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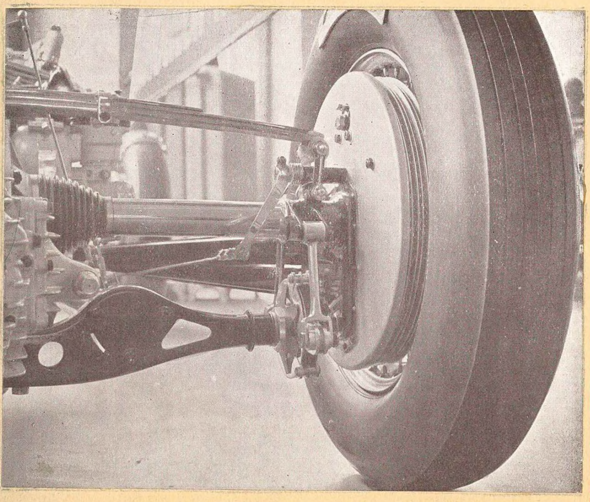

MOTOR RACING

EDITOR

The Rt. Hon. the Earl Howe, P.C., C.B.E.

By PETER BERTHON, L. G. CALLINGHAM, H. N. CHARLES, JOHN COBB, S. C. H. DAVIS of "The Autocar," G. E. T. EYSTON, N. W. H. FREEMAN, LORD HOWE, W. HASSAN, CAPT. J. B. IRVING, CECIL KIMBER, RAYMOND MAYS, L. MANTELL, REX MUNDY, REID RAILTON, GEORGES ROESCH, R. J. B. SEAMAN, H. E. SYMONS

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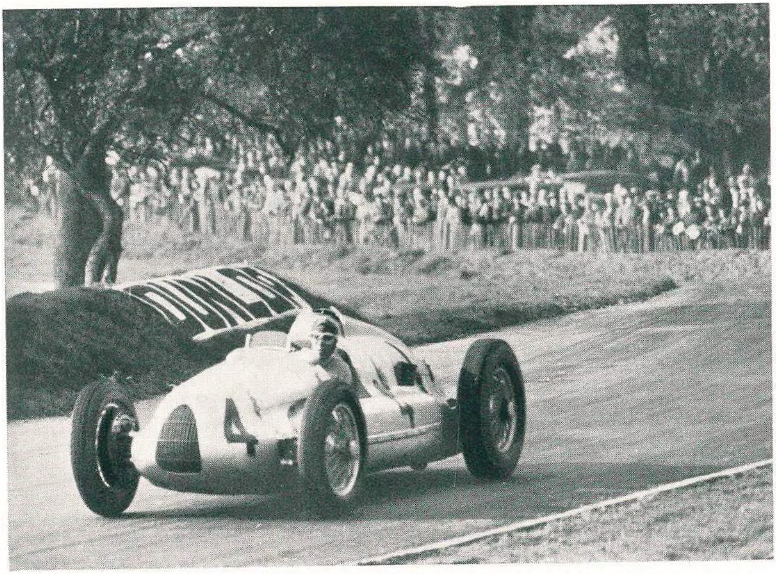

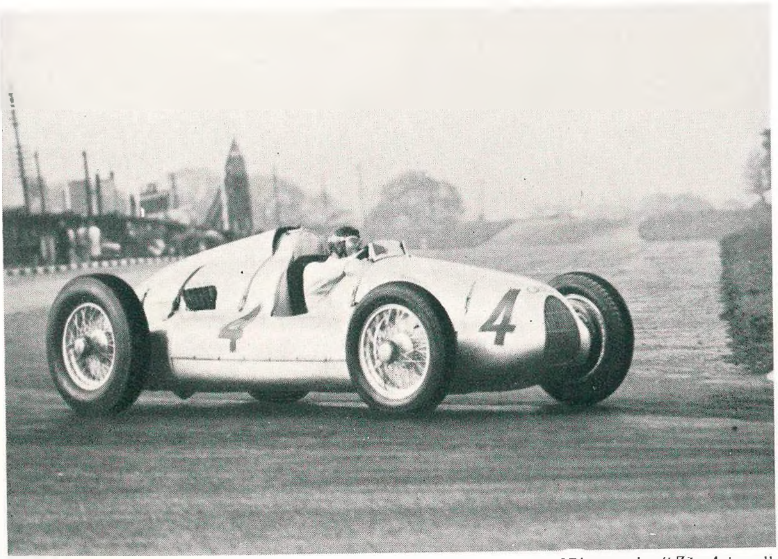

Plate 1. [*Photographs: "The Autocar."*

A GREAT DRIVER AT WORK.

TWO VIEWS OF NUVOLARI WITH THE AUTO-UNION WHICH WON THE 1938 GRAND PRIX AT DONINGTON. IN THE UPPER PHOTOGRAPH THE CAR HAS JUST ROUNDED HAIRPIN BEND ; IN THE LOWER IT IS ON RED GATE CORNER.

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VOLUME XXVII

MOTOR RACING

By The Right Hon. The Earl Howe, P.C. (Editor), Peter Berthon, L. G. Callingham, A.M.I.A.E., F.I.M.T., H. N. Charles, B.Sc., Eng. A.M.I.A.E., M.S.A.E., J. R. Cobb, S. C. H. Davis ("*Casque*" *of* "*The Autocar*"), Capt. G. E. T. Eyston, M.C., N. W. H. Freeman, A.I.A.E., W. Hassan, A.M.I.A.E., Earl Howe, Capt. J. B. Irving, M.I.A.E., M.I.Mech.E., A.F.R.Ae.S., Cecil Kimber, M.I.A.E., L. Mantell, M.I.A.E., Raymond Mays, Rex G. Mundy, Reid A. Railton, B.Sc., Georges Roesch, M.I.A.E., Richard Seaman & H. E. Symons

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EDITORS' INTRODUCTION

BY

THE RT. HON. THE EARL OF LONSDALE, K.G., G.C.V.O. D.L.

IT is now a long time since a Library of volumes on Sport and Games was first put before the public. During these many years great changes have taken place, in men and in methods; how numerous and how great those changes have been, it needs no more than a glance at the text and illustrations of the older existing volumes to discover. The traditions, the customs, the guiding principles of the great sports and games doubtless remain; but as the years go on new discoveries are made, new developments follow, new methods are found to be successful. In the process of time these demand notice and explanation.

It would not be difficult to give examples of many such changes. A few may suffice. To take the sport of shooting first, even some twenty years ago almost nothing was known of the nature and causes of what was vaguely called "disease" in grouse. The knowledge which research and examination have given us of these to-day has profoundly affected methods of moor management. Again, in regard to fishing, it is only of recent years that we have been able to piece together the life history of the salmon by means of the reading of scales; we have learned much of the powers of vision of fish; and there have been many improvements in the manufacture of rods and tackle. To come to games. In cricket there have been alterations in the rules, fields are placed differently, modes of batting and of bowling are not what they used to be; in golf, changes in the standards of clubs and of the ball have in turn altered standards of play; and the lawn-tennis of modern Wimbledon is a different game from that of a past generation.

It is believed, therefore, that the Lonsdale Library should fill a gap. Its aim is to help and to instruct. It is intended in the first place for the beginner who wishes to learn all that the written word can teach him of his chosen subject, and to obtain authoritative advice on gear and in practice. But it is also hoped that the more experienced sportsman may find matter of interest in the pages of the Library, either in the bringing together of newly discovered facts or new suggestions for study, or in the comparison of other sportsmen's or players' opinions with his own. No pains have been spared to make the text and the illustrations as full and representative as possible, and if the various volumes succeed in their double appeal to the tyro and to the expert, the Library will have fulfilled the purpose of its Editors, which is, to make it complete.

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EDITORS' ACKNOWLEDGEMENT

With the exception of those in Chapters 9, 10, & 11, all the diagrams are reproduced by the courtesy of the Proprietors and Editor of "The Autocar" to whom the Editors of this book are deeply indebted for their help.

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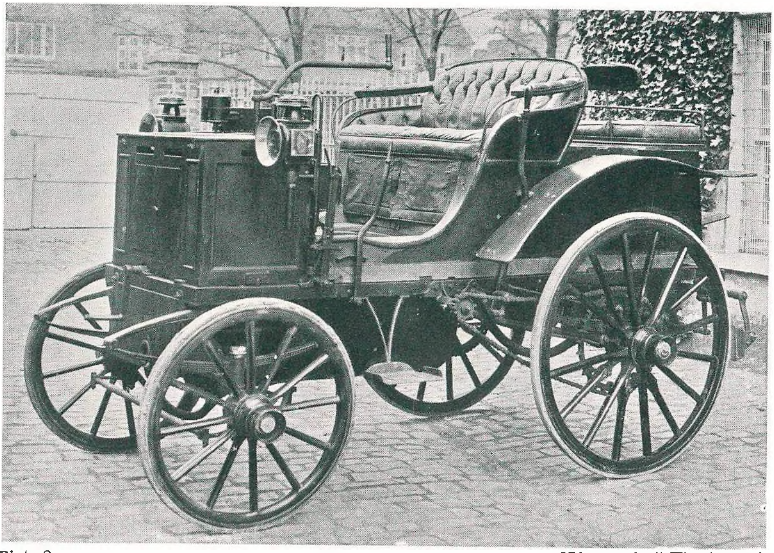


Plate 2. [*Photograph:* " *The Autocar.*"

A PANHARD LEVASSOR OF THE TYPE WHICH WON THE EARLIEST RACES IN MOTORING HISTORY.

THE TILLER STEERING HAD TO BE ABANDONED AS TOO DANGEROUS.

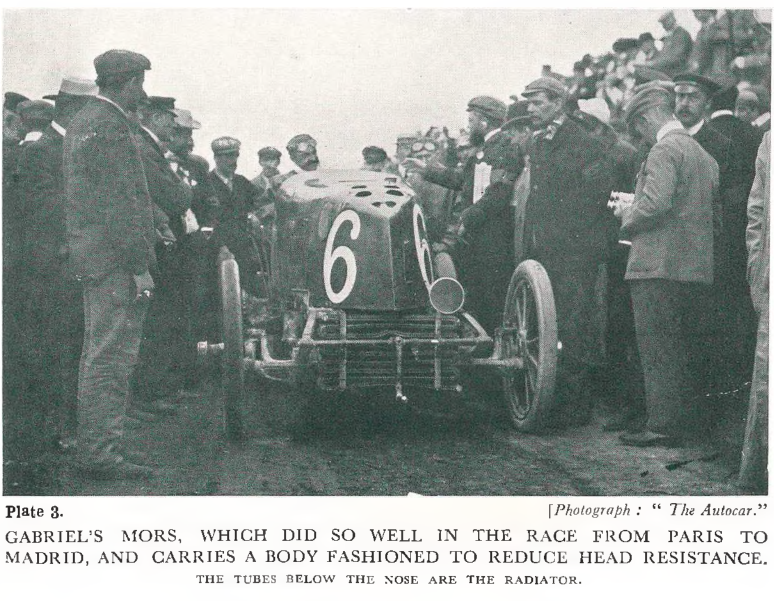


Plate 3. [*Photograph :* " *The Autocar.*"

GABRIEL'S MORS, WHICH DID SO WELL IN THE RACE FROM PARIS TO MADRID, AND CARRIES A BODY FASHIONED TO REDUCE HEAD RESISTANCE.

THE TUBES BELOW THE NOSE ARE THE RADIATOR.

CHAPTER ONE

AN HISTORICAL SURVEY

By S. C. H. Davis
("*Casque*" *of* "*The Autocar*")

GENERALLY speaking, history is a bit on the dry side, and it really remained for the authors of *1066 And All That* to show that something interesting and amusing could still be history any way.

Fortunately the historical side of motor racing is anything but dry, and it is rather fascinating to look back along the years to see how the sport grew, and why certain types of races superseded others.

In the beginning, of course, these new-fangled motor machines, variously called horseless carriages, autocars, and automobiles, made their appeal chiefly because they could travel from one place to another, in theory at all events, rather faster than anything else on the road. Naturally, therefore, claims and assertions anent the performances of particular makes of cars reached that giddy state of exaggeration which such things always do when tackled by enthusiasts, and enthusiasts with mechanical minds at that.

And so it very rapidly appeared that some sort of official confirmation of the alleged speeds was desirable. Accordingly racing began, but not, mark you, the sort of racing we understand to-day, for the events were filled with the latest type of ordinary touring car. Not one of the competing machines was specially made for racing, and with each its manufacturer hoped to demonstrate convincingly that the car he was offering for sale was, in fact, faster than its rivals, and anything more unsuitable than the machines of the period for any form of race it would be difficult to imagine.

Steered by a long and wobbly tiller, accurate only within a matter of feet and liable to be twitched out of the hand by a pothole or a stone, these cars were further unsuitable because they had solid tyres and were nearly as high as they were broad or long. Brakes existed, but not for the purpose of stopping suddenly, being descended direct from the useful block of wood which had hitherto to arrest the horse-drawn vehicle when jammed down upon its solid tyre.

Moreover, the roads for years had been a place for cattle, dogs, and people, with only an occasional vehicle, so the sudden arrival of the snorting, panting mechanism was resented from the commencement, and the drivers' already unhappy task was rendered the more precarious by the occasional ruminant cow and the repeated savage attacks of dogs. It was not unusual for a machine to be overturned completely as a result of an attack by a dog, and more than likely that more than one-third of the competitors in a race would have an accident of one sort or another. Of the remainder few survived, for the effort to obtain prolonged speed resulted in mechanical trouble involving the assistance of a skilled blacksmith as a rule.

Anyhow, the thing was extraordinarily exciting. The cars actually ran, some of them really got to the finish, and it was obvious at once that as a sport this new game was terrific, as obvious as it was that the driver who first could master the purpose of all the mechanism would score heavily over his less knowledgeable rival.

There was, of course, no effort to clear the road, and though it is customary to regard France as having been always enthusiastic for mechanical transport, France being the place where the big races took place at the commencement, this was so far from being the truth that before long the authorities actually endeavoured to stop the competitors in one race with the aid of a section of guns and a squadron of light horse.

And the cars, of course, were unlimited, so naturally engines became larger and larger, one daring manufacturer actually endeavouring to use four cylinders, as though two, or even one, would not be quite enough trouble for any human being.

All this was naturally experimental. Rules were few and far between, as nebulous as they were disregarded, and even the timekeeping was not all that it might have been. But in comparatively few years a great change occurred. The tiller steering disappeared, to be replaced by the wheel; the cars became longer; pneumatic tyres, surviving a hundred catastrophies, actually began to stand up to the work, and with that the dawn of the racing car broke;—the big, clumsy, four-seater bodies were replaced by two sketchy seats; the car was practically a chassis, and where the rear seats had been, a pile of tyres were stacked.

And the races themselves took form and shape, began to appeal to the imagination; races from Paris to Bordeaux, or Paris right across the map to Vienna, or Berlin, races which for ever afterwards were to be landmarks in history. There was still an effort to obtain a larger engine for each race, but there was a hazy idea of classes, so that one section of the event would be for *voiturettes*, which now we would call light cars, and the other for the big machines, whose speed was becoming fantastic. Assembling in the early hours before ever daylight appeared, these racing machines would be surrounded by enormous crowds who had usually cycled to the start with little paper lanterns which made the scene eerie beyond belief, especially to a background of thunderous exhaust noise.

Then, when the appointed moment came, each car in turn would be brought up to the timekeeper, its driver often concealed behind an enormous brown beard—the veteran de Knyff having the best example—perched high in his seat, leather-clad, and with that peaked cap which now the chauffeur uses, while the mechanic, sitting sideways on the floorboards, tested and adjusted rows of drip-feed lubricators along the dashboard. Each competitor in turn was dispatched, almost with the vague but thrilling statement, "This is Paris; down there is Berlin. Get there as soon as you can." And the getting there was full of complications. These cars were running up to 70 m.p.h. at times; they had no shock-absorbers, their steering no castor action, and the brakes were definitely difficult, while a tyre rarely lasted long. Behind the machine welled an enormous cloud of dust trailing astern for miles; ahead lay the white roads of France covered with vehicles, cats, dogs, and that ever-present menace the enthusiastic spectator standing in the road the better to see the show.

Nowadays we know every inch of a racing circuit; in those far-away days a driver only knew a small section of the route because he happened to have used that section in ordinary touring. What the next corner was like exactly neither he nor his mechanic had an idea, and very often there lurked just round an S bend the inevitable level crossing of France, with its gates most firmly closed. Passing was as dangerous as ever racing could be, or has been. You drove blind in the dust-cloud, steering sometimes by what could be seen of the tops of the two lines of trees which normally flanked the road, continuing to do so until dimly in the smother the stern end of another car could be seen; and then you had the job of passing on a road, remember, that was often steeply cambered, with a car which could not be placed with any exactitude—yet pass you must.

Usually the race was divided into sections. After a day's run the competing cars were locked up in a paddock, the drivers dismissed to hotels in which they were often received with diffidence, creatures so oily and dirty forming no part of the regular custom. Early next morning away the machines would go again, and thrice blessed he whose engine could be made to start after a night in the open following a day of racing. Repair depots were dumped along the course by firms concerned, places where tyre-fitters would slice with knives the old tyres from a car, fit new tubes and covers, oil, fuel, and spares would be used as requisite, and, of course, if the car was in trouble, and the depot you saw ahead was not your own, well, a little ingenuity plus a genius for scrounging would usually obtain all or more than was necessary.

But in those epic struggles the one terrible thing was continuous tyre trouble, for then driver and mechanic had to lever off the cover, tear out the tube, replace it or mend it, in the process nipping their fingers with those evil things security bolts, then, in the blazing sun inflate the tyre, restart the engine, and get away, only to suffer the same trouble a mile or so farther on. It isn't surprising that many a man has left a tyre lever between cover and tube, and the state of one's fingers after repeated work of this type had to be seen to be believed.

And the great thing about racing in those days was that it brought out in full measure the endurance and tenacity of the men concerned who, fighting their way through every trouble car has ever given, succeeded at last in finishing and thereby gained a place which, when the trouble commenced, had seemed visionary and impossible. Temporary repairs were essential, genius in concocting them valuable above gold. Charles Jarrott once used much of the wardrobe of an hotel in order to mend the broken frame of a racing car, and that is only one instance out of many.

Great were the names made in that wonderful period. Levassor, who, with a Panhard, won the race from Paris to Bordeaux and back to Paris in 1895; Charron, who won, also with a Panhard, the race from Paris to Amsterdam and back, and the race from Paris to Bordeaux in 1899; Fournier, hero of the 1901 Paris-Bordeaux with a Mors, winner of the Paris-Berlin the same year, 687 miles at over 44 m.p.h.; Henri Farman, afterwards to be a pioneer of aviation, winner of the race from Paris to Vienna with a Panhard in 1902; Jarrott, winner of the Circuit des Ardennes the same year; Gabriel, Rougier, de Caters, Jenatzy, Salleron, and the first woman driver to achieve fame, Madame du Gast, who now is President of the Society for the Prevention of Cruelty to Animals in Paris.

Then, in 1903, came disaster. A race was organized from Paris to Madrid on even greater scale than anything had seemed before, and greater still were the preparations made by the competitors, who entered in enormous numbers. Cars had bigger engines than ever, and were much faster, but the method of racing, the unguarded roads, the uncontrolled spectators, and the dust, remained. There ensued one of the greatest tragedies that has ever occurred in racing. From the start the rivalry was immense, speeds for the day were terrific, and the crowd invaded the course, leaving only a thin lane through which the cars might pass. Smash after smash occurred. An Englishman, Delaney, wrecked his car on a heap of stones; Barrow was

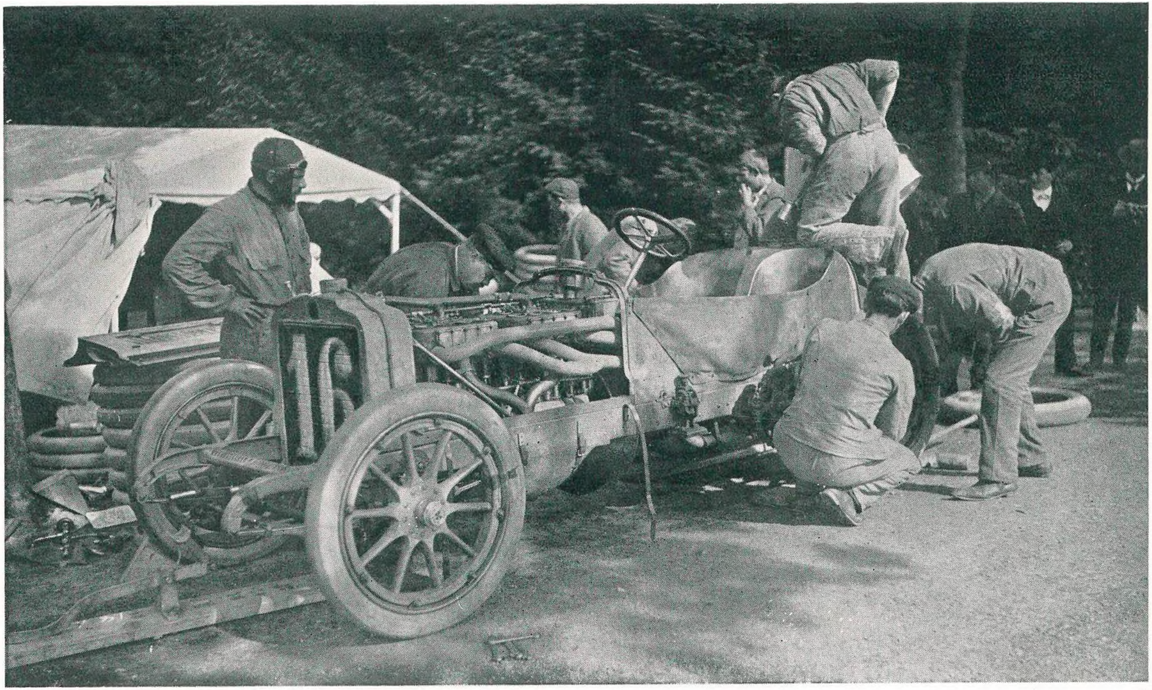


Plate 4. [*Photograph : " The Autocar."*

1906.

REPLENISHMENT AND TYRE CHANGING DURING THE GORDON BENNETT RACE, WHEN DEPOTS HAD TO BE ESTABLISHED AT THE SIDE OF THE ROAD BY THE FIRMS CONCERNED, AND ANY NUMBER OF MECHANICS COULD WORK ON THE CARS.

killed, his car being torn to pieces; Marcel Renault was killed; Stead's car crashed after collision with Salleron; Mark Mayhew's Napier ran into a tree; Porter's Wolseley overturned and caught fire; Tourand crashed into the spectators; Gras crashed at a level crossing. It was the end of racing on the open road. When the machines arrived at Bordeaux the atmosphere was tense. Then the whole of the race was stopped, the cars sent back officially by train, but that small, swarthy man, Gabriel, who is still alive to tell the tale, made one of the most wonderful runs there have ever been from Paris to Bordeaux in a Mors, passed wrecks on all side through dust and trouble all those miles, at the average of over 65 m.p.h., and Salleron's Mors came in second, with the Englishman, Jarrott, on a De Dietrich, who had driven the race of his life, third.

It was a moot question whether racing would ever be allowed again.

But there is always a way round, however great the difficulty. And soon it occurred to people that if the long, straight, main roads from the capital of one country to the capital of another could no longer be used for racing, adequate guards could be provided for a shorter course. Since the plan of roads rarely provides a circle at any point, three adjoining roads forming a triangle offered the best possibilities.

Now it so happened that a most interesting contest had achieved great fame, for the previously subsidiary race for a cup given by Mr. Gordon Bennett had suddenly become of the first importance. In distinction to other races, this was run by one country against another, not by one manufacturer against a rival manufacturer. Teams of three cars had to be chosen to represent a country, and every piece, be it tyre, or coil, or plug, or split pin, in the chassis of those cars had to be made in the country concerned. The Gordon Bennett Cup went to the automobile club of the winning country. It was an idea which was distinctly new and obviously sporting, but it attracted little attention when Charron won the cup in 1900 or Girardot in 1901, since the French were pre-eminent in any case; but in 1902 S. F. Edge, with the British Napier, was the winner, and that made all the difference.

The race had to be run in the country which had won it, a problem only solved by special permission to use a peculiar course in Ireland composed of two triangles with one common side, and this race, in which the Napier cars endeavoured to uphold our colours, was won by Germany, with a Mercedes piloted by that extraordinary man, Jenatzy, whose theatrical, forked red beard and excitable nature had made him a distinct character.

The race itself was run on a heavily guarded circuit, spectators not being allowed on the road, and the roads themselves being closed to ordinary traffic. That was followed by race after race for the Gordon Bennett Cup, the British team being decided by eliminating races held on a long course in the Isle of Man, the contestants being Wolseley and Napier. Similar trials were held in other countries to decide which team should carry the country's colours, and in 1904 France won again with a Richard Brasier driven by that robust but most regular driver, Théry, who had previously won the French eliminating trials. It is of interest that the circuit at Homburg was 79·46 miles long as far as the racing was concerned, for on that circuit there were still the controls which had been used in the straight-away races, and, of course, the cars were still dispatched one after the other. Thery became famous, as did Richard Brasier, by winning the French eliminating trials, and the race itself, in 1905, and a very great measure of the car's success was due to the use of a new component, a shock-absorber, while as the cars became larger and larger and faster and faster, tyre trouble was rife.

But in 1906 there was trouble once more. The French argued, quite rightly, that a race in which they, the premier automobile country, were represented by only three cars was intrinsically wrong, since their trade had no chance of showing its power, being on an equal footing with other less favoured countries, and after much argument the Gordon Bennett race faded in its turn, to be replaced by a French race, the Grand Prix, run near Le Mans on a gigantic triangular course heavily guarded, and with palisades along the side of the route. The winner was Szisz, who averaged 66·8 m.p.h. with a Renault for two separate days' racing, and the success of the venture was assured.

But the cars were becoming enormous; and not only that, they were differing considerably from anything used in production—were, in fact, becoming simply machines for racing only, and consequently expensive. The recipe remained: as much engine for as little car as it was possible to evolve. The actual race rules, it is true, contained a minimum weight limit of 1007 kilograms; but rules are really an exercise set the designer, and the ingenuity of man will always get round some apparently insuperable obstacle, hence cars much larger and much faster than had been thought possible.

That first Grand Prix was intensely interesting in another way. It was a burning hot day, and the tyres almost melted. Some unfortunate car crews had to change tyres twelve or thirteen times, but Renault and one or two other teams had overcome this difficulty in advance, being provided with detachable rims, to change which was not only quick but easy, and it was that bright idea, evolved beforehand, that won the race, as far as Renaults were concerned, without a shadow of

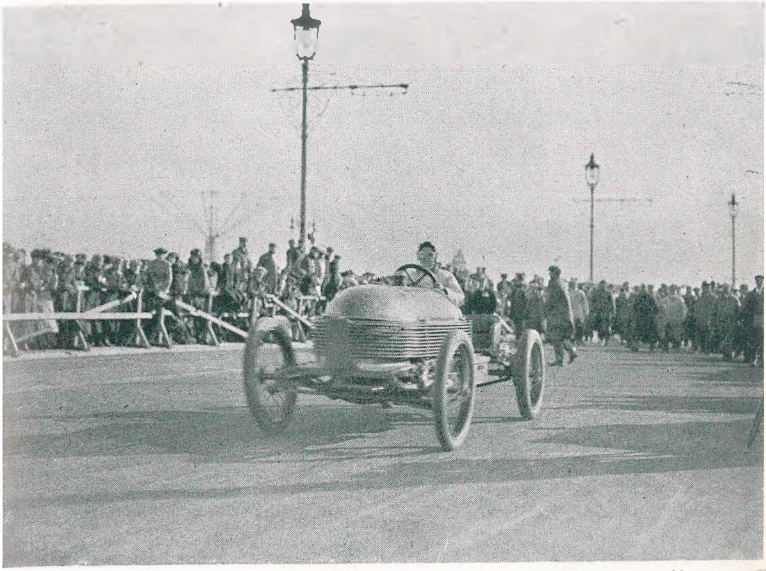


Plate 5. [*Photograph : " The Autocar."*

AN EARLY SPEED TRIAL.

THE SIX-CYLINDER RACING NAPIER WHICH WAS USED FOR RECORDS AND SPEED TRIALS, AND WAS DISTINGUISHED BY HAVING PLAIN COPPER TUBES ALL ROUND THE BONNET TO SERVE AS A RADIATOR.

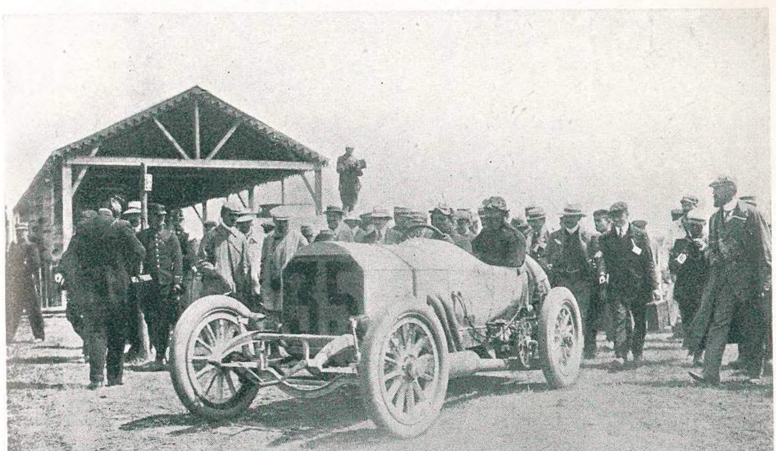


Plate 6. [*Photograph : " The Autocar."*

LAUTENSCHLAGER'S MERCEDES, WHICH WON THE 1908 FRENCH GRAND PRIX.

Plate 7. [Photograph : Argent Archer.

THE NAPIER TWENTY-FOUR HOUR RECORD.

THE NAPIER WITH WHICH S. F. EDGE EVENTUALLY SET UP THE FIRST RECORD FOR TWENTY-FOUR HOURS ON THE TRACK AT BROOKLANDS, WEYBRIDGE, AND INCIDENTALLY ONE OF THE FIRST SIX-CYLINDER RACING MACHINES.

doubt. There was another point. The dust nuisance was met by using tar on the road surface, but in the blazing heat the tar melted, and liquid was flung by the wheels of one car into the face of the driver of a machine astern, while the acrid tar fumes seriously affected the men's eyes. In addition, the rules of the race made it necessary for the driver and mechanic alone to do all the work necessary to keep the car going, and even to restart the engine after the night's rest. No other person could touch the machine; the hordes of mechanics who had descended on a competitor from some carefully prearranged roadside depot had been eliminated; in their place shallow pits had been dug at the side of the road, in which everything necessary for the car could be got, but from which no man might so much as hand a spanner or rag to the unfortunate car crew.

But it was obvious that the race had great possibilities, and it was repeated in 1907, an endeavour to restrain design being made by withdrawing all restrictions on the machine save that the fuel used was doled out in quantities corresponding to 9·4 m.p.g. Now races with limited fuel are excellent technically, but difficult as spectacles. Cars driven at real speed usually lead most of the race only to fail for want of fuel almost within sight of the line, and that made the whole thing extremely unpopular, not only among drivers but the spectators.

As it happened, this race at Dieppe brought the Italians to the fore, for it was won by an Italian Fiat driven by another of the legendary figures in motor racing, Felice Nazzaro—handsome, athletic, and a fine driver—who was to prove extremely hard to beat and to attain to victory after victory. In fact, the French supremacy was being definitely challenged. Panhard had been unbeatable up to the Paris-Madrid, Richard Brasier in the Gordon Bennett, but things went very wrong with the Grand Prix for quite a while.

The 1908 race proved absolutely devastating on account of tyres; car after car called at its pit, one or other tyre in shreds. Detachable rims of early type tended to detach themselves, and one man, Rigal, actually succeeded in changing nineteen tyres with his mechanic, and yet averaged over 60 m.p.h. The fuel consumption limit, by the way, had been abandoned for this race; the cars were not allowed to weigh more than 1100 kilograms, and the engine bore was limited to 155 mm. None the less the cars were bigger than ever, faster, and more violent, and this time it was Lautenschlager, with the German Mercedes, who won at 69 m.p.h.

Once started, the Grand Prix became the premier race of the year. There were many other races—the Targa Florio, for example, and the Kaiserpreis—but the Grand Prix was the only race worth winning, and enthusiasm worked up to it for six months of the year, the remaining six months being occupied in technical discussions about the result, and attempts to get ready another set of cars Unfortunately hot disputations arose as to the value of the race in comparison with expenditure, and this led to there being no Grand Prix race in 1909, 1910, or 1911.

And then, in 1912, France came into her own again, and there rose to fame that magnificent team of Peugeots which has become historic. The beginning of their success was the marvellous race in 1912 at Dieppe, when the last of the monstrous cars fought all through the race against a new-type, smaller, lighter Peugeot. Though the big car, represented by that most spectacular red Fiat handled by the American Bruce-Brown, had the advantage up to half distance, it was the smaller blue Peugeot, driven by Georges Boillot, that was victor in the end. And there was something about Georges Boillot and the Peugeot which stirred the imagination, made both national heroes. The car looked so essentially right; the man short, immensely powerful, with a heavy moustache, had many of the attributes of those romantic heroes of *The Three Musketeers*, a way of doing things which appealed, and when, the following year, he won again, the enthusiasm in France rose to fever heat.

These races were extremely popular. Troops guarded thoroughly, at all events for the first part of the race, the palisaded circuit; processions of people from all over the country, and indeed from other countries, wended their way to the course. Valiantly carrying the necessary food, they sat by the roadside for hours and hours, intensely alert to everything that was happening. The road itself was now treated with a special liquid which, though unpleasant if splashed in one's face, was less painful than tar, and the only fly in the ointment was that, before the race had run half its distance, the road itself was torn to pieces on the corners, a veritable hail of sharp flints bombarding the radiator, bonnet, and scuttle of the cars, and making it a matter of considerable risk for the driver when circumstances forced him to follow another machine into a turn. Tyre trouble itself had been reduced, because the tyres were better for one thing, and because, after much argument, detachable wheels were allowed, the quaint part of this being that in the early history of the race the British Napiers were barred from competing because they had detachable wheels, which the technical experts thought a dangerous adjunct and against the spirit of the rules.

Racing also was becoming more organized. The teams ran definitely as teams, very often with one star driver supported by lesser lights. Efforts were made to keep track of the position of the car, and to signal it to slow or increase speed as the circum-

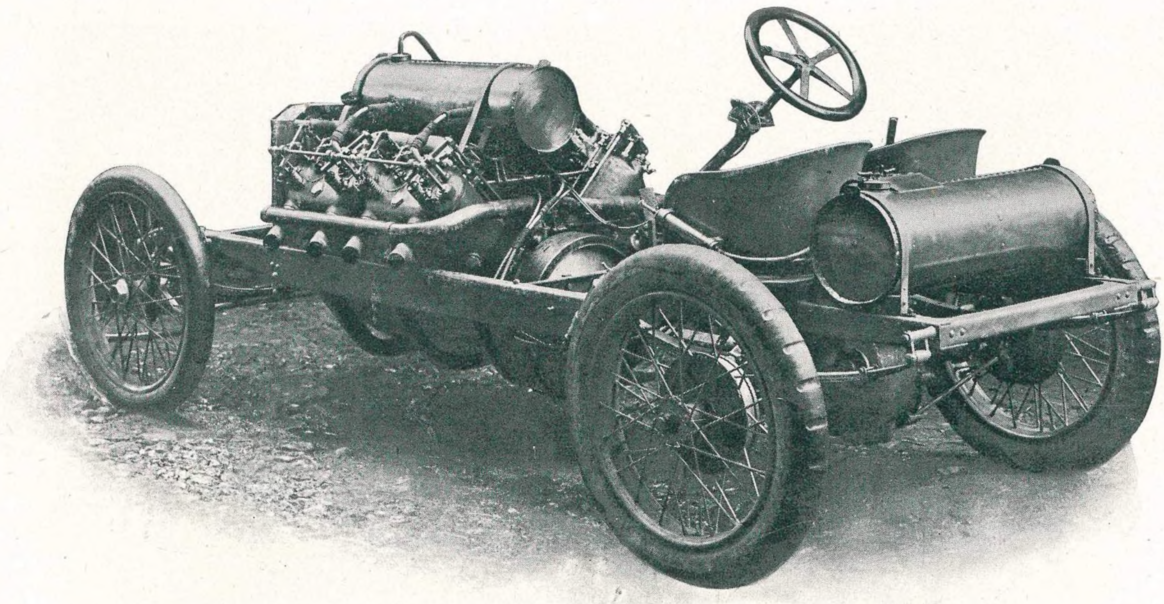


Plate 8. [Photograph : " The Autocar."

A FAMOUS DARRACQ SPEED TRIAL WINNER.

DRIVEN BY SIR ALGERNON GUINNESS. THIS CAR ACHIEVED 117·73 AT OSTEND. IT HAD A V-8 ENGINE, AND WAS RUN, AS SHOWN ABOVE WITHOUT BODYWORK OF ANY KIND.

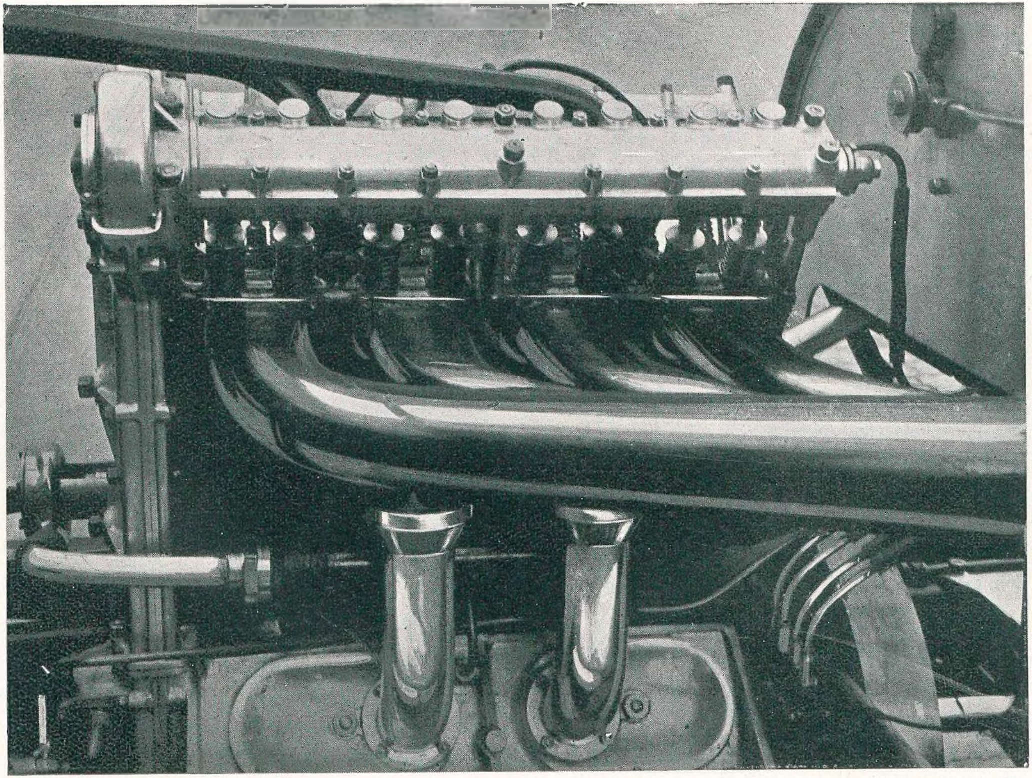


Plate 9. [*Photograph : Meurisse.*

A FAMOUS PEUGEOT ENGINE.

OVERHEAD CAMSHAFT ENGINE OF THE 1913 RACING PEUGEOT, A TYPE WHICH SET THE FASHION IN RACING CARS FOR MANY YEARS TO COME.

stances dictated. Moreover the finale was tremendous, for the winner, announced well in advance, completed his final lap to the strains of the national anthem rendered by massed bands, and the enthusiastic crowd combined to make the spectacle something which would be remembered always. Even the start was dramatic, with bands and flags, and cheering, and the arrival in ceremony of high officials of the State at the elaborate grandstands.

As far as this country was concerned, Napiers had fallen out of the running, and the British colours were now borne by the Sunbeams, which for race after race did their best, with Sir Algernon Guinness, Kenelm Lee Guinness, Dario Resta, and Rigal as drivers, the Guinnesses having been trained mainly on that exciting circuit in the Isle of Man which was being used alone as far as English racing was concerned. The construction of the first motor track in the world at Weybridge had given, by the way, a tremendous impulse to British racing and afforded at last a place on which to test the British cars.

And then in 1914 came a climax as dramatic as anything that could be imagined. The entry for the race on the famous circuit at Lyon was as good as could be wished, teams of cars from the best manufacturers handled by the best drivers, immense enthusiasm, immense rivalry, but there was something curious in the air, just as there was something curious about the white-painted team of Mercedes which were kept to themselves in an outlying village, were prepared, handled, and governed by a rigid discipline, and which bore engines remarkably like those then being developed for aeroplanes. Never had the French Peugeot gone so well, or André Boillot himself driven so magnificently as in that race; never was he better supported by Goux and the remainder of the team. But the Mercedes were handled on a strategical plan; their charts, signals, and pit-work were organized to a high degree of efficiency, for up to the last few rounds the Peugeots fought, and as they got rid of one Mercedes, so another took its place, until finally the German team came home first, second, and third, led by Lautenschlager, and came home in a silence that could be felt, was, in fact, emphasized by the blare of "The Marseillaise" when the first French car came over the line. There was very little talking after that race; it was in July 1914.

Not very many months later machine-gunners were fighting amid the ruins of what had been the Sunbeam headquarters.

While all this was happening, interest in England had swung to sports car racing, though Sunbeam and Vauxhall aspired to Grand Prix honours, and Sunbeam were remarkably successful against Peugeot in a special race for 3-litre cars; but the Tourist Trophy, as it was called, was run year after year in the Isle of

Man for a touring type of car, and the results were extremely satisfactory, the expense very much less than that entailed in Grand Prix racing.

After the war it was difficult to know what would happen, but in 1921 a French Grand Prix for 3-litre cars was run on a new Le Mans circuit just over 17 kilometres long, a course which it was proposed to make permanently available for racing, using it also as an official test for road surfaces. Unfortunately the result was disappointing. Few teams were anything like ready, six cars were withdrawn at the last moment, then a frantic endeavour made to reintroduce some of them, with the result that none of them was ready, and the only cars that were really fit for the test were the American Duesenbergs, which was all the more interesting as America had not so far achieved any successes in European road racing.

In the race itself the new Talbot straight-eights obviously suffered from lack of preparation, though Segrave, a new driver for this work, gave a wonderful display of tenacity, and the only cars that could challenge the Americans at all were the French Ballots, which themselves were not at their best, and as a result the American driver, Jimmy Murphy, scored a fine victory at 78 m.p.h.

Once more the circuit was torn to pieces, the sight of the curves on one leg of the course resembling a pebble beach more than a main road, and several drivers were injured, more or less severely, by flying stones.

The following year Strasbourg was selected, and the size of the cars cut down to 2 litres, whereupon there reappeared a wonderful team of red Fiats, the most workmanlike racing cars that had been seen for some time, and at their head was Felice Nazzaro once more, whom people said must be much too old to handle the "modern" racing car. For the first time, also, the cars of that enthusiastic and temperamental designer, Bugatti, appeared in the French, instead of the German, colours, some definitely experimental chassis giving promise of future possibilities. England was represented by Sunbeam once more, and by Aston-Martin, the latter only 1½-litre cars which were outclassed from the commencement but struggled gamely, while a bout of valve trouble eliminated the Sunbeams at about half distance. The Fiats, on the other hand, ran well away with the race, and in the last few rounds were first, second, and third, miles intervening between them and their nearest rivals. For some reason which will never be satisfactorily explained, the cars did not then slacken speed, and as the circuit once more was torn to pieces, one leg being covered with deep potholes, the stress on the machines was terrific. A few rounds from the end two Fiats broke their back axles, the crew of one car being

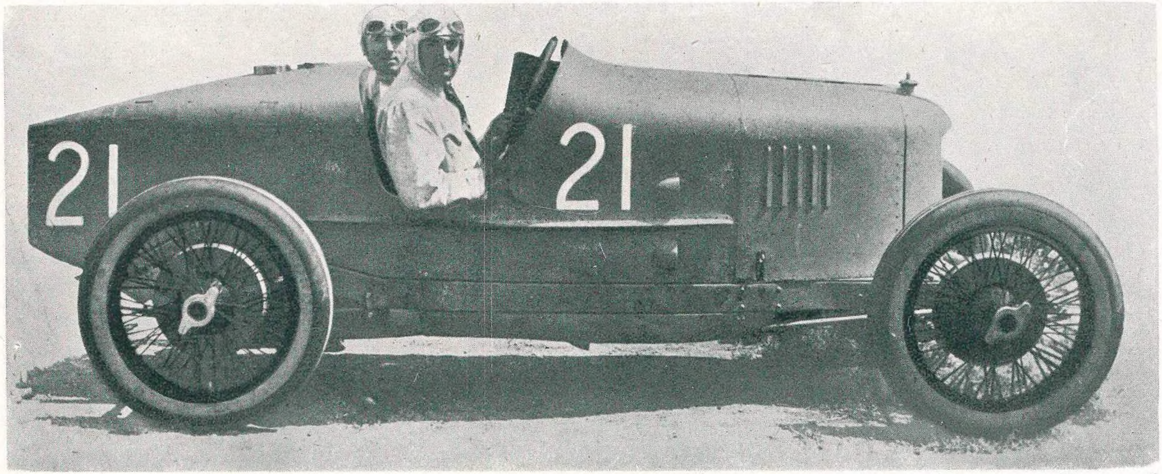


Plate 10. [*Photograph : " The Autocar."*

THE FIRST SUPERCHARGED GRAND PRIX CAR.

THE 1923 RACING FIAT, A 2-LITRE ENGINED CAR OF THE TYPE WHICH FIRST RACED WITH A SUPERCHARGED ENGINE.

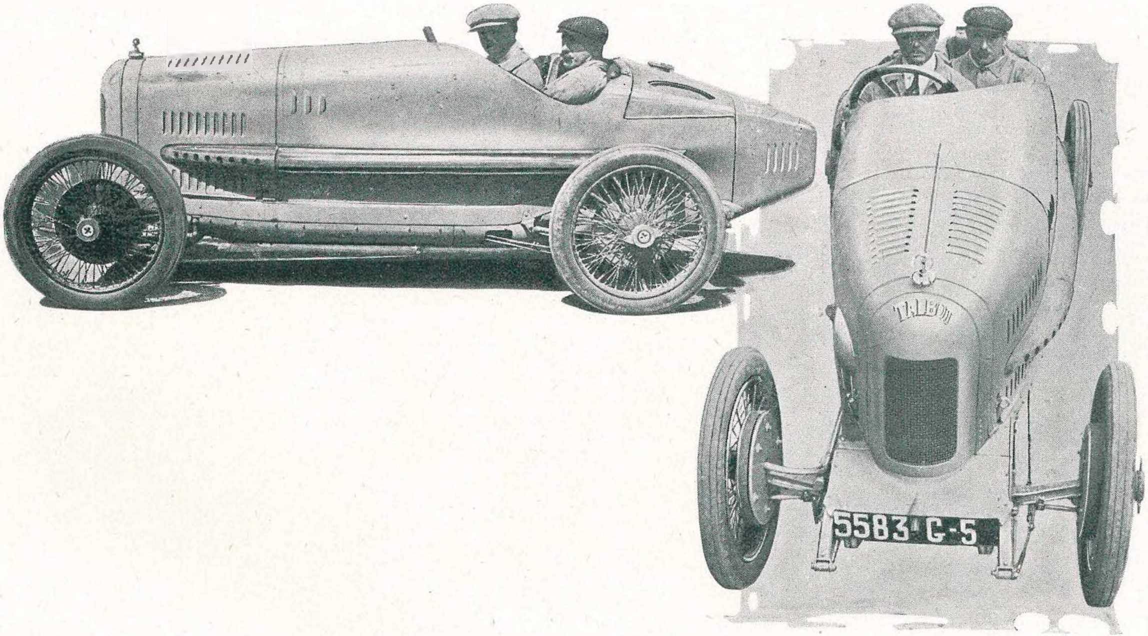


Plate 11. [*Photograph : Meurisse.*

THE $1\frac{1}{2}$-LITRE TALBOT.

THE $1\frac{1}{2}$-LITRE TALBOT, WHICH WAS ONE OF THE MOST SUCCESSFUL CARS OF ITS DAY, AND WHICH HAD A LONG HISTORY OF RACING VICTORIES.

killed, that of the other escaping by a miracle, and Felice Nazzaro won with the greatest ease, though his victory was spoiled by knowledge of the death of his nephew, who had been driving one of the other cars of the team.

Continuing the following year on a circuit at Tours, again with 2-litre cars, saw the arrival of the supercharger, the Fiat engines having Roots type blowers and being extremely fast, but prone to trouble, and in a wonderful race these machines were hunted first by Kenelm Lee Guinness with one Sunbeam, then by Divo and Segrave with two more. Guinness' run served its purpose, though his car in the end suffered; Divo lost his place because a mechanic accidentally jammed the fuel tank filler at the pit, and Segrave came to fame as the driver of the first British car to win a Grand Prix. It is probable that this happy result to years of effort would never have been attained had it not been once more that we possessed that track at Brooklands, which, as has been mentioned before, not only serves to increase the enthusiasm for racing, but did train drivers who otherwise had nowhere on which to practise. It is therefore rather astonishing that we owe the track entirely to the enthusiasm of Mr. H. F. Locke-King, who, in the face of great opposition, converted a most picturesque section of his land into the gigantic track that set a pattern for all the world, and is still being as useful as ever to-day.

From then onwards superchargers became the rule, but the last of the really magnificent races occurred on the Lyon circuit in 1924 when the teams were both numerous and excellent, and all through the long day the fight was grim and great. The supercharged Sunbeams went well, but were soon in trouble, the Fiats also, but Italy's colours were now borne by a new *marque*, Alfa-Romeo, which had a wheel-to-wheel duel with the French Delage, the Italian Ascari leading. When Ascari's engine finally failed, it was Campari, with another Alfa, who took his place, and so secured yet another victory for Italy.

From then onwards the history of the Grand Prix is chequered. Mechanics were not carried in 1925, and disaster to the Alfa-Romeo team, Ascari being killed, led to the withdrawal of that team and a Delage win. Then the rules were altered to bring the cars down to 1½ litres in 1926, and those wonderful little 1½-litre Delages became supreme. But the competition was waning, and for years to follow, under various regulations, Bugatti had it all his own way, race after race being won by the *marque*, until Bugatti, in his turn, ceased to run a team, and Alfa returned to the fray with the low-built, straight-eight machine we know so well to-day. The racing distance was gradually reduced, the speed rose year after year, Nuvolari became famous, and Chiron, who in 1934 won a race on the artificial road of Montlhery track against the German Mercedes and Auto-Union teams which had produced the most formidable cars seen for many years.

The new German teams were extraordinarily interesting. It is to be presumed that they had a certain national backing. Certainly they were run under discipline as a national affair, and having once got over their teething troubles, they proceeded to score victory after victory, first Mercedes, then Auto-Union, and in the meantime the Alfa-Romeo concern practically handed their racing interests to a private stable. The formula under which these cars were built set a *maximum* weight limit of 750 kilograms, and a certain minimum frontal area for the body, allowing the designers choice of any size of engine, and complete freedom otherwise. It is now proposed to set limits of engine size from 666 to 3000 c.c. for supercharged cars, and 1000 to 4500 c.c. for unsupercharged cars, with weight limits corresponding to each size of engine, in the rather pious hope that cars of all sizes within the limits mentioned start on an equal footing, which is a manifest absurdity.

There is another interesting point. A well-known British driver, Mr. Humphrey Cook, has actually succeeded in running a very small firm solely for the manufacture of racing cars, under the name of E.R.A., and this private venture has had remarkable success, as there are still a number of races available with an engine limit of 1½ litres. Probably this is the first instance in history in which a completely private team has managed to exist successfully. In these secondary races, cars with engines smaller than those for the Grand Prix, very considerable success has also been obtained by some British sports cars altered into racing cars; M.G., for example, and Riley, and, on the Continent, Austin, which firm have recently produced a very remarkable little overhead valve, 750 c.c., genuine racing car.

The expense of full-scale Grand Prix racing had now grown enormously. It was necessary for teams not only to have prize money and bonuses, but substantial financial assistance, before they could start in a race, spare cars seemed essential for practice, and the construction of the cars themselves became more and more expensive as the chassis became lighter and lighter. Moreover, the French Grand Prix was not quite what it had been, for not many years after the war races were being run in every country in Europe, until in each country there was a race of the equivalent value of the Grand Prix. This process had been accelerated by international agreement, not only as to the type of race but as to the formula under which the cars were built, so that once a team was formed it could run in Germany, France, Spain, Belgium, Czecho-Slovakia, and, in certain cases,

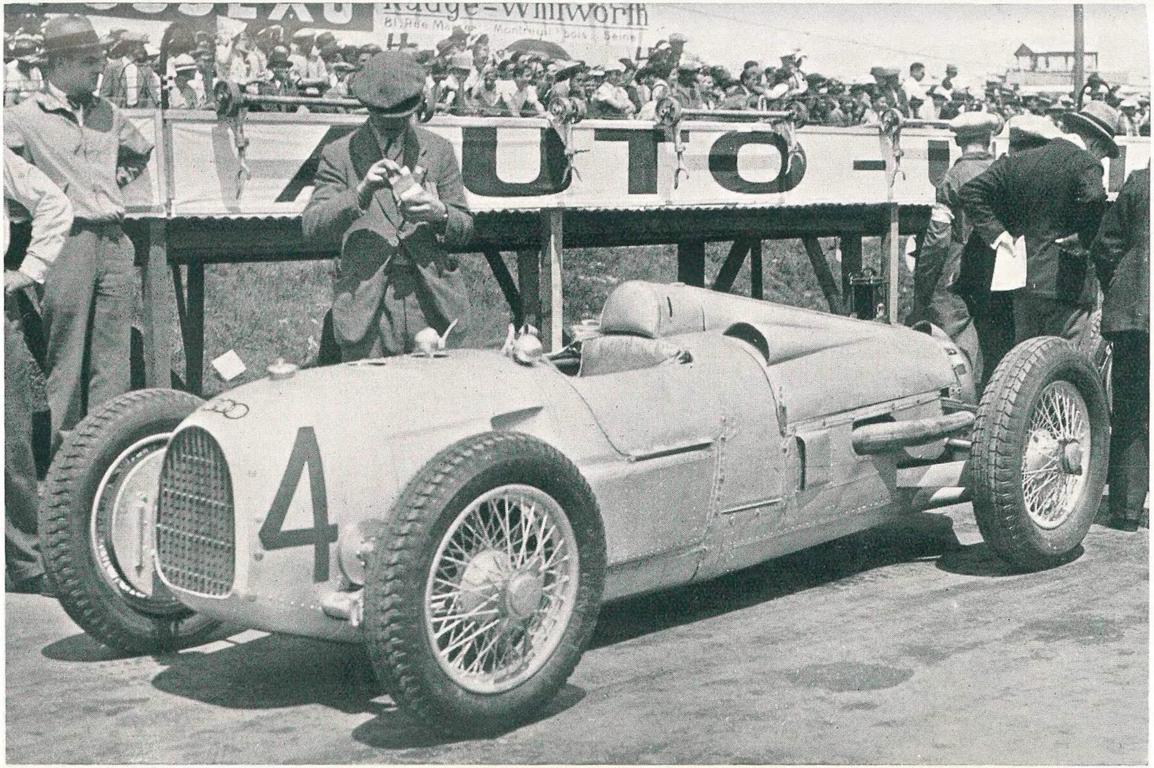


Plate 12. [*Photograph : "The Autocar."*

FIRST APPEARANCE.

1934 AUTO-UNION, A PHOTOGRAPH TAKEN DURING THE FRENCH GRAND PRIX, AND SHOWING THE GENERAL APPEARANCE OF THE CARS AT THAT DATE. ON EITHER SIDE OF THE WINDSCREEN ARE MIRRORS IN STREAMLINED COVERS.

in the British Isles. Fewer and fewer firms supplied the teams, the balance of entries being made up now by men who owned their own cars and had really no works backing.

More tracks had come into being: the artificial road at Nurburg Ring, the special track with its long straights at Avus, the road course at Montlhery and Monza, and even in this country artificial circuits were made, with the aid of barriers, at Brooklands track, while a special circuit had been constructed at Donington near Derby. Still more artificial road circuits are at Brooklands, at the Crystal Palace grounds, and in South Africa. The old type road racing has almost disappeared. On these tracks the surface could be prepared, especially for motor racing. No longer was the road torn to pieces on corners, there was no dust, and every possible precaution was taken to safeguard competitors and cars. The number of mechanics allowed at the pits was increased, and with them now had come a most elaborate organization for dealing with the tactics and strategy of racing, or with the repair and refilling of a car when it stopped at the pits. The expense of racing had, indeed, grown to such a point as to be deemed out of proportion by many people, but as it happened the sports car racing developed, as far as this country was concerned, was growing apace and becoming more interesting. It had been greatly fostered by the 24-hour-long race annually held on the Le Mans circuit, in which the French supremacy was first challenged by that famous team of Bentleys, and the race itself afterwards contained almost every well-known make of British sports car, their success making history—Aston-Martin, Riley, Singer, Talbot, Lagonda, and M.G. It was a fine record, and the workmanlike organization of the British teams caused great comment on the Continent. In Italy a race for sports type cars over 1000 miles of ordinary road has had a marked success.

In these islands the Tourist Trophy, after changing into a racing car race just before the war, had been revived, this time in Northern Ireland, and had benefited sports car racing enormously. At Brooklands track there were races for two consecutive periods of 12 hours for sports cars following an experimental 6-hour race; in Belgium a 24-hour race was successful, and finally, in 1936, the French Grand Prix was reorganized as a sports car race in three sections according to engine capacity, and was an immense success, Bugatti winning one section, Lagonda a second, and Riley the third. In a way the wheel had turned a full circle. Racing had begun with ordinary production cars, had grown to fantastic machines bearing little relation to touring, had reverted to modified versions of the sports car which now was itself a different type of machine from the touring car, and, like the original races, the sports car races were run on normal fuel, whereas the racing cars used very special fuels which were not only costly but unsuitable for ordinary work.

The future alone will see whether the Grand Prix race, as we now know it, will fade and be replaced by sports car racing. That will really depend entirely on the amount of support available from manufacturers; and there is another point of view. Great numbers of artificial circuits are being constructed, usually quite short, matters of two or three miles at most. With them available it is possible that a new form of racing altogether may appear, where a man buys and maintains a racing car trusting to his success in races for the necessary finance. That is very largely what has happened in America in connection with their one big race for 500 miles on a track at Indianapolis, but even the Indianapolis authorities are doing everything they possibly can to interest the manufacturer, and in America the new type of road circuit is also becoming popular. It remains that whatever form racing may take in the future, the sporting side will be just as strong, enthusiasm just as great, and the romance, drama, and adventure at least the equal of all that has gone before.

CHAPTER TWO

FAMOUS RACING CARS

By S. C. H. Davis
("*Casque*" of "*The Autocar*")

ALL through the history of racing you find that from year to year some particular racing machine stands out as historical, has a prestige far above that of its rivals, is for the moment a household word.

Probably the first car to achieve this height of fame in the racing world was that wonderful old machine, the 70 Panhard, in its day considered something monstrous, incredibly fast, very difficult to handle, allowed only to the favoured few drivers who could control such an animal.

Even to-day it would look impressive. The engine had four separate cast-iron cylinders made extremely decorative by corrugated copper water-jackets soldered in position round the cylinders, a construction the easier because the inlet valves were suction-operated, only the exhausts mechanical, and therefore only one pocket was necessary in the head, which, of course, was not detachable. Gears drove a camshaft in the side of the crank case, plain big ends lubricated when they dipped in the crank case oil, the carburettor fed the inlet valves through an enormous length of unheated copper pipe.

The ignition current was supplied by an accumulator with four separate coils, a very simple contact-maker being driven from the camshaft, and, of course, the control of the car consisted of pedal and hand throttle controls, with a hand ignition lever.

Behind the engine, in a big flywheel, was a massive leather cone clutch, then came an equally massive four-speed sliding gear-box driving a countershaft with sprockets from which chains drove the rear wheels. The size of the driving sprocket was a source of joy to the driver as indicating speed, and the car's speed was controlled more by the gear used than by the throttle. Only with extreme difficulty could the machine be brought down to slow speed at all. For brakes there were contracting bands on the rear wheel drums, and on drums on the driving sprockets. One single transverse spring was used for the front axle, two lateral half-elliptics at the rear, with adjustable radius rods which served to tension the chains.

The frame was excellently constructed of ash, with steel plates, and was remarkably stiff, though at first it would not stand up to the stress of racing, and to this frame the engine was bolted direct. There was no castor action, a very rudimentary form of steering, and in front of the bonnet was a formidable-looking zigzag steel tube heavily finned to form the radiator, water being pumped through this tube by a centrifugal pump driven quite simply by a friction wheel on a spindle pressed against the engine flywheel by a spring.

It is probable that this engine developed very nearly 70 h.p., and at 80 m.p.h. it must have been a monstrous car to handle away in 1902 and 1903.

About the same time a British car achieved great fame—the Napier, manufactured by a concern which had been interested in machinery for making coins, and which won the Gordon Bennett in 1902, the first time a British car had ever succeeded in a first-class Continental race.

It was a very queer little car, with a four-cylinder engine of 127 × 127 mm. bore and stroke, giving about 44·48 h.p., the cast-iron cylinders themselves being in pairs, and the inlet valves differed from those of the Panhard in having two seatings, one the usual cone, the second a series of holes uncovered when the suction of the engine lifted the cone valve from its seat, the idea being that this gave the valve a greater area of opening. The exhaust valves, of course, were mechanically operated, as in the Panhard, and again the inlet valves were fed by enormously long pipes radiating from a single and rather simple carburettor. The remainder of the chassis was normal for its time, with a big cone clutch, four-speed gear-box, and chain drive to the rear wheels, but the gilled tube radiator in front was provided with an engine-driven fan which could be put in and out of action by the driver, and was really used to keep the water cool when the car had to be driven very slowly.

All brakes, of course, operated only on the rear wheels. All were contracting bands that operated by the pedal and took effect on a drum behind the gear-box, but the water pump was not friction-driven, a complete chain drive, which was far more positive, being adopted instead.

The frame was of ash, as in the Panhard; the weight of the entire machine was 16 cwt. 3 qr. 27 lb., some idea of its size being obtained by the wheelbase, which was 7 ft. 7 in., and the track, which was 4 ft. 8½ in. The ignition, of course, had an accumulator and four coils, with the usual contact-maker, and it was thought interesting at the time that the mechanic was provided with a proper seat alongside the driver instead of having to sit on the floor.

Such were the earlier types of machines. Going forward along the years, one of the next cars to achieve unusual prominence

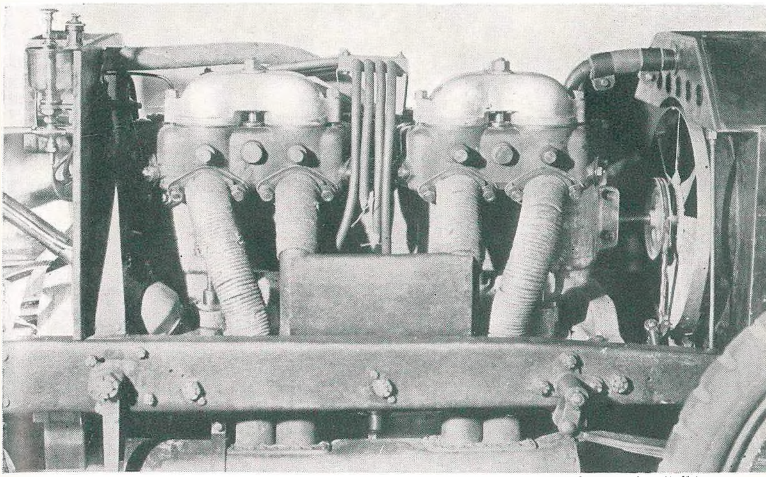


Plate 13. [*Photograph : " The Autocar."*

GORDON BENNETT NAPIER ENGINE.

FOUR-CYLINDER ENGINE WITH SUCTION-OPERATED INLET VALVES FITTED TO THE 1902 GORDON BENNETT NAPIER RACING CAR.

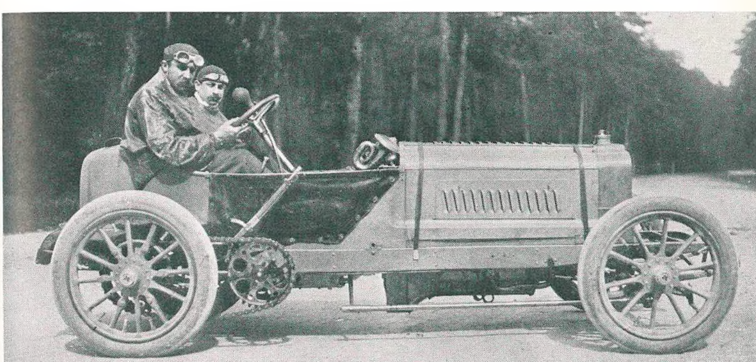


Plate 14. [*Photograph : " The Autocar."*

A GORDON BENNETT RICHARD BRASIER IN FULL RACING RIG.

THE ENORMOUS LENGTH OF THE FORE AND AFT ROD FOR THE STEERING IS INTERESTING. THE ENGINE WAS A FOUR CYLINDER OF 160 × 140 MM.

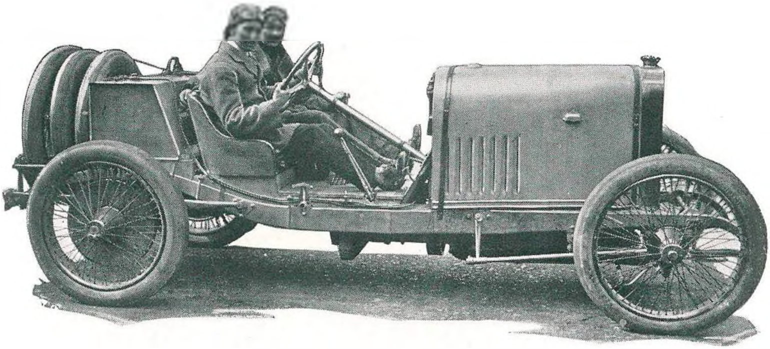


Plate 15. [*Photograph : Meurisse.*

4½-LITRE PEUGEOT, 1913.

A PEUGEOT WITH ITS ROUGH TEST BODY UNDER TRIAL BEFORE A RACE. THE ACTUAL BODY WOULD BE COMPLETED BY THE ADDITION OF A SCUTTLE WITH THE SIDES EXTENDING TO THE SEATS.

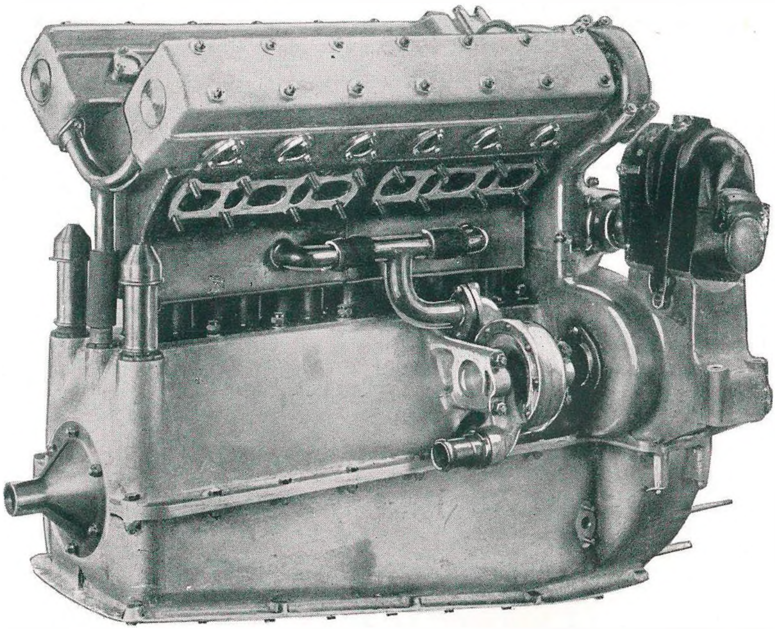


Plate 16. [*Photograph : " The Autocar."*

A BRITISH GRAND PRIX WINNER.

TWIN OVERHEAD CAMSHAFT ENGINE OF THE 1923 GRAND PRIX SUNBEAM, THE YEAR SUNBEAMS WON THE RACE AT TOURS.

was the 90 h.p. Richard Brasier, a French machine which, in the hands of Théry, was practically invincible. Longer and quite a bit lower than the earlier cars, this machine had a four-cylinder, 160 × 140 mm. engine, with the cylinders in pairs, and its normal rate of revolutions was 1200. Both valves were mechanically operated through a camshaft at the side of the crank case, and the inlet valves were put out of action when necessary by the governor to prevent the engine racing. The crankshaft, of course, was quite simple, with plain bearings, but the ignition was unusual because current was supplied by a low-tension magneto to an arm inside the combustion space, which normally made contact with a stud but was jerked smartly from that stud by a cam to cause the spark.

Trouble having been experienced with the big cone clutch, a peculiar arrangement of dogs was used to lock the clutch to the flywheel when the car was at full speed, but still the drive was normal, a three-speed gear-box with a countershaft, and chains to the rear wheels. The frame, on the other hand, had become of pressed steel, and though the brakes were still on the rear wheels and liable to become extremely hot, the car actually had the first attempt at shock-absorbers for its half-elliptic springs, an accessory which had a great effect on the steadiness of the machine.

It was thought right to bring the driver, the tank, and the spare tyres as far back as possible, almost on top of the rear axle, so that the engine, bonnet, and radiator were well behind the front axle, giving the car a remarkably attractive appearance.

For some years on, no particular car seemed to establish itself pre-eminently above the others. Many that were interesting technically were built, many won races, but something more than this goes to a very special car.

In 1912 and 1913 the star of Peugeot was in the ascendant. Wherever the cars were sent nearly always they were victorious, but what was more interesting was that these were much smaller, more graceful, finer-looking cars than had been seen in racing before. The most famous type was a 4½-litre, four-cylinder, of 92 × 169 mm. with a very neat engine having two spur-gear-driven overhead camshafts operating the valves through small inverted pistons, and there were four valves for each cylinder, each valve having three springs to overcome spring periods. The engine was light, and workmanlike to look upon, and it drove a four-speed gear-box through a cone clutch, and then a bevel-driven rear axle through an open propeller-shaft with two joints.

To bring the machine lower, the half-elliptic springs were carried below the axles. The frame itself was of pressed steel, and though the first bodies used had merely a receptacle at the back for the spare wheels, the last and most famous of the cars had the streamline tail which Brooklands had made popular.

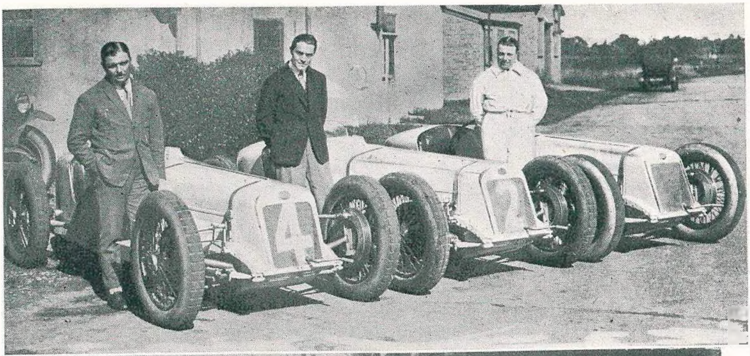
Note that the detachable wheel had now come into its own, over and above which the car had brakes on all four wheels, which at the time was a novelty, the Perrot type brake being used and arranged so that the front brakes were controlled by the pedal, the rear brakes independently by the lever. That chassis set a fashion in racing for years, just as the rather beautiful shade of blue which the cars were painted was for years the outward sign of a Peugeot.

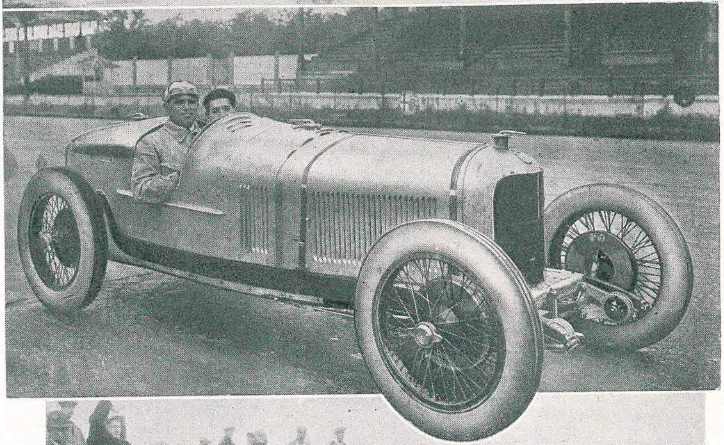
Final victory over this car was achieved by what amounted to an aeroplane engine mounted in a car chassis, for the German Mercedes of just before the war in 1914 was a $4\frac{1}{2}$-litre, 93 × 164 mm. four-cylinder, with steel cylinders, each separate from the others, welded water-jackets, four valves in each cylinder in pairs at an angle of 90 degrees driven by an overhead camshaft, while there were no fewer than three plugs per cylinder fed by two separate magnetos, one of which gave a dual spark.

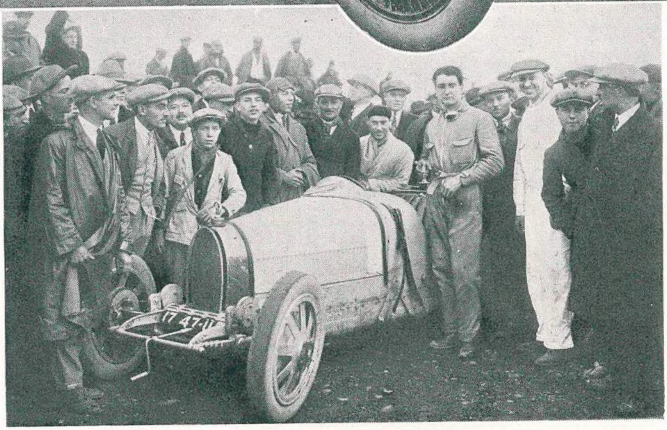
In distinction to the Peugeot, the Mercedes had a large brake drum on the propeller-shaft behind its four-speed gear-box, and then drums for each rear wheel, the shoes being lined with cast iron. Other interesting points were that a peculiar form of double-cone clutch was used, making in effect an expanding apparatus, one clutch moving to the rear, one forward, on engagement, and on the frame were twin shock-absorbers for the axles, while a castor effect was obtained not by raking the axle, but by setting the stub axles behind the main axle. The weight of this car, in its racing condition, was slightly heavier than the Peugeot—21 cwt. 13 lb. against the French car's 20 cwt. 3 qr. 8 lb.

After the war particular interest in this country attached to the 2-litre Sunbeam, which was the first British car to win a Grand Prix, the 1923 race at Tours. It was an interesting little machine, with a six-cylinder engine giving about 108 h.p., running up to 6000 revs., and having a bore and stroke of 67·03 × 93·7 mm., the compression being about 7 to 1. The cylinders were of steel, and had welded jackets. There were two overhead camshafts driven by spur gearing, each valve had three springs, and there were no plain bearings in the engine, those for the crank and big ends of the connecting rods being composed of rollers. No oil was kept in the crank case, which was scavenged by a special pump, oil being supplied to the engine by a second pump from a large auxiliary tank.

The drive was taken from a disc clutch to a four-speed gear-box, thence through an open propeller-shaft to the now usual bevel-driven rear axle, all the springs for the pressed steel frame







Plates 17, 18, and 19.

SOME CELEBRATED GRAND PRIX RACES.

Top : THE GRAND PRIX TEAM OF 1½-LITRE DELAGE CARS WHICH WERE MOST SUCCESSFUL DURING 1927. IT IS INTERESTING THAT NEARLY TEN YEARS LATER ONE OF THESE CARS WON A RACE AGAINST MODERN MACHINES IN THE ISLE OF MAN. (*Photograph : Barratts.*)

Centre : ONE OF THE 2-LITRE ALFA-ROMEOS WHICH WON THE FRENCH GRAND PRIX IN 1924, AND FIRST ESTABLISHED THE NAME OF THE FAMOUS ITALIAN FIRM.

Bottom : THE BUGATTI, ONE OF THE MOST CELEBRATED RACING CARS THAT HAVE EVER BEEN BUILT, WHICH CREATED A SENSATION IN 1924, AND IS STILL BEING RACED TO-DAY. (*Photograph : Meurissc.*)

being half-elliptic, backed by very large friction shock-absorbers. Castor action was obtained by canting the front axle, and—an interesting point—as water was liable to pile up in the top tank when the centrifugal pump was at full speed, there was a by-pass pipe from the top to the bottom of the radiator. The body was very light and of streamline shape, with a pointed tail, and the exhaust pipe close to one side, the tail being composed almost entirely of fuel tank. The weight of this car was 13 cwt. 1 qr. 9 lb., and it had an 8 ft. 2 in. wheelbase, and a track of 3 ft. 11 in.

Thereafter there seemed to be one of those *crises* which are recurrent in racing. Delage made history for a very short while with a wonderful little 1½-litre machine, with eight cylinders, two overhead camshafts, roller bearings throughout the engine, and an enormous number of gear-wheels to drive the camshafts, the magneto, water pump, and the Roots type supercharger, for supercharging had now become the rule, not the exception, after the appearance of the Fiat, unsuccessful in the 1923 Grand Prix, and the addition of superchargers to all the cars save the Bugatti in the 1924 Grand Prix.

Delage in their turn retiring, the subsequent years belonged to Bugatti for an unusual period of time, practically every race resulting in a Bugatti win. These cars were not only interesting, but were almost unconventional, and showed much of that unusual genius of the designer whose name they bore.

The first successful machines were 2-litres with straight-eight engines, which appeared for the first time in the 1924 French Grand Prix, and attracted enormous attention principally because they were the first racing cars to have the coat of paint and nickel plating usually associated with a production machine, and were the first racing cars to be produced in quantities.

The straight-eight engine had no detachable head, its cylinders in two blocks of four, and an overhead camshaft driven by bevels and operating three valves for each cylinder—one exhaust and two inlets—through rocking fingers, with a shim adjustment on the valve stem. The appearance of the engine was odd, since plates bolted to the block to form the outer walls of the jacket were of light alloy, and, with the rectangular casing for the camshaft, gave the whole power unit an unusual, but neat, shape. The cylinder walls themselves were of cast iron, and the crank case, which was separate, of light alloy. One magneto was driven from the camshaft and mounted in the dashboard. The crankshaft was a wonderful piece of machining, being made in parts and bolted together so that the main bearings could be ball races, the connecting rod big-end bearings rollers, and all could run direct on the journals and crank-pins. The pistons, of course, were of light alloy, the rods of steel, and there was a quite plain inlet pipe with two big Zenith carburettors. What amounted to jets threw oil at the connecting-rod bearings. Then the four-speed gear-box which, in accordance with Bugatti's usual practice, had a lever which moved forward to engage top, was separate from the engine, and the drive to the rear axle passed through an open shaft, the torque being taken by a pressed-steel member running parallel to the propeller-shaft and anchored to the gear-box by a fabric joint. A fabric joint was also placed in the steering column.

The frame itself was very light, almost fragile-looking in front, but with a certain thoroughbred neatness about the detail work, and the front axle was a miracle in that it appeared to be a tubular beam, becoming of box section in two places, so that the very short half-elliptic front springs passed right through these boxes in the axle, the puzzle being, of course, to know how the axle was drilled out although it was not straight. Actually the drilling was done before the axle was set.

Oil was contained in a large separate sump below the floor-boards of the cockpit, and the engine had the usual scavenger pump and pressure pump. At the rear, again following standard Bugatti practice, the springs were quarter-elliptic, anchored at the back to the frame, projecting forward to the axle, and Bugatti had adopted for the first time a most unusual form of light-alloy wheel made in one piece with its brake drum, so that the brake drum was changed with the wheel during a race. There were brakes on all four wheels operated by cable compensated by a chain running round two sprockets on the actuating gear, the lever being connected up to the rear shoes by an additional cable, and neither operation having an adjustment.

The appearance of the car was made extremely pleasing by a streamlined body and bonnet and radiator of very fine shape, the tail being almost entirely fuel tank. In the initial race the tyres did not fit the wheels, but this car subsequently became most successful and famous, a supercharger driven from the timing gear being added the following year, from which time onwards this machine remained practically the same, though its engine size, which had commenced as 60×88 mm. bore and stroke, was slowly increased. The weight of the car complete was 12 cwt. 3 qr. 5 lb., the wheelbase 7 ft. 11 in., the track 3 ft. 11 in.

A special type of friction shock-absorber designed by Bugatti was fitted, and the track fore and aft was the same, which was unusual because at this date racing cars were usually crab-tracked, being narrower at the rear than at the front.

The next car to rise to a peak of success above all others was

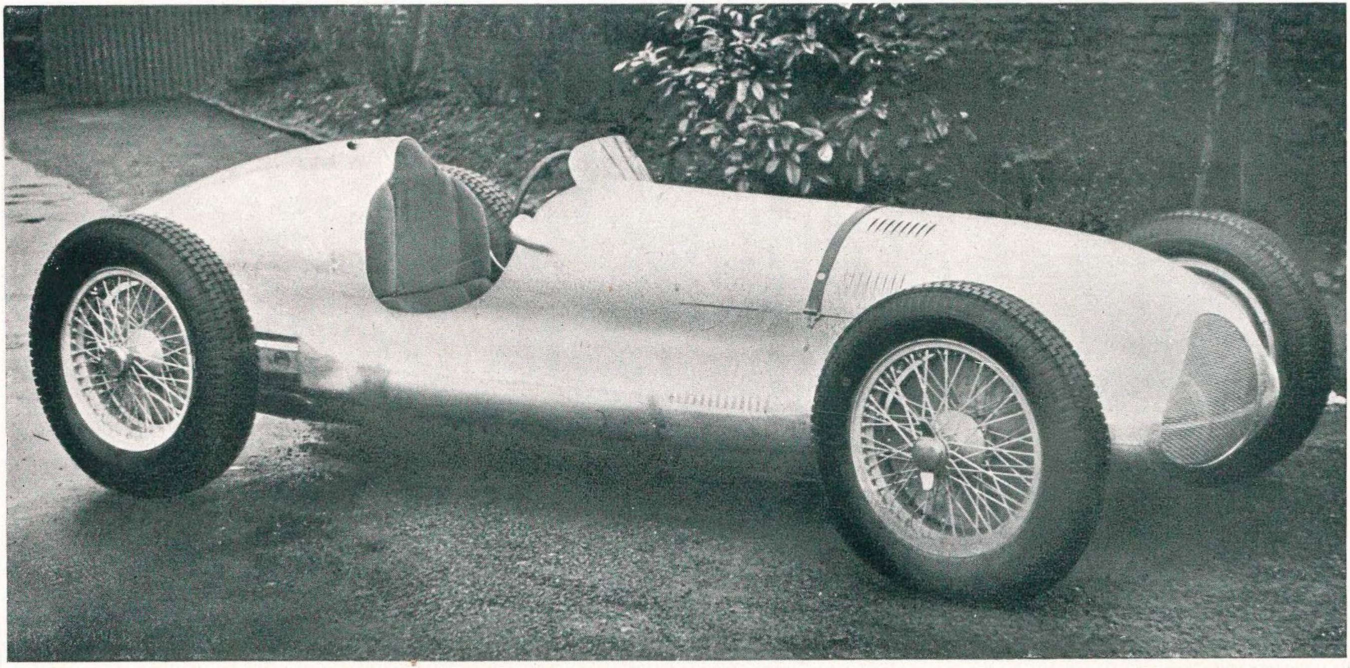


Plate 20. [Photograph: "The Autocar."

THE 1939 1½ LITRE E.R.A.

THE LATEST DESIGN OF THIS FAMOUS "PRIVATE" RACING-CAR FACTORY. FREQUENT SUCCESSES HAVE BEEN ACHIEVED BY THE MARQUE IN MANY PARTS OF THE WORLD IN THE FACE OF COMPETITION FROM THE MOST FORMIDABLE RIVALS.

the Italian Alfa-Romeo, which differed almost entirely from the Bugatti in design. The cylinders were of aluminium alloy, with steel liners, and in two blocks of four arranged to be interchangeable. The head was detachable, which was unusual in racing, and was of light alloy sometimes with special material for the valve seats, and the plugs in the centre of the head, which plugs were, for some time, shrouded. The camshafts ran along the top of the head operating the inlet and exhaust valves for each cylinder. Each valve had three springs and an unusual form of attachment for the collar, the cam actuating the valve through a finger which also served as the clearance adjustment. The timing gears were in the centre, the crankshaft being in two pieces. From this timing gear was driven on one side the magneto and oil pump, or, in certain instances, the distributor for battery ignition, while on the other, gears drove two small superchargers of Roots type, each with its separate carburettor, generally a Memini, each feeding a short inlet pipe on which safety-valves were mounted.

In this case all the ten crankshaft bearings were plain and of white metal, as also the big end bearings, and the rods had much in common with those of a standard sports car, as also the light-alloy pistons. Again the engine oil was stored in a separate tank with a scavenger pump and a pressure pump, and a very big centrifugal pump circulated the water through a radiator which had a protective shell and a grid guarding the front against stones. In the flywheel was a light multi-disc alloy clutch, and in this case the four-speed gear-box was in one unit with the engine, and the gear lever mounted centrally, a special ventilation system directing cold air into the bellhousing.

The transmission of the later cars was unusual, for there was a bevel just behind the gear-box which drove two pinions on two separate propeller-shafts carried at an angle outwards to two more bevels and crown wheels mounted close beside the rear wheels, the axle none the less having the ordinary centre pump. This was probably done to equalize the drive on both rear wheels when accelerating.

The frame was very light, rigid in front, but more flexible at the rear; the tank, of course, was mounted as part of the tail, air pressure in that tank being maintained by an engine-driven pump. The brakes were very large, on all four wheels of course, and actuated either by the pedal or a lever, each brake drum's shoes having independent adjustment.

On still later cars, too, a front axle was not used, each wheel being mounted independently on the Dubonnet system, and the rear axle had quarter-elliptic springs anchored at the back, instead of half-elliptics.

The first cars of the type to make a name were the 65 × 100 mm., 2654 c.c. machines developing about 198 h.p. at 5400 r.p.m. The later model, with independent suspension, had a bore of 71 mm., a stroke of 100 mm., and a capacity of 3168 c.c. On these later cars, also, the front brakes were hydraulically operated. It is probable that these cars have attained 150 or 160 m.p.h. on the road, and weighed about 13 cwt. 3 qr. 3 lb. There was marked experiment. Some of the earlier cars, for example, had cast-iron cylinders, and the engine size increased from year to year.

Usually built as single-seaters, these machines had the seat higher than was normal to allow the driver a better view of the two front wheels, and the Alfa history of successes is particularly marked considering the number of years during which the *marque* has been racing.

Coming down to 1934, there appeared suddenly two teams of German cars, the Mercedes-Benz and the Auto-Union, which were obviously something out of the common. The Auto-Union was, in fact, built by a group of firms, as its name implies, but both teams—at all events according to rumour—were backed by a Government subsidy, and both were undoubtedly backed by national opinion.

Naturally teething troubles were encountered during the earlier stages, but once these were over, the new German cars attained an astonishing number of victories, breaking completely the sequence of Alfa successes. In 1935, in fact, the Mercedes was victorious almost wherever it went.

The car used was interesting, because every advantage possible was taken of modern light alloy. The engine had eight cylinders with steel liners inserted in an alloy water-jacket and in contact with the water, the valves being overhead, actuated by two separate gear-driven camshafts.

In distinction to most other supercharged cars, the Roots type blower for these engines forced air through the carburettors, the blower itself being mounted vertically and driven from the front end of the crankshaft. The usual practice adopted both by Alfa and Bugatti was to make the supercharger suck air through the carburettors and deliver the consequent gas under pressure. The Mercedes system entailed making the carburettor function under pressure instead of a depression, and that in turn entailed balancing the pressure in the float chamber against that in the inlet pipe, and, of course, pressure in the fuel tank as well.

Considerable secrecy was observed as to the details of these cars, which incidentally had to be very light, the regulations calling for a maximum weight of 750 kilograms without tyres, fuel, water, or oil, but the capacity of the engine was certainly 4 or 4½ litres, and it must have developed something in the

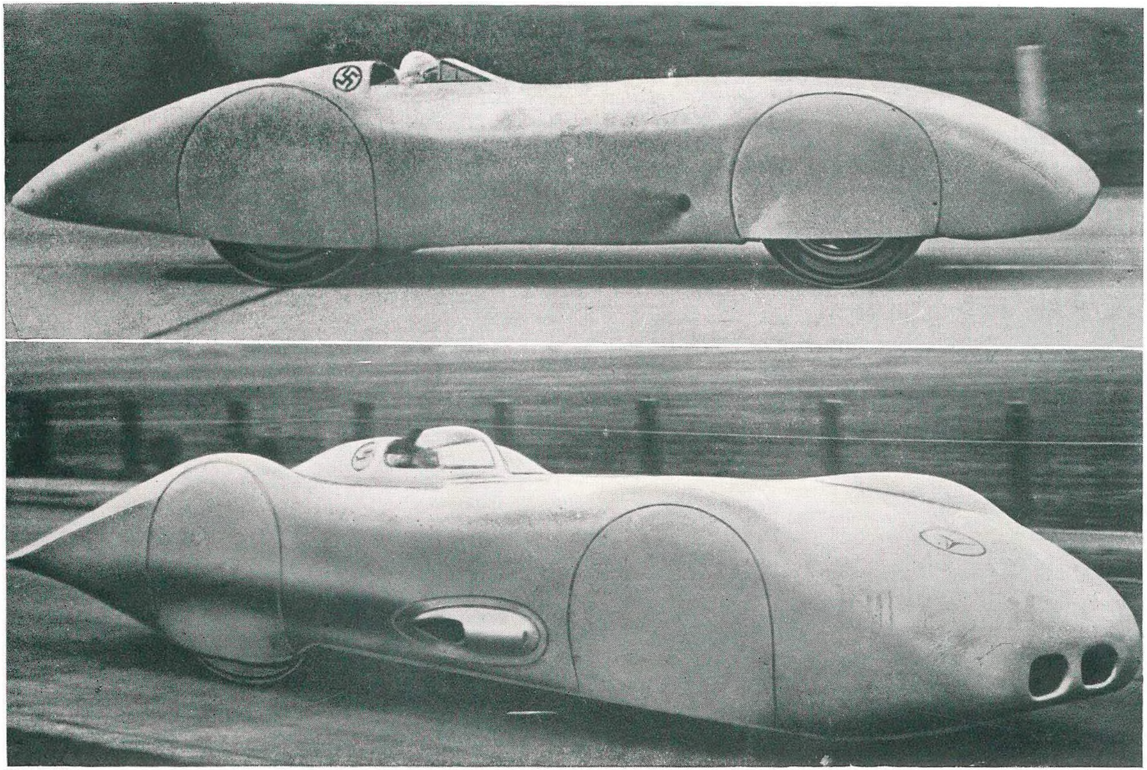


Plate 21. *[Upper photograph : Keystone ; lower : Sport and General.*

STREAMLINING FOR MERCEDES-BENZ SPEED RECORD ATTEMPTS.

TWO VIEWS OF A RECORD-BREAKING MERCEDES-BENZ. THE CAR TENDED TO LIFT WITH THE BODY SHOWN IN THE UPPER PHOTOGRAPH, AND WAS MODIFIED TO THE SHAPE SHOWN IN THE LOWER.

neighbourhood of 400 h.p. The crankshaft journals had ball bearings, the rods rollers. The plugs were in a line in the centre of the combustion spaces, current being provided by a single magneto. A four-speed gear-box was mounted as part of the rear axle casing, the gear lever being at the right side of the cockpit. Drive from engine to gear-box passed through a stout steel tube propeller-shaft, and the rear axle assembly—that is, bevels and gear-box—were bolted rigidly to the frame. The front but not the rear wheels were independently sprung, the stub axles being located by rocking levers with coil springs in front, while at the rear the driving shafts were enclosed in tubes attached to the centre casing by ball joints, and moving against a single transverse leaf spring backed by substantial friction shock-absorbers. Behind this there was a single solid axle from hub to hub with a locating bracket at its centre.

The steering was unusual, too, the gear being mounted in the cockpit with its drop arm, and the fore-and-aft tube passing forward to a bell crank and link motion for the two wheels. All four wheels had very large hydraulic brakes with an elaborate system of air cooling for the shoes and operating cylinders. The frame was of box section pierced as much as possible to reduce weight, and practically every detailed part of the chassis was elaborately drilled for the same reason.

The bodies were things of beauty, extremely light, streamlined cowling taking the place of the radiator shell, and the whole shape being quite unusual. Even the filler cap for the fuel tank was covered over by a trap-door in the special faring for the driver's head. Finally, the entire machine was almost Show finished. It is a little difficult to assess its speed, but in all probability these cars were capable of 160 in road-racing condition.

Although the most famous of all the Mercedes-Benz cars will, if one can see future history, be the first of the type, the 1938 machine was changed considerably. It had a V 12-cylinder 3-litre engine instead of the straight-eight, the supercharger sucked from the carburettor instead of blowing through it, and the rear suspension was modified, being now of the De Dion type, with the hub assemblies joined by a tubular axle, an anti-sway device at its centre, and the wheels still driven by shafts from the bevels in a casing attached to the frame. Torsion bars replaced the springs previously used. The bodies were much lower than those of the first cars, and the grid in front of the radiator was of a different shape, being extended sideways partly to supply air to the oil-cooler.

The rival German car, the Auto-Union, was even more unusual in design. The most famous machine, however, was probably the 1938 design.

The 3-litre engine was a V with 12 cylinders. Each big-end had a roller bearing, each main a ball race. There were three camshafts operating the valves through fingers, there being two valves with multiple springs per cylinder. In this engine, too, the actual cylinder was a steel liner in contact with the water and inserted in a light-alloy jacket, the head being detachable, and the design allowing the supercharger, which was of Roots type and mounted vertically, to feed the inlet ports through a special passage between the two cylinder blocks.

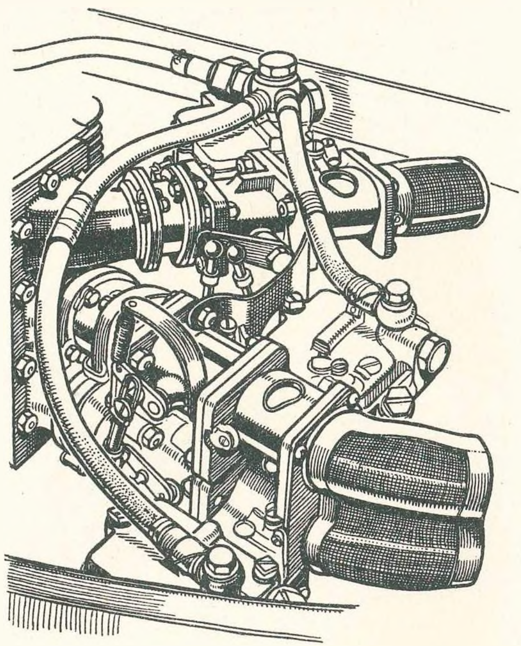


Fig. 1

CARBURETTOR ARRANGEMENT ON THE 1938 AUTO-UNION

But one of the most interesting points of the whole thing was that this engine was mounted slightly behind the centre of the chassis, and just in front of the rear axle, the drive passing back to a five-speed gear-box behind that axle, then forward again to the bevels of the axle itself. Thus the whole power unit and transmission were located at the rear of the chassis behind the driver.

The drive for the auxiliaries was taken from the power unit by a cross-shaft just behind the blower, magneto ignition being provided, but special provision had to be made to secure the extra long water-pipes as the radiator was in front of the car, where also were located the fuel, water, and oil tanks. In effect, therefore, the Auto-Union was arranged in exactly the opposite manner to any other racing car.

As to detail, the blower was supplied by three Solex carburettors flexibly mounted and arranged so that the third came into operation only at full throttle. The blower itself had an elaborate individual lubrication system from a special oil pump driven from the camshaft gears. The lubrication was on the

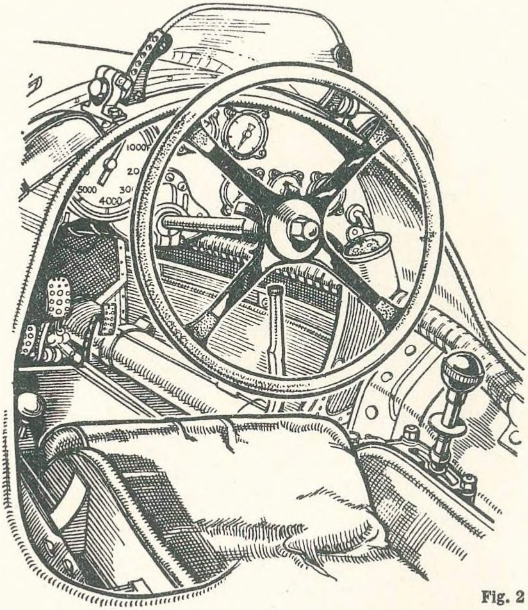


Fig. 2

AUTO-UNION

The Driver's Cockpit. The engine being at the rear, very lengthy water-pipes have to be carried to it from the radiator, which is in the normal position.

dry-sump principle. The water cooling was extremely elaborate and well spread over the head and barrels, a small steam valve being placed in one of the pipes and the filler being under the bonnet. Fuel was carried amidships, the tank forming the top of the tail just behind the driver and continuing in saddle shape with extensions which went down to the frame on either side of the driving seat. There was a mechanical pump to force fuel to the carburettor. The drive passed from the clutch across the main bevels to a heavily ribbed five-speed gear-box controlled by a short right-hand lever. The centre of the rear axle was carried on the frame, the final drive passing through a patent differential to two side shafts, each with two universal joints and a sliding joint, but the wheels were coupled together by a separate tubular axle, and the wheel assemblies were mounted through levers on torsion bars within the tubes of the main frame, each bar having a separate friction shock-absorber and also a hydraulic shock-absorber. The brake drums were of light alloy, lined, and with many fine cooling fins, each of the two brake shoes being operated by its own hydraulic cylinder so that each was in effect a leading shoe, and the same idea was used

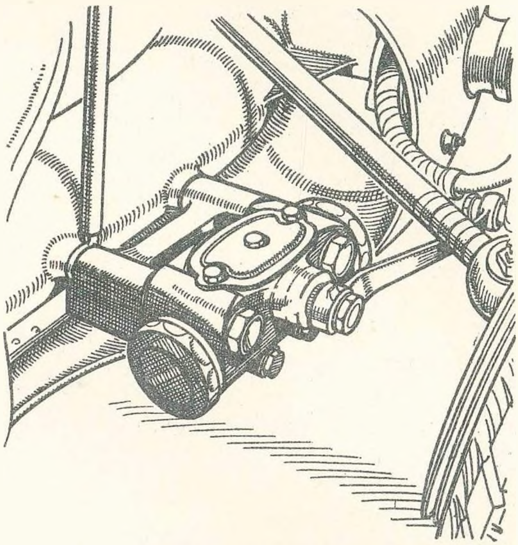


Fig. 3

AUTO-UNION

Suspension and shock-absorber of the offside wheel.

for the front brakes. All wheels were of light alloy, the tyres for the rear wheels being enormous.

The frame was made of very light, strong steel tubes welded together, the front wheel hub assemblies being carried on the frame by two trailing arms, while the rear wheel assembly is positioned by a radius stay; the two assemblies, as already stated, being connected together by the tubular axle. Incidentally, the tubular axle was prevented from moving sideways relative to the frame.

As in the case of the Mercedes, the body was a wonderful piece of work, very light, of special alloy, and streamlined. The driver sat much farther forward than was usual, and had only a short imitation bonnet as a guide. The cars, of course, had

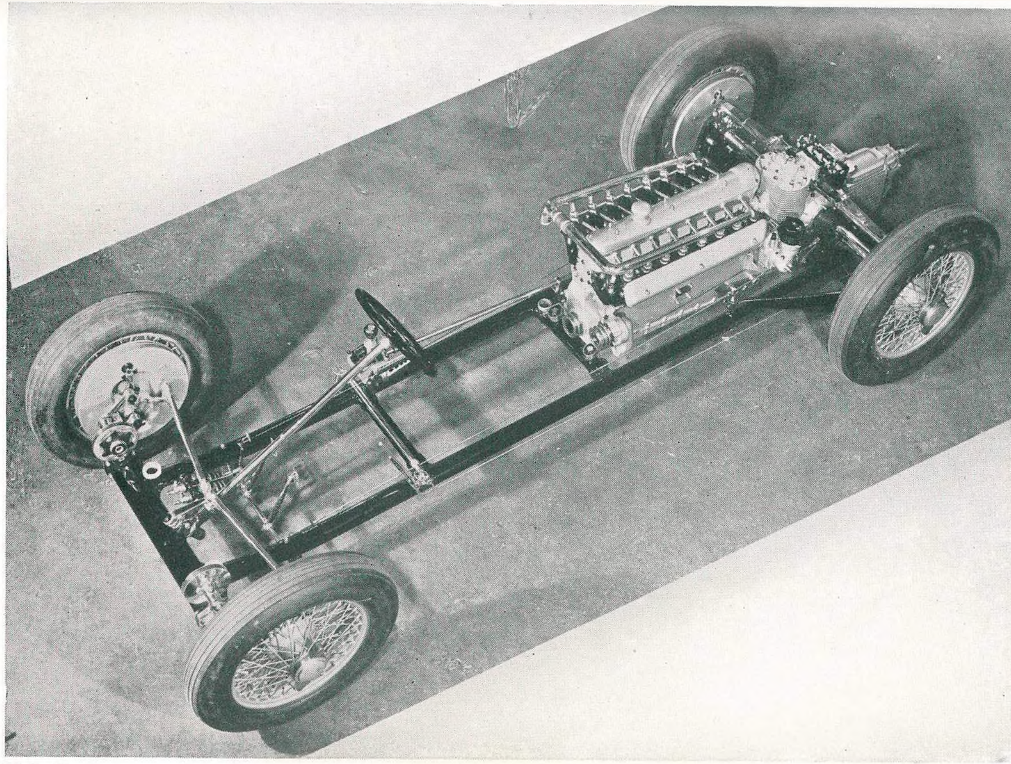


Plate 22. [*Photograph : Auto-Union.*

AN UNUSUAL DESIGN.

THE ORIGINAL AUTO-UNION CHASSIS, SHOWING THE TUBULAR FRAME AND THE ARRANGEMENT OF ENGINE AND GEAR-BOX ABOUT THE REAR AXLE.

to weigh not more than 750 kilograms without their fuel, oil, water, or tyres, and therefore were exceptionally light.

The speed would be about that with which one may credit the Mercedes, but it is interesting that both types of cars were used for records, though they may have had slightly larger engines than those used for road racing. A 6008 c.c. Auto-Union recorded 252·5 m.p.h. for the mile in November 1937. The 1938 Mercedes record with the 12-cylinder of 5576 c.c., with a bore of 82·0 and a stroke of 88·0 mm., was 268·8 m.p.h. for a flying kilometre. In 1939 the 3-litre Mercedes with a special body attained 248·27 m.p.h. over a mile on one of the German motor roads, and this was also an average of runs in two directions.

Thus far the cars described have been the fastest road-racing machines built for the premier road races of their time, but the British E.R.A., which did not fall into this category, deserves a place not only because it was extraordinarily successful but because it became famous. Practically all its racing history was achieved with the 1½-litre car, and the unusual point is that this machine was built entirely because of the enthusiasm of a private competitor, Humphrey Cook, who financed the venture from the commencement.

The car itself was developed from experience with a special supercharged Riley, with which another private competitor, Raymond Mays, had attained considerable successes, especially in hill-climbs. In its first form the car had a 6-cylinder engine with cast-iron cylinders and crank case, a crankshaft with two plain bearings, one at each end, and a roller-bearing in the centre, plain bearings for the connecting rods, light alloy pistons, and a light alloy head, a feature of the design being that the two camshafts were carried one at either side of the cylinder block and operated the valves through push rods and rocking levers, there being two valves for each cylinder.

In front of the crank case was a Jamieson supercharger sucking from an S.U. carburettor, and the drive was taken through a Wilson epicyclic box with pre-selector mechanism for the gears so that any of the four-speed could be selected in advance, the change of ratio only taking place when the driver moved the equivalent of a clutch pedal. Three epicyclic trains were brought into play by band brakes. On top gear a cone clutch operated and locked the mechanism solid. Behind the box the propeller-shaft ran in a ball-ended torque tube, and the final drive was a bevel-and-crown wheel with, in certain instances, a special type of differential limiting the amount of wheel spin.

The front axle was an H section beam, and ordinary suspension was employed, with half-elliptic springs front and rear, backed by friction shock-absorbers of an especially light type, and the brake mechanism had all its operation in tension. Across the chassis and below the frame was carried a large tank in which was all the oil needed for the engine, as the crank case was scavenged by a special pump, and the filler for this oil tank projected at one side of the car. The tail was almost entirely fuel tank, and pressure in that tank was kept constant by an engine-driven pump with an automatic pressure-governing valve. The fuel pipes were of light alloy, and the car itself only weighed 13 cwt.

Some of the characteristic appearance of the car was due to the fitting of small wheels with a very wide rim, and a tyre of very large section. All, of course, were single-seaters with the steering wheel in the centre of the cockpit, and the steering column running at an angle to the steering gear in its case on the frame. The seat was unusually high.

The exact speed which an E.R A. could attain is difficult to give, as the cars were mostly used for road racing and no timed stretches were available, but they must have been able to get up to 135 m.p.h. at least.

The fame of the E.R.A. rests, of course, on the original 1½-litre, but it is worth mentioning that the 1939 machine, also a 1½-litre, had plain bearings throughout, the supercharger at the side, a very small multi-disc clutch, an ordinary four-speed sliding gear-box as part of the rear axle, with synchromesh mechanism, the same type of axle at the rear as the Mercedes and Auto-Union, which is now known as the De Dion type, torsion bar suspension, and a tubular frame, while the whole of the body and radiator was very much lower than in the preceding cars.

Of cars other than Grand Prix machines, the Bentley certainly earned its niche in the temple of fame. It was a sports car modified for racing, and as a sports car it was famous throughout the world principally as a result of successes at Le Mans. Two types were especially prominent; the original 3-litre, which was interesting because it had four cylinders and no detachable head, both unusual features in the last few years. A single overhead camshaft operated the four valves of each cylinder, and was itself driven by bevels, the cylinder block was detachable from the crank case, all the bearings were plain, the sump below the crank case was wide but very shallow, and there were plugs on each side of the combustion space, each line of plugs being fed by a separate magneto and both magnetos being driven by a cross-shaft. Water was circulated by a very large slow-speed centrifugal pump. Then the four-speed gearbox was separate from the engine instead of being a unit, though otherwise the design was normal, incorporating an open propeller-shaft and a pressed-steel, double-banjo type back axle.

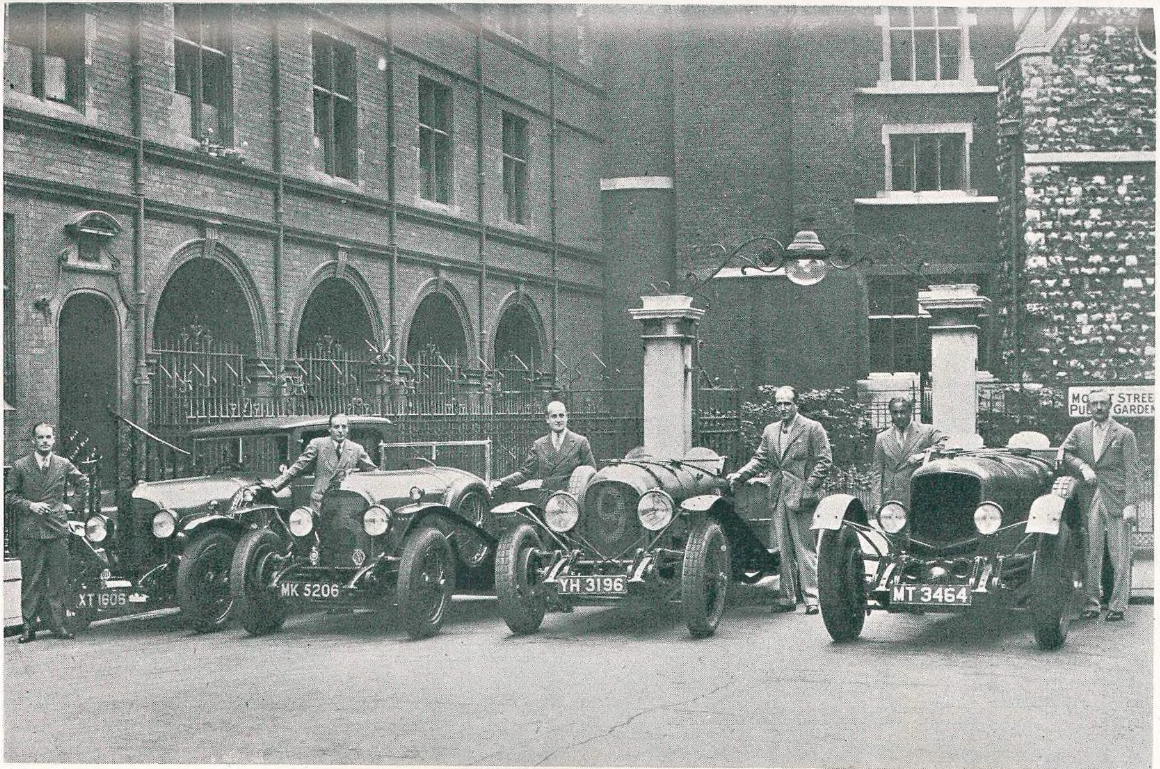


Plate 23.

[Photograph : " The Autocar."

A FAMOUS MARQUE.

IN ITS VARIOUS FORMS, THE BENTLEY MADE A GREAT NAME FOR ITSELF, ESPECIALLY IN THE SERIES OF 24-HOUR RACES AT LE MANS. THE DRIVERS SHOWN ABOVE ARE: F. C. CLEMENT, S. C. H. DAVIS, DR. J. D. BENJAFIELD, BERNARD RUBIN, WOLF BARNATO AND SIR HENRY BIRKIN.

All four springs were half-elliptic, and four very large brakes were operated by rods and levers from the pedal or lever. The racing machines usually had an auxiliary oil tank under the scuttle of the body feeding the sump, an arrangement whereby the sump could be replenished without lifting the bonnet, a special hand-operated adjustment to take up the brakes while the car was running, and they were the first to have a special throttle pedal arranged so that it could be operated by the driver's heel while the brake pedal was applied. Every car was most elaborately fitted out with quick-acting fillers, and the detail preparation was extraordinarily good.

After that 3-litre came a larger version of 4½ litres, which in its turn was extremely successful in racing, and then the famous 6-cylinder, which differed in detail because its camshaft was driven by eccentrics with sheaves and connecting rods, one set of eccentrics being on the crankshaft, the other on the camshaft. Neither this 6-cylinder nor the 4-cylinders were usually supercharged, gas being supplied from a pair of S.U. carburettors as a rule, and fed to those carburettors by air pressure generated by a hand pump, but a special series of 4½-litre cars were given Roots type superchargers and run as a team by Sir Henry Birkin.

That at the moment closes the list of exceptionally famous racing cars which, by the way, are as a rule quite different from the record-breaking type of car, as different as are the purposes of the two different types. Other *marques* will arise in the future, become equally famous, but whatever pitch their fame may reach, they can never supplant the older cars or be, for their day, more wonderful.

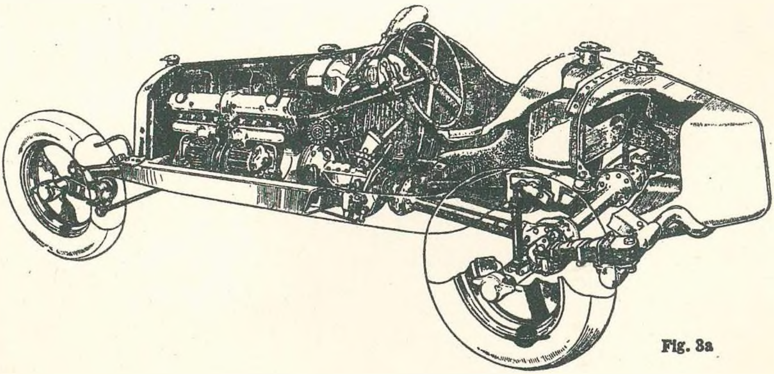


Fig. 8a

STRAIGHT EIGHT ALFA-ROMEO

Starting with an engine of 2654 c.c. these cars originally had four half-elliptic springs; they were gradually developed over a course of several years; on the later models, shown above, the engine capacity had been increased to 3168 c.c. and independent suspension was provided in front.

CHAPTER THREE

RACING & THE MOTOR MANUFACTURER

By Cecil Kimler
Managing Director of the M.G. Co.

THE question as to whether racing is of benefit to the motor manufacturer is one to which there is no direct answer. It depends on the type of manufacturer and the type of racing. The Morris and Austin organizations—the largest in this country—have both been built up without any stimulus from the race track, as no one would contend for a moment that the small amount of racing which the Austin concern has done with their smallest model has had any effect at all on their bulk sales.

On the other hand, the M.G. Car Company, a concern with which the writer is associated, built up in a short space of less than ten years a prestige and world-wide renown that could not otherwise have been achieved, but in this case the type of product was entirely different from that of the large-quantity manufacturer, being one that had a deliberate speed and performance appeal. Also the cars that were raced bore a very strong resemblance to the models that were sold in the ordinary way, and very many lessons that were learnt in the stress of racing were embodied in the subsequent production cars, to the ultimate benefit of the user. Brakes, steering, and engine-bearing life were perhaps principally affected and improved.

A few years ago the oil, petrol, tyre, plugs, and other accessory firms vied with one another in offering bonuses and financial assistance to both drivers and manufacturers, and the successful manufacturer also had the very estimable benefit of having thousands of pounds' worth of publicity spent on his product, if successful, by these accessory firms. To the manufacturer this advertising was perhaps the most valuable adjunct to a successful racing season.

A few years ago this practice ceased, and the manufacturer who still indulged in racing not only had the expense of building and preparing the cars, paying drivers and supporting a team of highly trained mechanics and pit assistants, but after winning a race, such a manufacturer was then faced with further big expenditure in order to advertise his win. As a manufacturer can only regard racing from a commercial standpoint, many quite rightly considered that such publicity was too dearly pur-

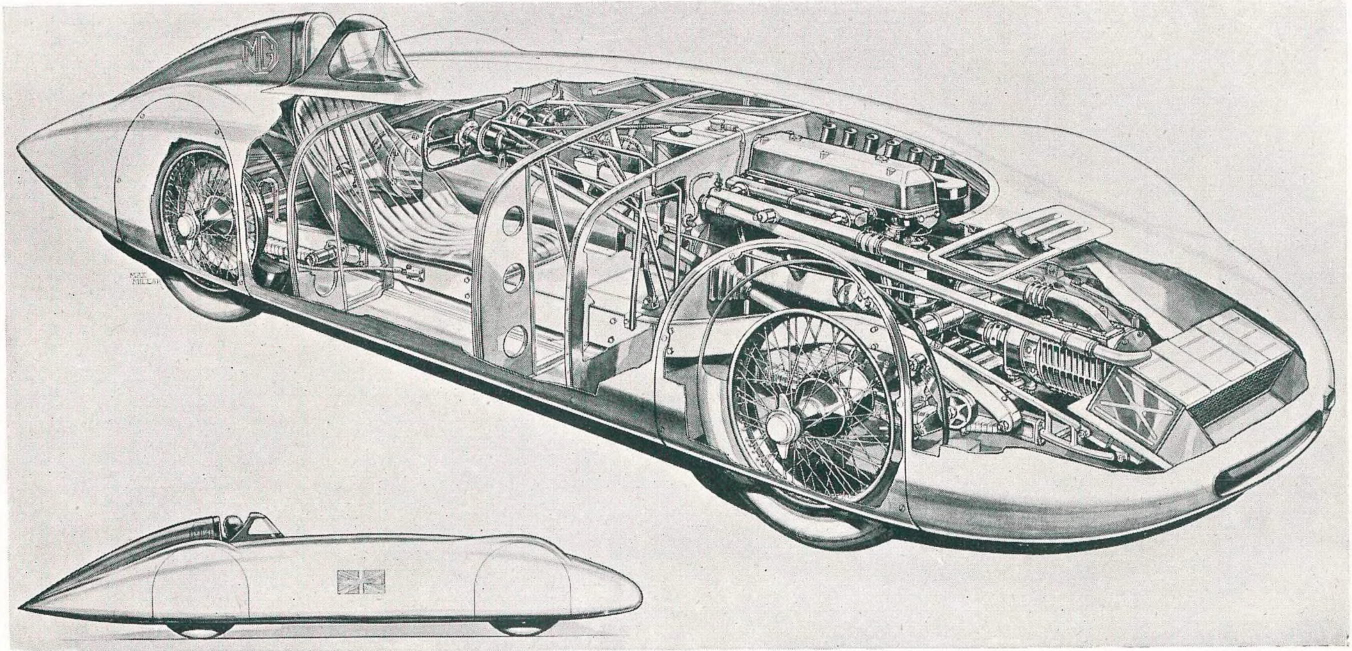


Plate 24. [By the courtesy of "The Autocar."

MAJOR GARDNER'S STREAMLINED M.G.

THIS "12 H.P." CAR HAS ATTAINED SPEEDS IN THE NEIGHBOURHOOD OF 180 M.P.H. THE ENGINE AND PROPELLOR SHAFT ARE OFFSET IN ORDER TO SEAT THE DRIVER VERY LOW AND THUS MATERIALLY REDUCE FRONTAL AREA. THE ENGINE, WHICH IS OF VERY SPECIAL DESIGN, HAS A BRONZE CYLINDER HEAD AND AN EXCEPTIONALLY HIGH DEGREE OF "BOOST" IS APPLIED BY THE SUPERCHARGER.

chased, and one by one they ceased to be interested in motor racing as a means of advertisement.

This is one reason why the outlook for British motor racing is so gloomy, but there is another aspect that affected the manufacturers to a very great extent, and for this the race promoters have only themselves to blame. These promoters wanted a large field with plenty of entrance fees, and were obsessed with the idea –fostered to a very large extent by the daily press—that the general public always wanted to see the largest and fastest car win, regardless of the fact that the largest and fastest cars that used to compete in these races were generally of Continental make.

The British manufacturer, making a diversity of models and concentrating largely on the small and medium-sized cars, very naturally prepared and entered these particular types. This necessitated some form of handicapping, and it says well for the small British car, and its reliability under very severe conditions, that when they won it was generally due to the lack of reliability of the larger Continental car, which so often broke up after, perhaps, leading the race for most of the time.

This handicapping by some of the race promoters would not have been too bad in providing a reasonable spectacle for the general public if they had gone about it in a fair and more logical way. The system was to divide the cars into various classes according to their engine capacity, but having done this, these handicappers did not, as they should have done, handicap *pro rata* to size, but would deliberately favour one particular class in order to encourage the entry of a certain manufacturer who would normally be competing in that class, but who, on a strictly *pro rata* handicap basis, would have no chance of winning. For example, assume that the 1500 c.c. class in a certain race was set to lap at 70 m.p.h. and the 2500 c.c. class to lap at 80 m.p.h., and assume that both these speeds were within the capabilities of the particular cars likely to be entered in such classes, then to be logical, any car that appeared in the 2000 c.c. class should have automatically been handicapped to lap at 75 miles an hour. However, if the only possible entrant in the 2000 c.c. class was a certain manufacturer whose products were known not to be particularly fast, then, in order to encourage the entry, the race promoters and the handicappers would gaily set that particular class to do only 72 m.p.h., which gave them a distinct chance of winning, and which was naturally distinctly unfair to the manufacturer with a far more efficient 1500 c.c. car. The more successful a manufacturer was in any particular size or class, the more the handicap was operated against him, and this was the second, and perhaps more important, factor which has operated against the continued interest in racing by manufacturers, at any rate as far as Great Britain is concerned.

No manufacturer with shareholders could, with the serious repercussions that occurred if they were constantly unsuccessful, afford to jeopardize their firm's prestige under such conditions.

Perhaps the best attempt by any Club staging a race to create fairer conditions and produce, in effect, almost a scratch race was made by the Junior Car Club, and in this particular event which they staged, a series of channels were formed at one point on the track containing corners, the larger and faster cars having to negotiate the channels with more acute corners than the smaller fry. This was fairly successful and all right as far as it went, but owing to the impossibility of providing a sufficient number of channels, a certain element of unfairness crept into the race owing to the fact that cars of different capacities were given the same channel to go through. In theory this particular race was supposed to have all the merits of a scratch race, so that the public would know that the car first past the chequered flag was the winner, but in actual practice, when a comparatively large field had begun to string out, some cars were lapped by others, stops were made at pits, and so on, so that after a time, on a small circuit, this race was just as difficult to follow by the general public as the handicap race, in which the various classes were set off at different intervals and given credit laps, and so on.

One has to remember also that, owing to the fact that racing on the King's highway has never been permitted in this country, the British public has never had an opportunity of seeing any real road racing, and has not received the education in this respect that our friends across the Channel have. In consequence, motor racing of the Grand Prix variety is a closed book to the average Englishman.

Whilst this gloom was settling over the British motor industry and affecting its attitude towards road racing, a much more sinister aspect came into being in the shape of Government-subsidized racing teams. Italy was the first to start this, and at one time practically swept the board at all the Continental Grands Prix. It was undoubtedly done as a form of national propaganda, and there is no doubt that it obtained for her motor products a reputation that was sometimes, not always deserved. Germany was quick to see the advantage of this, and went into it with typical Teutonic thoroughness. The Mercedes-Benz and the Auto-Union teams were the result. The amount of money that these two teams must have cost their respective firms in designing, building, testing, and maintaining would obviously never be justified looked at as an individual commercial proposition. However, as an advertisement for Germany and her motor products they were undoubtedly magnificent. We, fools that we are, invited these all-conquering German teams to come and compete at our Donington Road Racing Circuit. The race promoters, no doubt with an eye to the gate money but with little regard for the prestige of the British manufacturer, are well known to have offered these German teams special inducements to come over, such inducements, of course, being of a financial nature.

Naturally these colossally expensive and extremely fast cars of $4\frac{1}{2}$ or so litres capacity made our own 1500 c.c. racing cars, good as they are, look silly, and what is the result? The British public obtained the impression—and who shall blame them?—that the German motor cars are invincible and that Germany obviously builds good cars. Then, when Germany begins exporting large numbers of her ordinary product, although these technically are not to be compared with a British product of the same size and price, they sell on the prestige obtained for them by the Government-subsidized German racing cars, which undoubtedly are magnificent examples of engineering. This is how German racing cars assist the German motor industry, and it now remains for the British Government to consider whether we, as a nation, should not take our place in Grand Prix racing, in view of the fact that our motor industry is the third largest industry in this country, and larger than any other country in Europe. This racing can only be done nationally: there is not the incentive or the reward to-day for the individual manufacturer to build and race cars on his own.

CHAPTER FOUR

AUTOMOBILE RACING FROM THE DESIGNER'S POINT OF VIEW

By G. Roesch
Chief Designer of Clement Talbot

AUTOMOBILE racing is a sport based on financial considerations. All types of automobile racing are good, provided they are carried out intelligently, and by that I mean the cost must be justified by the knowledge acquired and the possibilities of utilizing to the full the benefits derived from this knowledge and the publicity resulting.

A good deal of racing has been and is done without proper advice, and if this latter were sought, large sums of money would be saved to those participating by reason of the fact that much valuable knowledge is already available.

To be effective, racing must have its own strategy, tactics, and showmanship. It must take account of all aspects so as to determine the reactions of the section of the public one wishes to reach, and thereby also satisfy personal aspirations.

It is sometimes more difficult not to take part in a race than to do so, but above all racing should never be weighed up without taking full account of the sporting aspect, and whatever work is involved should be done well : as well as is possible with the means available.

In racing one must always take into consideration the prospect of losing, and whilst I would not like to say that in motor racing the biggest gamble is likely to yield the biggest result, nevertheless it is quite possible to participate in a race and so to act that in case of defeat the losses are not unnecessarily heavy. The public is particularly appreciative of a worthy effort having been made under certain unfavourable conditions.

Grand Prix Racing

There is no doubt that Grand Prix racing is a most desirable form of this branch of the sport, but as it has developed it is to-day a game which can only be played by nations. Only when the objects to be attained, looked at in the light of international conceptions, are matters of propaganda and prestige, is it satisfactory.

No individual motor car manufacturer can be reasonably expected to participate in this type of racing because his busi-

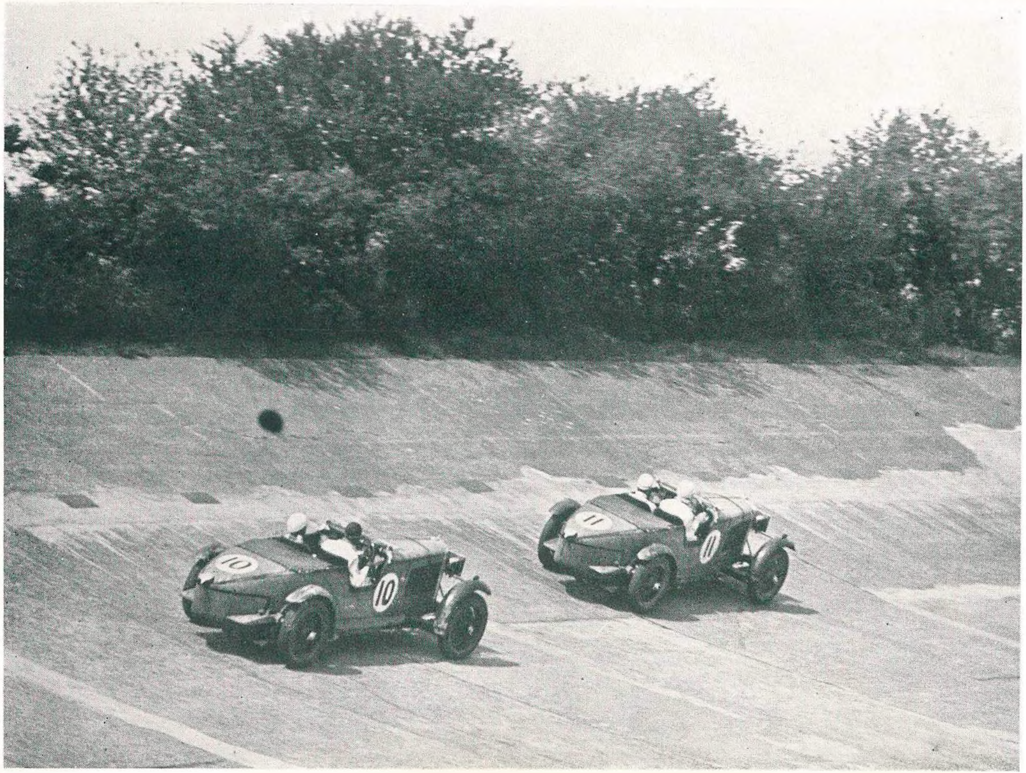


Plate 25. [Photograph: "The Autocar."

TWO CARS OF THE TALBOT TEAM RUNNING IN FORMATION AT BROOKLANDS.

THESE VERY SUCCESSFUL SPORTS-CARS WERE OF JUST UNDER 3 LITRES, AND BORE A VERY CLOSE RESEMBLANCE TO THE STANDARD PRODUCTIONS OF THEIR FIRM.

ness does not necessarily demand international prestige to further sales in his own country. It may be that the time is approaching when propaganda abroad will have to be undertaken in a general manner to make known the qualities and performance of individual British products.

It is significant to note, in this connection, the recent growth of the German automobile industry in parallel with their successes in Grand Prix racing.

It must be clear, however, that serious motor-car manufacturers to-day have to cater for the multitude and cannot therefore waste time and money on other occupations. Mercedes and Auto-Union make Grand Prix cars, but Opel do not, although they make the greatest volume of vehicles. If Grand Prix racing were a serious factor in the sale of popular cars, all manufacturers would be forced to it with the result that the cost of their products would be increased and the sales reduced.

It is of interest that this type of racing is the prerogative of the Totalitarian states, where national propaganda plays such an important part.

Grand Prix racing involves what is newest in conception in scientific advance. The problem is mainly a technical one and is a designer's dream. The design is based on existing knowledge plus the experience derived from it and the experimental work expended on modified notions. Cost can be counted out, the main consideration being to obtain maximum power for the minimum mass consistent with the rules prevailing.

If, as in the 1938–40 racing formula, the weight of the car is fixed as well as the engine size, then other means to increase speed will be adopted irrespective of commercial issues, one of them obviously being an increase in the blower size to give maximum performance for a given weight. A large blower on a small engine will increase the weight of the power unit and correspondingly force the designer to build his frame and body correspondingly lighter. Naturally the car will be so designed as to make use of as much power as possible on any road circuit involved.

Can the results of this activity be of use to motor-car producers on a large scale?

Experience shows that the firms which take part in this form of sport are not large producers in the industry. Such firms are, I believe, all subsidized by their Governments and their current touring car productions show evidence of a lack of concentration which is now so necessary in order to obtain commercial ascendency. Such manufacturers make too many models, all very different from one another, thereby dividing their attention, experience, and available capital for investment in tool equipment.

At the last Berlin Motor Show, the exhibits of some firms which are to-day most prominent in Grand Prix racing, clearly illustrated the very great difference between their racing and touring cars.

When cars were all made in small quantities, the racing car of to-day was the touring car of to-morrow, but this no longer applies, and at the present time—apart from the essentially individual requirements of the Grand Prix car, such as ultra high speed, single-seater bodies, &c.—the hitherto common technique has become divided by the factor of production cost. Thus, to-day, there is little in common between the respective methods of production.

There is, however, valuable knowledge to be derived from the application of so much power to a car on the road, and in this respect it has been learned that light and rigid construction, light unsprung weight, and low centre of gravity are essentials of a good car. But these desirable aims are obtained by very different methods in the case of the racing and touring cars. In the former case, for example, light metals are used profusely, whilst in the latter, ferrous metals are used almost exclusively, so that it will be seen the design of the two types of cars proceeds along very different lines. It may be, of course, should production methods so evolve as to again introduce greater flexibility in manufacture, that we shall see a change in design conceptions.

I would surmise, in the case of the German manufacturers already referred to, that in each firm separate organizations handle the two problems, namely that of the racing car and that of the production car, with very little in common between them except possibly an executive who may, or may not, decide whether and to what extent one department shall profit by the experience of the other.

It is therefore clear that under present conditions a Grand Prix car is mostly an instrument of international propaganda and cannot be considered as a sales factor benefiting the factory which produces such cars. It must not be accepted, however, that these existing conditions, may not be subject to change in the future.

Tourist Trophy Racing

Turning now to the question of Tourist Trophy or Le Mans racing, this is a very interesting proposition from the motor manufacturers standpoint provided he is aiming at the production of a type of car essentially suitable for the Sporting driver. It goes without saying that such a car must have high speed performance.

In so far as this subject concerns the motor manufacturer to derive the maximum benefit from Tourist Trophy racing, the publicity value should offset the racing expenses, which can be regarded as charged to Experimental work. Whether one races or not, one has to expend money on research, and therefore this type of racing, if successful, can be profitable to the firm which undertakes it, and does not adversely affect the selling price of the product to the public.

It will thus be appreciated that it is not of interest—to the manufacturer—to race cars which are already well in production and on which all research expenditure has already been incurred. One should race with a car which is about to be produced, or which is in the early stages of production. The rules should exclude a vehicle which is not genuine in these respects, and, once the vehicle is defined, permissible alterations should be limited to the body, gear ratios, tyres, wheels, and compression ratio. Nothing else should be permitted, because such modifications are in the nature of "plussing" up the product, and since everybody does the same the effect is negative and results only in an unnecessary waste of money.

Alterations such as fitting larger inlet pipes, petrol tanks, double ignition systems and fuel feeds, defeat their own purpose, and only prove the unsuitability of the car for the purpose for which it is primarily sold to the public.

In that it aims at decreasing weight and increasing power and stability within the ambit of economic production, Tourist Trophy racing is of definite benefit, but unfortunately these aims are sometimes subordinated to the gambling aspect with the result that there is a lack of proper method, and ultimate disappointment. In the long run, however, the competitor who does his job thoroughly well, other things being equal, will gain ascendency over those competitors who subordinate the cardinal essentials mentioned above.

Stock-Car Racing

Racing, to be successful, must be spectacular and for this reason it is a matter of some doubt whether stock-car racing could command the necessary public support and enthusiasm.

From the designer's point of view it does not present any valuable interest because it represents what, to him, is past history; furthermore, since it cannot capture the public imagination it would be devoid of that element of hero-worship which, although they may be diffident to admit it, cannot but be in some measure attractive to the drivers. Consequently, I do not think the commercial elements of an organization would view with favour the racing of cars without the backing of enthusiasm and drive of the technical men.

Trials, Rallies, & Competitions

There is now the question of trials and competitions. This form of the sport does not possess the defect of the stock-car race because it is not run on a closed circuit, and, on the other hand, it does supply a good story appertaining to the cars which the public uses. A great deal of growing interest is now taken in this form of motoring, which consequently represents a source of sales propaganda.

Trials and Rallies represent an easy way of making a public demonstration of a car's capabilities and possess the advantage of forming an assembly of a variety of production cars—modified or not—performing under similar touring conditions. Such events as the Monte Carlo and the R.A.C. Rallies are now receiving a great deal of publicity and, on account of the public taking a great deal more notice of them, they are becoming important from a sales angle. This is emphasized by the fact that in addition to the makers of the more expensive cars, makers of popular cars are now taking part in these competitions on equal terms.

These trials have greatly benefited the industry by proving that the power to weight ratio, apart from reliability, is one of the governing factors of success irrespective of price.

Thus the public are enabled to compare performances of various cars in a similar price range, and there is no doubt that future sales will become more influenced by this development which truly promotes efficiency in its true aspect; namely, direct service to the public.

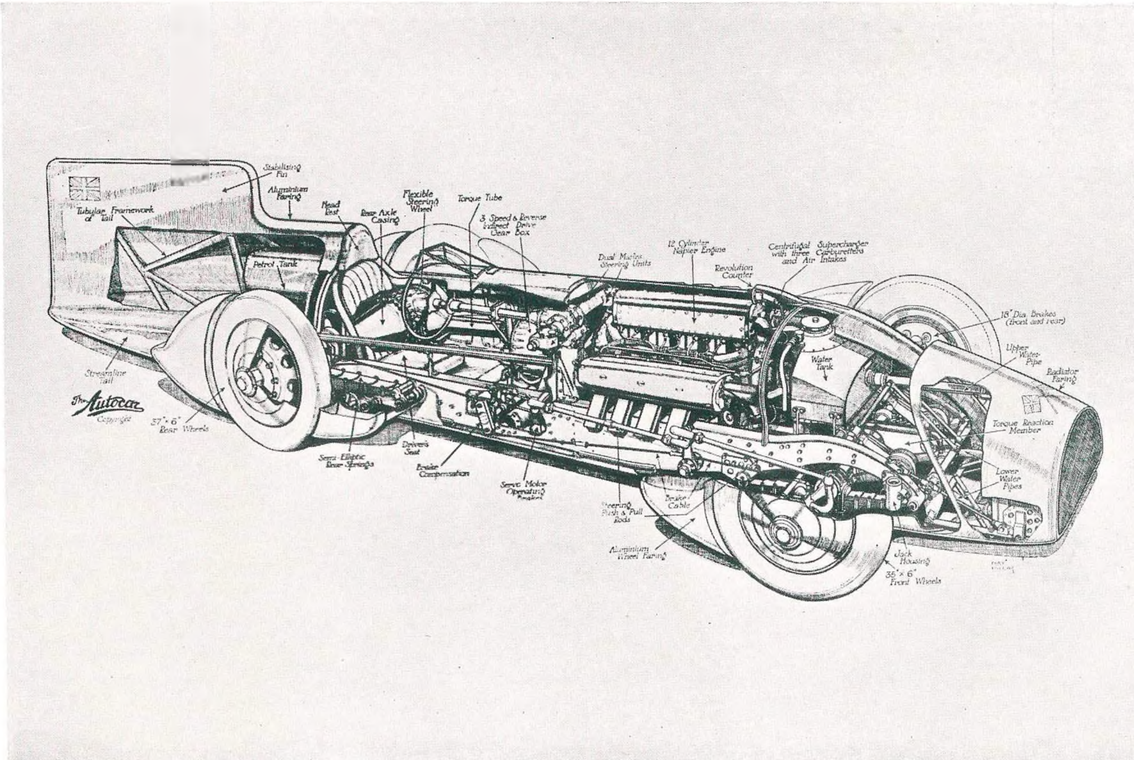


Plate 26. [By the courtesy of " The Autocar "

" BLUE BIRD."

AN EARLIER FORM OF SIR MALCOLM CAMPBELL'S LAND-SPEED RECORD BREAKER. IN THIS FORM THE RECORD WAS RAISED TO 276·82 ON DAYTONA BEACH IN 1935.

CHAPTER FIVE

THE DESIGNING OF SPECIALIZED CARS

By Reid A. Railton

Designer of many World's Speed Record-Breaking Cars

FOR the purposes of these notes, "special" cars will be defined as fast cars built for purposes other than competitive racing. By this is meant a car intended to travel a given distance in as short a time as possible, or to go as far as possible in a given time.

Various arbitrary distances and times are established for which the Governing Body will recognize "Records," but there are only a few which attract much attention generally. The most popular is of course the one-mile record, or the Land Speed Record as it is often called. Perhaps the next favourite is the "24-hour Record," which, as its name implies, is the greatest distance travelled in one day.

Special cars have frequently been built for both these records, but the requirements for each are very different. To start with, the "mile" car only runs on a straight track, while the "long distance" one must for obvious reasons be constantly going round bends. Then again the one need only have a short life, while long life and extreme reliability are essential in the other. Finally the sprint car has to be at least 150 m.p.h. faster than the mere 180 m.p.h. or so required of the other. This all leads to such differences in design, that we had best consider them separately.

(1) *Land Speed Record Cars*

The designer's problem is very simply stated. It consists in getting the most powerful engine he can, and the smallest tyres he dare, and arranging them inside the smallest space he can think of consistent with certain minimum requirements as to track and wheelbase. The skill comes in in finding room in the space that is left for the driver, and for all the rest of the machinery. The shape of the body is of the utmost importance and may well influence the relative position of the wheels, but the important thing is to keep the car *small*.

The final body shape is determined by wind tunnel experiments to make sure that it offers the least possible resistance to the air. The air resistance is in fact enormous at full speed, but even so it only represents about half of the total forces holding the car back. The rest arises chiefly from the "rolling resistance" of the tyres; in other words, the force required to keep the wheels rolling along the track. For reasons that are not fully understood the rolling resistance increases very rapidly with the speed, and to roll a pneumatic tyre along at 300 m.p.h. requires about 25 times the power required at 60 m.p.h. Now this big factor of rolling resistance also varies with the weight on the tyre, and it is for this reason that it is extremely important to keep the car as light as possible.

The question of weight leads us to another major point of design. If the weight is cut ruthlessly, without reducing the bulk and wind resistance, we should obviously come to a point where there was not enough weight on the driving wheels to provide the grip or adhesion necessary to drive the car against the air resistance. In such a case, the wheels would start to spin before the car had reached its top speed. This point of development has already been reached, and recent cars have in fact been ballasted on their driving wheels to supply the necessary adhesion, much to the detriment of their speed. It is for this reason that these cars will in future probably be driven on all four wheels, thus making the whole weight of the vehicle available for adhesion.

The design of the mechanical details boils down to the problem of transmitting the enormous power of the engine to the road wheels with the minimum weight and bulk. The brakes call for rather special consideration, as owing to the enveloping body they cannot be cooled in the ordinary way. On the other hand, no very violent braking is required, as the car usually has the same distance in which to pull up as was available for getting up speed. At the Bonneville Salt Flats in Utah, U.S.A., where the present record was established, the distance is about six miles, and the provision of brakes to stop the car in this distance from 300 m.p.h. is not difficult. In the future, however, as speeds increase and the aerodynamic resistance of the car (a great help in pulling up) is reduced, the designer will have considerable scope for his ingenuity in this direction.

An obvious thought is to fit air-brakes, or movable flaps emerging from the body, which artificially increase the air resistance when slowing down. Such devices have already been fitted experimentally to two or three cars and their use will be increasingly indicated as time goes on. They can in any case only supplement the ordinary friction brakes, as their effect is generally negligible at speeds below 200 m.p.h.

(2) *Long-distance Cars*

Motor cars used for long-distance records need not be nearly so "special" as those just discussed; in fact, the modern road-racing car (a vehicle outside the scope of these notes) would be

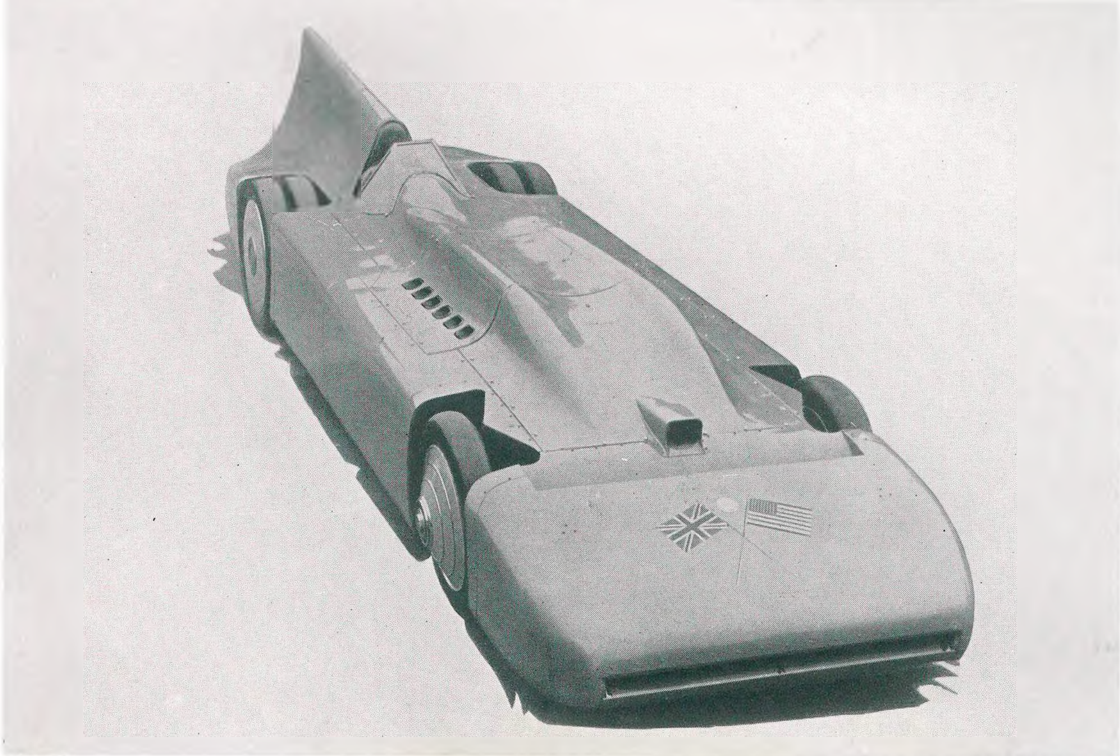


Plate 27. [*Photograph : " The Autocar."*

" BLUE BIRD."

SIR MALCOLM CAMPBELL'S FAMOUS CAR IN ITS FINAL SHAPE, WITH TWIN REAR WHEELS AND A NARROW SLOT IN THE NOSE, ADMITTING AIR TO THE RADIATOR. THIS SLOT COULD BE SHUT OFF TO REDUCE HEAD RESISTANCE WHEN NECESSARY. IN THIS FORM THE MEAN SPEED FOR THE MILE WAS INCREASED TO 301·13 AT UTAH IN 1935.

in many ways almost ideal for this purpose. However, the few firms (mostly German) who make such cars are not, for the most part, interested in record-breaking, nor are they willing to sell them to others for this purpose. In the present circumstances, therefore, these cars have to be specially built.

To keep the cost within reasonable limits, it is generally necessary to use an existing power unit (usually an aero-engine). The car is then built to fit the engine, the design being largely conditioned by the amount of money available.

Here again the chief aim is (or should be) to keep the car light; not, in this case, in the interests of the ultimate speed, but to enable the tyres to last as long as possible. It is clearly desirable during a long-distance record attempt to make as few stops as possible, and the number of stops is usually determined by the distance the tyres will run without changing.

Extreme reliability of the mechanism is obviously important, and to this end it is preferable to use a large engine running easily rather than a small one running at full power all the time. This consideration again favours the use of an aero-engine.

In considering the body, it is always a nice point to decide how far to go in the matter of streamlining. The more perfect the streamlining, the more sensitive is the car to the effect of a side wind and the more tiring to drive under these conditions. Furthermore, good streamlining usually means extreme inaccessibility of the machinery, and it is most important to be able to get at the works quickly if any minor breakdowns should occur during a record attempt.

On the other hand, on the flat circular course in America, where these records are usually run, good streamlining may enable a car to negotiate the curve faster than would otherwise be possible. The effort required to push it through the air is so much less, that less adhesion is, so to speak, wasted in driving the car, and more is available to prevent it from skidding out. Some sort of compromise is therefore desirable.

The mechanical design is usually very similar to that of the ordinary touring car. The car seldom has to stop suddenly or unexpectedly, and not many stops in all have to be made, so the brakes can be kept on the small side in the interests of weight-saving.

The springing depends largely upon the nature of the track to be used. If this is bumpy the suspension must be carefully considered, otherwise the jolting he receives may tire the driver unduly and thus interfere with his efficiency. If the surface is good, considerable weight can be saved in the design of the suspension.

The car is equipped with tanks large enough to carry sufficient fuel and oil to last the life of a set of tyres—between 2 and 3 hours, or 350 to 500 miles as things are to-day.

It is impossible to leave the subject of record-car design without some mention of the tyres upon which the car runs. For an important record attempt the tyres are always tailored to suit the particular combination of speed, weight and road surface that will be encountered. Contrary to the popular idea, the severe punishment which a racing tyre undergoes does not kill by wear and abrasion, but by the excessive heat set up by friction, which causes the fabric of the tyre to disintegrate. When a certain combination of speed and temperature is exceeded, the rubber tread, weakened by heat, is apt to fly off under the action of centrifugal force.

The design of the tyres, therefore, consists in a nice compromise between many manufacturing considerations and particularly between the low abrasion margin of a thin tread, and the liability to disruption of a thick one.

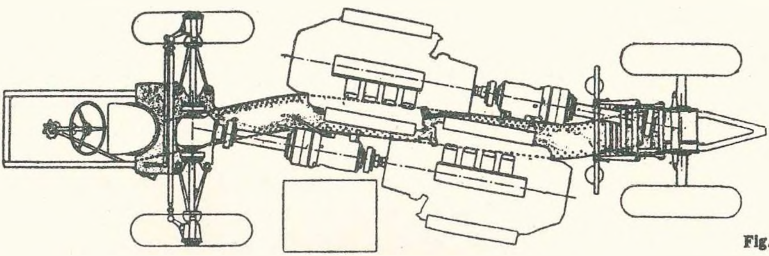


Fig. 4

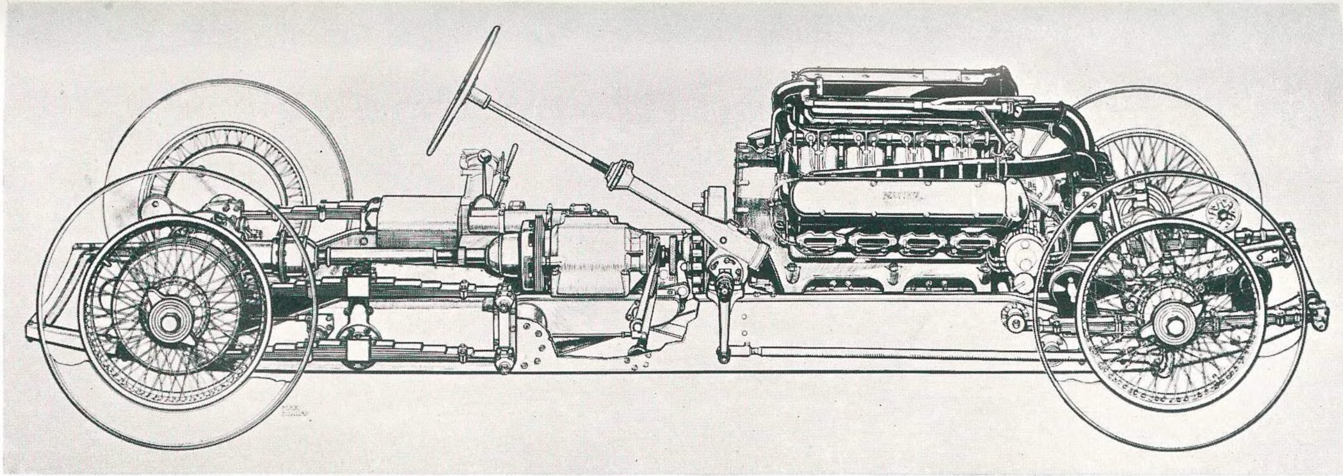
PLAN VIEW OF THE CHASSIS, SHOWING THE DISPOSITION OF THE TWO ENGINES

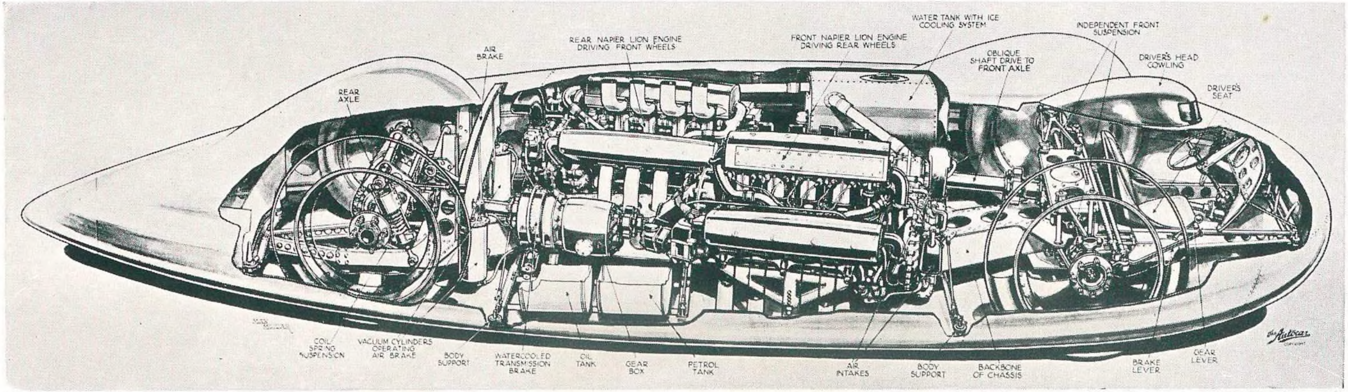
In the special case of the land speed record, the tyre life required is so short that the abrasion factor can be disregarded, and the "tread" becomes a mere waterproof covering a few thousandths of an inch thick.

To illustrate these remarks and to show how they work out in practice, it may be of interest to consider one or two actual cars that have been built recently. Plates 28 and 29 are sectional drawings of two cars that have been built for one owner —Mr. John Cobb. Plate 29 shows a vehicle designed for the Land Speed Record, and Plate 28 a Long-distance Record Car.

Plate 29 shows clearly how everything has been subordinated to fitting the two large engines and four large wheels inside the smallest possible space, and furthermore to making that space conform to the lines of a streamlined body. The peculiar S-shaped frame and the unusual positions of the engines were dictated almost entirely by these considerations.

Again, the two rear wheels are placed much closer together than the front ones in order that the car may approach more closely to the bluff-fronted, fine-tailed shape of the ideal streamlined body.





Plates 28 and 29. [*By the courtesy of " The Autocar."*

TWO RECORD BREAKERS DESIGNED BY REID RAILTON FOR J. R. COBB.

THERE ARE TWO DISTINCT TYPES OF RECORD CAR—THE LONG DISTANCE MACHINE, AN EXAMPLE OF WHICH IS SHOWN ABOVE, AND THE HIGHLY STREAMLINED AND VERY COMPLEX

In the interest of weight-distribution the heavy machinery had to be packed between the axles. This left no room for the driver, who consequently had to be accommodated right in front of the front axle, where his comparatively low weight was not objectionable.

Note that, for reasons already mentioned, all four wheels are driven. In the particular arrangement adopted there are two engines, of which one drives the front and the other the rear wheels. There is no special reason for this except that no single engine of the requisite power and shape was available, while these two aero-engines together were considered a satisfactory substitute.

Both the air- and friction-brakes are clearly shown in the drawing. The air-brake takes the form of a transverse panel immediately in front of the rear wheels. When in use, pneumatic cylinders underneath force it upwards through a slot in the body, in which position the air-pressure upon it may be anything up to half a ton. There are two friction brakes, one behind each gear-box. In order that they may be kept small and light, both brakes are water-cooled—the water being taken from the engine-cooling system.

Plate 28 shows the chassis only (for complete car, see Chapter 21) of a special Long-distance Car. The radiator and fuel tank are not shown. This car was designed to run for long periods at speeds around 150 m.p.h. and has actually done upwards of one hundred hours at more than two miles a minute.

Since considerations of streamlining were in this case relatively unimportant, the general layout of the car could be kept practically normal. As usual, it was designed round an existing aero-engine, and the chief considerations were strength and reliability with the least possible weight.

The car was originally intended for two separate uses—for Long-distance Records, and for short races at Brooklands. This dual personality has left its mark in the suspension. Ability to "hold the road" under the peculiar conditions obtaining at Brooklands has called for a heavier and more elaborate system of springing than would otherwise have been necessary.

Only the rear wheels are equipped with brakes, the object being again the saving of weight. This, however, turned out to be a weak feature, as the limited braking effort available made it difficult for the driver to judge his stops accurately when coming into the pits.

A hundred-gallon fuel tank is carried—sufficient for four hours at full speed. At 150 m.p.h. and over it was, however, found necessary to change the tyres at least every three hours, so that correspondingly less fuel was actually carried.

CHAPTER SIX

FUELS

By L. G. Callingham, A.M.I.A.E., F.I.M.T.

ALTHOUGH the fact that the fuels employed in the majority of races to-day differ very considerably from those used for ordinary motoring is common knowledge, the natures of such fuels and the reasons for employing them are by no means generally understood.

A very common fallacy, for instance, is the belief that racing fuels contain in themselves, gallon for gallon, considerably more energy than normal petrols; neither is it unusual to hear that certain particularly successful drivers, or teams, possess secret formulae and are able to add that "little extra something that the others haven't got" to their mixtures, thereby producing incredible horsepower and unheard of acceleration.

In actual fact the chief ingredient, indeed almost the full amount, of most genuine racing fuels consists of alcohol, which may be either ethyl alcohol derived from grain, molasses, or other vegetable matter, or methyl alcohol made synthetically.

Compared with petrol, the alcohols have considerably less internal energy, their respective calorific values being 20,100 British Thermal Units approximately per pound for petrol and 10,000 to 11,000 B.T.U.'s per pound for the alcohols, which is equivalent to about 150,000 B.T.U.'s and 80,000 to 90,000 B.T.U.'s per lb. respectively. It is thus clear that, gallon per gallon, less power can be obtained from the alcohols.

Owing, however, to the heat conditions prevailing in the internal combustion engine there are very definite limitations to the power output which can be maintained, and limiting conditions are reached, when petrol is used, very much earlier than they are when alcohol is employed.

A complete understanding of this subject is impossible without a fairly extensive and practical knowledge of the laws of thermodynamics as applied to the internal combustion engine, and to those desirous of a full explanation *The High Speed Internal Combustion Engine*, by H. Ricardo, is earnestly recommended.

For the present work it is perhaps sufficient to explain that the internal combustion engine, whether that of a lumbering lorry or of the most highly developed racing thoroughbred, is to all intents and purposes but a hot air engine—in other words, its source of power depends on the expansion of a quantity of air which has been heated, in a confined space, by the combustion of fuel.

The more air, by weight—and this is an important point—we can cram into a given combustion space, and the more highly we can heat it, the greater will be the expansion and, consequently, the driving force upon the piston. In addition, compression of the air, before ignition, adds considerably to its power of expansion afterwards, therefore high compression pressures, or ratios, are sought whenever a high power output is demanded.

Compression pressure and compression ratio are, in theory, directly related—in practice, however, this relationship may vary considerably for the following reasons:

Compression Ratio

Compression ratio is the ratio between the combustion space volume (often called the clearance volume) when the piston is at the top of its stroke and the same volume added to the volume swept by the piston (*i.e.* volume of bore and stroke); thus if considering an engine with swept volume equalling 1000 c.c. and with a combustion space of 250 c.c., the compression ratio would be 5 to 1. Since

$$\frac{1000 \text{ c.c. (swept volume)} + 250 \text{ c.c. (clearance volume)}}{250 \text{ c.c. (clearance volume)}} = 5.$$

Expressed another way, we might say that this engine compressed its charge to one-fifth of its normal volume before igniting it. Under such conditions, and assuming that the engine was not supercharged, we might imagine that with induction at atmospheric pressure of 14 lb. per sq. in. approximately, the final compression pressure was 70 lb. per sq. in. This, however, for several reasons, would not be correct, since unsupercharged engines are not 100 per cent volumetrically efficient and do not inhale a charge of equal volume to that of the space vacated when the piston is at bottom dead centre. Again, the exhaust gases are not completely evacuated as the fresh charge flows in, and this residue, together with the already hot cylinder walls, combustion head, and valves, heats up the new charge considerably, compression heats the charge still further until, with petrol it may attain 700° F. to 800° F. Even then, although the engine may be only some 75 per cent volumetrically efficient, the final compression pressure will be well over 100 lb. per sq. in.

Employing alcohol, however, instead of petrol, or benzole, we should only arrive at a compression temperature of 475° F., and at the same time get a compression pressure of 110 lb. per sq. in., or slightly higher since the volumetric efficiency of the engine on alcohol, due to its much higher latent heat value is, approximately 82 per cent as compared with 76 per cent for petrol.

The latent heat value of a fuel, which is expressed in B.T.U.'s per lb., is regarded as the heat extracted by the fuel from its containing body when changing from a liquid to a gaseous state, and it is regarded as changing its state without alteration in its own temperature.

The latent heat values of the alcohols are from 400 to 500 B.T.U.'s per lb., petrol averaging about 135 B.T.U.'s and benzole 150 to 170 B.T.U.'s. It is thus obvious that the carburation of alcohol produces a very much greater temperature reduction in induction pipes and valve ports than either petrol or benzole, and as a certain amount of alcohol usually gets as far as the combustion chamber in liquid form, while petrol and benzole do not owing to their lower boiling points, the cooling effect is carried on even inside the engine.

These cooling properties of alcohol are of the greatest value in so far as racing machines are concerned, in the first place the density of the charge entering the engine is much higher than it would be with petrol and a greater weight of mixture is available for combustion per engine cycle. Secondly, the cooling effect created by part of the fuel evaporating after it has reached the combustion space is most beneficial in its effect on plugs, valves, and pistons, and in counteracting the tendency to detonation which is promoted by high internal temperature.

Detonation is generally agreed to be due to excessive rapidity of combustion of the last part of the charge, the excessive rise in pressure during the early stages of combustion compressing the unburnt portions of the charge beyond a certain rate, creating therein such a temperature rise that the unburnt portion ignites spontaneously, producing a practically solid explosion wave, which, impinging on the cylinder walls gives rise to the phenomenon known as "knocking" or "pinking."

The final results of running under such conditions are overheated valves, plugs, and pistons with subsequent mechanical breakdown, this latter generally being brought about by the mechanical stresses caused by the pre-ignition which normally follows detonation.

Fuels vary widely in their tendencies to detonate, petrols being free from this objectionable habit up to compression ratios of between 5·1 and 6·1 according to their nature, benzole apparently resisting the tendency up to about 7 to 1, and the alcohols being free from it at 19 to 1, and in certain cases much higher.

It should perhaps be remarked here that it has been customary in the past to designate the anti-detonating, or antiknocking values of fuels in terms of compression ratios, the H.U.C.R. of a fuel meaning the Highest Useful Compression Ratio at which it could be employed.

Such determinations are made in a special variable compression engine invented by Ricardo (known as the E. 35), and for a number of years they comprised the only definite means of evaluating the anti-knock values of fuels. Although Ricardo's method is not used generally, commercially it remains unquestioned in accuracy; for commercial purposes to-day fuels are rated by what are known as Octane Numbers, and it may not be out of place to explain briefly how such numbers are arrived at and what they mean.

An engine known as the C.F.R. (Co-operative Fuel Research) is used; this, like Ricardo's E. 35, has variable compression and, similarly, relies on a telescopic head for compression variation. Unlike the E. 35 engine, however, the C.F.R. does not tell us the compression ratio at which the fuel under test begins to detonate. The C.F.R. method consists of running on the test fuel and varying the compression ratio until an electrical recorder indicates that a definite maximum pressure is arising in the combustion chamber. Keeping the engine set on this compression ratio (which is not recorded), a series of runs are made on various blends of two standard reference fuels until the same reading is held on the electrical indicator as indicated by the fuel under test. The reference fuels consist of Iso Octane and Heptane, two almost chemically pure hydrocarbons, Iso Octane having an anti-knock value regarded as of 100 and Heptane one of nil. The percentage of Octane blended in with Heptane to give the same reading on the electrical indicator (the knockmeter) as the fuel under test is then stated as the Octane Number of the fuel. Thus if 70 per cent Octane and 30 per cent Heptane equal the fuel under test, that fuel's Octane Number would be stated as 70 O.N.

While there has been considerable argument as to the merits, and accuracy, of the C.F.R. method of fuel rating it must be admitted that it is coming into everyday use and that it is possible to correlate its results quite well with road performance.

Unfortunately Octane Numbers and H.U.C.R. values cannot be directly related and are apt to vary indiscriminately with individual fuels—for practical purposes, too, neither the E.35 or C.F.R. engines have been designed to deal with fuels of over 7·5 : 1 to 8 : 1 H.U.C.R. approximately, and they cannot, therefore, be usefully employed in exploring the alcohol types of fuels used for racing, since very much higher compression ratios are involved.

Although it is fairly simple to ascertain the compression ratio of an unsupercharged engine by filling the clearance volume space with liquid from a graduated measure, or even by calculation with a symmetrical design, it is by no means a simple matter when a supercharged unit is concerned. In the first place the supercharge pressure at full throttle, and at full engine speed, must be definitely known, and in the second the volumetric efficiency of the supercharger over its working-speed range has to be determined. On these facts the actual compression ratio could be arrived at if the final temperature of induction were known. An alternative method would be to take indicator diagrams of the engine pressures by "motoring" the engine, *i.e.* driving it with an electric or other power unit.

The characteristic pressures and temperatures of engines as ascertained by the methods just referred to are of considerable importance to designers and builders; their exact determination is by no means necessary, though, in order to decide the precise nature of fuel needed. The composition of the most suitable fuel is really a matter for practical experiment, and we are fortunately able to start off with the knowledge that pure alcohol will not detonate under the highest conditions of supercharger and compression pressure that engines have been able to withstand mechanically up to the present.

A considerable amount of data is also available on the fuels which have been found suitable for known engine conditions, and certain cases, which will be quoted later, will serve to indicate how a suitable fuel blend may be determined without a very exact knowledge of the engine's supercharger and/or compression pressures. As stated earlier, the bulk of the fuel will consist of alcohol, the remainder being principally petrol and benzole, their proportions increasing as compression pressures decrease.

Summed up, then, the reasons for employing alcohol fuels for racing are:

(1) Their freedom from detonation
(2) Their cool running tendencies.
(3) The greater volumetric efficiency given to the engine.
(4) The fact that higher compression ratios can be employed and a greater power output obtained.

The chief disadvantages of such fuels lie in starting difficulties, enormously increased consumption, the effect of the alcohol on certain metals used in tanks, filters, pipe lines, carburettors, and superchargers, and last but not least, their great affinity for water.

Starting Difficulties

Starting difficulties are at their worst when considerable proportions of alcohol are present, and the usual way to overcome them is to start up, and to warm up, on petrol.

In one particular case it was noted that Mrs. Hawke's Derby-Miller had a separate, small petrol tank for starting purposes and an arrangement whereby the throttle could not be fully opened until the fuel supply had been turned over to the alcohol system. It was also noted that the fan type supercharger of this car appeared to have been corroded by the fuel which deposited in the lower part of the fan casing when the engine was stationary. Subsequently arrangements were made for draining the casing.

Generally speaking, if a racing fuel contains 10 per cent of aviation or light petrol, starting difficulties do not arise.

Consumption

Consumption, due to the low calorific value of the fuel, must necessarily be very high compared with petrol. While the correct air-fuel ratio by weight for petrol is 14·1 to 15·1, it is but 7·1 to 9·1 for alcohol—jet sizes have therefore to be at least doubled with fuels containing 70 per cent or more alcohol, and a racing car cannot be expected to do more than five to seven miles per gallon on such a fuel.

Jet Sizes

It is a common mistake to tune a car too weakly when changing to a high alcohol-content fuel, after the compression has been raised, or the supercharger pressure increased.

Unlike petrol, alcohol continues to give increased power output for a considerable range above ideal mixture strength; that is to say, too rich a mixture on petrol means a drop in power very soon after less air is given than that required for perfect combustion. This, however, is not the case with alcohol and it is always wise when tuning-up to experiment with jets which are apparently very much oversize.

Effect of Alcohol on Metals

The possible effect of alcohol mixtures on certain light alloys has already been noted and it should further be stated that, in the case of a Napier "Lion" Schneider Trophy engine fitted to a racing boat, the magnesium alloy filters disintegrated under the effects of the fuel and had to be replaced by those of a gun-metal variety.

Alcohol has an extremely scouring effect and will dislodge all sorts of scale, &c., from tanks and pipe-lines, which is in no way affected by petrol. Thus if a change is made from petrol to alcohol type fuel all tanks and pipe-lines should be thoroughly flushed and drained; in fact if they have seen much service they should be discarded altogether. The solvent effect of alcohol on paint, shellac varnish, and many other substances is considerable.

Water

Alcohol is hygroscopic—possessing a great affinity for water—and it is quite likely that if it is left standing for any considerable time in a car's tank that it will accumulate a sensible amount of water, especially if the atmosphere be moist. Apart from the trouble water may cause in the fuel system, it will also probably cause the components of the fuel to separate and it will then be impossible to run the car properly, if at all. Correct procedure, if the car is not to be used again for several days, is to drain the fuel tank, and, when putting the fuel back, to strain it through a chamois leather or a gauze of at least two hundred mesh to the inch.

Such remarks do not apply to fuels originally containing water, which are occasionally used, these fuels will be discussed later.

Fuels Used in Racing

In certain races, notably the Automobile Club de l'Ouest's 24 Hours Grand Prix d'Endurance run annually at Le Mans, the R.A.C. Ulster Tourist Trophy, and the Isle of Man A.C.'s Tourist Trophy Motor Cycle Races, special fuels are barred—the regulations demanding that only fuels which are "generally and commercially obtainable" be used. Although these regulations were originally intended to permit only such fuels as are obtainable from the ordinary roadside pumps, they have of late years been modified to the extent of allowing the use of up to 50 per cent benzole in British races and an unlimited proportion at Le Mans.

Up to and including 1927 benzole was not allowed at all at Le Mans, and competitors had to use the common French petrol, which at that time was very much inferior to ordinary English No. 1 spirit. This, of course, kept compression ratios comparatively low, usually under 6 to 1, and even then necessitated a very rich mixture setting in order to keep detonation from becoming entirely destructive. The much higher speeds maintained in subsequent races on this circuit are in no small measure due to the better fuel permitted.

The destructive effect of a fuel with too low an anti-knock value is not always immediately apparent in a racing car, although the plugs usually give warning, by overheating, bringing about a loss of power and giving rise to a series of carburettor explosions which may easily be mistaken for symptoms of fuel shortage.

The writer has painful memories of driving an Alfa-Romeo at Le Mans, which, according to the Italian factory, had been tuned to perfection—the car, however, consumed an incredible number of the most heat-resisting plugs available during the race and, although finishing fairly well up, disclosed when the engine was stripped that the pistons had suffered very severely from overheating due to detonation—the top edges being burnt and the rings well stuck. This trouble was entirely due to the makers having tuned up the engine on a better petrol in Italy than that which was supplied in France for the race, despite the fact that they had been sent some of the French petrol to tune up on. This particular engine, which was a 1760 c.c. 6-cylinder supercharged model, really needed a fuel of 6 to 1 H.U.C.R., or some 72 Octane Number, the supercharger pressure appeared to vary between 3 lb. and 5 lb. to the square inch, and the geometrical compression ratio was said to be 6 to 1; no opportunity, however, afforded itself for checking this, but the writer's opinion is that it was somewhat lower. In a subsequent event the car ran perfectly well on a mixture of No. 1 petrol and 30 per cent of benzole, which had the H.U.C.R. quoted above.

The last notable case of a genuine racing car winning an important race on petrol was that of the late Sir Henry Segrave winning the French Grand Prix, on the Tours Circuit, in 1923—the car was a 2-litre, 6-cylinder Sunbeam and the fuel used was an ordinary No. 1 petrol sent over from England. Although the car won, the exhaust valves were badly burnt by the end of the race, and it is doubtful if the car could have continued much further. The characteristics of this engine are not known; the compression ratio, however, probably did not exceed 6 to 1.

Prior to this date racing machines had been run on alcohol-blended fuels, in particular the famous 3-litre T.T. type Vauxhalls; the motor cyclists, however, were the really active users of such mixtures, and Brooklands, long famous for its spicy aroma of burnt castor oil, acquired another odoriferous attraction, to wit, alcoholic exhausts, about 1922.

The peculiar tang of alcoholic combustion was further enhanced by the smell of the ether which some of the experts insisted on adding to their fuel—no doubt they used ether as an aid to starting; it took them some time, however, to realize that ether was a knock-promoting liquid and therefore by no means a desirable addition to a fuel which was designed to provide the highest possible anti-knock value.

A belief persists, even to-day, in some quarters that ether enhances power, but since its anti-knock value is only about half that of ordinary commercial petrol, one can only assume that any rough running it may promote is mistaken for power increase by the unenlightened.

The fuels used by racing motor cyclists to-day are, in the main, very similar to those used for car racing. Some years ago, however, there was a considerable tendency towards fuels which contained considerable amounts of water, in some cases as much as 25 per cent. The water, of course, was of no value at all as a fuel but its extremely high latent heat value (970 B.T.U.'s per lb.) made it useful as a coolant, and consequently as a knock suppressor, in certain very hot-running air-cooled engines.

The creation of a stable fuel mixture containing so much water requires an extremely careful adjustment of the proportions of ingredients used, and petrol and alcohol will not blend at all if more than 4 per cent of water is present. To effect a blend benzole, and probably acetone also, must be employed; even then if the proportions are not exact the mixture will be most unstable and very liable to separate at low temperatures or if a little extra water is added. It seems unlikely that any well-designed racing engine should need water in its fuel, and in any case an engine that does need it is inefficient because it is taking water, which has no fuel value, into combustion chamber space which should be occupied by fuel which can be turned into useful power.

Water injection has more than once been widely advertised as an accessory, for ordinary cars, which increases power, but the claims made for the devices employed have never been substantiated. They all disappear from the market in a short time for the very good reason that they have only a perceptible effect when used with engines with thoroughly bad combustion heads, or those which are habitually run on fuels of too low an anti-knock value for their needs. In other words, they just suppress knock in a few aggravated cases and certainly do not increase power, although some credulous people have imagined that steam was produced which aided the piston on its power stroke.

The effects of the deposition of water on the cylinder walls when the engine stops, and the sludge-producing effect of steam on the oil in the crank case, are further drawbacks, and it is unlikely that much more will be heard of water as a component of ordinary motor fuel.

Returning to the subject of racing fuels, the normal blends of petrol and benzole used in the car and motor cycle T.T. Races may be first considered; these are genuine mixtures of ordinary petrol and commercial benzole and the regulations usually limit a competitor to a fifty-fifty mixture, although in some events pure benzole is allowed if preferred.

Benzole, by itself, has a somewhat higher anti-knock value than petrol; in latent heat value and calorific value per gallon, however, there is nothing to choose between the two fuels. Petrol is more volatile than benzole at the lower temperatures (petrol boiling at some 30° C. and benzole at 80° C.) and thus is of considerable value for starting purposes and/or acceleration. The effect of 50 per cent benzole on a good petrol would be to bring the H.U.C.R. of the mixture to about 6·2 : 1, which means that it could be safely employed in small-bore racing engines (not perhaps exceeding 70 mm. bore) with compression ratios up to 7 to 1 unsupercharged, or a little over 6 to 1 with a very slight degree of supercharge.

If regulations allow 50 per cent of any standardized Ethyl petrol to be mixed with benzole, slightly higher compressions can be employed because ethylized petrols in this country have higher anti-knock values than the straight varieties.

The effect of the tetra-ethyl-lead used as an anti-knock dope in petrols is very limited, since the "lead response", as it is called, of petrol ceases after a few c.c. per gallon of the dope has been added. This "lead response", while ample for ordinary car requirements, is of slight use for real racing work and it is futile to imagine that, by increasing the amount of lead dope, detonation can be suppressed and petrol employed instead of alcohol. Tetra-ethyl-lead will not improve the anti-knock value of benzole and it does not affect alcohol so far as is known, although some people believe it to be beneficial. It has done no harm, in the writer's experience, in racing fuels, but proof of its value has not yet been forthcoming.

It has been stated that in the Indianapolis 500-Mile Race—held on a track annually in America, and where petrol has to be used—considerable amounts of lead fluid (up to 10 c.c. per gallon) have been used with advantage. This, however, is a freak case, and the use of such a high lead concentration for any length of time would inevitably lead to valve and plug trouble. Knowing the limited "lead response" of petrols, one is inclined to think that the effect of the high lead content in the Indianapolis fuel was psychological rather than actual.

In any event, however much we could enhance the anti-knock value of the petrol, it could not be used in modern ultra-efficient racing engines because the heat conditions prevailing are such that the necessary weight of charge could not be got into the cylinders to produce the power demanded owing to the expansion of the air before it passed the inlet valves and the large proportion of air required to produce a combustible mixture with petrol. We must turn to alcohol, which requires only nearly half the amount of air and which, by virtue of its much higher latent heat of vaporization, keeps engine temperatures much lower.

Composition of Racing Fuels

The actual composition of the fuels used to-day varies very considerably, although all of them contain from some 50 per cent alcohol and upward. Many individuals and many racing teams prefer to regard their fuel formulae as secrets to be closely guarded; this is perhaps only natural, nevertheless the information is not really of much use to rivals unless cars of the same make and type are concerned. This is because racing machines are so selective in their fuel requirements that minor modifications in the proportions of the constituents of the fuel blend have to be made to suit different types of engines. The volatility of the fuel, for instance, may have a profound affect, and if the induction system of the engine is a cool one, there may be difficulty in persuading the alcohol to vaporize rapidly enough to give quick enough warming up in the early stages of the race; in fact with some designs, unless the radiator was blanked off and engine run quite fast, the carburettor would freeze up altogether. On the other hand, the engine might keep going on full throttle, but would "damp out" and fail sadly in acceleration after every check.

Such a state of affairs must be remedied by judicious blending in of the right sort of volatile petrol to overcome the trouble, or, if the compression pressure is so high as to preclude lowering the anti-knock, and perhaps also the latent heat value of the fuel, steps must be taken to apply more heat to the carburettor. The latter is undesirable, however, because any pre-heating of the charge encourages its expansion and consequent loss of weight, with a consequent reduction in volumetric efficiency.

The effect of supercharger pressure in fuel volatility is not generally realized, and it must be understood that with the increase of pressure the temperatures at which fuels boil rise—thus with a high degree of supercharge a fuel may not be as volatile as its ordinary boiling point indicates and the induction system may, at certain throttle positions, be almost swamped with liquid, instead of gaseous fuel.

Banks draws attention to this fact, and also throws much light on the subject of racing fuels in his work in connection with special fuels for the Rolls-Royce Schneider Trophy engines in 1931. Much of this very informative work has been published, it is believed, in *Aircraft Engineering* and similar papers, *circa* 1933; this is a matter of great interest to the student of special fuels.

As actual details of the fuels used by modern racing cars are of more general interest than generalizations, the following details of fuels employed in recent years are put forward.

Round about 1927, when the Delage cars were being extremely successful on the Continent they were understood to be using a fuel called "Eleosine"; this proved to be a mixture of fifty-fifty ethyl alcohol and benzole, to which 1 per cent of castor oil was added to lubricate the supercharger and inlet valve stems. Some of the Grand Prix machines are still in existence, and Lord Howe has notably demonstrated their excellence in recent years—the continual tuning and rebuilding of the cars, however, possibly calls for the employment of rather more alcohol in their fuel to-day.

In the same era Sunbeams, both the 2-litre G.P. variety and the larger 12-cylinder models, originally handled by Sir Henry Segrave, were run on a mixture of equal parts petrol-benzole and ethyl alcohol. With a modification in the shape of toluol in place of petrol, the same type of fuel was used in the Rolls-Royce engines fitted to both Segrave's ill-fated boat *Miss England*, and Kaye Don's later *Miss England III.*

Here it is of interest to note that the winning Schneider Trophy Rolls-Royce engine in 1931 used fuel comprising 20 per cent petrol, 70 per cent benzol, and 10 per cent methanol (methyl alcohol), while for the same machine taking the World's Speed Record shortly after a fuel consisting of 30 per cent benzole, 60 per cent methanol, and 10 per cent acetone was used—tetra-ethyl-lead dope was also added, as was the case with the fuel used in the race. About 2350 h.p. was developed in the first case and some 2650 h.p. in the case of the Speed Record—it is not thought that supercharger pressure was increased in the second case, but that more throttle opening was given.

The reason for adding acetone to the sprint fuel was to improve its volatility and avoid "damping out" at comparatively low speeds (about 200 m.p.h.) Acetone has a higher anti-knock value than petrol or benzole and a boiling point between the two.

Similar fuels to the foregoing have been used by Sir Malcolm Campbell in his famous *Blue Bird.*

Other large aero engines installed in record-breaking cars have used non-alcoholic fuels; for instance, Captain Eyston's *Speed of the Wind* used a normal petrol, as did John Cobb's *Napier Railton* in their successful record attempts on the Salt Lakes, Utah, U.S.A. (1935). The respective engines, a Rolls "Kestrel" and a Napier "Lion," did not, of course, have the ultra-high-compression pressures employed by Campbell, or as used in the Schneider Trophy Race.

Recent years have seen great development in European racing and a very considerable number of cars have been built by Alfa-Romeo, Bugatti, Maserati, Mercedes, and Auto-Union on the Continent, while at home Austin, E.R.A., M.G., and Riley have been very active; of the British cars only E.R.A. and M.G., however, have been especially designed racing cars.

Common characteristics of the engines of all these modern racing machines have been their comparatively small size, viz. one to some three and a half litres capacity; their extremely high crankshaft speeds (6000 r.p.m. and over); their superchargers; and their enormous power outputs.

In most cases those responsible for these cars have had their own ideas on fuels, and although nearly all of them differ in detail they mostly agree in essentials which, briefly, are that the road-racing fuels are built up on a 40 to 60 per cent alcohol base and the sprint fuels approach the 100 per cent alcohol content.

It is impracticable here to discuss the composition of the fifty or so different racing fuels which have been used by the leading racing *équipes* in the last three years, but it is fairly safe to say the multiplicity of fuels has been most unnecessary and that a maximum of half a dozen blends would have covered everybody's requirements.

The standardization of racing fuels is unlikely, though it would be of much assistance to the petrol companies since the production and handling of what, after all, are very small quantities indeed, of a large number of special fuels gives them a deal of trouble for a problematical return for the work entailed. Engine design, however, will not stand still, and there is no doubt that every new engine will create a demand for fresh fuels for experimental purposes.

The best advice that can be given to the designers and engineers is to experiment with a racing fuel they have used previously and to vary the alcohol content, increasing it if the engine overheats and reducing it if the signs are to the contrary; always assuming that carburation has been properly adjusted. If no previous experience is available, the following known facts may be helpful: with engines from one to three litres capacity B.M.E.P.'s of 180 lb. to 200 lb. per sq. inch, running to 6000 r.p.m. and higher, with supercharger pressures of 10 lb. sq. in. and 6 to 1 compression ratio (geometrical), a fuel consisting of 60 per cent methyl alcohol, 30 per cent benzole, and 10 per cent aviation petrol is very generally satisfactory for road racing, where the road conditions, *i.e.* corners, &c., give an occasional relief from full throttle. For all out-track racing, short flying records, &c., the alcohol should be increased, first at the expense of the benzole, until a maximum power reading is held for five minutes or more.

It must, of course, be remembered that as the alcohol content rises the jet sizes must be increased. Jet ratios on pure alcohol are in the order of 250 to 100 if a mixture of fifty-fifty petrol benzole be regarded as 100.

Fuel consumption will rise as alcohol content is increased, and it has been found that a 1200 c.c. 6-cylinder engine used fuel at the rate of nearly twenty gallons an hour when attempting records.

When experimenting with fuels it is infinitely preferable to carry out the work on the test bench, where accurate records can be kept, adjustments made easily, and some control held over the innumerable variables which influence engine performance, and if the services of an expert from one of the big petrol companies can be obtained, so much the better. Exhaust gas analyses should be made since they are essential if corroboration of proper combustion is to be ascertained. Final tuning on road or track is, of course, necessary; accurate research or experiment there, however, is extremely difficult, if not impossible, under the conditions which prevail. One or two fuel blends and carburettor settings can be ascertained on the bench and then tried on the track. It is a good plan to have one fuel available for lower external temperatures than obtain in the test shop, not only because test-shop conditions generally are hotter, but because if a race is run on a colder day than usual the engine may not be happy on its apparently normal fuel. This is because the special racing fuels so often boil only over a very close temperature range, such as from 60° to 70° C., and are so very susceptible to atmospheric variations in temperature that when it comes to the production of a homogeneous air-fuel mixture the fuel giving satisfactory results on a hot day may fail on a cold one.

Petrol, being a very complex mixture of hydrocarbons, boils over a very wide temperature range from 30° C. to 200° C. approximately; it is, therefore, much more adaptable to climatic conditions and is invaluable in adjusting racing mixtures to varying circumstances. The nearer a liquid approaches chemical purity the more constant its boiling point becomes, and this is why, in preparing racing fuels, the induction temperature conditions have to be carefully considered and the fuel blend adjusted so that there is a reasonable chance of a good air-fuel mixture being supplied over the probable working temperature range of the carburettor and induction system.

The major components of to-day's racing fuels include alcohol, benzole, petrol, toluol, and acetone; minor components have included ether, water, naphtha, lubricating oil, xylene, and cyclo-hexane. It has been rumoured that picric acid and other explosives have been added to racing fuels but it is extremely doubtful that such substances have reacted normally when in the combustion chambers; in fact it seems probable that if they had done so the projectile-like quality desired of the car would have been conferred upon the cylinder heads instead! Doubtless the most practical exponents of the use of explosives for the propulsion of motor cars have been the Adler concern with their rocket cars and the enterprising German who once demonstrated at Brooklands; rockets, however, cannot be fairly classified as racing fuels although they generate considerable energy for a few moments.

Reverting to the more usual fuels mentioned above, a short description of their origin and characteristics may serve to clarify the reader's mind and explain more fully some of our earlier statements.

Alcohol

Two distinct types of alcohols are employed:

(1) Ethanol, or ethyl alcohol, which is a product of the fermentation of grain alcohol, a by-product of the manufacture of molasses, or a product of other vegetable matter.

(2) Methanol, or methyl alcohol, which is usually a synthetic product which may be made by passing carbon-monoxide and hydrogen over a catalyst at an elevated temperature.

Their chemical formulae differ slightly: Ethanol $= C_2H_5OH$; Methanol $= CH_3OH$. Both, however, contain oxygen, wherein they differ from petrol and benzole. In latent heat Methanol possesses a distinct advantage, since its value is 500 B.T.U.'s per lb. as compared with Ethanol's 400 B.T.U.'s per lb. approximately. Thus a cooler and denser charge might be expected from Methanol. On the other hand, Methanol is thought by some observers to be more prone to pre-ignition than Ethanol—the fact, however, has not been clearly demonstrated; nevertheless it may reduce Methanol's effectiveness in relation to that of Ethanol and account for inconsistencies in the running of some engines which are otherwise apparently inexplicable. The calorific values are 11,840 B.T.U.'s per lb. for Ethanol and 10,030 B.T.U.'s per lb. for Methanol in equal volumes; therefore Ethanol contains slightly more potential energy; the gravity of Methanol, however, is 0·791 as against 0·785 for Ethanol, and this tends to counterbalance the former's advantage in this respect. Methanol only requires 6·5 parts of air by weight for perfect combustion, while Ethanol needs 8·9 (petrol needs 14·8), therefore Methanol will be the more extravagant for equal power output. Ethanol boils at 78° C. Methanol at 66° C; thus Methanol is more volatile and might have an advantage in warming-up and in acceleration, and might even give a direct start in warm weather.

The properties of the two fuels are really very similar and in many cases it seems to matter little which is employed. If a maximum cooling effect is desired, Methanol seems preferable, but if a persistent pre-ignition is encountered, and which cannot be traced to other causes, experiment with Ethanol is worth trying.

Methanol is easier to obtain than Ethanol because it is not subject to Excise Duty, and pure Ethanol would be hopelessly expensive in this country for that reason. Unless denatured with 25 per cent benzole, or something similar, ethyl alcohol has to pay full duty and we are therefore precluded from using it alone; there seems to be no reason, though, why even denatured Ethanol's latent heat value should not be improved by judicious admixture with Methanol.

Both alcohols are miscible with petrol, but the mixture is not stable and will separate out in the presence of a very small amount of water, as little as ½ per cent being sufficient to effect separation at low temperatures. The addition of benzole, and more particularly of acetone, increases the stability considerably. Low temperatures again cause alcohol petrol mixtures to separate, and although the alcohols have freezing points of – 100° C. approximately, any temperature approaching 0° C. (32° F.) will promote separation. This, be it noted, is one very good reason for ensuring that carburettor float chambers do not become too cold when the engine is running at low speeds.

The anti-knock values of the alcohols are very high indeed, and though their compression ratio values have not been actually determined, it is clear that they are safe up to 10 to 1 with car engines and somewhat higher with those of motor cycles.

It has been found that tetra-ethyl-lead has no effect on the anti-knock value of alcohol, and it may be that the ultimate anti-knock value of that compound lies below the 10 to 1 compression ratio mark. On the other hand, alcohol has a lower flame temperature than petrol and it may be that the lead dope's chief value lies in its flame temperature-reducing property; the point, however, is very obscure and is likely to remain so until a great deal more research has been made into the phenomena of combustion processes in internal combustion engines.

Benzole

Benzole is a product of the distillation of coal tar and, like petrol, is a pure hydrocarbon—unlike alcohol its molecules contain no oxygen. Pure benzene differs somewhat from ordinary motor benzole in that it contains no impurities in the shape of toluol or xylene, both of which are derivatives from coal tar, and which are constituents of ordinary motor benzole.

In racing fuels motor benzole is generally used; it has been considered to possess a better anti-knock value than the pure product, and its boiling point is somewhat higher—80° C. being the figure for pure benzole, or benzene, as it is technically termed, and 80° C. to 150° C. for the commercial product. The calorific value is akin to that of petrol, though slightly lower (18,000 B.T.U.'s per lb. approximately) but its higher gravity, 0·870 approximately, sets this off on a volumetric basis. Its latent heat is about 170 B.T.U.'s per lb.—much lower than that of the alcohols, but somewhat higher than the petrols at 140

B.T.U.'s per lb. The anti-knock value of benzole is considered to be of the order of 7 to 1 compression ratio value; this, however, has not been definitely determined, but it has been ascertained that benzole will pre-ignite before audible detonation sets in, a deceptive and rather dangerous characteristic.

In racing fuels benzole can be employed in much greater quantities than petrol on account of its higher anti-knock value and better latent heat value. It has considerable value too as a binder of alcohol and petrol and it increases the water tolerance of such mixtures perceptibly. Its freezing point is high, about 5° C. (41° F.), and for this reason it is unsafe for aircraft fuels because low atmospheric temperatures are so frequently encountered at all times of the year at very moderate altitudes.

Petrol

Petrol is chiefly of use in racing fuels on account of its very wide boiling range, which not only confers startability on the fuel but gives a good mixture at all temperatures and so the excellent "distribution" to the cylinders, which means clean unhesitant acceleration. Its chief failing in racing is, of course, its comparatively low anti-knock value.

Such petrol as is used should be preferably of aviation quality; that is, one of greatest volatility and highest anti-knock value. The present Air Ministry D.T.D.224 specification is quite suitable, and if a leaded variety is needed the D.T.D.230 type meets the case.

Toluol

Toluol is closely related to benzole; it is not often used in car racing fuels on account of its expense and the difficulty in obtaining it. Its anti-knock value is similar to that of benzole, but it has an exceptionally low freezing point of − 70° C. approximately. It can, therefore, be employed where low temperatures are a source of danger. Its boiling point of 110° C. is higher than that of benzole and it has its uses if volatility of a high order is not required. It is also a primary dye and a war material—it is therefore seldom available for other purposes.

Acetone

Acetone, which is a derivative of alcohol, is chiefly of use as a solvent and binding agent for the alcohol-petrol-benzole blend. It has some value as a fuel with a calorific value of 13,000 B.T.U.'s per lb. and a latent heat value of 240 B.T.U.'s per lb. It boils at 56° C., is therefore useful in conferring volatility, and with an anti-knock value between alcohol and benzole is sometimes an asset. There are grounds for believing that acetone may attack certain light alloys and it should not be left long in contact with supercharger casings, carburettor parts, &c., after the engine's running it over. It is also a solvent for most organic products, particularly those unaffected by petrol, benzole, or alcohol.

Ether

Ether, as earlier stated, has been used to enhance starting and probably mixture distribution where very high alcohol contents are used. It is, however, a pro-knock substance and for that reason to be avoided. Ethyl ether is what is employed and it should not be confused with petroleum ether.

Water

Water, as already explained, is not a fuel but has a very high latent heat value, viz. 970 B.T.U.'s per lb. For this reason it can be employed as an internal combustion chamber coolant. It must of necessity detract from the maximum power output of the engine, and if engine conditions are such that water is needed to keep it running on anything like 100 per cent alcohol fuel, it would be far wiser to modify the engine somewhat and remove the mechanical or physical causes leading to the overheating of the combustion chambers; *e.g.* by extra cooling of the exhaust valves, plugs, &c.

As a temporary expedient the use of water might be justified; its controlled application or injection, however, is a matter of great difficulty with a racing car, and though the project has often been discussed, no practical method of putting it into effect has been mooted.

Naphtha

Naphtha, or solvent naphtha as it is called, is but a crude product of coal tar, related to benzole; its only use would appear to be as a binder of petrol and alcohol if benzole is not used.

Xylene

Xylene again is a derivative of coal tar and related to benzole and toluol; it is generally present in motor benzole. In its pure state it has a high boiling point, about 140° C., and if used alone can, like naphtha, be but a binding agent or perhaps confer a slightly wider boiling range on the final mixture.

Cyclohexane

Cyclohexane is a petroleum product of the naphthene series, very seldom found in racing mixtures. It boils at 80–81° C. and might be useful in adjusting the fuels distribution characteristics. Its anti-knock value is not exceptionally high, and it is also one of the fuels which pre-ignites before detonating audibly. It has been used but it seems undesirable; it is, too, hard to obtain and very expensive.

Lubricating Oil

Lubricating oil is frequently employed in racing mixtures to take care of supercharger bearings, inlet valve stems, and top piston rings. It certainly is necessary to some superchargers, but its effect on the other engine parts is extremely doubtful; however, it may do some good and is unlikely to do harm, therefore its use is justified in racing. The quantity of oil used must be strictly limited, since oil, especially castor, has a pro-knock tendency. About 2 per cent by volume is as much oil as should be put into any known racing fuel.

Tetra-Ethyl-Lead

Tetra-ethyl-lead is a very excellent anti-knock compound when used with petrol, but its effect therein is limited to that given by a maximum of about 5 c.c. per gallon. Petrols vary considerably in their response to lead but none will respond to much more than the amount stated.

As it has been shown that lead dope does not improve the anti-knock values of alcohol or benzole, there seems little point in adding 5 or 10 c.c. of lead dope to a racing fuel which is unlikely to contain more than 10 per cent of petrol, so giving the petrol ten times more lead than it will respond to.

The effect of lead dope on overheated exhaust valves can be extremely serious. However, racing cars seldom run long enough without a strip to permit serious corrosion of valves from this cause. Nevertheless 1 or 2 c.c. of lead per gallon is all that need be put in a racing fuel.

Lead fluid is not obtainable by the ordinary mortal, for the petrol companies using it would not supply it. If it is needed it is best obtained by using one of the standard ethylized petrols as sold from the pump for the fuel blend. In general, however, racing motorists do not blend their own fuels but obtain them from the petrol companies.

In years gone by it was thought that extra oxygen would enhance power output since more fuel could be burned; this, of course, was in the days when petrol was the only fuel used. No doubt a certain amount of reason existed in the idea, but the effect of the extra heat on the crude materials and mechanisms of the times would no doubt have been disastrous. It is not known whether any real efforts were made in this direction, but certainly the late Ernest Eldridge carried a cylinder of oxygen which could be turned on to the induction pipe of the enormous F.I.A.T. with which he set up a World's Mile Record on the road at Arpajon in 1922. His passenger related how he turned on the oxygen at the start of the first run, but was so overcome with his experience that he completely forgot to turn it off whilst the car was turned round for the return run over the measured mile. The oxygen was exhausted before they started back again, and as the car went just as fast the oxygen appears to have had little effect.

Although this article is not a scientific treatise on racing fuels it comprises the practical experiences of some ten years' active participation in the work of producing and applying them. The problem of selecting the most suitable fuel cannot be solved on paper, nor in the laboratory, and actual experiment, with engines, of an empirical nature is the only effective method of dealing with it.

In conclusion, the essentials upon which to concentrate are: the introduction of a charge of maximum density and calorific value to the combustion chambers; a fuel which burns rapidly and without detonation or pre-ignition at the compression pressures employed; a fuel with a wide enough boiling range to ensure startability, fairly rapid warming up, and one which, in particular, has those distribution characteristics which ensure a rapid pick-up and no likelihood of damping out when the throttle is opened after slowing down for a corner or other check.

CHAPTER SEVEN

CARBURETTORS
INDUCTION & SUPERCHARGING

By L. Mantell

ONE of the first things that must be mastered before undertaking the choice, fitting, or tuning of a carburettor is the co-relationship of engine "characteristic" with choke diameter, main jet size—as regards its metered flow—and correction.

While many drivers of experience have ears trained to interpret the engine's needs from its audible behaviour, they can only do so as a rule in terms of rich or poor mixture, either locally or generally; but how many know whether a change in the running mixture strength is to be effected by main jet or by choke tube variation? and again, how many know whether bottom and flat areas are to be cured by choke change, main jet change, correction, or variation of the pilot output?

For clarity of comprehension we will confine our attention to static carburettors only, *i.e.* that class which effects their fuel metering and correction by fixed orifices only, as distinct from the constant vacuum class in which suction-operated moving parts are employed for this purpose.

From a racing or high output point of view the choke tube is the most important of the tuning units. In touring practice this choke receives little attention, everything being focused on the jets. This does not, however, mean that its size is any less critical in production touring engines than in racing motors, for in the former class it has had to be determined with just as much care as in the latter. Once having ascertained the right size choke, however, it can be reproduced for thousands of more or less identical engines, and any small mixture corrections that are subsequently called for can generally be made by variation of the jet size and correction.

In racing engines it is different; there are relatively very few of them, and as each receives as a rule much individual attention amounting frequently to the change or modification of major parts, each of these motors is apt to become a law unto itself. The considerations governing choke selection therefore must be thoroughly understood, so we will proceed forthwith to analyse them.

The duty of the choke tube is twofold; its first is to create, with a minimum of pumping resistance, the necessary velocity round the spraying orifice, to break up the fuel to the degree required by the engine. Its second function however, which is less generally recognized, is to create an optimum depression in the induction system. Possibly the significance of such a need may not be very clear. It must therefore be explained that petrol sprayed into an area at atmospheric pressure has a much greater tendency to coalesce into coarse particles and deposit, than when drawn into an area in a state of partial vacuum, because the higher the pressure the more readily does it coalesce or *vice versa*. For this reason alone therefore the selection of a suitable choke diameter becomes critical, because the presence of a vacuum, despite the above advantage, represents on the other hand a loss on two counts—pumping resistance, and reduced volumetric efficiency; the degree of vacuum must in consequence be as limited as possible. Unfortunately the factors controlling the depositing tendency are not restricted to spraying velocity and vacuum only, there are many more influences at work, none of which is closely calculable.

From an induction standpoint it will be obvious that the longer and colder the pipe the greater is the depositing tendency and the higher therefore must be the local velocity to counterbalance it. A well-shaped pipe also will have less depositing action than one in which the bends are sharp or rectangular. And yet again a pipe with a very smooth interior will be better than one with a rough internal surface; these, however, will be discussed later. On the engine side spray suspension is greatly affected by gas pulsations.

These are, unfortunately, inseparable from all internal combustion engines, and are greatly influenced by valve timing and by all factors controlling the flame rate.

At infinitely low speeds it would be correct to open the inlet at top dead centre and close it at bottom dead centre precisely; and to do exactly the reverse with the exhaust—opening at bottom and closing at top dead centre. This, however, is a purely hypothetical condition, for the petrol engine is essentially of the high-speed order, and immediately r.p.m. intrudes, new and progressive sets of conditions accompany the rising speed. Because of gas lag, for instance, we must advance the exhaust opening and must similarly delay the inlet closing point. The latter especially is very troublesome from a carburettor standpoint because, owing to lag, the cylinder is nowhere nearly full at the completion of the induction stroke and the valve-closing therefore must be delayed to obtain the best filling possible; the higher the peak revs. the smaller the valve and the lower the lift, the later must be the closing point for a maximum charge inspiration. Nor does it end there, because further complications set in at the scavenging top centre where the exhaust closing and inlet opening points must overlap. The object is twofold. Firstly we delay the exhaust closing to allow the rapidly moving column of ejected gas in the pipe to react on the un-scavenged contents of the combustion space, which it does very much after the manner of the piston of an extractor pump. This alone, however, would be ineffectual as a scavenging factor unless we relieve the tendency to over-extraction by giving the inlet valve an opening lead to follow up the growing vacuum with a fresh charge, thus improving the scavenging, starting the induction current in advance of the piston action, and allowing the valve to be more fully lifted when the real induction stroke, mechanically speaking, commences.

So far so good, but, as the value of these scavenging and filling incentives increases and decreases respectively with rising and falling speed, it will be clear that the best results can only be attained at one definite r.p.m. It will be equally evident that if we set this point at a fairly high speed, which we probably will do for racing purposes, troubles will progressively set in as we slow down, for, the escaping gases' extractive effect will fall off and re-inspiration of the spent charge may occur. The inlet opening will now become automatically too early and part of the spent gas will therefore tend to upset the new gas.

Although it is popularly thought that the induction manifold contents are a "gas," there is actually very little gas present—at least in the form of fuel vapour—for recent research shows that the proportion varies between 1 and 5 per cent.

And this is quite as it should be, because, although we speak of burning fuel, the real physical fact is that in this case we employ fuel and *burn oxygen*, and that the greater the weight of oxygen we can burn per unit of time and per unit of cylinder capacity, the greater is that engine's efficiency—other things being equal.

Such being the case, it clearly follows that as burning a maximum of oxygen is our need, the so-called fuel must occupy the smallest possible space in order to avoid oxygen displacement. In short, the fuel in an induction pipe must *not* be gas but *liquid* in a broken up and suspended condition.

That is the reason why power during high output immediately drops if the pipe gets hot enough to produce any appreciable vapour, and it also explains why, if we open the test shop door on a cold day, the power immediately rises. The cause is *not* fresh air as many think, but *cold* air.

To return, however, to the inlet valve functioning as a disintegrating agent, gas velocity and temperature are, as we have seen, the primary factors in disintegration, but we cannot attain these fully by manifold design. It is therefore necessary to obtain the assistance of the inlet valve, and while making this big enough to pass a quantum of live charge, it must on the other hand be small enough to speed up the charge locally and so put the final finishing touch on the so-called atomization of the fuel. This valve therefore has a critical size like the choke; too big a valve may cause a loss of power just as an undersized one will, because while in the latter case "filling" will suffer—in the former case the final state of the fuel in the head will be too coarse to effect a sufficiently complete evaporation and admixture with the oxygen. The result will be that all the large particles of petrol will burn too slowly to have their full driving effect, causing not only power loss but a flame which overheats the exhaust valve causing pinking and firing back in the carburettor.

Late ignition, whether caused by unduly retarded timing or badly placed plugs, will have the same eventual effect.

Here therefore we have various factors which produce undue induction pulsations.

Inlet valve closing too late, inlet valve too big and/or unsuitable valve timing, and any factor which will cause too high a final pressure—all have the same result—progressive interference with the steadiness of the inlet current, and it is the sum of these influences which constitutes the "Choke Characteristic" of the engine.

While all this explains the impossibility of calculating choke sizes on a bore/stroke/speed basis it does not mean that there is no guidance at all but only that there is no *mathematically calculable rule.*

The basic relation both of inlet manifold and choke diameter is empirical and although not necessarily correct it is fairly suitable to most engines, but it should be understood that it is only approximate and must be confirmed by trial and error. Here, then, is the general rule: The inlet pipe diameter is calculated to produce at the peak, 180 feet per second gas velocity, and the effective choke diameter about 300 feet per second for racing engines, although in touring-engine practice it can often go to 450 feet per second.

These figures are arrived at by a somewhat arbitrary but generally recognized procedure which can be described without the use of mathematical symbols as follows: To arrive at an average pipe or choke optimum velocity the peak piston speed in feet per second is multiplied by the number of times the piston crown *area* is greater than that of the pipe interior, or as the case may be—the choke waist less the main jet assembly obstruction, which of course restricts the full space available.

To do this by simple arithmetic obtain the piston speed in feet per second by multiplying the stroke in inches by 2 and again by the r.p.m., after which divide by 12 and by 60 to bring inches per minute to feet per second, Multiply this then by the piston area, *i.e.* the bore in millimetres squared, again multiplied by $3\frac{1}{7}$ and divided by 4, after which divide this dividend by 180 to get the induction pipe area or by 300 for the effective choke area. The answer will of course be in square millimetres and must be reduced to a diameter by the inverse of the above in the case of the pipe, but where the choke is concerned allowance must be made for the obstruction offered by the spraying assembly. We now have a basis on which to tune.

Having now a clearer idea of the influences governing the choke, the normal procedure for obtaining a racing setting is relatively simple, and usually resolves itself into a series of systematic step-by-step trial and error changes.

Start therefore with the choke size calculated by the above method and use therewith the main and correction jets recommended as a basic commencement by the makers of the carburettor. It is most improbable that the first selection will be right, because there are too many unknowns in every engine for any maker to be able definitely to state the correct jets.

The point now is the necessity for strictly systematic progress and the avoidance of indiscriminate choke and jet changing.

Neglect for the moment the question of correction, which incidentally should be as low as possible so that the tendency is rather to enrich than to become weaker with rising revs.

Having got a maximum reading over a definite road stretch or as the case may be—over a lap, make a main-jet change by one size—up or down as broadly indicated by the engine's behaviour. If an improvement results, go one size further in the same direction and so arrive at the peak performance—*with that particular choke.* Be very careful incidentally (1) to get your engine up to its full working temperature before commencing to tune; (2) to do nothing else whatever that can confuse the test; and (3) to make tests always in the same direction—or if it is a there-and-back run, make all of them similarly.

Now change the choke by one size—bigger if lower end and middle speeds seem fairly brisk; smaller if, on the contrary, it is necessary to attain considerable revs. before the engine seems to "get hold"—and—once more step the jets up or down progressively until the maximum speed with the new choke is obtained. If it is the same as before—which will be unusual, it is best to retain the smaller choke, because this will always give better acceleration, but if there is improvement, repeat the procedure as above until the final maximum is established.

This however does not end it, for it is quite conceivable that —especially if a very large choke is found to be best—the bottom and middle parts of the acceleration range may be too flat. If so, and if improvement at these parts is noted as the main jet sizes increase, higher correction is then called for, and this is provided for in different ways according to the make of carburettor installed. In the Solex there are two methods, because, while in the earlier models a single jet of tubular design called Assembly 12 was made to function both as a metering and a corrective member, the later types dispense with this and effect correction by two separate jets, called Assembly 20; a small submerged main like a pilot in appearance, uncorrected in any way, and to be regarded solely as a metering member, and a second mechanically similar member but with a much larger orifice which deals with the correction.

In the first case application to the makers had best be made stating the present correctional number on the jet and enquiries made as to the higher or lower correctional types likely to suit, because these values do not vary in numerical progression but are designated by figures which have no mathematical relation therewith. Where Assembly 20 is used, however, the fuel metering and air correctional jets are numbered to correspond with the diameter of their orifices, 100 being, for instance, 1 mm. and 200 2mm, &c. &c., so that the upward and downward steps can be determined without reference to the makers.

In the Zenith and Stromberg carburettors the metering and corrective arrangements are also separate but differ functionally in one slight respect, namely a change in the main jet of either extends further over the whole range than with the Solex principle which is so conceived that alterations in the 20 assembly main effect the bottom end and mixture more than the top, and the same holds good of the correction jet which affects the top more than the bottom. If therefore the bottom is already good here it is often better to enrich the top end by a smaller air corrector than by a bigger main.

Correction generally does not greatly enter however into racing adjustments, because by intelligent use of the gear-box the engine is kept at all times well up towards its peak.

And now we come to consider cases where the engine does not respond to calculated treatment. Firstly perhaps it will not take a choke based on the peak velocity formula. In that case do not necessarily blame the carburettor for something else has probably intruded.

Over-correction or any other condition which will produce apparent top end weakness can be very closely simulated by (1) faulty ignition, (2) exhaust valve springs too light, or (3) insufficient freedom of exhaust.

The first-named is frequent and very often traceable to a badly designed coil in which the "saturation" lag becomes too great at high revs. and the spark intensity falls off.

Confirm this by having an additional battery wired up in series and in such a way that it can be switched in by the driver at high speeds.

If the saturation lag is too great this will show an immediate increase in speed. It need not, however, indicate a basically defective coil but only insufficient period of contact "make" through points being separated too widely, pull-off spring too light, or cams badly cut.

Exhaust valve bounce through weak or unsuitable springs will have the same result but in a different way, because while the ignition does it by retarding directly the initial inflammation development, a bouncing exhaust valve retards it by permitting the re-inspiration of spent charge which slows the flame rate. In both, and in fact in all such cases, the troubles resolve themselves into a high terminal exhaust pressure in the head and become externally observable at the carburettor air intake. Accelerate up therefore in short full-throttle bursts with the car at rest while holding the hand near the intake.

An initial blow-back of spray at the first quarter or third of the acceleration can generally be ignored, for it is usually due to the over-long closing inlet lag, and disappears quickly as the speed rises. A second blow-back, however, appearing towards the top of the curve cannot be ignored, for this means flame lag and high terminal pressure.

First be sure therefore that the petrol supply to the float chamber is adequate by trying a bigger needle valve or higher delivery pressure and experimentally lower the correction considerably. If these are ineffective, look then for an engine or ignition fault, for the odds against the carburettor being the cause are long. Possibly basic engine design is the limiting factor. This is improbable in pukkah racing motors made by a responsible firm, but if the engine in question is a "hotted up" sports engine, one is very apt to be pulled up short by limitations which are too numerous and complex to be discussed under "Carburation".

Where constant vacuum carburettors—represented in England by the S.U.—are concerned, tuning conditions are quite different. All considerations *re* choke selection here resolve themselves into (1) a carburettor of the correct size and (2) a valve of the right weight—or, opening resistance if a spring controls its movement. These should combinedly be satisfied by assuring oneself that the valve is approximately fully open at the peak, after which both metering and correction is effected by needles of different sizes and shapes.

If a "characteristic" kink in the engine's air-fuel ratio curve should demand any one short area to be locally enriched, this can be met by very carefully filing a small flat on the needle at the defective spot. To correlate this spot, however, with the characteristic kink in question may be quite difficult unless one is tuning on the bench, when it is easy. Reference of the problem in close detail to the manufacturers is generally best so that more suitable needles can be recommended, because handmade flats are the work of an expert and difficult to carry out.

Where superchargers are fitted the same methodical rules of trial-and-error progression apply, but here the choke critical is of course subjected to different influences if the carburettor is mounted—as nearly all are—on the atmospheric side of the blower.

Up to a point the same choke velocity rules apply, but, as the charge volume passed is greater, speed for speed, than in a similar engine unblown, the area of the choke should be as much greater now as the blown h.p. exceeds the unblown power, plus a source of loss which cannot be prevented and which will now be described.

One hears of the power absorbed in driving the blower and is apt to regard this as an unrecoverable price paid for the extra power, but, in theory and in practice also, it need not be so, because the h.p. necessary to drive the blower is mainly required for pumping purposes, and as the normal induction effort of the engine is relieved by this amount the only actual wastage involved is the additional mechanical loss in operating the blower and its transmission plus the thermal loss due to radiation from the transfer pipe, which is generally hot owing to the adiabatic action of compression.

To keep this pipe cool is essential in order to prevent pre-evaporation of the fuel for reasons already mentioned, and in doing so energy is dissipated, but although this represents a thermodynamic loss, improved power per cubic capacity of the engine through the greater oxygen density is obtained as an offset. The loss is not great, however, and can perhaps be put down at about 10 per cent. As, however, the carburettor has to supply this, it must be given the additional volume and the percentage in question put down to the fuel efficiency loss account. If therefore a bench reading has been obtained from an identical engine similarly blown or its b.h.p. ascertained in any other way, the basic choke area plus 10 per cent should go up in like ratio compared with that on the unblown engine at the same speed, and the selection of suitable jets can then be proceeded with systematically as before. The choke critical, however, is less sensitive here, being free from periodic blow-backs through the various causes already enumerated that will now be absent, and as it is automatically raised on that account alone, apart from the supercharging, a lower peak choke velocity can generally be employed. How much lower is easier to ascertain by trial and error than by more involved calculations and comparisons, for it depends upon the percentage relief afforded to the choke by the steadying action of the blower.

Cases are known where a *pro rata* rise cannot be obtained, probably due to an over-large and over-cool transfer pipe, but as a rule the above will be found to hold good.

And now we come to the question of carburettor selection and general induction layout.

One would normally expect a discourse in carburation to commence rather than to end with considerations of this kind, but it is preferred here to leave it to the last, when the reasons given for various recommendations and objections will be easier to understand after a fuller appreciation of the causes influencing the choice.

Where supercharged engines are concerned there need seldom be more than one carburettor. If, however, a very large choke is required, *i.e.* in excess of 45 or thereabouts, a duplication of carburettors is best as a rule if there is accommodation for them in the blower, because, above a certain choke size the ratio of the area of the air column to the point of fuel efflux is apt to become too great for a homogeneous mixture. It must be remembered that although the choke alters greatly in size the spraying holes and general assembly of this member do not, and when the difference therefore becomes excessive, which point is approaching the middle "forties" of choke diameter, two carburettors become preferable.

Where unblown motors are concerned there are quite a variety of layouts.

First as to the carburettor type itself, that is as regards a choice between vertical, horizontal, or downdraught—a word may be said.

Downdraughts are popularly supposed to give better power than the alternative types but from a peak output point of view this is incorrect, for horizontal carburettors are just as good. This popular fallacy arises from the fact that, owing in the downdraught to gravity assisting the main jet at full throttle and therefore low choke velocity, one can employ larger choke sizes in touring engine practice than is practicable with the other types. On an all-out bench test with horizontal and to a still greater extent with verticals, a choke which will give maximum power is generally unusable on the road because of the difficulty of "lifting" the fuel against gravity with a big choke when suddenly opening up fully on top gear at low road speed, and a snap flat spot results. To cope with this a choke reduction is generally necessary in both these types, but, with the downdraught which requires less local velocity because here there is *no* "lift" owing to gravitational assistance, less choke reduction is needed and therefore with equal bottom end flexibility the peak power is greater.

In racing practice this is of little if any account, but what *does* matter is the number of inlet pipe-corners involved. If a horizontal will save an induction bend, as it will when bolted directly to a port, its choice is always preferable on that account.

This brings us to the question of general layout, and it may be said right away that a multiplication of carburettors for racing purposes on unsupercharged engines is always desirable. Not because of deficiencies in the supplying capacity of the carburettor but due to the reduction of corners, bends, and pipe lengths, all of which tend to increase pumping resistance.

A horizontal carburettor per inlet port and directly fitted thereto with complete suppression of all inlet pipe-work is always best for power, if there is room for it—but, unfortunately, there often is not. "Fours" with a single inlet port and an internally cast induction passage are now rare and fortunately so; but two- and four-port 4-cylinder engines are frequent. For the former a horizontal carburettor fitted directly on to the port, or at least in precise line with it, to suppress corners is best. Where possible it is preferable that the port diameter and that of the carburettor should agree, but sometimes the "characteristic" is such that the engine will indicate by its response to systematic choke "step-ups" its desire for a still bigger one, and in that case a larger carburettor is desirable.

It is advisable, however, to interpose a conical adaptor if so, because the sharp annular ledge may otherwise cause undesirable whirls.

Where O.H.V. "fours" with bilaterally symmetrical heads are concerned and provided with four inlet ports on one side, four exhaust ports on the other, and two camshafts with valves at 45 degrees, an ideal method of high efficiency carburettor layout is possible by scrapping the existing manifolding—both exhausts and inlets—also the camshafts, and dividing up the ports as follows:

Fit carburettors straight on ports 1 & 3 on near-side and 2 & 4 on exhaust, and to the remaining ports fit exhaust pipes. Have then two new shafts cut with their cams in the following order. Near-side inlet-exhaust-inlet-exhaust, and on the off-side exhaust-inlet-exhaust-inlet. By doing this there is room for a carburettor per port; also, the heat of the head and block is equalized, thus avoiding distortion; and finally, each cylinder has the single-cylinder motor-cycle engine advantage of getting direct spray cooling for its exhaust valve—the carburettor, inlet valve, and exhaust valve being in line. This practice will give almost, if not quite, the effect of a supercharger and far transcends any other scheme of carburettor fitting for sheer power.

It is equally applicable to "sixes", and its only shortcoming is that the number of engines so designed is unfortunately very limited.

Finally as regards unblown "sixes" with six separate ports on the same side as the exhausts, the best alternative arrangement is 3 downdraughts with down-swept Y adaptors to three pairs of inlet ports.

The same can be done with 4-port "fours" when all of the ports are on one side, but the results are not as good as in the "sixes" because of the very irregular intervals of inspiration. For this reason also two carburettors on a "six" are more successful than two on a "four," namely, the order of inspiration is regular on the former and most irregular on the latter.

Irregularity of this kind makes carburation difficult because, owing to the fuel and air column inertia difference, the first cylinder inspiring after the long interval gets a considerably weaker mixture than the one immediately following, and a compromise therefore is necessary in the jet setting, by which both suffer slightly.

Lastly, dismiss the general impression that when two carburettors are used they can be smaller than a single one. This is quite erroneous because, although neither carburettor does its full-time work, its duties are just as rigorous when it *is* working. Think it out and this will be obvious.

CHAPTER EIGHT

LUBRICATION IN RELATION TO RACING PRACTICE

By L. G. Callingham, M.I.A.E.
Shell-Mex Technical Expert

ALTHOUGH the scientific production of fuels has been highly developed in the racing world and an exact technique is employed in their production in the specialized departments of the major oil companies, by no means the same amount of effort has been expended upon lubrication problems.

On the other hand, immense strides have been made towards the attainment of ideal lubricants for ordinary engines—research and development in the last few years has been truly remarkable, and ideas on the subject, in general, have been revolutionized.

Lubrication, from an applied art, has rapidly become an exact science, and in this field, contrary to normal, the racing-car benefits from improvements made as the result of research and experiment carried out primarily on behalf of its less spectacular, though more numerous, brethren.

Until about 1924 a general idea persisted, especially among both drivers and engineers, that castor oil in some form or other was a vital necessity to the well-being of any racing or high-duty engine. Just what bred this idea is obscure; it seems probable, however, that it was fostered by early aero-engine practice, since all the old engines of that sort, rotaries in particular, were copiously dosed with it.

Although "Safety First" was not exactly the motto of our pioneer flying men, or of our War Birds, it was no doubt reasonable to presume that they used the safest lubricant available for their engines, and as this was invariably castor oil, in some shape or other, the racing men of the early 1920's adopted it on the score of reliability, despite the unpleasant fact, as one of our famous motoring correspondents wrote, that their wakes were highly reminiscent of Polperro Harbour on a hot summer's day.

In actual fact, users of the old rotary aero engines, like the Gnome and Rhone, fitted to Camels and other fighting aircraft, had good reason for employing castor oil, for in the first place the oil was continually in contact with the petrol mixture in the cylinders and crank case, and in the second had to withstand the effects of the centrifugal forces, due to the rotating cylinders, which, as most pilots knew only too well, tended continually to throw the oil out of the engine.

The explanation is that castor is nothing like so soluble in petrol as is ordinary mineral oil, and its sticky nature enables it to cling to hot engine parts as well as to other parts which, strictly speaking, do not need it.

Castor oil is very messy stuff, especially when half burned and liberally spread over pistons and valves, as those of us who have had to strip some of the old engines know, nevertheless it was the universal racing lubricant for many years.

The alternative, though not one very generally used, was really thick oil—another fallacy that modern practice has dispelled.

Superficially it was not perhaps unreasonable to regard thickness as a virtue in an oil, the popular idea being that, as all moving parts were comfortably isolated from one another by films of oil of appreciable dimensions, the thicker the oil the more resistant it would be to pressure and other disruptive forces.

Oil, however, does not possess the physical powers such reasoning must argue; neither do the conditions of fluid, or complete film lubrication postulated, exist throughout any engine, ancient or modern.

In practice a shaft rotating in a bearing does its best to develop and maintain an oil film of a sort—the shaft takes up an attitude eccentric to its bearing, it draws in oil to the major clearance, which is approximately opposite to the point of greatest loading, it even develops a certain pressure in this oil-filled space and some oil is forced towards the loaded points; there is not, however, a film of appreciable dimensions throughout the bearing, and where, as is usually the case, the loading is intermittent, the attitude of the shaft varies in relation to the bearing and there are points at which the oil film is at times discontinuous and, except in the molecular sense, practically non-existent.

Oil is of course forced into the bearing under pressure from the oil-pump—this pressure may even exceed 100 lb. per sq. in. at its source and is reduced by the time it reaches any particular bearing, and as big-end bearings are sometimes loaded to over 500 lb. per sq. in. it is unlikely that the pressure generated by the oil-pump is of much assistance in supporting the bearing loads.

Here be it remarked that extremely high oil pressures are another fallacy that modern research has dispelled.

Fortunately, as already explained, the bearing sets up a natural oil pumping effect and can, if properly designed, take care of itself, provided the oil-pump provides a reasonable supply.

The reason different engines favour different oil pressures lies in the dimensions of the oil-pipes and conduits, for example, if a circulation of five gallons of oil per minute is needed it takes more power to send the oil through a small pipe than through a big one, consequently the pump exerts more pressure and shows higher reading on the pressure gauge.

Piston and cylinder lubrication is more difficult than bearing lubrication; when moving, pistons, if supply is adequate, ride upon a film of oil. At the top and bottom of each stroke, however, pistons reverse their directions—at the moment of reversal there is not enough movement to build up an oil film mechanically, and conditions of what are known as boundary lubrication exist.

The greatest wear in cylinders takes place at the top and bottom of the piston-ring travel, and this may be taken as evidence that lubrication is by no means complete at all times in these regions.

It should now be clear that some other property than the mere physical ability to interpose a solid buffer between moving parts gives oil its lubricating power, and it is in the development of this power that modern research has done so much.

Lubricating oil, as most of us have observed, is very susceptible to temperature—the heaviest oils soon thinning out when warmed up. All oils, though, do not behave precisely alike under heat; all, however, follow the general rule of becoming thinner as the temperature rises.

A very common mistake is that of criticizing an oil's thickness after use and when it is run out of the hot engine—a not infrequent comment being that "it came out like water." It is most unfair to blame any oil for being thin when it is really hot, and it may surprise many to learn that the best of oil ought to be more or less like water in consistency, though not in nature, when it attains a certain temperature.

The thickness of oil, or its viscosity as the technicians call it, is measured at various temperatures by taking the time, in seconds, at which a stated quantity takes to flow through a jet at various temperatures. An ordinary good engine oil to-day might have a viscosity of perhaps 2500 seconds at 70° F.—290 seconds at 140° F. (a very general touring crank-case temperature) and 80 seconds at 200° F. Thus unless the temperature of the oil is known, it is futile to judge its consistency as it flows from a hot crank case.

At one time knowing individuals would rub oil between finger and thumb, adjudicating learnedly upon its quality, or "body," as they put it—the more knowing ones might even sample the oil upon the tongue-tip, pronouncing solemnly upon its value, impressing the unenlightened, and acquiring much kudos.

Opinions based on such methods are, of course, valueless and definitely misleading; one might as well argue that a thick copper wire was stronger than a thin steel piano wire because it was thicker.

It is not body, or substance, that makes an oil lubricate; it is a much more elusive quality, and moreover a quality that has not, to this day, been determined exactly. It is known, however, that lubrication, under extremes of heat and pressure, becomes a matter of molecular functions and dimensions.

Some quality, in the right sort of oil, enables its molecules to combine with the metallic molecules of the surfaces needing lubrication and to exert forces which prevent the surfaces touching and seizing.

Scientists can explain the incredible powers of attraction and repulsion existing between tiny molecules, and they will show how the right sort of oil molecule adheres firmly to metal surfaces and repels the molecules adhering to the opposing surfaces—they will also show how these molecules slip freely over one another provided their ends are anchored elsewhere. —finally they will demonstrate how molecules torn from their anchorages rapidly orient and re-establish themselves elsewhere, or are replaced by others.

This rather crudely explains the modern idea of the action of lubricating oil and shows why an oil need not be thick to lubricate effectively.

Viscosity is resistance to flow, and a thick oil is one in which the molecules are strongly attracted to each other—thick oil is, therefore, a power-waster and may detract from the power of an engine as much as 10 per cent in comparison with a thin oil which has good lubricating properties.

Around 1923 Ricardo carried out a most interesting experiment, comparing castor oil in an aero engine, for which it was the recommended lubricant, with a thin oil which the Shell Company had devised after considerable research.

At normal operating temperatures the engine produced 10 per cent more power on the thin oil than it did on castor oil, and inspection showed that lubrication was perfect. As a result several tests were made on the Brooklands Track with the thin oil and lap speeds were improved from three to four seconds —a very considerable gain when lap times are of the order of one hundred seconds.

Such thin oils did not suit the cars of the day in all respects as bearing and piston clearances were excessive, leading to high oil consumption and a certain amount of plug-fouling.

The author had considerable difficulty at first in persuading drivers that the lower oil pressures, due to the thinner oil, were safe; but a few successes soon convinced the sceptics, and it is interesting to note that famous cars like Cook's and Park's Vauxhalls, Zbrowski's Ballot, Parry Thomas's Leylands, and Clement's Bentley, all won races on this very thin Shell oil.

At the present day castor oil is seldom, if ever, used in racing or aero engines—what are known as mineral oils, or pure petroleum products, are practically universal.

The Air Ministry early realized the disadvantages of castor oil, both physically and economically, and after much experiment and consultation with the oil companies' technical staffs they evolved the present D.T.D. 109 Specification oil, a pure mineral product on which all of to-day's high-powered service engines run.

Such an oil is identical with that sold by the reputable oil companies for ordinary touring cars, and it is suitable for practically any modern racing engine.

The development of such oils was not achieved without much arduous work and considerable expense—as an instance the author attended a three-hundred-hour continuous full-power test of a 600 h.p. air-cooled Bristol Jupiter aero engine some years ago, and has vivid recollections yet of the trials and tribulations undergone in bringing what was then regarded as a desperate enterprise to a successful conclusion.

Quite recently full-power bench tests have been made with the super-charged Napier "Lion" engines which John Cobb has fitted to his Railton Land Speed Record car. In this case the highly supercharged engines run at some 3600 r.p.m. and develop nearly 1500 h.p. each. Previously they had never been run (they are Schneider Trophy aero engines) on anything but castor oil, but now they behave perfectly on the type of mineral oil just discussed.

The secret of the efficiency of these modern mineral oils lies in their manufacture and refining—in the past oil was roughly refined by drastic washing with sulphuric acid, followed by earth filtration, after which the oils were blended to suitable viscosities.

Such treatment removed some impurities but left others behind, and it also destroyed properties which research later proved necessary to real lubrication efficiency.

Modern methods comprise what is known as solvent refining —here the oil is gently washed with solvents which wash out the impurities and unstable elements in gradual stages and without effecting chemical changes.

In certain highly developed processes some of the valuable lubricating components are specifically extracted during the cleaning process, retreated and returned in controlled quantities to the finished article, conferring a hitherto unattainable durability upon it.

One might compare solvent refining and acid washing with cleaning a delicate soiled fabric by floating out the dirt with a solvent cleaning spirit and scrubbing it harshly with a brush and soap.

Another advantage conferred on oils made by the solvent process is that of retaining their viscosity under increasing temperatures to a much greater degree than the old-fashioned oils—viscosity curves of solvent refined oils plotted against temperature are much flatter, and we can, therefore, employ a thinner oil with consequent much better cold starting properties, resting assured that there is ample viscosity or "body" when the oil attains working temperature.

Another advantage, too, of the thinner oil is that it reaches the working parts directly the motor starts, keeps down wear and enables the driver to get under way without delay.

Oils from these modern processes are cleanly in action, their resistance to oxidation and the ensuing carbon and sludge is very high, and in general they may be considered very durable.

Since touring oils to-day are really identical with racing oils, they have been discussed at some length, as it is felt that the facts may be appreciated even if the subject is not a very exciting one.

Points concerning lubricating oil in racing and which merit attention are the temperature the oil is likely to attain, the flow called for by the engine in terms of gallons per minute, the probable consumption in a race of any length, the control of the oil temperature, the tendency towards plug-fouling, and the lubrication of superchargers.

Additional points are the introduction of oil to the fuel, and of course the lubrication of those parts of the machine which the engine system does not cater for.

Firstly it can be accepted that any good-quality mineral oil made by the solvent refining process will be suitable for a racing engine; if such an oil meets the Air Ministry D.T.D. 109 Specification it ought to be perfectly satisfactory; if it comes within what is known as the S.A.E. 40 to 50 range and is the product of a good firm it will probably be reliable—in terms of viscosity as quoted in this country an oil of approximately 3000 secs. at 70° F. and 80-90 seconds at 200° F. on the Redwood Scale will meet the case.

Other items included by oil technologists in their specifications are not easily understood by the ordinary mortal and certainly need not be bothered about by the racing driver if he is content to take the advice of his selected oil supplier.

The temperature attained by oil in racing engines varies considerably and may lie between 70° and 120° C. (158° F.-248° F.). A safe and satisfactory temperature is 75°-85° C., but higher temperatures need not cause alarm if attained gradually.

Sudden rises in oil temperature are signs of trouble; they may be due to lack of cooling water or to sudden losses of oil due to damaged oil tanks or crank cases. Such a rise would presage bearing failure or seizure, but an overheating bearing or tightening piston would be unlikely to give warning by overheating the oil.

Realizing that water boils at 100° C. (212° F.) many drivers become apprehensive if their oil gets anywhere near the 100° C. This is unnecessary as oil does not boil at 100° C., or anywhere near it; it needs to be several times as hot before it can boil.

The danger, though, of allowing oil to exceed the 100° C. point by much lies in the risk of bearing failure, since one function of the oil is to carry heat away from the bearings and cool them.

White metal bearings become plastic around 140° C. and will run when this temperature is exceeded; it is obvious that the bearings run somewhat hotter than the oil in the crank case, therefore the oil therein, on being extracted therefrom if a dry sump is employed, should be maintained below the danger point.

Thin oil keeps bearings somewhat cooler than thick oil, and for this reason the lighter oil should always be taken if there is any choice.

Those readers who are members of the Institution of Automobile Engineers and have access to the work of the Research Department can glean much useful information on the running temperature of bearings, and the effect thereon of differing oil viscosities, from experimental work recently completed.

The measurement of oil temperatures in a racing car is best effected by distant reading ether bulb type thermometers. The bulb is fitted into the hottest part of the oil sump and the dial mounted on the instrument panel. A similar thermometer can be incorporated in the water cooling system.

When fitting and using such thermometers care must be taken not to fracture the copper piping leading from the bulb to the dial gauge, otherwise the ether escapes and puts the instrument out of action.

Where a dry sump system is used, thermometers in the oil inlet as well as in the outlet are useful, as this gives some idea of the cooling efficiency of the tank or oil-cooler.

The amount of oil carried in the engine system is primarily one for the designer, and quantity is more important in long races than short ones.

Experiments made by the author indicate that the quantity of oil carried in circulation does not affect its ultimate temperature in a run of any length—two gallons of oil merely attain normal maximum temperature a little sooner than do three gallons; both eventually reach and maintain the same temperature.

In short races a thin oil is advantageous because it attains maximum fluidity quickly and full engine power is developed earlier; some drivers even add hot oil to their engines shortly before starting in a race.

Control of oil temperature by coolers, ventilated sumps, or radiators is sometimes practised. Unless very carefully designed, such devices are usually ineffective.

Oil behaves somewhat peculiarly in pipes; it has a habit of swirling and coring, with the result that only the outer layer, adjacent to the pipe, cools off at all and the majority of the oil remains as hot as ever.

Oil, having a low specific heat, gives up its heat unwillingly and so cools down slowly.

If oil is to be cooled rapidly it must somehow be spread out in the thinnest possible layers, and a most interesting method was adopted on the Supermarine S.E.5 Schneider Trophy seaplane.

Here, where streamlining was of the utmost importance, no excrescences could be permitted, and it was ascertained that carrying even a small oil-cooler outside the machine caused a loss of speed of several m.p.h.

The problem was ultimately, and most ingeniously, solved by running flat thin tubes all along the sides of the fuselage—these gave no parasitic drag and cooled the oil effectively. This idea might well be incorporated in a modern racing car.

It is extremely difficult to cool oil in radiators of the type used for cooling water, and the flat tube type is much more effective.

Borrowing from aircraft practice again, there is, or used to be, a flat tubular cooler known as the Vickers-Potts which could undoubtedly be copied on a small scale and found suitable.

With engines having roller-bearing big-ends and main bearings the crank-case oil temperature is not so serious and somewhat greater latitude may be afforded.

In connection with bearings it is of interest to note that where white metal is employed the thinnest layer of metal is advisable. White metal is comparatively soft and if thick metalling is used in a racing engine it is liable to be crushed out or seriously deformed.

Oil temperatures are usually much higher in races on the Brooklands Track and similar circuits than they are in road races, and it may be found, for instance at Le Mans, or in the T.T. Race, that the oil temperature does not exceed 70°-80° C., while on the track in a race like the 500 Miles the oil will reach

100° C.—the difference in temperature when continuous full throttle, against even occasional let-ups on corners, is used, is considerable.

In the same way oil consumption is affected, and a machine which does 300-400 m.p.g. under high-speed touring conditions may put the consumption up to 100-150 m.p.g. in a long track race.

Oil consumption is a point to be considered, especially when racing standard sports type cars, and it is well to make provision for the addition of supplementary oil to the crank case unless frequent pit stops are contemplated.

In one of the old Boillot Cup Races on the Boulogne Circuit the author had the misfortune to break an oil-pump on a Bentley when some 20 miles from the pits—luckily the car had a reserve oil tank, and by running oil judiciously into the crank case it was possible to drive around to the pits, relying on splash lubrication, and to effect repairs to the pump without having harmed the engine.

Oil pressure, as has already been explained, must be read in relation to the type of oil employed—and if a thinner oil than usual is concerned a somewhat lower pressure reading may be expected—in the same way, as the oil gets hotter and thinner the pressure may drop.

The important point is rate of oil flow, and if the requisite quantity is passing round the pressure recorded is immaterial.

Many drivers like to put lubricating oil into their fuel, and it is sometimes necessary to do so in order to lubricate the supercharger.

When alcohol type fuels are used castor oil is useful, as it is more soluble in alcohol than is mineral oil.

It is extremely doubtful whether any upper cylinder lubrication is effected by adding small quantities of thin oil to fuel, and in any case only small quantities (2 to 3 per cent) should be used, since lubricating oil has a pro-knocking effect, and 5 per cent or more will definitely lower the anti-knock value of the fuel. If mineral oil is added it is advisable to use engine oil.

It goes without saying that oil should be changed after every race and that the engine should be well washed out with flushing oil, if it is not dismantled.

In conclusion, it is advisable to use the thinnest oil that the engine can stand, bearing in mind the permissible consumption, the ability of the pump to deal adequately with the supply, and the nature of piston and bearing clearances in relation to the amount of oil the plugs can stand.

Supercharger lubrication is sometimes effected from the main oil system, and in such cases some adjustment of the feed may be required if the type of oil is varied.

Chassis or transmission lubrication again calls for the lightest oil which can be safely employed, as the amount of power wasted in churning oil in gear-boxes and axles can be considerable.

In a car the author is running at present there is a drop of 20° C. in the gear-box temperature when a medium oil is used instead of a heavy one on a fifty-mile road run—this temperature difference represents quite a lot of horsepower.

The Wilson type of self-changing or pre-selector gear-box is very susceptible to oil thickness, and if efficiency is aimed at, a very light oil indeed is required.

Back axles of racing cars should not be lubricated with gear oils—a medium type of what is known as Extreme Pressure lubricant is very suitable, or as an alternative, castor oil; in this case castor does not get hot enough to carbonize or sludge, and its ability to lubricate at high pressure is useful.

The Extreme Pressure lubricants contain chemical dopes which are slightly active—they were really devised to take care of the extreme pressures set up by the hypoid gears used in many current American cars—they are, however, useful in racing practice and provide a margin of safety over ordinary gear oils.

Extreme Pressure oils (known in the trade as E.P. oils) are not a necessity, and there are several modern mineral products, such as Shell Spirax, which are perfectly suitable.

Wheel bearings are best cared for by a suitable grease; it is important to select one which is not easily separated and which has a reasonably high melting point, otherwise there is some risk of the lubricant reaching the brake shoes and impairing their efficiency to a dangerous degree.

CHAPTER NINE

THE SELECTION & CARE OF SPARKING PLUGS

By Rex G. Mundy
Competition Manager of Messrs. K.L.G. Sparking Plugs, Ltd.

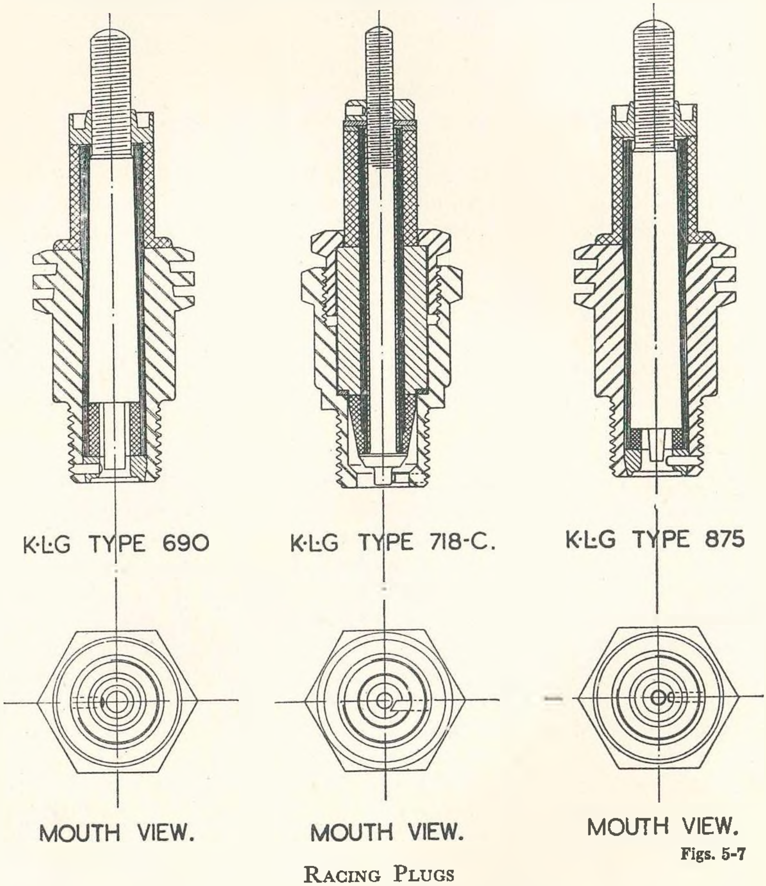
IN the old days sparking plugs had a comparatively easy time and were not given as much consideration by racing drivers as they are to-day. A set of sparking plugs removed from an engine will, if examined intelligently, reveal quite a lot of invaluable information. A note should be made showing from which cylinder each plug has been removed, or better still a small board should be drilled to accommodate one or two sets thick enough to hold the plugs firmly, but thin enough for an inspection to be made of the business end when held upside down.

After a little experience one may quite easily read whether distribution is correct, the carburettor or carburettors correctly adjusted, and whether the correct fuel is being employed under the conditions ruling. Should one plug be badly oiled in, say, No. 3 cylinder, a soft warming-up plug should be installed before fitting a new racing plug in order to burn all excessive oil from this particular combustion chamber. If this procedure is not followed, the new racing plug may oil up before the car gets under way with engine approaching maximum revolutions.

Should one cylinder persistently oil up its plug, a careful examination of valve clearances, magneto, and high-tension leads should be made, assuming of course that piston rings are in first-class condition and doing their job. Having checked the foregoing it may be necessary to use a different type of plug in one or more cylinders. This was done not many years ago in the unit of one of the world's most famous drivers, who won Britain's premier road race of that year; he actually used three different types of plugs in a 6-cylinder engine. In such circumstances a careful entry should be made in the car's log-book, for it is hopeless to expect anyone to remember a detail, although that detail is really of paramount importance.

The racing driver of to-day is well catered for by the plug manufacturers in the way of various types for particular engines. A comparatively low compression or atmospheric engine (*i.e.* unblown) will obviously generate a low internal gas heat compared with a higher ratio well boosted up. Illustration A shows a detachable type of racing plug which is actually used for racing in certain engines, but in the case of some super-efficient blown units it is their warming-up plug. Illustration B is one stage up in heat resistance, whereas C is at the top.

By careful examination it will be noticed that in the case of



Figs. 5-7

Racing Plugs

A. A comparatively "soft" plug. B. A cooler plug to withstand greater gas heat. C. The extreme of heat resistance.

C the mica insulating washers, which are situated directly inside the body, are very short, likewise the electrode exposed to the flame. The gas space is also small. The B plug, however, has a much longer insulating surface; a longer electrode exposed to the flame; also the gas space is much longer. Plug C therefore will in service keep very much cooler than plug B, and thus, by standing more internal gas heat, will more readily oil or soot up.

There are within this range three other types to select from, one most suited to each unit, for after all it is really a compromise, as a plug that stands most heat stands least oil, and that designed to withstand a lot of oil is useless in a very hot engine. While on this subject, it may be useful to explain that the temperature of the water in the radiator is no guide in the selection of plug type, as many people seem to imagine, but the internal gas heat in the combustion chamber is the deciding factor.

Many people seem to be of the opinion that a "soft" plug, that is one designed to withstand a lot of dirt but little heat, will enable the engine to start more readily than a racing type. This idea is entirely erroneous, for provided the plug is in first-class condition the engine will start no matter what the *type* of plug installed.

It is, however, always advisable to warm the engine up on a touring or "soft" type in order to obviate the possibility of sooting or oiling-up the racing plug. The touring plug will quickly get hot and burn any oil or soot that may come near to it, whereas the racing type will keep cool and allow oil or soot to deposit on the internal insulating surface, thus preventing the spark occurring between the points.

The gap setting with a racing engine is important, and it is advisable to keep the gap at between 0·12 and 0·0150 in. The cleaning of a non-detachable mica plug is extremely difficult, although a cure can sometimes be effected by pouring some ether into the mouth and shaking it up well. If the oil is really burnt into the plug, only the manufacturers can make a satisfactory job of it. A ceramic plug can, if not too badly oiled, be cleaned by a sand-blasting machine without fear of damage, but a mica insulated plug should not in any circumstances be subjected to such treatment. If ether or petrol does not effect a cure, it should be returned to the plug manufacturer for reconditioning.

The reach of a normal plug is approximately 12 mm., but in some cases, particularly where an alloy head is used in an air-cooled engine, an 18 mm. reach plug is usually employed. In some engines a baffle is left at the inner end of plug-hole in head, and the mouth of the plug then seats on this baffle with a copper, bronze, or aluminium solid washer. As it is impossible to cut the thread right down to the base of the head, the last few threads are removed from the plug and the face of the mouth slightly tapered in order to ensure a gas-tight seal.

When practising for a race it is always advisable to stop at the depot or pit by switching off and slipping the gear into neutral; in other words "cut clean." The plugs will then tell their story. It on the other hand the engine is allowed to idle, an oily or sooty deposit will be left on the mouth of the plug covering up the true condition while flat out.

It should be borne in mind that although a plug may spark outside the combustion chamber, that is under atmospheric pressure, before a definite decision can be made it is necessary to apply at least 100 lb. per sq. in. This, of course, can only be done in a special apparatus at the factory.

The 14 mm. diameter racing plug as issued nowadays is a very delicate part and should be treated during its life with the same care and trouble expended upon it during manufacture. When screwing these plugs into your engine, do not over-tighten. There is not only a very good chance of shearing the body at base of thread, but the end of the plug will be stretched, thus relieving the weight on the external insulating washers, resulting first in a gas leak, and finally a burnt-out plug.

Pit organization will doubtless be dealt with in a separate chapter, but I cannot too strenuously impress upon the racing driver how essential it is to give this matter his very careful study. When the old Bentleys were running at Le Mans, pit-work was undoubtedly excellent, but since then only one British driver has excelled in this respect. Nowadays it is left to the Germans, who are excellent organizers in motor racing. There is absolutely nothing overlooked, and it would pay a British driver to attend some races where the Germans are running, if only to study their pit management. The cars are warmed up on a soft touring type of plug which, when the engine is at a correct temperature, is removed. A plush-lined case containing the racing plugs is then produced with numbered compartments showing from which cylinder each plug has been removed during the former practice. Each plug is then carefully fitted to its appropriate cylinder and the engine is started up and the car immediately dispatched on its practice laps. The signal is in due course given for the car to come in, when the engine is cut clean. The plugs are removed, a careful examination being made of each and every one to ensure carburation, &c., is in order. The practice concluded, the racing plugs are finally replaced in the case under their correct number, and the soft plugs reinstalled in the engine to drive the car back to its lock-up. One mechanic is made responsible for the plugs, and such care is really essential if the best results are to be obtained, and incidentally money saved, for sparking plugs can be a very expensive item during a season's racing if the utmost care is not expended.

During the majority of the important International races, the plug manufacturers have a representative in attendance both during the practice and the race. Now it is useless to expect these people to give you of their best unless you tell them all you know concerning the engine. It is then their job to hear all kinds of confidential information, but you can very quickly learn from other competitors as to whom you can rely upon for advice. On one occasion a man came to me at the first race of the season and asked for some plugs for use in his engine, which he assured me was precisely the same as the previous season. I therefore advised him to continue on the same type as he had used with entire satisfaction in the last race of the previous season. After the race he was very cross with me because my plugs had let him down. I examined them and found that they were in a shocking state owing to excessive internal gas heat. Obviously the conditions had changed, and I asked him why he had not told me the compression ratio had been increased. The driver was furious and asked me who had told me, because it had to be secret owing to the handicap. After I explained to him that the plugs had told me, he swore me to secrecy and I gave him a more suitable type of plug. With these installed he went out and won the next race. This is an instance where the closest collaboration must exist between the driver and all the accessory people concerned.

Progress in manufacture is still going on, the latest idea being to make the body of Baronia metal where strength is maintained and heat conductivity assisted. In all such progress, however, it is only after protracted tests that a new design of plug can be released to the public. In some cases certain fuels attack certain metals, which, of course, has to be guarded against.

In conclusion, wherever you run into trouble do not, as one famous writer facetiously says, "If in doubt, blame the plugs," but on the contrary find out and eliminate the root cause of the overheating, oiling, or sooting.

CHAPTER TEN

TYRES FOR MOTOR RACING

By N. W. H. Freeman, A.I.A.E.
Racing Manager, The Dunlop Rubber Co.

MANY years of intensive research, wide, varied, and costly, have been necessary to produce tyres to stand up to the colossal speeds of to-day's record-breaking, track-, and road-racing cars.

The racing tyre is basically the same as an ordinary touring car type.

To outline the pneumatic principle and tyre construction.

A tyre involves a flexible air chamber (the tube) containing air at a pressure greater than that of the atmosphere; this is enclosed in an outer cover having a construction of cotton plies insulated with rubber and covered with rubber for adhesion, protection from water, road damage, &c.

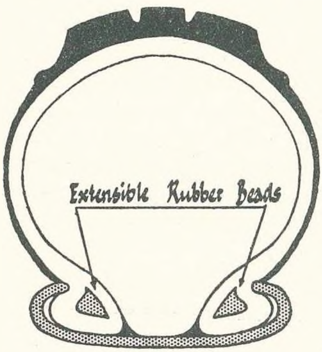
The progress which has been made and has resulted in the reliable article used on racing cars to-day, is the result of the development of knowledge which has mainly effected the materials, the design, and the method of constructing and assembling the various parts. Broadly, the main changes that have taken place, and are general to all tyres, including racing, are: method of attaching the tyres to the rim, the use of cord material instead of canvas for the casing, and the change from the use of very high pressures to medium pressures.

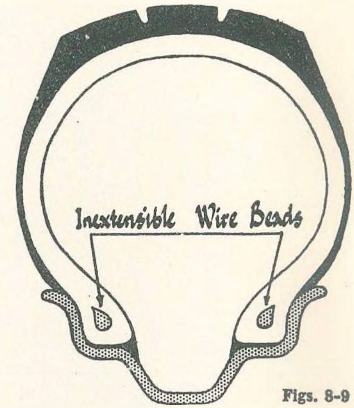
The more detailed problems connected with the design, construction, and use of racing tyres will be discussed later in this article.

Regarding the method of attachment of tyre to the rim. The earlier tyres were what is known as the Beaded Edge type; that is, the covers were manufactured with the edges having a flexible bead of fairly hard rubber, which, when the tyre was stretched over the rim, fitted into the "clinches." The retention of the cover beads in these clinches was mainly dependent upon air pressure. The disadvantage of this system was that, should a puncture occur, the tyre would come off the rim. On the Wired type now used, the cover edges are made of high-tensile wire and are inextensible. The tyre is therefore attached to its rim in a way that does not depend upon air pressure for retention on the rim, and being inextensible effectually prevents the tyre leaving the rim, as long as the rim itself is intact. It can be seen that the safety factor of a tyre is enormously increased—a very comforting thought for a racing driver.

The second development mentioned—the use of cord fabric—enables a casing to be made capable of withstanding flexing to a much greater degree, therefore allowing a lower inflation pressure to be used, and as the various layers of material and rubber are united more efficiently, there is not the chafing action of warp and weft threads, internal friction and heating is reduced and the subsequent tendency to disintegration.

The large-section medium-pressure tyre naturally followed on the adoption of cord casing, as the greater degree of flexibility permitted the use of correspondingly thinner casing, and





Figs. 8-9

BEADED EDGE TYRE AND RIM

WIRED EDGE TYRE ON WELL BASE RIM

with the employment of lower air pressure, gave greatly increased shock absorption. Also the larger tyre meant greater road contact area of tread, which helps braking power and road holding.

So much for the broad outline of general tyre development. Now for some considerations that affect the design, construction, and use of specialized tyres for racing.

There are two types of racing tyres—Track and Road, but each type is subdivided according to the car and conditions of use. In the Track class there are :—

(*a*) The ordinary track tyres for slow or medium-fast cars, or long-distance work at medium speed;
(*b*) Medium-distance tyres for higher speeds;
(*c*) Sprint tyres for high-speed short-distance work; and
(*d*) The very special tyres for Land Speed Record work.

In the Road Racing class there are only two types—Normal and Speed. The Road tyre having a definite tread pattern, necessitates a certain thickness of tread rubber, therefore it is restricted to the two types.

As speeds go above the normal range, as in racing and record-breaking, the effect of speed becomes a serious problem to the tyre designer. In the first place, the tyre has to stand up to vastly greater stresses. The dynamic stresses due to impact increase with speed, and in addition speed directly increases tread wear and the generation of heat, with consequent reduced performance.

Therefore, in designing racing tyres a number of main points

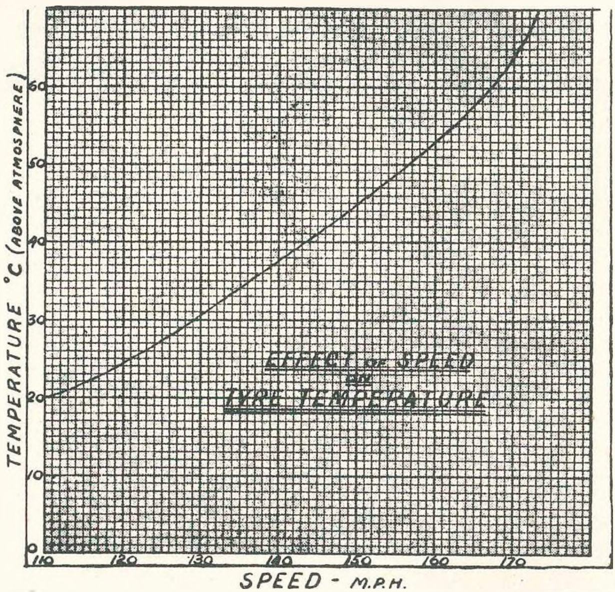


Fig. 10

have to be considered. Broadly they are as follows, but not necessarily in order of importance :—

(1) Tread life (Wearing qualities).
(2) Pattern (in the case of Road Racing tyres).
(3) Casing strength.
(4) Low power-consumption rubber compounds.

One of the chief problems with racing tyres is to prevent stripping of the tread. Heat is generated in all tyres to a certain extent, but due to the enormous number of revolutions per minute made by racing tyres, these naturally get a good deal hotter than a tyre used at a more moderate speed for touring. Excessive heat in a tyre means disintegration and rapid failure. When the strength of the under rubber is reduced by high

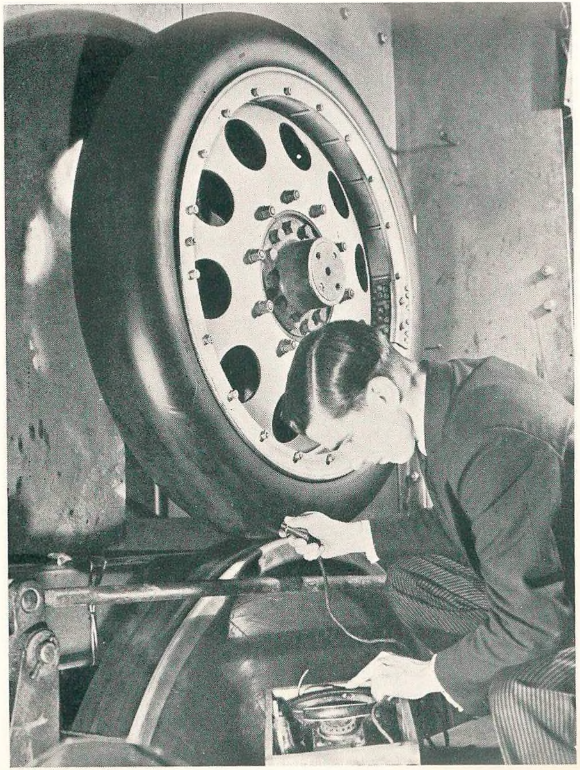


Plate 30.

[*Photographs* : " Dunlop."

THE PREPARATION OF HIGH-SPEED TYRES.

Left : TESTING A SPECIAL TYRE WHICH WILL BE USED FOR THE LAND-SPEED RECORD.

Right : THE WHEEL AND TYRE SPINNING AT HIGH SPEED DURING THE TEST.

temperature, looseness occurs, and at high speed the tread is torn away from the casing by centrifugal force. The problem then is to produce a tyre capable of attaining high speed without getting unduly hot; and as speeds are increasing daily, the problem becomes more acute.

Racing compounds therefore are designed to give the maximum heat resistance and the best conductivity (consistent with other properties) to get the heat away from inside the tyre.

The source of heat is the power consumed by the tyre and depends upon a number of factors, among which are:—

(1) Speed.
(2) Deflection of tyre.
(3) Size of tyre. (This is an important factor within the control of the racing motorist or car designer.)
(4) Construction of tyre.

The rate of increase of power consumed becomes greater and greater with increasing speed.

It is difficult to appreciate the magnitude of the forces operating to destroy a tyre in Land Speed Record attempts. At 357 m.p.h. the 7·00 × 31 tyre, as used by Eyston, makes about 2700 revolutions per minute, or 45 per second. The flexing and pounding on the ground at this speed generates heat with extreme rapidity and reduces tyre life in this particular instance to a matter of minutes.

The wheel revolution of 2700 r.p.m. causes a stress in the wire coil of each bead of 12 tons, due to centrifugal force acting on the mass of the cover, which is supported by the bead wire. The total force actually *all round* the cover, tending to break it from the bead, is about 120 tons.

In a similar way, the material of the casing is also acted upon by centrifugal force in proportion to its mass. These forces, which tend to break the cords in the region of the bead, are in proportion to the square of the speed.

Of course, 357 m.p.h. is not achieved by every racing driver, but with smaller tyre equipment, say a 6·50 × 19 tyre at a speed of 150 m.p.h., which is reached by many cars to-day, the tyre is revolving at 1590 r.p.m., that is 26 revolutions per second. This means that every portion of the tyre is alternately compressed and released twenty-six times per second. By this it can be readily seen that temperature is generated rapidly and should bring home to a driver what his tyres have to stand.

Tests of racing tyres are made on a special high-speed testing machine. On this, a driven tyre revolved on a perfectly balanced fly-wheel, which can be raised or lowered by a motor-actuated beam to give any desired load. By this machine valuable tests can be carried out, with load, inflation pressure, speed, &c., accurately controlled.

This machine is only particularly useful for comparative tests in the laboratory. Under racing conditions a tyre of exactly the same process may behave in an entirely different way, on various makes of car, or on different circuits that may involve higher speed and faster cornering. Likewise driving methods vary, which all have a definite bearing on the behaviour of a tyre.

The deflection of a tyre depends upon load and inflation pressure. This is a vital point and, together with size of tyre, merits the serious consideration of every racing driver. The effect of reducing the inflation pressure from, say, 50 lb. to

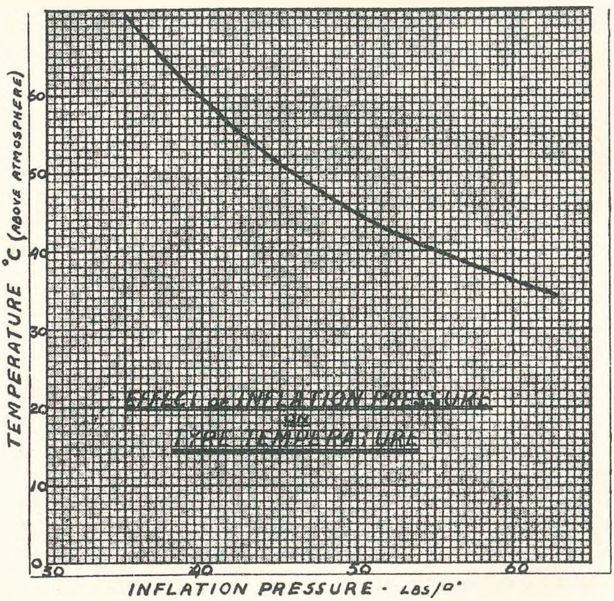


Fig. 11

40 lb. per sq. in., the load being the same in each case, would mean at high speeds an increase of temperature, and thus power consumed to the same extent as extra miles per hour at the higher pressure.

As regards temperature: at certain speeds a steady temperature and power consumption is maintained, but, as the speed increases, the curve shoots upwards and would ultimately lead to tyre failure.

There are distinctly improved results to be obtained by increasing the tyre diameter, even if the section is unaltered, but with both increased, still greater improvement results. This cannot be too greatly stressed to drivers and designers.

The size of tyre affects its performance. Firstly, the larger the diameter, the fewer the revolutions per minute and the fewer the impacts any section of the tyre has to sustain for a given speed, consequently the lower the temperature attained. Secondly, the greater the diameter and cross-section, the smaller the deflection and the larger the mass of material to be heated up; therefore, for a given load, the lower the temperature developed. Further, the larger the section in reason, the greater the tread contact with the ground, which, besides giving better road holding, reduces the intensity of pressure on the tread, which in turn distributes the work over a larger area, thus helping to keep down temperature. Unless an adequate diameter and section of tyre is used with correct inflation pressure to keep tyre temperature within reasonable limits and prevent weakening of under rubbers, as mentioned before, centrifugal force will tend to strip the tread from the casing.

Centrifugal force, which of course is always working in a revolving tyre, is a serious factor to be considered. As before mentioned, this stress increases with the square of the speed and in high-speed race tyres becomes the major stress in the tyre. At 200 m.p.h., which is now the speed of the faster road-racing cars, centrifugal force on every ounce of tread rubber is 134 lb., and on every pound, nearly a ton.

The effect of racing-tyre construction is of course a very wide subject, and for obvious reasons cannot be intimately discussed. It involves casing construction; the bias angle of the cord fabric has a marked bearing on the bogey of tread stripping owing to its control of casing deflection.

During the case building, the beads, which in racing tyres arc high-tensile 150-ton steel wires, are fixed so that the material is under and over to anchor them in position. The bending under load and distortion of the tyre at speed, tends to cause separation of the various layers, thus necessitating very careful design.

After the raw cover has been built up comes the important process of vulcanization. Much time and thought has been given to the determination of the most suitable construction and rubber compound for race covers, but unless the "cure" given to the tyre is that which develops the best physical characteristics in the compound, all that is more or less wasted. Tyres are vulcanized in an autoclave at high temperature for a certain period, both temperature and time being under careful and accurate control. There is a very appreciable change in both the strength and the extensibility of some of the compounds, both under and over cure, leading to a very considerable reduction of strength and an increase in extensibility. Therefore the most suitable "cure" must be given to each type of cover, since the degree of vulcanization of the under rubbers is partly dependent upon the tread quality, thickness, &c.

Compounds for tread, under rubbers, and insulation, of course, are of primary importance. Tread life or wear is one of many problems; apart from sheer speed, the compound and thickness largely determine the life of a tread. There are limitations to the thickness of tread that can be used owing to temperature difficulties. A compound has to be used having a good abrasion value, but with a low power loss. The best mixing for touring speeds is not necessarily the best for racing.

In an investigation into the abrasion of various tread rubbers, it has been proved that "slip" between the rubber and the abrasive track is an important factor. The rate of abrasion increased rapidly with the amount of "slip." It is very evident that the tyres of a racing car, particularly the rears, have to endure a great deal of "slip." At the commencement of a race alone, the power transmitted to the rear wheels when the engine is revved up and the clutch engaged, causes wheel spin for a distance until the tyres settle down to their grip. In that time an appreciable amount of rubber is rasped off the tread. Again, any irregularity in the track or road, causing the tyre to leave the ground momentarily, causes tremendous wheel spin, and when the tyre makes contact again, the abrasion is severe.

A racing tyre has comparatively hard rubber and therefore is not suitable for touring purposes where necessarily lower pressure would be used than for racing, and cracking would probably take place. Also the ageing qualities of a racing tyre are not good, and an old tyre should not be used for high-speed work. At one time it was generally thought by drivers that a racing tyre a day or two old was unsafe—that the rubber had to mature—that myth is definitely exploded.

Weather has a considerable influence on tread life. Wet weather slows down the rate of abrasion considerably. On ordinary touring car tyres, dry summer wear is approximately two or three times that of winter wear, while with racing tyres, wear on a wet track or road is approximately one-third of that in dry conditions. On the other hand, tread cutting and puncturing is more frequent under wet conditions. The tread pattern of a road-racing tyre is most important. It should have good fore-and-aft grip and side grip which is involved in cornering. From a road-holding point of view it is important to have a tyre-tread pattern which remains as constant as possible in non-skid value throughout the life of the tread.

Cotton as the basis of a tyre, that is the casing, has to undergo careful and exhaustive tests to obtain information as to its suitability for racing tyres. The cords have to have the valuable properties of high resistance to fatigue combined with flexibility.

A racing tyre demands a cord fabric of the greatest uniformity in construction and the highest degree of elasticity.

So much for the general outline of tyre development, design, construction, and facts concerning its characteristics.

From the foregoing it is hoped that enough has been said of the complexity of the problem of racing tyre design to show that co-operation between racing drivers and the racing service of the tyre manufacturers is essential for mutually best results.

To summarize a few points:—

(1) Use the largest diameter and section of tyre possible; alter your gear ratio rather than use an unsuitable size.

(2) Use the correct and recommended pressure. Do not penalize the tyre by using it to damp out all vibrations, and provide all cushioning because of indifferent suspension and shock-absorbers.

(3) Use the widest rim that the tyre will correctly fit. Particularly for road racing, lateral stability is improved and prevents undue deformation when cornering.

(4) It is important that wheels be kept in correct alignment. The shocks and blows received by the front axle and wheel assembly during racing may produce misalignment. If the wheels are out of alignment, it is clear that the tyres will be subjected to excessive abrasion which will grind off the tyre treads.

(5) Do not use very old tyres. A tread may look good enough, but rubber ages and cotton fatigues, especially in racing tyres.

(6) Whenever possible, allow the racing service of the tyre company to fit your tyres. While this operation is much the same as for a normal tyre, it is more difficult owing to the close tolerances of tyre and rim. Very small bites of the tyre lever have to be taken to prevent bead damage and distortion.

(7) A racing tyre is generally in fair balance, but when mounted the whole unit of tyre and wheel should be carefully balanced by driver or mechanic. This refers particularly to front wheel equipment.

(8) Show as much respect as possible and compatible with racing when accelerating, braking, and cornering.

CHAPTER ELEVEN

AUTOMOBILE BRAKING

By Capt. J. B. Irving, M.I.A.E., M.I.Mech.E., A.F.R.Ae.S.
Chief Designer, Bendix Ltd. Formerly of The Sunbeam Co.

IT is not intended that this article shall be a historical record but rather a clear exposition of the subject based on the experience of yesterday and to-day so that the performances of to-morrow may be of a higher standard.

To obtain this desirable advance it is necessary that the designer and user shall have a very clear idea of the problems to be faced, and it is therefore proposed to devote some little space to the theory of braking as applied chiefly to fast automobiles.

It can be accepted that from the performance point of view the brakes are at least as important as the engine, and it is necessary that their development shall proceed accordingly.

Theory of Automobile Braking

The car can only be retarded by the adhesion between the tyres and the road, and if we accept for the moment that this adhesion cannot be higher than unity, then the maximum rate of deceleration cannot exceed the force of gravity, and to obtain this standard it is necessary that the retarding effort of each wheel shall exactly balance the weight it is supporting at the moment.

When all wheels are braked in direct proportion to their effective weight, the total weight of the vehicle, whether it be an Austin 7 or a 56-seater bus, does not affect the rate of deceleration, and both vehicles can stop in the same time and distance.

The question of distribution of braking load should be explained here.

If the C.G. of a vehicle were on the road surface, no change in rear and front axle weights would occur, but as this is impossible, the load on the rear axle is reduced and the front axle load increased in proportion to the height of the C.G. to the wheelbase of the car, and this transfer of weight is proportional to the rate of deceleration.

Fig. 12 illustrates this fact as applied to three cars which are typical: A, 25 h.p. Saloon, B, 12 h.p. Saloon, C, 7/8 h.p. Saloon.

In each case the static rear axle weight is assumed to be 55 per cent of the total weight.

At a deceleration equal to Gravity (a stopping distance of 30 ft. from 30 m.p.h.) the effective rear axle weights change from 55 per cent to A = 30 per cent, B = 26·5 per cent, C = 21·7 per cent.

With car C the rear wheels would lose contact with the ground, *i.e.* overturn at a deceleration of 1·65 gravity equal to a stopping

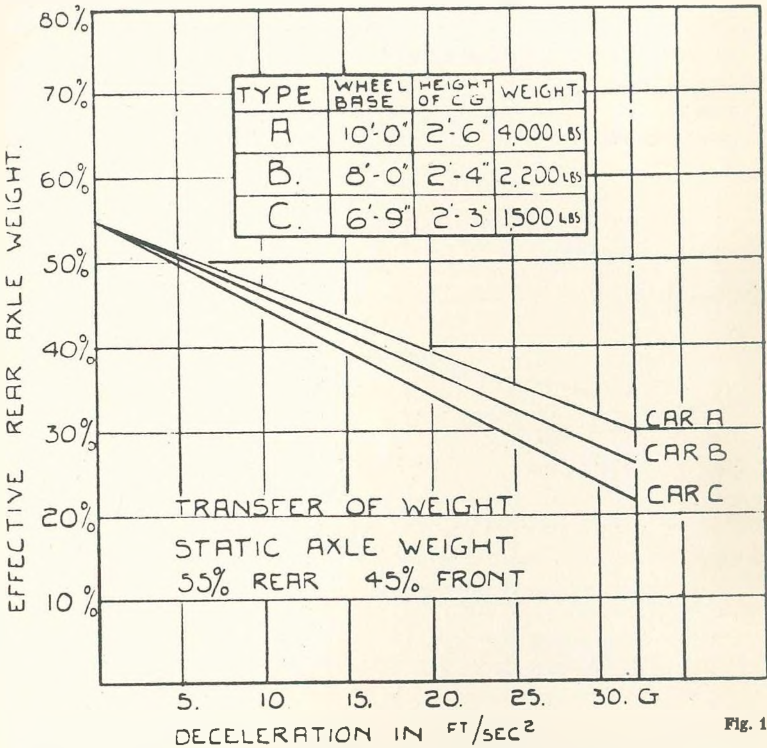


Fig. 12

GRAPH SHOWING HOW THE WEIGHT OF A CAR IS TRANSFERRED FROM THE BACK WHEELS TO THE FRONT DURING BRAKING

distance of 18·2 ft. from 30 m.p.h., but this would require an adhesion factor of 1·65 between the front tyres and the ground.

To obtain the maximum rate of deceleration it is necessary that the braking torque shall be equal to the wheel adhesion, so it is obvious that to obtain a deceleration equal to gravity the fore-and-aft braking proportions must be on car A = 70%/30%, car B = 73·5%/26·5%, and car C = 78·3%/21·7%.

The above ratios are only correct with a ground adhesion equal to unity, and at the normal adhesion factor of 0·7 the front wheels would skid at 19 ft./sec.² (0·6 of Gravity).

These ratios would obviously cause undue stresses at the front end, unequal brake wear, and general instability during normal driving conditions, during which the rate of deceleration rarely exceeds 0·5 of Gravity. It is therefore the modern custom to use fore-and-aft ratios of between 55%/45% and 60%/40%, in which case the rear wheels will always skid first. Fig. 13 illustrates this point. Using a ratio of 60/40 it will be seen that the rear wheels will slide at a deceleration rate of 25 ft./sec.²

These conditions have been accepted as a compromise, but the demand for safe and sure braking of a high order is causing attention to be directed to what has been termed Differential Braking.

Speaking generally it can be accepted that it is desirable to

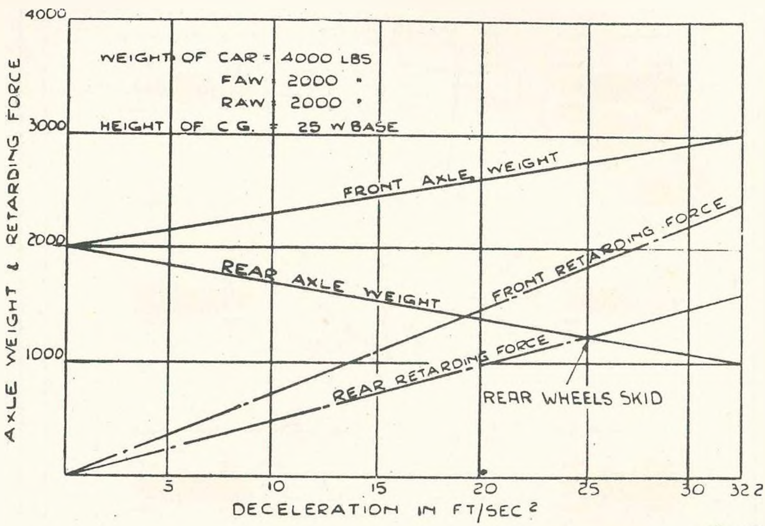


Fig. 18

restrict the braking forces on the front wheels to a minimum for all normal conditions; this relieves the steering, front axle, and springs of considerable stresses and adds to the general stability of the car.

The maximum rate of deceleration possible by using the rear brakes only is in the region of 0·4 G. on the average car under favourable conditions and is generally about 10 ft./sec.². 90 per cent of the normal braking requires decelerations of very little above 0·5 G. (16 ft./sec.²), and to obtain the desirable features of equal wear, minimum front wheel braking, and greatest stability, a fore-and-aft ratio of 50/50 will give the best results for 90 per cent of brake applications, but unfortunately the remaining 10 per cent can be regarded as "emergency braking" and has to be considered most seriously.

Safe emergency braking depends entirely upon satisfactory wheel adhesion, and it has been shown that this can only be obtained by so proportioning the braking torque that each wheel is doing its true share of the whole.

Since the introduction of front wheel brakes there has been considerable apprehension regarding the skidding of the front or steering wheels. To skid any wheels, front or rear, creates a

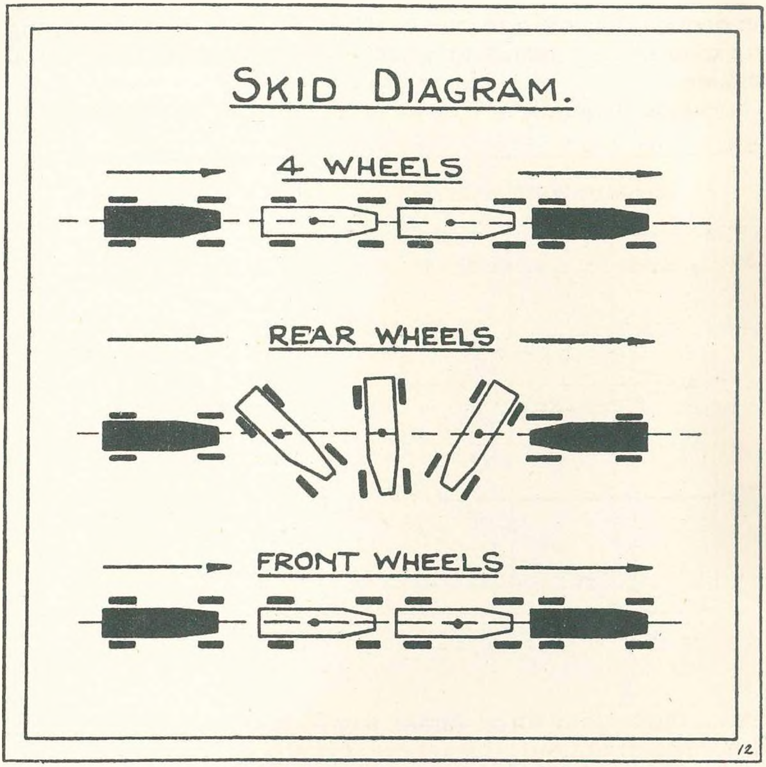


Fig. 14

dangerous condition, but it is possible to prove that a front wheel skid is less dangerous than a rear wheel skid. See Fig. 14.

If it be assumed that the proportions of braking effort on front and rear wheels is in accordance with their effective weight when decelerating, all four wheels should skid together when the rate of deceleration is equal to Gravity.

If all four wheels are skidding, the car will keep a perfectly straight course. If the proportion of braking is such that the rear wheels skid first, there will be a violent tendency for the car to swing round and this has to be checked by steering "into the skid." If the car is not checked and there is sufficient room, the car will turn round until the locked wheels are leading and then continue in a straight line. It will be appreciated that considerable room laterally is required either to correct the skid or allow it to continue to its natural finish.

If the front wheels skid first the car will continue in a perfectly straight line.

When emergency braking is called for there is rarely room for the antics following a rear wheel skid.

The foregoing will indicate that ideal deceleration could be obtained with a true differential braking system in which the

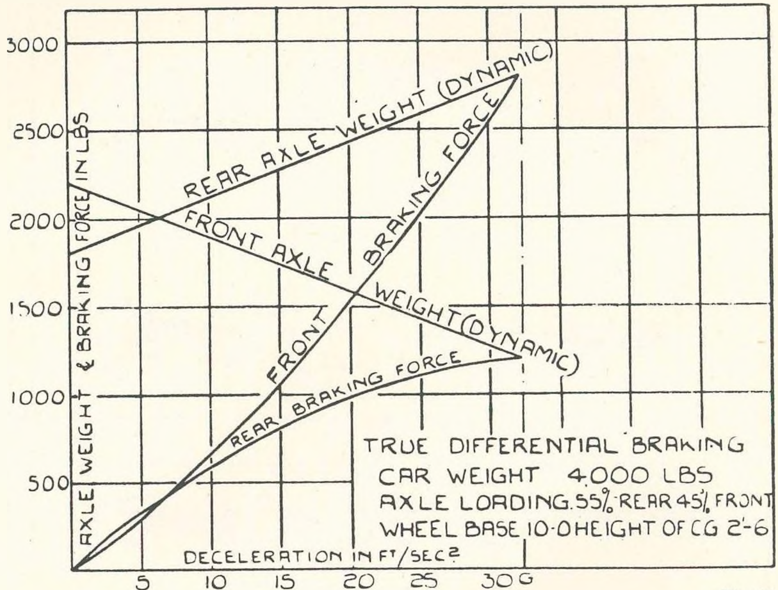


Fig. 15

True Differential Braking

proportion of the braking torque on the two axles started equal with the static weights and varied precisely with the change in effective weights caused by the rate of deceleration.

Fig. 15 shows car A fitted with a close approximation to this ideal.

If such a system be used it must be appreciated that it is only correct for one condition of car weight, and any variation of the number of passengers, &c., would cause a departure from the ideal, also, owing to the continual variation of fore-and-aft torques, the lining wear would be unequal.

Here again a compromise is desirable and it is suggested that this should consist of arranging the brake hook-up so that for

90 per cent of the braking the fore-and-aft ratio should be 50/50, and this should hold good for all decelerations below 0·5 G. Above that point, the required increase of braking

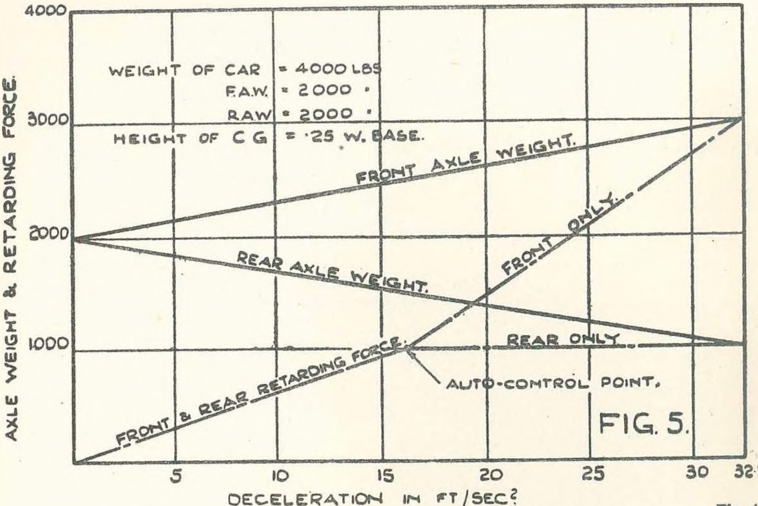


Fig. 16

Distribution of Ultimate Braking Forces

torque should be obtained from the front brakes only. See Fig. 16.

If the maximum torque on the rear brakes is adjusted so that it is equal to the effective rear axle weight at the maximum rate

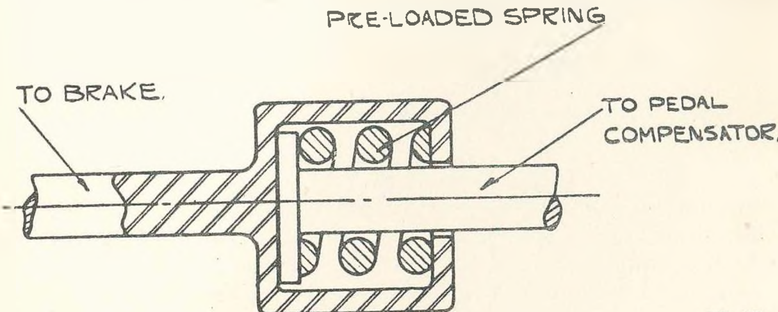
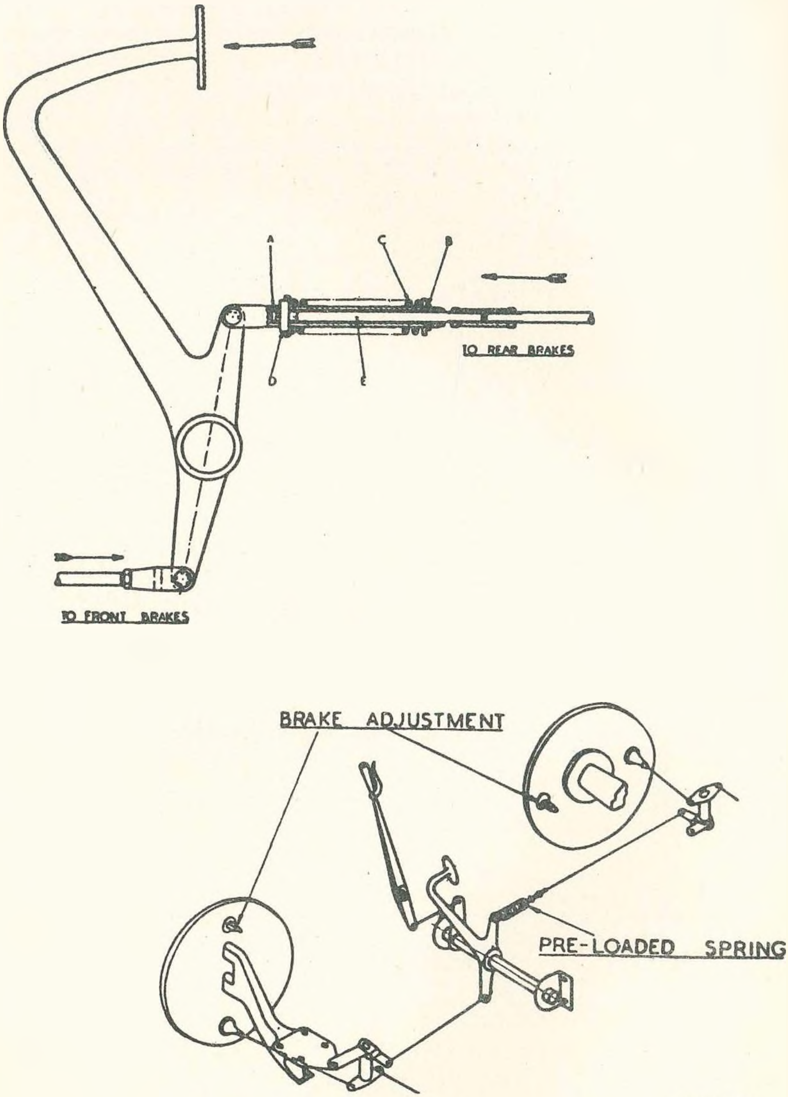


Fig. 17

of deceleration (see Fig. 1), the increase of front brake torque would approximate to the increasing rate of deceleration.

It is proposed to describe briefly two methods of obtaining differential braking.

Many years ago the Rudge Whitworth Co. patented the introduction of a preloaded spring (see Figs. 17-19) in the rod to the rear brake. The preload on this spring is such that the rear wheels are just "not skidding" under maximum decelera-



Figs. 18-19

tion. Up to this "preload" point the fore-and-aft braking torque is equal, and equal wear and maximum stability is obtained.

The disadvantages of this system are that the results are affected considerably by any variation in the rate of the spring and that compensation between front and rear brakes cannot be used.

Another method recently developed by the Bendix Brake

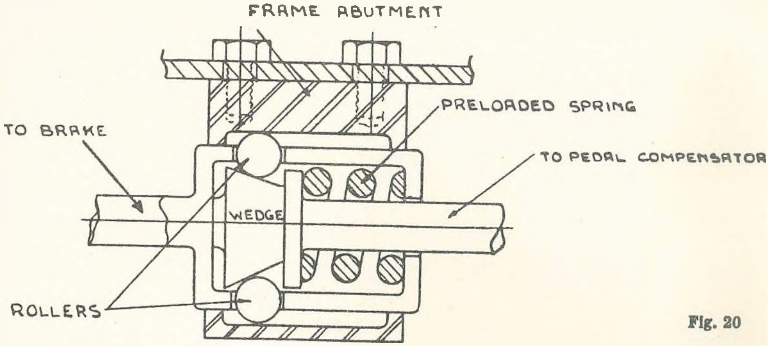


Fig. 20

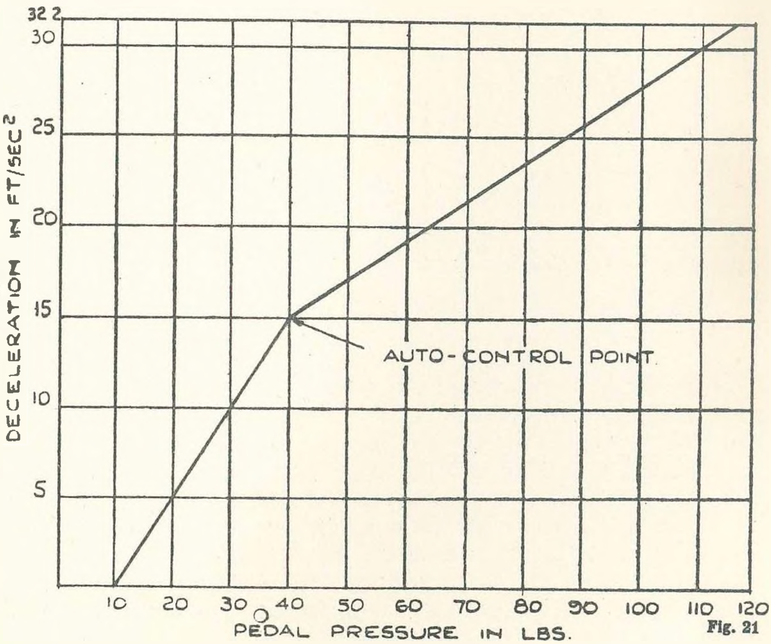


Fig. 21

Auto Control

Company is illustrated in Figs. 20, 21, and 22 and called the "Auto Control."

This device definitely limits the torque of the rear brakes and enables fore-and-aft compensation to be used.

The wedge is connected to the rod from the fore-and-aft compensator and is held against the sleeve by a preloaded spring in such a position that the sleeve is free in the fixed housing. The sleeve is connected to the brake rod.

While the pull from the pedal is less than the "preload" of the spring the whole unit is free to slide in the fixed housing, but when this is exceeded the spring compresses further and the wedge causes the rollers to lock against the fixed housing and prevents any further pedal effort being transmitted to the rear brakes.

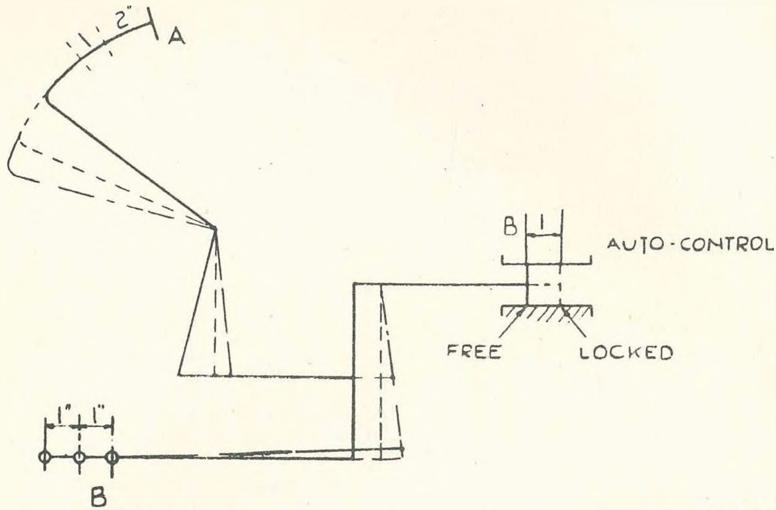


Fig. 22

It will be appreciated that when this device comes into operation three things happen:—

(1) No further effort can be applied to the rear brakes.
(2) All further effort is divided between the front brakes and the rear frame abutment so that there is a definite alteration in the shape of the deceleration curve. See Fig. 25.
(3) The pedal travel is halved. See Fig. 22.

This last feature is a precaution against fouling the floorboards during an emergency application, particularly if the brakes are worn.

The advantages of this system compared with the preloaded spring system are that the rear brake torque is definitely and easily limited and is entirely independent of the spring rate, and the droop in the deceleration curve is a definite advantage as it enables the braking to be more readily controlled during emergency conditions.

Immense forces are involved during deceleration; all moving bodies possess kinetic energy which must be dissipated when bringing them to rest. With a car it is only possible to do this by converting this energy into heat by means of the brakes. Fig. 23 graphically illustrates the amount of energy (transformed

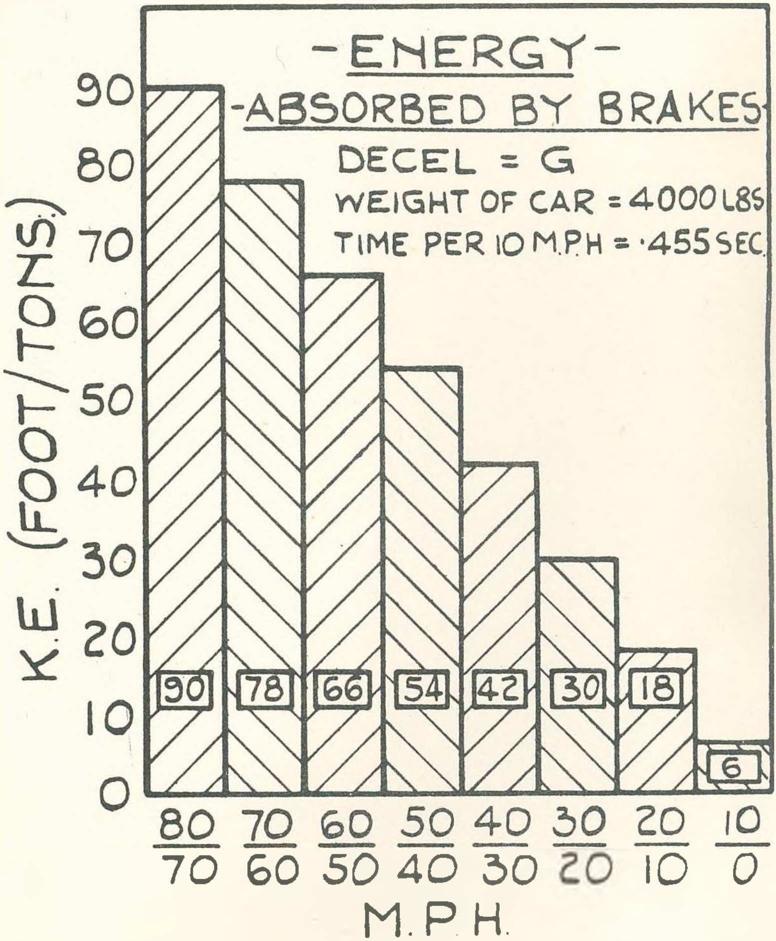


Fig. 23

into heat) which is absorbed by the brakes in decelerating a car weighing 4000 lb. from a speed of 90 m.p.h.

It must be noted that the Kinetic Energy varies as the square of the speed, *i.e.* at double the speed it is four times as great; the 4000 lb. car at 60 m.p.h. would deliver a blow equivalent to falling off a building 128 ft. high. See Fig. 24.

On the Sunbeam car which raised the World's Speed Record from 166 to 203 m.p.h. cast-iron brake linings were used, and owing to the speed attempts also including the Five-Kilometre Record and the stopping distance being shortened, the brakes were used more severely than was originally intended. The heat generated was sufficient partially to melt the aluminium shoes, due of course to the comparatively high heat conductivity of

Fig. 24

THE KINETIC ENERGY OF A 4000-LB. CAR TRAVELLING AT 60 M.P.H. EQUALS THAT OF THE SAME VEHICLE FALLING FROM A BUILDING 128 FEET HIGH

the cast-iron linings; if asbestos linings had been used, this effect would have been less marked.

To obtain a deceleration equal to Gravity (30 ft. from 30 m.p.h.) the retardation at the tyres must equal the weight of the car; assuming the car weighs 4000 lb., is fitted with 30 in. diameter tyres and 10 in. diameter brakes, the retardation effort at the drums will be 12,000 lb. ($4000 \times 30/10$).

From 30 m.p.h. this force will be exerted for 1·365 sec.

The pressure on the lining surface will be equal to the total effort multiplied by the coefficient of friction of the linings; assuming this to be 0·33, the total pressure between the lining and the drum will be 36,500 lb., over nine times the weight of the car.

With the old-fashioned two-shoe brake with fixed cam actuation the required pedal pressure would be prohibitive, and if a

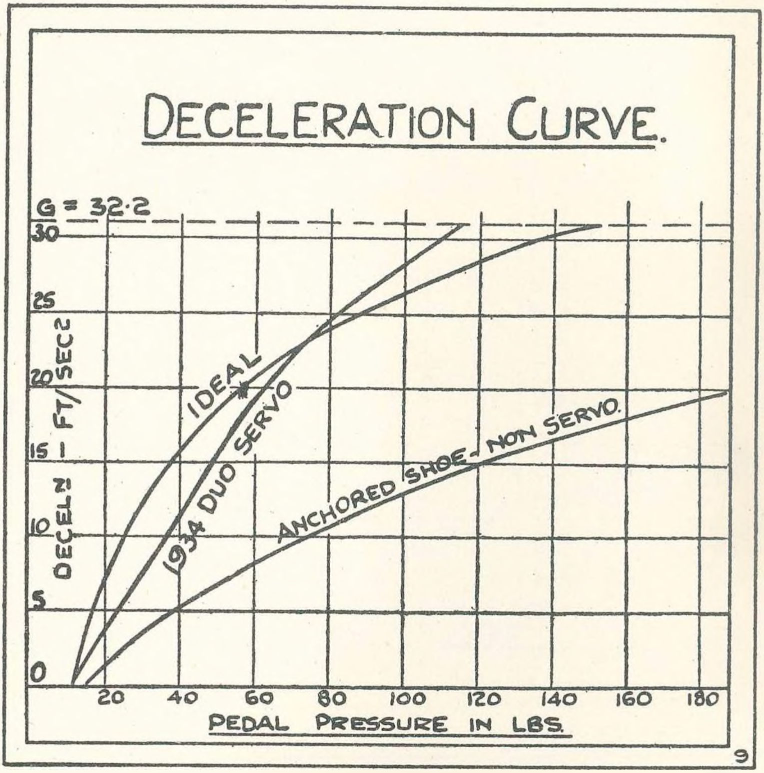


Fig. 25

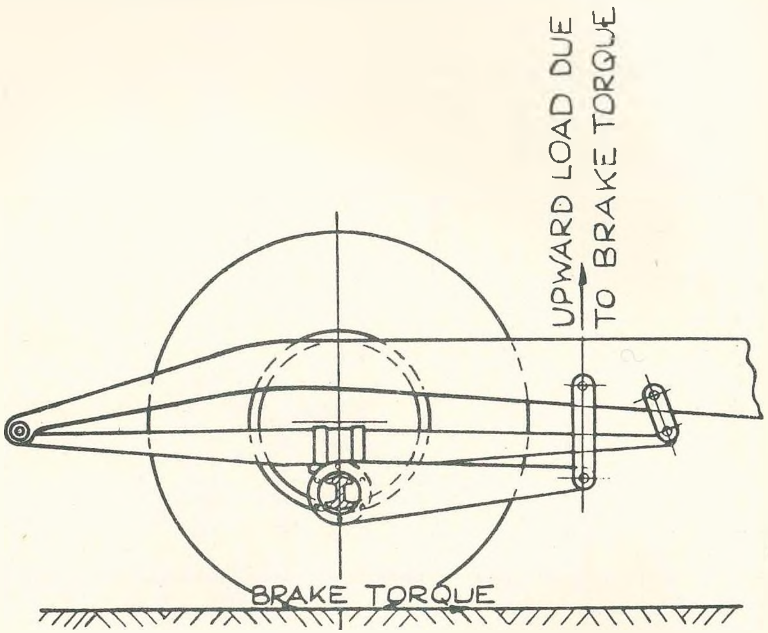
BRAKE PEDAL PRESSURE

servo boost is used the stresses on the brake hook-up are excessive and so the brakes required for modern standards must necessarily have some self-energizing or inherent servo action which will increase their power as brakes and reduce the pedal pressure required.

Under modern conditions a pedal pressure exceeding 150 lb. should not be considered, and even this figure is very tiring; there is no reason why the pedal pressure should exceed 50 lb. for a rate of deceleration of 0·5 G., with a pressure of 20 lb. for a rate of deceleration of 7 ft. per sec. per sec. (0·155 G.).

To take full advantage of the maximum braking power now available with modern brakes it is absolutely necessary that the car itself should be designed to remain stable when the great braking strains are imposed, and this requires accurate location of both axles, correct steering geometry, and the entire relief of the road springs of all braking stresses.

The axle radius arms (see Fig. 26) should be so disposed that the braking torque tends to balance the transfer of weight caused



FRONT AXLE TORQUE ARM

Fig. 26

by the deceleration and to prevent any twisting of the axle which would cause instability by altering the castor angle and seriously effect the steering geometry (see Fig. 27).

If all these requirements are met decelerations equal to Gravity (32·2 ft./sec.^{2}) can be obtained on dry roads without serious danger or discomfort.

Types of Brakes

For modern automobile installations the types of brake available can be divided into four classes:—

(1) Conventional Two Shoe with fixed camshaft.
(2) Conventional Two Shoe with floating camshaft.
(3) Servo (Self-energizing) brakes.
(4) Two Leading Shoe brakes.

Class 1 has only the advantage of even lining wear, and this entails a very considerable sacrifice of power in the brake itself and therefore very high pedal pressures or alternatively a

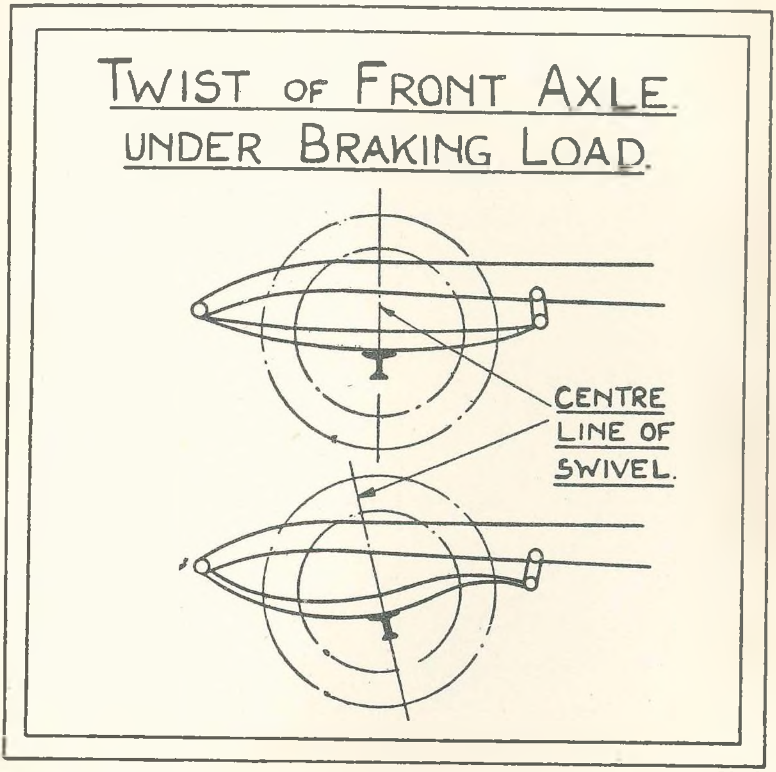


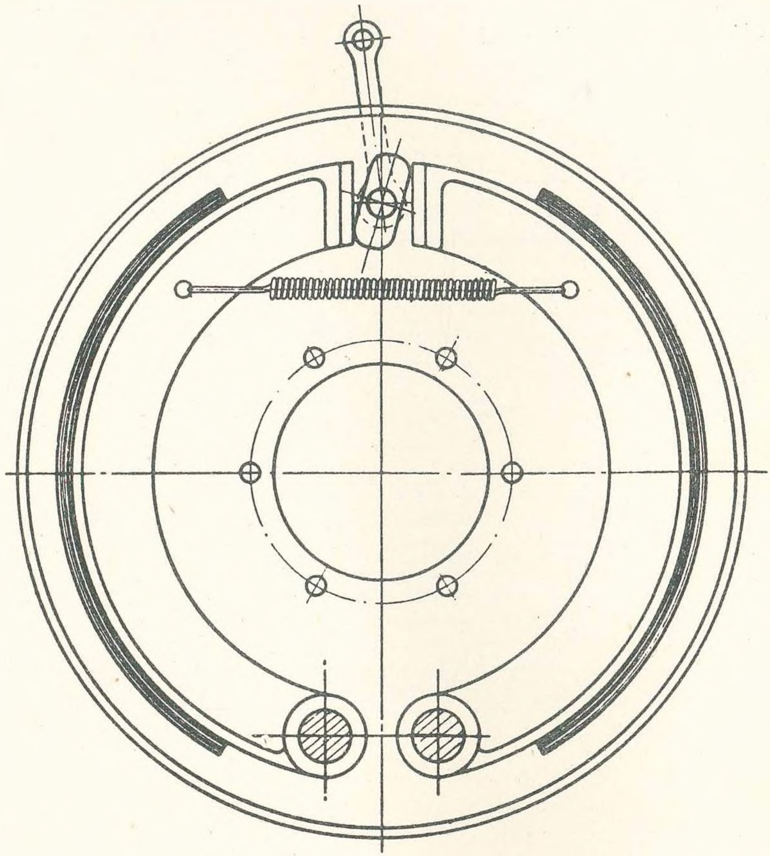
Fig. 27

powerful external boosting system, either of which impose considerable stresses on the chassis hook-up and, in the case of the boost, increased weight, cost, and complications. For these reasons this type of brake has been practically superseded by classes 2 and 3.

Class 2 consists of a brake similar to Class 1, but owing to the camshaft being "floating" the leading shoe is free to exercise its inherent self-energizing feature. This enables more powerful braking to be obtained at the expense of increased lining wear on the leading shoes.

This class of brake includes hydraulic actuated brakes with internal cylinders.

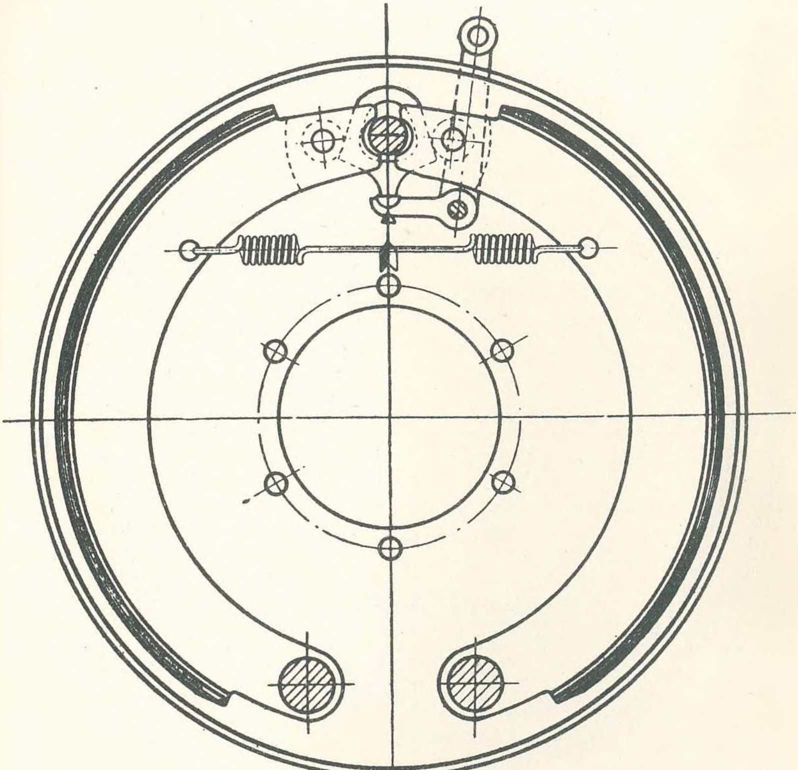
The torque available from this class of brake is approximately 50 per cent greater than that obtainable from Class 1 brakes, with proportionately lower stresses in the hook-up.



NON-SERVO (FIXED CAMSHAFT) Fig. 28

Class 3. Servo brakes are a development of the original Servo brake invented by Perrot and are the most powerful brakes available at the moment. This increased power is obtained by anchoring the heel of the leading or primary shoe to the toe of the secondary shoe so that the torque of the primary shoe is applied to the secondary shoe, which is pivotally anchored to the fixed backing plate. With linings of equal coefficient of friction the power of this brake is three times that of Class 2 and four and a half times greater than brakes in Class 1.

The disadvantages are that two-thirds of the torque is supplied by the secondary shoe and the wear is proportionate and that the output of this brake varies as the square of the coefficient of friction of the linings; it is therefore necessary to use brake linings with a lower coefficient of friction than with the



NON-SERVO FLOATING CAM, FORD.

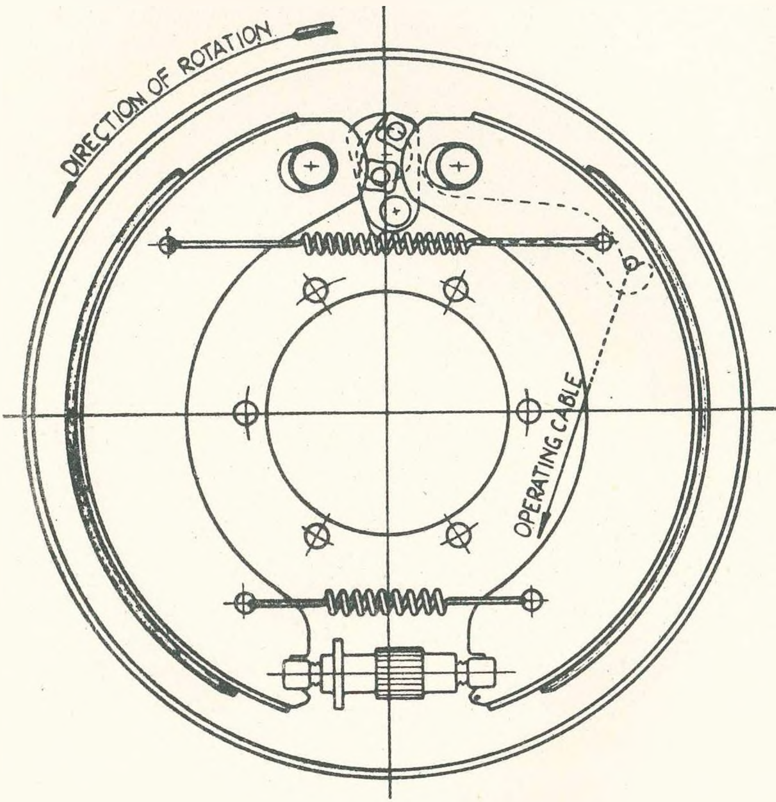
Fig. 29

non-Servo brakes so that, on the brakes generally used, the maximum torque available is approximately twice that of Class 2 brakes. This brake is also less progressive.

By many users its power advantage with decreased weight, &c., is held more than to balance its disadvantages.

Class 4. Two Leading Shoe. This is a comparatively new development; its outstanding advantages have been well known to automobile engineers, but it is only recently that this brake has been developed into a commercial possibility.

From a consideration of brakes under Class 2, it will be realized that approximately two-thirds of the torque is obtained from the leading shoe, and the "two leading shoe" brake design consists of so arranging the actuating mechanism that both shoes act as leading shoes and therefore the torque capacity is increased proportionately, even lining wear is obtained, more even

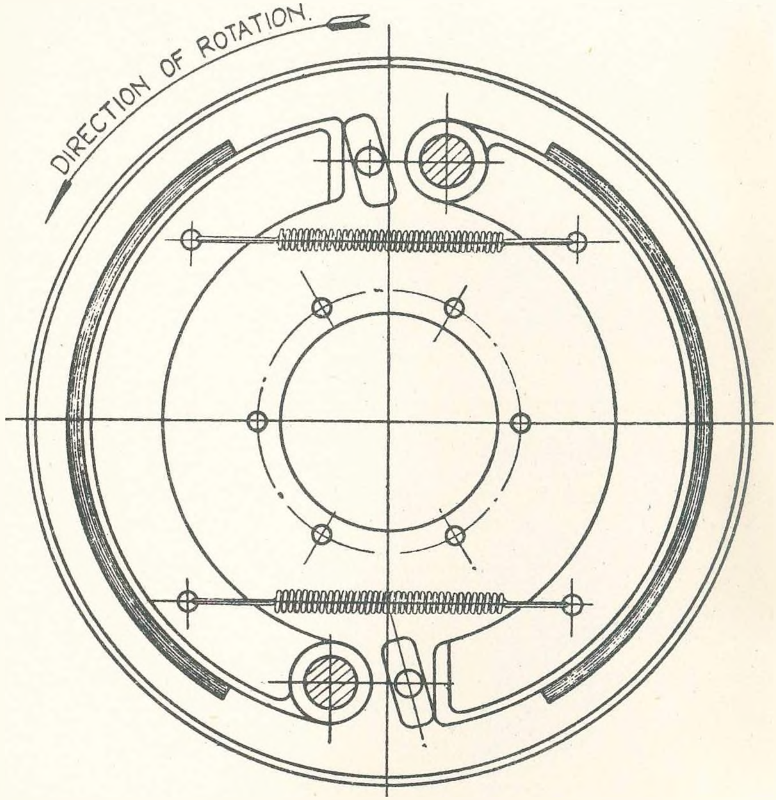


SERVO BRAKE.

Fig. 30

distribution of the load over the whole lining area, and absence of high local loading with consequent reduction of temperature and reduced fade and wear. Also the fundamental advantage of a non-Servo brake, *i.e.* progressive action, and the torque varying directly with the coefficient of friction are retained.

It is interesting to note that this type of brake was used on the Mercedes and Auto-Union racing cars of 1936–37 and is used on the present E.R.A. cars. The separate actuation of each shoe being obtained by using a hydraulic cylinder for each, these particular brakes are only "two leading shoe" in a forward direction and comparatively inefficient in reverse and it is necessary to have a separate adjustment for each shoe; for racing cars this is satisfactory, but it would not be acceptable for the normal cars; but leading shoe brakes are available without



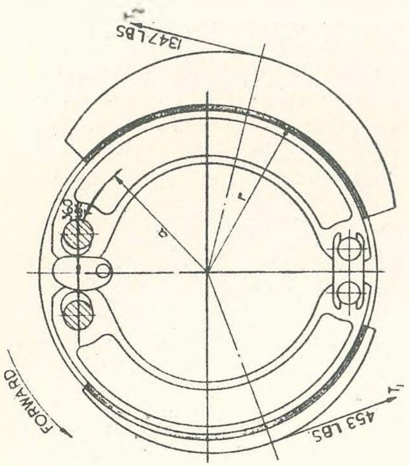
TWO LEADING SHOE. NON-SERVO.

Fig. 31

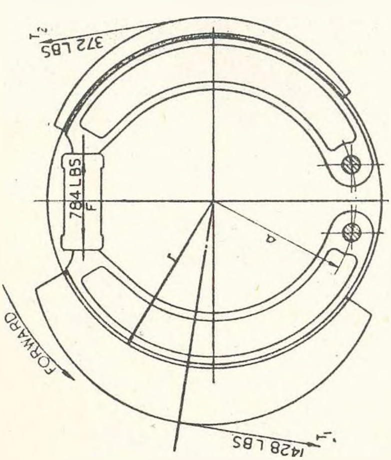
these disadvantages. Fig. 35 shows the comparative torque capacity of these four classes of brakes.

Details of Design: Brake Drums

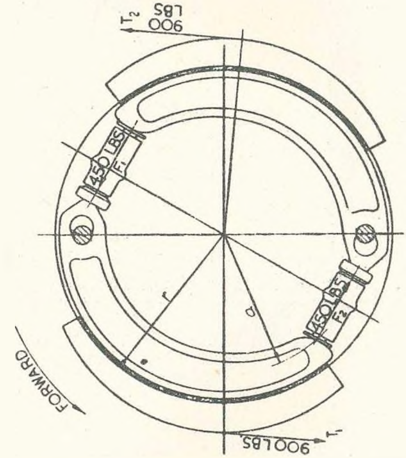
The increased requirements of modern braking necessitate attention to this much-neglected detail; a little thought devoted to the tremendous amount of heat to be dissipated and the pressure involved will indicate that the drum of the "washing-up bowl" type is quite inadequate.



SERVO BRAKE.
EFFECTIVENESS = 5.



NON-SERVO BRAKE.
EFFECTIVENESS = 2·3



TWO LEADING SHOE BRAKE.
EFFECTIVENESS = 4.

Figs. 32-34

The drum design must include cooling fins of correct thermodynamical design, materials must be studied from a heat transference point of view and provision made for an adequate air flow if optimum results are to be obtained.

The finest material for a braking surface is undoubtedly alloy cast iron, which must be tough and resistant to wear. The use of a cast drum enables circumferential cooling fins to be placed in the most efficient position for heat dissipation and strengthen-

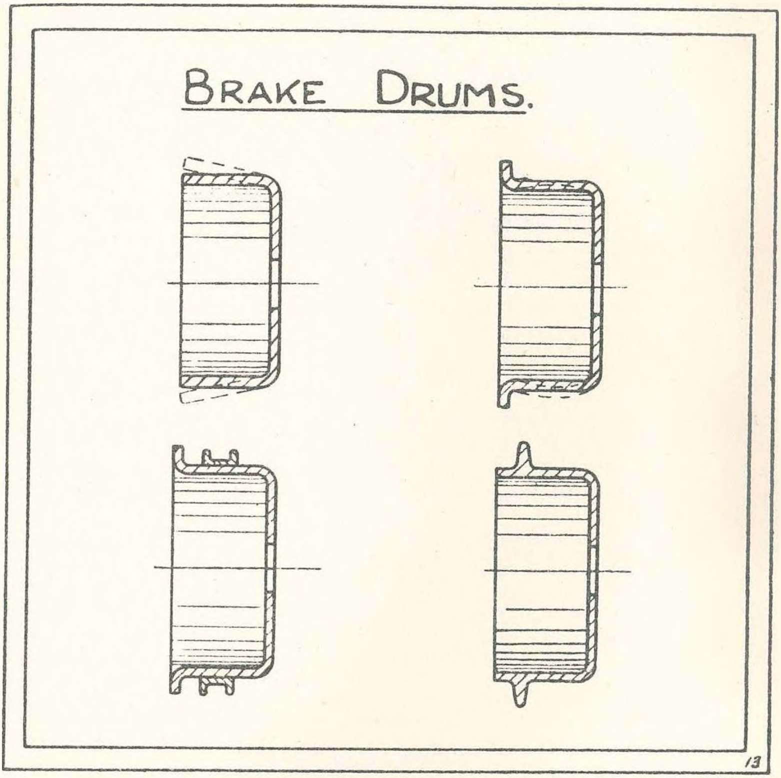


Fig. 35

ing. The finish must be excellent or rapid lining wear will occur, and the design must be such that the drum remains symmetrical under all conditions of heat and pressure. Distortion of the drum causes high local loading, excessive temperature and "fade," together with rapid lining wear.

Fig. 36 conveys graphically the possible distortions and means for partially curing these effects; for the ordinary installations a drum with one fin situated approximately one-third of the shoe width from the mouth of the drum will ensure reasonably satisfactory service; this fin should have a base thickness of one and a half times the drum thickness and the depth should be five times the drum thickness.

Fig. 37 illustrates a drum with a steel outer case and a cast-iron braking surface. Fig. 37, the Holley drum, is chiefly remarkable for the attempt to prevent distortion; probably some trouble with heat dissipation would occur. Figs. 38-39 (Talbot) show the drum design used successfully on the French Talbot

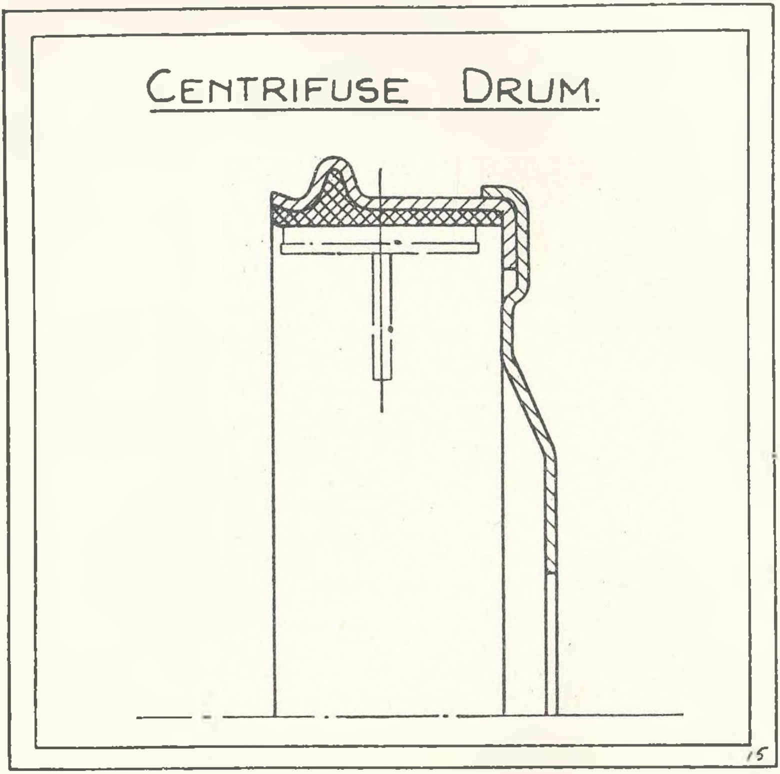


Fig. 38

racing cars of 1936–37 in combination with Bendix Servo brakes; the material is heat-treated steel with a 0·45 carbon content.

Brake Linings

The technique of modern lining manufacture has advanced rapidly in recent years and the user is now reasonably safe in adopting the recommendation of any leading manufacturer. It is highly important that the manufacturer should know exactly

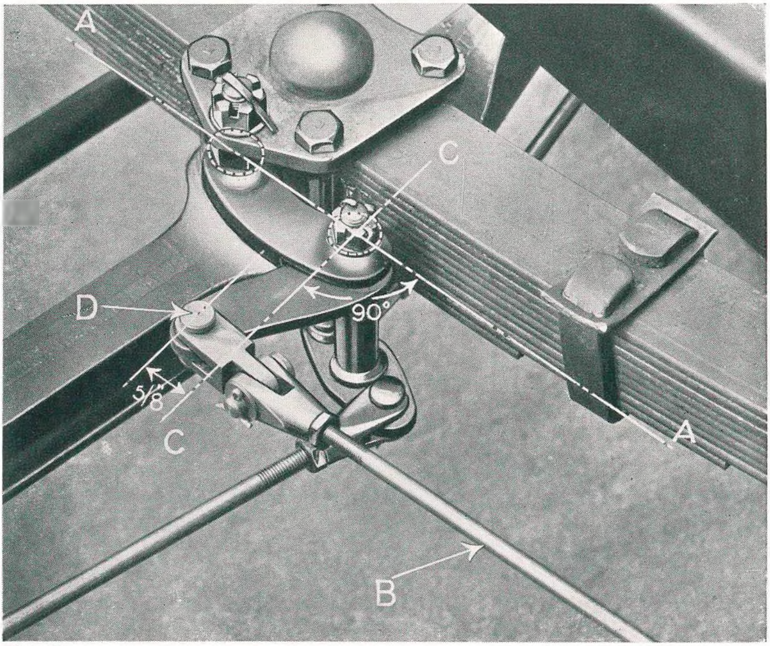


Plate 31.

BRAKE SHOE PRESSURE EQUALISER (GIRLING).

the conditions of use and the type of brake to be used. Linings are available which will operate consistently at very high temperatures and with minimum wear or fade.

Shoe Actuation

It is necessary that the shoe actuating mechanism should exert a constant rate of leverage throughout its range to ensure

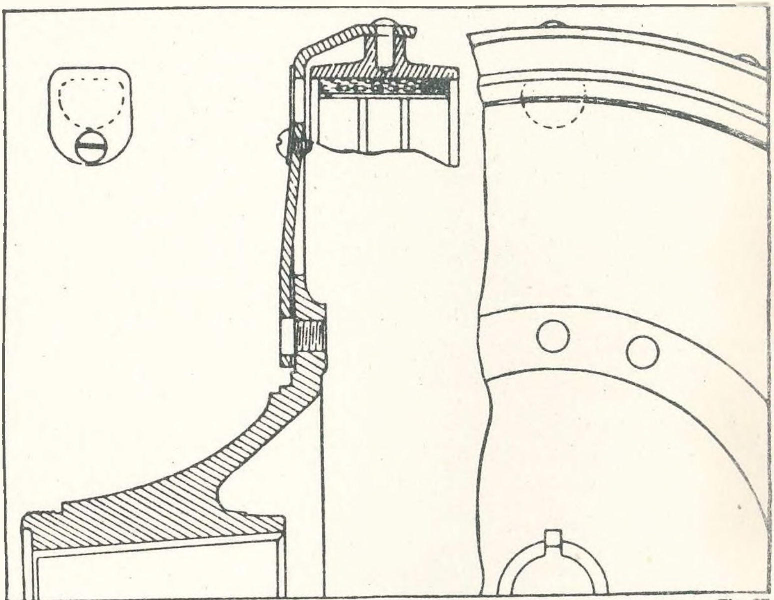


Fig. 37

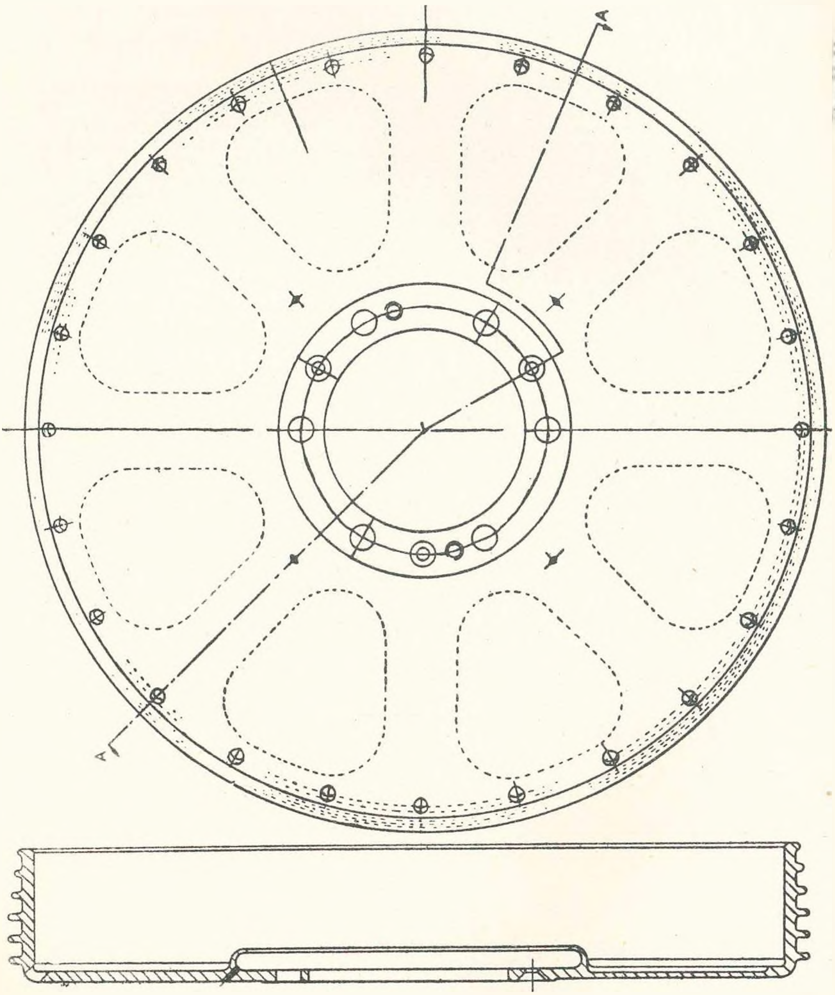
SECTIONAL AND SIDE VIEW OF WHEEL HUB WITH HOLLEY CAST-IRON BRAKE DRUM

even brake torque if one brake should wear more quickly than the others.

Compensating Mechanisms

100 per cent compensation of the brake actuating mechanism is now becoming usual. This is a tribute to the improvement in the consistency of the brakes themselves and modern brake linings, as unless the brakes remain consistent the use of chassis compensation is impossible.

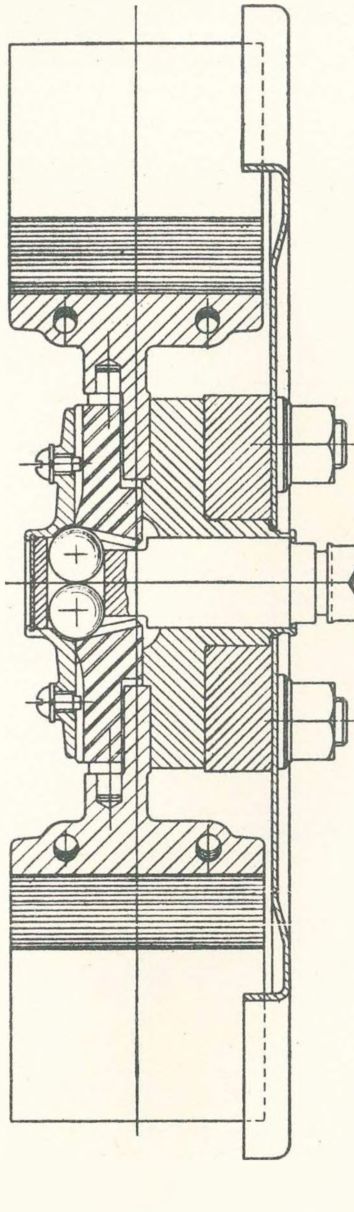
Hydraulic actuation is reasonably certain of providing this equalization of effort. A typical mechanical device for providing fore-and-aft compensation is shown in Fig. 41.



Figs. 38-39

Talbot Racing Car Brake Drum

Section AA



MECHANICAL OPERATION

Fig. 40

Plate 31 (facing page 135) shows a fairly common means of providing equalization of effort on each axle.

All these devices must be fairly robustly constructed as they are mounted on the unsprung axle and are subject to considerable vibration and exposure which will otherwise cause excessive wear and rattle and ultimate failure.

Adjustment

With all modern brakes the adjustment is located in the brake itself. It should be simple to operate and accessible. A single adjustment per brake is desirable. Fig. 42 shows a fairly com-

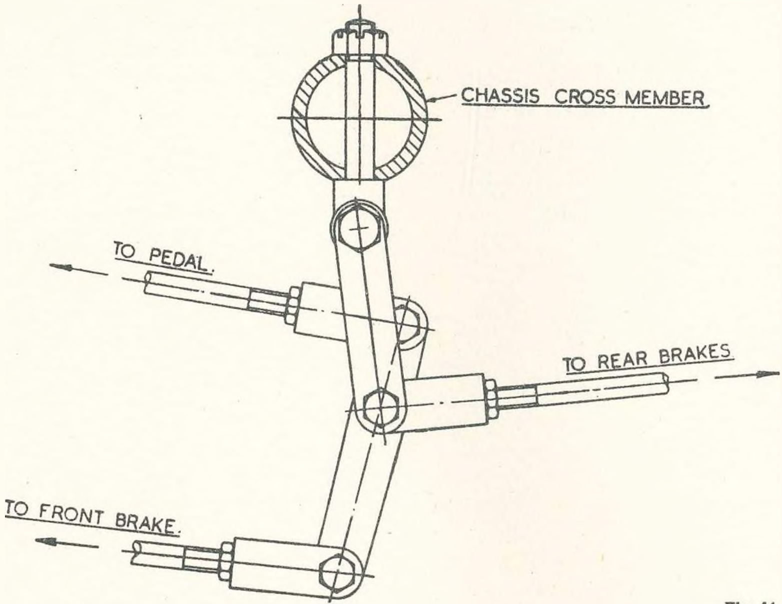


Fig. 41

mon type used on non-Servo brakes. Fig. 30 shows that used on the Bendix Servo brake. The latter also includes a spring device for keeping the shoes in a central position when the brake is "off."

Boosting System

These can be grouped under two headings:—

(1) Vacuum Servo.
(2) Mechanical.

A typical Vacuum Servo system is illustrated. This makes use of the depression existing in the induction system of the engine when the throttle is closed. This may amount to – 12 lb. sq. in.,

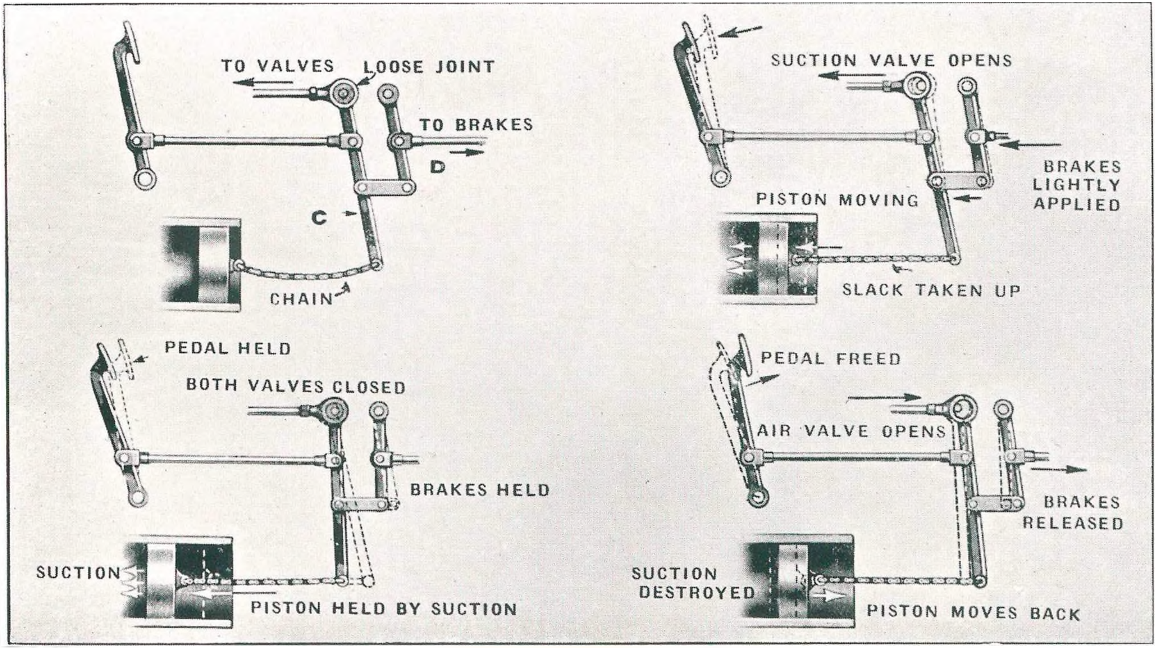


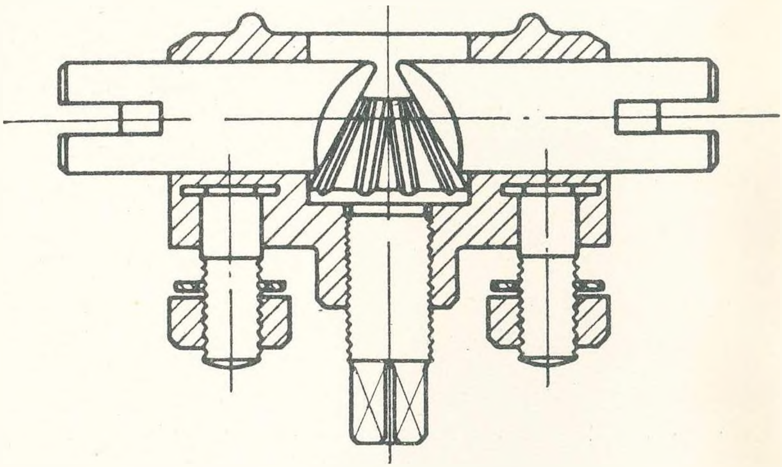
Plate 32.

VACUUM SERVO (DE WANDRE.)

but it is not safe to design on a depression exceeding 8 lb. sq. in. or a partial failure of the "boost" may be experienced at low speeds.

With this system the degree of "boost" is controlled by the pedal pressure by means of a "follow up" valve interconnected to the rod from the brake pedal. The effect on the required pedal pressure is shown in Fig. 43.

The mechanical Servo originated with the Hispano Suiza Company about fifteen years ago. It consists briefly of a cross



BRAKE SHOE ADJUSTER.
WEDGE TYPE.

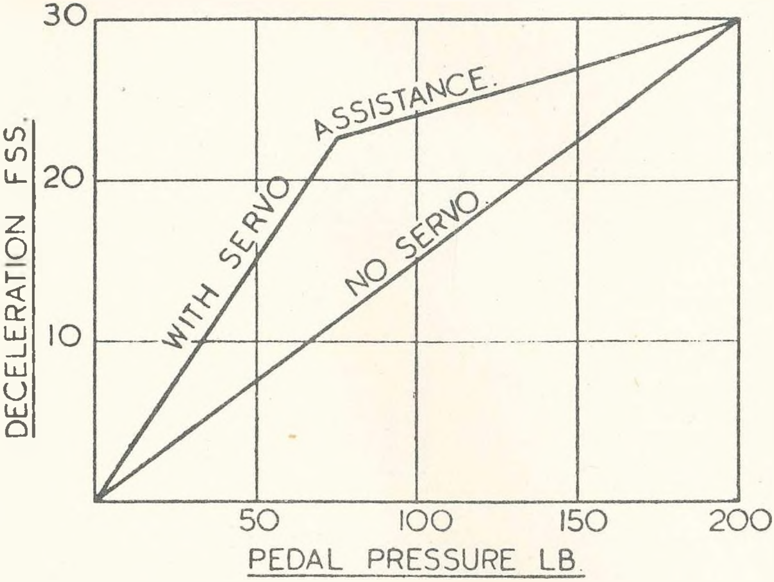
Fig. 42

shaft in the gear-box which projects through the side of the box, and on its extremity is mounted a brake drum. This shaft is worm-driven from the main gear shaft and rotates at a comparatively low speed.

Mounted freely on the shaft is a brake shoe carrier which is connected to the main brake actuating mechanism. The brake shoe actuating cam on this is connected to the brake pedal and the whole assembly is free within limits to rotate with the drum. When the brake pedal is depressed it applies the brake on the gear-box shaft. This causes the shoe carrier to rotate slightly and apply the vehicle brakes; by suitable proportions of drum and leverages very considerable Servo effort on the vehicle brakes may be obtained from comparatively light pedal pressures.

It will be understood that the final development of this scheme is rather involved as it has to act equally in both forward or reverse and it generally entails a fairly expensive gearbox.

The Rolls Royce Company are the chief exponents of this type of Servo. See Figs. 44-45.



LEVERAGE FOR VACUUM SERVO

Fig. 43

Proprietary Brakes

One of the accompanying illustrations is a Servo brake which is universally popular. The type shown is for mechanical actuation, but in America the actuation is chiefly hydraulic. It will be noted that the heel of the primary shoe is connected by means of a floating adjuster to the toe of the secondary shoe. The total braking torque is carried on the anchor pin at the operating ends of the shoes.

Plate 35 is similar to the above except that the operating mechanism consists of a plunger containing two balls or rollers mounted in a transverse hole and free to move circumferentially.

These balls contact directly on the angled ends of two tappets

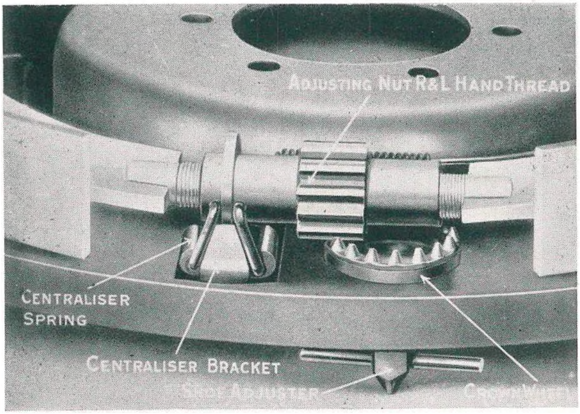


Plate 33.

BRAKE-SHOE ADJUSTER (BENDIX).

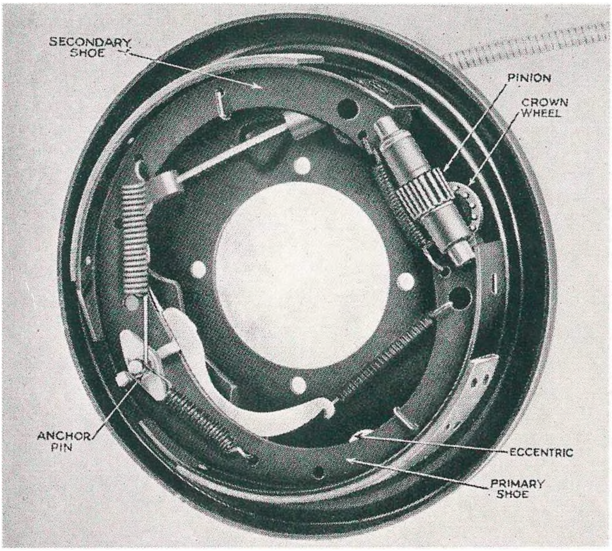
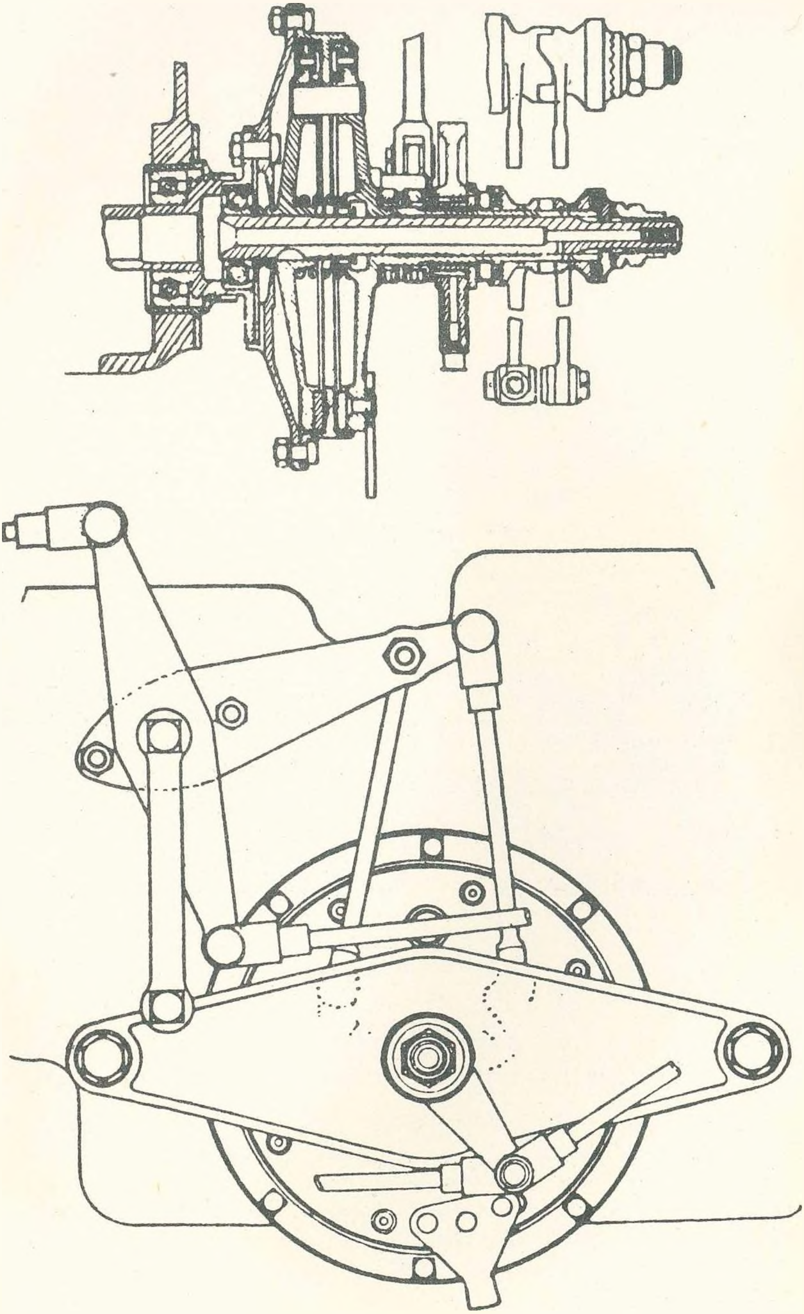


Plate 34.

MECHANICALLY-OPERATED SERVO SHOE BRAKE.

THIS TYPE OF BRAKE IS POPULAR BOTH IN EUROPE AND IN THE U.S.A. IN THE STATES IT IS NORMALLY HYDRAULICALLY OPERATED.

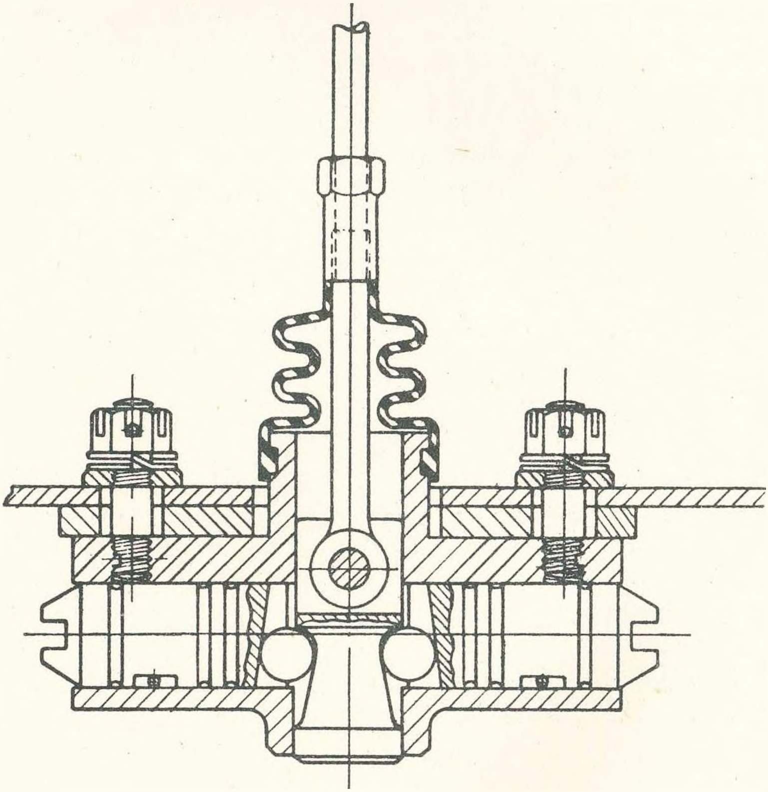


Figs. 44-45

Rolls-Royce Servo Mechanism

which, when forced out, will open the ends of the shoes and apply the brake. This design is particularly good for hydraulic application, as the actuating cylinder is mounted outside the backing plate and is not subject to the heat effects always present inside the drum. The shoe and adjuster construction is similar to that described above.

In Plate 36 the shoe actuation is very similar except that use



WEDGE OPERATED BRAKE.

Fig. 46

is made of two floating rollers which are interposed between the angled ends of the shoe tappets and the operating wedge. The relative angles of the wedge and the ends of the tappets are similar; the travel of the rollers is one-half that of the Cowdrey balls and the tappets may be made of less diameter.

This type of brake can also be actuated by an outside hydraulic cylinder.

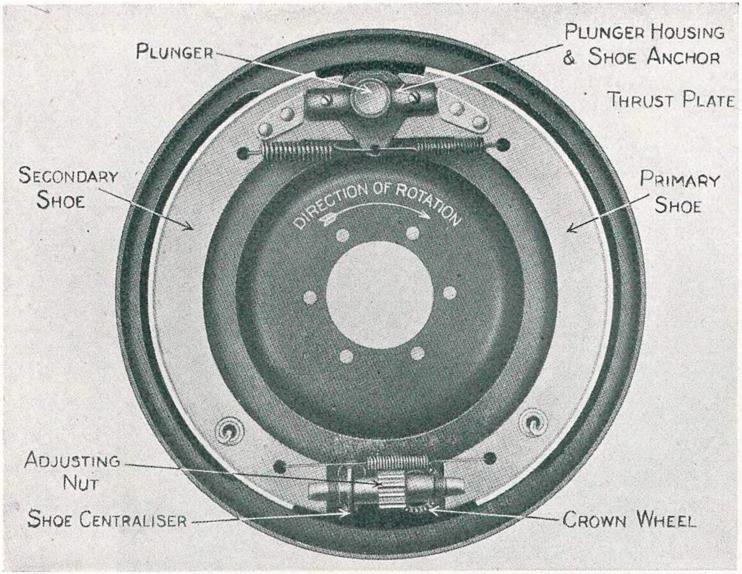


Plate 35.

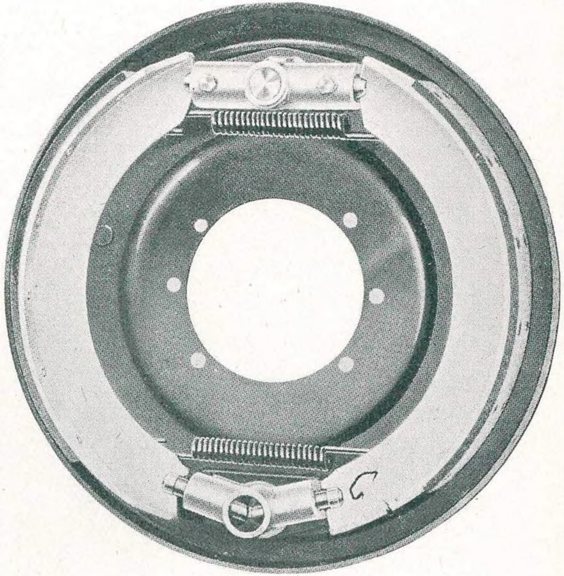


Plate 36.

PLUNGER-OPERATED SERVO BRAKES.

ON THE LEFT, THE ADJUSTMENT IS SIMILAR TO THAT IN THE PREVIOUS ILLUSTRATION.

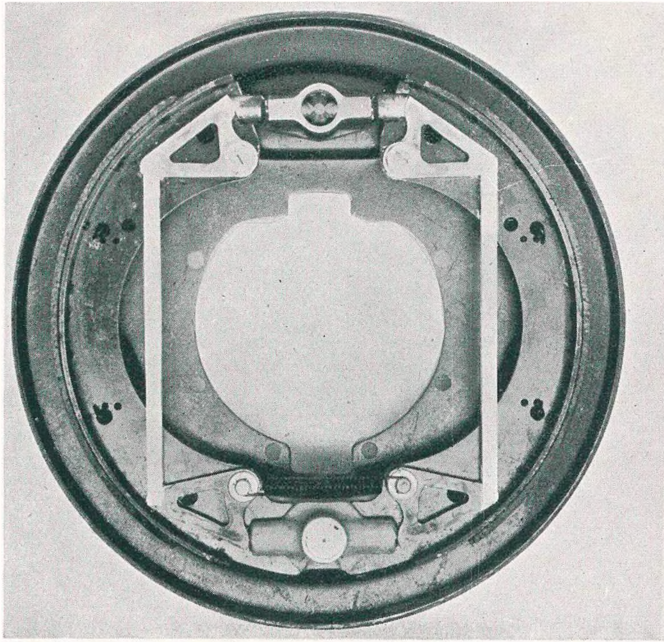


Plate 37.

TWO LEADING SHOE BRAKE.

MECHANICALLY OPERATED.

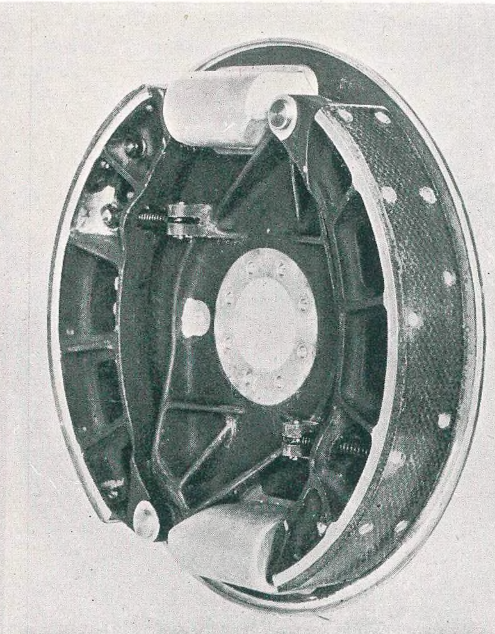


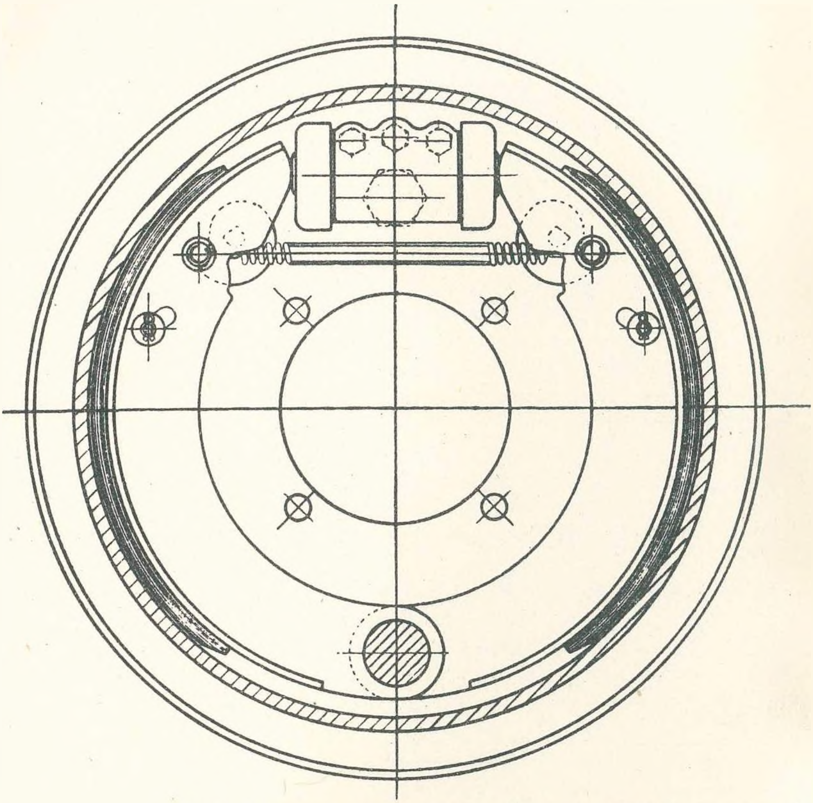
Plate 38.

TWO LEADING SHOE BRAKE.

THIS IS THE HYDRAULICALLY OPERATED TYPE USED ON E.R.A., MERCEDES AND AUTO-UNION RACING CARS.

This type of brake is used in very considerable numbers. Separate adjustment for each shoe is necessary and is provided by the eccentric shown near the operating ends of the shoes.

A later development of this brake is shown in Fig. 48 (Slotted Shoe) in which the increased power is obtained by slotting the fulcrum end of the shoes so that the leading shoe tends to drive



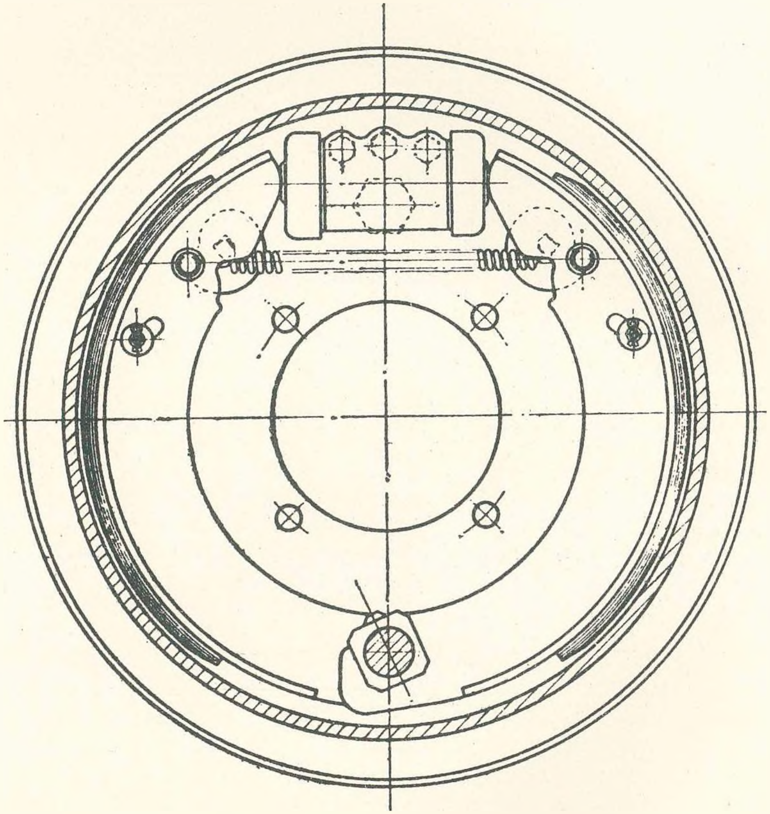
HYDRAULIC NON SERVO. (LOCKHEED)

Fig. 47

into the drum when under load. Increased power is obtained at the expense of increased wear and local loading; the increase in wear has been met by using a thicker lining on the shoe which acts as the leading shoe in the forward direction of the car.

Plate 37 illustrates the "two leading shoe" development; the brake shown provides this desirable characteristic in both directions of rotation combined with a single point adjustment and equal lining wear.

The action is as follows: The roller operating unit actuates the bell crank pivoted on the end of the shoe and not direct on the shoe itself as is usual. This actuating force is transmitted through the compression rod to a second bell crank which is also pivoted on the shoe, and thence to the fixed abutment which also acts as the adjustment.



SLOTTED SHOE. (LOCKHEED)

Fig. 48

The result is that both shoes are lifted into contact with the drum by the equal pressure on the pivots of the bell cranks at each end of each shoe. This equalizes the load along the periphery of each shoe and contributes to equal lining loading, equal wear, and the avoidance of any local high-pressure points which would tend towards high temperatures, wear, or fade.

This brake can be actuated hydraulically by the outside cylinder described in Cowdrey brake description.

The hand brake acts through the same operating unit and is equally efficient.

The brake shown in Plate 38 is a Two Leading Shoe brake as fitted on the E.R.A., Auto Union, and Mercedes racing cars: the "two leading shoe" characteristic applies only to the forward rotation of the car, but by suitable modifications it can also be made to apply in both directions of rotation.

Separate adjustment for each shoe is necessary, and owing to the use of two hydraulic actuating cylinders (one for each shoe) the hand brake connection cannot easily make use of the principle, in which case it will be relatively inefficient.

Special Brake Equipment for Captain Eyston's Car "Thunderbolt"

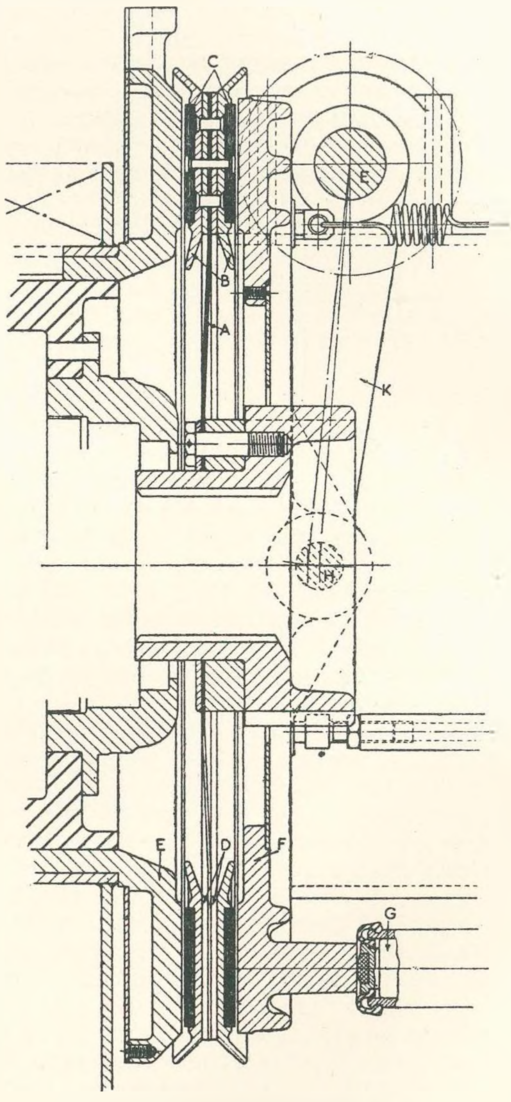
In view of the great weight and anticipated speed of the car, it was considered that drum brakes were inadvisable owing, amongst other things, to questions of heat dissipation, diameter restriction, and the possibility of "grabbing."

It was therefore decided to consider the problem from a clutch point of view. The Borg and Beck design staff prepared preliminary drawings and details, which were accepted, and the final design is as described hereafter. The calculations were based on a total weight of over seven tons, and the speed at which the brakes would be applied as in the neighbourhood of 180 m.p.h. At this speed the kinetic energy stored up is, of course, very considerable, and the car had to be brought to rest in approximately one mile.

The same type of brake is used for the front wheels, as well as in the transmission to provide the rear wheel braking.

General Description (see attached illustration for reference).—The spinning member consists of a thin flexible high carbon steel disc (A), to which are riveted on either side carrier plates (B), the segmental friction facings (C) being riveted to these in turn. The carrier plates are attached to the steel central disc in such a manner that there are radial spaces (D) on either side; this arrangement produces quite an appreciable turbine or blower effect, and materially assists in dissipating the very high temperatures which have to be met. The spinning member is bolted to the transmission shaft extension or, in the case of the front wheels, to the rotating hub member extension.

Close to one side of the spinning member is a fixed clamping disc (E), and on the other side a disc (F) capable of swinging axially and adapted to "sandwich" and clamp the spinning member when braking is required. The movable disc is brought into contact with the spinning disc by four Lockheed hydraulic brake cylinders (G), and is supported on two diametrically dis-



BORG & BECK TRANSMISSION BRAKE.
CAPT EYSTON'S "THUNDERBOLT"

Fig. 49

posed trunnion pins (H) carried by swinging drop arms or levers (K) which take the brake reaction.

In order to obviate any possibility of a pulsating effect being set up, the upper ends of the drop arms are supported on a torsion bar (E); this torsion bar permits only a small amount of flexure, so to take care of any additional "weave" or chassis distortion a slipping friction damping device is provided at one end of each brake torsion bar. Both the fixed and swinging clamping plates are provided with radial and spiral ribs on their outer surfaces so as to distribute the air flow produced by the turbine effect of the spinning member evenly over the surfaces to carry away the excessive heat produced when braking.

Incidentally tests of a much more severe nature than would be called for in actual service were carried out and proved entirely satisfactory.

Sufficient has been said to impress upon the reader the magnitude of the subject and some idea of the underlying principles involved. Brakes are a "Safety" device and are becoming increasingly important owing to the growing congestion of modern traffic conditions. It is imperative that the safety device itself shall be safe, and this can only be if the vehicle is designed in accordance with the principles dealt with in the preceding pages.

For those who wish to delve more deeply into the subject, an appendix containing certain formulæ is attached. Space will not allow of the inclusion of the comparatively involved mathematical calculations necessary for the detail design of the brakes, but these are readily accessible in the publications of the technical press or from papers read at different times before the Institution of Automobile Engineers and other learned Institutions. The author will be pleased to supply any further information to interested readers.

APPENDIX

Stopping Distance

$$D = \frac{3{\cdot}32\ V^2}{E}\ \text{feet.}$$

D = Stopping distance in feet.
V = Speed in m.p.h.
E = Braking efficiency (100% = 32·2 ft./sec.^{2}).

Stopping Time

$$T = \frac{2D}{R} \quad \text{or} \quad 2{\cdot}5 \quad \frac{D}{E}\ \text{seconds.}$$

T = Stopping time in seconds.
R = Rate of retardation in feet per sec. per sec.

Retardation

$$R = \frac{1{\cdot}07}{D} V^2 \text{ft./sec.}^2$$

Adhesion between Tyre and Road

Road Surface	State	Adhesion Coefficient	
		New Tyres	Smooth Tyres
Rough Tarmacadam	Dry Wet	0·9 0·7	0·9 0·5
Medium Tarmacadam	Dry Wet	0·8 0·65	0·8 0·55
Smooth Tarmacadam	Dry Wet	0·8 0·6	0·8 0·35
Smooth Asphalt	Dry Wet	0·65 0·6	0·6 0·3
Smooth Concrete	Dry Wet	1·0 0·7	1·0 0·5
Wood Blocks	Dry Wet	0·9 0·7	0·8 0·4

Graph Indicating Stopping Distances from Speeds 5/50 m.p.h.

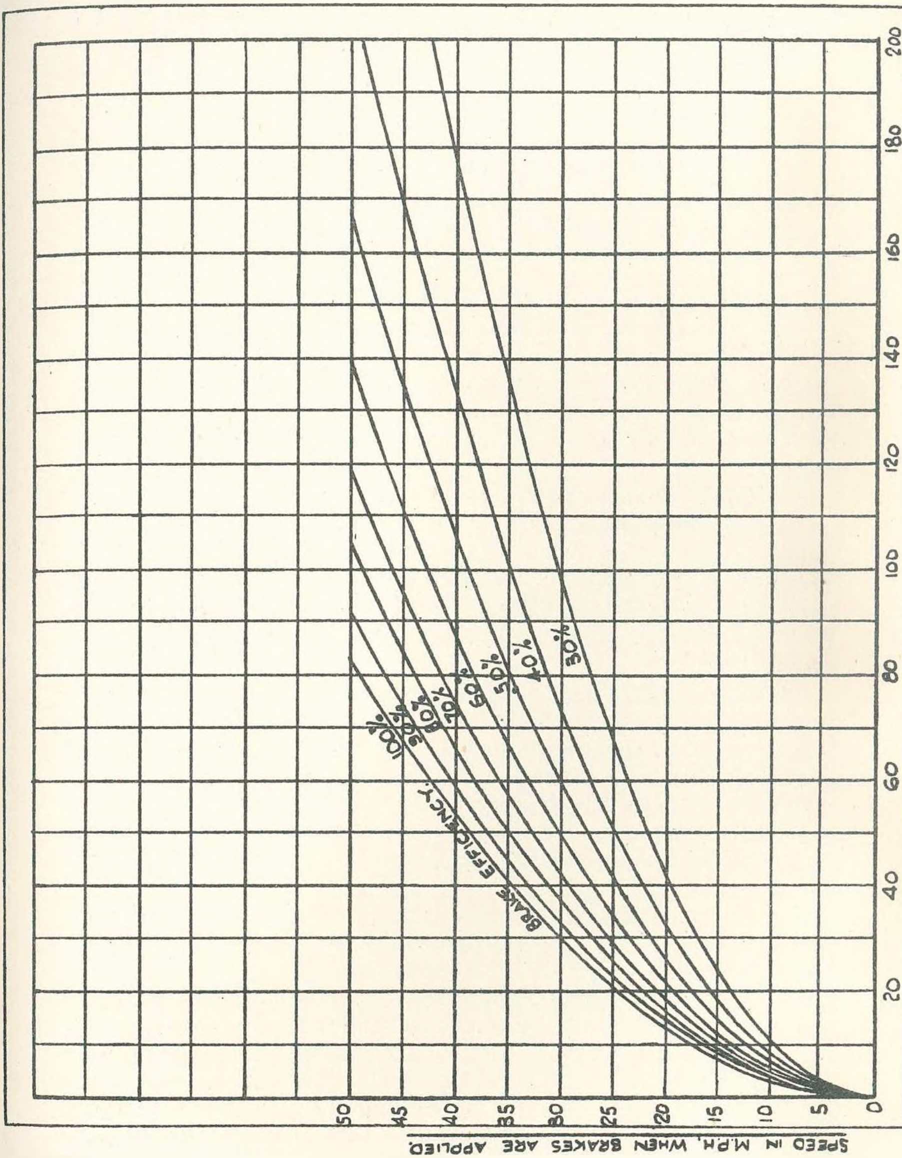


Fig. 50

CHAPTER TWELVE

WHEEL SUSPENSION

By Peter Berthon
Chief Engineer & Technical Director, E.R.A. Ltd.

MOST people interested in motor racing are familiar with the time-worn argument as to the pros and cons and how far the development of the racing car affects that of the commercial vehicle.

Such controversy is outside the scope of this article, but it is perhaps in place to stress the fact that since these suspension problems on both types of vehicles have a great deal in common, the development of racing car suspension in recent years has had considerable influence on that of the modern passenger vehicle.

As should be expected, the commercial products of manufacturers, and even countries that are nearest concerned with motor racing, show direct results of their racing car experience, so much so that cases can be found where manufacturers have commercially produced their racing suspensions and modified such layouts soon after the modifications have been tried out in racing.

Germany and Italy are perhaps the greatest supporters of international motor racing and it is certain that independent front wheel suspension has become almost standard on the products of both countries.

In this country the change-over is taking place much more gradually, and some manufacturers are not yet convinced that independent front suspension presents sufficient advantages over the orthodox layout.

America on the other hand has practically standardized independent front suspension on passenger vehicles, but the change has been gradual and on fairly consistent lines.

Only in recent years have designers of racing cars seriously considered the possibilities of independent suspension, and before the appearance of the two great teams of Auto-Union and Mercedes-Benz in 1934–35, very few racing cars were equipped with anything but the orthodox layout, each carrying slight variations. The development of independent front suspension prior to this was more or less confined to racing cars having front wheel drive, and in all probability the independent suspension was considered the necessary accessory to such a layout.

In recent years of English motor racing, the M.G. Car Company realized the advantages that independent suspension offered in racing and produced their "R" type 750 c.c. car, which had independent suspension on front and rear. It was unfortunate that this company, who have done so much to carry the British flag in motor racing, decided to discontinue their racing activities soon after this model was produced, since it marked a pioneer development in racing car design in this country.

The application of independent suspension, so far as front wheels are concerned, has now been universally adopted by racing car manufacturers, and to-day an independent layout is considered essential.

Independent rear suspension, however, in common with touring car design, has not fared so fortunately, and although it appeared in the form of swinging half-axles on the Auto-Union cars of 1934 and later on on the Alfa-Romeo, it is by no means considered essential, and recent work shows its value to be extremely doubtful. We will, however, go back to this point later.

The last few years have shown enormous strides forward in the development of racing cars, and maximum speeds and performance of road-racing circuits have reached fantastic figures, and there seems every possibility of continued improvement. This great increase in performance has been brought about by improved design on three counts, which can be classified under the headings of—

Road-holding.
Reduction in weight, hence power-weight ratio.
Streamlining.

The most important of these three items and the one that has had the closest attention is that of road-holding, which embraces this whole question of suspension, as obviously the most startling engine power or power-weight ratio cannot be used unless this performance can be converted into propelling the vehicle along the road. Similarly such performance can become an embarrassment to the driver, however good he may be, unless the car can be handled under the conditions of acceleration and maximum speed that such performance will permit.

To revert to the touring car suspension comparisons, here lies the chief difference in that the racing car suspension has to be able to cope with a very much higher speed range and a much greater percentage of variation in load.

Let us then consider broadly the problems that have to be faced in the suspension and general layout of a vehicle to enable us to use the very high performance that present-day constructors have achieved, in terms of power-weight ratio, which controls acceleration, and power-streamline ratio, which controls the maximum speed.

(1) To provide suspension characteristics that will give good road holding for all speeds, *i.e.* between the slowest cornering speed and the maximum obtainable.

(2) To remove all disturbing influences on the directional stability of the vehicle, such as drive and brake torque.

(3) To provide as far as possible suspension characteristics that are unaffected by variations in weight.

The first is mostly a question of type of suspension, and from the many layout schemes that are practised to-day only a few are really suitable for application to a racing car. One of the

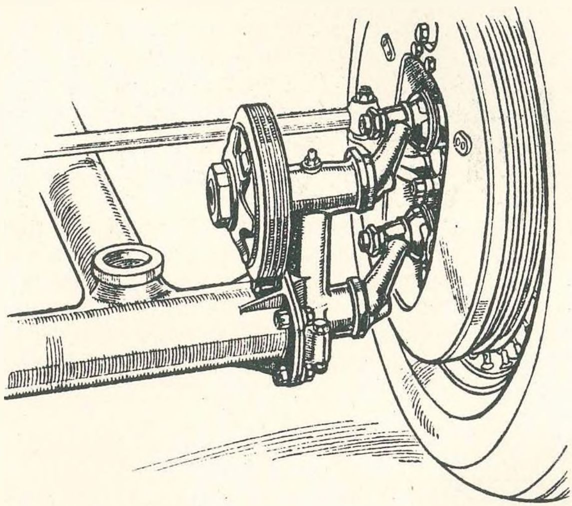


Fig. 51

PORSCHE TORSION BAR FRONT WHEEL SUSPENSION ON AUTO-UNION

major considerations is that of unsprung weight, and every effort to reduce the unsprung weight materially helps in securing suitable springing characteristics over the required very wide range. The most-favoured types seem to fall into two classes: the first the parallel swinging-arm system which is used on the Auto-Union, E.R.A., and Alfa-Romeo cars. This layout permits a very low unsprung weight, which need be a little more than the weight of wheel, tyre, and brake mechanism. Its characteristics give constant track and variable wheelbase.

Variable wheelbase seems to have an advantage over variable track, since with the latter the gyroscopic effect on the wheel travelling at high speed tends to affect the suspension characteristics. The two swinging-arm suspension as patented by Dr.

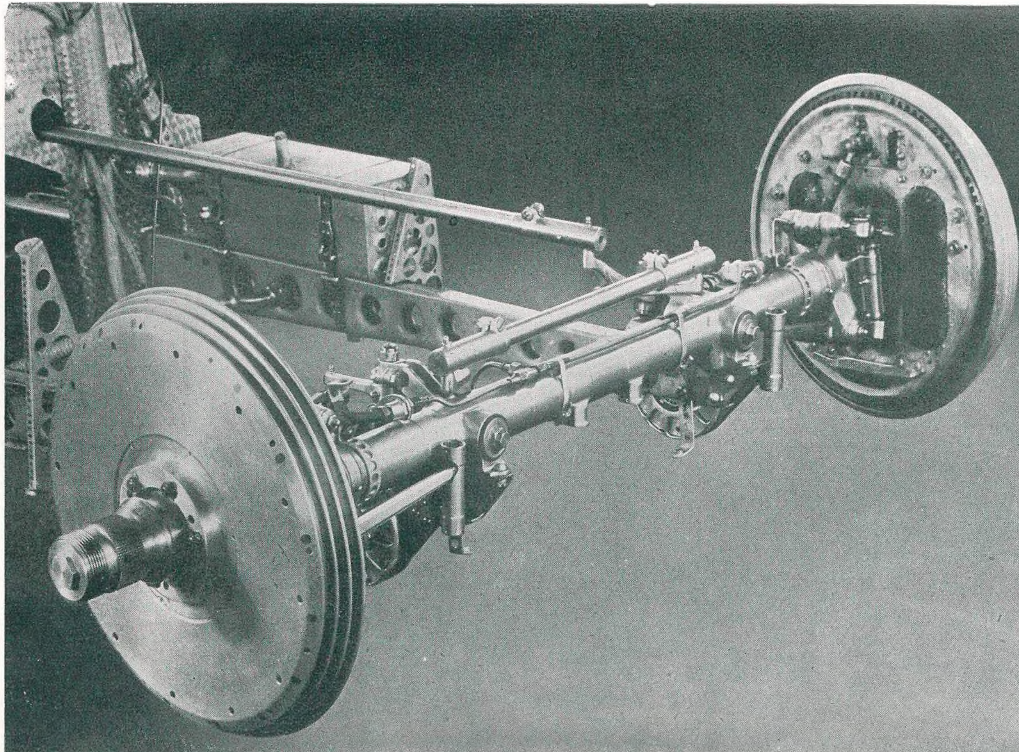


Plate 39. [*Photograph : Mercedes.*

FRONT SUSPENSION.

FRONT AXLE OF THE EARLIER TYPE MERCEDES-BENZ, WHICH FORMS AN INTERESTING CONTRAST WITH THAT OF THE AUTO-UNION.

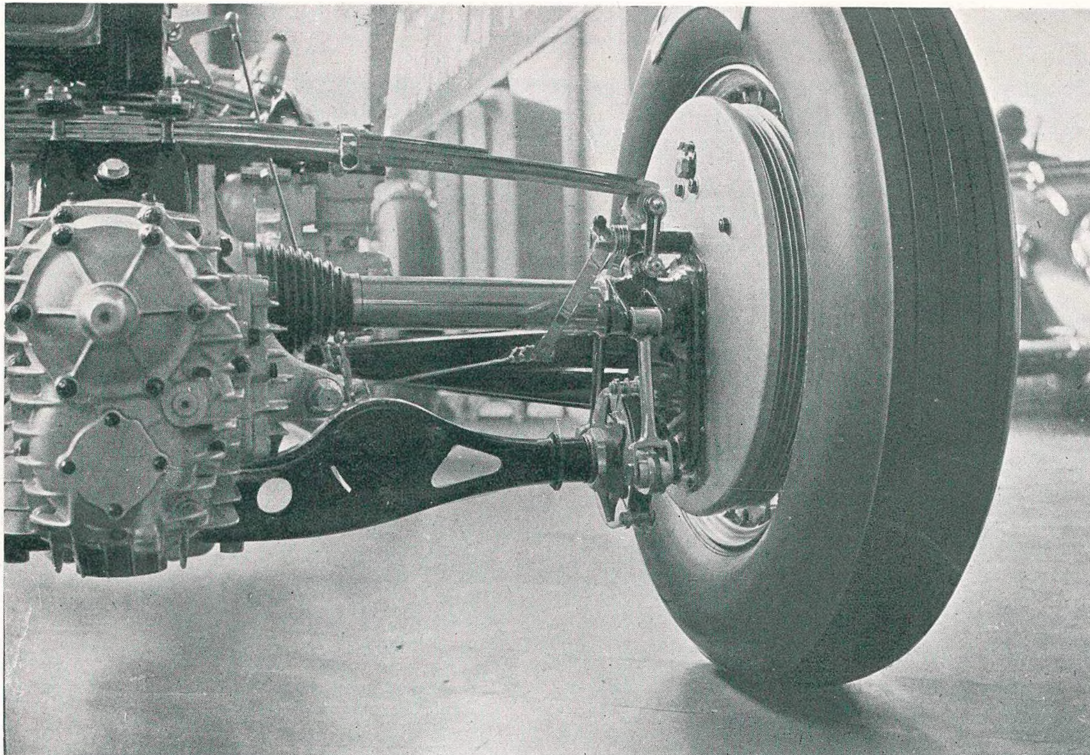


Plate 40. [*Photograph : " The Autocar."*

REAR SUSPENSION.

REAR AXLE OF AN EARLIER TYPE AUTO-UNION. THIS TYPE HAD A SINGLE TRANSVERSE SPRING, AND THE GEAR BOX, WHICH IS RIBBED FOR COOLING, BEHIND THE REAR AXLE.

Porsche—the designer of the Auto-Union racing car—is in itself very compact and light. In the earlier layouts trouble was experienced through the arms not being capable of withstanding the cornering thrusts. Later versions, however, have considerably shorter arms which reduce the offset so that the cornering loads can be absorbed without wheel displacement. The only slight disadvantage and a restriction the designer has to face is that the torsion bar length is limited by being mounted across the frame in the front tube which carries the swinging-arm mounting portion.

Apart from this, true steering geometry can be readily obtained, and on the whole this layout offers a very satisfactory answer to the requirements.

The Alfa-Romeo layout differs slightly from that of Dr. Porsche, and in place of the ball ends which attach the swinging arms to the stub axles and act as steering pivots, an arrangement of stub axle and king-pin is used. This is effectively the same thing but has the disadvantage of increasing the unsprung weight.

The second system which is used on present-day racing car design is the parallelogram type consisting of two parallel arms arranged transversely. This system provides constant wheelbase and variable track, although the position and lengths of the top and bottom arms are arranged to give the minimum amount of lateral displacement between tyre and track. Actually lateral displacement hence tyre "scrub" is not an important factor, since fast cornering and heavy braking will account for a much more rapid rate of tyre wear. On the grounds of unsprung weight there is little to choose between the other system. Mercedes layout uses a coil spring and the Maserati torsion bar, which runs parallel with the frame.

Both systems are excellent from the point of view of absorbing brake torque, and in neither case is the brake torque taken through the spring, which would affect the stability when braking from high speeds.

A further point which has a slight bearing on the type of independent suspension employed is that of streamlining. It is the least important factor but a type of suspension that can be included in the cowling or fared in by other means has a slight advantage. We have already seen that the two independent front suspensions most generally used on racing cars are excellent from the point of view of absorbing brake torque, in a manner that has the minimum amount of effect on the direction stability of the vehicle. This factor, together with a much reduced unsprung weight and a scope for employing other means of springing than the normal leaf spring, sums up the main advantages of independent suspension as compared with the orthodox layout. Undoubtedly, although considerable strides forward have been made in front wheel suspension, there is still more room for further improvement. Perhaps the best results would be obtained in still further reducing the unsprung weight, and now that the effective weight of an axle beam and the part weight of the road springs have been removed, the next largest slice that can be tackled is the brake torque and mechanism. Future designs will make an effort to include all brake gear in the sprung mass. This feature is, of course, more readily obtained on the rear suspension than in the case of the front; the problem of providing cooling to the brake mechanism and at the same time securing effective streamline becomes a serious consideration.

It has been previously mentioned that although independent suspension has been tried out on the rear of racing cars it has recently been dropped—at any rate for the time being—by Mercedes-Benz and Auto-Union in favour of a non-independent layout. Nevertheless great improvements have been made over the Hotchkiss drive, which until a few years ago was to be found on the rear of every racing car. Improvements have been tackled on the same basis as with the front end, and unsprung weight has been reduced by mounting the final drive casing solidly on the chassis frame and continuing the drive to the wheels through half-shafts and universal joints. The most-favoured rear layout at the present time, and one used by both Mercedes-Benz and Auto-Union, is in principle similar to the De Dion layout, which was one of the earliest efforts of rear suspension on a motor vehicle. This ties the two wheels together by a solid member of round or rectangular section running underneath or behind the final drive casing. This member is located to the chassis frame in the manner that arrests any lateral movement, so absorbing cornering thrusts, but is free in the vertical plane. Drive thrust and brake torque is absorbed through reduced arms on the frame ahead of the rear axle. The characteristics of this layout, besides giving a lower unsprung weight than the normal Hotchkiss-type rear axle, permits the use of coil springs or torsion bars. The most important feature, however, is that the drive torque reaction, which in the case of the normal layout tends to reduce the weight on one wheel, is absorbed in the chassis frame and has far less tendency to cause instability during hard acceleration. The most recent designs include the rear axle and gear-box in one unit. This is even more advantageous since it can be readily arranged for the torque reactions of gear-box and axle to cancel out. Present tendencies in racing car design are to build cars lower and to reduce as much as ever possible the frontal area. This must of necessity, in order to accommodate driver and fuel, mean a longer car, so that the combined rear axle and gear-box helps to restore the weight distribution to recognized proportions.

Although the De Dion layout is popular at the present time, in its present form it is by no means a final answer. It can readily be seen that since the rear wheels are positioned by the radius arms, when one wheel is deflected, the change in angularity at the wheel centre puts the connecting member in torsion, and since, in the case of one wheel being deflected, the movement comprises half bump and half roll, the torsional performance of this connecting member has a very different bearing on the suspension and roll characteristics around the back axle. If, therefore, this member is too solid there will be very marked

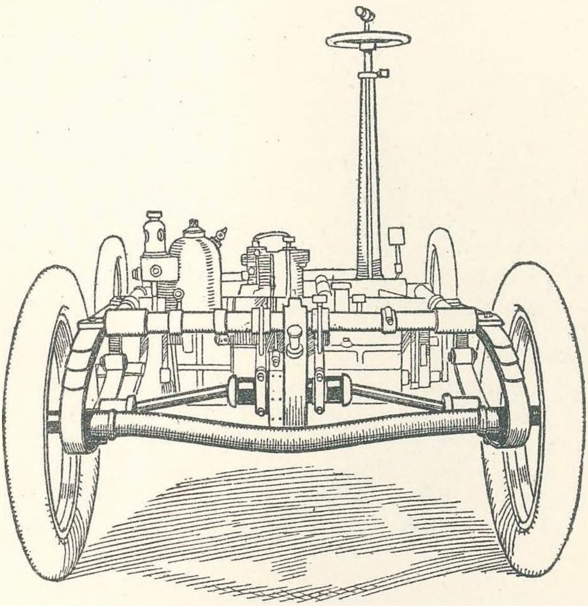


Fig. 52

THE ORIGINAL DE DION AXLE

anti-roll tendencies which will destroy the adhesion on corners. Broadly, this means that the torsional performance of the connecting member, plus the performance of the springs which in present layouts are usually torsion bars, can be made to accommodate between them the loads required for the deflection of one wheel or the other. If both wheels are deflected equally, as in the case of a car hitting a hump-backed bridge, the movement will cancel all bump purely and the torsion bars have to cater with the loading, which they cannot do if they are out to specify the first condition of movement on one wheel only.

The last item is perhaps the most difficult to find the answer to, since engines running on alcohol fuel of necessity have a poor fuel consumption, which means that the total amount of fuel to be carried must be fairly large, since for various reasons only one stop can be permitted in the course of a race, for re-fuelling. This means that the full capacity must be sufficient in a Grand Prix race for 150 miles, and if a fuel consumption of the order of 5 m.p.g., which represents an average, a minimum of 30 gallons plus an additional amount to cater for various emergencies, must be carried. The car therefore will, just before it is due to fill up, have a lost total of 270 lb., which may represent about 20 per cent of the total weight of the vehicle.

The obvious place for such a variable load lies in the fore-

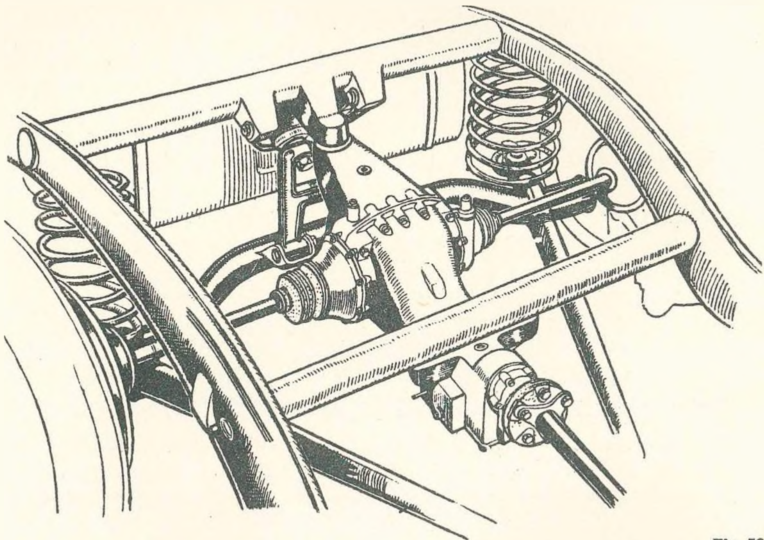


Fig. 53

MERCEDES REAR WHEEL SUSPENSION ON THE DE DION PRINCIPLE

and-aft position of the C. of G. of the car, as here the variation of the weight, as the fuel is used, will not upset the weight distribution but will lighten both ends by a similar amount.

The Auto-Unions were the first to cater for this requirement, and on the score of weight distribution, light weight, and the position of the fuel, their layout is certainly the best answer from a theoretical standpoint.

The effect of the engine at the rear places the greatest mass that has to be carried in the right place for weight distribution, saves weight by being made integral with gear-box and rear axle, and enables the driver to be placed in a very low sitting position in front of the fuel tank, which is situated just ahead of the engine in the middle of the car, roughly on the C. of G.

Unfortunately, good as this layout may seem theoretically, practically it suffers from one severe handicap, and that is that the driver, being placed relatively near the front axle, is not in a position to sense lateral displacement on the rear axle until it has developed to a fairly large angle. From the point of view of controlling the vehicle it is essential that the driver is in a position to sense the slightest lateral movement on the rear of the vehicle which will eventually develop into a skid, as after this movement is allowed in its very early stages to develop, it will end in a skid that cannot be controlled by the efforts of the driver.

Mercedes-Benz, on the other hand, have developed another layout in an effort to achieve similar fuel disposition, and on their 1938 cars were able to offset the propeller shaft, permitting a very low sitting position for the driver and provision for a large-capacity fuel tank to be placed within the scuttle and over the driver's legs. This layout must of necessity be a compromise, as in the interests of streamlining, the area, and consequently space available, must be kept as low as possible, and with a front-engine layout it is extremely difficult to obtain a correct weight distribution fully laden without some weight of fuel being carried over the rear axle. The Mercedes layout is a clever compromise since only the fuel carried in the rear tank will affect weight distribution.

CHAPTER THIRTEEN

SHOCK-ABSORBERS

By Charles Houghton

ALLIED with the problem of suspension is another problem, the shock-absorber, the two being intimately connected yet entirely separate. As a matter of fact, few components have

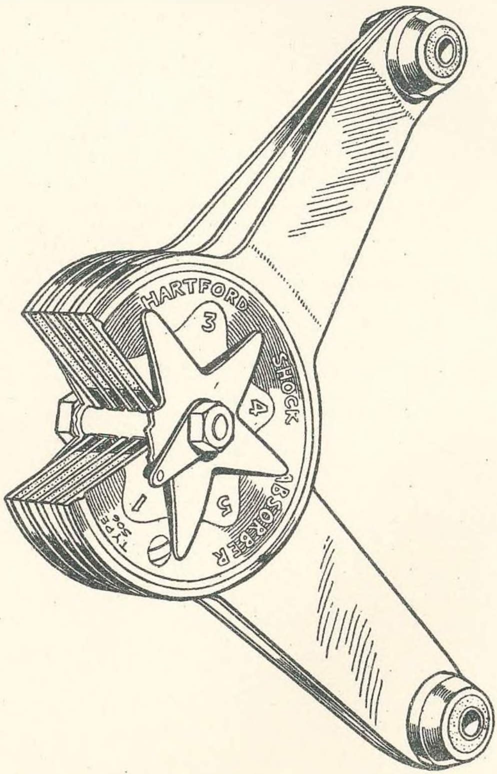


Fig. 54

Hartford Double-acting Friction Shock-absorber with its Star-shaped Spring. The Discs and Arms are generally made from Light Alloy

made so much difference to the racing car as the shock-absorber. As the big cars of the olden days became faster and faster, so they became more and more difficult to hold, and the greatest part of this difficulty was that the unchecked springs tended to reach a period of vibration which not only rendered steering difficult, but prevented the car from holding the road at all. It is not too much to say that it looked as though the limit of possible speed had been reached. Then the shock-absorber appeared, at first consisting of a very small band brake working on a drum fixed to the frame oscillated by an arm attached to the axle, and the effect of this being marked, progress was rapid.

Now the whole point of the shock-absorber is that it damps out the rebound of a spring and that, if this rebound is unchecked, the oscillation of the spring is actually increased until

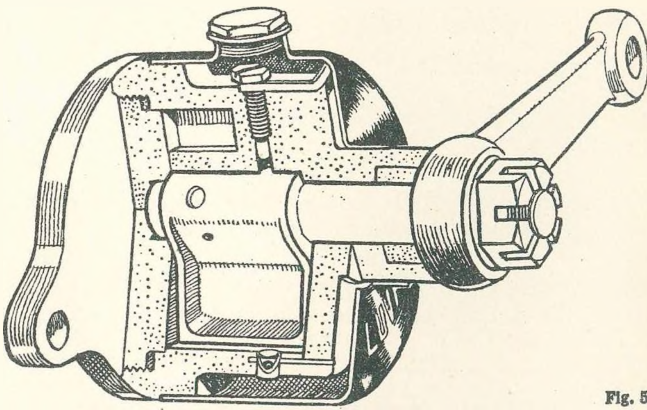


Fig. 55

PADDLE AND CASING TYPE LUVAX HYDRAULIC SHOCK-ABSORBER

it becomes an almost violent vibration. Consequently attempts were made to design shock-absorbers which only operated to check the rebound, leaving the movement of the spring to absorb the initial shock unhampered.

We have progressed a long way since those early days, and the problems of the shock-absorber have become if anything still more complicated. Part of the trouble lies in the fact that the designer of the car may have devoted a great deal of thought to the suspension—and no part of the machine needs greater thought; may have undertaken numerous experiments to prove his theories; but the only shock-absorbers that are available are those that can be purchased in the ordinary way and which in most cases are not designed solely for racing. It is admitted that they have proved extremely suitable for high-speed work, but that does not alter the problem.

A further complication arises owing to the fact that a few years ago most racing cars held the road better if the shock-

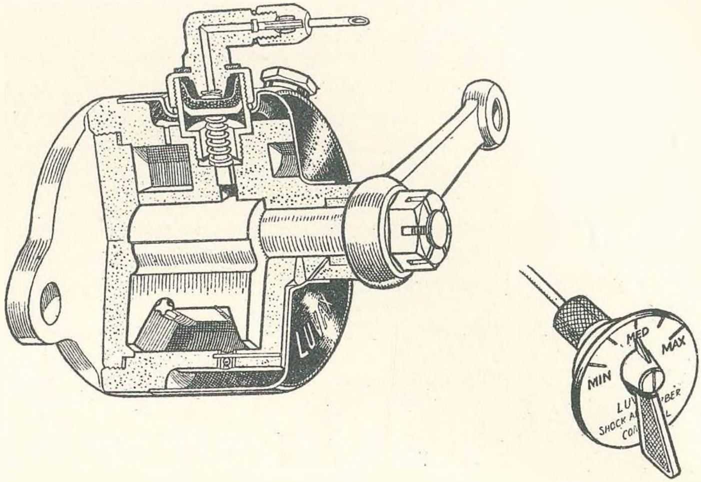


Fig. 56

Luvax Paddle-Type Hydraulic Shock-absorber with Hand Control to vary the Effect of the Shock-absorber according to the Speed of the Car

absorbers were exceedingly tight, and as these shock-absorbers were generally double-acting and consisted of a number of discs

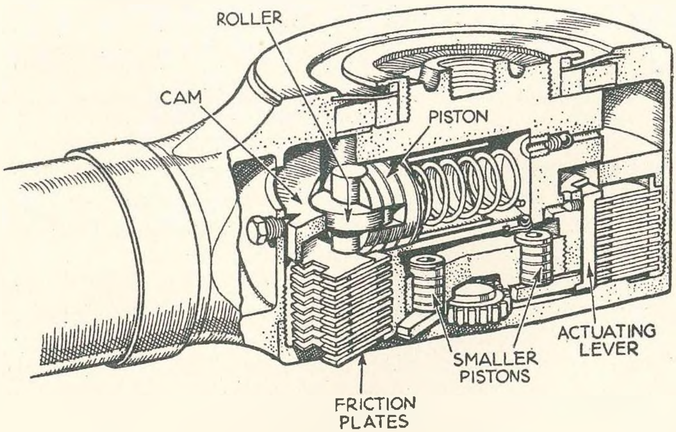


Fig. 57

The De Ram Shock-absorber illustrating the General Arrangement of the Parts

held against each other by a strong spring, the effect was to stiffen the action of the leaf spring. As a result, drivers soon formed the opinion that if the car was difficult to hold the shock-absorbers were too loose, proceeding from which they tightened the shock-absorbers at every possible opportunity, with the result that at certain speeds the springs were unable to operate at all.

Now it is quite plain that the best results are not obtained in this fashion; plain also that, as the speeds increased, the springs should be allowed more movement and their vibration damped out more softly. This fact became very much more apparent when coil springs which had no self-damping effect, or torsion bars, came into use. But habit being strong, it is still quite difficult to convince a driver that the softer action of shock-absorbers gives the better result.

At the present moment shock-absorbers are usually of two

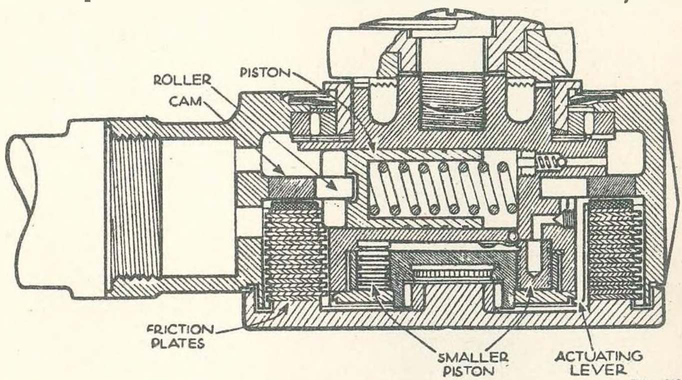


Fig. 58

A SECTION OF THE DE RAM SHOCK-ABSORBER SHOWING THE CAM-OPERATED PISTON WHICH OPERATES A PISTON AGAINST FLUID PRESSURE, AND THE ADDITIONAL FRICTION PLATES WHICH COME IN AT NEED

types; in the one a series of discs are assembled so that one set of discs rubs on the other as the two arms of the shock-absorber open and close, the pressure being regulated by adjusting a nut controlling the spring, and the nut very often being split-pinned when the adjustment is correct. The second type of shock-absorber is hydraulic, its action consisting of making some form of pump force oil gradually through an orifice. With the latter type it is of course easy to arrange for the shock-absorber to work freely in one direction but with difficulty in the other, and easy also to arrange that the size of the orifice should be controlled from the driving seat. Further progress evolved a shock-absorber which, within certain limits, controlled its own pressure according to the amount of work the spring was doing at the moment. Either a piston in a cylinder or a paddle in a circular casing with suitable non-return valves is the usual form of the hydraulic mechanism, and provided care is taken to avoid leakage at the glands and the shock-absorber is well made, very good results are obtained.

Nowadays, with the very fast road-racing machines it is not unusual to fit two sets of shock-absorbers to each axle—one hydraulic, to do most of the work; the other friction, to provide in effect an easy form of adjustment. The two types can be

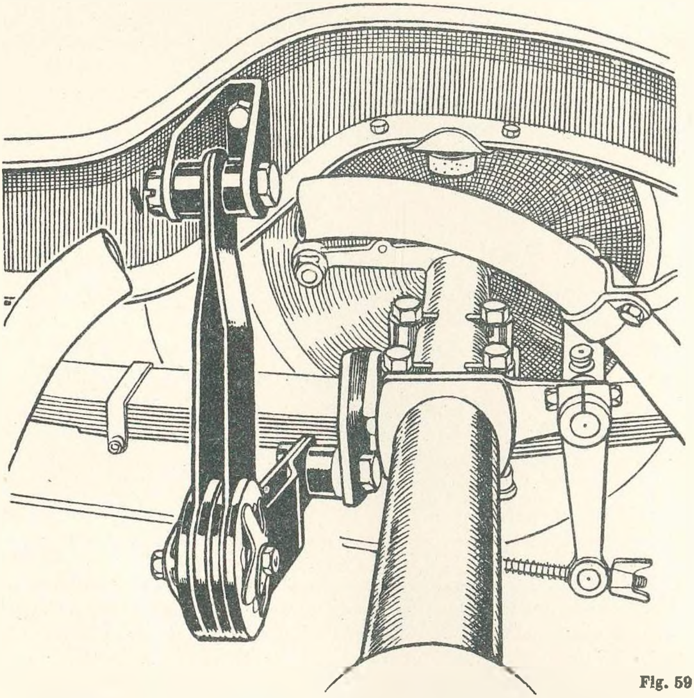


Fig. 59

HARTFORD FRICTION TYPE, DOUBLE-ACTING SHOCK-ABSORBER ARRANGED ATHWART THE CHASSIS

combined into one, as in a very expensive Continental shock-absorber in which the hydraulic mechanism functions so long as the shocks received by the suspension are normal, but any extra violent shock brings friction discs into play to support the hydraulic mechanism.

Again, the shock-absorber can be used with effect as a stabilizer, in which case the operating arms are placed athwart the chassis instead of parallel to it, the better to counteract any tendency of the frame to tilt relative to the axles.

Shock-absorbers are also used occasionally to damp the action of the steering, especially in older racing cars and some of the very high-speed record-breaking machines, the shock-absorber then being mounted as a brake on the action of the track rod.

CHAPTER FOURTEEN

THE DESIGN OF SMALL RACING ENGINES, AND SOME NOTES ON THE DIFFICULTIES LIKELY TO BE ENCOUNTERED

By H. N. Charles
Responsible for the design of the M.G. Racing Cars

EVERYONE interested in motors is bound to say at some time or another, "Now if only the designer had been a practical man like me, that trouble would not have happened." Few of us ever get the chance to design small racing engines, and the following notes convey the impressions of one who had that experience in designing small racing cars from 1930 to 1934, one of the cars designed in 1930 being at the time of writing still the holder of the official class record for maximum speed in the small-car class. This car, known to the drawing office as EX 127 and to the world at large as the "Magic Midget," is, in revised form, still being used.

Are such cars designed in an atmosphere of intellectual calm? How do you start? What tests do you make? Who pays for it all? How do you decide what to do next? A hundred questions spring forward to be answered, and the answers to some of them can be found by hard work and the co-operation of keen minds and clever fingers guided by someone with an instinct for the right course to follow.

First of all it is necessary to find someone whose enthusiasm is so infectious that he can persuade others to follow him. He will have many difficulties in getting a plan agreed on, and by the time agreement has been reached, the work will be urgent. The money and time available are always deciding factors, and your dreams of what could be done always change to morning daylight when you know how little money and time you can have for an enterprise of this kind. Such difficulties, however, are your job; if enough money and time were available the job could eventually be done by almost anybody; in the presence of actual conditions you know that real skill is needed, and your reputation depends on whether you have that skill and can stand the nervous strain of promising to supply all the answers on time.

The small racing engine first came into the limelight through the regulation limiting the engines in the smallest racing class for many events to 750 c.c. displacement, and because of the belief that extraordinary performances might be possible if such small engines were intensively developed.

The work done in this belief produced fine engines and fine men, and the work left its mark on the minds of petrol engine engineers all over the world.

Since we are primarily concerned with the engine in these notes, let us face up to our problem and see clearly what forces we intend to let loose and to control. To develop our power we intend to pass through our 750 c.c. motor all the air we can, and in particular all the oxygen we can, and to supply enough fuel to burn with that oxygen. Quite apart from whatever else may happen if we want to get five times the power, we must take in five times the air supply and fuel in proportion, and our tiny engine must burn all this fuel and turn its crankshaft harder and faster until five times the previous brake horsepower is attained.

Probably owing to extreme pressures, speeds, and the necessity for providing forced induction for the air, we shall need more than five times the normal air supply to turn out five times the brake horsepower. What a heat problem, what a mechanical problem! Can we ever do it? Won't it burst itself? Who knows these answers? We must have courage and go forward steadily into the unknown.

One thing, however, is now clear, and that is our starting point, which must be at the carburettor. "Show me the carburettor and I will tell you the maximum possible horsepower" is evidently no idle statement. Yes, our whole plan starts at the carburettor, which must be large enough to pass the air and fuel required in conjunction with a suitable compressor or supercharger to compress the mixture into the tiny engine. Of course, since it is more oxygen we want, it would be potentially better to admit more oxygen into the engine to burn the increased amount of fuel, but no simple means exists for separating the oxygen from the nitrogen in the air in the supercharger, and we are obliged to simply pump both into the engine in the increased quantity.

The carburettor-maker will quickly say how big the carburettor must be to pass the amount of air and fuel required for the intended horsepower, and the enormous size of it in relation to what is usual on such a small engine provides a clue to the next step in our train of thought.

Surely if the carburettor size is settled, the inlet pipe size is approximately settled, together with the inlet valve. This settles roughly the size of the exhaust valve, and the two valves with the sparking plug settle roughly the size of the cylinder head. This is almost a dramatic moment in our plans, because we suddenly realize that the most basic thing in our whole scheme is settling itself so quickly that we must evidently be tremendously careful in regard to exact proportions at this point because everything we propose to do afterwards, from the radiator to the back axle, will be affected by it to an extent which may cause serious delays.

We now have our basic source of horsepower production in front of us—the cylinder head. The mixture goes in, burns, and comes out again at the exhaust. What matter the size of the engine under the cylinder head. Put a small engine under a big head and put up the crankshaft revolutions until all the mixture the head can cope with is being utilized. Why worry about the engine; it is only the cylinder head that matters. Such thoughts run wild, but are evidently only partly true.

So great is the importance of the proportioning of this cylinder head that the art and philosophy of the subject contain alone sufficient work for several lifetimes of study, and since time is short you must usually guess the answers by reason and instinct, and guess them right.

On the engines dealt with by the author the type of cylinder head adopted was a compromise design capable of being machined mainly on existing jigs, the inlet and exhaust valve stems being sloped towards each other, and the sparking plug being positioned in a semi-recess which pointed at the exhaust valves to reduce detonation by burning the gas near the exhaust valve first, but at the same time keeping the actual sparking plug points reasonably close to one side of the inlet valve to ensure good idling. These combustion spaces could not be machined and had to be polished to correct volume by hand, but they were nevertheless very efficient if carefully prepared. One definite peculiarity has been proved to exist in connection with the cylinder heads of supercharged engines, which is that the port shapes must be as perfect as possible. Everyone knows that this is so in connection with engines having only atmospheric supply, and it was at one time assumed that in the presence of a high-pressure supercharger an extra pressure-drop across the valves of a pound or so per square inch would not matter. Actually this port or pipe resistance causes so much heat to be generated as to be a perfect menace to the success of the whole enterprise, and with high-pressure supercharging the most perfect possible ports should be used. And so we have found our starting point, and finally proportioned our cylinder head, including its inlet passages, exhaust passages, sparking plugs, water passages, and valve-operating mechanism.

When ordinary poppet valves are to be used, the design of the valve springs, cams, and rockers is in itself a special study peculiarly amenable to mathematical investigation. Parasitic disturbances may afterwards be experiences and cause valve-crash at an unduly low speed, but these can be dealt with by trial and error. Unless, however, the design is basically correct to start with, no amount of trial and error which is possible in the time can ever put the matter right. For a very high-speed engine the total duration of opening of each valve should be made as long as possible; otherwise, if a reasonable lift is given, the accelerations the valve springs have to produce become impossible, and the speed of the engine is limited by valve-crash. A well-designed valve gear for a 750 c.c. racing engine should not have its inherent valve-crash below 8000 r.p.m., and at these high speeds the valve springs must be designed to much lower stress figures than are usual in slower speed engines.

When it comes to finally designing the valve springs, it may easily be found that there is insufficient room for them, or that insufficient water space exists to cool the lower end of the exhaust-valve spring in an O.H.V. design, a state of affairs which causes endless difficulties in a practical design unless foreseen and allowed for right from the start. And so the cylinder head, the heart of a racing car, is born and developed, with seemingly definite possibilities of raising the power required. There is still, however, one great limitation not yet tackled by the head alone, and that is fuel detonation. No single factor in engine design has contributed as much to increased power production as have modern anti-detonating fuels. A fuel near the limit of anti-detonation as at present known is approximately as follows:—

Methyl alcohol, 50 per cent
Ethyl alcohol, 20 per cent
Benzole, 15 per cent
Petrol, 12½ per cent
Distilled water, 2½ per cent

Brake mean effective pressures of 335 lb. per sq. in. are quite possible with such a fuel, whereas 125 lb. per sq. in. would be about the limit with the petrol of twenty-five years ago, even with modern engines. The racing engines have been steadily altered to take advantage of improved fuels, whose action in preventing detonation is a triumph of modern chemical research, the great aim being to obtain anti-detonating qualities without high fuel consumption. A simple racing fuel such as the one mentioned above reduces detonation but increases fuel consumption very seriously, thus limiting its use. Petrol fuels are still being improved by means of chemical treatments, and may eventually be developed to equal the kind of "dope" mentioned above in respect of anti-detonation without its other disadvantages, such as high cost, high consumption, corrosion, &c.

Before leaving the cylinder head, some attention should be paid to the question of special cooling. If we are to have such a great increase of power, we are also obliged to face a great

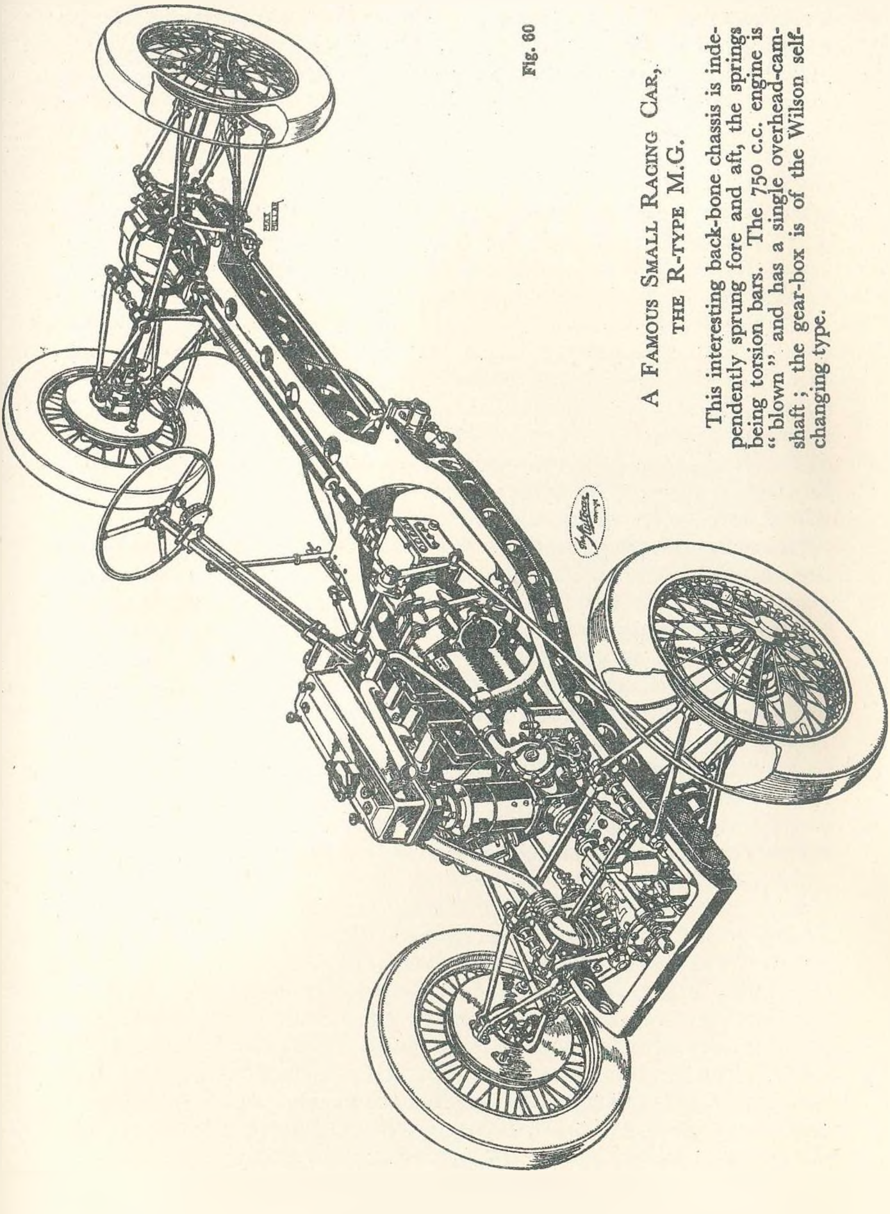


Fig. 60

A Famous Small Racing Car,
the R-type M.G.

This interesting back-bone chassis is independently sprung fore and aft, the springs being torsion bars. The 750 c.c. engine is "blown" and has a single overhead-camshaft; the gear-box is of the Wilson self-changing type.

increase in heat lost to the cooling water. To meet this difficulty it is essential that the cylinder head for a modern small racing engine should be made of material having the highest practicable thermal conductivity. Cast-iron cylinder heads are cheap and make a fairly good valve seat, but beyond a certain point they are hopeless for racing. The design of the cylinder head may be affected by the type of high-conductivity metal selected, since each type has its own peculiarities when in the molten state in the foundry. Every cylinder head was molten once; it is only a question of what has happened to it since—now and again they begin to become molten in use, and the "expensive noises" begin immediately in that case.

To prevent local boiling in a cylinder head it is a great advantage to have it under a slight pressure; even the water-pump should always be allowed to help by pushing the water into the cylinder head, and never the opposite. Such artificial aids as ethylene-glycol, or other substances to raise the boiling point of the liquid, can help up to a point, but their use is again usually limited by the fact that they tend to reduce the amount of heat which any given volume of water can carry away.

Sparking plugs again are a serious problem, the most obvious but usually overlooked fault with them being that they must be a good fit on the thread. We all experienced a thrill when the full possibilities of the 14 mm. sparking plug were tried out on the drawing-board in relation to improved port design; but even these plugs, with their reduced capacity for receiving heat, may still hardly cope with the conditions in a highly boosted engine.

Inlet pipes on these engines are again of peculiar interest, being a law unto themselves in each case. The brain of man is apparently not equipped with the necessary capacity for handling enough multiple variables to enable him to propound any entirely satisfactory analysis of the action of an inlet pipe over a wide range of speeds.

Forecasting the best design of inlet pipe is like forecasting the winner of the Derby—there is a doubt about it because even the weather may be a factor in the results.

A great deal is heard about exhaust systems, but actually the importance of this subject is much less than is ordinarily supposed unless extreme silence without loss of power is aimed at, in which case the whole problem becomes at once of great engineering interest, since recent researches into the nature of exhaust noise have shown that, to obtain perfect silence, it is not basically necessary to obstruct the gas in any way or even to cool it. The gas might be heated instead of cooled, so far as that is concerned, provided the discord of musical notes in the gas column itself is effectively damped out. An analysis of exhaust gas noise proves the presence of notes of all kinds, from very low notes to very high ones, and very efficient straight-through silencing systems exist for removing the high ones at any rate, and sometimes the low ones also, though this is always much less certain.

It has now been proved that there is no necessity whatever to have the exhaust valves anything like as large as the inlet valves, even when very high-pressure supercharging is used. This seems quite reasonable in view of the high exhaust pressure available to drive out the burnt gas, but it certainly needed a certain amount of courage to incorporate this feature in a new design. The exhaust systems of racing engines are often controlled by rules such as the Brooklands silencer regulations and others, and these may create incidental problems of an awkward nature; how often such pipes break their brackets and come loose, for instance, and how difficult it is to make sure that this is not going to occur. It is also of interest to observe that the flame frequency through the pipe itself has a great effect on the pipe temperature, four separate pipes from a 4-cylinder head keep quite cool until they join into one, and the temperature at the junction is very high indeed. Exhaust pipe temperatures are very likely to become serious on supercharged engines. The writer recollects driving one at Brooklands in the twilight late one evening in the autumn, and wondering where the bright light under the bonnet was coming from. It happened to be not a racing car but an ordinary supercharged sports model, and on opening the bonnet to see what was alight, the exhaust manifold lit up the scene for some distance on the near side of the car.

Tail pipes as a rule are made much larger than is necessary, with a consequent increase in weight. The Brooklands tail pipe rule allows for only a very small pipe, but except when very high supercharger pressures are used, the loss is not great.

Underneath the cylinder head we have to place the engine proper. Where swept volume is limited the idea, of course, is to place the smallest possible engine under the largest possible head, the limiting factor being only the compression ratio, which becomes impossibly low if the idea is carried to extremes. However, using very high supercharge a low compression ratio in the engine is necessary, and a very small engine can then be obtained in proportion to the size of the head.

Great difficulty may easily arise in connection with making a joint between the cylinder head and the cylinder block. Nearly everyone connected with racing has had to make wild last-minute experiments of one kind and another in this connection to deal with serious leakage at this point. The writer was once very harassed on this score, and walking quietly alongside the Thames near Oxford, watched some men mending a weir. They put boards up side by side and an old man then threw ashes into the river to fill the cracks as they pumped out. This immediately led to the idea that we might blow burnt oil and carbon into the joint if a washer could be made to receive it. The body shop happened to have a piece of mild steel sheet which was remarkably even in thickness, so a gasket was cut from it and lapped on. The edge of the gasket was stepped back a millimetre all round the combustion space to trap any available burnt oil or carbon, and so the first successful gasket was born for our high-supercharge engines. As an example of the self-sealing properties of one of these gaskets, a car in the 500 Miles Race with a properly fitted steel gasket lost all its water from a broken radiator hose and came in with the head blowing badly. When things had cooled off a bit, a new hose was fitted and we filled up slowly with water, everyone wagging their heads on the job, however, since the cylinder head joint having blown it was assumed useless to continue. Inside three laps the car was up to normal lap speed, and eventually finished the race with its head joint quite perfect again.

Now what about the pistons, connecting rods, crankshaft, flywheel, &c.? Are they as hard to design as the cylinder head? The answer is both "yes" and "no." There are some very difficult problems down below in the engine, but very skilled assistance is also to be had in dealing with some of them, pistons and piston rings for example. Few people realize that the piston is one of the most important problems in the design of the whole engine. More horsepower can be lost in friction at the pistons than anywhere else; in fact, in extra-high-speed engines small alterations in the piston design of an apparently trivial nature may easily result in a 10 per cent improvement in brake horsepower; or a 10 per cent loss, the difference between the two being equal to quite a large change in the supercharger pressure. The high-speed engine puts a tremendous amount of heat into its piston owing to the frequency of its explosions, and the piston-tops only too easily become weakened by the resultant high temperature. At present it appears certain that nearly all the heat which enters the top of the piston passes to the cooling water via the piston rings. There is a film of oil of appreciable thickness between the slipper surface of the piston and the cylinder wall, and the heat only passes through this with difficulty, causing a severe temperature gradient. The piston rings make contact with the cylinder wall and scrape away nearly all the oil, thus providing a suitable path for the escape of heat. It is this condition which for so long retarded the development of the sleeve valve engine, the old double sleeve valve engines, for instance, having an oil film between the piston slipper surface and the inner sleeve, another between the inner and outer sleeves, and another between the outer sleeve and the cylinder.

This made it basically impossible to achieve anything but quite low-power outputs in proportion to engine size when using double sleeves. Now that the true facts are coming to be realized, designers are beginning to be able to utilize sleeve valves and make them successful, which might have happened long ago had better research facilities been available at that time.

So difficult is it to design a really good piston that it is safe to say that the man is not yet known who can guarantee to do it at the first attempt except in the simplest case. On all high-performance engines careful tests of the engine are essential, and such matters as the water circulation through the cylinder block must be settled at the same time, as this may easily affect the final shape and clearances of the piston. One sometimes comes across specially shaped piston-tops, and these shapes may be important. Usually a flat piston-top is all that is needed on supercharged engines, but on unsupercharged engines with high compression ratios the piston-top may have to be shaped to assist flame travel, provide clearance for the valves, or both. Very peculiar results can definitely be produced with high-compression engines, one case where the writer recorded a failure being the absolute refusal of the mixture to burn more than half-way across the top of the piston. After half an hour, the pistons when examined proved to have a slight carbon deposit half-way across, and the remainder clean bare aluminium alloy which looked as if it had never seen a flame. In this case we had to tilt the piston-top to get successful burning right across; the idea was proposed by the foreman on the job, who said, "You want to hold the gas on the far side well up, hold it up so that it can see the flame," and his idea was correct in that instance.

The question of flame travel having been touched upon, we cannot leave the subject without a reference to detonation, or "pinking," as this is always a limiting factor in the performance of small racing engines, or any larger engines for that matter. "Pinking" started before the war and was diagnosed as a "gas knock" by the leading spirits of that time, but from then till now real progress in understanding it has been slow. This is most reasonable because progress in understanding anything complicated is always slow; if the subject is sufficiently complicated it is never fully understood. Some facts, however, do emerge by experience regarding detonation, a most important one being that the flame always starts at the sparking plug and hence the detonation is most likely to occur at some distance from the plug. Once the gas has burnt, detonation is no longer possible. Whilst it is agreed that port design and combustion space shape can influence detonation to a considerable extent, the fuel itself is the real factor, and even the best modern engines

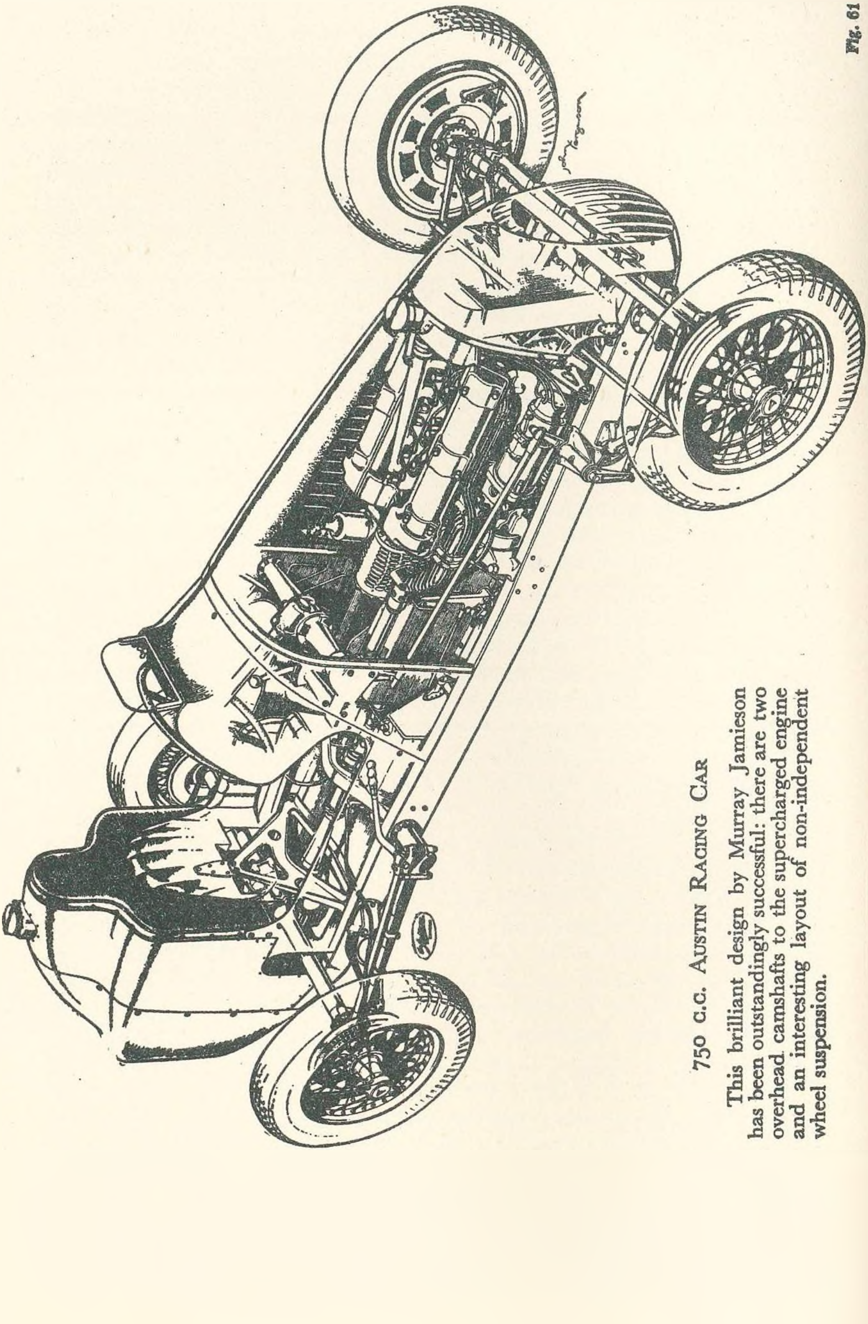


Fig. 61

750 c.c. Austin Racing Car

This brilliant design by Murray Jamieson has been outstandingly successful: there are two overhead camshafts to the supercharged engine and an interesting layout of non-independent wheel suspension.

would detonate badly on fuel of lower rating than that specified after tests have been made.

Poppet valves have become quite a study these days, the latest types being very clever indeed. On small engines simple valves are usually the best, it being possible to get rid of the heat through the valve guides and valve seatings in the ordinary way, but on larger engines the conveyance of heat along the valve stem is a considerable problem, hence the very beautifully designed sodium-filled (or half-filled) valves, some of which are formed from a sheet of metal being shaped right over, forming a hollow head and a hollow stem. No one knows how much longer the poppet valve will last for small racing engines; with all its faults "it's brutal but it works," to quote a famous remark in regard to another part of the car. Given the necessary number of thinking hours and a reasonable sum of money, much better valves than poppet valves could eventually be developed; but even if such a valve were believed known to-day, few people would want to include it in the design of a new racing car for the first season or two. Racing conditions are so severe that it would be best to acquire skill in using the valve on the test bench and the road for a good long time beforehand.

Racing cars have to be prepared and repaired very quickly to meet practical conditions in a season's racing, and skill in dealing with such problems is not rapidly acquired. Lower down in the engine we have the connecting rods and crankshaft to consider, these two items being very closely related. Actually all big-end bearings and all crankshaft main bearings should be self-aligning in a racing engine to allow for the whip of the crankshaft. No one has yet developed an entirely satisfactory method of doing this, and we all know that the loads on these bearings are very difficult to determine in consequence. At very high speeds the inevitable shaft deflections tend to load the bearings very unevenly. Taking conventional design as a basis, it has been the writer's experience that on small racing engines great stiffness is essential in the bearings themselves, and the oil temperature must be kept low. The bearing clearances must be adjusted to allow a reasonable flow of oil through each bearing at the standard oil pressure adopted. If one bearing is tighter than the others less oil will flow through it, and the temperature of the oil leaving the bearing may in consequence become dangerously high with consequently increased risk of failure at that bearing. Every possible effort should be made on high-speed engines to make the bearings float on the oil film. Instances are known where, when using benzole fuel, the white metal bearings turn quite dark brown, and when removed for examination show no signs of wear at all. This dark-brown deposit is not produced to any extent when using alcohol fuels, and it is less easy to judge the state of the bearings in consequence.

Much can be written regarding counterbalanced and non-counterbalanced crankshafts, but since light weight is essential nowadays, every effort should be made to avoid heavy counter-balanced crankshafts; hence the inference above to the need for developing self-aligning bearings if power outputs are to increase.

On high-speed engines very difficult conditions will be found to exist, due to the centrifuging of solid deposits out of the oil in the crank pins. These deposits are unaffected by oil filtration, and can only be prevented by careful choice of oil. There is, in fact, much to be said for drilling the oil-ways in crankshafts in such a way that no centrifugal traps are formed, or else going to the opposite extreme and providing an ample trap capacity; a middle course may be a failure in this instance. Oil cooling has already been referred to, and is again a special subject. Where weight and space allow, the introduction of separate oil-coolers is a great advantage provided they can be successfully protected from flying stones.

On very small racing cars it is often sufficient to use a large sump cast in magnesium alloy with the necessary cooling fins. This method involves little risk of injury to external piping, but the amount of heat which can be got rid of from the sump is rather limited. It has also been found that these sumps do very little cooling on the test bench even when cold water is sprayed on them, and their action is partly dependent on the oil in them being well shaken, no doubt to prevent a coating of cold oil forming and acting as a heat insulator around the pool of hot oil in the sump. The great improvements in suspension which will eventually become possible now that the theory of suspension is more fully understood may tend to make this method of cooling much less efficient.

Our notes must now close with a few general remarks, leaving many subjects untouched, but the writer feels that any readers who get this far may be glad rather than sorry on that account. The scope of our subject makes it essential to refer to some extent to the car itself, since this influences the engine design. The small racing cars of the past, converted from sports car chassis, required but small departures from standard engine practice to produce the results required, but as cars themselves improve, the engine must tend to be designed specially to suit the layout proposed.

No matter how much power the engine can produce, the actual performance of the car is controlled by the grip of the wheels on the road. With cars having a very low centre of gravity the weight transfer on to the rear wheels when accelerating is quite small, and to get more than a certain figure of acceleration, rear wheel drive alone is insufficient. If, therefore, the power-to-weight ratio of the whole car is improved by better engine design beyond a certain point, the engine itself will probably have to be entirely re-designed to provide four-wheel drive during the accelerating period. The advent of automatic gear-changing as a possibility would also tend in the same direction as the risk of wheel slip would, if anything, increase on that account. Stability at high speeds may also impose definite weight distribution requirements on the car designer, which no longer allow the engine to assume any arbitrary shape to suit itself. Skill in engine-designing is increasing so fast that we may eventually be able to fit a power plant into any shaped space which it is best it should occupy. If small racing cars continue to develop, it is becoming more and more certain that the whole car will have to be laid out in one man's mind as a thing complete in itself, and that man must know what can be done in all parts of the car, including the engine.

It now seems certain that even in small cars the problem will no longer be how to get enough horsepower, but how to use the power which can be provided. At the risk of being accused of provoking controversy, let us look at an approximate specification of what might be considered an "advanced" small racing car on the drawing-board of the present day, the reader being then left to speculate on the details or on other possible arrangements, whichever he prefers. The car would be a skin-stressed structure built without a chassis, this being essential to obtain the figure of torsional rigidity modern suspension would require. All four wheels would be independently sprung, with "track variation" or equivalent methods for preventing roll on corners, the front frequency being lower than the rear. The engine and the driver would constitute the two most important masses in this very light small car, the big petrol tank, whose weight changes as you go along, being probably placed in the middle between them. Owing to the lightness of the car it would probably be impossible to place the brakes in the wheels, and since four-wheel drive is essential and very refined designs of universal joints are possible, the brakes would probably be mounted on the chassis and water-cooled by passing their cooling water through the main radiator. Entirely automatic gear-change would, of course, be used, since several good designs exist, although they are more expensive and so have not yet come into general use. Probably the rear wheels alone would be used for the drive at speeds above 80 m.p.h., but the necessary disconnection would be automatic. 150 h.p. per litre would be quite a safe figure for a modern small racing engine, and the engine size should be adjusted to suit the performance required; by using excess boost 200 h.p. per litre could be obtained for short periods.

The streamlining of the car could be carried to extremes only if it is intended for running in calm weather. For road racing in windy weather a streamlined body of short length and exposed wheels is unavoidable to prevent the car being lifted off the road sideways by gusts. Possible modern refinements could include an automatic exhaust gas analyser of the hot wire type correcting the mixture at all times by controlling the carburettor through a relay.

And so thought travels on through the many possibilities until finally it returns to the beginning of this article, where the other deciding factors, money and time, are mentioned.

Who has the money, who has the time for these small racing cars? Who knows?

Plate 41. [*Mercedes Photograph.*

FINAL ADJUSTMENTS.

THE EARLIER TYPE MERCEDES-BENZ STRAIGHT-EIGHT ENGINE. IN THIS DESIGN THE SUPERCHARGER BLEW AIR THROUGH THE TWO CARBURETTERS.

CHAPTER FIFTEEN

PREPARATION OF RACING CARS

By W. Hassan, A.M.I.A.E.
One of the Chief Mechanics of the Bentley Racing Team

THE preparation of a car for racing is largely a matter of compromise, as is, for that matter, all engineering. It is always a case of making the best use of the materials and time at hand, and bound up with this is the unfortunate problem of finance. How few people realize the cost of labour until they receive their account! In connection with this question of cost, it pays to think well into the future, and arrange for the work to be carried out in such a way as to cut out the excessive amount of overtime which is worked in this racing game. Workmanship always deteriorates in proportion to the lateness of the hour worked, and the job suffers accordingly. Of course on occasion it is found necessary to burn the midnight oil, and much good work has been done, but it is to be avoided if at all possible.

The actual work to be carried out depends on three things: firstly, the type of race entered; secondly, the car selected for the job; and last but not least, the amount of cash available. There are two types of race: the Grand Prix type, and the long-distance endurance races for sports type cars. Of the two, the latter requires the most preparation, in my opinion, although it is equally vital for both.

In the case of the Grand Prix type racer everything is cut to the limit of safety in the quest for lightness, and engines are boosted to the limit to last just long enough. There is now no question of pit repairs—the loss of a few seconds will put one right out of the running; the reliability of the modern motor has reached such a high standard, a pit stop other than for refuelling is now the exception rather than the rule, as in the old days.

In the long races, such as the Le Mans 24-Hour, it is possible to make up time lost at a pit stop if the car has speed enough, but as compared with a stripped racing car with only the bare necessities of traction, the sports car has many more components which are possible sources of failure, such as electrical equipment, wings, spare wheels, &c. Head lamps have been known to go out down the straight at Le Mans, and to be suddenly without light at 120 m.p.h. on a fairly narrow road is no fun at all.

Some cars lend themselves to preparation for racing more than others, and those developed from racing experience, of course, are the most satisfactory. Having acquired a car, we will take it for granted that it is of a suitable type, and is fitted with all the sports equipment, quick-action fillers, &c. The first thing to do is to strip it down to the last bolt. Having done this, and laid the parts out for inspection, we should take the engine first and examine all parts thoroughly. The connecting rods would need to be balanced accurately, both the big end, and the small end, the method being to get them down to the weight of the lightest of the set, and at the same time arranging to remove the metal from the correct place so that the point of balance is identical on all the rods when the shank is balanced on a knife edge. These rods should, during the balancing process, be polished all over, all scratches and surface blemishes removed, then, with the crankshaft, it is advisable to have them tested for cracks on the electromagnetic type of crack-testing machine; this will show up any crack which may not be visible to the eye. This all being satisfactory, one may proceed to get the bearings metalled and machined, care being taken that the correct nip is given, and that the bearing shells fit their housings perfectly; modern methods of machining bearings produce results which are infinitely better than the old method of hand scraping, it now being necessary only to remove the machining marks, and any high spots round oil-holes, &c., by hand. The flywheel can usually be lightened considerably with beneficial effects on both the acceleration and on the magnitude of any crankshaft torsional vibration which may be present. It is very important that this component should be balanced carefully and that its attachment to the crank should be sound.

The cylinder head will require attention, the ports polished, and all rough seams and sharp corners removed, valve seats cut and ground with no ridges, manifolds and carburettors mated correctly with the ports, and water-ways cleaned out, making certain that all core wires and loose pieces are removed. The valves should be made of good-quality steel, and top edge, which is exposed to the combustion chamber, well radiused to minimize the burning effect which may start if the edge of the valve is left sharp and square. Valve springs should be checked for strength, and any out of standard changed. Rockers, push-rods, &c., should be well scrutinized and polished, any excess metal removed, as every dram on the valve-operating mechanism adds to the work of the valve spring, and will tend to accentuate valve bounce and kindred troubles. Cylinder head studs are to be treated with suspicion and should be made of alloy steel of about 60-ton tensile. This will save the snag of the broken stud on the day before the race, and is well worth the little extra expense. The cylinder head will need to be scraped flat and true to a surface plate, as should be the top of the cylinder block, then the two lapped together, making a 100 per cent joint. This joint is most important, and has caused more trouble than any other. It is advisable to make sure that the water-ways of the head and the block match up properly, to assist the cooling as much as possible.

When the engine is erected finally it is absolutely essential to exclude all dirt and foreign matter, and the best way is to erect with as little delay as possible. All fitting jobs should be finished and parts washed off and laid out just prior to commencing erection, then a straightforward job is made of building up the engine complete. It is bad policy to build, say, the crank case and bearings, and then put it by while the cylinders are operated upon for a day or so. It will not matter how carefully you cover it up, dust will find its way in, and eventually it will enter the bearings, get embedded in the metal, and will then do its worst. In erection great care in timing the camshafts and ignition is taken, and should be checked on every cylinder in turn, and if any great variation is found steps should be taken to rectify it.

We will now leave the engine and take a look at the chassis. The steering may well be taken first. All steering arms and links ought to be filed up and polished all over, then, with the axle beam and stub axles, subjected to the electromagnetic crack test. When erecting the front axle all bushes must be absolutely free, but at the same time must have the minimum of shake, as any slackness in the swivel pin will result in loss of stability and accuracy of steering. Spring shackles and mountings also contribute largely to the road-holding or otherwise of the car, and should not be neglected. Even at the present time insufficient care is bestowed upon attachment of that most important part of a car, the shock-absorbers. A great deal of thought should be given to the brackets and method of mounting, as many frames have had sections pulled out as a result of haphazard hanging on of shock-absorbers. It is to be recommended that all bolts used on the car should be of high-tensile steel and that they really fit the holes into which they are placed. Furthermore, all nuts that have any job at all to perform should be split-pinned; this split-pinning serves a double purpose. Firstly it positively locks it, and secondly it acts as a visible check, and nothing looks more like a job than a neatly turned split-pin in a castle nut.

Brakes play an important part and need careful attention. At this stage all the rods should be examined, and any with kinks or bad threads should be scrapped. In the case of an hydraulic system the tubes should be treated with extra respect. Great care is needed that the tubes are securely clipped in such a way that no vibration can be set up; that they should also be laid where they are safe from accidental damage; that is, where no mechanic's boot can rest on them when he is removing the clutch, or a crow-bar touch them when prising the engine into position. It would also be fatal to this system if the heat from the exhaust or engine could reach the pipes; therefore much forethought is required on this job.

All moving parts of the brakes should be made as free as possible; that is, in the case of the mechanical operation, but lost motion must not be permitted. It is advisable to consult the brake-lining companies as to the type of lining which will give best service, it depending entirely upon the material used for making the brake drums.

The fuel tank and pipes are often neglected and have at times been a source of trouble, so that here again one may save much by adequate consideration. The tank should, of course, have sufficient capacity for your needs, and would be designed accordingly. It should be made strongly by a conscientious tradesman, as once it is soldered up no one can tell how badly it is made until it leaks, and then it is too late to rectify it. The tank must be built thoroughly from the start, and it is well worth paying the higher price which will be charged for such an article. The pipes supplying the carburettor should be large enough to pass at least 50 per cent more fuel than the engine can possibly burn, and it is advantageous to have the feed in duplicate, controlled by suitable cocks. These pipes require adequate support in the form of clips at frequent intervals along the chassis, and where it leaves the frame to connect with the tank and engine some form of flexible joint is necessary so that these components may move in relation to the frame without causing the pipes to fracture. These joints, if made in petrol-proof rubber, are quite satisfactory providing they are changed at least once during every season. Petrol pumps, electric or otherwise, should be tested for flow when mounted, and connected to the pipe-lines and carburettors, as insufficient fuel flow is often the unsuspected cause of lack of performance.

The exhaust system must be soundly constructed, with sufficient clips made and placed with an eye to strength with lightness, and it is a good scheme to incorporate a sliding expansion joint where the manifold connection enters the silencer or tail pipe.

In the case of a sports racing car the electrical system must be thoroughly attended to. The dynamo is usually specially wound for sports work with a higher cutting-in speed than usual, in order that it may stand up to continuous running at a high rate of r.p.m. The wiring must be most carefully laid and clipped out of danger, and through insulating bushes so that vibration will not cause them to chafe through and short. Also, there are many little nuts and screws which must be locked—soldering is most satisfactory—as any one of these many tiny screws can lose the race if they slacken off. Head lamps can, as has previously been mentioned, cause the driver to have uncomfortable moments.

Coach-work is not always above reproach, and such points as clearance over wheels, axles, and shock-absorbers, &c., should be carefully checked up and a little extra allowed, as most remarkable things happen to a chassis going round a race track in the way of deflection and twist. Brake connections deserve special attention wherever the body approaches them. Spare-wheel brackets and wing supports need a technique of their own, and, providing that the wing itself is light and the supports are well placed and the frame suitably strengthened where these parts are attached, there should be no shedding of wings, as has happened many times previously.

One of the most important items in the tuning of a racing car is the correct interpretation and application of the rules of the race for which it is being prepared. Size of bonnet straps, seat dimensions, area of driving mirror, racing numbers, &c., they all seem such petty affairs, but how small ones feels when "Mac" turns one down at the weigh-in and says come back later! This sort of thing always stops the more important adjustments being done properly. Take, for example, the trouble caused if, the day prior to the race, one has to re-stuff the cushions so as to support the stipulated weight at the correct measurement from the floor, especially if the driver cannot now get under the steering-wheel! This has happened on quite a few occasions, and it is well worth consideration when building the car at the beginning.

Of course, after the car is built up, the exciting day eventually comes when it is tried out. After the car has been run in sufficiently to bed in the piston rings properly, and any minor adjustments made—quite a few are usually needed—the all-important question of carburation is now to be tackled, and it is quite a sticky problem with this liquid dynamite fuel which has to be used nowadays. If one is not careful, getting the gas-works right may cost the price of quite a few pistons. It is advisable to start on the rich side, gradually working the revs. up, cutting, and examining the plugs at every change until they show a correct mixture right through the range. This should be done and a note taken of the carburettor setting in relation to the temperature and weather. It comes in very useful when, after having beautiful weather in practice, on the morning of the race it suddenly changes—modern racing cars are very sensitive to atmospheric changes.

There are many things to test. The brakes have to be altered sometimes in order to adjust the percentage of braking fore and aft of the car, and it is a very good thing to practise on a set of spare brake shoes, changing before the race to a new set which have been previously fitted up and tried. This is most necessary, as it is foolish to start a race on a set of virgin liners; there is always the preliminary expansion to account for, and it takes some time before they bed down to show 100 per cent marking. This is worth spending quite a fair time on, as a few high spots will soon ruin a perfectly good brake drum.

One most important thing to check is the consumption of fuel. Many a race has been lost through a miscalculation of the amount necessary to complete the course. The method adopted is to get the car out on the course, mark the place upon which it is standing, then measure the height of fuel in the tank by means of a metal dip-stick. Wood is no good as the fuel creeps up and spoils the accuracy. The driver is then sent out to complete a few laps at racing speed, after which he should pull in on to precisely the same spot in order that the car may stand at the same level, and the tank then topped up from a measure, careful note being made of the quantity. In this way a fairly accurate estimate of consumption may be made. The oil may be treated in a like fashion. These tests must, of course, be carried out when all the tuning, &c., is complete, and the car is exactly as it will run in the race.

Pit work and equipment is, of course, more in the public eye than any other part of this racing preparation, and certainly it plays a very important part. The equipment must all be made and tried out under correct conditions, the jacks must be able to lift the cars on the ground outside the pits—and this surface can vary very considerably from the ideal garage floor. It is well to practise a few of the common occurrences, such as changing plugs when the engine is hot. This can cause quite a lot of fun, especially on an old type Bentley.

The fuel-filling appliances must all be tried out, funnels fitted with gauze of sufficient area to pass a churn-ful of fuel without spilling, and fine enough to catch water, since it does happen sometimes that the race is run in rain. Very interesting gadgets have been evolved in connection with this quick refuelling at times. I remember that we made a mechanism once that opened the oil-level overflow valve when the oil cap was opened. Then the overflow valve was shut when the driver depressed the clutch pedal to engage first speed. The mechanic then would not have to close the valve and so valuable seconds would be saved.

The road wheels must, of course, be tried on the hubs, oiled and kept clean so that they slip on and off with ease.

A most important job in the pit is that of the man of figures, who, with a complicated system of charts, can tell the pit manager almost anything he requires to know about the race: as, for instance, the position of any car at any time; the distance the car has gone; how many laps he has to go on the fuel he has in the tank, this providing the fuel-consumption test was accurate.

A combination of first-class preparation, driving, and pit management is necessary to win races at this present time, and a better example of this than the case of the Princes Chula and "Bira" would be hard to find.

There is one other point which should be observed, and that is to come to the line with a car which looks the job, and this should not be neglected. The car should come to the line looking spick and span, nicely polished, with clean windscreen and body. It looks as though some pride has been taken in the job, and while one is going over the car with a polishing rag it is often the cause of spotting some little forgotten something which could be improved and might easily otherwise have escaped attention, while at any rate it helps to raise the tone of the show.

CHAPTER SIXTEEN

PIT MANAGEMENT & CONTROL

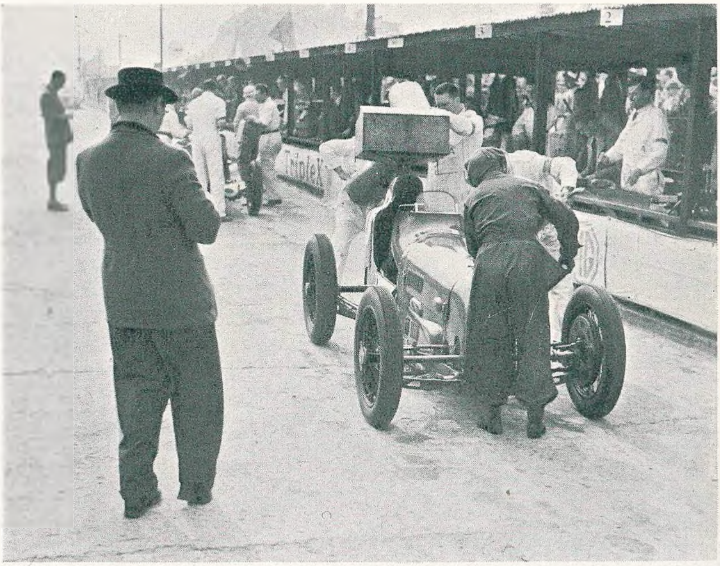
By S. C. H. Davis

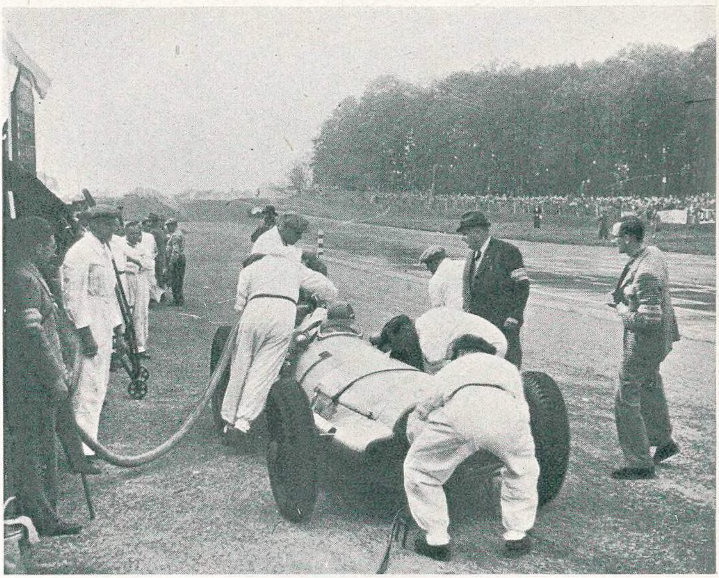
IN racing, especially where a team of three cars is concerned, the pit, its personnel, and management is of the utmost importance. Since the term may be odd, a pit is just one of a series of sheds erected near the grandstand on a racing circuit as depots to contain all the spares, fuel, oil, water, or tyres the racing cars may need, and also the mechanics. Nowadays these pits can be very elaborate, and though usually of wood, are sometimes even of concrete, forming permanent structures with a grandstand on their roof, but the name "pit" persists because that was the term for the first of these depots ever used, a pit dug in the grass border of the road.

According to the rules, all assistance the racing car may need must be obtained only at the pit; anywhere else on the circuit trouble must be overcome by the driver unaided in any way.

Now it is perfectly obvious that a car will need more fuel and oil, probably more water, certainly more tyres, during the course of a race; equally obvious that the time the machine is stationary for refilling has to be made up during the race, and has in any case to be as short as possible. That in turn means a high degree of organization. Firstly, the mechanics have to be trained so that when the car comes in each man knows exactly what to do, has practised until he attains nearly to perfection on his particular job; can, moreover, do that job at speed but without interfering with his fellows. "At speed," incidentally, does not mean rushing about, but doing the job with the minimum amount of movement, in the most economical way.

The exact routine is necessarily governed by the number of mechanics. Sometimes there will be one, sometimes two, sometimes three, the necessary jobs being divided up as requisite. When the car stops, front and rear axles have to be raised. That means the provision of a light but effective jack made of steel tubing so designed that by placing the two curved heads of the jack under the axle one movement of the lever will raise the axle so that the tyres are clear of the ground, and subsequently one other movement will drop the car off the jack. The jack itself is usually provided with little wheels because its action would otherwise entail moving the car forward or backward, and it would be manifestly impossible to jack up both axles simul-



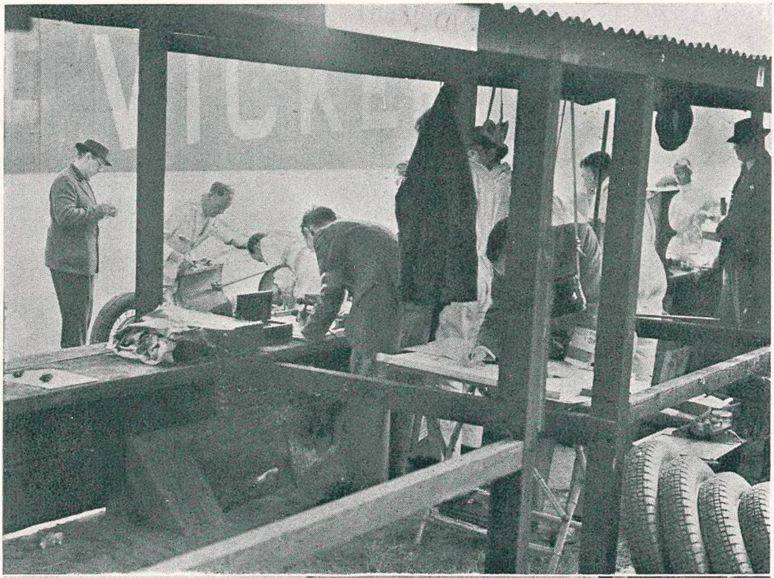


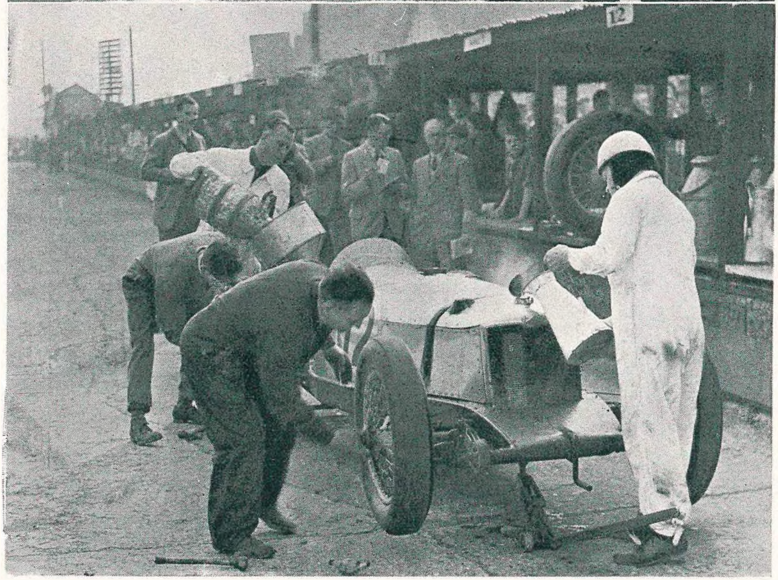
Plates 42 and 43. [*Photographs : " The Autocar.*"

REFUELLING AND PIT-WORK.

Above : REFILLING AN AUSTIN DURING A RACE, THE FUNNEL BEING SPECIALLY DESIGNED TO PREVENT FUEL FROM SPLASHING OVER THE DRIVER.

Below : REFILLING A GRAND PRIX MERCEDES AT DONINGTON. FUEL IS BEING FED BY PRESSURE THROUGH THE HOSE, WHILE THE REAR WHEELS ARE CHANGED, AND A MECHANIC HOLDS THE ELECTRIC STARTING MOTOR AT THE READY IN FRONT. THE OPERATION IS BEING WATCHED BY THE MANAGER, HERR NEUBAUER.





Plates 44 and 45. *Photographs : "The Autocar."*

Above : INTERIOR VIEW OF A "PIT" AT BROOKLANDS.

EVERYTHING THAT MAY BE NEEDED IS LAID OUT ON THE COUNTER, AND AT THE BACK MAY BE SEEN THE CHART KEEPER AT WORK, KEEPING AN EXACT RECORD OF THE POSITION OF HIS TEAM IN RELATION TO OTHERS.

Below : WHEEL CHANGING AND REFILLING.

MANY VALUABLE SECONDS CAN BE SAVED BY SMOOTH ORGANIZATION.

taneously if this movement were allowed. Further, the column supporting the head of the jack must be at such an angle that the car when raised will not accidentally fall off the jack. Sometimes a mechanic, sometimes a driver, can use this jack while another man knocks off the wheel nut with a hammer. Here again the man concerned should have a hammer of his own of a suitable weight that he knows well, and the wheel nut should be kept quite clean and so fitted that, after being freed from the hub, it will spin right off the thread when hit hard.

The man at the wheel can commence operations before the jack lifts the car, which is worth noting, but must finish before the jack is withdrawn.

When the car pulls up it must be in such a position that the mechanic can withdraw the wheel, throw it on to the counter, lift from the counter the new wheel, and place that wheel on the hub without having to take a step one way or the other. The car should obviously be stopped in a position allowing the man freedom of movement when tackling a near-side wheel. All this means that the driver must stop the car with one front wheel almost touching a special signal held out over the counter so as to get the car in the right position.

The rear wheels are dealt with in similar fashion, but it has to be remembered that the driver cannot release the jack because he should already be in his seat ready to re-start, and unjacking may be the last operation of all. One of the mechanics must also know that he has to start the engine with its handle, with the special electric starting motor acting in place of the handle, or by pushing, in which latter case he should know exactly which side of the tail he has to be when pushing.

The refilling process depends on what regulations are enforced. If 5-gallon churns are necessary, a mechanic has first to open the filler cap if the driver cannot perform that operation just before stopping, put in the funnel, then pour in the contents of churn after churn until the tank is full. Obviously, therefore, the churn should be very light indeed—the churns I have used only weigh 10 lb. 3 oz.—the design should be such that the handles are exactly right for the man lifting the churn, the mouth of the churn should be specially formed so that the fuel will flow out at high speed in a broad stream without splashing, and the churn must not be full to the brim when it takes five gallons, otherwise, when the mechanic lifts the churn fuel may splash in his eyes.

Before the churn is actually needed it will be on the counter and then must be covered by a lid. If the churns have internal marks, gallon by gallon, it is usually possible to estimate the fuel consumption of the car with reasonable accuracy, and the marks facilitate the mixing of the fuel, which may be of two different kinds in some odd proportion.

As to the funnel, the first necessity is that it should be able to take the contents of one churn at the highest possible speed. That means that the funnel spout must be large and also that the air in the car's tank can escape as quickly as the fuel runs in, which may entail two fillers. A crinkly gauze in the funnel prevents fuel splashing out, and the edge of the funnel can be shaped to the same end. The sooner the nozzle is covered by fuel in the tank, the sooner air is prevented from trying to escape up that nozzle, thereby impeding the fuel. Since a funnel of this type may be heavy though made of light alloy, it should be provided with legs or steadies to support it steadily on the car's tail.

It is most essential to avoid splashing any of the fuel over the driver, or spilling a quantity round the car. A special baffle on the driver's side of the funnel is worth having, and if it is best for the driver to remain in his seat during refilling, it is usual to cover him with a fuel-proof hood, which needs careful design. The essential thing is to know when the tank is almost full, so as to stop any further fuel in time. That is where two fillers are useful, for the mechanic refilling can then see through one filler the state of affairs in the tank. One funnel we used had a slide valve in its spout. The moment the fuel rushed up the filler the mechanic struck a knob, closed the slide valve, and prevented further fuel from entering. This meant that a stand had to be provided in the pit to hold the funnel, which would be partly full of fuel when the mechanic had finished.

A certain amount of skill is necessary in using churns, and it is quite difficult to make a mechanic pour quickly enough, but the operation is extremely fast if properly carried out.

Another method is to have in the pit a drum of fuel with a hose and nozzle which can be carried to the car's tank, and compressed air available to drive the fuel from the container down the nozzle. With this a mechanic is freed for other work, since all he has to do is to place the nozzle in the car's tank, allowing somebody in the pit to control the fuel flow. If expense is no object it is possible to make this nozzle automatic, a valve shutting off the supply as soon as the tank is full.

A tank acting under gravity through a hose and nozzle is rarely effective, principally because the flow becomes very much less as the tank empties, and the size of hose necessary is at least 3 in. bore, a size for which it is difficult to obtain a tap. If no automatic cut-off is provided, a mechanic has to use a quick-acting tap on the hose at the car end of that hose, and to shut the tap instantly to prevent overfilling.

Oil can either be poured in out of a jug, the oil tank filler being supplied with a quick-acting cap, or forced in with a large squirt or gun. It is possible to make a can which will pour a circular stream of oil, and that is faster than the ordinary jug. The gun is effective only if it has a big nozzle, which in turn usually means that the nozzle must have a spring-loaded valve so that the oil only comes out when the handle of the gun is pressed. We once made an ingenious can which, when placed in the filler of the auxiliary tank, automatically opened its own valve and discharged its contents, thereby saving considerable time. Be it noted that the driver should not, as a rule, deal with the oil, as he is liable to get it on his hands and then on the steering-wheel.

As long as the oil is contained in a separate tank, refilling is easy. If the crank case oil has to be replenished the operation is more difficult. First of all a tap which discharges when the right amount of oil is in the engine is obviously quicker than a dip-stick, and it can be contrived that opening the filler cap opens the drain tap, so that ne movement is saved. But as a rule oil is still going down the filler when the cap is shut, and so it is best to arrange that the oil-level tap is shut not by the filler cap but by the next movement of the clutch pedal, that is as the driver gets into gear ready to start, the interval allowing the surplus oil to drain away. That in turn entails a small pan to catch the oil which does drain out.

Loss of water can generally be obviated by eliminating the ordinary vent-pipe and having in its place a pipe of larger diameter guarded by a spring-loaded valve. The strength of the spring is set so that the valve will lift only if steam generates in the radiator, but will not lift when the water surges in the top tank, so that loss of water when braking is avoided. By the way, a filler cap that can be opened or closed by *one* movement is desirable as against one that takes two or more.

Replenishment of the radiator can, of course, be effected with a can. It is, however, absolutely necessary that the shape of the can used for the oil should be quite different from that used for water. As an additional precaution it is wise to paint the two cans different colours. The routine must also include provision for adjusting the brakes or the shock-absorbers, or changing plugs, the operations being laid out in such a way as not to be confused.

The T-headed box spanner is probably as good as anything for changing plugs, and if the cars stop for misfiring a routine for changing plugs is worth having. One mechanic, for example, can remove all the wires while another follows him unscrewing all the plugs. Then the first mechanic puts in new plugs, the second does these up, and the first man follows him, replacing the wires. The old plugs should always be put on the pit counter so that they can be identified with the cylinders, as plugs give valuable evidence as to what is happening in the cylinders.

Naturally the pit should always have a spare set of plugs ready to use, and very often a box is provided for each car, with sockets holding the requisite number of racing plugs, other sockets holding the soft plugs which otherwise would be lost, each socket being numbered and the number of the car, or its driver's name, being painted on the box. Soft plugs are used when the car is touring to the pit before the race, away from it afterwards, the racing plugs being substituted just before the start. If these soft plugs are kept about anyhow, they are almost certain to be lost. For anything else that may happen in the race and could with advantage be cured, an appropriate routine should be set up.

Continuing, however, with the normal pit stop, the driver will need a drink or something to eat, and that must be ready for him on the counter, probably a change of goggles or visor and he will have to clean the windscreen, for which a chamois leather or sponge should be provided specially; and all these things should be set out on the counter so that the driver always knows where they are, the old goggles or visor being cleaned immediately and got ready again in case of an emergency.

It is always possible that there may be a fire. Consequently mechanics who are not engaged in refilling should be allotted exact duties if a fire does occur; the team chief and one other mechanic should have fire extinguishers ready. The working mechanics should have instructions to get right out of the way if a fire occurs, or detailed to look after the driver, which in turn means the provision of a fire blanket in which a man can be wrapped at once if his clothes catch alight. It is essential to act instantly, as a man whose clothes are alight always tends to run. Somebody might be detailed also instantly to remove any churns that are full of fuel, and by the way, the fire party should know exactly how the fire-extinguishers operate.

After the car has got away, everything must be returned to its proper place, and a further supply of fuel ensured in case the car should need more. Fresh wheels should be moved into place, and that means being careful that the wheels are right, because sometimes the size of tyre for the back is not the same as that for the front wheels. Complications do ensue in this way. Sometimes one car of the team has tyres of a size different from the others, just as in awkward cases one car may have two different types of plug in its engine at the same time.

The arrangement of the pit now becomes obvious. Cans are put out in definite places only, of course, just before they are required; but it is valuable to have a standard layout for the tools, so that when work is to be done the mechanic has not to search for what he requires, and as a rule the handles of the tools should be towards the road. Since there is not over-much room in the pits, some care has to be exercised over this general arrangement, and often it is a good thing to keep one of the three pits given to a team for repair work, and another entirely for refilling and wheel-changing.

Now we come to the question of control. Obviously a race can be won or lost with great ease if the control does not know exactly where the car is and cannot assess the probabilities of a win at once. The whole organization, therefore, is simply for the purpose of discovering the situation. Unfortunately the average official scoreboard lags far behind the actual situation, so that a chart has to be kept in the pit itself. In its plainest form this chart consists of vertical columns showing the relative position of every car in the race for each lap, the numbers of the cars being written down in the corresponding column in the order in which they pass each lap. This is not as easy as it seems. The spotter has to be really efficient and experienced, writing the numbers down in vertical columns on a pad before tearing off the page, and handing it to the chart-keeper. The chart-keeper enters the numbers on his chart, taking precautions that the same number does not appear twice in one lap. The spotting sheets should always be numbered and kept on a file in case a mistake is made. From this chart the team chief can see the exact order of the cars. Chronometers operated by a timekeeper should show him the opening or closing rate; that is, whether the team's cars are catching the rival in front or being caught by somebody else, and the essence of the whole business is this opening and closing rate, not the lap speed. Occasionally a lap speed may be necessary to see whether the team's cars can possibly go any faster, but that is all. If the timekeeper can use split-second watches he is a very much more valuable man than one who has to have a number of single-hand watches, because with two split-second watches every car in the race can be timed. Both the chart-keeper and the timekeeper have to be men of phenomenal restraint, taking no notice whatsoever of anything or anybody, but just going on with their job; and it is best, too, if they do not have even to answer questions.

The position ascertained, remains to signal the drivers. There are various methods of doing so, but the best seems to be one which conveys everything you want to the driver, but cannot be understood by anybody else. The ordinary semaphore arm, which is very popular, can be made to do this quite easily, especially as the meaning of each position of the arm can be changed whenever required, and the arm removed, various shaped symbols substituted, in order to extend the range of signals. In a signal-book I once used there were 22 signals quite easy to remember, and these were grouped under code numbers, and proved very useful, code numbers avoiding the necessity for naming the signal so that somebody else could hear it.

Another form of signal consists of telling the driver the number of the car ahead of him, his position, and how many seconds he is behind the leader, which is good but gives all that information away to everybody else.

The signaller also has to be trained, the signals being held out always in exactly the same way, and he should be a man provided with a stop watch so that he knows that the car he wants is due in a certain number of seconds, and can get the signal ready. He also can tell if the car is overdue, or missing. The driver in turn can have a certain organized system of signals to tell the pit how the car is running, and a certain set series of acknowledgment signals to show he has understood the signs displayed at the pit.

Since if a car ran out of fuel it would be serious, it seems wise to acknowledge a signal to come in and refill in a manner quite different from that used for any other order. The signal to come in may be preceded by a preparatory signal just to make sure the driver will not miss an all-important message, and having been acknowledged, the "come in" signal will be replaced by the position signal showing the car exactly where to stop at the pit. It is wise, also, to have some very easily visible sign on the pit itself, for this enables a driver speedily to pick up his own pit as he passes.

It is easy to make a signal that can be taken to pieces for transport, the painted portion being carried in a bag so that it will not be damaged during the journey, and, of course, it is essential that the signal shall be different from that displayed in any other pit.

If a race is run with some kind of handicap, the system adopted has to be correspondingly different, but then everything depends on a knowledge of how the car is doing almost from the first lap. By studying the handicap a chart can be prepared showing that, if the leading car in each class completed each lap in such-and-such a time from the start, all those cars would come in equal at the finish. If a watch or clock is started at 12 o'clock, exactly when the first car is sent away, and the clock time is compared with the chart, it is possible to tell which class is doing best and by how much they are better than any other. A subsidiary chart scoring the laps covered by each car is, of course, necessary, but it need only consist of a vertical column of numbers of the cars and a pencilled tick showing each lap completed. The leader of each class will then be easy to identify as the one having the greatest number of marks. The whole principle of this system is that of a reliability trial. A, B, and C are due at a certain spot at a certain time; whichever of them is the earliest is doing best.

It must be remembered that the whole object of a race is not to go as fast as possible, but to keep the cars' speed down to the minimum possible to win.

Other ingenious forms of charts are worth studying. By having a board drilled with holes equal in number vertically to the number of cars in the race and horizontally to the number of laps to be covered, it is possible to use two rows of metal pins, each pin in each row bearing the number of a competing car. Placed in the holes in the order in which the cars pass, these pins show the position of the cars in the race each lap. In order to prevent mistakes, one row leap-frogs over the other as the race proceeds. One row of pins will suffice, but if a pin is withdrawn from its hole in error, it may be difficult to find exactly from whence it came.

Remains the question of strategy and tactics. It is not always best to have the three cars exactly the same. It may be better to have one car made much faster than the other two. The chances of that car finishing are correspondingly reduced, but for the first part of the race the machine in question, if properly driven, will go at such a pace that it ought to take the lead. In any case the rival machines have to match its speed, or the fast car will obtain a lap lead then slow down to the speed of its fastest rival, which is a very awkward position for the latter. By this means it is sometimes possible to cause rival cars to go faster than they want to and so develop trouble, the result being that you have lost your fastest car in the end, but you have also got rid of your most formidable rivals. The next machine of the team can then be pushed forward in an attempt to win.

There are all sorts of variations. For instance, in a scratch race it is probably better for a car to remain second until nearly the last lap, for that means that the leading car is setting the pace and not your car. To do this successfully, of course, you have to have something in hand, but the idea has its points. If your fast car under this scheme leads most of the way, it will probably go faster than it need have done, and fall out of the race.

A strategy has to be considered. Naturally it has to be modified instantly during the race when you find that the situation is not exactly as you estimated it would have been, but the strategy must always be such as can be changed to suit the new position, unless the situation is hopeless because none of your cars is fast enough to do anything.

It is necessary to consider refilling. For example, it might be wise to run one car with so much fuel that it can go right through the race without refilling, so saving the time rivals have to waste for this purpose, and it is just possible that, as you do not disclose this fact, rival teams, imagining that the car is going to stop to refill, will be upset accordingly when it does not, a little by-play with the filling cans having a marked effect on occasions.

The question of tyre wear enters into it. If you know that a car going at a certain speed will have to change tyres twice, but at a slower speed only once, it may be worth running one car slower to save the tyre change. It is quite easy to imagine variations of all this, and it is one of the things which make racing so fascinating.

Essentially both strategy and tactics are based on the report of the intelligence system, which ought to be able to discover what rival cars really can do, and, which is important, what troubles they are likely to have in given circumstances. It may be useful, also, to know the peculiarities of the drivers. For instance, that one man gets very rattled in circumstances that would cause another no trouble at all, and there is fine opportunity for spreading a flock of rumours that may prove quite effectively in your favour in the race. The rumour that one car had done a record lap in practice once caused a rival team to lower their gear ratios, which in turn led to engine trouble in the race.

Over and above all this there is the question of drivers, temperamental people at the best of times. In a team which is entirely professional things become easier, always provided the financial situation is satisfactory. Where the driver is not paid, difficulties increase in proportion to the independence of the man concerned, but it does seem essential that a driver should know how to remedy such troubles as are likely to occur in a race, and not only that he should know how to do it but he should have done the thing in question before ever the car gets to the race. Many a car has been put out of a race entirely because its driver has not known how to do something simple—changing the magneto, for example, or dealing with an erring fuel-pump. Racing is too expensive for this kind of thing to happen.

Then the team chief must at least see that the drivers know the signal code from beginning to end, the exact routine expected from them at the pits, and their part in the strategical plan. Temperaments being rife, it is just as well to consider practice times before telling them to a driver. For instance, one man may be greatly encouraged by being told that he has actually done a lap faster than the speed he really did. Another can be curbed by the reverse statement, and a great deal can be done to clear up difficulties in cornering that beset one driver, but not another, owing to his line of approach being wrong.

The essential thing, of course, is not to have one star driver in the team to whom all the others are subservient, but to give each driver in turn his chance to obtain the success which results in exciting publicity. Somehow or other drivers should be persuaded to organize their own kit so that they know exactly what to do with spare goggles, helmets, overalls, or coats, when they get into the pit, and special little hooks put in the walls of the pit with the drivers' names under them, do help to prevent personal property from being lost as they are when just left lying about the floor.

It is always difficult to know quite how to deal with drivers. Some respond best to what amounts to a continuously disciplined control which may be anathema to others Some can keep themselves reasonably fit for a race if left alone, others cannot; but the main point is to avoid at all costs any personal jealousies, and to spread the value of the success over the team as a whole, not allowing it to rest entirely on the one man who that time happened to be the winner.

CHAPTER SEVENTEEN

CONTINENTAL CIRCUITS

By the Earl Howe

CONTINENTAL motor racing from the point of view of a driver can be and is extremely interesting, owing to the large variety of circuits and the different character of the races which take place on them.

For any racing driver who wants to improve his standard of driving I, personally, should regard it as absolutely essential that he should go abroad and take part in as many of the great events on the Continent as he possibly can. Those who can arrange to do so will never regret it; it will provide them with experiences which they will always remember. The differing character of the people he will come across and, on the whole, their extraordinary kindness and good-nature towards strangers will leave an unforgettable impression.

When talking about Continental road racing it is rather difficult to know whether it is better to give a description of each circuit in turn, or whether it is better to describe the races; I think it is better merely to take a certain number of circuits and to describe the character of the races which take place on them.

I think perhaps in some ways the most outstanding race which takes place on the Continent is the Italian Mille Miglia. It is the only race of its sort which takes place now anywhere in the world. The circuit is a huge figure of eight, starting at Brescia and skirting Cremona and going down what is really the Italian Great North Road to Bologna, a succession of long straights, upon which enormous speeds are possible. Like most Italian roads in the wet, this stretch of road becomes incredibly slippery and very dangerous.

As the start now takes place about three o'clock in the morning, the initial stages of the race have to be tackled in darkness. From Bologna the road climbs over the mountains by means of the Raticosa and Futa Passes to Florence; this section of road is unbelievably difficult; there are stretches where for mile after mile there is not more than 20 yards straight with a big drop on one side or the other. As the road gains height, under bad weather conditions quite thick fog is often encountered.

From Florence the road now goes along an autostrade to Pisa, and then goes on to Rome. After Pisa this stretch of road

THE MILLE MIGLIA

Fig. 62

is more normal in character. From Rome, which is, of course, the bottom of the figure of eight, the road passes by Terni and Perugia to Porto Reconati, on the Adriatic coast. This stretch of road in many places is very difficult and two or three different passes have to be encountered. There are also a certain number of level crossings, some of which have to be negotiated very carefully, otherwise a severe bump may wreck the springs of the car.

From Porto Reconati the road joins the southern section of Italy's Great North Road and proceeds through several towns such as Ancona and Pesaro, back to Bologna, which is the centre of the figure of eight. This section of road is extremely fast in places, consisting as it does of long straights where the highest speeds are possible.

From Bologna the road goes through Padova to Venice and returns through Vicenza, Verona, to Brescia.

From Padova to Venice the road proceeds along an autostrade where high speeds are possible again. After Venice, however, the road is extremely difficult in places; in fact the chief character of the road after Bologna are long straights with absolutely right angle turns at the end of them.

The circuit is 1000 miles in all, and, as I have already said, the race now starts in the darkness at three o'clock in the morning, and the cars begin to get back to Brescia between nine and ten o'clock in the evening. Such a stretch of road presents enormous difficulties for the driver.

As in every other race, it is essential for a driver to know the circuit. On the other hand, to get enough practice on a circuit of such enormous length, where no section of road is ever seen twice, makes practising extremely difficult—a practice lap under ordinary conditions takes two to three days. Another factor which complicates it very much is that the circuit is not closed either for practice or even for the race, and where difficult blind corners are encountered the driver must always remember that he may find anything round the corner; it may be livestock, or it may be a motor lorry, cyclist, or human beings. The only real safeguard even during the race is that the whole population of Italy appears to take a most lively interest in the race and, therefore, they are somewhat more careful to keep to their own side of the road than probably would be the case in the ordinary way.

Each car taking part in the race has a crew of two; it is quite possible for a driver to drive through single-handed, providing he is extremely fit, and a number of the Italians do so, and are merely accompanied by a mechanic driver who is able to take the wheel if necessary for a short distance so as to give the driver a rest on an easy portion of the circuit. Other drivers prefer to be assisted by another fully competent racing driver; this has the advantage from the driver's point of view in that each driver can practise separately and learn the portion of the circuit over which he intends to drive during the race. This was the course that I myself adopted when tackling this race. I look upon myself as being an individual of normal intelligence in learning a circuit, and I found that, after four drives over the stretch of road which I intended to drive on during the race, I had a very fair knowledge of it; that is to say, when I came to the race itself I only made a mistake at one corner in the 750 miles which I drove. I covered the other section of the course, which I did not intend to drive on, twice in practice, and therefore had a slight knowledge of that section as well, but I found when I got to the end of my 750 miles drive that I was not in the least tired and could easily have covered the whole distance myself.

Pit organization becomes very difficult on such an enormous circuit. Some of the competitors have solved the problem by practically having no pit organization at all, and merely relying upon previously selected filling stations for their requirements; others, especially important *équipes*, establish special depots. About three stops are usually necessary during this race, and it is possible for a depot to be established on a movable basis; that is to say, that as soon as the cars have filled up at the first depot, the staff, by means of fast cars and motor vans, can get across Italy and meet the cars coming back on the return journey on the other side. Incidentally, this has been known to give rise to sort of private races, where the depots are in close proximity to one another. In the case of the M.G. team running in this race, we also entered a large Mercedes in the race, and filled it with certain spare parts which we thought might possibly be required, the idea being that the large car, starting last, would overtake any of the team which might have broken down on the way and would be able to help them on their way; actually the services of this car were never called on, and our travelling depot actually managed to win its own class in the race, notwithstanding the fact that it was carrying a complete spare gear-box plus a good many spare wheels, &c., amongst other things.

The organization of this race is always extraordinarily good. A large number of controls are established round the circuit; each car is provided with a book, rather like a passport, in which there are photographs of the crew; at each control, which is marked by a banner hung across the road, the car has to almost stop while officials run alongside with rubber stamps, take a hurried look at the driver and his accomplice, and if they think he resembles the photograph they stamp the book; at the same time others will run alongside, and in some cases give the driver something to drink, and clean his windscreen for him. This organization is so good that it is able to compete with two or three cars at a control simultaneously.

As I have already said, the course in general is not closed, but everybody knows the race is on; the Fascisti Militia, however, on certain sections of the circuit come out and practically hold up the traffic during the two or three hours which it takes for the competing cars to pass any particular point. Any car, however, which encounters trouble and loses a good deal of time, may have the wildest adventures when trying to make it up. Enormous crowds, as a rule, come out to see the race, and after the favourite has passed any given point the traffic generally resumes a more or less normal atmosphere, quite regardless of the fact that fast racing cars are still about and may appear in the middle of it all. It is a remarkable thing how very few serious accidents ever take place during this race. I could continue a description of it for hours, but time and space would certainly not permit. The general impression left by the race is that it is very much the same in character as the great motor races of days gone by, between Paris-Vienna, Paris-Berlin, &c.

From the circuit 1000 miles round, the driver in search of experience may be invited to compete at Monaco. Here the circuit is slightly under two miles per lap, making a total distance of just under 200 miles. Starting just outside the Tennis Courts, it goes up the hill round the bend between the Hotel de Paris and the Casino, round the flower-beds, down past the Metropole into the Station Yard, out again by a little alley leading round the Terminus Hotel on to the front, through the tunnel under the Tir aux Pigeons, along the Quai de Plaisance, and round the Harbour to the Gas Works, and so back again. Important points are protected by sandbags, which I have always heard are filled with the sand from Monte Carlo beach, and the sand is returned to the beach after it has been used. A wooden palisade is erected on the Quai de Plaisance to prevent the cars charging into the harbour, which certainly would have happened on several occasions had this barrier not been there.

The race is a terrific test of a driver's physical condition; only a driver who is physically super-fit can hope to stay the course. I have taken part myself in this race on six occasions, and invariably after about 30 laps, notwithstanding the fact that I have trained most carefully for the race, I have felt so done that I have wondered whether it was really humanly possible to continue the race; somehow one sticks to it, and after that it seems to get somewhat easier.

The chief thing for the driver to remember about the race is that practically everywhere there are kerbs and if a car gets into a slide and hits a kerb sideways it is almost certain to break a wheel or to capsize, and therefore, if there seems to be any danger of hitting a kerb, it is better to steer at it and go on to it rather than slide at it sideways.

Another point which should always be borne in mind is that as this race goes on, owing to the same bit of road being continually covered by cars all taking the corner very much the same way, there are two tracks where the wheels of the cars run round each corner, but that between the wheels there are usually a lot of oil droppings, and if a car gets slightly out of position on a corner and in fact gets on to these oil droppings, it may start a terrific skid.

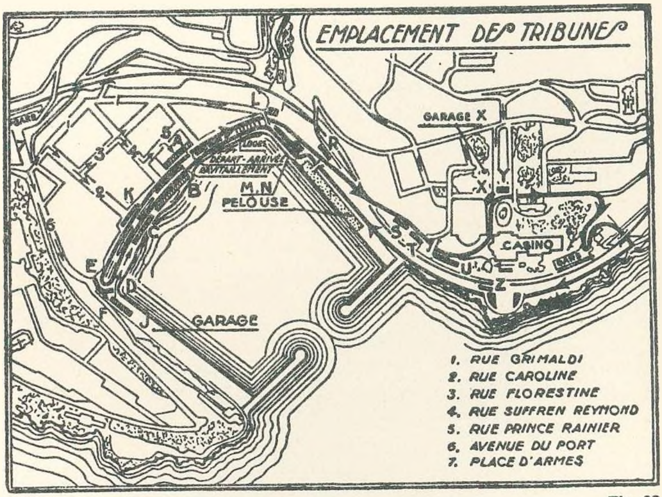


Fig. 68

THE MONACO GRAND PRIX

There are ten severe corners on each lap, and constant braking, gear-changing, and acceleration for these corners puts a tremendous strain on the brakes and upon the transmission. Practically every year a number of cars have to stop owing to failure of the back axle. All that a driver is conscious of during the race is that all the time he is rushing up to or accelerating from a corner, or that he is trying to pass somebody, or that somebody else is waiting eagerly for an opportunity to pass him. I can safely say that the Monaco Grand Prix is the hardest work of any race which I have ever taken part in.

From Monaco the driver in search of further experience may go to the great Nurburg Ring in Germany. The full length of the Nurburg Ring is, I believe, about 29 kilometres. I think I am right in saying that about 8 kilometres of this are really never used for the race. The circuit is situated roughly at the apex of a triangle, with its base on Coblenz and Cologne. It is in the Eifel Mountains, and for the most part the circuit runs along the tops of the hills. The road surface is about 30 to 35 feet wide in most places, and is constructed for the most part of a rough tarmac. There are, however, stretches of the circuit constructed of ordinary concrete.

The central feature of this circuit, from the driver's point of view, is that there is no escape road, and that if a driver makes a

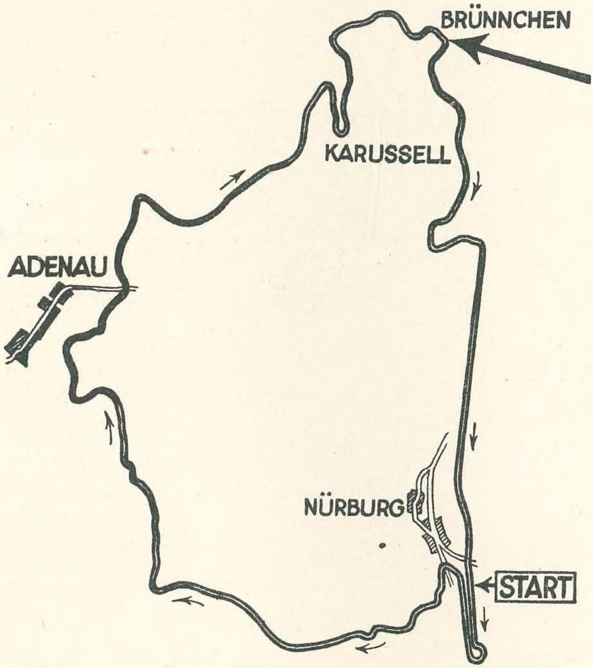
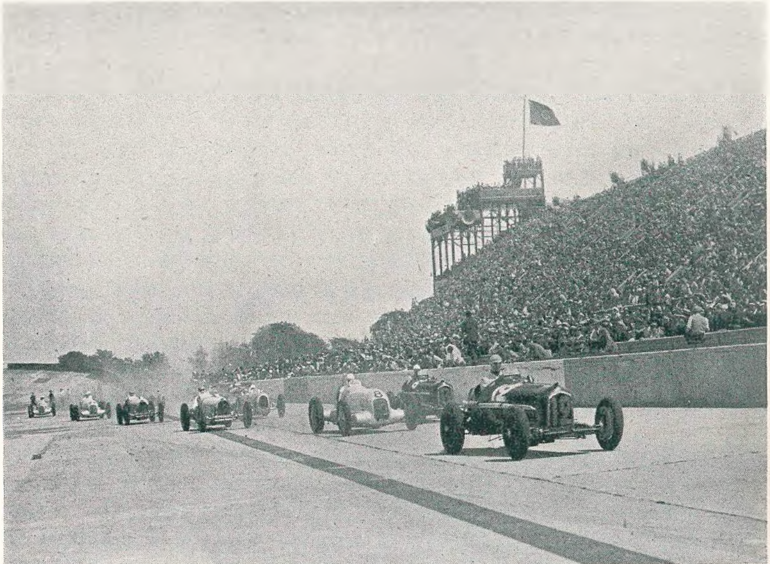


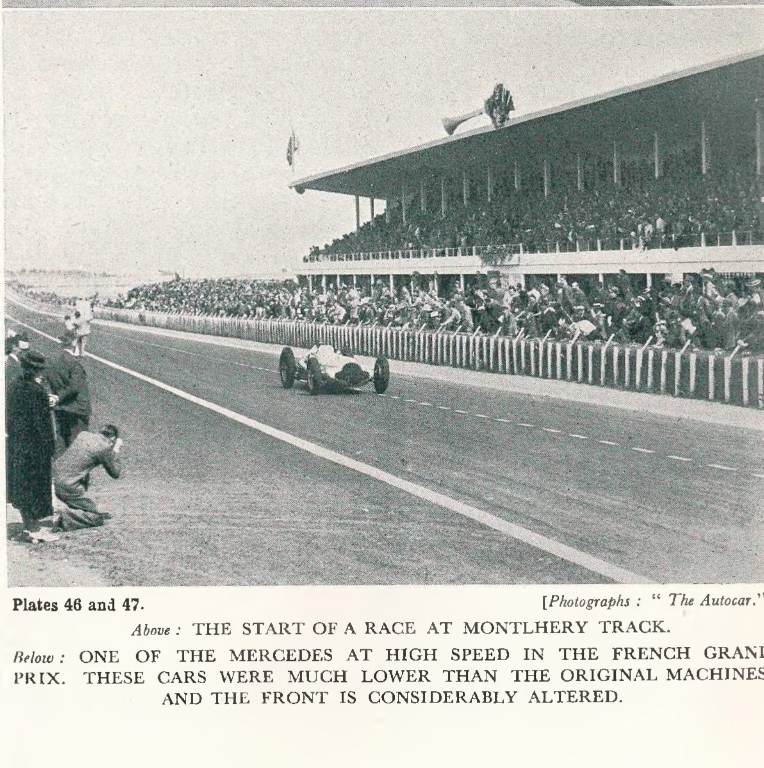
Fig. 64

THE NURBURG RING

mistake on a corner or a bend he has very little or no chance to recover.

Another curious feature of this circuit is that the road is continually running up to the crest of a hill, over which it is not possible to see; only previous practice and first-class knowledge of the circuit will enable a driver to know how to take these points, and whether he can keep his foot down, or whether he should take his foot off before he arrives at the crest, so as to be able to negotiate a turn to the right or to the left over the crest.





Plates 46 and 47. [*Photographs :* " *The Autocar.*"

Above : THE START OF A RACE AT MONTLHERY TRACK.

Below : ONE OF THE MERCEDES AT HIGH SPEED IN THE FRENCH GRAND PRIX. THESE CARS WERE MUCH LOWER THAN THE ORIGINAL MACHINES, AND THE FRONT IS CONSIDERABLY ALTERED.

The course as a whole is extremely difficult, and the maximum amount of practice is essential for any driver who does not know the circuit.

Another thing that a driver should always remember at the Nurburg Ring is that, owing to the length and extent of the circuit, it is necessary to watch the weather with some care; if a shower crosses a portion of the circuit it is easily possible for a driver to arrive at a stretch of road which, when he left it last, was bone dry, and when he returns to it he may find that it is all wet and therefore extremely slippery.

There is not very much in the way of a straight; in fact there is only one stretch which can really be called a straight at all, of about one mile in length, which begins with two bridges which, at high speed, become almost hump-backed bridges, and the straight itself, perhaps owing to the nature of its foundation, is somewhat bumpy.

A driver should also be somewhat careful of the wind on this stretch, as indeed on many other circuits in Europe. It is possible to encounter severe gusts of wind just as they come over the top of one of these bridges. I myself have almost met with disaster due to this cause, and I am not at all sure that one or two accidents that have happened on the Nurburg Ring have not been caused by the wind.

I regard the Nurburg Ring as being a tremendous test of the driver's real ability; in fact, with the possible exception of the old Targa Florio Circuit in Sicily, it is probably true to say that the Nurburg Ring is the most difficult circuit in the world. Some of it looks easy until you start to drive to the limit of the car's capacity, and then the driver probably discovers what a small margin of safety he really has in hand.

Another feature of the Nurburg Ring is that, in order to assist the drivers to remember the circuit, nearly every important corner has been given a name, in very big letters on a big board; this is very helpful even if, like myself, the driver's knowledge of German is very small, for the driver can always take a look at the name to see the first few letters and judge from the length of the board, even if he cannot read the whole of it, which the corner is. There is one corner on the Nurburg Ring which is utterly unlike any other corner on any circuit that I have ever heard of; it is known as the Carrousel (I have sometimes seen it spelt with a "K"). This corner occurs at the top of a rise; it is really a very small radius bend, slightly superelevated.

When I first saw the Nurburg Ring on the inside there was a ditch and drivers discovered that, by putting the near-side wheels over the edge, they could get round this corner very much faster than if they took the corner on the road normally.

The result of this was that a year or so afterwards the side of the ditch near to the roadway was surfaced with a sort of very fine tarmac; the result of this was that every car, when taking this bend, deliberately drove straight into the ditch. During the first lap or two of a race there was always a regular scramble to get up this hill and, so to speak, to get into the ditch, because only one car could go round in the ditch at a time, and they all therefore had to follow each other. Now, however, the matter has gone one stage further and the ditch has now been surfaced with concrete, and the available space, while only sufficient for one car at a time, is slightly broader.

If a car comes out of the ditch the driver would expect to get into a terrific skid, which would be quite uncontrollable, for the speed in the ditch would be far higher than would be possible on the road surface itself; and on the outer side of the road there is a big drop down, so there would be very little hope for the driver.

The whole course consists of a series of bends of varying radii and corners with several little dips and bends to the left or right at the bottom.

The paddock at the Nurburg Ring is perhaps the best equipped paddock of its sort on any track in he world, and contains a number of lock-ups for the racing cars. There is an enormous grandstand which is capable of holding about 15,000 people, and to indicate the size of the building, underneath the grandstand there is a small hotel and several large restaurants in it.

The pits themselves are permanent structures of ferro-concrete, and are situated opposite the grandstand between two legs of the circuit. The cars go down the broad stretch in front and come back along a somewhat narrow back stretch, which enables pit signals to be shown both ways.

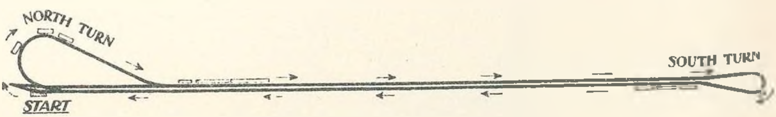
The enthusiasm of the Germans for races on the Nurburg Ring is almost incredible; in fact the spectators start to arrive forty-eight hours before the race takes place; there is no accommodation for them, but they are content to camp out for the intervening period.

On the day of the race it is as well for the driver to arrive very early; there are not too many roads leading to the circuit, and they are all of them choked with traffic. I myself have all but missed arriving in time for the race owing to this reason.

From the Nurburg Ring, before leaving Germany, the driver may like to see the Avus Track on the outskirts of Berlin. This track consists of two straights both of them rather narrow—I should think not more than 25 to 30 ft. broad—about 6 miles long, with a very small radius curve at the Potsdam end, fairly steeply banked, and a large radius curve at the Berlin end, which has now been so steeply banked that it almost approaches the idea of that popular entertainment "The Wall of Death." The two legs of the circuit are separated by a grass strip in the middle; the grass strip is only about 10 to 15 yards wide, and there is a danger that if a car should get into difficulties owing to a tyre-burst, or hitting another car, on one leg of the circuit, it may charge across and hit cars coming in the opposite direction. I do not think this has ever happened, but it did very nearly happen on one occasion a few years ago.

The road goes through a forest and there are gaps in the trees, and if there is a side wind blowing it is as well to remember this, because you may suddenly emerge from an area of calm air into a strong wind, and this may make things very difficult for a driver of a very fast car.

Owing to the nature of the circuit the lap speeds are the highest in the world; in fact the race has been won at an average



THE AVUS TRACK Fig. 65

speed of over 148 m.p.h., and cars have lapped at considerably higher speeds even than this.

The spectators are able to come quite close up to the track, and if a car did by any chance get into difficulties, a most serious accident, perhaps involving hundreds of spectators, could easily take place. This fact seems to be realized by the German authorities and the track is considered to be so dangerous that races no longer take place on it. Owing to the proximity of the track to Berlin the crowds of spectators are simply gigantic, and when a race is on, if you happen to look away from the circuit the neighbourhood of the track reminds one of nothing so much as an enormous ant-heap.

From the driver's point of view under bad conditions of weather the track can get very slippery. Owing to the turns taking place at the end of long straights, it is essential for the driver to know his braking points and for his brakes to be beyond suspicion. The surface of the turn at the Berlin end is surfaced with brick and, I believe, still is, and a driver ought to remember that, as Indianapolis has shown us, slight oil droppings on a brick surface produce one of the worst skid surfaces in the world.

From Germany the driver in search of experience may perhaps go to Le Mans, in France; or, as the French prefer to call it, "Le Circuit Permanent de la Sarthe."

This circuit at one time used to run from the outskirts of Le Mans itself along the road to Tours, as far as Mulsanne; it then turns right and goes through the forest to what is known as the Arnage corner, where another right-angle turn is negotiated, bringing the circuit back past the pits.

The portion of the circuit on the outskirts of the town has now been cut off, presumably to avoid danger, and a short length of artificial road has been constructed to join up with the Route Nationale once more.

The length of the circuit is a little under 8½ miles. The straight

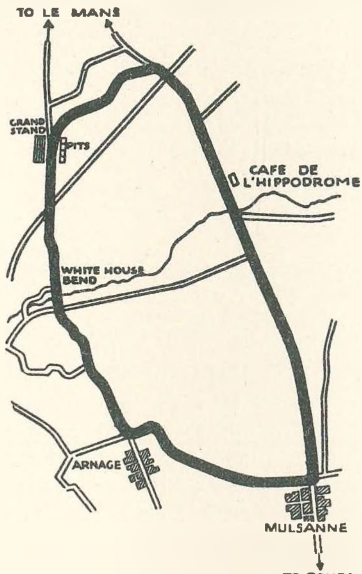


Fig. 66

LE MANS CIRCUIT

is about 4 miles long and consists of a Route Nationale of average and, therefore, ample width.

From the point of view of the driver the circuit at Le Mans is, on the whole, an easy one, but there are one or two points on the circuit which are, or can be, very dangerous, the chief of which appear to be the "S" bend, which exists just before the turn at Arnage, and a bend which is usually referred to as White House bend, which occurs just under a mile before arriving at the pits. The danger of the "S" bend at Arnage is, of course, an obvious one, but the danger at White House is not always so obvious to the driver, and several multiple crashes have occurred at this point. The essential feature of the White House bend is, as its name implies, a house, the corner of which juts right on to the road, and while the bend itself is a perfectly normal one, the presence of the house makes it completely blind. It is possible for a car to get into difficulties on this bend and to skid round, perhaps overturning and blocking the road; if other cars are following fairly close behind they are apt to run into the overturned car before they can see it or be warned. At least three of the worst multiple crashes in the history of racing have taken place at this point owing to this reason, and any driver taking part in the great 24-Hours Race at Le Mans ought to treat this corner above all with great respect, particularly during the initial stages of the race. In fact owing to the large number of cars which usually start in this race, and owing to the fact that the suitability of a number of the cars is sometimes very doubtful and the experience of some of the drivers very limited, I have always advised drivers to be very careful of the first hour or two of the race, unless they have got a clear lead over everybody else, until everybody settles down.

There is usually terrific competition amongst the drivers in this race to be the first past the pits in the first few laps, and many people drive in this race as if it were a 24-Minute Race instead of a 24-Hour Race.

A totally different circuit exists in the Royal Park at Monza, close to Milan in Italy. Monza is partly a track and partly a road circuit. The principal features of the track are large-radius bends with very low banking, which will not permit cars to go round at anything like the speed of which the modern racing car is capable. This opens out into a flat road circuit with a series of fairly sharp bends and corners, which are hardly super-elevated at all. For ten out of its fourteen kilometres the track proceeds through woods and the trees are fairly close up to the road; the result of this is, should a car leave the track it is almost certain to hit a tree. I think I am correct in saying that Monza holds the very unenviable reputation of having brought about the death of between twenty and thirty of the world's best drivers due to this cause.

The track is beautifully laid-out and its surroundings are most attractive. There have been many proposals for modifying the track and the races held on it, but so far as I am aware up to the present this has not been done.

The record lap speed of the track is not very high, being only in the region of 130 m.p.h. Like all tracks of this nature, when wet it becomes very slippery. The surface is a sort of very coarse tarmac.

I myself regard the insufficient banking on the two main bends of the track, and the fact that a large portion of it runs through woods, as being its most dangerous features, and I believe that, if it is impossible to provide banking sufficient to take the more powerful racing car at the peak of its performance, it would be better if the banking were done away with altogether. This, however, is merely a personal expression of opinion with which probably many people would not agree. Certain, however, it is that any driver who enters for a race at Monza should be a man of great experience, otherwise the way to disaster is easy.

There are, of course, many other circuits in Italy, but time and space will not permit me to deal with them all. There is, however, a magnificent circuit at Pescara; it is a triangular circuit about 13·9 miles long. One leg is chiefly notable for a series of very difficult bends and corners, and runs through two villages; there are at least two hairpin bends in this section on a downward grade. The other two legs of the circuit consist of long straights, where the maximum speed of which the fastest cars are capable can be used. The road is none too broad for cars endeavouring to pass one another at very high speed, and there are a number of trees fairly close up to the road. The surface is that of an ordinary tarred road, and with a little wet on it the road becomes incredibly slippery.

The driver on this circuit in a very fast car should also not forget to watch the direction and force of the wind.

The speeds at Pescara have gone up so much owing to the terrific performances of the modern racing car that chicanes have been introduced into both the fast legs of the circuit. This, of course, pulls the lap speed down considerably, and imposes a great strain on the braking system of the car. I myself dislike chicanes intensely; they always seem to be artificial and never reproduce the effect of an ordinary road corner, and I always consider that a corner produced by a chicane is much more difficult to judge than a corner met with on an ordinary road.

The Pescara Circuit is a tremendous test of the skill of the individual driver. The winding leg of the circuit requires a cool head and calm judgment, and a good deal of practice for the driver who is new to the circuit; but I have always regarded the circuit generally as being one of the finest and most attractive that I know.

The principal races staged on the Pescara Circuit usually take place at a time of year when it is extremely hot, which imposes a very great strain on the tyres; owing to this reason and owing to the length of the circuit, the more important *équipes* have found it advisable to have a second pit on the far side of the circuit in addition to the official one close to the start.

Another course which is quite different in character is the one at Berne, in Switzerland. The circuit consists of a road more or less circular in character, most of it through a wood on the outskirts of the town of the city. There is a stretch of about one mile past the pits and grandstand which is surfaced with very good pavé and the rest of the circuit has a rather fine tarmac surface.

The pits are situated on a sort of little by-pass in front of the grandstand, and just between the two there is a fast bend which can just be taken flat out by the fast cars, provided they are in exactly the right position on the road. For this, of course, everything depends on practice, and the ability to judge exactly when to start making the turn; if a slight error is made and the

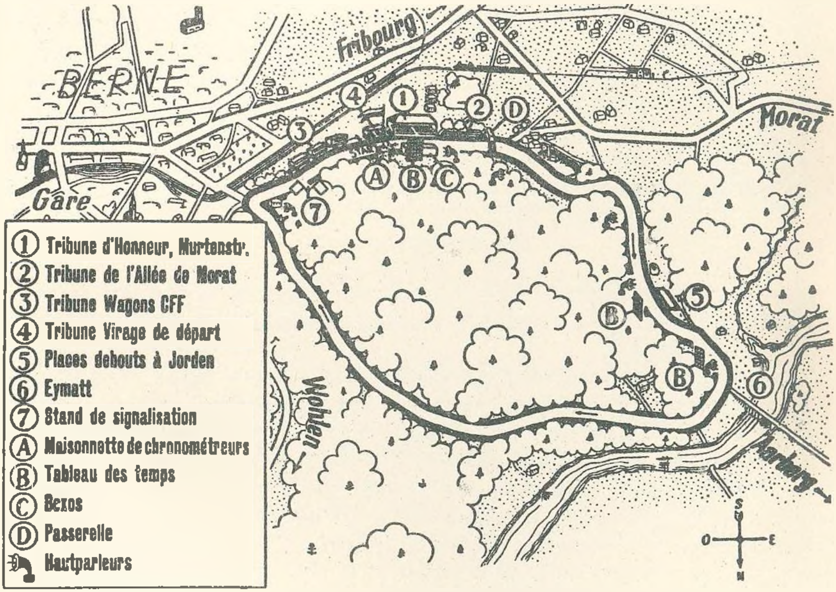


Fig. 67

THE BERNE CIRCUIT

car is only a few inches on the wrong position on the road, it has a tendency to fly off the track about 100 to 200 yards past the bend, and one or two very bad crashes have resulted from this.

As in all other cases where pavé is encountered, if the track should be wet the driver must exercise the very greatest possible care; the effect of rain on the pavé is to make it extraordinarily slippery. This tendency is, of course, accentuated towards the end of the race by oil droppings from cars.

The race at Berne has always struck me as being perhaps the best-organized race of any that I have entered for. Instructions are issued by the organizers and these instructions have to be obeyed. More care is taken, I think, at Berne to safeguard the spectators than perhaps on any circuit in the world, with the possible exception of Brooklands. Safety barricades have been erected all round the circuit so as to prevent cars in difficulty getting into the spectators, and fences are put up even through the wood to keep the spectators well back.

The pits are a model of what pits should be, both in design and construction, and during a race there is always an impres-

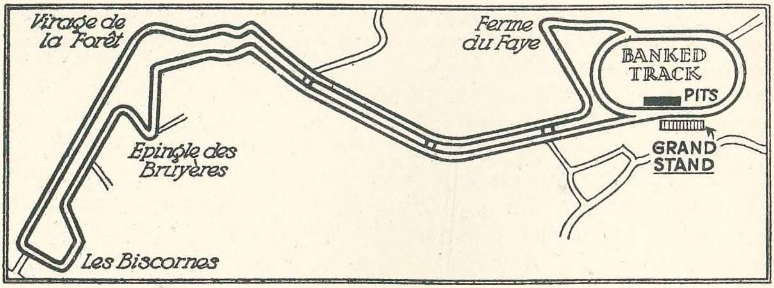


Fig. 68

MONTLHÉRY TRACK

sive number of firemen in full uniform, with the very latest fire-fighting appliances, available in case of emergency when a car arrives at the pit.

There are, of course, many other circuits on the Continent which I have raced on, such as Nice, Rheims, Montlhéry, Dieppe, Albi, Livorno, &c., but the ones that I have selected are really all completely different both in the character of the races which take place on them and the nature of the tracks themselves. The ones which I have not mentioned are more or less similar to those which I have; and any driver who wishes to acquire real experience of Continental road racing would find that a thorough knowledge of the circuits that I have mentioned would equip him completely for any circuit, however difficult.

CHAPTER EIGHTEEN

BRITISH RACING CIRCUITS

By S. C. H. Davis

Sports Editor of " The Autocar "

CONSIDERING the antagonism there has been to motor racing in these islands, the number of racing circuits which have been used and are available is extraordinarily high. The foresight and enthusiasm of Mr. H. F. Locke-King provided us in 1907 with the first real track, Brooklands near Weybridge, for motor racing which was really suited for its purpose, and before his death he was able to see the immense effect that track had, not only on racing generally, but on racing cars as well.

At the moment the track consists of an outer circuit, 2 miles

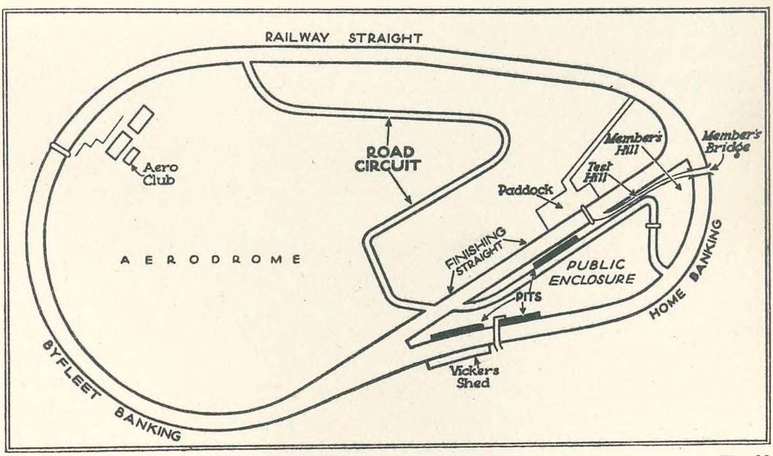


Fig. 69

BROOKLANDS RACE TRACK

1350 yards in length, an elongated oval, with a dent in one side, in shape. The banking is not sufficiently high to permit the full speed of the modern racing car, notwithstanding which the lap record stands at 143·44 m.p.h. to the credit of John Cobb and the Napier-Railton, and lap speeds of 130 m.p.h. are not in the least unusual.

When the track was first built it was immediately used by Mr. S. F. Edge with the Napier to set up the first World's 24-Hour Record, the circuit being illuminated by lamps for the night run. Unfortunately the noise of the cars used, for there were three, resulted in an injunction being obtained against the track authorities which in turn made it necessary for all racing cars to have a regulation size of silencer, which in turn has made it difficult for the very latest racing machines to be used at all.

The dent in one side was originally innocuous, being a curve to avoid private property of such radius as to form no hindrance to the machines; but at modern speeds this curve, now termed the Vickers turn because it runs close to the Vickers Aeroplane Company's works, is one of the problems before a driver, and is anything but easy to accomplish at full throttle without sliding, further difficulties being introduced by the "rebound" of the wind from the large surface of the works itself.

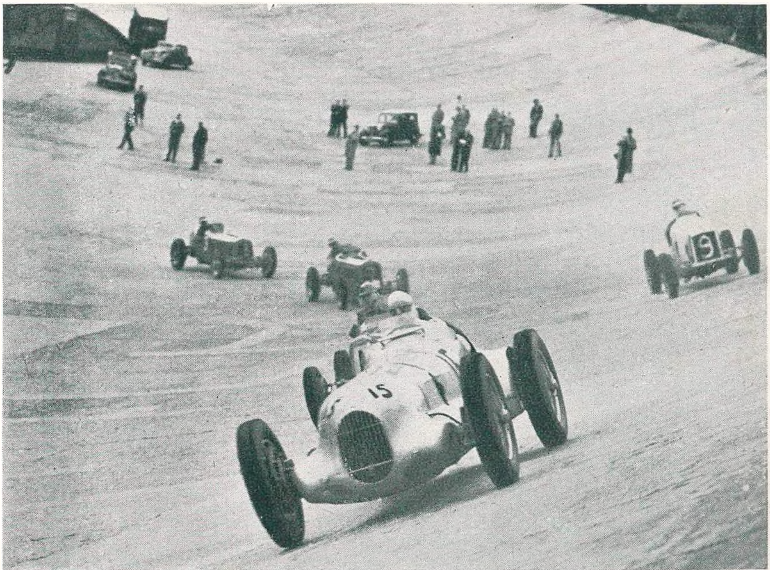
Running on to the Home Banking curve in itself requires care, and a hundred yards or so after the car is on the curve some peculiar formation of the track makes a fast machine swerve either up or down so quickly as to require great skill on the driver's part to avoid trouble, and again prevents a car being driven at full speed. The Home Banking itself is comparatively easy, though at the point where the car comes behind the shelter of the Members' Hill, the wind is liable to be troublesome, and an inexperienced driver, unaccustomed to the track, finds that his machine leaps bodily from the banking on to the Railway Straight.

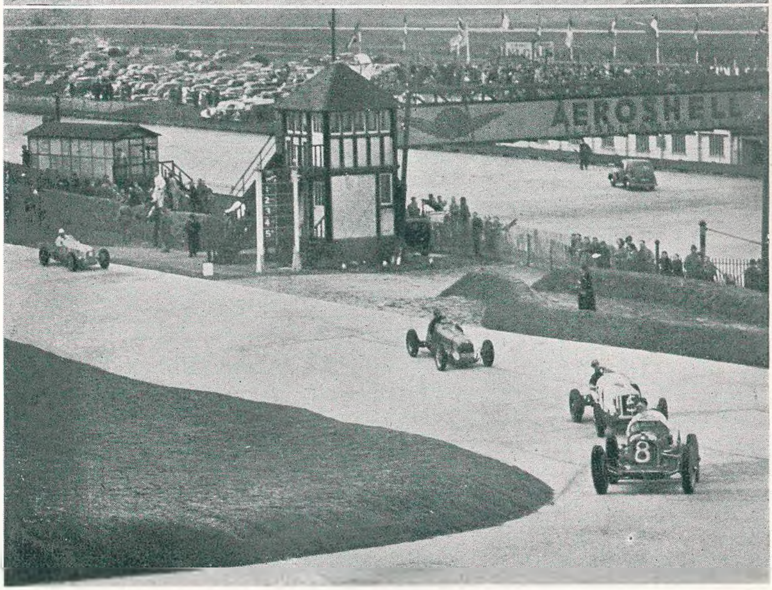
The Byfleet Banking itself requires a certain amount of care, not being so high as the Home Banking, the most troublesome place being at the end of that banking which comes just before the Vickers turn.

Originally cars raced for so many laps of the outside circuit but finished in a special finishing straight. As the cars were handicapped individually they tended to bunch at the finish, which fact, coupled with the very high speed and the difficulties of stopping the cars by the end of the straight, led to this plan being abandoned, cars then finished on the Railway Straight.

The hill aforementioned forms part of the public enclosure, bounded on one side by the outer circuit, on the other by the Finishing Straight. This allowed races to be run on what is termed the "Mountain" Circuit, cars turning right-handed from the Finishing Straight on to the Home Banking, using that banking to help the turn, then right-handed again at the Vickers shed back into the Finishing Straight round an acute turn without banking. This circuit measures 1·2 miles and is extremely exciting, though too artificial to represent road racing.

In 1937 a special road circuit was opened, a concrete road being built from the Railway Straight in a series of curves to the Finishing Straight, and continued by another road, also in





Plates 48 and 49.

Above : CARS TAKING THE MEMBERS' HILL TURN DURING A MOUNTAIN RACE AT BROOKLANDS: THE SPEED ON THE TURN IS ASSISTED AT THIS POINT BY THE BANKING. [*Photograph : " Wide World."*

Below : THE TEST HILL TURN OF THE ROAD CIRCUIT AT BROOKLANDS, USUALLY NICKNAMED " DUNLOP'S DELIGHT." [*Photograph : " Autocar."*

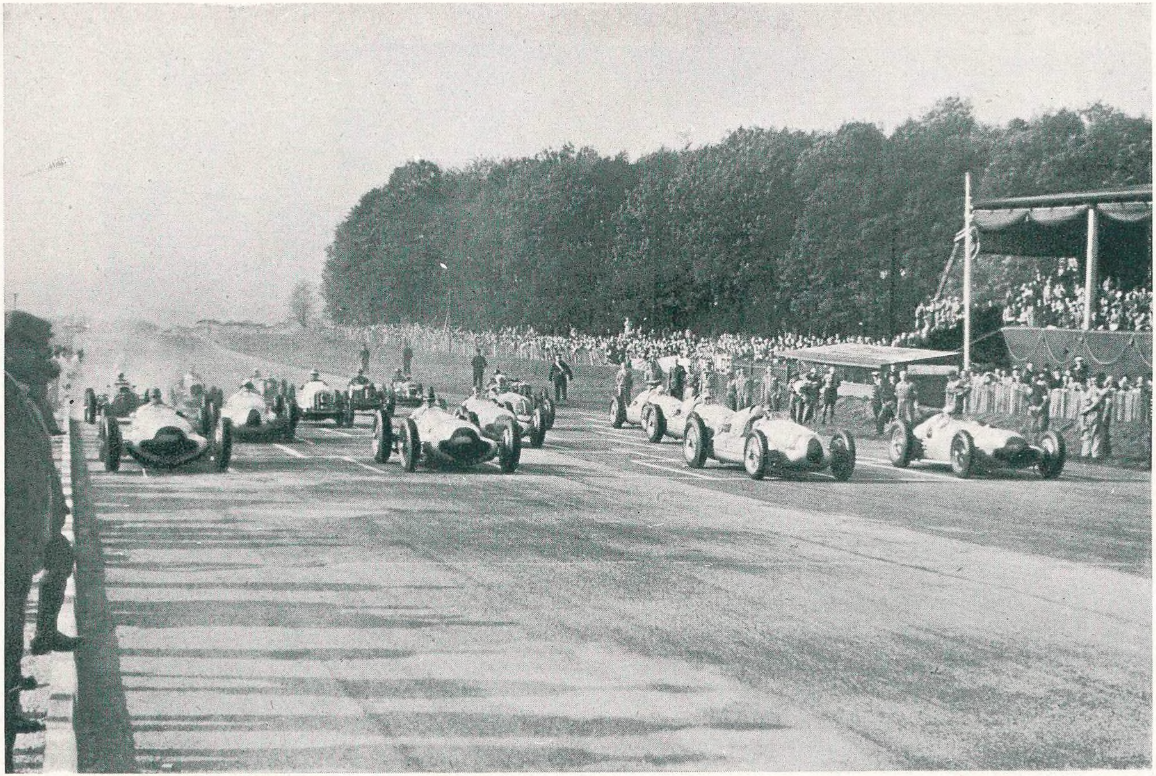


Plate 50. [Photograph : " The Autocar."

GRAND PRIX RACING IN ENGLAND.

THE START OF THE 1938 GRAND PRIX AT DONINGTON. IN THE FRONT ROW ARE TWO MERCEDES-BENZ AND TWO AUTO-UNIONS.

a series of curves, through the public enclosure to the Home Banking, the circuit being completed by a run round the Home Banking and down the Finishing Straight, and the length being 2·26 miles. This is not quite a road-racing circuit either, but serves its purpose and has certainly introduced the art of cornering to the Brooklands driver, but the corners are rather slower than they need have been, and the only ones that are really interesting are the aerodrome curve and the curve as the car crosses the Finishing Straight on its way to the new pits.

Infinite variations of circuit are possible with the aid of this road and the outer circuit.

Donington Park Circuit, originally developed by the enthusiasm of the Derby and District Motor Club in the grounds of Donington Hall, near Derby, with the aid of the owner, Mr. J. G. Shields, has been growing steadily since 1933, extensions

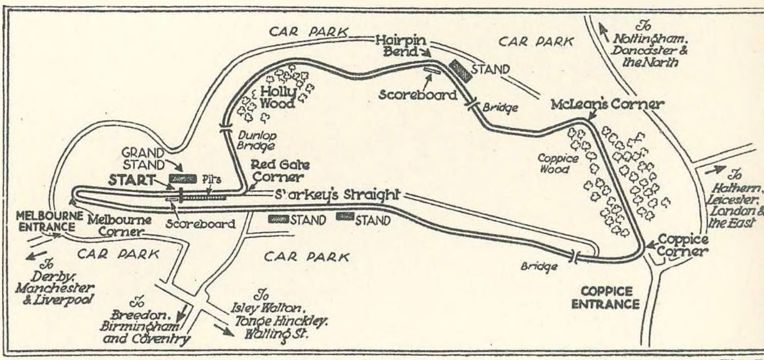


Fig. 70

Donington Park

being constructed from time to time and the roads widened until it is now our premier road-racing course, and the surroundings set the thing off to the best advantage. There is one long run extending, with only a few high-speed bends, from Coppice Corner to the hairpin at Melbourne, but difficult because Melbourne is approached over the top of a rise and then downhill, while after the corner there is a steady uphill section which provides a rather hearty bump before it flattens out in front of the grandstand. On the remainder of the course there are many corners, most of them very interesting, and there is not over-much opportunity for passing, while the run from the right angle which is termed the Hairpin back to Coppice Corner is enlivened because the trees on either side of the road throw patchy shadows on the circuit when there is strong sunlight.

It is, however, an excellent circuit, both for training and for racing, and will undoubtedly improve still further as the years go by. For testing purposes there is also a special road joined to the circuit in such a way that the cars can use the relatively straight leg of the course, turn Melbourne Corner, then have an even straighter run back almost to Coppice. The length of the racing circuit is $3\frac{1}{8}$ miles.

The latest addition is the Crystal Palace Circuit at Sydenham, in the very confined space of the Crystal Palace grounds, with the idea of providing a popular spectacle. As the plan shows, there are very many corners per mile, the lap distance being 2 miles, which certainly makes the racing spectacular, but makes it difficult to pass and puts a heavy premium on brakes. The most difficult corner is probably Stadium Curve, as to taking

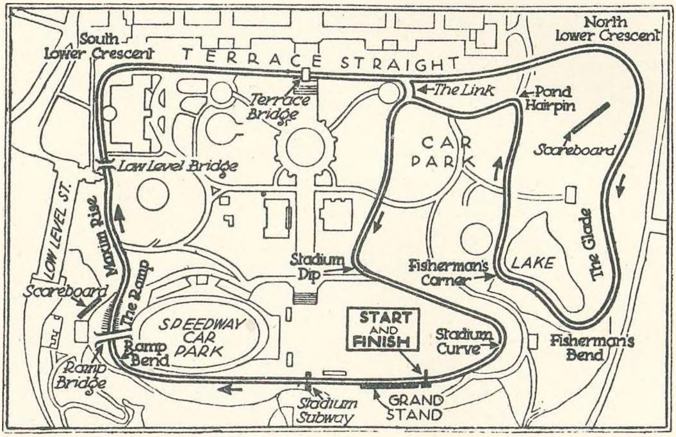


Fig. 71

THE CRYSTAL PALACE CIRCUIT

which no two drivers agree, and the easiest to misjudge, the left-hand right angle at Stadium Dip.

Most famous of all the circuits, though, alas, it is now out of use, is that at Ards, near Belfast, a real, genuine road circuit better than any of those on the Continent, and used exclusively for the tourist Trophy. On this circuit there is practically every type of corner, and all of them are extremely interesting, the most fascinating probably being Bradshaw's Brae, the level crossing, and the turns in Comber village itself. Being 13 miles round, this circuit gave the driver breathing space, and abolished that feeling that one was chasing one's own tail, which is very prevalent on the shorter runs. At first the circuit was disastrously slippery, but in later years a special dressing overcame the trouble completely.

Unfortunately there was a very bad accident in the 1936

Tourist Trophy, and as many spectators were injured or killed, racing on this circuit had to be abandoned.

Of the other circuits, the one in Phoenix Park, near Dublin, is

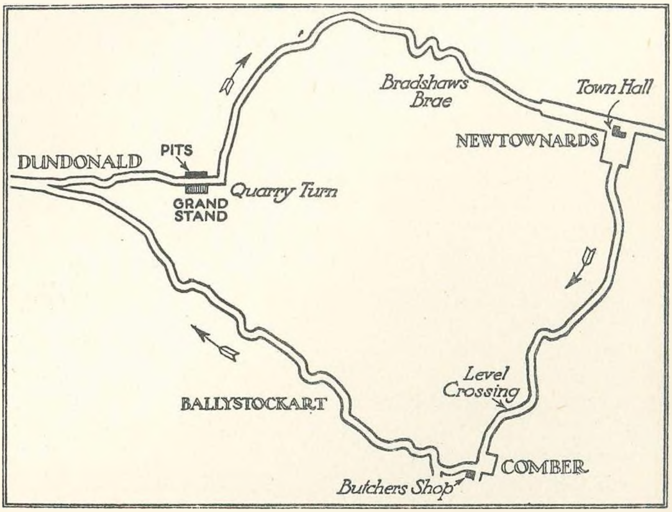


Fig. 72

THE ARDS CIRCUIT

short and D-shaped, the curve of the D being indented, and the straight being slightly uphill, while the circuit at Cork has one very fast leg, and that at Limerick is "round the houses," Monaco fashion.

CHAPTER NINETEEN

GRAND PRIX RACING

By R. J. B. Seaman

MOTOR racing, as far as the man in the street is concerned, is much the same the world over—just a lot of crazy fellows rushing round a road or a track on very fast and expensive cars. Actually, of course, the conditions of racing in different parts of the globe are as different as chalk from cheese, and as the English driver knows only too well, the main difference between racing in this country and Grand Prix racing on the Continent is that while here it is almost entirely a sport supported by amateur drivers running their own cars, on the Continent the chief support comes from big factories running their own teams with professional drivers.

In England there is only one big manufacturer of production cars who takes any active interest in racing, and that is Austin. This firm, together with the privately run works of E.R.A., make up the only two factory teams who run in English races at the moment. This, of course, does not in the least mean that the sport in this country is in an unhealthy condition, for there are plenty of extremely capable amateur drivers to make up the fields. Drivers like "B. Bira," Arthur Dobson, Charles Martin, Percy Maclure, Lord Howe (though this year he is driving as a member of the E.R.A. team), Johnny Wakefield, Kenneth Evans, and others, are all capable of putting up an extremely fine show indeed, and, odd though it may seem, more often than not one of them gets home before the works' teams. All these men, however, are amateurs, running their own cars for the sport of driving.

Entirely different conditions exist in Grand Prix racing on the Continent. Probably owing to the fact that there are not nearly so many other sports forming counter-attractions as there are over here, and because racing has never been restricted by legislation, the sport has always attracted very much greater public interest, which has, naturally, encouraged the big manufacturers to compete.

For the last few years, while there have of course been several independent drivers running in most races, the chief contestants have been Mercedes-Benz and Auto-Union of Germany, and Alfa-Romeo of Italy, with the smaller factories of Bugatti and Maserati occasionally entering. This year the French Delahaye factory has joined the fray.

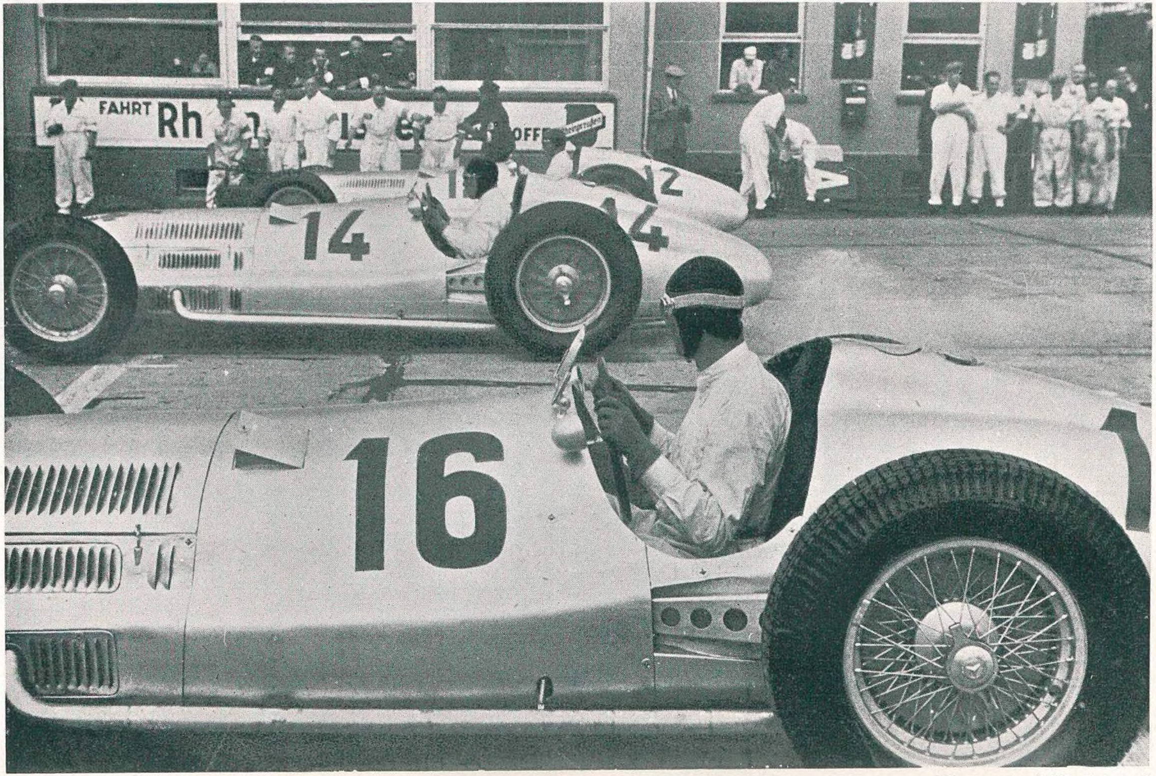


Plate 51. [*Photograph :* " *The Autocar.*"]

RICHARD SEAMAN AT THE WHEEL OF A MERCEDES-BENZ.

ENORMOUS SUMS OF MONEY ARE SPENT UPON THE BUILDING AND PREPARATION OF THE CARS, AND PICKED DRIVERS FROM SEVERAL COUNTRIES ARE CAREFULLY TRAINED TO COMPETE IN THEM IN ALL THE MOST IMPORTANT GRAND PRIX RACES.

While all these firms go to great lengths in the building and preparation of their cars, the methods adopted by the three chief teams are little short of amazing to anyone brought up on English methods, where each driver has at the most his three mechanics and probably prepares his car in his own garage.

The firm for whom I drive, Mercedes-Benz, has probably had more experience of Grand Prix racing than anyone else, and its methods serve, therefore, as an excellent example. Altogether about three hundred men are employed in building and preparing the cars. In charge of the entire racing programme is Director Sailer, ex-racing driver of pre-war days, and now chief technical director of the whole factory. Under him work his two lieutenants, Ing. Uhlenhaut, who has the very responsible duty of testing and preparing the cars, and Alfred Neubauer, who organizes the actual racing of the machines.

About the middle of each season, when that year's cars have run in several races and their good and bad points have shown up, work is begun on the designs for the following year. These are usually completed by the autumn, when they are sent down from the drawing office to Uhlenhaut in the experimental department, where the building and testing will be carried out. Early the next year the first car is usually complete, when it is subjected to the most exhaustive tests. When Mercedes first resumed Grand Prix racing in 1934, nearly all this testing was done on the road, which necessitated stays of weeks on end at Monza track in Italy, the only suitable circuit for this sort of thing in mid-winter. Since then, however, the most elaborate testing apparatus has been evolved at the factory so that first of all every component, such as the gear-box, brakes, petrol-pump, water-pump, valve gear, and complete engine, can be subjected to the most stringent tests individually, and finally the complete car is mounted on an ingenious system of rollers and driven the equivalent of hundreds of miles inside the workshop. Also, the completion of the near-by autobahn has provided a further convenient testing-ground within a few miles of the factory. Lang or Uhlenhaut at first did tests along this road while it was still open to traffic, but after one or two "avoidances," they arranged with the authorities to have one side of the road closed; but if one happens to be motoring peacefully along the other side, one is still liable to be passed by a Mercedes at 180 m.p.h. a few feet away over the central dividing strip.

Good as these methods are, however, there is nothing to equal driving the car round a road circuit under racing conditions, so one trip to Monza is still made when the car has come through the other tests. At Monza the car does many hundred kilometres, while tests are made on points such as springing, road-holding, and petrol consumption, which can only be tried properly under genuine road conditions. During these tests Uhlenhaut does most of the driving himself, and succeeds in getting the car round amazingly quickly. It is quite unique to find an engineer in his position capable of driving the car as he does, and needless to say it is very useful indeed for a chief engineer to be able to know at first hand how his cars behave at racing speeds.

After Uhlenhaut has completed his tests, Caracciola usually takes the car out for a considerable time, and when he finally brings the car in, his opinion is awaited with the greatest interest, for it is naturally very valuable in view of his fifteen years' experience of racing, and the ultimate success of the team during the coming season depends to a great extent on how he and the car "hit it off."

Finally the car is sent out on a 500-kilometre flat-out run, driven in turn by each of the drivers.

The first experimental car having at last proved itself as nearly as possible "hundred per cent," the other cars of the team, whose main components are now ready, are completed in accordance with the result of these tests. The experimental car has by now probably covered so many miles that it is no longer fit for racing, and will probably be allotted the degrading position of practice car, while its younger and fresher offspring obtain all the glory of running in, and perhaps winning, the races. The same sort of methods are adopted, in varying degrees, by the other teams, so that the winter is just as busy and important a time for the various racing departments as the actual season itself.

Vitally important though this work of preparation may be, the cars have got to be driven when they are finally pushed on to the starting line by their mechanics, so what of the drivers? Each team retains its own professional drivers, and it was an interesting and satisfactory fact that until the end of 1937 Mercedes, Auto-Union, and Alfa-Romeo each had the services of one of the three wizards, Caracciola, Rosemeyer, and Nuvolari, respectively. These three were all absolutely "+100 A.1," and acknowledged to be in a class of their own. Both Rosemeyer and Nuvolari had an absolutely uncanny control over their cars, and could indulge in the most extraordinary "carobatics" to extract themselves from any difficult situations whilst cornering. Caracciola, however, a quiet and unassuming figure against the colourful personalities of his two rivals, is in my opinion the most technically perfect driver in the world. It is very rare that one sees his car cornering in anything but a perfectly controlled slide, and the fact that during the past three years' racing he has not had even a minor accident is a record which does not receive the recognition it should. While Rosemeyer and Nuvolari usually gave a terrific impression of speed, Caracciola makes driving look like child's play, a sure sign of the past-master.

Alas, poor Bernd has met his death, while Nuvolari has announced his retirement from the sport. I have an idea that the absence of these two great figures, whose terrific driving was such a feature of every race, will have a bad effect on the popularity of Grand Prix racing.

Another of the outstanding features of Continental racing is the large number of different road circuits on which races are held all over the Continent. The result is that a season's racing provides one with a very complete sight-seeing tour of Europe. The circuits differ just as widely in their characteristics as they do in locality. The circuit through the streets of Monaco, for instance, is as different from the twisting Nurburg Ring, switchbacking its way through the Eifel Mountains, as the latter is from the triangular Pescara Circuit, with its 12-mile twisting section and two 4-mile straights. Then the Tripoli Circuit is again quite unique, with its many flat-out curves and entire absence of slow corners which give it such a very high average speed and make it the fastest road circuit in the world, and faster even than any track, except the Avus at Berlin.

Ruling out the Avus as a track pure and simple, it is interesting to note that the highest speed attained on the road during racing is reached on the long, slightly downhill, straight at Spa, where in 1937 the German cars were reaching a speed of 310 k.p.h. Second fastest speed is attained on the Masaryk Circuit in Czecho-Slovakia, which with its 28 kilometres is the longest circuit now used for racing, where a speed of 300 k.p.h. has been attained. Tripoli comes third with 290 k.p.h.

Most of the Grand Prix teams pay their drivers a regular salary and give them, in addition, a percentage of what they win. Some of the teams pool their prize money and bonuses after a race, and share it out equally among their drivers, while others allot each driver the percentage of what he actually won himself.

The various methods of team control during the actual race adopted by the various firms are all quite simple, each driver being kept informed by signals of his exact position in the race and being left to drive as he thinks fit. This often seems rather a happy-go-lucky way to those who are used to the comparatively complicated methods of team control necessary in English handicap and long-distance sports car races. It must be remembered, however, that the competition is usually so keen in modern Grand Prix racing that every driver has to go flat-out all the time, so that there is never any question of one or more drivers being kept back in reserve.

Many people often wonder, too, why one driver is not sent out to drive as fast as possible on a specially boosted car to encourage his rivals to chase him and thereby blow up, as was done so successfully by Sailer of the Mercedes team in the historic 1914 French Grand Prix. While this method was quite effective in those days when there was only one classic race each year, it would not work nowadays with a race almost every week, for each team knows the methods and capabilities of its rivals so intimately that they would be sure to tumble to such a ruse.

Looking at Grand Prix racing from a broader angle, however, what are its objects, and does it really justify its terrific expense? Now the two original reasons why firms raced were for research and publicity. None can deny the value of the latter, especially if properly handled, but it is often claimed that a firm obtains no technical information applicable to its production models through racing that it could not quite easily obtain in the laboratory. I cannot see how this view can possibly be substantiated.

Though normal experimental methods may seem as good on the face of it, the fact remains—human nature being what it is—that a firm is always very inclined to hang on to a certain good design unduly long and shelve any further experiments in that direction, thereby saving the alteration in production methods which a new design would entail. But when the incentive of racing has *forced* it to perfect fresh designs for the cars which it is racing under the public gaze, it is naturally loth to have these designs available without incorporating them in its production models.

The theory that designs developed for racing cars are unsuitable for touring cars does not in my own experience hold water for a moment. The basic problems to be faced in designing, for example, the suspension system are exactly the same for a racing car or a touring car, and are merely very much more difficult of solution on the former. The object in both cases is to provide as much spring travel as possible in order that the wheels may follow even the most irregular contours of the road, without affecting the chassis. At the same time the springing must not be unduly "sloppy" or cause the car to roll on corners.

These objects have been accomplished on the most advanced Grand Prix cars to a degree which four years ago would have been considered utterly incredible. At that time the maximum rear spring travel which could be allowed without the car becoming unstable was about two inches. The latest Grand Prix cars have a rear spring travel of a foot, thus absorbing quite big road undulations without setting up roll or rear wheel flutter. The principles thus developed are being applied to the

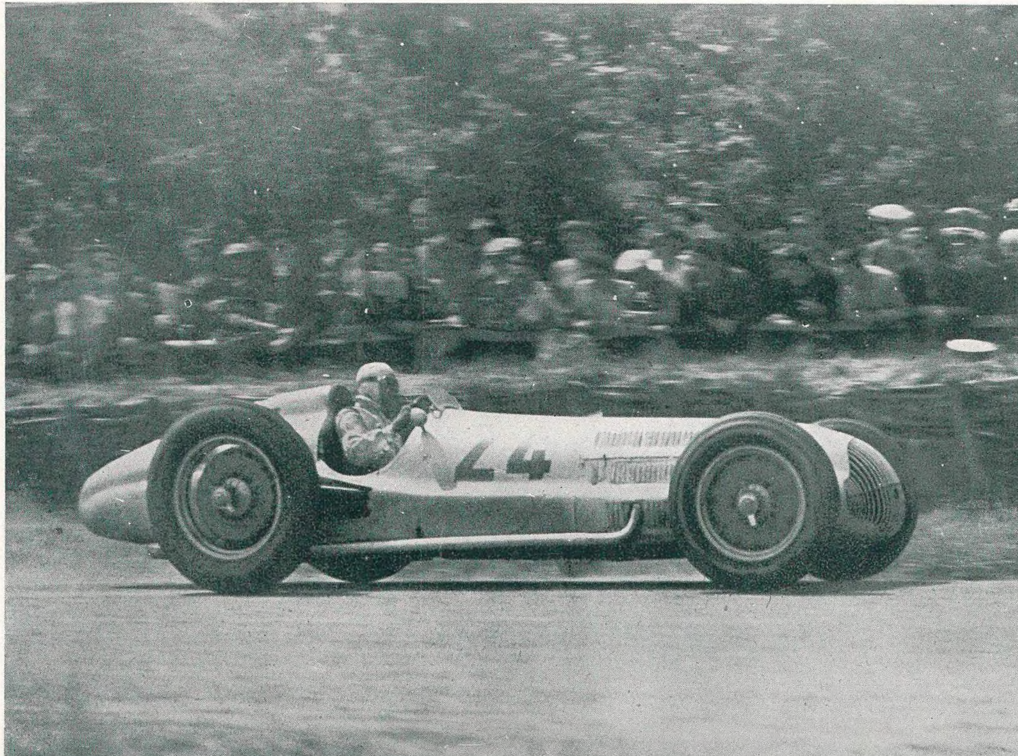


Plate 52. [*Photograph* : " *The Autocar*."

MERCEDES-BENZ.

CARACCIOLA AT HIGH SPEED. NOTE THE GREAT DIFFERENCE IN SIZE BETWEEN THE FRONT AND REAR TYRES.

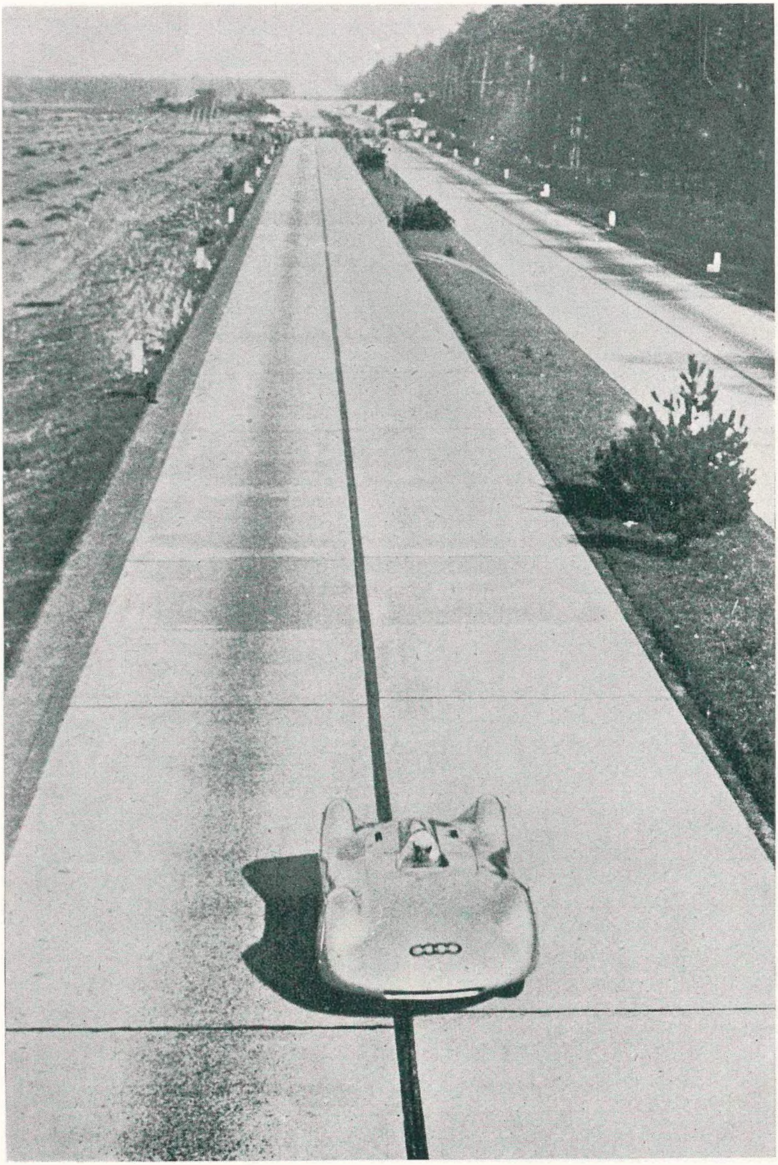


Plate 53.

RECORD BREAKING ON THE ROAD.

SECTIONS OF THE GERMAN "AUTOBAHNEN" ARE CLOSED FOR SPEED RECORD ATTEMPTS. HERE THE LATE BERND ROSEMEYER IS SEEN DRIVING AN AUTO-UNION WITH A SPECIAL STREAMLINE BODY, DESIGNED SOLELY FOR THIS PURPOSE.

production cars of these firms, an excellent example being the new "Grosser" model Mercedes-Benz, which incorporates the same design of chassis and suspension as was used on the Mercedes racing cars.

Valuable though these technical developments are, however, I don't think there is much doubt that no firm could justify the expense of present-day Grand Prix racing on the technical and publicity scores above.

Why, then, are these Continental firms, especially the Germans, spending such vast sums on racing every year? The reason is, of course, for national propaganda. Much as one may dislike the fact, there is no denying that Grand Prix racing has become a political force on the Continent. Anyone who has seen the enthusiasm and publicity accorded to the German teams, the lofty hall, rather resembling a cathedral, in which the victorious German racing cars were enshrined at the last Berlin motor show, and the keen interest taken in the cars and drivers by the Führer himself, must admit this fact. The success of this policy as a stimulant to the German motor industry and to the prestige of the nation as a whole cannot be denied. All the more pity, then, at a time when we are told how important it is that Britain should show her true strength to the world, that this effective and genuine way of upholding a nation's prestige should go neglected by this country.

CHAPTER TWENTY

HILL CLIMBING

By Raymond Mays

TO my mind "speed hill climbing" is quite the most thrilling form of motor racing. It is entirely different from road racing and really requires a different technique. Hill climbs, particularly in England, are all over in the space of a few seconds, and it is obvious therefore that the driver has no time to make up for mistakes, as in road racing. In road racing it is the usual procedure not to go too fast at the commencement of the race, until one has had time to settle down, but in hill climbs it is impossible to adopt this technique, because the event is over almost before it has started. It is absolutely essential to collect one's nerves together from the very start for these few seconds of real thrills; every corner and every part of the course is taken at the maximum possible speed, having no thought for the car at all. In other words, engine revolutions and tyre wear are hardly considered, as they would be in road racing.

In the earlier days of motor racing in England, before the War, hill climbs were the general form of motor sport and there took place practically every week-end the famous old hill climbs such as Shelsley Walsh, South Harting, Holme Moss, Caerphilly, &c., &c. All the best drivers, such as Malcolm Campbell, Parry Thomas, Kensington-Moir, Segrave, and other well-known men, regularly attended; and there were works entries of Vauxhall, Sunbeam, and Bentley cars, &c. Unfortunately these events were held on public roads, and as certain accidents occurred with the spectators, they were stopped.

To-day there are still important hill climbs abroad, which are of rather a different type from the English events, because they are considerably longer. However, before dealing with any of the foreign hill climbs, I should like to go back to our one and only remaining hill climb in this country—Shelsley Walsh—and give you my impressions of a fast ascent.

This event is now the only international hill climb open for competition in this country, and though the meeting is held twice each year, one can never have enough practice in the all-important art of stealing split seconds off one's previous best time.

I do not like to be on the starting line any longer than neces-

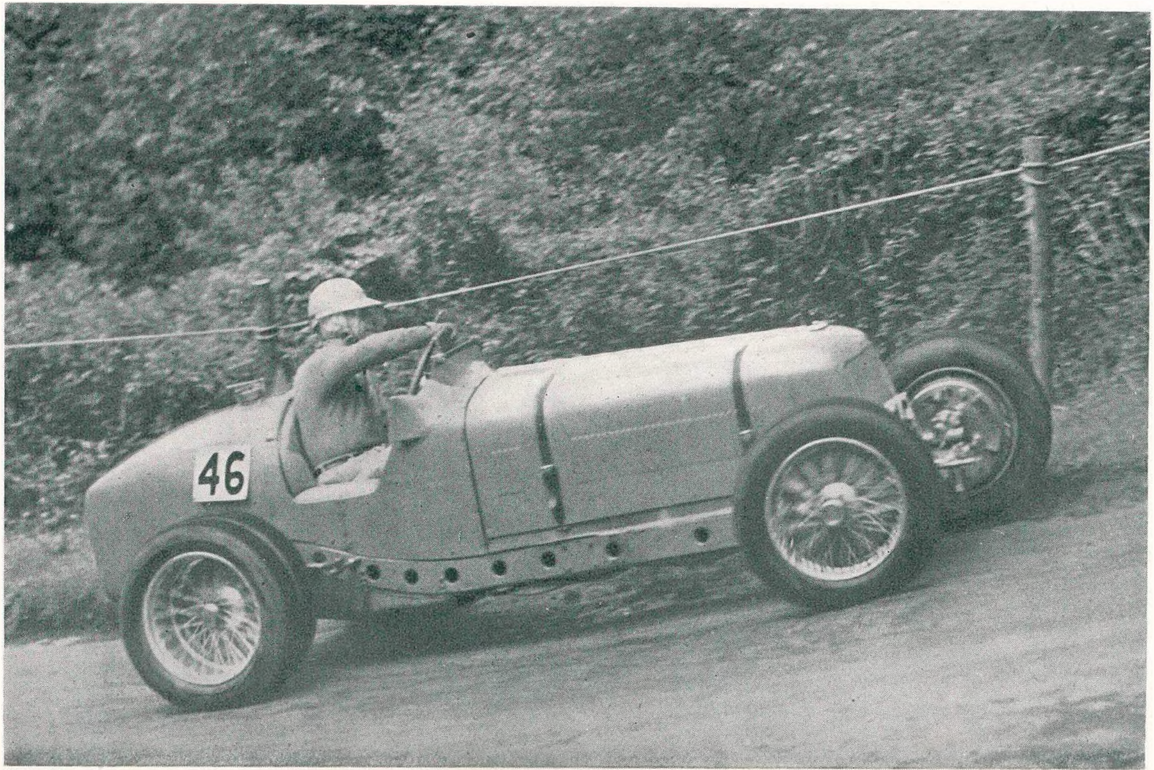


Plate 54. [*Photograph : " The Autocar."*

SHELSLEY WALSH.

RAYMOND MAYS ON THE S BEND OF SHELSLEY WITH THE ZOLLER SUPERCHARGED E.R.A., A TYPE BUILT JUST BEFORE THE $1\frac{1}{2}$ LITRE FORMULA MACHINE.

sary, as, apart from the engine, the longer you stay there the more nervy you become, and to my mind a speed hill climb of the type of Shelsley Walsh is quite the most nerve-racking type of motor racing. This is chiefly due to the fact that the climb is so short and so hectic, and it is necessary for the driver to be at the peak of performance from the very moment he starts, while there is not time to make up for a single mistake, as in long-distance races. On corners one takes far greater risks, both as regards driving, as regards tyre strain, and as regards engine revs.

When arriving at the starting line I always try to place the nose of the car at a slight angle to the left, with a view to cutting in close on the right-hand bend before approaching the railing bend. For the last two years the driver has been allowed to start in his own time. In other words, there is a small electric apparatus placed in front of the wheel, and the moment the front wheel of the car crosses this the timing has commenced. I think I prefer the old method of starting by the flag, as waiting for the flag to fall makes an extra difficulty for the driver and any advantage gained by quick reaction to the fall of the flag is now lost with the new timing method.

About ten seconds before I leave the mark I rev. the engine up to 4000, and just previous to letting in the clutch I press hard on the accelerator pedal; the moment the car has left the line it is necessary to ease the throttle to check wheelspin. The get-away is all-important, it being only too easy to lose a fifth of a second or more at this point.

On the E.R.A. I remain in first gear until just over the peak of the first steep part, which brings you to a slight bend to the right. It is necessary to pre-select your gear the moment you have moved off the mark, so that you have both hands on the wheel for the railing bend.

Wheelspin tends to drag the rear of the car into the off-side bank, which cannot be allowed, as if you do get into the right-hand side you are wrongly placed for the slight left-hand and right-hand kinks that lead into the railing bend. So I try to clip the grass on the right-hand kink, which places me in the correct position. Revs. are now well over 6000 and one has got to find time to change up before going into the railing bend.

This bend is very tricky, and one must enter it as fast as possible in second gear. All fast cars are going much too quickly to get round the railing bend without easing off, and if you are a fraction late cutting out it will be impossible to get round without a bad skid and possibly hitting the bank with your rear wheels. This bend gives one the impression that it is worse than it really is, but if you can manage to keep a steady slide on the corner, helping the back round with a little throttle and finishing against the grass with the rear wheels on the right-hand side of the road, you are in a good position for the next corner.

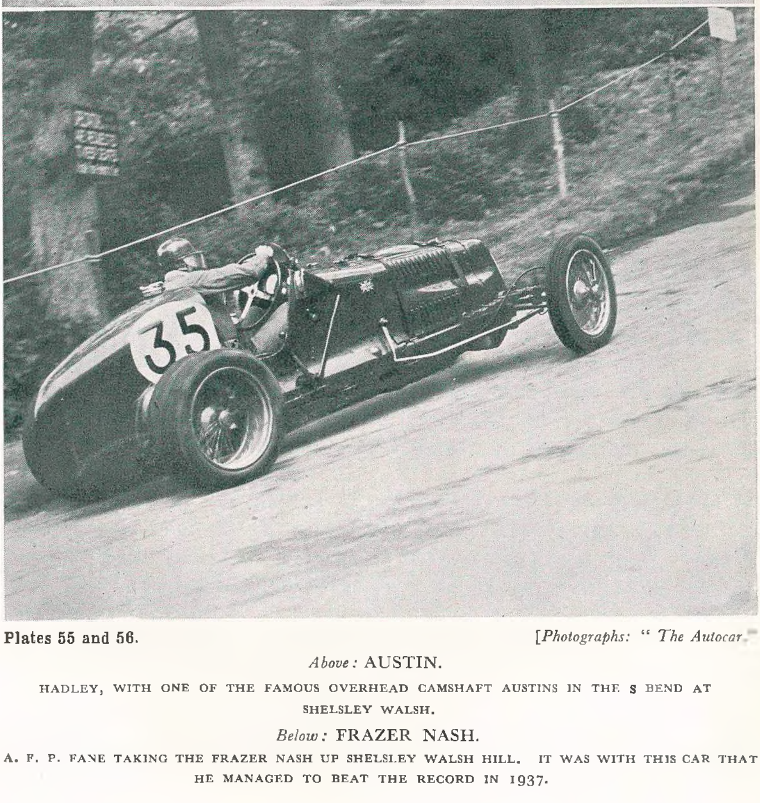
The placing going out of the railing bend is extremely important, as now you want to be plumb in the middle of the road, and it is here that I change into third gear at over 7000 r.p.m. in second, and again have to ease slightly for the next bend, which I call the "crossing." The road is steeper here and has become very bumpy, but the car must be positioned for the "lower slopes," which are all taken in third gear and are by no means straight. I try to come out of the crossing bend in the middle of the road, the object being to get a position which enables one to take the next kink to the left, which I call the "concrete" bend, owing to a concrete patch on the inside, flat out.

From here all the way up to the "S" bend it is very difficult to remember exactly what happens, but the road surface is very bad and a trip up on a touring car would convince anyone how bad some of these bumps really are. There are two outstanding bumps, one just as you leave the concrete bend; if you hit the worst part on the right-hand side of the road it is impossible to get away from the right bank without taking your foot off. The second bump is just before the "S" bend, and the car actually leaves the ground with all four wheels for quite a considerable time, so that you only just strike the road again when it is necessary to give a hard application of the brakes for the "S" bend.

All this time the speed has been rapidly increasing on the 1 in 8 gradient, until one is nearing the "S" bend at about 90 m.p.h. During the preceding run up the lower slopes, it has been necessary to pre-select first gear, ready for the "S" bend, and I must say that it is a dreaded moment when one has to take a hand off the wheel to pre-select the gear, though there is no doubt that this type of box is an enormous help. One can take the second bump which I have mentioned, as an excellent landmark, which tells you that you have got to brake immediately, and brake hard, to have time to change down into bottom.

The approach into the "S" is one of the most difficult parts of the hill. All I ever remember after leaving the line is seeing a mass of spectators' heads on the corner loom into view before I know where I am. Placing for the "S" bend is of terrific importance, and I try to get into a position to enter the bend just fast enough not to skid but to get a swing at the corner proper, which means the use of full throttle as soon as you leave the apex. This method is, to my mind, quicker than having to fight out a slide into the right-hand bank.

Between the two bends of the "S" you need colossal acceleration for a second or two on the 1 in 6·8 gradient. The second



Plates 55 and 56. [*Photographs: " The Autocar."*

Above: AUSTIN.

HADLEY, WITH ONE OF THE FAMOUS OVERHEAD CAMSHAFT AUSTINS IN THE S BEND AT SHELSLEY WALSH.

Below: FRAZER NASH.

A. F. P. FANE TAKING THE FRAZER NASH UP SHELSLEY WALSH HILL. IT WAS WITH THIS CAR THAT HE MANAGED TO BEAT THE RECORD IN 1937.

half of the "S" is a very unpleasant corner, banked the wrong way and very acute. Further, the road narrows considerably just at the point where you want the most width. On the E.R.A. I have to cut out and slow appreciably in order to take the second half of the "S" in a slight slide, helping the back round with a little throttle. It seems ages before you can put your foot down when going out of this corner, and again, the more you can avoid the left-hand bank, for which the cars seem to hold great affection, the quicker you can open out.

Then it is a matter of full throttle, through second and into third gear. Even on the finishing straight which one has now entered, the road surface is so bad that one quick glance at the instruments—at which, indeed, it has been impossible to get a look since the crossing bend—is sufficient to put you off the road. From this point to the finishing line one's whole time is occupied in correcting a series of swerves, and it is a very unpleasant moment when you have to let go of the wheel for changing to second and third gears.

Soon the car has attained over 90 m.p.h. and you begin to wonder whether you are going to slow sufficiently after the finishing banner to get into the field at the top of the hill and avoid that nasty-looking bank on the right-hand side through the gates. I kept the E.R.A. in second gear over the finish, and a desperate glance at the rev. counter showed the needle getting perilously near the 9000 mark. I accelerated to something between 90 and 100 m.p.h. before passing the finishing line, and I must say it is one of the finest moments in life when you pass the finish after these few seconds of real thrills.

The outstanding hill climb on the Continent to-day is the Grosser Bergpreis von Deutschland, held annually near Freiburg im Breisgau, in the heart of the Black Forest. The road is a public highway winding and twisting up the Schauinsland Mountains, and a section of 12 kilometres is taken for the event itself. The difference in altitude between the start and finish is 2440 feet, which gives a varied range of landscape and road conditions.

This event is organized by the German Automobile Club (D.D.A.C.) and contains classes for motor cycles, sports cars, and racing cars. Freiburg is an extremely important event on the Continent, but unfortunately it is not known much amongst English drivers as it has usually clashed with other important dates in England, which has prevented our own drivers from competing. Its reputation for popularity is well testified by the attendence, which in 1937 included 100,000 spectators and entrants from every country in Europe. For the last few years the latest type of German Grand Prix racing cars have been supreme, and most of the famous drivers, such as Caracciola, Rosemeyer, Stuck, Brauchitsch, and Lang, have all competed. The present record is held by Hans Stuck on an Auto-Union.

The start is in a narrow country road between high hedges, there is a straight for about half a mile and then a left-hand bend commences the real climb. Onwards then to the top of the hill there are a series of corners of every description, some fast open curves, and others "tight" hairpins, which run from one into another. Some of these corners are so sharp that one only just has time to lock the wheel over from one full lock to another. When I drove an E.R.A. at Freiburg in 1935 my greatest difficulty in the short space allowed for practice was to make myself familiar with the landmarks introducing each section. On a long hill of this nature there are one hundred and forty corners to be learnt, each one of which is different. An enormous amount of study is needed because it is essential to leave one's breaking point to the last possible moment. Unless the driver has complete confidence that he knows exactly which corner is coming, many valuable seconds may be lost.

As one ascends the hill the surrounding scenery changes. From the lower slopes and picturesque valley at the bottom one comes gradually into the pine forests, passing, incidentally, beneath the aerial railway to the top of the mountain. For the last half of the climb you pass through densely packed trees on either side of the road with steep ravines. Many accidents have occurred here through cars leaving the road and the driver being hurled down the mountainside through the trees.

The gradient varies from the easy incline at the start to the steep zigzag hairpins on the higher slopes of the mountain, but in no place is it as severe as the 1 in 5 "S" bend at Shelsley Walsh.

Driving up Freiburg is extremely difficult, as one may have imagined, and a severe test to both driver and machine. Similar tactics to those employed at Shelsley are necessary, the driver giving his utmost in concentration of mind and skilful handling of the machine. With so many corners, even the fraction of a second lost through early braking or inaccurate placing adds many seconds to one's complete time for the hill.

The most alarming section is after the ninth kilometre, where, driving at a very high speed with a sheer drop of several hundred feet on one side and a cliff on the other, one approaches, over the crest of a rise, an acute and very narrow right-angle corner with a frontal visibility of only a few yards. From here a series of acute bends lead to the short last straight, then suddenly, between dense trees, the finishing banner comes into view. In comparison with Shelsley Walsh, an unfortunate rule to English competitors is that only one ascent is allowed, and the

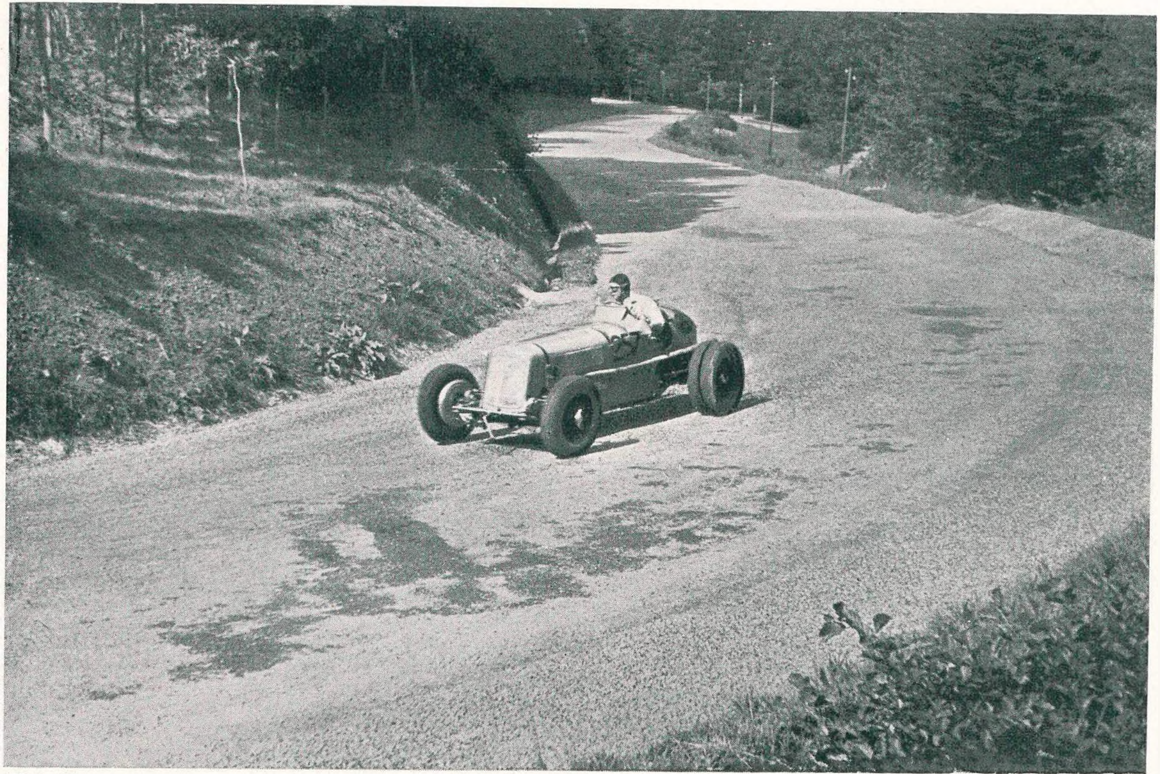


Plate 57. [*Photograph : Karl Muller.*

FREIBURG HILL CLIMB.

A GOOD VIEW OF THE BROAD SURFACE USED FOR THE ANNUAL HILL CLIMB. THE CAR IS RAYMOND MAYS', FITTED, IT WILL BE NOTICED, WITH TWIN REAR WHEELS.

driver always feels that he could have saved many seconds if only he could have a second run.

When arriving at the finish every driver of a fast car is physically exhausted; arms are aching with the heavy manœuvring of the wheel and one's head is buzzing from the sudden increase in altitude, and it is not pleasant to look back on all the narrow escapes packed into those few minutes of exciting driving.

CHAPTER TWENTY-ONE

RECORD BREAKING

By G. E. T. Eyston

THERE is an enormous fascination about records. Lots of people cherish a time in their minds, a record that they have taken for some quite simple routine matter, and when they manage to do it a little quicker than ever before, they exclaim "That's my record!"

One might hold that without records there would be very little progress in any sphere, business, sport, or what you will. Record profits, record taxes, record production, record journeys! Records in sport have always been keenly sought, for here there is an individual performance, or a team performance, for which there is a definite time established, and honour goes to the man or group of men who can do better. There are Ground records, Native records, National records, Empire records, Olympic records, and World's records in athletics alone.

Ever since motor cars began, records have been similarly sought after. The official list for the holders of the fastest speed on land begins in 1898, with the remarkable speed of 39·24 m.p.h. by a Frenchman named Chasseloup-Laubat, driving a Jeantaud. Even before this time there had been unofficial trials, each man striving to do better than his fellows.

Soon all kinds of other records began to be established, for different sizes of cars, for long and short distances, and for periods of time. Thus records are now recognized for cars from 350 c.c. to an unlimited capacity, for distances from 1 kilometre to 180,000 miles, and for times from 1 hour to 133 days, this being the longest period during which any drivers so far have been timed under official supervision.

There is, however, only one list of World's records officially recognized by the *Association Internationale des Automobile Clubs Reconnus*, which is the governing body of the sport so far as cars are concerned. For World's records there is no limit as to the size of engine or car which may be employed. Either may be as small or as large as the designer wishes, but the performance over a given time or distance must beat the best that has ever been set up before.

All other records, for cars of various engine sizes, are known as International records. Their sponsors occasionally noise

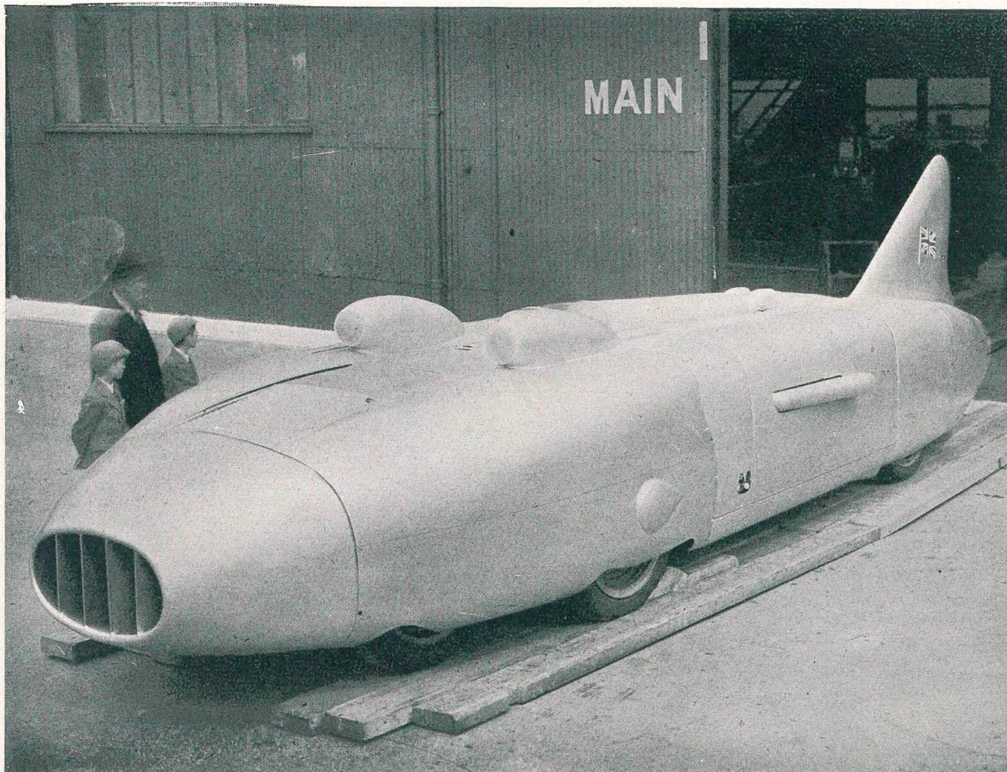


Plate 58. [Photograph: "The Autocar."

CAPTAIN G. E. T. EYSTON'S LAND-SPEED RECORD-BREAKING "THUNDERBOLT."

THE TWO PROTRUDING SHAPES ON TOP OF THE BODY ARE AIR INTAKES FOR THE SUPERCHARGERS OF THE TWO ROLLS-ROYCE ENGINES.

them abroad as World's records, but this is entirely erroneous. Motor cycle records may similarly be set up by machines of various sizes, and classes are recognized, but all records are termed World's records by the F.I.C.M. which controls motor cycling sport, although the limit to engine capacity is 1000 c.c.

For International car records there are a number of classes, and cars are only eligible to take records in that particular category under which their engine capacity falls. Thus a 1500 c.c. car can only take records in the class for machines with engines from 1101 to 1500 c.c., and even if the figures which it sets up are superior to those in the classes for bigger cars, no further ranking is accorded, unless actually the World's record for the particular time or distance is beaten. Here again there is a difference from motor-cycling sport, in which a small machine with a phenomenal performance may scoop up the records in all the classes by one run.

It will simplify matters if the various car classes are set out as under:—

Class A, over 8000 c.c.	Class F, 1101-1500 c.c.
„ B, 5001-8000 c.c.	„ G, 751-1100 c.c.
„ C, 3001-5000 c.c.	„ H, 501-750 c.c.
„ D, 2001-3000 c.c.	„ I, 351-500 c.c.
„ E, 1501-2000 c.c.	„ J, Up to 350 c.c.

A few years ago a separate class for compression ignition or diesel-engined vehicles was also recognized for the first time.

It follows from these strict class limits that, before an International record can be recognized, the engine of the car must be carefully measured by the officials concerned, to ensure that its capacity lies within the limits laid down. A re-bored engine may well have been so increased in size that it no longer comes into the category for which it was originally made.

Class A in the above list, for cars over 8000 c.c., must not be confused with the World's record list, which is quite separate altogether. By no means all of the World's records are held by cars with engines greater than 8 litres. If a car is attacking World's records only, then the engine need not be measured, but if at the same time the corresponding records in an International Class are to be claimed, the engine size must be checked. Sometimes, when very secret engines are being used for World's records, their drivers do not claim the Class records, so that they shall not be compelled to disclose the bore, stroke, and capacity of their engines.

All records are timed from a standing start, except that there are special flying-start records for distances of 1, 5, and 10 kilometres or miles. Amongst these special records lies the most coveted of all, the World's Land Speed Record, which at the present time I am fortunate enough to hold. Actually the

"Land Speed Record" has no official standing as such, and the flying mile or kilometre is the one that is set down in the list. My own Land Speed Record with "Thunderbolt" was set up over the mile at 357·5 m.p.h. And the speed one way over the kilometre was 359·64 m.p.h.

It does not always follow, however, that the fastest speed is recorded over the shorter of the two distances, for when my old friend Sir Malcolm Campbell was the first to exceed 300 m.p.h. it was over the mile that he recorded 301·13 m.p.h. Out of the last ten occasions upon which new figures have been set up for the Land Speed Record, five have been over the kilometre, and five over the mile. I suppose that there is no reason why the Land Speed Record should not be set up over 5 kilometres, if a driver so wished.

There is one important point about these short-distance records, that they must be set up as the mean of two runs in opposite directions. This is to make sure that a driver is not gaining advantage by a following wind, or by a slope in the ground, though as regards the latter point there is a definite limit set by the International Authority to the permissible gradient on any course for short-distance records.

This rule concerning mean speed has only been in force since about 1922. Before that date short-distance records could be set up in one direction of the course only. In the early days drivers used, indeed, to wait patiently for a wind blowing in the right direction.

There is also the famous story of the driver who, after waiting for a long time and making several unsuccessful attempts, received an impatient telegram from the works asking the reason for the delay. Stirred to action, he got up early one morning and with his associates repaired to the course. There they carried out certain nefarious operations, and returned. Some days later another telegram arrived, to which they replied "Am waiting for the grass to grow." They had moved the kilometre stone at one end of the course, and their ensuing attack on the figure was highly successful! Or so the story goes.

That was in the very early days when the Land Speed Record was set up on the road. The last occasion upon which this was done was in 1924, when the late Ernest Eldridge averaged 145·9 m.p.h. with the big Fiat at Arpajon, France. Since then much higher speeds have indeed been attained on the road, and only quite recently Rudolf Caracciola, the German driver, averaged a mean speed of 268·9 m.p.h. for the flying kilometre, driving his Mercedes-Benz. This amazing performance, set up on the Frankfurt-Darmstadt autobahn, ranks as an International record in Class B, for cars from 5001 to 8000 c.c.

The existing World's records for the standing-start kilometre

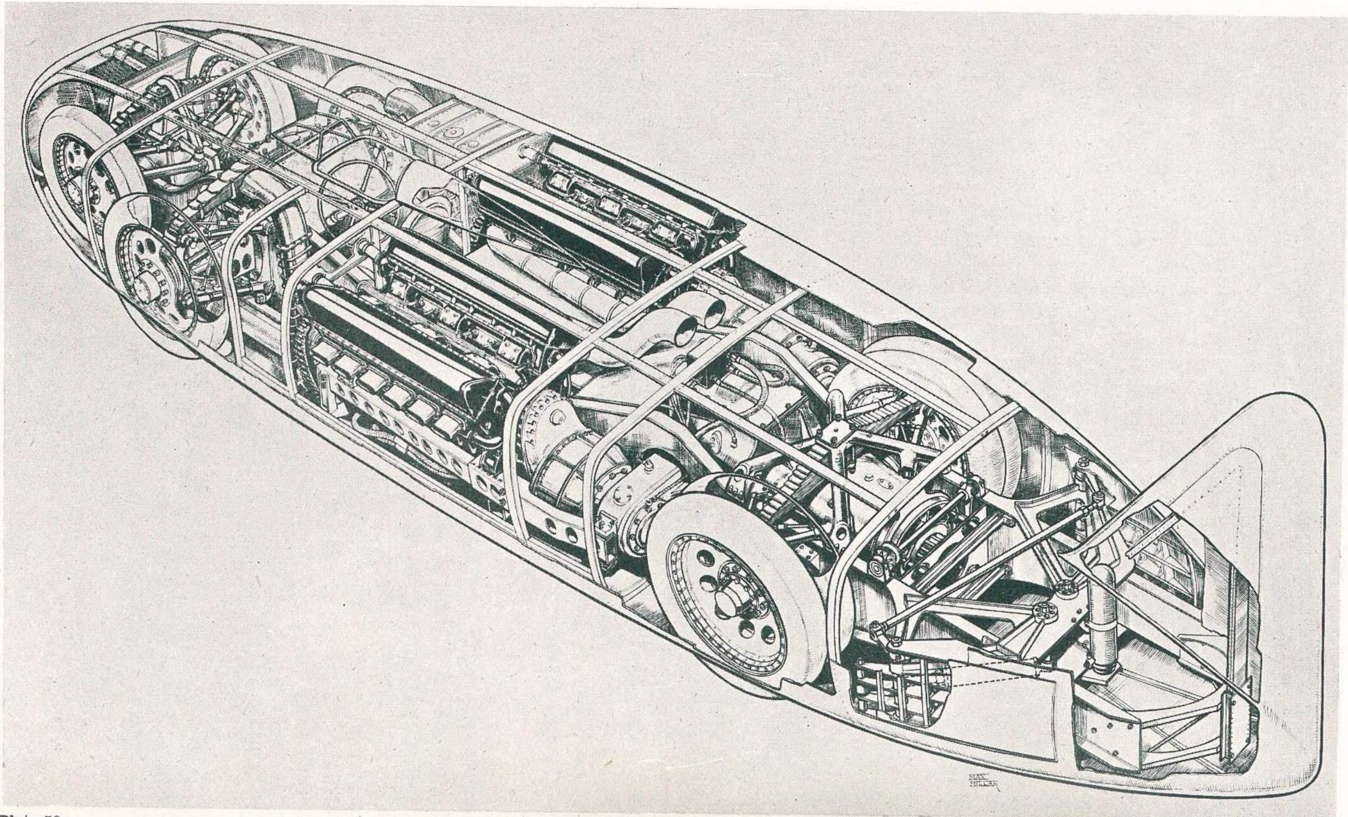


Plate 59.

[By courtesy of " The Autocar."

" THUNDERBOLT."

THE TWO ROLLS-ROYCE ENGINES TOTAL 73 LITRES IN CAPACITY AND DRIVE FOUR WHEELS. THE WHEELS THEMSELVES ARE ALL INDEPENDENTLY SPRUNG AND DO NOT CARRY THE BRAKE-DRUMS, THESE BEING IN THE FORM OF PLATE-CLUTCHES INCORPORATED IN THE TRANSMISSION. (FOR FULL DESCRIPTION OF BRAKES, SEE P. 145.)

and mile were actually set up on the same stretch of road, remaining to the credit of the late Bernd Rosemeyer, with an Auto-Union, at 117·3 and 138·7 m.p.h. respectively. Rosemeyer also holds the 10-Miles Flying Start World's Record on the road at 223·9 m.p.h.

Whereas on the Continent there is usually little difficulty about closing a road for record purposes, in Great Britain this is not allowed by law. However, so far as World's records are concerned, speeds have become too high even for the autobahnen, though the position may be altered later this year when the new road on the Leipzig plain near Dessau is constructed by the Germans. This will be about 25 metres wide, and some 14 miles in length.

Although there is little doubt that this special stretch will be both long enough and wide enough for a car travelling at over 300 m.p.h., *provided that all goes well*, I do not think myself that there is sufficient margin to allow for emergencies. If a car gets into difficulties at this speed, it may not, contrary to the general belief, be entirely uncontrollable, but I myself would like a width of a clear quarter-mile in which to straighten things out, merely to be on the safe side. The unfortunate accident to Rosemeyer, when a gust of wind on the narrow autobahn caused his car to swerve into a bridge, is too fresh in every one's memory.

A road or special track a quarter of a mile in width would scarcely be a practical proposition, and it is fortunate, therefore, that we have available the marvellous natural course on the Bonneville Salt Flats, Utah, U.S.A. Here one has a clear run of 13 miles, and an almost unlimited width except for timing apparatus, while the surface of dried-up salt is, in its best condition, practically equal to concrete.

The trouble is that it is only in its best condition for a short period in the year, as for the rest of the time it is under water. If this water takes unduly long to evaporate during the summer, or if further heavy rains fall, the surface may never reach its best and hardest condition that year at all. We drive little stakes into the crust to see how far down in the salt the water lies, as it is always there underneath. It is estimated that it must be at least two inches below the surface, and remain at that or a lower level for a few days before the salt will give the necessary grip.

The Salt Flats are without equal not only for short-distance work but for the long records as well. Instead of the straight 13-mile course, a circle is marked out, 12 miles in circumference if conditions are good. If the outer edges of the salt lake are soft, however, as was the case on my last visit, we have had to use an 11-mile or even a 10-mile circle.

Compared with Brooklands, which is only 2·3/4 miles in circumference, the smallest of these circles may seem very large. One must realize, however, that the surface at Utah is not prepared in any way (apart from sweeping) and is quite flat, with no banking. In consequence, as a record-breaking car is continually rounding a curve, there is a constant tendency, due to centrifugal force, for the car to skid outwards.

I had two cars in Utah during 1937, having brought "Thunderbolt" for the Land Speed Record, and "Speed of the Wind" for the long-distance event. Even with the smaller car we were at times lapping at 180 m.p.h., and on an unbanked 10-mile circle this means that very considerable stresses are put both upon the driver and, worse still, upon the tyres. With the 12-mile circle matters are improved, but the absence of banking is still very noticeable.

Amongst the longer records there are a few which stand out, for some reason, as particularly important, such as the 1-hour, the 12-hour, and the 24-hour periods. Not long ago it was still possible to set up these records on the various tracks such as Brooklands, Montlhéry, and the Avus. Several great feats of driving have taken place on all these tracks. As I am writing the towering banking of the new North turn had not been constructed, and the two 6-mile straights of the Avus were connected by only slightly banked turns at each end.

With the new banking at one end, the Avus is easily the fastest track in the world, having been lapped at 171·6 m.p.h. Even this, however, is not fast enough for modern World's records, for at the moment the "World's Hour" stands to the American, Ab Jenkins, at 177·05 m.p.h. (standing start), set up on the Bonneville Salt Flats of Utah, and the World's 24-Hour at an average speed of 157·27 m.p.h. During 1937 with co-driver A. Denly I obtained the 12-Hour World's Record at 163·68 m.p.h.

Salt Lake City, which is the nearest town of any size, is 125 miles away from the Salt Flats, while Los Angeles, which is the nearest place with serious engineering facilities, is 800 miles distant. Wendover, the village close to the Salt Flats, is a place with only about 300 inhabitants, but they are all very helpful, and fortunately there is a railway depot where it is possible to get a certain amount of work done.

It has often been held that the World's Hour Record is the most difficult of all to obtain, as it is too short to allow car or driver any respite, but quite long enough to give them both a very hard time! This was particularly the case when the Hour record used to be attacked on the various artificial tracks, for it came about that one had to lap continuously at something very close to the Track record, and this was no mean task. I remember several gruelling rides at Montlhéry in my Panhard

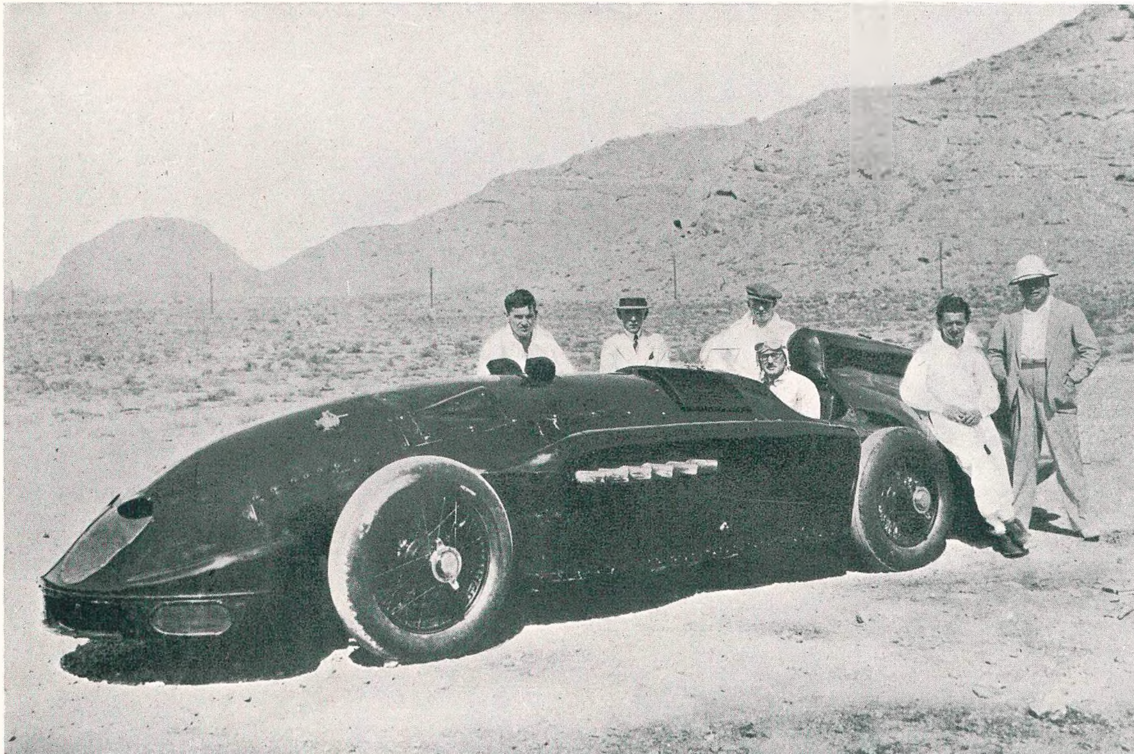


Plate 60. [Photo : Planet News.

SPEED OF THE WIND.

CAPTAIN EYSTON'S SMALLER CAR IS USED FOR LONG-DISTANCE RECORDS. IT IS HERE SEEN, WITH CAPTAIN EYSTON AT THE WHEEL AND HIS CO-DRIVER, A. DENLY, SEATED ON THE TAIL. THE PHOTOGRAPH SHOWS THE NATURE OF THE SALT FLATS IN UTAH WHERE MANY WORLD'S RECORDS HAVE BEEN SET UP.

car, when the record stood at just over 132 m.p.h. Now we are reaching the danger point even at Utah, unless the largest of the circles can be used.

I have found the various "milestones" representing the increase of speeds among the smaller cars scarcely less fascinating, and no less difficult, than the actual World's record attempts. I look back on being the first to reach over 100 m.p.h. for the first time in 1931 in a 750 c.c. car, and later the satisfaction of covering over 100 miles in one hour, and then on reaching two miles a minute.

In all these record attempts there is the interesting technical angle quite apart from the personal satisfaction of doing better than anyone else over a particular distance. There are some who say that figures set up by a vast machine like "Thunderbolt" are not of any great value, but that is a mistake.

First of all national prestige is involved, for the country whose engineers have the reputation of having produced the fastest car on earth. Then there are all the bits and pieces of the car, which receive a thorough testing-out under great stress. Tyre design alone has profited enormously from the series of attempts on the World's record. A critical stage appeared to have been reached at about 200 m.p.h. some ten years ago, at which speed the tyre life was estimated to be 3½ minutes. Now we reach 360 m.p.h., and the tyre life, with all the stresses more than trebled, is one minute at maximum speed.

Greatly indebted as record-breakers are already to the tyre manufacturers, I think that the limit of speed will eventually be set by these components. One may fit higher axle ratios, to get greater speed without increasing the engine revolutions, but the larger the wheels the greater is the centrifugal force on the tyres. It is estimated that on "Thunderbolt" the tops of the tyres relative to the speed through the air were already travelling at approximately the speed of sound!

The steering gear on "Thunderbolt" was of an entirely new pattern, with four steered wheels, apart from the four driving wheels at the back. The brakes were not on the wheels at all, to reduce the unsprung weight—all wheels being independently suspended. Furthermore, these brakes were constructed like a plate clutch, a novel application of the principle which is of considerable value for heavy-duty work. My gear-box and transmission, too, made use of novel principles, and it was a step towards transmission development.

One may say that engine development is not advanced by the use of two huge engines totalling 73 litres, but I counter that we are lucky to have such engines at all.

To build a new car entirely with everything special, including the engines, would take several years and cost a vast sum of money. Meanwhile one's rivals would be forging ahead, and it might be that when the special car was finished one would have to start re-designing it to bring it up to date, before ever it ran at all!

Moreover, in order to transmit a certain horsepower there must be a certain weight pressing down upon the driving wheels to give the proper adhesion. A car as light as those developed by the recent Grand Prix formula is admittedly a marvellous piece of engineering, but for safety at over six miles a minute I would rather sit inside the solid bulk of "Thunderbolt."

CHAPTER TWENTY-TWO

TRACK DRIVING

By J. R. Cobb

TO most people a track must seem to be a place where it is possible to drive at nearly the utmost speed of which any car is capable, without let or hindrance, a specially prepared circuit with banked curves and a surface as smooth as man can make it. Consequently the idea has grown that track driving is an easy matter, at all events in comparison with road racing.

In actual fact, all the endeavours of all the engineers have not resulted in making the ideal track. Not one of them—Montlhéry or Brooklands—has the ideal smooth surface, and even that very latest design, Avus in Germany, has, so it is stated, several unpleasant bumps on at least one of its banked curves. Apart from that, the two chief tracks, Montlhéry and Brooklands, were designed some years ago, and were then constructed to suit the fastest cars it was thought could be made in the future, but the design of racing machines has progressed much more rapidly than anyone could believe, and as a result even the banking of these tracks, high as it is, is not sufficient for the modern track-racing machine running all out.

That is why track racing, though totally different from road racing, is equally interesting, for at lap speeds of about 130 m.p.h. or over Brooklands, to take an example, is much more like a road than a track. The banking helps the car to turn, but does not suffice by itself, leaving the driver to judge how to get the best speed by tackling the turn as though it was a curve on the road, and judging exactly where to ease or cut-out entirely. You cannot take a really fast car on full throttle right round Brooklands, since quite apart from the difficulties of the Byfleet Banking and the Home Banking, there is a quite unbanked curve round the Vickers shed which is not at all easy to tackle at full speed. This curve, as a matter of fact, is made more difficult because the driver of a car coming fast off the slope of the Byfleet Banking cannot see clearly round the turn, which means that if the car is travelling at 150 or more, and another slower, unseen, car is on the curve but close to the shed, the situation becomes very difficult for the driver of the faster car.

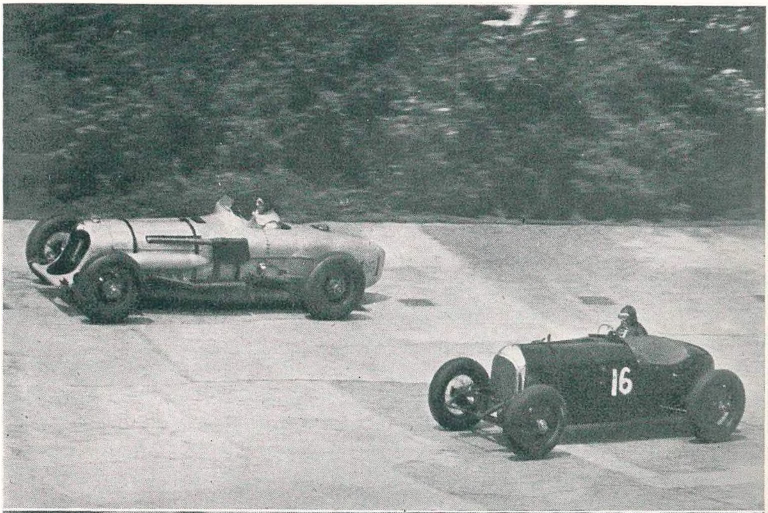
The turn itself has to be judged very like a turn of equal radius on the road. The ease with which the car goes round depends to no little extent on exactly where one leaves the preceding Byfleet Banking, added to which, if the wind is in a certain direction, it seems to bounce off the side of the Vickers shed and tend to push a fast car towards the inner edge of the track.

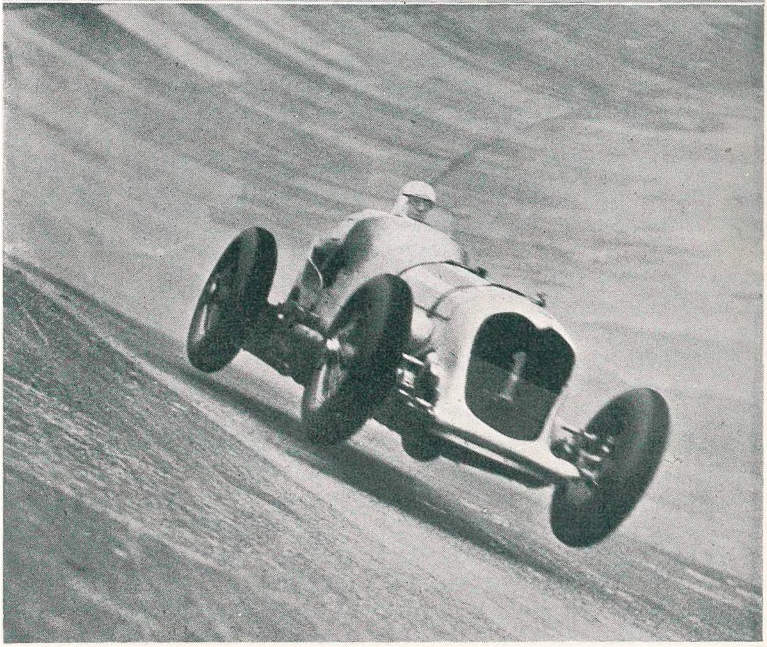
The run on to the Home Banking is comparatively easy, though again it is necessary to select the right position of entry, and a car's width up or down will make all the difference to the turn; but once on the banking the driver's difficulties are not ended, for in a matter of fifty yards or so there is a most peculiar portion of the track. Quite what is the matter nobody seems to know. There is no bad bump, the radius of the turn does not seem to alter, but at this precise spot the car tends to swerve up or down in a manner which is most alarming when first encountered, and it is extremely difficult to cross this point at any time with the throttle wide open. This particular point in the track takes every bit as much knowing as a corner on the road.

Further on the car is sheltered by the Members' Hill, as it runs round the top of the Home Banking, but this has its drawbacks because the machine comes out from under the Members' Bridge just where the protection of the hill ceases, and if the wind is blowing in a certain direction it tends to make the car swerve towards the top of the banking.

A little further still there is another problem. As the Home Banking sweeps down to the Railway Straight it crosses over a bridge straddling the river Wey. Possibly this bridge has settled somewhat; at all events the track suddenly slopes downwards, and a section of it resembles a hump-backed bridge, becoming more humped towards the top of the banking. If the car can be pulled down off the top of the banking, cutting the corner, as it were, on to the Railway Straight, the bump, though bad, is not appalling. If, on the other hand, the car has to run at full speed near the top of the banking at this point, it leaps into the air for a very considerable distance, and alights on the Railway Straight with a crash which certainly does no good to the mechanism.

All these things show that track racing is not as easy as it sounds to the uninitiated. Over and above that, the surface has a certain number of bumps. The effect of these bumps is much the same as that of potholes in the road on the ordinary car, but the depression that causes the shock is not in any sense of the word a pothole. It is sometimes so shallow that only with the utmost difficulty is it possible to identify the thing at all when repairs become necessary. In a long race if the car were taken round on a course running over a number of these depressions, the ultimate result would probably be a broken





Plates 61 and 62. [*Photographs :* " *The Autocar.*"

Above : BROOKLANDS.

TWO CARS ON THE BANKING AT BROOKLANDS, THE HIGHER MACHINE BEING THE NAPIER-RAILTON, WHILE THE LOWER IS ONE OF THE OLDER BENTLEY'S STRIPPED FOR RACING.

Below : J. R. COBB IN THE NAPIER-RAILTON.

JOHN COBB AT FULL SPEED ON BROOKLANDS TRACK, A PHOTOGRAPH WHICH GIVES SOME IDEA OF THE SHOCKS TO WHICH A FAST CAR IS SUBJECTED.

axle, as has been proved in many a 500-Miles Race, and consequently the driver must endeavour to find another course on which he can maintain speed but miss the bumps, which keeps him busy and amused for the greater part of the time.

The fact that there is no definite edge to Brooklands is always interesting, for if a fast car is travelling within two feet of the upper edge of the banking, it appears to its driver that the outer tyres are running actually on the edge, a somewhat intimidating experience.

Montlhéry is much the same. The track, being newer and not used so continuously as Brooklands, has a better surface. The banking, being of later design, is higher. Nevertheless, the surface of the track tends at times to break up, and in any case possesses bumps which, though fewer, are rather more shattering than those of Brooklands, and definitely have to be avoided during a long run for records. The banking, too, is a little more disquieting than that of Brooklands, because a considerable portion of the so-called retaining wall has been blown down, and when therefore the car travels close to the top of the banking, all the driver can see on his right side is the tops of a number of trees. Montlhéry's banking, I may say, is built up on concrete columns, and there is a sheer drop from its top to the ground.

By some peculiarity of design, the track tends to cause a car to swerve badly inwards just where the banking meets the straight, while the surface, though excellent in dry weather, is extremely slippery during or after rain.

In races at Brooklands, of course, the main difficulty confronting a driver is to pass other cars. In Brooklands races all sizes and types of cars run together, but evolution has made even the smallest of these cars very fast, which means that that car cannot lap near the inside edge of the track, but must be rather more than half-way towards the outer edge, and sometimes higher. That in turn means that less than half the banking is available for all the other cars, leaving the scratch car, which is usually the fastest of the lot, to get by how and when it can. The difficulty with the very fast car is that the driver has to know that he will have room to pass quite a time before he overtakes another machine; otherwise he will run up to that other machine's tail, have to slow, and take half the track to regain speed.

More difficult still is the question of passing when there are two very fast cars and one succeeds in passing the other. The second car, then taking advantage of the slipstream behind the first, increases speed considerably, and will probably in turn pass, the process being repeated until one or other driver decides that it is becoming too dangerous.

Ten feet from the top of the banking a line of yellow dots is painted, reserving, as it were, a space in which cars can pass. If it were possible to drive in the ordinary way below this line, all would be well, but owing to the speed of the modern cars this is impossible, and consequently the driver has always to watch for another faster car coming from behind, and to drop below the line to allow this car to pass. But on Brooklands it is not over-easy to use a driving mirror, and in the circumstances it is not easy either to glance round on the Railway Straight to see whether a faster car is coming, so that baulking is not rare. Even if a car does drop below the dotted line, it is often impossible to pass in the 10 ft. width, as a fast car is unsteady and 10 ft. is not much.

As to the cars themselves, my preference has always been for the big machine—the Delage or the big Napier-Railton—and taken as a whole, it is probable that the Napier-Railton is the least expensive car to run of any used on the track to-day. With small wheels and tyres for short-distance work, this car handles beautifully. Its difficulties, of course, increase when larger wheels and tyres have to be used for long-distance races or records, but the car is certainly comfortable for its speed, much more comfortable than the very small car, which can be handled properly only if its driver is strapped in, for otherwise he is so thrown about by bumps that most of the time he is holding on only with the steering-wheel and is not in the seat at all.

No two cars are alike. The Delage handles quite differently from the Napier-Railton; the 4-litre Sunbeam is different again. The smaller cars—the Bugattis and Alfas—are quite distinct, and the line they take on the track is entirely different.

But there is one great thing about a track, and that is the speed. After all, the essence of motor racing is high speed, and the exhilaration of the speed, even allowing for the difficulties mentioned, is in itself sufficient to make track racing worth while.

Records, essentially a matter for tracks, are always good. The ordinary record run is a lonely business, especially if there is no other machine at all on the track, but if things go well, you have the satisfaction of knowing that you have driven a car faster for a certain distance or time than has anybody else in the world.

At Montlhéry the lap distance is so short that after an hour's run you almost appear to be chasing your own tail, and there appear to be two grandstands instead of one, but the greatest sensation of all is a record run at night. Then the inner edge of the track is marked by a ring of red lanterns like those used by road-menders, plus another ring of small lights on the outside edge of the track, and the car itself has to carry head lights; but there can be nothing in the world quite so weird as the sensation of charging round that track in such circumstances. It seems an almost impossible feat, for neither the lights nor the head lamps are really sufficient, and driving can be extremely difficult, for example, as when we attacked the World's 24-Hour Record with the Napier-Railton on that track. Even the flicker of blue flame from the ends of the short exhaust pipes can make it hard for the driver to see accurately, and on this car we had to shield the flame so that from the driving seat it was invisible.

Curiously enough, the thing looked highly dangerous when someone else was driving, much more so than when one was at the wheel. All you could see were the head lights going round in the darkness at an almost incredible pace, and the fantastic play of flame from the exhaust pipes. It did not look the sort of thing that a man could do for long.

Both in records and in racing on the track, the driver can do much to save the car's tyres. Drive one way and the tyre treads will be worn off in a relatively short time; drive in another and those same tyres will last a complete spell, which will make all the difference between success and failure. Tyres nowadays are extremely good, but all the same there is the ever-present possibility of a tyre bursting, which, as you will imagine, could be most unpleasant.

In record work it happens that the mechanics at a depot can only touch the machine if it stops *in* the depot. Consequently, the bursting of a tyre may lead to the driver accidentally stopping the car's engine, after which, according to the regulations, he would have to push the car, single-handed, all the way to the depot, a manifest impossibility in the case of the Napier-Railton.

Depot work is, of course, important, and the amount of organization necessary to refill the car and change wheels quickly during a record has to be seen to be believed.

At first sight it appears of advantage that you can use any number of mechanics. In actual fact, a number of mechanics would merely get in each other's way and delay proceedings, unless every man was carefully coached as to what he had to do and did his work in such a way as not to interfere with anybody else.

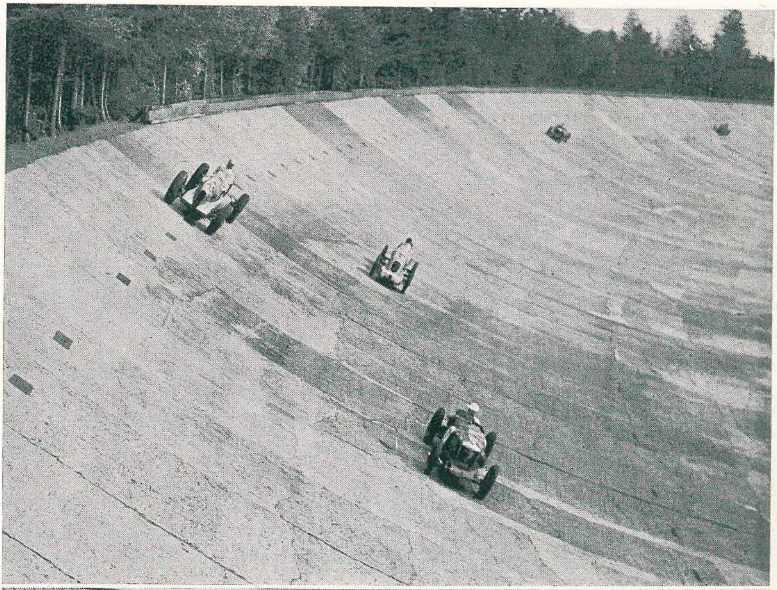
To-day it is rare to find a car designed for track work in particular, but it would make a great deal of difference if Reid Railton, or somebody like him, were given a free hand to design a machine solely for racing at Brooklands, let us say, for it does not seem impossible to make a car that would beat the Napier-Railton's present lap record of 143·44 m.p.h., and yet would not necessarily have to run at the top of the banking. It would all be a question of the design of car and the position of its centre of gravity, and if the car did not have to go to the top of the banking, it would be much easier to handle.

The value of track racing will be admitted by all. In the first place it gives the engine a much more thorough test than is possible on the road, for the throttle can be kept open, or nearly open, for very long periods of time, and the engine for most of its run will be at full revs. In a road race the period for which the engine is at full revs. is necessarily limited.

Then streamlining is of much more importance for track racing than for road racing, and be it noted streamlining began as a direct result of racing at Brooklands Track. Streamlining itself is of most use for prolonged high speed, and it is doubtful whether even now the best form of streamlining has been fully developed. That is one of the reasons why a road-racing car is rarely at its best for track work, quite apart from the fact that it may be too light to be satisfactory, and its engine may not be altogether suitable for the stress. Time after time well-known road-racing cars have come to grief through being entered in a purely track race. The ideal track-racing car, on the other hand, is not in the least suitable for road racing. For one thing it does not possess or need very efficient brakes, and for another the long streamlined tail might swing the car round on corners. Complete development, therefore, would be attained as a result of experience both in road and track racing.

As a test of tyres, track racing is far more severe than road racing, and tyre development of recent years has been, as every driver knows, phenomenal.

To-day one of the troubles is that the older tracks are no longer suitable, as they were in the past, for records, and that has made a great deal of difference to record breaking generally. There are very few world's records which can be tackled any longer at Brooklands, and in fact every year there are fewer and fewer places in the world suitable for these records as cars are at the moment. This might be overcome by designing a special car for the work, but on the other hand it would make a great deal of difference if it were possible to re-design the existing tracks so that on them much higher speeds could be maintained, and while motor racing and record breaking exist, there will always be an immense attraction in speed as speed.



Plates 63 and 64. [*Photograph :* " *The Autocar.*"

BROOKLANDS.

Above : CARS ON THE HOME BANKING AT BROOKLANDS DURING A RACE ON THE OUTER CIRCUIT, A VIEW WHICH SHOWS THE NATURE AND CURVATURE OF THE PRINCIPAL BANKING.

Below : START OF A SPORTS CAR EVENT ON THE OUTER CIRCUIT. THE SHEDS ON THE LEFT ARE THE VICKERS WORKS, WHICH GIVE THEIR NAME TO A TURN ON THE TRACK.

CHAPTER TWENTY-THREE

MOTOR RELIABILITY TRIALS

By H. E. Symons

Definition

MOTOR reliability trials have long been popular amongst those whom financial or other considerations debar from taking part in racing and speed events. In a race the winner is the driver covering the greatest distance in the shortest time, but in a reliability trial the competitor is expected to run to schedule at a reasonable average speed. The ideal trial is one in which the nature of the course is so difficult that the driver can only just maintain the speed imposed, and that any trouble, mechanical or otherwise, occurring *en route* will delay him so that he is unable to be on time at the next check or control.

Checks or controls are as a rule set up at intervals, either to make sure that every competitor has covered the proper route or to make certain that he is running to time. As a rule, a competitor is not allowed to be ahead of scheduled time anywhere on the route but must not be more than five minutes late; the trial therefore becomes one of time-keeping ability as well as of motor car reliability, and a good watch is as important as a good car.

The average speeds imposed in reliability trials vary with the countries in which they are run. For very many years it was impossible in the British Isles to set a higher schedule than 20 m.p.h., because that was the legal limit imposed by law. When this limit was abolished, the imposed speeds rose gradually, but higher speeds are generally maintained in Continental countries, particularly in Italy. France, Switzerland, and Germany, however, frown on fast driving in competitions and do not permit scheduled average speeds in organized trials above a certain figure.

The typical reliability trial, as held in Great Britain and most other countries, consists of a journey between two points over a route specially selected for the natural difficulties which it offers. It is easy, for example, to go from London to Edinburgh or from London to Land's End on the main road, but the Motor Cycling Club, which originated the classic London to Edinburgh and London to Land's End events, shows great ingenuity in planning a route through the narrow, winding lanes of Somerset, Devon, and Cornwall or over the wild, wind-swept moors of Yorkshire. The steep gradients and narrow roads combine to make the maintenance of high average speeds difficult.

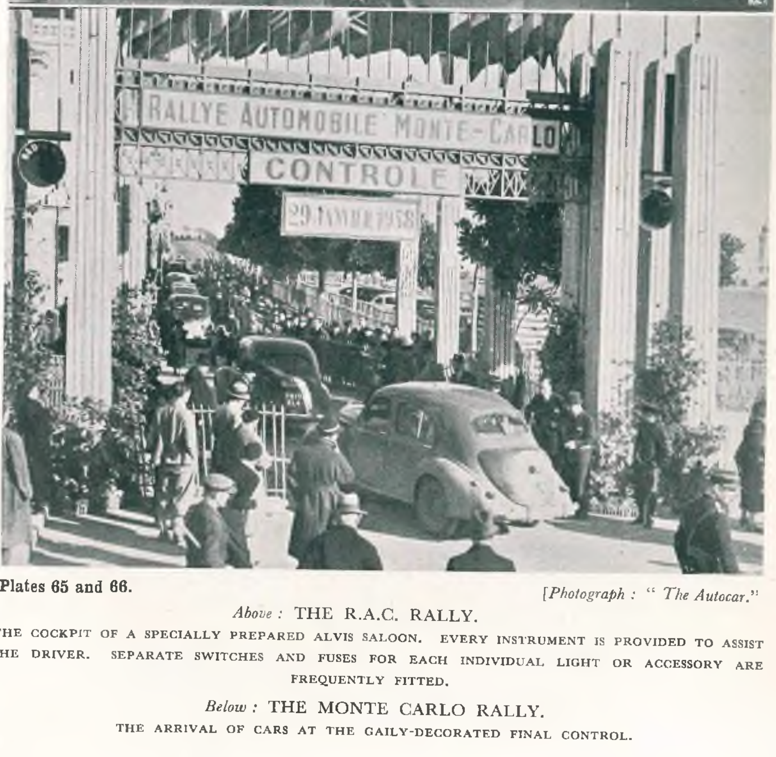
A number of test hills are generally included in the route, and failure to climb all or some of these entails a loss of marks. In some trials, also, there are timed sections of some length on which a certain average speed has to be maintained exactly. There are also what are known as "colonial" sections, generally consisting of disused roads across very rough country and notable for deep mud in wet weather, boulders, bushes, or long grass. The popularity of these waned, however, when low-built cars began to suffer serious damage owing to the obstacles encountered.

In their search to find hills which would stop a large proportion of the competitors, trials organizers have discovered a number of hills which can only be described as freaks, in that no ordinary motorist would ever attempt to climb them. These are often mere footpaths up extremely steep gradients, rendered more difficult, not infrequently, by acute hairpin bends or a really slippery surface. Freak hills, like colonial sections, are not popular on account of the risk of damage to competing cars, and trials organizers, therefore, have great difficulty in finding suitable acclivities.

The modern reliability trial is really developing a special type of sports car. Mountains, which a few years ago were frankly admitted as being unclimbable, are now surmounted with comparative ease, not only by sports cars but sometimes by genuine closed touring models as well. This is largely because the introduction of such gradients forces manufacturers wishing to do well in reliability trials to fit extremely low first-gear ratios. A number of acute hairpin bends on certain hills call for a very small turning circle and a short wheelbase. A special type of tyre has also been developed for competitions work. In the early tests drivers used to fit non-skid chains before climbing very muddy hills, but owing to a desire to increase the difficulties of the reliability trials the organizers, all over the country, agreed that no chains or any other non-skid device would be allowed. Now, however, special "competition" tyres with very prominent treads are in common use for trials purposes. The protruding bars of rubber cut through the mud and slime, giving the wheels a firm grip on the road surface.

As many modern trials include acceleration and braking tests, the tendency is to make a sports car as light as possible, which is one of the reasons why the so-called sports model is often such a lively and pleasant car to handle.

The driver who wishes to do well in a reliability trial should remember that the event is half won before the car ever leaves



Plates 65 and 66.

[*Photograph : " The Autocar."*

Above : THE R.A.C. RALLY.

THE COCKPIT OF A SPECIALLY PREPARED ALVIS SALOON. EVERY INSTRUMENT IS PROVIDED TO ASSIST THE DRIVER. SEPARATE SWITCHES AND FUSES FOR EACH INDIVIDUAL LIGHT OR ACCESSORY ARE FREQUENTLY FITTED.

Below : THE MONTE CARLO RALLY.

THE ARRIVAL OF CARS AT THE GAILY-DECORATED FINAL CONTROL.

its garage. Nothing must be left to chance. A choked petrol filter or dirty sparking plugs might easily cause a failure in a non-stop section. Therefore, before going off on a trial, the enthusiastic competitor will go over every detail of his machine. If, for example, the oil in the engine, gear-box, or back axle has not recently been changed, it will be an advantage to drain and refill with fresh oil. The clearance between the valves and their tappets or rockers should be carefully checked, and if a lot of low-gear work is expected, slightly more clearance than is usual should be given. The sparking plugs should be examined, and if there is any doubt about their condition they should be replaced. It is to be assumed that the driver has already tried his car on really steep hills to ascertain whether the plugs are of a suitable type, that is to say, that they do not overheat going uphill or oil-up when going down the other side. If the sparking plugs are detachable, they should be cleaned and replaced.

The whole petrol system should be gone through carefully and all filters cleaned, including those of the carburettor and fuel-pump, and any short lengths of piping, especially if they have bends in them, should be blown through to make sure that there is no obstruction in them. All petrol and oil unions should be carefully checked to see that they are not slacking off. The radiator should be examined to see that it does not leak, and the fan belt (if a fan is fitted) tightened. The entire chassis should be carefully oiled and greased, not forgetting those more inaccessible, and therefore frequently neglected points, beneath the floorboards or under the car As well as wheel bearings, the nuts holding the wheels should all be checked over to see that they are not working loose.

It is well to test the clutch by attempting to get away with the hand brake on. If it slips, a visit to the maker's service station is generally the best course to adopt, though often the slipping is merely due to dirt on the friction surfaces which can be removed by squirting petrol or Pyrene liquid (which is safer) between the contacting areas. The brakes should be carefully tested and if necessary adjusted, the best plan being to test them on one of the excellent devices installed for the purpose in most first-class garages. Even after this, however, a final test should always be made on the road.

The tyres should be carefully gone over, and if the weather is warm and some of the inner tubes are known to have been patched, it is far better to replace them altogether. It is hopeless to start with almost smooth rear tyres in any reliability trial, for the chances are that bad wheelspin will develop on a test hill, bringing the car to a standstill. For all ordinary purposes the driver should run with his tyre pressures normal, using as a basis the manufacturer's instructions. Many people prefer to have the tyres a little harder than recommended by the manufacturers, if they are indulging in much fast driving. Although, as will be seen later, there is often an advantage in letting down the tyre pressures for climbing very steep hills, consistent running with the tyres soft tends to make the car roll on corners and detracts from its controllability, while running on under-inflated tyres is always bad for them, as it puts an excessive strain on the walls.

The batteries should be topped-up with distilled water, and all electric connections should be checked for tightness. The contact-breaker in the ignition system should be checked over to see that the points separate to the required gap, and any carbon brushes should be checked to see that they bed-down properly. Unless the dynamo is in first-rate order it often pays to clean the commutator and see that the brushes bed-down properly to it.

The steering should be gone over and any excessive play taken up, while the shock-absorbers call for special attention. For general trials work it is far better to have these set to give hard riding rather than soft riding. Tight shock-absorbers at the rear diminish the likelihood of wheelspin occurring and prevent dither and rolling at corners. Tight shock-absorbers at the front contribute towards more accurate steering, especially on very rough road surfaces.

In regard to equipment, it should be borne in mind that as reliability trials are worked on a time basis you may have to put something right in a very short space of time. Unless the right tools are carried, there is always the risk that much precious time will be lost and the premier award lost in consequence. Generally speaking, there is no need to carry a great many spare parts as they only add to the weight of the car, thus detracting from its performance on hills.

It is always desirable to have a spare set of sparking plugs and a long-handled plug spanner, enabling hot sparking plugs to be removed and new ones inserted in the shortest possible time. A half-gallon can of engine oil should always be carried, for under arduous conditions the oil consumption may increase considerably above normal. A really good jack is always worth having, but one should make sure that it fits under both axles and will give sufficient lift to change a wheel without having to put blocks of wood under it. Many cars are fitted with permanent jacks, which speed up wheel-changing to a remarkable extent. On the other hand they add to the weight of the car.

If one is going on a very long trial it is often desirable to carry a spare inlet and exhaust valve and valve springs, a spare cylinder-head gasket and small gaskets to go between the exhaust manifold and the exhaust-pipe proper. A selection of nuts, bolts, and spring washers of the sizes mostly in use on the car, as well as a coil of copper wire and a few yards of strong blind cord, are always useful. A good tyre-pump and a tyre pressure-gauge are indispensable.

For night work a large electric torch is preferable to a spotlight mounted on the car, as it can be carried about more easily and used by either the driver or passenger. The large-sized torch can be focused, and throws nearly as long a beam as a spotlight worked off the batteries of the car.

An ignition coil, a set of contact-breaker parts, and a couple of spare condensers should always be carried in a handy position, for nothing is more irritating than ignition trouble. A spare windscreen-wiper blade is also useful.

Clothing

Where a closed car is used ordinary everyday sports clothing is adequate, though a pullover of really warm, soft wool should be carried for use on a cold night's run. The same applies to gloves, and a woollen scarf or muffler.

In an open car the question of clothing assumes much greater importance. A leather coat is universally admitted to be among the most satisfactory garments, although by itself it is apt to be chilly. A fleecy lining, or even one of actual sheepskin, takes up very little room and is very warm, while a mackintosh sufficiently large to go on *over* the leather coat provides the last word in protection against cutting wind or drenching rain.

Where the weather is likely to be very wet, an oilskin of the non-sticky pattern is almost the only solution, as it does not hold the wet like a gabardine raincoat. It is a good idea to carry a pair of goloshes in case one has to get out to effect roadside repairs on a very wet stretch of road. Nothing is more uncomfortable than driving away afterwards with wet feet. A pair of sun-glasses are always necessary, while a green celluloid eye-shade is often appreciated. Most closed cars are, of course, fitted with sun visors as standard, but tinted glasses should be taken as well. A tube of sunburn cream and a bottle of eye-lotion are great assets to comfort, while another small item, which should really have been mentioned under the heading of "Equipment," consists of a sponge bag with a damp sponge and leather for cleaning the screen when it becomes very dirty.

Driving Methods

The motto of the trials driver is the same as that of the racing man: "You can't win unless you finish." It follows from this that the driver's first duty is to keep his car on the road, and should so treat it that it keeps in perfect condition. This means that not only the engine, but the whole car, must be "nursed" over difficult sections. Just as unduly high engine revolutions may have a bad effect on the sparking plugs and the adjustment of the valve clearances, and ultimately on the whole state of the engine, so does very fast driving over rough and bumpy roads hasten troubles due to vibration, and culminating in such major troubles as broken springs or axle-shafts. Therefore, when the going is bad the driver should slow down to a reasonable rate.

If very bad surfaces are expected it is best to fit the largest section tyres available. Large tyres, run at very low pressure, do much to prevent things shaking loose, and protect the springs and chassis against the disturbing effects of vibration. They give better adhesion and thus better braking, in tests where braking is important, and they provide a greater bearing surface on sand, mud, or snow.

In many reliability trials very steep and loose-surfaced hills are introduced into the route, the idea being to stop as many competitors as possible. The wise driver lets down his tyre pressures so that a bigger area of tyre is in contact with the ground and so that the rubber, as it were, "wraps itself over" small stones, &c., instead of the tyre bouncing over the ground with the imminent likelihood of wheelspin developing. Although, generally speaking, it is sufficient to deflate the back tyres slightly, it should be remembered that with a very hard, rough, and rocky surface the front wheels may bounce clear of the ground and make steering difficult, not to say impossible, if the tyres are over-inflated.

When approaching a twisting hill, the competitions driver should always engage the lowest available gear so as to be prepared for any eventuality. If a corner is rounded to find a gradient like a ladder straight ahead, it may be too late to change down, for way may thus be lost, and wheelspin may be started when the clutch is re-engaged.

Wheelspin should be avoided at all costs. The general rule is to give as little throttle as is necessary to climb the hill in question. When driving on a very muddy section, one should keep the car running steadily on a given throttle opening, avoiding either braking or acceleration. This is the only way one can ensure following a straight course through deep and slippery mud.

It is to be assumed that the driver has got to know his car thoroughly before he attempts any sort of competitions work with it. If he has done so he will know just how much or how little he dare apply the brakes without skidding on any sort of road surface.

The Alpine Trial

It is impossible to deal individually with every one of the big international trials, the nature of which varies with the district in which they are held. A classic example is the International Alpine Trial, which takes place most years, in August, amidst the Alps and Dolomites. Even this is, in some ways, a combination of different sorts of trials, for it combines the excitement of the road race with the thrills of a speed hill climb and the necessity for running to schedule of the normal reliability event. Instead of being confined to the roads of England or of some other comparatively flat country, it is run up and down the highest mountain passes in the Alps, often half a dozen or more passes being climbed in a day.

Of these the chief which is included is the Stelvio, towering 9042 ft. into the sky. It has 46 hairpin bends on one side and 49 on the other. Its over-all length is something like 17 miles, of which 12 at least are very apparent climbing. Next in altitude to the Stelvio comes the Galibier, 8399 ft. high and an entirely different sort of ascent. Whereas the Stelvio is beautifully engineered and has a constant gradient of about 1 in 10, with a maximum of 1 in 7 for a short distance only, the Galibier possesses some of the attributes of the English trials hill. For one thing it is, on the side usually ascended in the Alpine Trial, quite short, measuring only about 3 miles from the junction with the Lautaret road to the summit. From the moment the main road is left it climbs steeply with many hairpin bends, the gradient in places amounting to 1 in 5. The competitors are generally expected to climb it at so high a speed that only those in adapted racing cars usually succeed in keeping to time.

Taken as a whole, the roads and passes in the Alpine Trial route may be divided into two groups, which may be termed the Latin and the Germanic. The roads in the former are skilfully engineered, their gradients being modest and the roads consisting of a number of short straights joined by acute hairpin bends. The Germanic type of pass, however, is very steep and resembles some of the famous hills of Devon and Scotland except that, in general, it is longer. Instead of being byways only, the steep passes of the Austrian Alps are all main thoroughfares, chiefly because they represent the only possible way for wheeled traffic to get over an otherwise insurmountable barrier.

The Katschberg is a wide main road and for the most part pretty straight, yet its gradient varies between 1 in 6 and 1 in 3, stretches of one alternating with the other, forming a sort of rough staircase. A little to the east of the Katschberg is the Turracher Höhe, which is about 4 miles in length and 1 in 3 for practically the whole distance. There is not only the gradient to contend with, but scores of deep gullies, numbering over a hundred altogether, which impose a tremendous effort on the road-springs.

In between such extremes as the Katschberg and the Stelvio there are scores of less difficult passes with sweeping curves alternating with hairpin bends, and sometimes with rough and dusty surfaces.

To prepare for the Alpine Trial, therefore, one must bear in mind that cooling and braking are of paramount importance. Many cars that are considered more than adequately cooled in the British Isles have been known to begin boiling quite low down on a mountain pass. Brakes that are able to cope with any emergency, even when driving fast in comparatively flat country, become useless by the time the third or fourth hairpin is reached on the descent of a pass. There is also the question of steering lock A turning circle of 40 ft. is the absolute maximum permissible if the Alps are to be negotiated without reversing. To be on the safe side, a turning circle of 36 or 37 ft. is desirable.

With the essentials of a good lock, good cooling, and good braking, a competitor should cover the course of the Alpine Trial without difficulty if his car is otherwise well prepared. But the average speed set, particularly up the timed ascents of mountain passes, two such climbs normally being included in the itinerary, necessitates a high power-weight ratio. This means that, comparatively speaking, the car should be as light as possible while the engine develops as much power as possible. For this reason, although the trial is normally supposed to be run to test standard production touring cars, the so-called sports type of car, providing it complies with the regulations, is almost essential.

The ideal way to prepare a car for the Alpine Trial is to be able to go over to the Alps shortly before the start of the event, and try the car to see what modifications are required in order to enable it to put up the performance required by the regulations. It may be found, for instance, that a rear axle ratio which suits the car admirably in England may be too low to give the desired speed on the French and Italian mountain passes. The danger of raising the ratio is, however, that the car may be too highly geared to get up the Austrian passes. In the end, it is probably necessary to compromise and use the back axle ratio normally fitted, being content with a little less speed on the easier passes to make sure of climbing the more difficult.

As the regulations for the International Alpine Trial generally state that the specification of competing vehicles must coincide in every way with that of the production model of the same type, very little latitude is allowed to the competitor who would modify his vehicle. The regulations are particularly definite as regards the cooling system, and unless there is a loophole in the rules which allows a cunning competitor to circumvent the intentions of the organizers, he is obliged to run the car very much in the condition in which it was delivered. Unless a fan is fitted as standard, one may not be fitted for the event. A header tank, or the capacity of the cooling system, cannot be increased. A water-pump may not be added.

Generally there is no ban on fitting a small pressure-release valve in the radiator cap, which prevents water or steam escaping until a certain pressure has been reached. The advantages of this are twofold. In the first place the radiator overflow is closed at all ordinary pressures, and consequently sudden braking, fast cornering, or negotiating a very rough road will not cause any water to be lost through the overflow. Secondly, boiling occurs at a higher temperature when the steam is under pressure. The chief danger is that the release valve may be too small, with the risk of the radiator bursting, due to a sudden rise in pressure. There is also the danger of a somewhat flimsy radiator collapsing, due to the formation of a partial vacuum inside the radiator as a result of blowing off so much steam and sucking in no air to take its place.

Another method of getting over the difficulty of boiling is to use a solution of alcohol, such as Glico Ethyline, which boils at a very much higher temperature than water. Although it sounds paradoxical, a non-freezing solution usually makes an admirable non-boiling one for the radiator. Care should be taken, however, to see whether the use of anything else but pure water in the radiator is allowed by the regulations.

In regard to the brakes, it is sometimes possible to improve these, if they are deficient, by using cast-iron drums instead of steel pressings, or by shrinking over the steel drums a series of aluminium fins. Some brake linings, too, maintain their condition very much longer when hot, and the manufacturers of brake linings should always be consulted before taking the car abroad for the start. Lost motion in the braking gear should be reduced to a minimum, and all pivot points, &c., should be well lubricated. The importance of ample lubrication was never greater than in the case of enclosed cables. Where the brakes are applied by cable it is particularly important to make sure that these have stretched as much as they are likely to do, and that all slack should be taken up, leaving the maximum amount of adjustment available at the normal points. Finally, every effort should be made, by fitting suitable oil-seals in the hubs or axles, to prevent the leakage of oil into the drums. The wise competitor will also see which is the quickest way of removing the drums should it be necessary to clean them out in the course of the trial.

The advice already given regarding the preparation of a car for a reliability trial naturally applies in the case of the Alpine Trial. There are many special points, however, which require to be watched. The daily stages are often very long and the heat intense, so that the comfort of the occupants becomes of some importance. The ventilation of the driving compartment can best be effected by arranging for the doors to stand a little way ajar, being held thus by a hook. It will often be found desirable to add extra ventilators to the scuttle, while the most important thing is to get the heat away from under the bonnet as rapidly as possible.

Louvres should be made not only along each side of the bonnet but also along the top. It does not require a moment's thought to appreciate that by the time the air has passed through a radiator full of almost boiling water it will have expanded considerably, and therefore more space must be allowed for the air to get out than is available for the cold air to get in. If hot air is thus prevented from accumulating under the bonnet, the scuttle dash is less likely to get hot, and with it the driving compartment. Some competitors have found it beneficial to fit canvas deflectors or "sails" between the sides of the radiator and the front wings so as to catch a greater volume of air and force it through the radiator.

Naturally a competitor will see that his oil-level is always kept well up. In fact it may be necessary to run with considerably more oil in the sump than usual, as if the oil-pump be on one side, the lubricant may surge away from it on the hairpin bends, thus starving the bearings. The makers of the oil should be consulted, as it may be necessary to use a heavier oil or one better fitted to stand up to intense heat. It should also be remembered that the gears are working much harder than normally, and it may be necessary in the course of the trial to replenish the oil supply in the gear-box and even in the back axle. In the same way, the steering and other points on the chassis will probably require greasing at more frequent intervals.

Nature comes to the aid of the competitor when tackling a long, high, and difficult pass, for owing to the rarefied atmosphere the relative tyre pressures increase, giving the sensation that they are harder, and the steering thus becomes lighter and lighter as the pass is climbed. In the same way, if pneumatic upholstery is fitted, the driver will rise in his seat, thus getting a more commanding view of the front of his car when rounding corners!

Physical fitness is of some importance also. It is advisable to go to bed as early as possible and get plenty of rest. Meals taken during the day should be light as there is otherwise a risk of the driver becoming sleepy on a road where to doze would be fatal. As the result of long experience, I have found that the most sensible clothes to wear are a short-sleeved sports shirt and shorts, with a light linen dust-coat worn over. It should be recollected, however, that in the early morning it is often intensely cold, and a good, thick sports jacket, a mackintosh, an overcoat, gloves, and a woollen muffler should always be carried in the car.

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