-float to allow for any end movement of the crankshaft, which it was felt must certainly not be communicated to the supercharger reduction gear. The type of joint finally detailed for the job is based on a design formerly used in an old-fashioned friction-drive car, and consists of four steel balls half recessed into a spherical end fitting. The exposed parts of these steel balls engage in four grooves cut to suit in the housing. The strength of these joints is, for their size, remarkable, as they will easily break the coupling shaft without sustaining any damage. They also allow for end movement to quite a considerable extent, the coupling shaft in practice being left to find its own position with coil springs at each end. A power curve of this engine is shown in Curve No. 4, Fig. 12, using 80 per cent benzol fuel, a 6 : 1 compression-ratio, and 12 lb. per sq. inch inlet-pipe pressure at full speed.

For the 1932 season the bore and stroke of this series of engines remained unaltered at 57 mm. by 73 mm., but the cylinder head was re-designed, a task always involving considerable difficulty when a high performance as regards power output has to be guaranteed by the designer. In this re-design the first step taken was to consider a wide range of types ; several semi-spherical head designs were evolved with both single and twin camshafts, and a variety of freak heads with various forms of valve gear were contemplated in sketch form. Against these a re-design of the existing head was undertaken, the objects sought in this case being improved inlet-port shape and area, better conditions for the water passages from a foundry standpoint, and an attempt to improve the shape of the top of the head in directions which it was thought would improve the flame control, as signs of irregular burning had always been discernible with the old head. It was found in this design that 14 mm. sparking-plugs would have to be used to make room for the desired inlet ports, and this caused considerable concern at the time when this head was on the drawing board, as this size of plug was in an exceedingly undeveloped state at that date, and there was a long period of anxiety on that score to follow when the racing season began. After all, machining costs won the day, as the revised head could be produced, so far as machining is concerned, with a minimum of alteration from the existing equipment. The head was a complete success straight from the drawing board in all respects, except for the fact that when fitted as a conversion to existing cylinder-blocks the rearrangement of the valve ports necessitated several water holes being added to the existing blocks, which weakened them so much that the cylinder-head gaskets failed to stand up.

The crisis occasioned by this contretemps left all concerned for the moment helpless in the face of a whirlwind of advice, cries for help from infuriated racing men, and downright criticism from some of our strongest supporters, who felt that the new head was fore-doomed to failure with its gasket troubles and its 14 mm. plugs.

Goaded on by despair, the author risked all by starting over again, and forgetting all previous experiments as if they had never happened. The re-start began with high-pressure grease experiments in an old cylinder-block having the bores closed by brazed-in plugs representing the pistons. The grease escaped at a low pressure and told the story that the joint must be self-sealing in spite of considerable deflections of the head and block which could not possibly be remedied by any alterations. A grease pressure of 1,000 lb. per sq. in. would bend the head and spring the block against any simple joint, and the test was conclusive. Various self-sealing joints were hurriedly made and tested, the first one being nearly successful, but blowing after a few laps. A steel gasket made from good grade sheet, dowelled to the head, was then tried, the edge of the gasket being stepped back $\frac{1}{64}$ in. to $\frac{1}{32}$ in. round the combustion space of the head in an attempt to make a self-restoring burnt oil seal—we have never blown a gasket on a racing engine since.

The reaction set in, the 14 mm. plugs improved with each new type tested, the new head had won. Curve No. 5, Fig. 12, shows a typical bench test with the 750 c.c. engine and the new head, the fuel being 80 per cent benzol and the compression-ratio 6·4 : 1, maximum inlet-pipe pressure 18 lb. per sq. in.

Apart from variations of small detail, no important change occurred until the Q. type engine of 1934, still 57 mm. bore × 73 mm. stroke, development of which started in the autumn of 1933. In this engine an attempt was made to push the engine up to about 140 horse-power per litre, a figure calculated to set the pace again in the small-car class. The development also had for its final object the proving under the severest conditions of the structure of the new P. type Midget production engine, which utilizes the same cylinder block and head, although with a longer stroke crankshaft. Roller bearings, floating bearings, and all kinds of water cooled and oil cooled bearings had been reviewed on paper for this engine, which was to have a third main bearing for the crankshaft, but when the decision was made, it was decided to try and carry on with white-metal. The white-metal has made good to such an extent that no counterbalances are used on the crankshafts, and none are necessary. The metal used is a well known brand to a published specification, success being primarily due to the strength of the job and a careful study of the deflections involved in the engine and its bearings. The whole valve gear, except the valves and springs, is standard production material of the present day. A high-pressure supercharger of the Zoller McEvoy type is provided, running at 69 per cent of engine speed with an internal tooth reduction-gear similar in type to the gears used on the older models; the inlet-pipe pressure is 28 lb. per sq. in. normal maximum. A dummy clutch which slips when hot at 1·25 times engine torque was designed into the flywheel, which is lightened to a mere shell, and a Wilson 4-speed box is fitted behind it. This engine with alcohol fuel produces a power curve such as Curve No. 6, Fig. 12, which was taken from a stock engine as sold for racing. The engines do not give too much trouble, and on the whole the Q. type unit looks like a stable type.

There must be very few poppet-valve enthusiasts who will not look at this power curve and say " I told you so," although, actually, the performance of this unit does not apparently approach the ultimate, so far as poppet-valve engines are concerned. These engines are at present run on a methanol-alcohol-benzol-petrol fuel, which is supplied as required by the principal petrol concerns.

The development of the 1,086 c.c. 6-cylinder supercharged racing engines follows so closely on the 4-cylinder types, that, in the main, what applies to the one covers the other. There has been, of course, nothing corresponding to the 4-cylinder, 2-bearing crankshaft condition to contend with, as all the 6-cylinder engines in this series have been of the 4-bearing type. On the other hand, the 6-cylinder engine does have troubles of its own, especially in relation to distribution and consequent inlet manifold design. This trouble is lessened, but not cured, by the use of superchargers, and it is only by careful experiment on the individual engine type that a 6-cylinder engine can be made to yield a 50 per cent increase in power over the corresponding 4-cylinder. Actually, of course, it should yield more than this figure, as usually the auxiliaries are not increased in proportion, but in practice at present the 6-cylinder engines give only just about the same m.e.p. as the fours, whether supercharged or not.

Supercharging.

This subject is so controversial at the present time that it is necessary to adopt a certain amount of reserve in making statements in regard to it. The author has tried in development work on racing engines to approach supercharging without prejudice and from a strictly engineering standpoint. In general there seems no reason why a pump for feeding the engine with its supply of air and fuel should be regarded with any more suspicion than a pump for supplying it with oil, water, or any other fluid, the only question is whether the pump is worth having or not from a performance standpoint. So far as engine performance is concerned, if measured in terms of horse-power per unit of piston displacement, then the supercharger is an obvious accessory to a racing engine, but at present it appears that there are, in fact, certain important limitations. The chief of these are:

(*a*) The quality of fuel required.
(*b*) The amount of oil required by the supercharger.
(*c*) The difficulty of obtaining suitable sparking-plugs.

With un-supercharged engines it is usual to rate the fuel on a basis of its " highest useful compression-ratio," the ratio being generally taken as the ratio of the apparent initial volume to the apparent final volume. This ratio is, of course, somewhat vague, since the initial volume may easily be affected by the fact that the inlet valve does not close at the bottom of the stroke, and the final volume, while it cannot be more than the volume of the cylinder-head above the piston, may conceivably in effect be less, owing to inertia effects, unless it can be assumed that the instantaneous compression-pressure in all parts of the cylinder-head is uniform, which seems rather a doubtful assumption. However, taking the usually accepted meaning of " compression-ratio " and " expansion-ratio," if the compression-ratio of an un-supercharged engine is raised apparently two things result, first, the compression-pressure is raised, and, secondly, the shape of the combustion space is usually spoiled. The second factor is at least as important as the first, and detonation sets in, partly because of the increase in pressure, and partly because the facilities for flame travel in the head are obviously impeded by the very bad shape. By introducing a supplementary pump or supercharger, it is possible to raise the compression-pressure without spoiling the shape of the head, thus making it in effect possible to use a much higher overall compression-ratio. Unfortunately, the proceeding does not improve the true " expansion-ratio," but makes it in principle somewhat less in proportion than it was before the supercharger was fitted, the effect being like an arrangement giving two different strokes, an increased stroke for induction and compression, but the original stroke for expansion.

The supercharger also, due partly to various inefficiencies, requires a certain amount of power to drive it, comprising various forms of pumping losses and mechanical friction. Notwithstanding these limitations, the results obtainable are certainly encouraging from a power production standpoint, as represented by a b.m.e.p. of 260 lb. per sq. in. at 7,000 r.p.m., using a 6·4 : 1 compression-ratio and an inlet-pipe pressure of 28 lb. per sq. in., which is at the moment the limit in the production types of racing engines under review.

If fuels continue to improve at the present rate, and power units continue to grow smaller to make room for increased passenger accommodation, luggage accommodation, etc., then it may be that superchargers will become an every-day fitting on touring cars—all the problems involved would gradually sort themselves out, since they are not fundamentally insurmountable.

The oil consumption of superchargers is a serious matter, since all the oil which actually finds its way into the pump itself either intentionally or unintentionally eventually gets into the inlet pipe and then into the engine. This fouls the exhaust and oils up the sparking-plugs, the latter point being a serious handicap on racing engines.

In our practice several different makes of supercharger have been used, comprising eccentric-vane types and Roots types. The centrifugal type has not been used, as it is difficult to apply to small engines for road racing conditions, although ideal for aircraft engines and other fair-sized units, while it can, if desired, be used to give the characteristics already well known in connexion with the American Graham installation on touring cars.

A typical modern high-pressure supercharger of the Zoller McEvoy type, as fitted to the Q. type Midget, can be seen in Fig. 10, Plate XXXII, complete with reduction gear, which reduces the compressor to 69 per cent engine speed, and a typical Roots installation at engine speed can be seen in Fig. 11, Plate XXXII. In both cases the installation is carried out between the front dumb-irons, as a conversion from our standard units, but in any case it would be difficult to find room for such large carburettors, etc., on our small cars in any other position without restricting the air flow round the engine under the bonnet, which would considerably increase the supercharger and inlet-pipe temperature as well as the temperature of the power unit in long-distance races.

Chassis problems encountered have been numerous and varied, and in some respects, in the author's view, are almost worse than engine problems, because test bench-data are not obtainable to the same extent. This paper being essentially intended to be a general survey, is not the place in which to enter into too close contact with any one problem to the exclusion of others which may be of interest, and we must therefore take clear points which definitely affect the racing cars under review, which the author proposes to do by giving a summary of the firm's practice.

Chassis Frames.

With the exception of the Magnette single seater EX. 135, which has box-section side-members, all the designs have been based on frames of quite ordinary construction, having channel side-members. Tubular cross-members have been used throughout on all types, with brazed fittings, such as are ordinarily produced in the cycle trade. Frames of this construction have the advantage that they can flex without imposing high stresses on the joints. The earlier cars had bolted-up frame assemblies, but the practice has now been discontinued, as it appears to be unnecessary, riveted assemblies being just as satisfactory. All the M.G. frames are assembled at the works, and there is therefore no doubt as to whether they are square and properly riveted. The rear end of the frame passes under the rear axle, and spring slides are included in place of shackles. Frames to this design may truly be said to be trouble-free, some of the first cars built, which have been raced for years, still having their original frames, including even the Magic Midget, which has never needed a new frame, in spite of the many races in which it has competed.

Springs.

Plain leaf springs of silico-manganese steel are used on all these cars. The rubber stops for both front and rear axles are set at positions which prevent the material being overstressed at maximum deflections, a precaution which is necessary to prevent the risk of the springs settling. The springs have normal eyes at the front ends without bushes, and are ground at the rear end where they enter the slides. The springs are bound with insulation tape and corded; this does not increase the rate per inch of the springs, but holds them together better than any form of spring clip, so that their resistance to driving torque or brake reaction is very dependable, a characteristic which helps also to steady the suspension. Rates per inch are somewhat higher than standard touring practice in the case of the faster cars.

Front Axles.

As regards the axles themselves, these are of conventional design, being, generally speaking, the firm's standard production axles converted for racing use. Ball bearings are used for the hubs, and provision is made for the Rudge-Whitworth type of wheel with a knock-on hub-cap. This type of wheel fixing is surprisingly reliable, only one instance of failure having occurred, which was due entirely to a wheel disk (it was the offside rear wheel) being nipped against the spokes so that the hub cap never went home on its taper, an accident for which the method of fixing was in no way to blame. This incident caused quite a stir at the time, and in fairness to the wheel makers the true facts are worthy of record. The information is at first hand, as the author was in charge of the pit and was responsible for the entrant being requested to withdraw the car from the race in the interests of safety, as a complete examination of the cause of the trouble could not properly be made in a hasty manner.

As regards track-rod and drag-link arrangement, steerings have all been transverse; a somewhat unconventional arrangement is, however, used on all the later types, a link being mounted on the axle beam and moved by the drag-link, the motion being communicated to the wheels through two independent track-rods, a system now commonly referred to as the twin track-rod system. The benefit of this arrangement arises from the fact that the track-rods operate with much greater rigidity in tension than in compression. With the twin track-rod arrangement the inside front wheel on a curve is always steered by a track-rod in tension and *vice versâ*, causing the car to steer to the right with the same " feel " as to the left, which was not the case at high speeds with the more normal arrangement where the offside front wheel was controlled by a long track-rod which might be either in tension or compression, according to whether the car happened to be turning to the right or to the left.

The good and bad points of the conventional front axle have recently undergone a tremendous amount of investigation from a mathematical and experimental standpoint, and the results have been incorporated in several very able papers read before various technical Institutions. The good points being accepted, the outstanding bad point has always been the tendency for a conventional front axle to tramp at high speeds when the brakes are applied. The motion when studied is an oscillation of the front axle about a fore-and-aft axis located approximately at the centre of the beam, coupled with a rotational oscillation of the axle about a transverse axis passing through the springs which are immediately under the axle beam.

The trouble is alleviated by using torque stay cables, which, although quite unnecessary for taking braking torque *per se* with such strong front springs, limit the rotation of the axle sufficiently to prevent the tramp becoming serious. If the shock-absorbers worked against a solid anchorage they might also be expected to prevent this movement, but in practice tightening the shock-absorbers beyond a certain point moves the frame instead, and the energy dissipated is reduced below the optimum figure. The use of multiple shock-absorbers on the front axle is also successful, provided that they are so arranged that rotation of the front axle alone is able to move the shock-absorbers, in addition to their being moved by a true up-and-down axle movement.

Rear Axles.

Provided that the rear axles are able to transmit the maximum torque, there seems little to do to make an ordinary design fit for racing, except to follow the almost universal practice of fitting straight bevel gears for all serious races. The straight bevel does not reverse its thrust on the over run, and this greatly aids the pinion-shaft thrusts.

Trouble with oil getting into the rear brakes is almost certain to arise, especially in races where the car is always turning one way round, but the development of spring-loaded leather oil seals seems to have cured this, after many other devices have been tried with no great success. Chrome-tanned leather is essential, or at any rate a chemical tan ; simple oak bark-tanned leather is not suitable.

Brakes.

As speeds have increased so much in recent years, attention has had to be focussed seriously on braking problems. At a deceleration of 32 ft. per second per second the speed dies down by 10 m.p.h. during each half second approximately, but the energy dissipated in the time is the loss of kinetic energy between the two speeds in question. Wind resistance, although appreciable at high speeds, makes but little difference to the stopping distances when decelerations of this order are in question, and the fact has to be faced that at a uniform rate of deceleration more energy is dissipated in the brakes when slowing from 100 m.p.h. to 90 m.p.h. than would be expended in slowing from 40 m.p.h. to a standstill.

The result is an alarming rise in the brake temperatures when heavy braking is used at the higher speeds, as is often the case nowadays when the pits hang out the " flat out " signal towards the end of a closely contested race. Furthermore, as the rates of deceleration increase, the time available for cooling decreases, nearly all the cooling being of necessity, therefore, carried out in the interval of time which elapses before the brakes are used again.

To decrease unsprung weight, the brake-drums also must be as light as possible, the total heat required per degree rise in temperature of the drum being proportionately reduced, unless some material with a proportionately higher specific heat could be utilised.

It is not for the author to embark here on a discussion as to the merits and demerits of the three main systems of brake actuation, by hydraulic pressure, by brake rods or by flexible cables ; a strong case can easily be made out by the supporters of each system. All these cars have had cable brakes for two main reasons : firstly, that they can easily be made independent of axle movement ; and secondly, that no ordinary crash can disconnect all the brakes even though the axles themselves are injured. Cable actuation has its limitations, most strongly emphasised in respect of the maximum permissible cable load which can be employed without causing "spongy" brakes, a point in connexion with which satisfactory information in plain engineering terms is not issued by cable makers. To provide great deceleration with a low cable load and a normal pedal pressure, the author and Mr. C. Cousins jointly evolved a design of cable gear in which inner cable and outer casing each work a brake-shoe, thus halving the cable load or doubling the force of application, whichever view is preferred. The two brake levers draw together like the handles of a pair of nut crackers and roll on each other by means of suitable rollers, the cams also rolling back to back as they expand the shoes. To centralize the shoes and permit no unexpected movement to take place, a coupling link is arranged connecting the two shoes, so that if one shoe moves the other must move also. This link acts as a safety device to prevent the brakes grabbing at high speeds, since if the resultant thrust from the brake-drum onto the leading shoe should accidentally pass across the shoe fulcrum, the couple so produced has to apply the opposite shoe, which, in the nature of things, is "toeing off" instead of "toeing on," owing to the rotation of the drum. In practice it is possible, owing to the limitation of this couple to a reasonable figure in the worst event by the geometry of the layout, to arrange that the fulcrum of the coupling link between the shoes is not fixed, but is only very stiff to move. If, therefore, one brake-shoe makes contact with the drum before the other, the first heavy application of the brakes can move the fulcrum centre so that both brake-shoes make contact and remain centred in future. The cams also permit of this movement by sliding over one another sufficiently to suit, after which they resume their normal rolling action. The brake-drums used with this gear are of cast elektron with shrunk-in steel liners, and the brake-shoes are of rolled mild steel T section.

This type of gear is now fitted to the K.3. type 6-cylinder racing cars which are fast enough to require the special arrangement. During the 1934 racing season these cars have repeatedly gained on other competitors by leaving their braking later at all corners and have continued to do so for hours on end. Sets of brakes used in the International Trophy, the Mannin Beg race and the Empire Trophy still have on them the original brake linings with which they were first assembled, and are still fit for several more such races, a state of affairs which indicates the great improvement which has been made.

Wheels and Tyres.

The fact that standard Rudge-Whitworth pattern wire wheels are used has already been referred to, and beyond this there is little comment to be made, as this type of wheel is so well known. On the K.3. cars triple-spoke wheels with extra wide hubs were specified, after careful tests on one of the Mille Miglia cars in Italy, to allow for the very severe conditions which exist in a race of that description; but on the other types of cars standard side-spoked wheels have always been used. In spite of the high standard of excellence which has been reached by modern wire wheels, the author still feels that some way ought to be found to reduce the weight of the wheel equipment if at all possible. At the moment a set of five wheels and tyres constitutes no small fraction of the total weight of a modern small racing car, built for general racing purposes, and lighter methods of construction would be very welcome.

Racing tyres fall into a class by themselves since they are only supplied by the principal tyre companies for bona-fide racing purposes. The reason for this is not that the racing tyres are superior to ordinary tyres at all, but that they are unsuitable for prolonged daily use. The tyre companies explain that the rubber used has a *higher coefficient of thermal conductivity than the* standard grades, and a lower wear value. On the track the heat generated is so great that the question of thermal conductivity is of the greatest importance, and a tyre of normal construction would fail by heat and not by wear.

The familiar white " breaker strip " under the tread of the racing tyres acts as a warning that the tread is worn through, and in long races all four tyres on a racing car are sighted from the pits all the time, so that should the white strip show, the car can be called in for a wheel change—a smart business to watch when a good crew is carrying out the job. It is usual to specify racing rims for high-speed work, these being slightly larger on the tyre seat circumference, and rolled with a shallower well than standard, to reduce the risk of a deflated tyre flying off the rim.

The specifying of " racing rims " also acts as a warning to the wheel makers to assemble the wheels with an extra high spoke tension if they think it necessary.

Wheel balancing is essential and is usually carried out by mounting the wheel on a spare hub assembly having the felts or oil seal removed, so as to leave only the friction of the ball bearings, the actual balancing being carried out with lead wire. The fitting of racing tyres must always be carried out by men who understand the work, as unless the tyre is fitted perfectly truly before inflation is completed, the tyre may be strained by the pressure in use and become incurably crooked, so that it is of no use for high-speed work.

Propeller Shafts.

Standard propeller shafts have always been used for racing. Generally speaking, on these racing cars the torque loading on the joints is far below what is usual on a commercial vehicle with the same size of joint, and failures on that account are not, therefore, particularly likely to be experienced. Failures by critical speed are, however, a certainty, and would be very dangerous were it not for the fact that the critical speed can be accurately ascertained in advance by calculation. It is the author's experience, and this is confirmed by at least one of the principal producers of these shafts, that the actual critical speed of commercially produced shafts may fall to 80 per cent of the figure for an ideal shaft of equivalent proportions, but not lower than this, and that even on this basis a 10 per cent margin of speed is the minimum safe margin. The basis of engine speed must be taken with the car going all out down hill and down wind, with the lowest rear-axle ratio listed for the model fitted, and the 10 per cent added as a minimum. On the later racing cars shafts with a very large margin of safety are fitted as regards critical speed, but on some of the earlier models, if owners fitted very low axle ratios for such purposes as " round the mountain " racing, it was just possible to reach the critical speed of the shafts provided, and failures were experienced.

Gear-Boxes.

The subject of transmission, of course, includes the gear-box, and on these cars both Wilson type self-changing boxes and ordinary sliding gear-boxes have been used. While it is perfectly true that some drivers can and do make wonderful changes with ordinary gear-boxes, everything being equal, the Wilson-type box obviously holds the field so far as racing gear changes are concerned. At first, when these boxes were used, there was quite a crop of rear-axle troubles due to the very merit that the gears could be changed so quickly. The box used had a very ample torque carrying capacity, and when sudden changes up were made, the flywheel torque, brought about by its very great deceleration, injured the rear-axle gears with the greatest of ease. The remedy adopted was to strengthen the rear-axle parts concerned. On a later design, the Q. type Midget, a different and much prettier method has been employed. A clutch is mounted in the flywheel and slips at a torque which, when multiplied by the bottom gear reduction, is just safely within the torque-carrying capacity of the rear axle. There is no means provided for working the clutch except that it is caused to slip by sudden gear changes either up or down, but as the Wilson type brake bands are self-wrapping in a driving direction, it is natural that it is more likely to slip when changing up than when changing down.

Radiators.

Generally speaking, radiators have not been a cause of much anxiety. As previously mentioned, the radiators on most of our racing cars have been mounted on an extension of the engine nose-piece, although in one or two instances a trunnion mounting from the frame is used. Both methods of mounting are satisfactory, the choice depending on the circumstances. When a semi-flexible frame design is used, the radiator is best mounted on the power unit, as any serious radiator shake is certain to be communicated by roundabout ways to the front axle, and may cause front end instability. Both film type and honeycomb radiators have been employed, the former being preferred in the ordinary way owing to the fact that they are generally somewhat lighter. On single-seaters with streamline bodies, the space available for the radiator is so restricted that the honeycomb design is generally to be preferred, since it lends itself much more readily to the construction of awkward shapes of film block. It is seldom possible to get an adequate frontal area on radiators of this description, and the use of an alcohol-base fuel becomes almost essential in order to utilize the latent heat of evaporation of the fuel as a means of helping to cool the engine. Oil cooling is also a difficulty in the restricted space available, the method employed on these designs being a large sump with ample cooling fins, thereby doing away with external pipes to an oil cooler, a method which would, however, be less suitable for larger power units owing to scale effect.

Steering Gears.

The author has never been satisfied in regard to steering gears, as the information issued in respect of these assemblies is always much too vague and frequently quite misleading from a technical standpoint. Statements in regard to "frictionless steering gears," and such like remarks, may be good publicity, but they are not good engineering. If all that was required was to connect the steering wheel to the drop-arm by a mechanism of definite ratio with a minimum of friction, a pair of well-cut gears with their spindles mounted on ball bearings would meet the case almost perfectly. Unfortunately, such a gear would be so nearly perfectly reversible, that the car would become completely uncontrollable at high speeds. Quite apart from the question of ratio, therefore, the reversed efficiency of the mechanism from drop-arm to steering wheel becomes of the greatest interest, and any frictional effects in the gears which affect this reverse efficiency from drop-arm to steering wheel also affect the forward efficiency from steering wheel to drop-arm, which immediately becomes very much less than 100 per cent. In the simplest case, if all the friction in the mechanism were journal friction and due to the load, the gear would become irreversible from drop-arm to steering wheel, irrespective of its ratio when the forward efficiency from steering wheel to drop-arm was exactly 50 per cent, and if the forward efficiency was more than 50 per cent, the gear would not be irreversible. Even allowing for the effect of the helix in practical designs, the forward efficiency of the gear at which it becomes irreversible always works out at $\frac{\tan \theta}{\tan 2\theta}$, where θ is a small angle, or expressions of that kind, or, in other words, very close indeed to fifty per cent. Owing to the limitations of practical leverages in the linkages, it is frequently not possible to attain the desired number of turns of the steering wheel from lock to lock without calling for a steering box having a different ratio from that previously used, and always when this is asked for the steering manufacturer promptly responds by supplying a gear having a different helix angle, or what amounts to a different helix angle. In addition to altering the ratio, this has completely altered both the forward and reverse transmission efficiencies of the gear, generally with bad results. The effect in practice is only too likely to be a rush to find out whether anyone happens to make a steering gear which by accident will be on or near its correct transmission efficiency at the ratio required, information which can only be obtained by trial, since the necessary engineering data on this point are seldom, or never, supplied by the different makers. There are several steering-gear makers to-day, whose designs are such that by allowing in the first instance for worms of various diameters, they could give all the change of ratio required without any change of helix angle, and as an additional refinement, could give slight variations of helix angle at any ratio, so that all requirements could be suited. In practice the best steering gears appear to have a forward transmission efficiency somewhat in excess of 50 per cent at light torque loads falling to just about 50 per cent at heavy torque loads on the drop-arm, an effect apparently due to a change in the coefficient of friction with load in the steering gear itself. This results in the steering being " self righting " after a corner, *i.e.*, reversible at light torque loads and irreversible to heavy shocks, *i.e.*, irreversible at heavy torque loads. It is in this respect above all others that the performance of the different makes of mechanism is most noticeably different on test.

It is greatly to be hoped that better information on these points will be forthcoming in future, and the author feels sure that steering-gear makers will find that even the most hard-boiled customers, who appear to think of nothing but price and delivery, would respond in the long run to the opportunity to get exactly the characteristics their jobs demand.

Petrol Tanks.

These are the *bête noir* of the racing car designer, and have often been known to give trouble. The requirements are only too frequently very difficult to meet, the tanks often being of the most ungainly shapes in order to get large capacity without destroying the room available for carrying spare wheels, hood equipment, etc. In addition, chassis frame flexure and considerable road vibration have also to be allowed for. Requirements in respect of filling are becoming more and more severe, one gallon per second being no longer considered any too quick for filling. The author did not construct satisfactory petrol tanks of light gauge material until the 1934 season, when the whole subject was drastically dealt with by starting all over again. In the new designs, the tanks are built up in a cellular manner, the internal baffle structure being riveted in all directions to form the cells. Considerable scope for ingenuity exists in arranging all the internal joints so that they can be successfully riveted, since, unless this can be done efficiently, the results will be a failure. The tanks are held down in position by means of cables which pull them down into a suitable bed of india rubber. These tanks weigh about 2 pounds per gallon complete, and up to the present time have given no trouble or shown any signs of local weakness.

Bodies.

The racing bodies fall generally into two types, single-seater bodies for track racing, and bodies built to comply with the international rules for road racing with full equipment. The present tendency in both cases is to make the bodies as light structures which are easily detachable, the latter feature being important from the point of view of chassis examination and maintenance. Single-seater bodies as used on these racing cars consist of a Duralumin structure built in the form of lattice work and girders, and panelled with thin sheet aluminium. The Duralumin girder work is essential on streamlined single seaters, owing to the length of the tail, which is necessary to ensure a satisfactory amount of "weathercock" stability at high speeds. With bodies of rough outline the question of stability is not very likely to arise, owing to the heavy stern drag which tends to keep the car steady at full speed, but as soon as a smooth outline is adopted allowing the air to close in again as gently as possible behind the car, instability may easily set in unless the body is correctly proportioned.

Bodies built for ordinary track racing show a tendency to become merely shells, either fitted to or encasing the petrol tank. When a tail is used, it is often short, and does not need a special internal structure, the panel itself being sufficiently strong when beaten and welded to the shape required. The bodies are usually mounted on rubber blocks and no doors are used, partly for reasons of strengthening the body and partly because there is a much greater feeling of safety in a body which has no doors to fly open. Bonnets are usually of aluminium alloy, and fitted with straps to prevent any risk of their becoming accidentally detached, which might be a serious matter for other competitors following on behind.

In regard to bodywork, the author considers that a few remarks on streamlining should be made, as the subject frequently crops up in connexion with racing cars, and has recently attracted a great deal of attention in connexion with new season's styles of saloon bodies. To dogmatize on this subject, would, of course, be unwise, as actually very little is at present known about the streamlining of complete motor cars, at least so far as published information is concerned. In the realms of theory, remarkable investigations have been made in recent years by various workers in the field of pure aerodynamics, and the results published, and, indeed, made use of to a considerable extent; but in the realms of practical daily construction, it is only necessary to look at the majority of military aircraft to see how far they depart, for various reasons, from the shapes they ought to follow if other circumstances permitted. In a sense the same applies to racing motor cars; such wind-tunnel tests as we have had made have proved that in the absence of a suitable artificial ground, and spinning wheels, the conversion to full-scale results is liable to be very disappointing, the amount of power actually required being anything from 60 per cent to 80 per cent greater than the estimates submitted by the wind-tunnel investigators. On the other hand, we have proved by actual speeds attained that for a given frontal area the streamline car is definitely considerably faster than the car of more normal shape, provided that it has a smooth-shaped body all the way from nose to tail, and a length great enough to allow of very fine lines.

So far as interference from the wheels is concerned, it seems certain that it is not a good thing to have the wheels too close to the body, and it is very doubtful whether wheel fairings as such are justified, on the score of head resistance, unless they are arranged so as to allow an unimpeded flow of air round the body. On the score of safety, wheel fairings are much better omitted, so that the tyres can be seen as the car goes by and the driver signalled, if necessary.

The Testing of Racing Cars.

It has always been the firm's policy to test the first or " type " car of each new series of racing cars at Brooklands very carefully before releasing the model to the racing public. During the last twelve months of the War, the author had the job of being sent personally from Headquarters at Hesdin to any Squadron in our line in France which happened at the moment to be paralysed or nearly paralysed with the aeroplane troubles of the period. A catalogue of the troubles and breakages which caused the bother would lead anyone who remained on such work too long to begin to feel that all flying consisted of fires, engine trouble, and wings coming off, *ad lib*—an effect solely due to excessive contact with such trouble. The cures had to be the cures of the period, drastic but effective. The testing of new types of racing cars always brings back to the author the recollections of those days, and the feeling of wondering whether any serious mistake has really been made anywhere, and, if so, what it is.

The usual procedure for testing is for the car to be run-in for some hours at steadily increasing speeds, with an experienced member of the works staff at the wheel. During this period it is most closely watched to determine exactly how everything is working, and whether anything is running hot or going to give trouble. The running-in period applies more particularly to the chassis than to the engine, as the latter has, of course, been run-in on the test-bench and passed off at full power on the correct grade of fuel, carburettor setting, etc. Running-in is often carried out on ordinary 75 per cent benzol fuel, even when alcohol fuel is specified, since during this period full throttle is not called for, a " medium " grade of racing sparking-plug is also all that is required, as the " hard " plugs which stand full throttle are exceptionally sensitive to oil.

When all is ready, the carburettor setting is altered to suit the specified grade of fuel for maximum power, racing plugs are screwed in, and the trials proper begin. At first the acceleration of the car is carefully checked to ensure that the " getaway is clean," and when the desired speed is reached, the ignition switch is switched off on full throttle, the car being coasted in for the plugs to be removed for examination. To an experienced eye the state of the plugs tells the story, mixture setting, distribution, any hot cylinders, anything unusual either generally or in any one cylinder.

All being well, the car is wound up to full speed for general steering and stability tests. Brooklands is an ideal place for this purpose, since it is possible to travel much too low and too high on the banking, and thereby determine a great deal in regard to the steering, and there is a flat turn to the right at the fork which can be exaggerated as required by leaving the turn too late, for testing control when skidding at speed.

Suspension also is given a thorough test, as in places the track is sufficiently bumpy to cause an unstable car to sway from side to side for a considerable distance after striking a bump ; the " bumps " are, of course, only very slight waves in the track, and can mostly be avoided, but for suspension tests it is usual to seek them out instead of avoiding them, and the result at speed is a jolt of surprising severity until the correct adjustments for the suspension have been found. The author finds that waves in the track which cause a severe bump to one car do not of necessity affect another to anything like the same extent, and variations in weight distribution produced by moving anything heavy like a spare wheel or a battery may have a considerable effect in improving matters or making them worse. This is only natural, since the centres of percussion corresponding to a blow at the front or rear end of the car may easily be moved into a more favourable position by a redistribution of the weights. If too much weight is removed from the rear end of a car the position of the centre of percussion corresponding to a blow from the rear axle, combined with reduced rear-wheel adhesion, generally causes the car to zig-zag on full throttle. The full reasons for this movement have not been ascertained, and the effect may be either controllable, in which case the driver gets used to it, or uncontrollable beyond certain throttle openings, in which case it limits the speed of the car. On this, the 1934 season's K.3 test car, after finishing the full-speed trials, the author carried out some very interesting trials with the new twin-lever cable brake gear, especially in respect of the safety link intended to prevent the brakes grabbing, and in regard to cooling. The procedure at first was to run up to about 100 m.p.h., and then brake hard down to 20 m.p.h., continually repeating the test to see when the brakes would " fade." Some fading, of course, always occurs, but with the latest design it is surprisingly small. As confidence increased, wheel-locking tests began, and all four wheels were eventually locked on the railway straight at 90 m.p.h., long enough to enable the observers beside the track to watch the movements of the car. As seen from the driver's seat, the movement is never perfectly controlled, the car snaking from side to side to some extent as long as the wheels are actually locked. By releasing the brake pedal slightly better control is immediately established the moment the wheels begin to revolve. The deceleration appears to be perceptibly improved by keeping the wheels just short of the skidding point ; in fact, when sliding with all four wheels locked at high speed, the impression is gained that the car would slide for a very considerable distance if only it could be controlled.

Tests of this nature provide the most surprising items of information at times, generally in connexion with some part of the car which no one anticipated would cause any trouble, even such a matter as a badly shaped seat, for example, being made quite clear by the size and position of the bruise which it very easily causes.

In conclusion, the author would particularly mention his indebtedness to Messrs. C. Cousins and A. V. Oak, who have contributed so much to the development and designing work involved, and to many skilled helpers who have done their utmost to make the cars a success.

Special mention should also be made of Mr. Cecil Kimber, Managing Director of the Company concerned, who has always given every possible encouragement to these efforts.

THE DISCUSSION.

(LUTON.)

Mr. G. F. GIBSON, in opening the discussion, said : I cannot help but feel that the paper has a specialised objective, and I wonder how much of it can be readily adapted to modern orthodox automobile engineering. The objective, of course, is that of obtaining the highest torque output per c.c. of cylinder volume, and general experience indicates that the limiting factor in power output is not perhaps sparking-plug design or troubles in connexion with the cooling, but lack of general refinement, attendant upon the development of a high figure of m.e.p.

Another point of interest is economy. In the case of a racing car, this does not matter a great deal from the point of view of petrol and oil consumption ; at any rate, there is no need to strive for that " last mile per gallon." This, however, does not apply to the ordinary car, where economy must be studied from all aspects.

Mr. R. PENTONY : The author has made some severe remarks about the makers of steering gears, and as one of the culprits he is no doubt expecting me to say something in reply. It is really quite refreshing to find somebody interested in steering gears at all, as in the whole of my experience I have only found two firms who showed a real live interest in their internal mechanism. The normal requests run : " We have designed a new 5-ton vehicle ; please let us have your quotation for the necessary steering gear " !

The author makes rather a point of the helix angles, and the ability to vary the ratio, but to maintain the same helix angle by altering cam diameters, and it might be interesting to know that we sometimes do this, but more from a commercial point of view than for technical reasons, and whereas it is important to keep the helix angle closely within certain limits, I do not agree that a change in the helix angle alters the transmission efficiency, but it does vitally affect the characteristics of the gear.

I think the efficiency remains much the same, but it does entirely alter the " feel " of the car ; but quite apart from that, the helix angle has to be made to suit the class of car to which the steering is fitted and the correct helix angle most suitable for the small racing cars dealt with in the paper is quite different from that required for commercial vehicles.

There are many points which are more important than the question of helix angles, and although the information is available it would probably not be wise for steering-gear manufacturers to publish a lot of data about the mechanical efficiency, as at the present moment it seems to be generally thought that the gear with the highest mechanical efficiency must be the best, whereas a gear that can automatically distinguish between light and heavy loads is much better than one which may have a higher efficiency all through. This important point is brought out very clearly in the paper.

Steering gears should be considered more broadly. I should like designers to consider the steering gear as a whole right through from the steering wheel to the road ; taking this line of approach one of the most important things is the front-axle design, and the connexions between the drop-arm and front axle are seldom right. The results of spring deflection also are often not properly appreciated and castor action needs more attention.

An enormous load can be put on the steering through flexibility of the springs if the ball pins of the front-axle lever and the drag-link are not in correct position, as the springs do not move in harmony. Designers do not seem to appreciate the load that can be put on steering gears from that point of view or from the sudden application of front-wheel brakes. It is not fair to say to steering-gear makers " Supply us with a steering gear for such and such a vehicle " without giving proper details of the rest of the layout. I feel very strongly regarding this and wish steering-gear users would take the manufacturers more into their confidence.

Finally, the author says that he hoped that better information on these points would be forthcoming in future, with the result that steering-gear makers would find that even the most hard-boiled customers would appreciate the advantages, instead of studying nothing but price and delivery. This is no doubt quite right so far as the technical department is concerned, but in the end negotiations have to proceed with the gentleman who is asked to " sign on the dotted line," and it is remarkable how many really technical questions are solved by finding the correct answer to the two questions " Who pays ? " and " How much ? "

Mr. G. PROPERT : I am particularly pleased to hear the remarks about steering gears. On another point the author referred to brake linings, and the result of some tests he carried out, but he did not say who was staggered by these results, and I am wondering whether it was the manufacturers of the brake linings or the manufacturer of the car. If it was the manufacturers of the brake linings who were staggered, then it must have been to their satisfaction.

May I ask what is the effect of disk wheels on motor cars ? Streamlining is known to be an important factor, but as regards wheel disks, although these would appear to be very helpful, there may be another side to the question. Further, regarding supercharging, is the eccentric-vane type or the Roots type preferable ? Superchargers of the vane type may be unsuitable on account of the amount of oil that enters the units, and from this point of view the Roots type may be considered preferable.

Finally, has the author any comments to make following his recent visit to the Berlin Motor Exhibition ?

Mr. H. O. FIELD : I have three questions I should like to ask. The first concerns the very earliest " M.G.'s " put on the market. These were sold as 8/33 h.p., and in view of the power curve produced in the paper, I should like to know how these figures were arrived at.

The second point is in connexion with road springs. Surely, if the springs are corded up the effect is comparable to rust between the leaves, which reduces the amplitude without effecting the natural period of frequency.

Thirdly, as regards those engines which are run at a b.m.e.p. of 260 lb. per sq. in.; how long is their racing life, and how long would these engines stand up to this load on the test bench ? Would it be out of all reason for, instance, to leave them under such conditions during a luncheon interval ?

There is one other question I should like to ask the author : how is it that the " M.G.'s " racing in the last T.T. suffered from such excessive wheel-wobble, when compared with their competitors ?

Mr. E. SWAIN : I believe that racing—taken up by a firm that does its job properly—forms the finest advertisement, whether the result be wins, losses or even break-downs. To my mind the details published in the motoring Journals create an impression which eventually enhances the reputation of the firm.

Years ago, as is well known, our firm was interested in the racing business and at that time an m.e.p. of 130 was thought to be high, but 240 m.e.p., as mentioned in the paper, is certainly amazing.

I should like to know what oil temperature the author can arrange to keep down to ; this is a very important factor. Also will he state what kind of troubles he obtains with big ends, and what clearances he allows. Another point I am not quite clear on is valve setting. From the expe-

(Mr. E. Swain.)

rience I have had with superchargers, I have found that it is necessary to shorten the dwell of the valve opening to prevent "blow back," even with 12 lb. per sq. in. in the intake pipe. The M.G. Co. seems to get away with even an abnormal overlap.

I cannot fall into line with the remarks regarding small high-speed engines fitted with superchargers with the attendant troubles, such as noise, being fitted to the bigger type of car, *i.e.*, the motor carriage. At any rate, it must be a long time before that stage of development is reached, since simplicity must remain the keynote of good design.

Mr. F. WESTCOTT : Has the author found it necessary to take any special action with a view to reducing the weight of the chassis, particularly as regards materials, special metals, or design ? Our firm is always being urged to "get the weight down" ; commercial limitations are hampering. I shall also be interested to know the weight of the chassis per horse-power that the author regards as most suitable.

Considering the enormous performances obtained from the German cars with the independent suspension, it would be interesting to know whether the author regards this as an aid to high performance, as the "knee action" design is adopted by our company more on the score of comfort. The Germans, however, seem to be tackling this problem from the point of view of control at high speed.

Our Company has paid a great deal of attention to dry friction shock-absorbers, and the tendency now seems to be towards the hydraulic type. Here again considerations have been in the direction of passenger comfort. Sports cars are fitted with both types, and I do not know which is definitely the best policy, but perhaps the author will enlighten me.

Finally, there is the vexed question of rear-axle attachment. The tendency in the case of commercially produced cars is towards the Hotchkiss type, and I should like to hear his views on this question.

Mr. K. C. HUNT : I think the author is rather pessimistic as to the limitations of supercharging. There is the question of fuel required : provided the inlet temperature is kept down by intercooling and the compression-ratio of the engine dropped suitably, then the limitation on the engine is set far more by the available heat flow than by any limitation in octane rating of the fuel.

Oil consumption is not now serious, consumption varying from 1000 m.p.g. for racing to 3,000 m.p.g. for touring.

It would be interesting to know if sparking-plugs are affected by supercharging, as this seems to be a very open question. Salt-cooled valves seem to help the sparking-plug question considerably, together with thick-crown pistons. I am also very interested in the reliability of supercharged cars. After all, I think curve No. 3, illustrating the unsupercharged "C" type, has the same horse-power as the "Q" type supercharged engine at 2,500 r.p.m., which means that the "Q" type is running at one-seventh of the intertia load of the "C" type for the given horse-power.

Also, has the author any data regarding the relative efficiencies of Roots and vane type compressors running at over 15 lb. per sq. in. boost ?

Mr. CHARLES, in replying on the discussion, said : I can assure Mr. Gibson that racing furnishes us with a splendid "testing ground" for all sorts of things, such as brake linings, brake-drum material, wheels, valve material, piston material, white metal, oil, etc. The ordinary motor car must benefit indirectly by the fact that we are a proving ground for such items as I have mentioned. We do not, of course, help on the questions of cellulose finish and silence.

As regards Mr. Gibson's remarks about power roughness, it is obvious that the m.e.p. of a commercial engine twenty years ago was much lower than it is to-day. A 10 h.p. car of to-day is giving off much more power than a 20 h.p. car of twenty years ago. Just how far this development will go depends very largely upon the quality of the fuel. The quality of the present-day ordinary fuel on the market in this country is remarkable for increased efficiency, without " knocking."

It is quite true that the building of racing cars does not prompt economy in any particular direction at all—except in " time." They are usually designed, built and, of course, used in a hurry.

I much appreciate Mr. Pentony's remarks and I sympathise with the man who is trying to sell steering gears to people who think of nothing but the price of the gear, particularly when asked to supply a steering gear for a 5-ton lorry, with no other details of the vehicle for which such gear is required.

I have asked in the paper for co-operation between steering-gear manufacturers and chassis manufacturers. The characteristics of the steering gear are quite complicated, and I should like to see some of its characteristics recorded.

As to brake linings, a point raised by Mr. Propert, the trouble was that our brake linings hardly lasted out one race. and we always said that the linings were rotten, and left it at that. As this policy seemed no good, we changed our attitude ; we assumed the linings to be good and the brakes wrong. This we actually found to be the case, and the improvements which have been made are in the brakes—not in the linings—which will now last almost indefinitely.

Front wheel disks do affect steering in a side wind, due to the fact that the centre of lift—in any sort of aerofoil section—is never in the middle. In the event of a gust of wind striking the car, an astonishing " lift " can be experienced, making control of the car exceedingly difficult. Our practice has been to leave the front disks off unless there is no wind.

People have different views on the design of superchargers, and each thinks he is right. There is a considerable amount of competition going on at the present time, and first one system and then another gets ahead. Makers of superchargers of all types have lately improved the oil consumption, and no doubt before very long it will be possible to obtain 6,000 to 8,000 m.p.g. Superchargers certainly call for a reasonably large engine, and a reasonably good cylinder-head. With the gradual improvement of fuels which is taking place, and if superchargers can only be made silent enough, then I think that their adoption may come in to a greater extent than many people think.

In reply to Mr. Field, what I have said in the paper about springs is quite correct ; our spring tester is of the " weight " variety ; we have a number of old iron gratings and hang them on the spring. The 500 lb. weight is not a matter of doubt ; it is a matter of fact. If a spring is so loaded it becomes slightly softer when taped and bound—the binding gives perhaps the world's finest spring clip, because when the brakes are applied the tendency is for the leaves to bend out on one side.

As regards testing, we do not have any air blast on our test-bench, which is rather hard on the engine. We can certainly hold full throttle at 6,000 r.p.m. for an hour on the test-bench, but we should only expect to maintain 7,000 r.p.m. for about 10 min., chiefly due to the absence of an air blast.

At Brooklands we can maintain 5,000 to 6,000 r.p.m. for a long time, but under those conditions there is a good air blast through the bonnet, and I have come to the conclusion that track conditions at 100 m.p.h. are better than our test-bench conditions.

We had fitted brake stay cables on racing cars to prevent wheel-wobble in the T.T., but under the rules we were not allowed to use them, and the cars had to enter the race minus their brake stay cables. The rules, how-

(Mr. Charles.)

ever, allowed for any type of shock-absorber being fitted—we fitted four on the front axle.

I certainly agree with Mr. Swain that racing is very good for publicity, and if a car breaks down during a race people may sympathise once, but if breakdowns occur too frequently their sympathy turns to laughter and sympathy finishes.

As far as the 240 lb. m.e.p. is concerned, this is not considered high to-day, largely through the efforts of the chemists. As regards oil temperatures, our experience is that the oil leaving the bearings of the engine is about 15 deg. C. higher than the oil in the sump, and for castor oil the temperature of the oil in the sump should not exceed 85° C.

Curiously enough, the oil cooling may be of no use whatever on the test bench; a layer of cold oil is formed over the surface of the sump and acts as a conductor. Yet the moment the car gets on the road or track that method of cooling is found to be perfectly successful.

We are rather proud of our big ends; we make them float, and the situation with us to-day is that a white-metal bearing will turn black, and if such blackened bearings are wiped the scraper marks will be seen. They never touch the shaft at all. The combined inertia and gas loads on the main bearings amount to just over 3 tons per sq. in. on these engines.

With regard to pistons for racing purposes, we use aerolite pistons, with about 0·006 in. clearance. These pistons are oval, and it seems easy to get a racing engine to free off with such pistons. These pistons are also used as standard; we have tried others, but with no better results.

The majority of the heat in the piston crown goes into the piston rings. I do feel that we are on right track in this direction, because we know that if one of the piston rings is taken out the horse-power of the engine drops considerably.

With regard to the timing used with superchargers, I am not an authority on valve timing; quite possibly there is a better timing than ours, but it is the best we know of at the moment.

It certainly will be a long time before superchargers are fitted on a very large scale to small engines. They are used simply to increase the power of the engine, and if it were necessary to increase the power of a small engine by, say, 20 per cent the method would be to increase the size of the engine. The only way, however, to get more power from an existing engine —without roughness—is by fitting a supercharger.

On the subject of weight reduction raised by Mr. Westcott, I cannot say anything at all, except that our racing cars are built just as cheaply as the production cars, and they are not sold at high prices. The ordinary track racing midget car, with every available kind of modern improvement only sells at £650 or so, and these are only put through in small quantities. In the past, the question of weight reduction has not been considered; we have taken the standard parts and made any slight alterations which might have been necessary to adapt them for the racing type of car. Speaking generally, the alterations have tended to increase the weight rather than reduce it, such, for instance, as the fitting of a heavier crankshaft. We have only built one car which could be said to be really light, that is the "Magic Midget"; we had to make a special rear axle for it, which cost about £120. The body only had one seat. The weight of the car, unladen, was 10½ cwt., the engine being a J.4 of 746 c.c. capacity, which gives about 80 h.p. to the half ton. With a modern engine of 100 h.p., which would ratio out at about 200 h.p. per ton, this should give quite a good performance.

As far as the German cars are concerned, I visited the German Show, and although the cars were very closely guarded by steel-helmeted guards, I managed to find out that the engine is of very light aluminium construction, giving about 265 h.p. The gear-box was mounted Citroën fashion. The engine would not weigh more than 1½ lb. per horse-power. By the look of it, the gear-box would weigh about 80 lb. and the rear axle appeared to be in the region of 120 lb. The frame appeared to be very light and the radiators were fixed at the front end of the frame. The driver sits just behind a transverse steering gear.

There is an enormous ratio of power to weight in the German racing car, which weighs, including fuel, water, and everything else necessary, about 14 cwt., with a power output of something like 265 h.p.

My view is that there is nothing to touch a properly designed hydraulic shock-absorber, and we have used both the hydraulic and friction types. The hydraulic shock-absorber manufacturers have collaborated with us very closely on the problem, and I feel that they will soon be able to give any characteristics required.

Regarding the Hotchkiss drive as against the torque tube, we use the latter chiefly because it is cheaper. As an engineering job the torque tube is a great help towards obtaining a silent rear axle. It has one serious objection, however, that the whole arrangement of the torque tube and rear axle forms a letter " T," which is liable to be strained out of square. Unless the positions of the torque tube and rear axle are perfect there is considerable strain on the torque tube, pulling the axle out of square with the torque tube. Allowing for first-class assembly or some sort of adjustment whereby shackle angles can be corrected quickly on assembly, I think the torque tube is better than the Hotchkiss drive.

The points raised by Mr. Hunt are very interesting. With regard to the fuel, we have always adopted a rather curious policy in our experiments, by not lowering our ratios. Lowering the compression-ratio does not improve matters as regards knocking, beyond a certain point. About 6 : 1 or 6·4 : 1 compression with our engine is the bottom ratio for supercharging. The conclusion we have come to is that each concern must ascertain the conditions which are best suited to their own engine. We have dropped the compression-ratio on some of our engines to 4½ : 1, and it does not seem to make anything like the difference that might be expected.

Regarding the heat flow the engine will take, that seems to be entirely up to the engine itself. If the horse-power of an engine were to be doubled, unless some drastic alterations were also made to the heat flow conditions, serious trouble would ensue.

Sparking-plugs and oil consumption are subjects of careful consideration in racing cars. If the consumption is too high, sparking-plugs will not last in a racing engine for any time at all.

We have never been able to afford such things as salt-cooled valves so far, but some day we may make some experiments in this direction.

As regards reliability, I think the supercharged car will be very reliable as time goes on, if only by the mere fact that it does develop so much power and all of it is not used often on the road.

(Bristol.)

Mr. W. Lewis Morgan, in opening the discussion, said: The paper, though it deals only with light vehicles, is, nevertheless, interesting to those concerned with heavy vehicles, because we often look to the experience and data obtained from racing-car work to guide us in dealing with problems arising in the design and operation of our own type of vehicle. From my experience, I am surprised to hear that the author has had no trouble with valves, running as they do at speeds of 7,000 r.p.m. in high-efficiency

(Mr. W. Lewis Morgan.)

engines; I should have expected that one of his major problems would have been keeping the exhaust valves sufficiently cool, and controlling the wear rate of valve seats. Has he experimented with stellited valve seats, or has he found that the rate of wear in his engines is not sufficient to justify the cost?

What type of petrol feed device has the author found most successful for racing-car work, an autovac or an electric or mechanical diaphragm pump? We have found that for public-service vehicle work the most reliable and efficient arrangement consists of a diaphragm pump actuated by an eccentric on the camshaft, which feeds a subsiduary tank of about 1 gallon capacity mounted above the carburettor, so that the feed from the subsidiary tank to the float chamber is by gravity only. Fuel level in the subsidiary tank is maintained by means of a large float working on a lever giving a 3 : 1 mechanical advantage over the needle valve which controls the supply. This device removes from the carburettor needle the duty of resisting the fluctuating pressures encountered on the delivery side of a mechanical pump, and has been found to be the most reliable method of fuel supply at present available.

Since racing cars have to be provided with silencers at Brooklands, has the author any data of the effect on b.h.p. of various types of silencing arrangements used for high-speed work?

My own experience in regard to brake trouble exactly corresponds with that of the author, namely, that the cure for most of the ills experienced is within the province of the brake-drum manufacturer. We used to suffer severely from brake squeal, drum scoring and the attendant ills, and constantly experimented with various special brake linings with indifferent success. The introduction of centri-cast iron drums and drum liners, and nickel-chromium iron alloys put an entirely new complexion on things, and we now find that the particular type of fabric liner used has a negligible effect on the performance, the material of the braking path itself being nearly all-important in this respect. Possibly weight is a factor which militates against the use of such drums for small racing cars, but it occurs to me that nitrided steel drum liners might be used with great advantage in this connexion.

The advantages of independently sprung wheels appear to be so overwhelming for road racing, where adhesion and stability are of vital importance, that I am astonished that British manufacturers have not given it much more attention in the past. A good deal of interest has been manifested in independent springing on the Continent for some years past, but we in this country are only just beginning to toy with the idea. Various spasmodic experiments have been made during the last twenty years, but as far as I am aware, no British manufacturer has really "got down" to it for production or racing purposes. Why is this, and what are the author's views on the future of this type of suspension?

Mr. L. E. W. POMEROY, Jun.: The author refers to the inefficiency of superchargers on account of the power required to drive them; I do not propose to state that superchargers do not require power for driving purposes, but I do wish to show that there is some return for the expenditure of power.

Before proceeding further, I should like to ask him if he agrees that on a normal engine, a fair assessment of the pumping losses will be 10 per cent of the b.h.p.?

Mr. CHARLES: Yes.

Mr. POMEROY: Then, if we take the Q type Midget as an example, the normal pumping losses of this engine if it were supercharged would be 10 per cent of 108 h.p., namely, 10·8; having established this, it is necessary to observe that on this highly supercharged engine there is actually an m.e.p. on the inlet stroke of 28 lb. per sq. in., which is worth approximately 11·8 h.p. Adding these two together we find that the total gains as a result of supercharging amount to 23·6 h.p. Now without disclosing any confidential information, I can make the definite statement that the power required to drive the compressor on this engine is well under 25 h.p., and so if the most pessimistic outlook is taken the net loss balancing power required to drive the compressor, against power returned by it, is under one h.p., whereas, comparing the b.h.p. given by the engine with that of the best unsupercharged type shown in the curves, there is an increase of no less than 64 h.p. I think everyone will agree that to gain 64 h.p. by an overall expenditure of 1 h.p. is a very fine technical achievement. The possibility of obtaining such results is, however, entirely dependent upon the overall compressor efficiency, which in turn is a function of mechanical efficiency, compressing efficiency, and what I must term for the want of a better word " aerodynamic efficiency."

Regarding the first two subjects I will not speak, as information is readily obtainable from various sources on these matters, but the last is interesting, and raises some novel issues. For many years it was known that on vane type superchargers the power required to drive went up disproportionately with increase in speed, and it had always been assumed, even by the manufacturers of these types, that this was due to mechanical losses. Later researches, however, showed that exactly the same phenomenon was noticeable on Roots type blowers, where it seemed impossible for friction losses to have any effect. I therefore looked for some common feature of the Roots and vane type which would account for this, and yet would allow for the fact that centrifugal compressors did not exhibit the same characteristic. I think that the explanation is almost certainly to be found in the fact that whilst over part of the pumping cycle the mixture is trapped between two rotors or blades and carried round between them at a common speed, over the arc subtended by the inlet orifice, the blade or rotors sweep across the mixture which is travelling at a relatively slower speed, as it has been accelerated from rest at the mouth of the carburettor possibly only 4 in. away. Over this portion of the cycle, therefore, it is reasonable to expect the power required to drive the blade to go up as the square of the difference in speed between the blade and the incoming air. Hence for all displacement types of blower or compressor it is reasonable to suppose that it will be more efficient to run at slow speeds than at high, which is in accordance with the observed effects on those types at present available.

Turning now to the matter of compression-ratios and superchargers as given by the author, I should like to point out that the H.U.C.R. of an engine is determined by the shape of the cylinder head, the pressure to which the charge is compressed, and the final temperature of the charge. Granted that suitable intercooling is employed, supercharge affects only one of these factors, namely, final compression-pressure, since the shape of the combustion remains the same, and the final temperature of the charge depends upon the compression-ratio in the cylinder and the initial temperature which can be held to approximately the same figures with supercharging as without. For these reasons it is not necessary to drop the compression-ratio for any given fuel in proportion to the supercharge, which results in the high-pressure supercharged engine being considerably more efficient than might be theoretically anticipated.

Finally, I should like to point out that the advent of compressors which will remain efficient at high supercharge pressure offers a means of substantially increasing effective engine capacity without raising engine r.p.m. So long as engines are unsupercharged, or can only be supercharged up to low pressures, the only way of increasing effective capacity for a given size

(Mr. L. E. W. Pomeroy, Jun.)

is obviously to raise engine speeds, a most wasteful procedure owing to the very rapid rise in friction horse-power.

The use of an efficient high-pressure supercharger does, however, offer the opportunity of obtaining large increases of effective capacity at quite moderate speeds, thereby securing an engine of exceptionally high overall efficiency. This has implications for the touring car as well as for racing cars, as it is well known that there are considerable difficulties in making a quiet and smooth touring car engine to operate at high revolutions.

Supercharging at low revolutions eliminates difficulty, and at the same time provides the moderate sized British car with a top-gear performance strictly competitive with those commonly known as the American type.

Professor MORGAN: Would you not use a mixture rich in Methanole ?

Mr. M. A. McEVOY: The author speaks of the large quantity of oil required by superchargers ; this certainly was true in the past, but I think he ought to give a little thought to the problems which are involved. Very small quantities of oil have to be pumped at one moment into a piece of mechanism against a pressure of 28 lb. per sq. in., and the next moment a depression of 14 lb. per sq. in. is trying to draw it out of the pump. Pumps used in the past were converted motor-cycle oil pumps, and not adequate for these special conditions.

Specially designed pumps have overcome this difficulty. I think that plug fouling is far more due to the fact that on small racing engines a large inlet pipe has to be used to accommodate the large volume of gas, which means that when idling there is likely to be a certain amount of fouling due to wet fuel and not to excess oil. Unsupercharged racing cars are just as troublesome with sparking-plugs as supercharged ones, in fact I know a great many that are more so.

As to the choice of sizes of superchargers and the speed at which they are going to be run, the author has stated that there is an advantage in running the supercharger at less than engine speed. This is a point which is much more important than is generally realised. In the past, with Roots blowers, when the speed of the supercharger was very high it was found that a point was reached when the ultimate pressure could go up without any corresponding improvement in power. The vane type was used and some improvement was found, and when the larger vane types were introduced still more improvement was gained.

The horse-power required to drive the supercharger, however, still went up more rapidly than the theoretical power required to compress the air used, which made people put it down to friction losses. The same occurred with the Roots blower, which obviously has very low friction losses. On the other hand, the centrifugal type supercharger runs best at very high speeds. As comparing the two, the air flow through the centrifugal type is obviously superior to either the Roots or the vane type.

This led us to experiment with vane type superchargers having ports giving a continuous flow rather like a centrifugal, and this has shown great improvement and confirms our belief that owing to the disturbances of the air round the vane tips the vane type supercharger should be of such a size as to give the required pressure for normal maximum r.p.m. at a compressor speed not exceeding 3,500 r.p.m.

A great deal can be done with the shape of the inlet port, and greater attention should be given to the attachment of the carburettor to the supercharger. Superchargers have been given the credit for improving distribution, which is a very important point for the touring-car engine. A supercharger is the only method of increasing the m.e.p. without any increase in engine roughness.

Mr. EGAN STORM: I am not sure what the author means by a recessed type of gasket. Is the face of the head and block recessed to receive it, or does the " recessing " amount to a hole in the gasket of slightly greater area than that of the combustion chamber ?

The author considers the M.G. head shape to be the best for that engine, but would not an hemispherical form be more efficient from a combustion standpoint, and that of allowing higher compression-ratios to be used more economically ?

On the " P " type engine the author has greatly increased the power at high r.p.m. without supercharging, and yet he uses a very easy convex cam. How does this agree with the fact that higher volumetric efficiency calls for more rapid inlet-valve opening, and cut-off, which was thought to be best obtained with a tangential if not hollow flanked cam ?

Mr. A. CUDDON-FLETCHER : The author states that the exhaust-valve temperature in the M.G. cars is very low. He gave no explanation for this, but I think it is primarily due to two things, one being the use of almost pure alcohol fuel and its very high latent heat, and the other that, during the induction stroke, the exhaust valve is more or less sprayed with alcohol vapour, especially in a supercharged engine.

Aeroplane manufacturers have definitely found that the power they can obtain is limited by a red-hot exhaust valve, and their only way to increase the power per c.c. is to have a greater number of smaller cylinders, which immediately puts up the machining costs. The alternative is to do away with the exhaust valve as such, and put a rotary or sleeve valve in its place. The latter seems to be very inefficient, both as to the port areas available and as to its actuating mechanism. It is almost impossible to transfer the necessary heat through to the cylinder wall, as it has first to pass through the sleeve valve, especially in the case of the double-sleeve engine. I have seen a rotary valve which is very efficient. In the case of the 2-stroke engine, using a rotary valve in the head as an inlet, a considerable part of the bottom end of the stroke is lost, corresponding to some 120 deg. of crank travel. That can be recovered by putting the inlet in through the base in a blown engine, and at the same time putting up the port area multiplied by time factor, so that the volumetric efficiency of the 2-stroke engine can be made *superior to present-day 4-stroke practice*. Thus the output of any 4-stroke engine and the torque can be doubled at the same speed. This does away very largely with the necessity for 4- or 5-speed gear-boxes. As an example, a 500 c.c. engine on these lines can have a power output equal to that of a 1,000 c.c. supercharged 4-stroke engine.

Further, owing to there being no local hot spots, such as an exhaust valve, the compression-ratio can be usefully raised to 10 : 1 *on a straight petrol ;* this obviates the necessity for using alcohol with its attendant disadvantages of high cost and low calorific value.

Mr. J. M. SAUNDERS : I notice that whilst transmission and rear axles are mentioned, there is no mention of differentials. With high-speed cars wheel spin may occur, and for a time we tried a differential with a species of free-wheel to drive both forwards and backwards when driven from the axle end. Owing to the difficulty of turning, when only the inner wheel was driven, we did not proceed further with it.

Capt. A. C. BURGOINE (Chairman) : The work of designing a small racing car is very fascinating. The author has carried out this experimental work at a very low cost, but some of us have to carry out somewhat similar work on very much larger units, thus making the cost much greater.

For the steel gasket referred to on p. 511, does the author use asbestos filling or a steel washer ? Regarding superchargers, the author mentioned the oiling up of plugs and trouble with bearings. I believe the Roots blower only functions well at moderate speeds.

Mr. CHARLES, in replying on the discussion, said : To take the Chairman's question first, the gaskets which we use are really very simple. All we do is to cut a steel gasket from 20-gauge panel material and dowel the gasket to the head, lap the head to the block and nip the gasket in, and before long the head seals itself. We had a car which had lost all its water during a 500-mile race owing to a broken connexion, and came into the pits with the head red hot and the gasket blowing. We fitted a new water connexion and in three laps the head sealed itself again and the car finished the race in good time. Pre-ignition is the thing that damages the gasket. With a 6·4 : 1 compression-ratio the maximum pre-ignition pressures are very considerable. The heads can be seen to jump on the test bench when pre-ignition occurs.

We have not ourselves had very much trouble with superchargers in the mechanical sense, because we have never run them at very high speeds. For motor cars the most successful types all run, if anything, below engine speed. Regarding the amount of power required to drive them, on the whole, my opinion is that eccentric vane superchargers run at three-quarters engine speed, represent the best thing available at the present time, and I think they would last as long as the engine.

Our petrol tanks are made of 24-gauge sheet steel. The ideal shape for a petrol tank would be spherical, giving the maximum of volume with the minimum of surface. The biscuit shape is the worst.

Replying to Mr. Morgan's questions, the scale effect would come into the matter of valves. Doubling the diameter of the valve gives four times the area, and the conditions I imagine must be very much worse on big engines. It is, however, very curious that the engines which are worst for valve heating are those which are not supercharged. On our very fast track-racing engines blowing at two atmospheres or so the valve temperatures are very much lower. The only trouble we have had with valves was due to cracks in the forgings. The aeroplane engine builders have got crack detection down to a fine art. We find our cracks out when the part breaks.

For petrol feed we use a simple electric pump made by an associated company. All our record-breaking cars have an air pump worked by the driver in the ordinary way, and we have also tried a connexion from the inlet pipe which takes the pressure from the supercharger. A small non-return valve is screwed into the inlet pipe and a release valve on the tank. Generally speaking, the supercharger is working 50 per cent of the time, which is enough to keep the pressure of the tank up.

I cannot claim to have much to do with silencers. Racing cars are fairly noisy, in spite of the Brooklands Regulations. Our experience leads us to believe that loss of power is greatly affected by the distance of the silencer from the engine. If the silencer is at the rear of the car it has very little effect on horse-power. The ordinary Burgess silencer put at the rear end of the car made no difference in horse-power at all, and yet it quietens the car considerably.

The brake-drums we use are made of a high-manganese steel, with about 40 per cent carbon. They have a very good hardness and wearing quality. The use of this steel for brake-drums was due partly to accident. The manufacturers found that this steel was about the best thing possible for electric butt welding. Then they offered it up for brake-drum test and found it possessed the other merits.

We used Nitralloy drums made from forgings last year ; the makers just hardened them on the wearing surface. Incidentally I found that this steel, although very dear to buy in England, is very cheap in Germany.

The car in which I learned to drive in 1910 was fitted with independent wheel suspension, and I cannot see why racing cars have not been so fitted for years. The Germans have now demonstrated that it is a good thing. A German who has an independently sprung racing car told me that it shoots up to 160 m.p.h. quite nicely, and at 190 m.p.h. it provides really good suspension.

It is rather difficult to reply to Mr. Pomeroy's remarks because he is interested in the manufacture of our favourite supercharger. To some extent I agree with him as regards the power required to drive the supercharger, but I have found the most alarming difference between the power required to drive one supercharger and another. All that power is lost partly in consequence of the power required to drive an inefficient supercharger. If an extra 20 h.p. is required to drive the supercharger nearly all that is expended in heating the mixture. Anything of that kind automatically reduces the power of the engine. One of the reasons why we do prefer the supercharger used to-day on these small engines is that it takes less power to drive it than any we know, and the inlet temperature is low. The fuel is blended by a chemist so as to give a satisfactory inlet pipe temperature.

For quick estimates of fuel consumption we use a rough-and-ready rule. For 10 pints per hour of petrol substitute 9 pints per hour of benzol, 16 pints per hour of alcohol, or 22 pints per hour of methanol. In long-distance races, therefore, too much methanol cannot be used owing to limitations of tank capacity.

Regarding valves, I quite agree with Mr. Pomeroy. The only difficulty is that, unfortunately, all these things have to grow gradually. To be logical, the ultimate motor-car engine will be assembled by the manufacturers to run for 50,000 to 100,000 miles without attention and then be thrown away. Anything of that kind is impossible with the poppet valve as we know it. Our small valves do not give much trouble, as things stand to-day. I note that one propeller-shaft maker has introduced a joint which is lubricated for life. After years of making joints with greasers they are now making shafts for light cars which have no greasers, and they will run as long as the car does. Eventually the motor car engine will be made to run like that.

Mr. McEvoy says that we have now got down to very low figures for the oil required, but I do not think that 3,000 m.p.g. is good enough.

As regards plug fouling being due to the large inlet pipe, as soon as the oil consumption figures get down to a certain point that is so. The engine manufacturer is to some extent to blame as well as the supercharger manufacturer. Any oil getting past the piston is bound to foul the plugs very easily. We have to be very careful indeed with oil control to the pistons. The small quantity getting by in that direction does not seem to oil up our plugs very much. Probably heads vary in that respect. We can, to some extent, distinguish where the oil comes from. Lower than engine speeds are favourable with the vane type supercharger, in the case of the centrifugal type, the air flow through it is smooth and uniform at very high speed. As far as fixing the blower between the dumb-irons is concerned, that is the only place to fit it in small racing cars. I do not fancy myself that a touring car with the blower between the dumb-irons would have a very good sale. As the blower pressures increase on our small cars, the supercharger tends to become nearly as big as the engine.

Regarding the shape of the head, Mr. Storm has put me into a difficult position. I expressly stated I would not say anything about the theory of burning. All the theorists seem to me to be definitely agreed on one point—the fire starts at the sparking-plug!

Regarding cam contours, our views really are catholic and conventional. The great trouble in practice is to make sure of the correct valve-spring pressure. The actual movement of the valve spring, when examined with an oscilloscope, is rather like a Hawaiian dancer. Very often valve failure sets in because the valve-spring pressure that ought to be there is not there. We calculate the theoretical accelerations by conventional methods and peg away until we get the theoretical result.

Tappet adjustment, as far as we are concerned, presents little difficulty. There is no royal road to meet all requirements. The first requirement has to be lightness. The rocker assembly and valve assembly are extremely light and as soon as the weight of the exhaust valve is increased a stronger spring has to be fitted to shut it in time. Weight cutting in valve gear is of paramount importance. We cut the section as low as we dare. The tappet adjustment is an eccentric.

Replying to Mr. Cuddon-Fletcher, our experience of racing cars has been that the exhaust-valve temperature is very greatly affected by the excellence of burning. Exhaust valves do not cause us as much trouble as sparking-plugs. I do not like the 2-stroke cycle ; it idles so badly. The ordinary 4-stroke cycle engine, when idling, discharges practically the whole of the exhaust gas in the up stroke, and idles with a very low compression-pressure.

In reference to Mr. Saunders' remarks, if the wheel leaves the ground the car can continue to be driven whilst one wheel is in the air for a short time. The effect of wheel spin is normally aggravated by light wheels and tyres. The Germans have had to invent a new differential, full particulars of which are not disclosed. If we do succeed in devising very light wheels and tyres we shall have to do something about wheel spin, probably by designing a special differential.

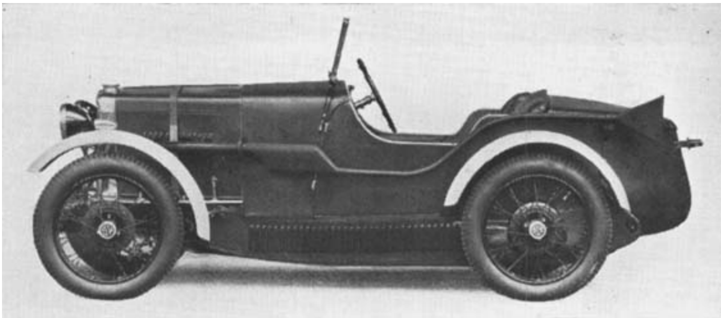

Fig. 1.—M. Type, 1930.
For text reference, see page 502.

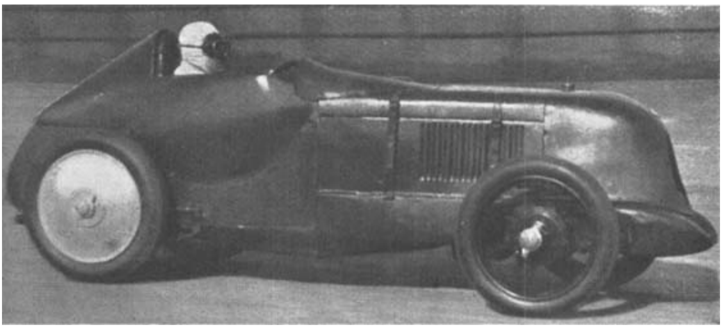

Fig. 2.—Single-seater.
For text reference, see page 503.

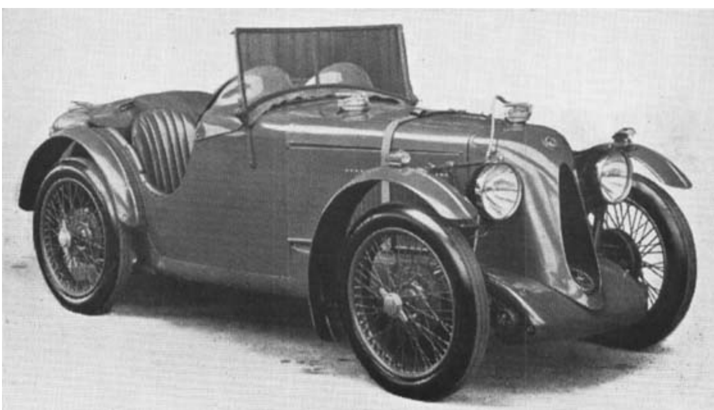

Fig. 3.—C. Type Midget, 1931.
For text reference, see page 503.

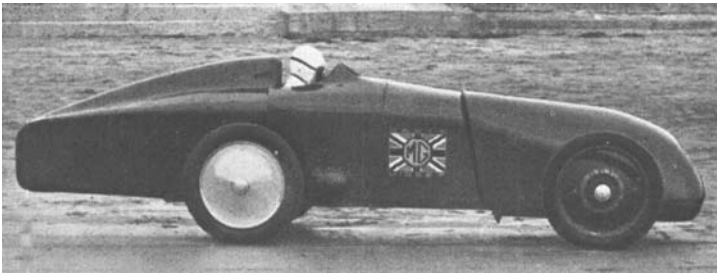

Fig. 4.—Single-seater.
For text reference, see page 504.

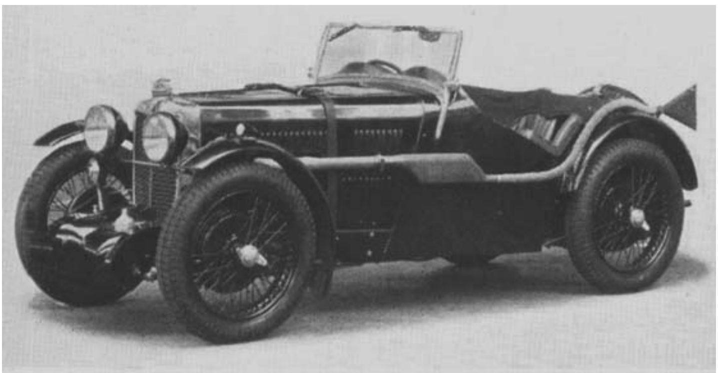

Fig. 5.—J. 4. Midget, 1933.
For text reference, see page 505.

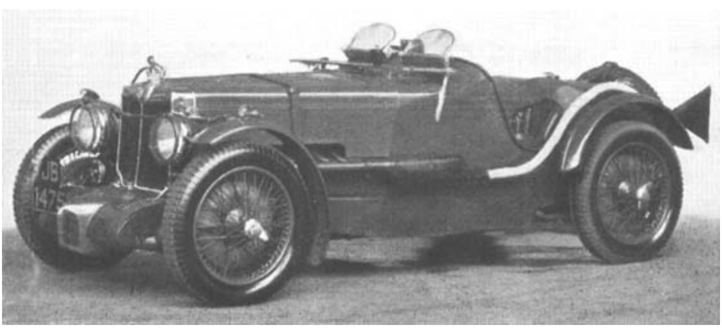

Fig. 6.—Series K. 3. Magnette.
For text reference, see page 505.

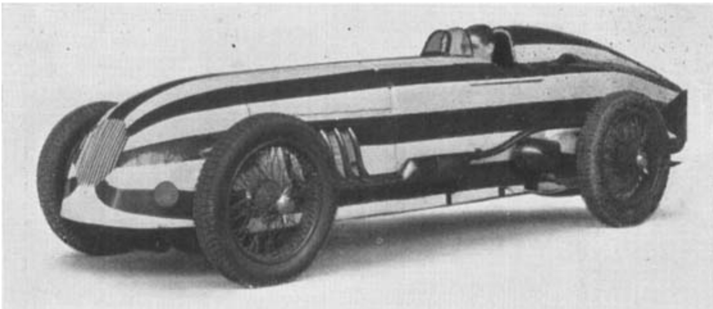

Fig. 7.—The M.G. Magic Magnette.

For text reference, see page 506.

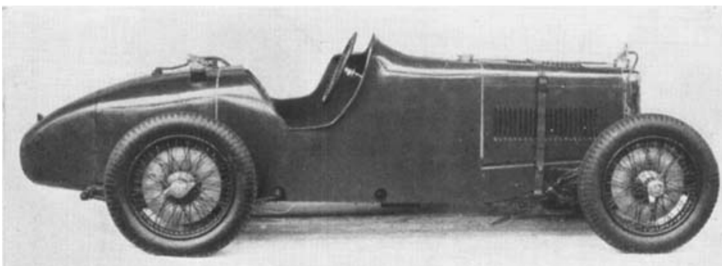

Fig. 8.—K. 3. Magnette, 1934.

For text reference, see page 506.

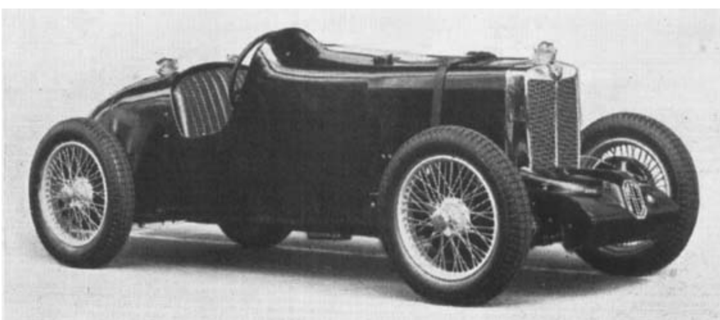

Fig. 9.—Q.Type, 1934.

For text reference, see page 506.

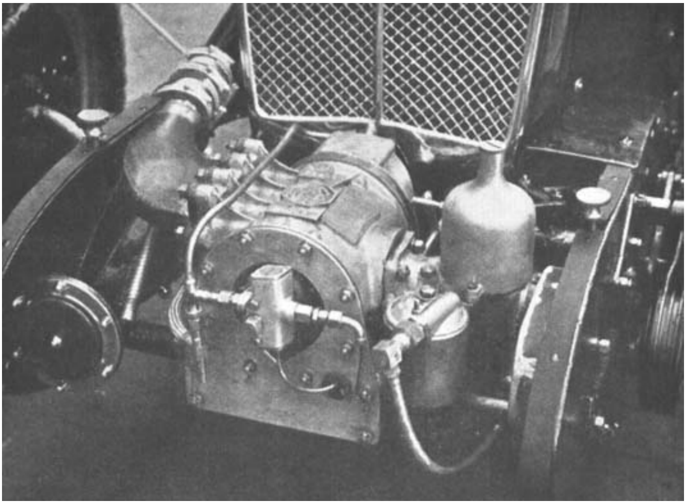

Fig. 10.—Q. Type McEvoy-Zoller Supercharger Installation.

For text reference, see page 514.

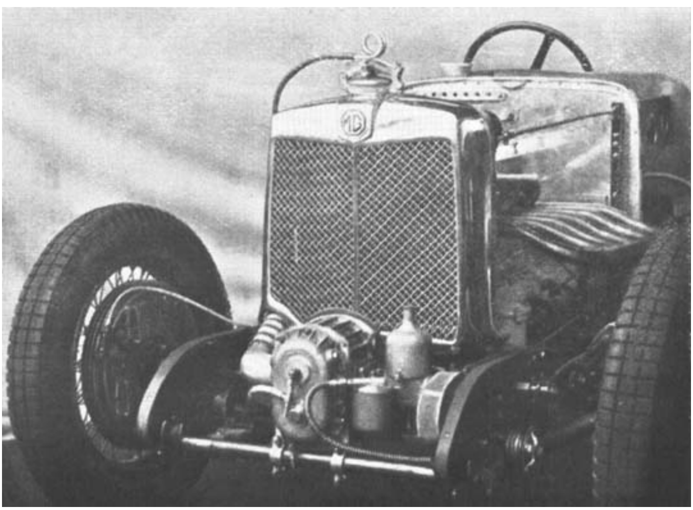

Fig. 11.—Roots Blower Installation.

For text reference, see page 514.