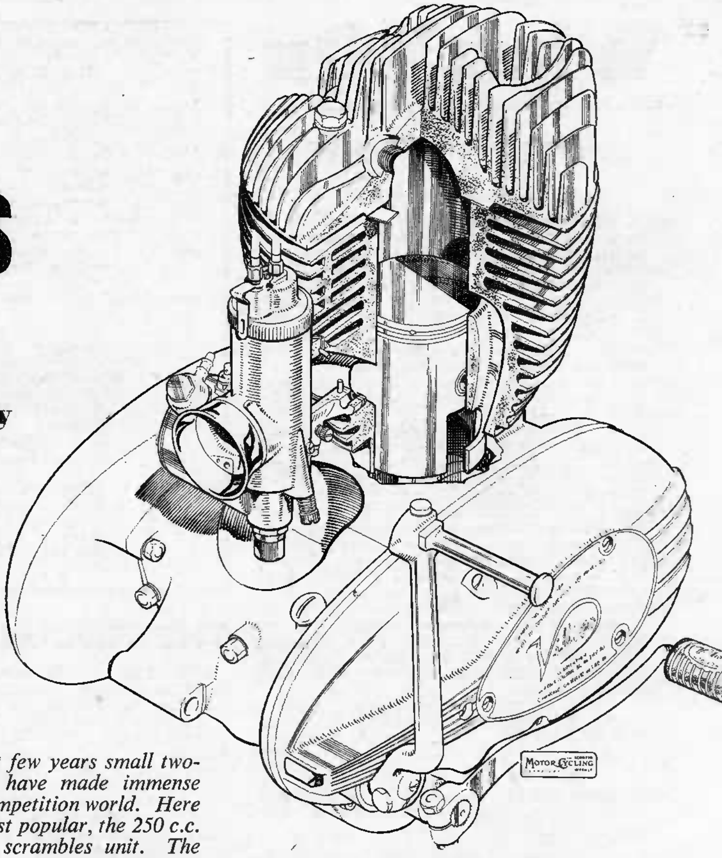
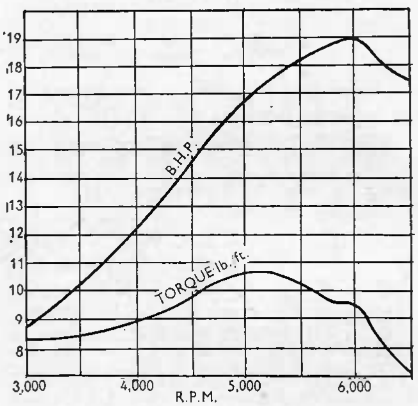
COMPETITION POWER-UNITS



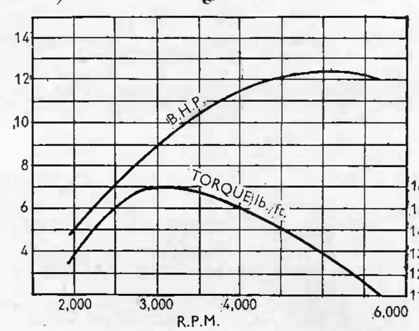
Horses for Courses — and how they are produced in specialized form

By PHIL IRVING

During the past few years small two-stroke engines have made immense strides in the competition world. Here is one of the most popular, the 250 c.c. Villiers 33A/4 scrambles unit. The 32A/4, for trials, is similar in general design.



(*Left*) *Output curves for the scrambles Villiers.*



(*Right*) *How the trials version curves are seen. Thermometer and barometer corrections have been made in respect of both this graph and that on the left.*

THIS is the age of the specialist and therefore of specialized machines. Gone are the days when one model of motor-cycle was expected to serve as a tourer, a racer, a hill-climber and a scrambler merely by adding or subtracting odd bits such as guards, lamps and silencers, and pouring different-smelling liquids into the tank, according to the requirements of the moment. A private owner can still get a lot of fun that way—especially if he is not upset by running last most of the time with an occasional "blow-up" for good measure—but the matter assumes different proportions to the executives of a factory which depends for its well-being and commercial prosperity upon success in the competition field.

Specific Design

Much can be, and has been, accomplished with a basic engine more or less modified to suit the conditions; but, generally speaking, an engine designed specifically with one object in view will out-perform one which has merely been modified.

The classic example is, of course, the pure racing engine, though again there are so many different varieties of racing that invincibility in any one branch can only be assured by directing all thinking and development towards the special problems and difficulties peculiar to it. Probably the prime exponent of this art was the late Joe Craig, who regarded the winning of the T.T. as the highest aim one could achieve, and about five minutes after collecting one Island event would be busy planning how to win it again next year. This policy, of course, paid handsome dividends; though, if the truth must be told, in the process he became so steeped in single-cylinder technique that he found difficulty in breaking away from it.

Let us consider the prime requirements of a road-racer. First of all, it must be reliable (the late Harold Willis' dictum, "They only count the winners at the finish," should be emblazoned on the walls of every drawing office)—but reliable in the sense that it has to keep going only for the distance of the race, after which it can be over-hauled by skilled mechanics. There is no need to build-in reliability of the "50,000 miles between overhauls" variety; but, on the other hand, there is no time nowadays to pull into the pits to repair some pettifogging trouble which a tourist might accept as being just a part of the day's fun.

Next, it must be faster *in lap speeds* than its rivals. This does not necessarily mean that its flat-out maximum must be higher, though that is obviously an advantage, especially on a very fast circuit or one containing a long straight where an ultra-quick model can build up such a lead that the rest of the field cannot catch it on the twisty bits.

Three or four extra horse-power at the top end of the speed-range may be dearly bought if they can be obtained only by sacrificing much power lower down, especially on difficult circuits, even if the gearbox has five, or even six, ratios to enable the rider to keep the revs. in the useful range at all times. The availability or otherwise of such a box has an effect on the shape of the power curve to be aimed at, and also on what might be termed the minimum useful speed. However, even if there are only four ratios, they can be so close for any of the courses used for today's International events that there is little need to bother about what happens below 6,000 r.p.m. to an engine which peaks at around 8,000.

Reliability and the ability to sustain power for long periods is bound up very closely with good cooling which, in turn, may be completely nullified by matters external to the power unit. In road racing, there is almost always plenty of cooling air available somewhere in the vicinity, but the problem is to utilize it effectively when it is deflected away from the engine by the wheel, forks and (in most cases) frame which lie in front of it.

The answer with unenclosed vertical singles was to widen the fins until they reached out into the air-stream, but the situation has been radically changed by the advent of frontal streamlining. A thorough investigation into its effects might conceivably lead to a return to shallower and therefore lighter fins, enclosed within ducts fed by air from the front of the shell—a scheme which, though it might work very well on racers and record-breakers, would be of little use for tourers, where the air-speed might often be down to nothing or even reversed in direction.

Power/Weight Ratio

For maximum acceleration, a high power/weight ratio is essential, but it is a false move to endeavour to save weight on the power plant if this entails any loss of performance or stamina. On the other hand, as manufacturing cost is of little moment, expensive steels and high-strength light alloys can be freely used, or components which commercially would have to be made from castings might be made, at very many times the cost, from solid forgings machined to shape. Even so, it is bulk, rather than absolute strength, which determines the rigidity of a component, and racing engines of this variety are, if anything, heavier than they used to be, despite the employment of materials of high specific strength.

Part of the weight of a touring engine is accounted for by the flywheels, which, even on a multi-cylinder engine, must have a considerable mass for the sake of flexibility and good manners when changing gear. In racing, with compulsory push-starts, strictly one-way traffic and very close, easily changed gear ratios, neither of these attributes is necessary to any marked extent, and flywheels, as such, can be almost dispensed with, the mere mass of the smallest discs which can just accommodate the crank-throw being sufficient in itself where rotational speeds approaching five figures are concerned. It is then up to the rider to avoid either stopping the motor or bursting it through inaccurate co-ordination of two hands and one foot when changing gear. This is not such a dreadful matter as it sounds, since the road surface is usually good, while gear-change points can be discovered in advance during practice and in any case are indicated by the tachometer, which the rider usually has the opportunity to observe.

It is sometimes said that powers have not increased as rapidly as they might have done over the years; but it must be remembered that we still have only 14.7 lb./sq. in. air pressure and the calorific value of petrol has remained substantially constant. That being so, the only really practical way to get more urge, in the absence of supercharging, is by increasing the rotational speed and designing the valve-gear so that it can accept these higher revs. This means the adoption of the double-overhead-camshaft principle, which is bulky, heavy and expensive, or even the "desmodromic" or mechanically returned valve-gear, which is even more complicated but enables fantastically high engine speeds to be achieved. With these developments goes the utmost utilization of pressure-waves in the exhaust and inlet systems, especially in two-strokes, a practice which is fast approaching the point where the realms of acoustical engineering are entered.

Fuel Consumption

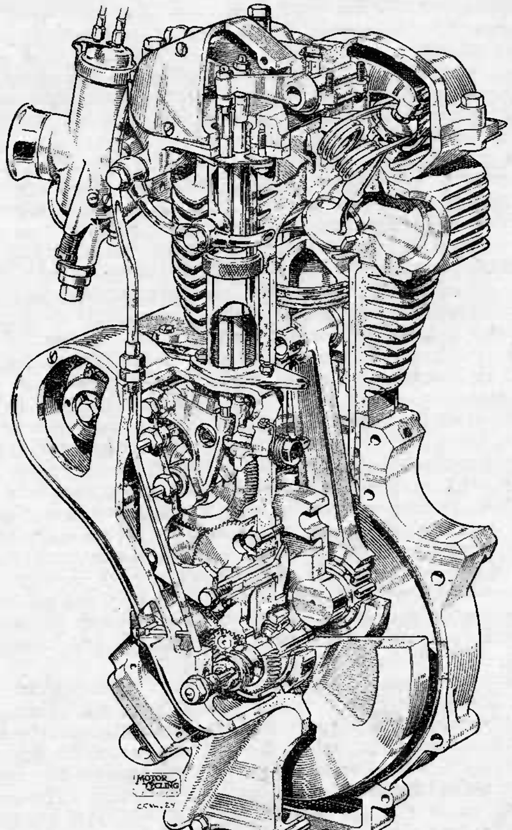
Contrary to what might be imagined, the specific fuel consumption (i.e., pints consumed per b.h.p. per hour) is not at all bad on racing four-stroke engines—and neither can it afford to be, for an engine with an insatiable thirst needs either an enormous weight of fuel on board or an extra pit-stop and the time-loss occasioned by whichever expedient is chosen may put it right out of the winning bracket. Here is another case in which an unbridled search for more power regardless of other things may defeat its own object. The trouble was particularly prevalent years ago with two-strokes, but of recent times it has been overcome to a large extent by the development of ports and exhaust systems which do not cause so much charge-loss as the older designs.

Thus we see that the trend in road-racing design has inevitably been towards robust but high-revving engines, which have good cooling, a high degree of stamina and reasonable consumption, but are expensive, mechanically complicated, not particularly light, and deficient in flexibility and low-speed pulling power.

Most of these characteristics are unsuitable or even undesirable for short-distance work such as grass-track or speedway racing, and the designer's approach to engines for such uses must be coloured by quite different thinking. Power is, of course, essential, but it must be there in plenty from perhaps 2,000 r.p.m. upwards. To be more accurate, high *torque* at low and medium speeds is required, because either the machines are single-geared or they should be capable of "holding" a gear at times when a change would not be practicable; in a sliding turn, for instance, continuous traction is essential and you cannot change gear in the middle of it.

These considerations limit the extent to which "long" valve timings and resonant inlet and exhaust systems can be exploited and so automatically reduce the ultimate power output; but this limitation is not wholly bad, because the mechanical and thermal stressing are thereby kept down to reasonable figures. This permits the design to be directed towards lightness, which is essential in the interests of easy handling as much as for acceleration, but as the majority of such engines will be sold to the public in quantity and not just built in small handfuls to be owned and maintained by the factory, manufacturing costs must be considered, and so must ease of maintenance. The gritty atmosphere usually present promotes rapid wear of barrels, rings and valve-stems (if the latter are exposed), but this assumes less importance if stripping down and reassembly is quick and easy and replacements are relatively cheap, which implies that they are light and of inexpensive materials.

For grass-tracking and speedway, alcohol fuels are permitted. This factor permits compression ratios as high as 14 : 1 to be used, and goes some way towards solving the cooling problem because the fuel possesses a high latent heat of evaporation—that is to say, it takes a lot of heat to convert it from liquid to vapour and



The 350 c.c. Velocette "Viper"—an engine at home equally on scrambles and road-race tracks or on the highway.

this heat must be extracted either from the ingoing air or from the interior surfaces of the engine. To obtain an efficient combustion chamber shape at very high compressions, it is best to make the stroke perceptibly longer than the bore, and this in turn makes for less area in contact with the gas at maximum temperature, thus further assisting cooling. Valve sizes may be restricted compared with those of a "square" engine, but will be adequate for speeds up to 6,000 r.p.m. or so, and will be better than the large valves for maintaining torque at low speeds—a matter which is also assisted by a considerable angle of offset of the inlet port, though this has an adverse effect on power as the speed rises.

Although an aluminium-alloy head is lighter than one of cast iron, it is not strictly necessary for this work, because iron warms up more rapidly—an advantage with alcohol when no extensive warm-up periods are allowed—yet will keep cool enough for short events even with scanty finning, a point which applies to the barrel as well. Push-rod operation of the valves is adequate and is lighter, less bulky and much easier to overhaul than any form of o.h. camshaft. Also, there is no necessity to circulate vast quantities of oil through the motor for cooling as well as lubrication, so even the "total-loss" system will serve.

Probably the best example of a true short-distance engine developed along these lines is the 500 c.c. J.A.P. which, though it has changed to some extent through the years, is fundamentally the same as when it started life. Weighing only about 70 lb. and developing some 42 b.h.p., it achieved pre-eminence in the speedway world and, together with its 350 c.c. brother, supplies the power for many a successful grass-tracker. A comparison between this motor and the double-o.h.c. Norton clearly shows how two lines of specialization have been brought to their logical conclusion; though the Bracebridge Street product is, of course, outmatched by the Italian multi-cylinder engines, which are even better examples of the pursuit of the ultimate for the job in hand.

Sprinter Group

An engine designed for short-distance racing makes a good jumping-off place to the construction of a real sprinter, intended for standing quarter-miles and kilometres, or hill-climbs which rarely take more than 40 seconds. Here, however, one can go to even greater extremes in cutting down areas or weights to save ounces, even at the expense of drastically shortening the life of the components concerned. But this is a field for the owner rather than the designer, since an individual can take risks with his own engine which a factory would not dare to do with units sold over the counter to anyone who comes along. It is worth noting, though, that sometimes the designer was right in the first place, and cutting down the original weight of some components at the expense of rigidity may lose far more than it gains, whilst reducing strength too far may result in a blow-up in the first hundred yards.

Scrambling, or moto-cross, confronts the designer with a very difficult set of conditions. A high power/weight ratio as well as low total weight is highly desirable, but tractability is almost as vital, partly because fairly wide gear ratios are demanded on some courses and partly because a rider may not always be in a position to change into the correct gear precisely when and where he should. An ability to withstand unintentionally high revs. without bursting anything is necessary, because the motor may on occasion find itself flat on its side screaming its heart out, with the rider temporarily detached and picking himself up some yards away.

The general conditions are often filthy in the extreme, with clods of earth or streams of mud flying in all directions, and therefore efficient air cleaning and complete protection against entry of dust or water into the engine is essential—especially for motors which are raced almost every week while the intervening days are spent largely in travelling somewhere else to wear them out yet further. Cooling also presents some difficulty because although the motor is working hard most of the time the air-speed is never very high and may at times be down to zero.

Dry-sump lubrication is of assistance here, as it achieves some internal heat removal by a copious circulation of oil. Aluminium-jacketed barrels with light-alloy heads can look after the air-cooling side whilst keeping the weight down to an acceptable figure—so long as they remain clear of mud. The fewer nooks and crannies there are around the cylinder, the better on this score! The fins will still clog up in time, of course, but they will at least be less difficult to clean out.

The valves of o.h.v. engines are always likely to become entangled with each other or to foul the piston crown above a certain rev. limit. Push-rod engines are rather more likely to suffer in this way than those with o.h. camshafts, but, in the larger capacities at least, the extra bulk and top weight of the latter layout is undesirable. A push-rod motor can be made proof against momentary overspeeding by providing enough clearance around and between the valve heads to avoid fouling even above valve-bounce speed, even though this may entail a lowering of the compression ratio. These precautions are in the nature of an insurance, and are not substitutes for ensuring, by careful cam and valve gear design, that valve-bounce speed is high enough in the first place.

In general, an all-aluminium push-rod four-stroke of solid internal construction fills the scrambling/moto-cross bill very well, but the two-stroke has more than a passing claim to attention. It has no poppet valves to be mangled; for equal capacities, it is smaller than a four-stroke and so can provide a greater ground clearance for less top-weight; and it can usually be made to develop as much power per c.c., though it is difficult to make it maintain this equality over the whole speed range. A two-stroke with very good top-end power is even more likely to be gutless at low speed than a four-stroke; but with greater attention being focused upon port design and the development of rotary or reed inlet valves this deficiency may be redressed.

Scramble Factors

Scrambles engines suffer more than most from violent shocks due to the machines repeatedly taking off over bumps and landing. The effort of the flywheels to accommodate themselves to the rapid changes of speed enforced by these circumstances is apt to pull a built-up assembly out of alignment, especially if the flywheel is located on the side opposite to the primary drive (as it often is on two-strokes because of the difficulty of placing both on the same side and also fully enclosing them). This means that great care should be taken in the design to see that there is no possibility of the crank-webs moving on the pin; this can be done by allowing plenty of high-tensile material around the hole and providing the largest possible crankpin with the correct amount of interference.

Basically, the Scott layout, with overhung pins and a central flywheel, is very good in this respect, as even if the two halves of the shaft did move they would still remain in alignment, while the flywheel's central position ensures its protection without excessive width or liability to strike the ground on corners or in ruts. The parallel-twin four-stroke with centrally placed flywheel is also good in this respect; furthermore, its crankshaft assembly cannot be pulled out of line, because it is either cast in one piece or built up with the components located by dowel pins on large diameters, instead of merely by frictional grip.

Engines for trials of the mud-and-rock-climbing variety beloved of British organizers require two outstanding characteristics—tractability from the maximum right down to tick-over speeds and invulnerability from mechanical damage, either self-inflicted or from external causes. Minimum width at or near ground level, to give clearance over rocks, is of prime importance. This and the "mechanical damage" item just about rule out the transverse h.o. twin and put a premium on the inherently narrow four-stroke single, for solo use anyway.

Tractability, vital when negotiating very difficult terrain, is gained by the use of "slow" valve timings and small carburetter sizes and the elimination of peaks or hollows in the power curve through wave-action or resonance in the inlet and exhaust systems—just the reverse of racing practice. Either flat spots or surges of power would obviously be very disconcerting to a rider picking his way carefully up a steep, rocky gully by skilful use of the throttle.

Sheer power is not of much importance, as any lack in this direction can be offset by a wide-ratio box, in which a "dreadnought" bottom gear can confer the ability to climb the side of a house, even if at a very low speed. In trials of this nature the ability to "get there" is paramount, and overrides any consideration of how fast you can go in the process.

But though the average speed from point to point may not be high in terms of m.p.h., in terms of physical effort it may be very high indeed—so much so that towards the end of the day fatigue begins to take its toll and undermines the rider's ability. Broadly speaking, a lightweight is less exhausting to handle than a heavyweight, and this would in some measure account for the increasing success of small machines in exceptionally severe events such as the Scottish Six Days Trial.

NEXT WEEK Phil Irving resumes his regular Motorcycle Engineering series with "No. 23—Air v. Water Cooling."