efficiency. This will only translate into a minuscule speed advantage (power required is proportional to speed^3) but for GP front runners at Hockenheim this means everything. At Darley Moor it will not change the world!

There is also a price to pay. Unless you have fuel injection capable of dealing with it, the air:fuel ratio will be modified according to road speed. The engine will get more air without getting more fuel in the right proportions. This will either lean out the mixture at high speeds or enrich it at low speeds according to how you set up the carburation. Accurate compensation is only possible with the interjection of electronics and that is the way things are going - Fig 4.43. For the average racer it is all a mixed blessing and the main objective is to obtain a decent supply of cool air.

Another aspect of ram-air induction is the possibility of using the airbox as a resonance chamber. In this case the objective is to get the pressure in the box to vary in sympathy with the induction requirements, ie a high pressure occurs when the inlet starts to open. I have no experience of this but can comment as follows. The idea is not new but it is difficult to sort out unless you have the appropriate instrumentation to investigate it properly. For a single-cylinder two-stroke a mathematical solution seems reasonable since it is fundamentally the same as the calculations required to achieve crankcase/transfer/exhaust resonance. Many people have now got this sorted out because we have been doing it for many years.

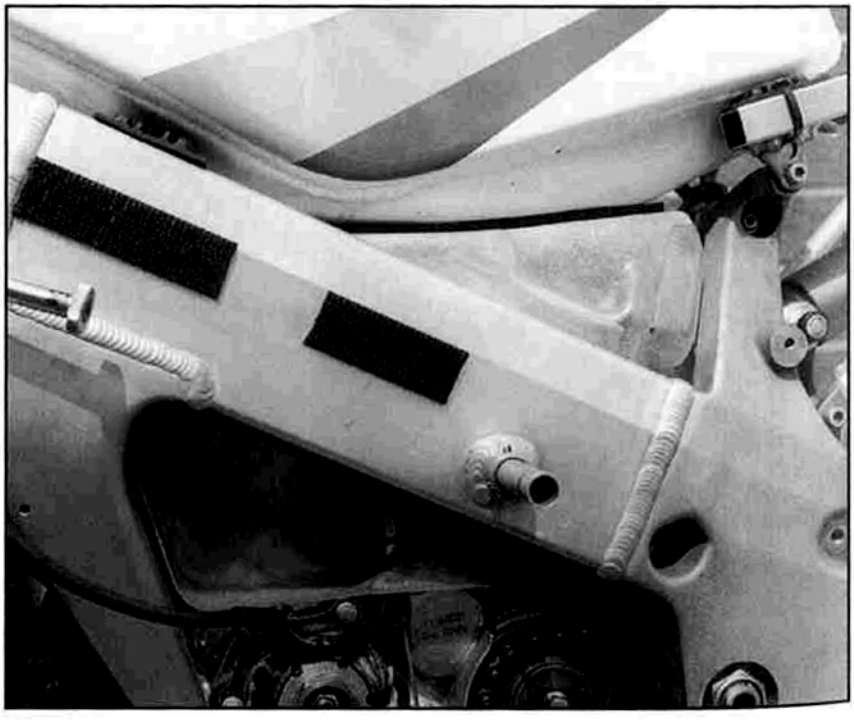
With multi-cylinder engines a whole new set of problems emerge because you are trying to synchronise the airbox frequency with each cylinder. Nevertheless, this is where the real gains can be made and a well designed airbox can go a long way towards removing mid-range troughs from the torque curve, thereby smoothing out the power delivery. You can experiment with airbox volume, the entry duct and the inlet tracts, particularly their lengths, but your chances of success without a lot of dyno time and good instrumentation are very slim. I must have a dabble at this sometime but at the moment my useful knowledge is nil!

The NACA duct

While on the subject of induction air, a brief discussion of the so called NACA duct is probably called for. These ducts are very common on racing

Below. Fig 4.43 *The airbox on a factory 125cc Honda. The tank is also at airbox pressure and when the throttle is closed the tank vents to the atmosphere. This is initiated by an electronic sensor on the throttle.*

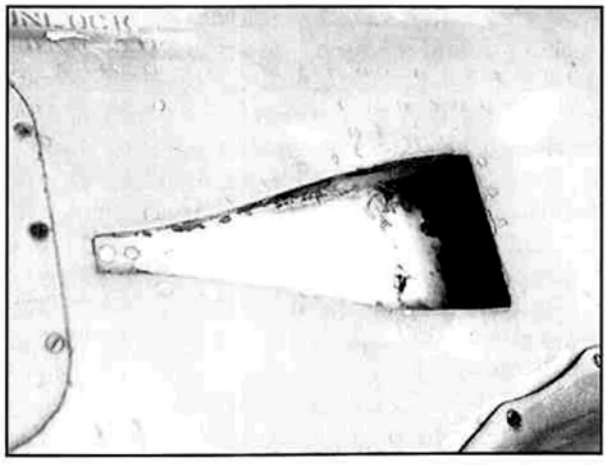




cars, reasonably common on sidecars and sometimes seen on solos. An example is shown in Fig 4.44. Some of the ducts you see will not work in the way the duct is intended to because they are not the right shape or in the correct location. They may well take in air but do so with a significant drag penalty. If the NACA duct is correctly designed and located then the increase in drag coefficient of the bike due to the duct can be less than 1% of its original value.

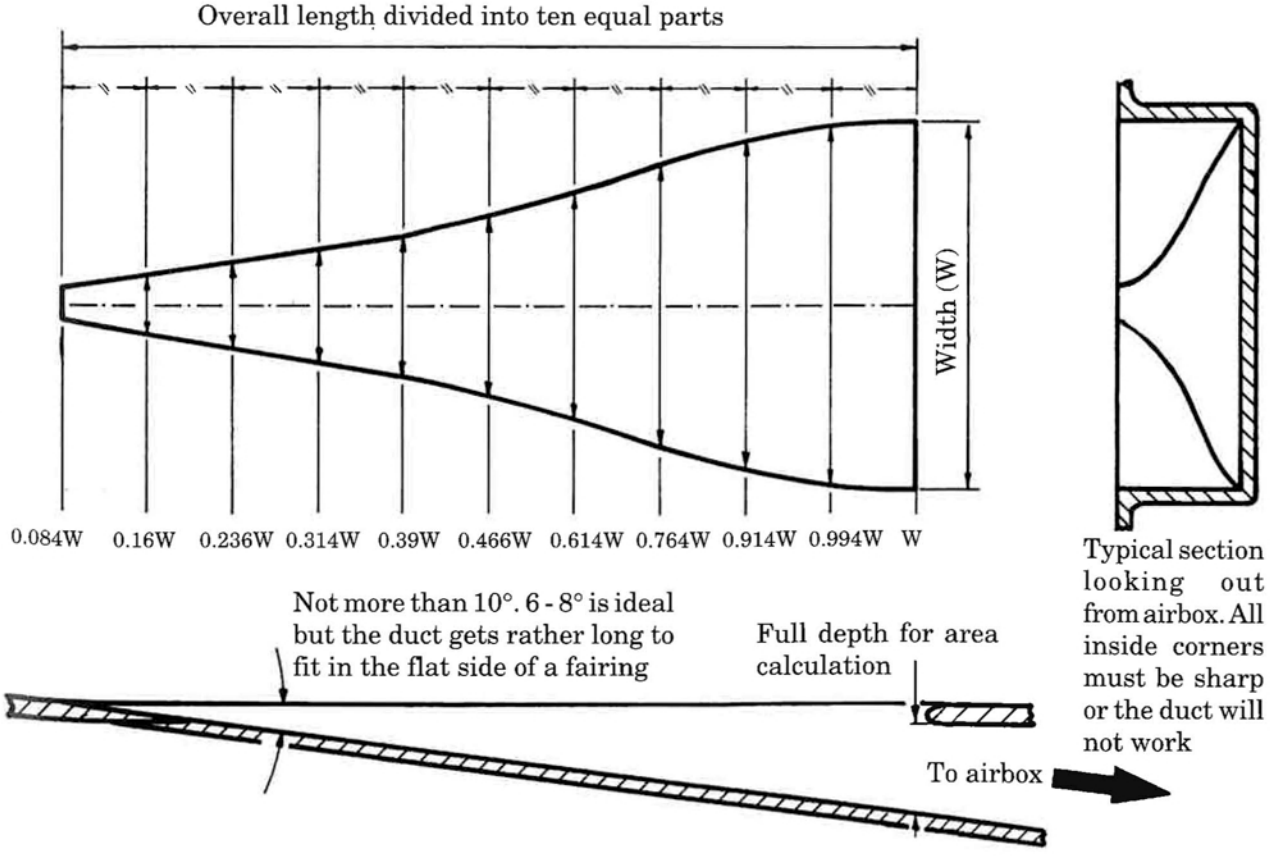
The NACA duct was developed by the aerospace industry as a means of providing maximum air flow rate with minimum drag. Any form of inlet that sticks out in the air stream will generate drag of its own and interfere with the normal flow as described earlier. The NACA duct is flush with the surface and is a very subtle device.

First a word of warning. The NACA duct fails to perform when it is yawed to the air stream. It is easily shrouded or placed in a wake and only works at its best when it is located in a relatively flat smooth panel where the relative air speed is high, hence the use on cars and sidecars. Short fairings with a lot of curvature are not ideal.



Above. Fig 4.44 *A 'real' NACA duct. This one is on a Hawker Hunter jet aircraft. Most aircraft have them.*

Below. Fig 4.45 *The key to the operation of the duct is the S shape and the sharp corners at all side edges. The rear outer lip should, theoretically, be quite thick but tests show that it will still work using just the fairing skin.*



Given the right conditions and design this duct is one of the most efficient but it must be made to the correct dimensions and, even more important, the edges must have sharp corners - Fig 4.45. This is because of the way the duct works.

When the air passes the sharp edges at high speed a vortex is set up, ie a rotating air flow. The effect of this is to scavenge the floor of the duct and thin out the boundary layer that would otherwise build up and block the duct. Provided this happens, the air is persuaded to jump into the hole it would otherwise ignore. The key is the sharp edges and the S type shape.

Theoretically, the trailing edge of the duct should have a relatively thick streamlined section of specific proportions but NACA ducts using just the thickness of the fairing skin have been shown to work perfectly well in wind tunnel tests. They are not quite as good, but much easier to construct.

To estimate the duct size, use the method given previously to calculate the required entry area. This will then be equal to maximum width multiplied by the depth at that point. Make the width at least three times the full depth and preferably more, up to five times if you have the space to do so. Keep the floor angle to less than ten degrees, preferably six, and use this to calculate the length. Make a card template first. Once you have decided on the width and length, divide the length up into ten equal strips and mark off the widths according to Fig 4.45. Do it as accurately as you can and then create the full duct in the fairing. Don't forget the sharp corners.

Example. Design a NACA duct to provide an area of $30cm^2$.

Use a width that is four times the depth (3 to 5 acceptable). Calculate the depth using,

$$\text{Depth} = \sqrt{\text{Area}/(\text{Width} : \text{depth ratio})}$$

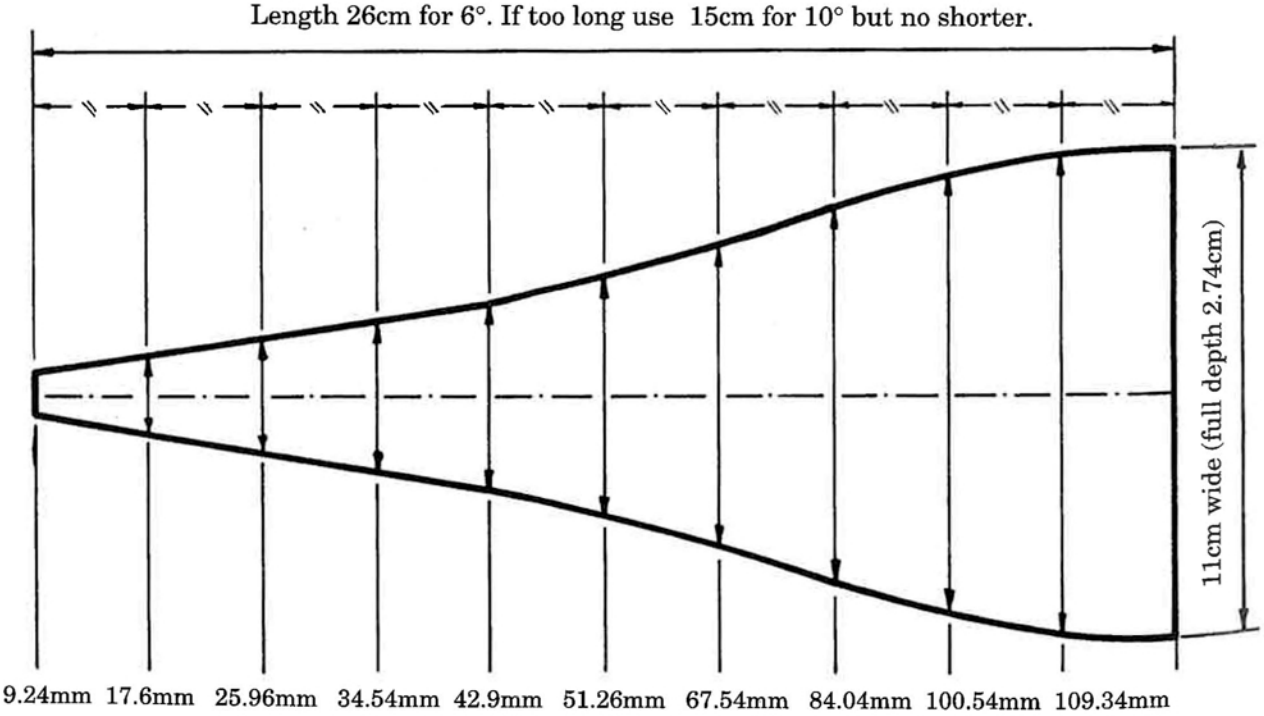
$$= \sqrt{30cm^2/4} = 2.74cm$$

Thus, width = 4 x 2.74 = 11cm approx

For a six degree floor,

Length = Depth/Tan(6°) = 2.74/0.105 = 26cm

Fig 4.46 *Duct shape developed in the example.*



Values are listed as calculated. Just make the shape as accurate as you can. Widths given every 26mm.

If this is too long to accommodate, ten degrees gives 15cm but do not go any steeper. Using 26cm, divide a pattern into ten strips each 2.6cm long and obtain the widths at each stage using the data given previously in Fig 4.45. Fig 4.46 shows the final design.

Cooling

Cooling is one area where there will be a lot of changes in the future, simply because at the moment we make a poor job of it. This is an undisputable fact, but as you might imagine there are reasons. Design is a compromise in which some things have to take priority over others and on most bikes the bit that loses out is cooling.

It does not lose out in the sense that the cooling is totally inadequate. When the cooling is inadequate the problems are very obvious. Water boils, pistons melt, power dwindles and so on. No, the real problem is the price we pay in drag for obtaining sufficient cooling.

The goal is very simple. The less air you allow to pass through the bike, as opposed to around it, the lower the overall drag will be. Set against this is the need to provide sufficient cooling and there is a great deal that can be done before you even consider the air.

It is essential to make the heat transfer as effective as possible at cylinder level, irrespective of whether you have water cooling or air cooling. The thermal conductivity of most aluminium alloys is about sixty times greater than that of carbon so carbon is a severe barrier to heat transfer. Similarly, the most minute amounts of metal oxides inside the water jacket (the creamy brown bits) also have a dramatic effect and it has been estimated that an even coating 0.5mm thick would reduce the overall conductivity by some 50%.

If your heads and cylinders are a carbon/aluminium/oxide sandwich then, assuming there are no overheating problems, the engine is overcooled. Keep it free from carbon, clean out all deposits and use a decent corrosion inhibitor. You can then get away with less air.

There are many other checks to make but I do not want to digress too far from the main topic. Most tuning books give some coverage to this even if it only amounts to the advice that black surfaces are best. Note that a thin high quality black coating might gain you 10% in heat dissipation. A thick one may make things worse.

Once the heat energy is transferred through the cylinder/head walls you then have the choice of air cooling or water cooling. Again, the pros and cons can be found in tuning books. Water cooling is the norm, but the advantages are often overstated. Water does provide more thermal stability, it does allow more power to be produced from two-stroke cylinders and it is virtually essential for two-strokes with cylinders that are close to each other. Despite this, it is generally heavier, there is much more to go wrong and it makes engine work more time consuming. It also lacks the air cooled engine's ability to increase its heat transfer by radiation when the bike is still.

Everything depends on what you are doing. If your racing consists of four laps at an airfield then you are not operating under GP conditions. At the risk of offending those who assume that only water cooling is acceptable, I would suggest that some people do not need it and can benefit from the simpler air cooling, provided the air does actually get to do the job required of it. This is particularly true of four-stroke single-cylinder engines.

If you are using water cooling, you have many other areas worthy of great experiment, ie the radiator, the volume of water, the block pressurisation and the water flow rates to name just a few. Radiators vary incredibly. There are tube and flat fin types, corrugated fin types, cellular cores and so on. If you broaden your horizons and look at heat exchangers in general the range of possible constructions is vast. Some are much more efficient than others, ie they need less area to do the same job and those are the ones you need to sort out. Unfortunately there are no simple rules and it is a case of experimenting. One useful observation is that increasing the thickness of the core does not produce a proportional increase in heat dissipation. Indeed, the gains can be very small for quite large increases in thickness. Do not even consider doing any sums on the size of radiator you need, they are too complex. Just look around at what is being used elsewhere remembering that most bikes have much bigger radiators than they need because the air is so badly managed.