Walter Kaaden was chief engineer of MZ's racing department through that firm's glory years on the Grand Prix circuit, and in that capacity Kaaden advanced the state of the art with regard to expansion chamber design very considerably. And one day while discussing the subject he remarked, only in jest, "You'll know when you have the design right, because the chamber will then be impossible to fit on the motorcycle without having it drag the ground, burn the rider's leg, or force the relocation of one or more major components". Of course, all present had a fine laugh, but the joke contained a large and bitter kernel of truth. In point of fact, that odd, bulky bit of exhaust plumbing we call an "expansion chamber" (a poor term for the device, but widely used) is exceedingly difficult to accommodate neatly on a motorcycle. Routed underneath, it is an acute embarrassment in terms of ground clearance even on a road racing machine and fights a losing battle with rocks on an off-road bike. Curled back along the motorcycle's side, it can force changes in the position of fuel tanks and frame tubes – and always roasts the rider's leg and/or forces him to ride bow-legged. Just as bad, it fiendishly assaults the ears of everyone for several hundred yards in every direction, and has done more to make the motorcycle – and the man astride one – unpopular than all the Wild Ones movies, and tabloid headlines of One-Percenter's misdeeds, put together.

Attended as it is by these manifold inconveniences, one almost (but not quite) wonders why we bother with the expansion chamber. Unfortunately, damnable nuisance that it unquestionably is, there is nothing else in the engineer's bag of tricks that comes anywhere close to matching the boost a two-stroke engine gets from a properly designed expansion chamber exhaust system. For that reason, it has become the ubiquitous helpmate of the high output two-stroke engine, and for that reason it will be with us until we all change over to electric motors or gas turbines. And until that time, experimenters will be tossing away stock mufflers and trying different expansion chambers as a major part of their endless quest for ever-higher performance.

Actual percentage improvements between engines fitted with their standard mufflers and the same engines with expansion chambers will vary greatly. A lot depends on how good (or bad) their muffler happened to be, and on carburetor size, porting, etc. – any of which can impose limits that cannot be totally compensated by even the best of expansion chambers. In most cases, however, the improvement will be in the order of 10- to 25-percent, and when the expansion chamber is given a bit of help from changes in timing, and the rest, it then becomes possible to get improvements ranging from 50- to (in some instances) over 100-percent. This difference is widely appreciated, even by those who know absolutely nothing about the expansion chamber itself and have no direct experience with the device, and that accounts for the brisk sale of accessory chambers as replacements for stock exhaust systems. It also has

led many an enthusiast to construct an expansion chamber of his own design.

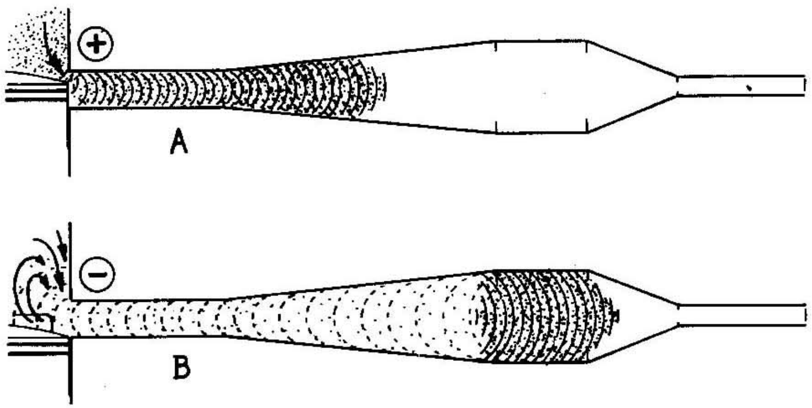
Sadly, the real result of most people's shade-tree experimental work is simply to discover that it remains possible to bring down on one's head all of the expansion chamber's considerable disadvantages without being compensated by an increase in performance. Or, as I heard one experimenter comment, looking bemused at the chamber he had cobbled together for his motorcycle, "It doesn't make much power . . . . but it sure is noisey". He was being funny, but I didn't laugh, because the only thing that distinguished him from his fellows was that he was honest about the results; most of the others do no better – but aren't willing to admit that they have made a big mistake.

Where does everyone go wrong? Usually, it is the result of simple, uncomplicated ignorance regarding the inner workings of the expansion chamber, which – all the folklore surrounding the device notwithstanding – are absurdly uncomplicated. Using a mixture of sonic wave behavior and controlled back-pressure, the expansion chamber helps pull exhaust gases out of the cylinder during the initial parts of the exhaust/transfer process and hauls the fresh charge into place – and then reverses itself to prevent the charge from escaping out the exhaust port. To illustrate the point, let's watch (in slow motion) the activity through a single operating cycle, from the time the exhaust port opens and through the transfer phase until the exhaust is once again closed. From beginning to end, the process takes only about 3- to 4-thousandths of a second.

THE BASIC PROCESS

When the exhaust port cracks open, gases still under a considerable pressure burst out into the exhaust tract, forming a wave front that moves away at high speed down the port and headed for less confined quarters. After travelling a comparatively short distance, this wave reaches the first part of the expansion chamber proper – which is a diffuser (commonly called a megaphone). The diffuser's walls diverge outward, and the wave reacts almost as though it had reached the end of the system and is, in the manner of waves explained in the first chapter of this text, reflected back up the pipe toward the cylinder with its sign inverted. In other words, what had been a positive pressure wave inverts, to become a negative pressure wave. The big difference between th action of the diffuser and the open end of a tube is that the former returns a much stronger and more prolonged wave; it is a much more efficient converter (or inverter) of wave energy.

As the initial wave moved down the diffuser, the process of inversion continues apace, and a negative pressure wave of substantial amplitude and duration is returned. Also, overlayed on this is the effect of inertia on the fast-moving exhaust gases, and the total effect is to create a vacuum back at



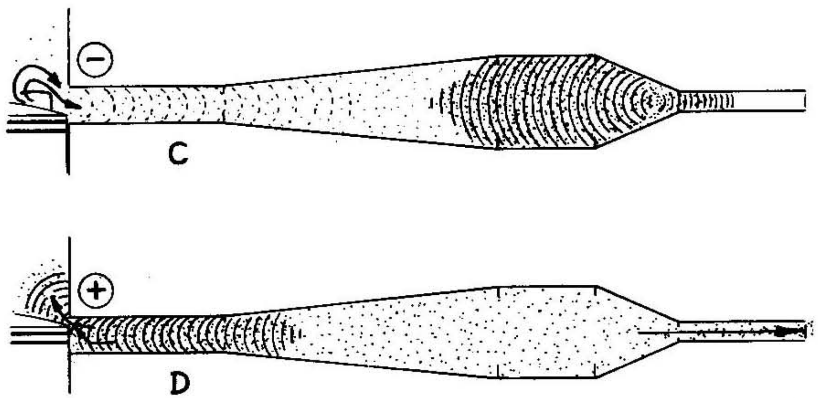
When the exhaust port opens, a strong positive pressure wave is formed and quickly moves into the diffuser (A) where part of its energy is reflected back as a negative pressure (B) to help clear the cylinder and draw the fresh charge up through the transfer ports.

the exhaust port. This vacuum is very much stronger than one might suppose, reaching a value of something like minus-7 psi at its peak. Add that to the plus-7 (approximately) psi pressure in the crankcase working to force the fresh charge up through the transfer ports and you will better understand how the transfer operation is accomplished in such a very short time. Obviously, too, this combined pressure differential of almost one atmosphere is very helpful in sweeping from the cylinder the exhaust residue from the previous power stroke. It's all a lot like having a supercharger bolted on over at the engine's intake side – but without the mechanical complication.

Years ago, the exhaust system ended right behind the diffuser. That was the arrangement on the old supercharged DKWs, and we saw stub megaphones used on the Greeves scramblers of the fairly recent past. Those devices did a job in clearing exhaust gases from the cylinder, and helped the fresh charge up from their crankcase, but their vacuuming effect was very much a mixed blessing: their problem was that they didn't know when to stop vacuuming, and would pull a sizable portion of the fresh charge right out of the cylinder. Horsepower being more or less a direct function of the air/fuel mass trapped in the cylinder at the onset of the compression stroke, this aspect of the pure megaphone's behavior was highly undesirable, and the two-stroke engine was not to come into its own in racing (where power is vitally important) until after a cure was found for the problem.

Here, our original wave reaches that "cure". Following the diffuser, and after perhaps a couple of inches of straight-walled chamber, the wave encounters a converging cone that effectively constitutes a closed end to the expansion chamber. A part of the wave energy will already have been inverted by the diffuser and sent back to the cylinder, but there is enough of its original strength left to rebound quite strongly from that closed end, and it reflects with its original, positive, sign. In due course of time, this wave arrives back at the exhaust port itself, stalling the outflow of the fresh charge. Indeed, it will momentarily reverse the flow there, stuffing what might otherwise have been lost back into the cylinder. The net result of all this activity on the part of the expansion chamber – first pulling and then pushing at the fresh charge to hold it in the cylinder – is a big boost in power. In fact, it is the only thing you can do to a two-stroke engine that will clearly be felt in the seat of your pants; you don't need a dynamometer to find the difference.

As was mentioned before, the expansion chamber is not purely a sonic-wave device: Back at the closed end of the chamber there is an outlet pipe, and it is too small to keep the pressures inside the chamber equalized with atmospheric pressure. Consequently, there is an abrupt pressure rise inside the chamber, toward the end of its operating cycle, that is felt at the engine's exhaust port and plays a very large part in preventing charge loss.



The vacuum created by the diffuser is strong enough to pull some of the fresh charge out into the pipe (C) but the original positive wave reflects back from the chamber's closed end to recharge the cylinder as the port closes (D). Then pressure in the chamber bleeds down *via* the outlet pipe before the next cycle begins.