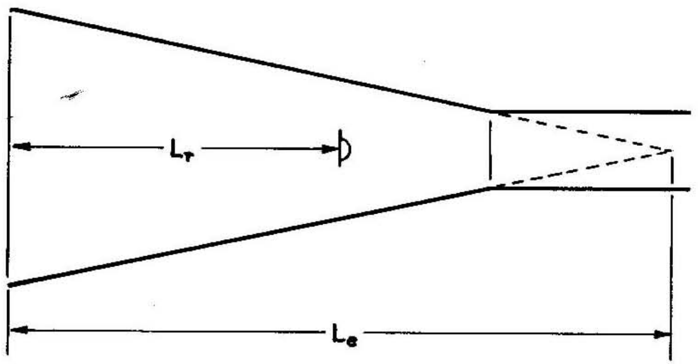
My experience in dynamometer-testing various expansion chamber configurations has shown that a 20-degree baffle-cone gives a good, strong power peak – and then simply cuts the engine dead, in terms of output, if you try to force the revs any higher. A 15-degree baffle-cone, in contrast, gives a somewhat lower maximum output – but helps the engine maintain its output well after the peaking speed has been exceeded. The implications of this influence on an engine's power curve should be obvious: motocross bikes can gain in engine flexibility from a long, gently tapered baffle-cone, but if you are "tuning" for some young man who often forgets to protect the engine from over-exerting itself by changing gears, then you can use a 20-degree baffle-cone. It will remind him about the gear lever by chopping the power drastically every time he tries to use too many revs.

There is another thing you need to know about those baffle-cones before you can design your own expansion chambers: they do, as stated earlier, reflect over their full length any wave entering them, but there is not an *even* reflection, for reasons too numerous and involved for serious discussion here. What you do find, however, is that there is a "mean" point of reflection – which is, as I said earlier, slightly more than half-way down the baffle-cone's length. The "tuned length" we discussed before, the length so critical to the expansion chamber's performance, is actually the distance from the exhaust port window, at the piston face, measured along the exhaust system's centerline out to this point of mean reflection. This midway point seems to be at the halfway point of the *complete* cone, which would be half the length of the cone if the cone were complete, right out to a sharp tip, instead of being truncated at its small end to make room for the outlet pipe. You can find this point of mean reflection either by drawing the complete cone, measuring, and dividing its length in half, or by using this simple formula:



The mean point of reflection inside the baffle-cone is $Lr = \frac{Le}{2}$

$$L_r = \frac{\left(\frac{D_2}{2}\right) \times \cot A_2}{2}$$

Where L_r is the distance from the baffle-cone's inlet to the mean point of reflection
D_2 is the baffle-cone's inlet diameter
A_2 is half the baffle-cone's angle of convergence (i.e. for a 16-degree cone use 8-degrees, etc.)

While we are on this particular subject, I will also give you the formula for finding the length of a cone, given its taper, major and minor diameters. The formula is as follows:

$$L = \frac{D_2 - D_1}{2} \times \cot A$$

Where L is length
D_2 is the cone's major diameter
D_1 is the cone's minor diameter
A is half the angle of divergence, or convergence.

OUTLET PIPES

Having gotten past the business of diffusers and baffle-cones, we can proceed onward to the lengths and diameters of lead-in and outlet pipes. The latter will, if the rest of the expansion chamber is proportioned fairly closely in accord with the advice I have given, have a diameter between .58- and .62-times that of the lead-in pipe, and a length equal to 12 of its own diameters. It is simply a pressure-bleed resister, which prevents the free escape of exhaust gases from inside the expansion chamber and thereby creates a backpressure to enhance the port-plugging efforts of the wave reflected by the baffle-cone.

This outlet pipe is much more sensitive to diameter than length. The rule I have provided for diameter will get you very close to the optimum, if the rest of the chamber is proportioned correctly (or at least as I have indicated, which I hope will amount to the same thing) and the length, of 12-diameters, will also be very close. Even so, they will only be "close" and I have found few instances, in my own experimenting, when a session of cut-and-try on the dynamometer did not lead me to a slightly different diameter and length for best results. You probably do not have a dynamometer, and that bit of news is in all likelihood not something you wanted to hear. Nonetheless, it is true. You will not get optimum results here simply by following the instructions I provide. In fact, a tad of adjusting is required, to meet a particular set of requirements, to make *any* strictly-formula expansion chamber give maximum performance. But there is a very particular problem associated with the outlet pipe that you should know about: Simply stated, the problem is that if you make the outlet pipe too small in diameter, or give it too much length, (both tending to over-restrict the chamber's outlet passage in terms of flow capacity) then there will be a price to be paid in overheating. I frankly do not know the mechanism involved in this; I only know that if the outlet is too restricted, engine temperature is very greatly elevated – and Yamaha's Naito has said that the same unfortunate result will be observed if the expansion chamber's baffle-cone is tapered too abruptly. From what I have seen, this increase in temperature is especially sharp at the piston crown, which tends to be the power-limiting part in a two-stroke engine in any case. So, you should keep a sharp eye on your engine's piston. There will be temperatures high enough to darken the underside of the piston crown, due to baked-on oil forming there, when the engine is healthy; just don't ignore the warning sign you see when that oil begins to char. The next thing you see, after you see ash, will be a hole.

Actually, the worst side of this whole matter of selecting the right outlet pipe is that while power rises quite sharply as you work your way down from a too-large outlet pipe diameter, there will be only a slight decrease in power output when you have gone too far in restricting the outlet. Therefore, unless you have a dynamometer and instrumentation for measuring engine temperatures, make all errors on the large side of the diameter you get by multiplying lead-in pipe diameter by the .58-.62 factor I have provided. In other words, if the factor-derived diameter (taken from a lead-in pipe diameter of say, 1.75-inches) is from 1.015- to 1.085-inches, then you should not try to use a piece of one-inch tubing for that outlet pipe, as its nominal diameter is an *outside* measurement. Subtract for a wall thickness of, say, .049-inch, and you'll have a passage only .902-inch in diameter. That isn't large enough to be safe – nor would a tube having a nominal diameter of 1⅛-inches, with an inside diameter of 1.027-inches be entirely safe. When skirting that close, go up to the next largest available diameter – in this case it would be 1¼-inches – and run the engine long enough and hard enough to permit a valid "reading" of the piston crown's underside. If it shows no sign of excessive heat, you can try a slightly smaller outlet pipe, and then check the piston again.

LEAD-IN PIPES

There probably is a better, closer, rule for determining outlet pipe diameter – if only because the rule I have offered is tied to the diameter of the expansion chamber's lead-in pipe, which is very, *very* difficult to determine on a strictly theoretical basis. For engines having exhaust port timings and port widths typical in racing terms, the expansion chamber's lead-in pipe should have a diameter providing an area 10- to 15-percent greater than that of the port window. But that only applies, I have found, when the parameters are as stated, and only then when a power curve very distinctly biased toward maximum output at maximum revs is desired. For motocross applications, the diameter chosen will be one that can be used in combination with a considerable pipe length to broaden the power range. In some instances, lead-in pipes are used with cross-sectional areas representing 150-percent of the exhaust window area. As a general rule, you may assume that the manufacturer of your particular engine knows more about lead-in pipe areas than you, or I, and you can't get into trouble following his lead. You may, by ignoring the possibilities in other directions, miss an optimum by some smallish percentage – but you won't get into trouble.

The thought may have occurred that my instructions are, in this regard, something far short of precise. And so they are, for good reason: the choice of lead-in pipe diameter must be shaped not only by unit cylinder displacement, port timing/area, and according to the application you have in mind for the engine – but also with an eye toward the lead-in length, and the configuration of the diffuser to which the pipe attaches. All of these things have their effect, but I have not as yet been able to isolate each item well enough to arrive at a quantitative pattern. So, for the moment, I make do with a qualitative understanding and a couple of handy rules-of-thumb: the first you already know (regarding the rough relationship between the port and pipe cross-section area); the second rule (more a suggestion, really) is that for maximum horsepower only, you should give the lead-in pipe a length equal to from 6 to 8 of its diameters, while for a broader power curve (and at some expense to the maximum) you may want to use up to 11-times pipe diameter. All these lengths are, of course, not just that of the pipes themselves, but also include the distance from the pipe mounting flange through the port to the piston face. A final note on lead-in pipe length: if, for reasons of easier installation, or a broadening of the power range, or both, you decide upon a lead-in pipe length greater than 8-times its diameter, plan to increase its diameter slightly. Resistance to flow is increased with length, and this can and should be offset by giving the gases a larger passage. Ideally, this reduction in resistance would be accomplished by using a lead-in pipe having a slightly-diverging taper (2 or 3 degrees) but that may represent a more