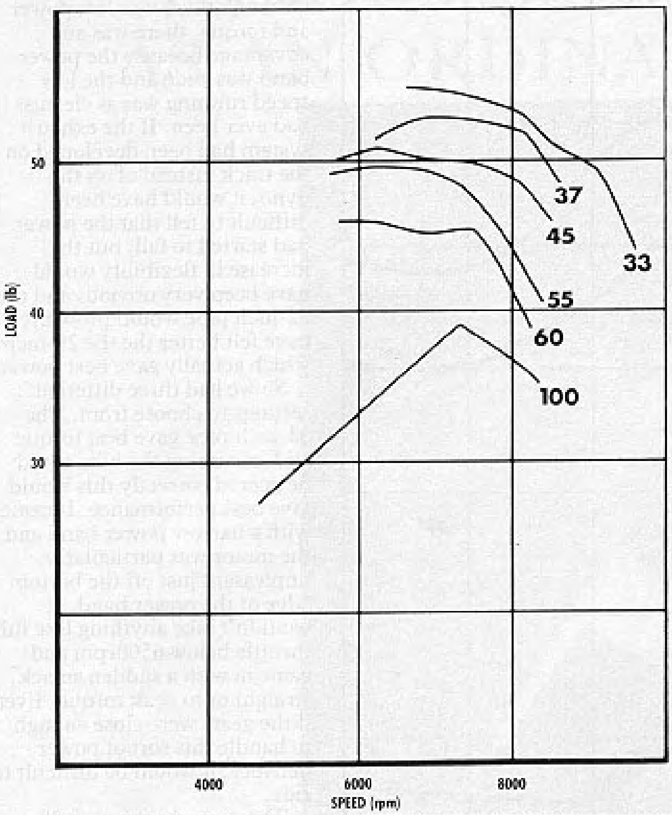
PIECE OF PIPE

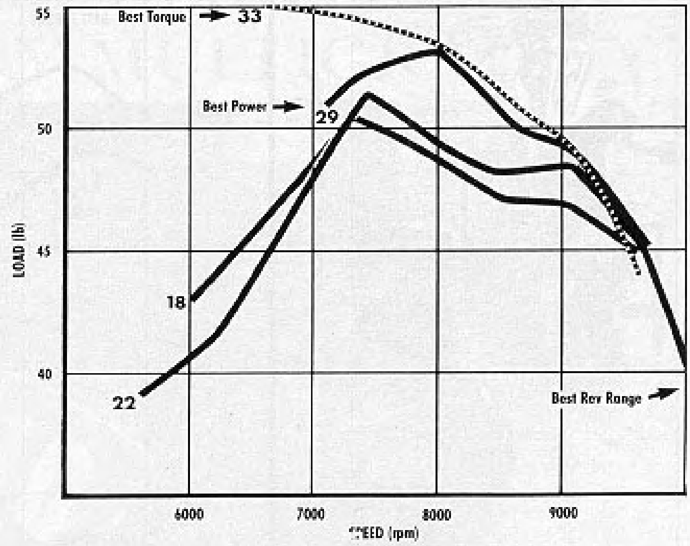
Exhaust systems make a profound difference to engine performance. If you don't believe it, accept it for now or skip to the results graph at the end of this article.

So now I am talking to believers, or at least quasi-believers. And you believe that the exhaust can seriously alter your bike's performance. You are right. Equipped with a suitable formula, a hacksaw and some welding tackle, you could therefore improve your bike's performance. There, unfortunately, you are probably wrong because most of the factories are also believers and they have got more hacksaws than you have.

If you wanted to change your bike from, say, a roadster into a racer, then you may well be able to do better than the stock exhaust without the encumbrance of a powerful silencing system. But don't believe it's easy. We spent two days chopping and welding with a bike on the dyno just to see where we were. The dyno time would cost around £200 and at the end we had enough figures to be able to produce a tailored exhaust — but we still had to make it, tuck it in for ground clearance, add a race silencer followed by another half-day in the test house to get the carburation right. And that was on a single cylinder, using a mild steel, very rust-prone exhaust with nominal silencing and no real thought about long rev ranges or flexibility. This was a racer — but you can see why roadster systems cost so much.

The racer in question was Mark's Rotax, a four valve 500 which is currently leading the single cylinder race series. It was originally in an Armstrong motocrosser and so had no exhaust suitable for road racing. Mark was running it on





Left: the effect of progressively shortening the plain pipes from 100 inches down to 33 inches. The total length is about 6 inches longer as these figures don't include the flange or port. Right: below 33 inches of pipe the load began to fall everywhere except at maximum speed. As soon as peak torque is forced where the cam doesn't want to go, the load (torque) begins to fall.

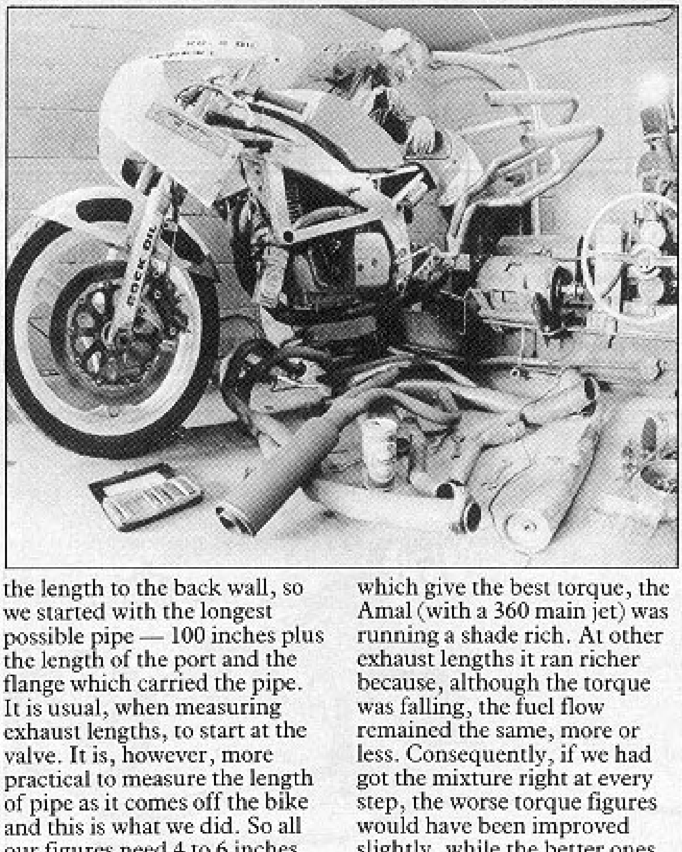
an exhaust which had simply been made to fit the Spondon frame and flattened off as necessary to give cornering clearance. As some of his competitors claim 60bhp, it came as quite a compliment to Mark's riding ability to find that the Rotax was only giving 43bhp. And no wonder an old G50 Matchless was getting past him on the straights.

To accomodate the change from motocross to road race, the Rotax had been fitted with a 675 cam and an open 38mm Amal roughbore carburettor. One problem was that, although the motor would turn to 10,000, the cam wanted it to give peak torque at about 6,000. It couldn't afford a narrow power band because it still had the wide ratio motocross gearbox. Within these restraints, all we had to do was find an exhaust system which would give the most usable power.

The Rotax has two separate exhaust ports, one for each valve, and we decided to run two separate pipes. The reason was that if we joined the pipes, the join might disrupt pulses travelling back down the pipe and it might make the system behave like two short pipes which ended at the joint, regardless of what we did further downstream.

At this stage we only used plain pipes. The complications of secondary pipes, megaphones and silencers could wait until later.

We'd seen odd formulae which gave very long exhaust pipe lengths which then had to be halved or quartered in order to fit the bike. The only restriction in the test house is



the length to the back wall, so we started with the longest possible pipe — 100 inches plus the length of the port and the flange which carried the pipe. It is usual, when measuring exhaust lengths, to start at the valve. It is, however, more practical to measure the length of pipe as it comes off the bike and this is what we did. So all our figures need 4 to 6 inches adding, to allow for the length of port outside the head and the short flange which was used to mount the pipe.

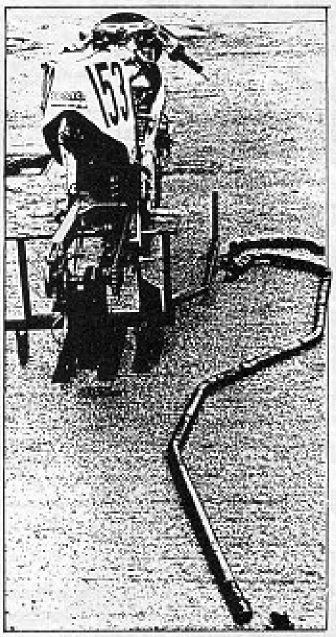
From the initial 100 inches we came down in steps of 10 and 5 inches until the engine torque started to increase significantly, then we shortened the pipe in smaller steps, carrying on until the torque dropped and the system was obviously too short. We didn't optimize the carburation at each step — there simply wasn't time. At the lengths which give the best torque, the Amal (with a 360 main jet) was running a shade rich. At other exhaust lengths it ran richer because, although the torque was falling, the fuel flow remained the same, more or less. Consequently, if we had got the mixture right at every step, the worse torque figures would have been improved slightly, while the better ones would hardly change but the difference is not (we hope) enough to alter the overall shape of the results.

We used 1.5inch tube, mainly because it was a convenient size. Other tests which Leon has made suggest that if the pipe is too large it will not be so sensitive to changes in length; if it is too small too it will eventually cause a physical restriction to the gas flow.

Several things changed when we changed the exhaust length. The amount of torque and power changed. The engine speed for peak torque and for peak power changed. The gap between the two changed. The rate at which torque came in/fell off also changed. This last item shows in the steepness of the graph; once it goes beyond a certain critical steepness, the dyno can no longer hold it steady and this effectively defines the upper and lower limits of the power band.

The engine also had ideas about where peak torque and peak power ought to be — away from these speeds, it was less happy about delivering, especially below 5000rpm, where it was inclined to splutter and run into a rich-mixture misfire. When the exhaust tried to force it to run at these speeds, it would run cleanly but with reduced load. When the exhaust did not match these speeds, the engine would get unmanageable, eight-stroking and misfiring until it was allowed to soar up into its power band.

So the exhaust not only determines the level of power and the width of the power band, it also controls the way in which the engine comes into the power band, and therefore has a serious effect on the overall driveability of the machine. The figures shown in the graphs are dyno load (in lb) which is directly equivalent to torque and was chosen because it relates to the air flow through the engine and shows how the exhaust system is affecting the air flow. (Horsepower is load multiplied by the engine speed and divided by a suitable constant, 9446.4 in this case).



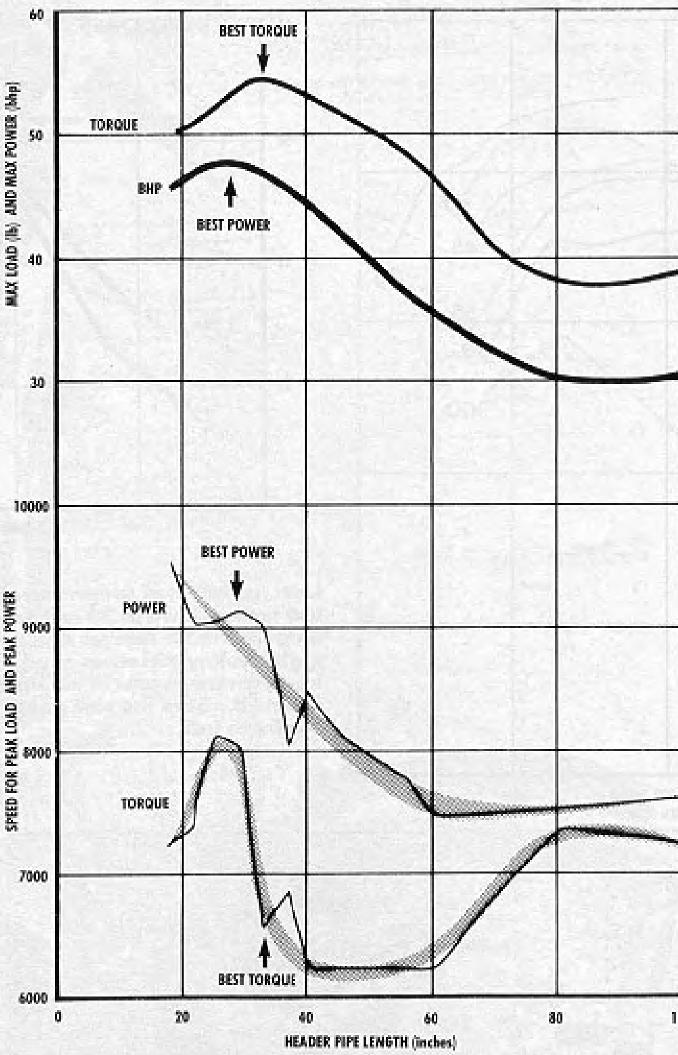
With 100 inches of plain pipe, the motor was flexible enough but didn't develop any power. Shortening the pipes through the 80-inch region made it very unstable, misfiring and running very rich. At around 70 inches it started to clean up and a clear pattern emerged, which is best shown by the graph. The torque curve was pushed upwards, although peak torque tended to be in the same place — around 6200rpm. Because the amount of torque was increasing, the horsepower also went up . . . and went up the rev scale too.

Peak power went from 7500rpm at a length of 60 inches up to 8500rpm when the exhaust was 40 inches. Moving peak power further away from peak torque means that the power band is increasing and the engine is getting more flexible.

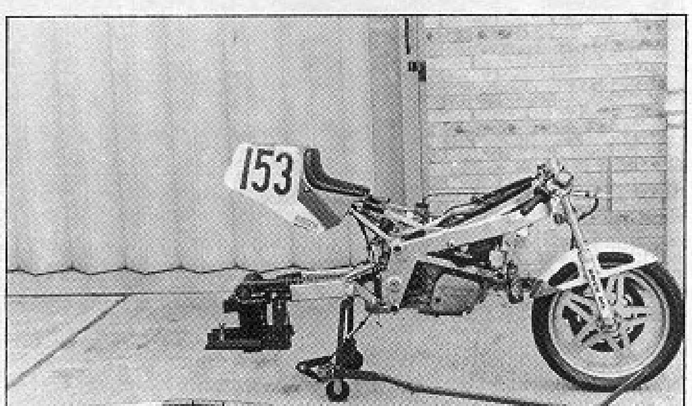
The way the engine came onto the power band also changed. At some stages it was smooth, progressive and responded properly to the throttle. When it had a length of exhaust which it didn't like, it was the opposite. With 45-inch pipes it would not accept full throttle at all between 3000 and 4500rpm and eight stroked badly in this speed range. At 40 inches, it cleaned up and ran predictably again. At 37 inches the obnoxious low-speed behaviour returned, and so on.

All the time the load and power were increasing, until we got to a length of 33 inches, which was the setting which gave the best torque. This coincided with bad running below 6500rpm, but it did allow the engine to run on to 9500rpm, about a thousand revs further than it had wanted to go on longer pipes.

We carried on shortening the pipes and running the engine. The torque now started to fall — gently at first — but it



Above: a summary of the tests showing how power and torque changed with pipe length (which doesn't include the length of the flange and port).
Below: the engine speed at which power and torque reached their peaks also varied with pipe length. Where peak torque is further from peak power, the engine is more flexible.



continued to hang on to its load at high speed. Consequently the power still rose and we measured the best power with pipes at 29 inches, although these gave much less torque below 8000rpm compared to the 33-inch pipes. The motor was still badly behaved below 6500.

Once the pipes were down to 25 inches, the load had dropped but it was once again running fairly cleanly below the bottom edge of the power band and it would drive easily through the rough patch at 4000 to 5000rpm. When the pipes were shortened further it lost torque everwhere except at the very highest speed. One result of this was that peak power didn't change very much even though peak torque was soon dropping rapidly. Eventually maximum power began to fall as well but although there was less power and torque, there was an advantage because the power band was wide and the low speed running was as clean as it had ever been. If the exhaust system had been developed on the track instead of on the dyno, it would have been difficult to tell that the power had started to fall, but the increase in flexibility would have been very obvious and the 22-inch pipe would probably have felt better the the 29-inch which actually gave best power.

So we had three different settings to choose from. The 33-inch pipe gave best torque and, assuming the bike could be geared correctly this would give best performance. It came with a narrow power band and the motor was particularly unpleasant just off the bottom edge of the power band. It wouldn't take anything like full throttle below 6500rpm and came in with a sudden smack, straight onto peak torque. Even if the gears were close enough to handle this sort of power delivery, it would be difficult to ride.

The second option, at 29 inches, gave most power (47.6hp at 9200rpm) but less torque. It would possibly be more sensitive to correct gearing and, technically, the power band was even narrower but, because it came onto the power band more gently it would probably be easier to handle. That's one thing that the dyno can't tell you.

The third option, at 22 inches, gave less power, less torque but it had the longest rev range. The ability to rev out would make it less sensitive to gearing and easier to ride but again, only a track test will tell if this advantage is worth the loss in power. Possibly Mark will need to make up two systems, one for fast, wide open circuits and one for twisty, slow circuits.

With this in mind we tried one last experiment. The best bottom end and cleanest running came with the 40-inch pipe; the highest revs were obtainable with the 22-inch pipe. What would happen if we fitted one of each, instead of having the pipes in equal-length pairs?

The motor pulled strongly from 5500 and split the difference between the two pipes, giving more bottom end than the 22-inchers but less than the long pipes. Between 6700 and 8000 it gave more than either of the other two — don't ask how. At high speed it held on to its power, not quite as well as the short pipes but close enough. The tricky bit will be in running these unequal lengths of pipe into a race silencer without losing the effect . . . but we've got to leave Mark some secrets. **JR**