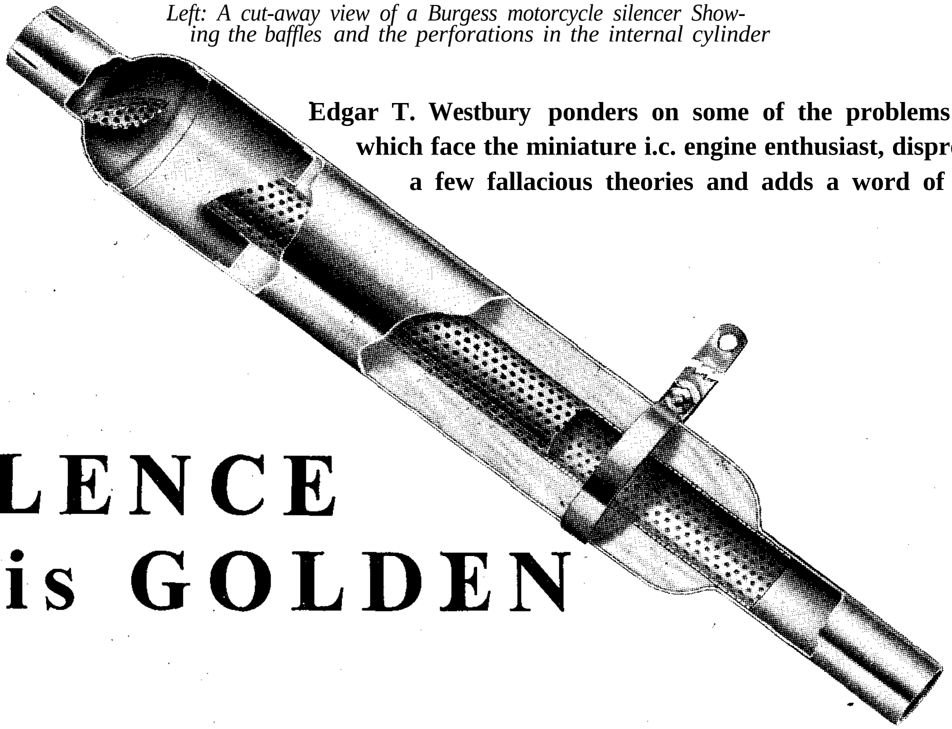


Left: A cut-away view of a Burgess motorcycle silencer Showing the baffles and the perforations in the internal cylinder

Edgar T. Westbury ponders on some of the problems which face the miniature i.c. engine enthusiast, disproves a few fallacious theories and adds a word of warning

SILENCE is GOLDEN

AMONG THE VARIED NOISES of modern life, that caused by the internal combustion engine, in any of its many forms, is one of the most persistent and aggressive. Reduction in the size of engines, so far from diminishing their propensity for noise-making, seems if anything to increase it, especially as it is the exception rather than the rule to provide even the most elementary means of muffling sound on the thousands of miniature engines now commercially produced.

Many model enthusiasts acquire a taste for noise and often resent any attempts to introduce rules for fitting silencers to their engines. Yet noise has been responsible, more than anything else, for the closing down of facilities for running these models in public parks and lakes-even in private grounds, if these were in proximity to residential areas. Moreover, many members of the community' have come to regard model engineers as irresponsible and anti-social pests for the same reason. Before we protest too loudly against this unjust assessment, however, let us not forget that noise is not only merely irritating, but also nerve-racking and distressing to many people who are not in robust health.

One reason why the fitting of silencers to high-nerformace miniature engines is often objected to is the belief that they restrict or reduce efficiency. While this can happen in many cases, it is by no means inevitable. Actual results with all kinds of engines have shown that the noisiest engines do not invariably put up the highest performance.

When the Model Power Boat Association instituted a rule for the fitting of silencers some years ago it was, as expected, a very unpopular move, but subsequent results, especially in the steady and consistent performance of boats, have fully justified it. At an important regatta held shortly after this rule was imposed, a prize was given for the most effectively silenced racing boat, and it is significant that the boat which won it was also first in its class for speed.

Principles of silencing

Admittedly, one swallow does not make a summer, and this performance may perhaps be regarded as a fluke, but it is by no means an isolated example and one of the present speed record holders is noted for its comparative quietness.

The term " silencer " is used only in a comparative sense of course; nobody has yet succeeded in car), celling out completely the noise of an engine; in this respect, the trans-atlantic term "muffler" is perhaps more technically accurate. Up to the present, exact knowledge on the theory of silencing is as incomplete and inconsistent as to the results obtained. Those who seek a " scientific" solution of the problem are likely to be disappointed.

The science of acoustics is extremely complicated and he who would attempt to reduce this particular aspect of it to figures and formulae would indeed be rushing in where practical engineers fear to tread. One can, however, examine the first principles of the problem involved, and show how a very substantial reduction in the noise emitted by miniature engines can be made by adopting simple measures.

The noise caused by an internal combustion engine does not all originate from one source; a part of it may emanate from the mechanical working parts such as gears, cams, tappets, bearing clearances, and the resonant effects of vibration on the structural parts; some noise is also caused by the rush of air into the carburettor intake. But by far the loudest noise occurs at the exhaust outlet, and it is with this that we are principally concerned.

Fortunately for us, it is not the actual explosion in the cylinder which causes this noise, as is sometimes wrongly believed; it would be far more difficult to deal with, if it were. Everyone knows what an awful bang occurs if the valve of an engine

SILENCE IS GOLDEN.. .

sticks so that the noise of the exvlosion is transmitted directly to the exhaust system. Sound, being the result of air waves,' cannot travel from an enclosed space, except by mechanical transmission through the walls enclosing the space, and an engine cylinder deadens sound pretty effectively, especially if it is liquid-cooled.

The cause of the noise

The noise is produced actually by the sudden release of the gases at the exhaust valve or port, at a pressure considerably above that of the atmosvhere. This sets up air waves of inheterminate form and frequency, but mostly well within the audible range. Different engines release the exhaust at widely varying pressures-from four or five to well over 100 p.s.i. at the instant of port opening, depending not only on combustion pressure, but also port timing; the intensity of the sound produced varies in more or less direct proportion. It is extremely difficult to measure the pressure at this stage, and this is one of the first difficulties encountered in a scientific approach to silencing problems.

Two-stroke engines present greater problems than four-stroke engines, not necessarily because the escape pressures are higher, but because they are much more abrupt and complete in a short period, due to the rapid opening of a port as compared to a normal type of valve. To borrow a musical term for a very unmusical sound, the exhaust is much more ***staccato*** in the two-stroke engine.

A comparison may be made here with steam engines, which are in most cases relatively silent, because efficiency demands that the exhaust should be released at as near absolute zero pressure as possible. But if, for any reason, it becomes necessary to release the exhaust very suddenly, at higher pressure, a steam engine can become just as noisy as an i.c. engine, and this occurs in racing flash steam engines. As a case in point, my " Spartan " uniflow engine sounds very much like a two-stroke when running on high-pressure steam.

A practicable limitation

The reduction of exhaust pressure by restricting port area or delaying the instant of opening is practicable on some types of engines, but only to a limited extent. Where high performance is required, it is generally considered fatal to adopt either of these measures. If the gases escape directly into the air, therefore, they must necessarily cause considerable noise; but it is possible to lower the pressure gradually in its passage to atmosphere, by means of a suitably designed exhaust system. The impact of the gases on the air, and consequently the sound produced, is thus very much less.

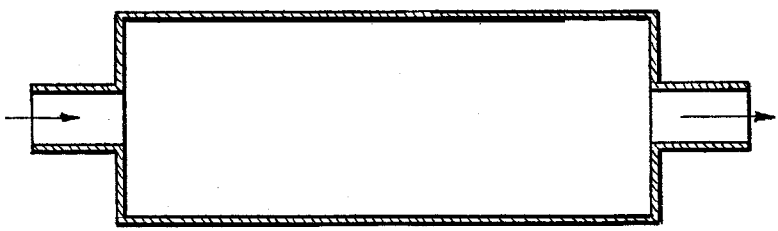
Lowering the pressure could be done by using nothing more than an exhaust vive with a restricted outlet. The result of this would be to set up back pressure almost as bad as that of a delayed or inadequate port. A much better method is to discharge the gases first into a chamber of large cavacitv in which thev have amvle robm to expand before passing out of the system. It may be said that an expansion chamber, in some form or other, is an essential for any kind of silencing system; indeed this provision alone is effective enough to satisfy requirements in many types of engines.

Some form of expansion chamber is essential in any form of silencer, and it has been found by experience that its volume should be not less than about five times the capacity of the engine cylinder.

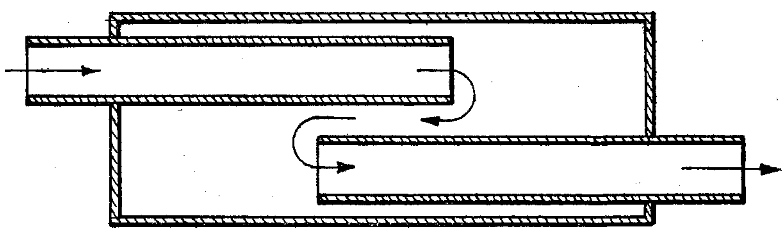
If, however, a simple expansion chamber is fitted in the exhaust line, with gas passages running directly into and out of it. a certain proportion of the gases will enevitably rush through with little interference in their velocity, and produce considerable impact with the air at the final outlet. It is, therefore, usual to adopt some means of preventing direct outflow, by causing the gases to change the direction of flow: this reduces their velocity. Sometimes the inlet and outlet pipes are arranged at right angles, or completely opposed to each other; a further variant is to extend each beyond the centre of the chamber so that the gases must " double back " to reach the outlet.

Perforated baffles

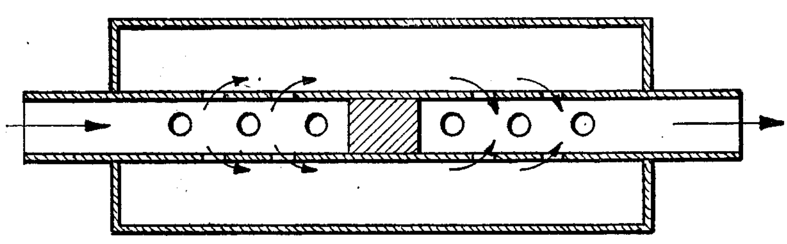
A still more effective method is to introduce baffles with a multiplicity of holes, which break up the flow of the gases and in some cases promote expansion in stages. One example which I have used with engines of fairly high performance has a con-



Above: Fig. 1: A plain expansion chamber



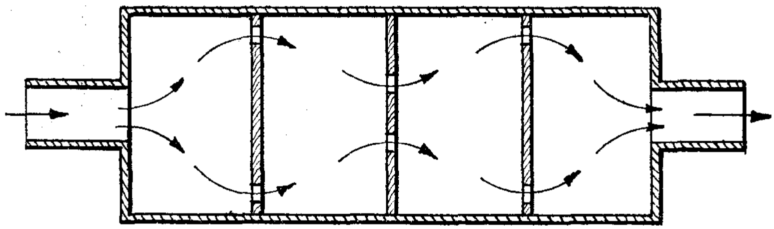
Above: Fig. 2: An expansion chamber with overlapping entry and exit pipes



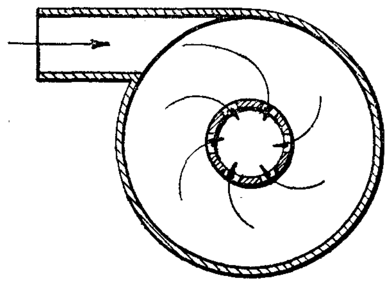
Above: Fig. 3 : A perforated exhaust pipe with a central plug

tinuous pipe through the centre of the chamber, but the middle portion is plugged, and the adjacent regions perforated, so that the gases must first pass at right angles, through the holes in the pipe, into the chamber, and back into the pipe by a similar devious route.

Absorbent material such as glass wool or the well-known "pot scrubbers" are often fitted to silencers, and undoubtedly increase their sound-absorbing efficiency by diffusing the gases and retarding their velocity. But there is no form of baffling device which can be entirely immune from the suspicion of setting up a certain amount of back pressure, and it would be very difficult to convince racing exponents that power output does not necessarily suffer when silencers of this type are used. They can, however be recommended without hesitation for engines which do not have to keep on their toes, so to speak, such as those used for propelling cruising boats. It may be said that in M.P.B.A. regattas, most i.c. engine-driven " straight runners " are so fitted, and give little offence in respect of noise.



Above: Fig. 4: A silencer with perforated cross baffles



Right: Fig. 5 : A tangential flow or " Vortex " silencer

Increasing noise by silencers

It is, however, quite possible that the fitting of a silencer, so far from reducing noise, may actually increase it or make it more prominently audible. This is due to the effect of resonance in the pipe system or expansion chamber, which is nearly always present to a certain extent, particularly in tubular and cylindrical passages, which have properties comparable to organ pipes in amplifying and modifying sound. Everyone knows the sonorous note produced by a racing engine with a long, straight-through exhaust pipe-a sheer delight, I may say, to the enthusiast, but a pain in the neck to everyone else.

The effects of resonance are complex, and include not only the vibrations set up in the gas column but also those due to the natural frequency of the metal, superimposed on the cyclic frequency of the exhaust beats when this is high enough to come within audible range, as it often is with miniature engines. Thus a sound track taken from the exhaust of one of these engines would show a complex pattern, as interesting as that from the voice of a *prima donna.*

First, the impact of individual exhaust beats would produce a " flat " bang of no predictable pitch. The effect of beats following each other at very high frequency produces a definite musical note (in the same way as the rotating disc of a siren) which is superimposed on this,. and yet again, resonance of the exhaust system, comes in on top of this, at a frequency which may either augment or heterodyne the primary vibrations.

Some designers of silencing devices have sought to use resonance to good effect by producing wave interference, but generally, it is a far safer policy to take steps to prevent or reduce it. One good method is to eliminate, as far as possible, anything which is inclined to " drum" or resonate freely in the system, or to deaden it by sound-absorbing packing. The primary exhaust pipe,, leading the gases into the expanston chamber, should be as short as possible, to avoid high-pressure impact on the inside walls; this is particularly important in two-strokes? but not always so easy to apply in four-strokes, which may demand a certain minimum length of primary exhaust pipe to promote kinetic flow, which produces a " ramming " effect to assist the flow of the incoming charge.

The Burgess silencer

Most readers, especially those who have motorcycling experience, are familiar with this type of silencer, the action of which may seem to be somewhat paradoxical in view of the fact that it employs a, " straight-through " exhaust pipe with no baffles of any kind in the way of the direct flow of the gases. Yet its effectiveness is beyond question. It is accepted by the police, who have had to abandon the ancient custom of poking a stick up the exhaust pipe to ensure that the silencer is " within the meaning of the act " !

The principle employed in this silencer is the absorption of sound waves transmitted by multiple reflection from the inside walls of the pipe. It embodies an expansion chamber which surrounds a portion of the straight pipe system, perforated to allow escape of the gases into and out of the chamber, which is packed with absorbent material to diffuse the pressure and deaden the sound. So far as I am aware, the makers of this type of silencer, although producing them in all sizes from marine diesels and jet engines downwards, have not got down to the minature engines yet, but many model engineers have made and used silencers based on the same principle to good effect.

No fear of choking

One particular advantage of the straight-through pipe is that it is not liable to partial choking, through fouling of the absorbent packing; the gases will always get through without let or hindrance, though the effectiveness of the silencer will suffer if it is so neglected. Small engines, and particularly two-strokes, are very liable to fouling by soot and partially-burnt oil; also, as they are generally run only for short periods, by water which condenses out of the gases before the system is properly warmed up. Silencers, should always be constructed so that they can be cleaned, either with or without dismantling.

The shape of silencers, either internal or external, is not usually considered of any great importance, and is generally a matter of convenience in construction or neatness in appearance. It would be futile to attempt " streamlining," to reduce flow resistance, in a silencer containing any form of baffles which deliberately produce the opposite effect. Nevertheless it is possible to study flow efficiency in silencer design, quite apart from the use of straight-through pipes.

A type of silencer which I have

employed with great success in several types of engines is that in which the gases are led by a tangential entry pipe into a cylindrical chamber in such a way as to produce a rotary swirling flow which has the minimum baffling effect, since there is no direct impact of gases on retarding surfaces. Moreover, this motion tends to produce a zone of low pressure-a vortex, in the centre of the cylinder. By fitting the exit pipe in this zone, the minimum impact pressure at the outlet is obtained. Silencers of this type have been fully described and illustrated in connection with the " Busy Bee," "Bumble Bee" and " Dolphin " engines.

Silencing problems are usually less acute in the case of multi-cylinder engines than those with single cylinders, firstly because the volume of exhaust gas from each individual cylinder is less for a given total capacity,, and second because the overlapping or rapid succession of individual exhaust strokes tends to produce almost a steady continuous outflow rather than intermittent bursts.

Up to the present, very few high-performance " multi's " have been attempted in the sizes with which we are concerned; the " Seal" engine, which is designed for flexibility rather than high power output, is almost inaudible with even the most elementary silencer fitted.

Twin-cylinder engines are sometimes made in quite small sizes, both four-stroke and two-stroke types, and one or two that I have encountered have been quite noisy, but they should be amenable to the silencing measures described in this article.

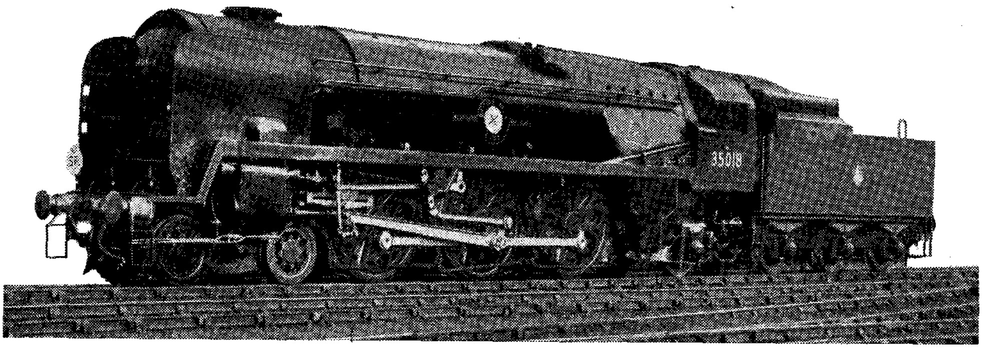
Exhaust pipes

It has already been mentioned that exhaust pipes have an influence on the noise emitted, and on engine efficiency; both their length and diameter affect gas velocity and pressure, and no definite rules can be laid down for these dimensions, even for a particular engine, much less for general application. In high-speed engines, there is reason to believe that impact of the exhaust gases on the air, and consequent back pressure, is greater with a port leading directly to atmosphere, than with a normal exhaust pipe and non-restrictive expansion chamber.

The shape of the exit pipe has a definite effect on exhaust noise, and this is evident in the case of megaphone tail pipes, fishtails, and so on. It is possible to reduce the area of the final outlet to a much greater extent than is commonly believed, without affecting power output, even on racing engines.

The commonly held belief that the outlet area should be not less than the area of the exhaust port is a fallacy. This is because the opening period of the cylinder port or valve is only about 1/4 to 1/2 of the engine cycle. During this period, the progressive opening and closing reduces the mean ***effective*** area to not more than half that of the full port. Moreover, the temperature of the gases, and therefore their pressure/volume, is falling rapidly in their passage through the exhaust system.

Some of the commercially-made miniature engines are designed with open exhaust ports which make it very difficult to fit silencers, but in no case is the problem insuperable, and many ingenious methods of attachment have been contrived. Where there's a will there's a way, and I trust that the hints I have given in this article will assist readers to take measures to reduce the noise of their engines immediately, rather than waiting until a " permanent silencer " is clamped on their activities by parks committees or other authorities. ❑



Southern Region's " Spam-can " *beautified*

THE PICTURE ABOVE shows British Railways Southern Region Pacific engine No. 35018. ***British India Line,*** after recent modification.

The engine now has three sets of normal Walschaerts valve-gear, two outside and one inside; no oil-bath; an orthodox type of smokebox, and the former air-smoothed casing has been discarded. The alterations have been made with the object of improving the availability, maintenance and accessibility, and the other 29 engines of the " Merchant Navy " class are to be similarly altered.

The changes have involved the provision of a new inside cylinder, 18 in. by 24 in., and the fitting of an eccentric, mounted on the right-hand web of the inside crank, for driving the inside valve. The new cylinder has its steamchest offset to the right, whereas the former outside cylinders, with steamchests directly above the centre-lines of their bores? are retained. The boiler is unaltered, except that it is now clothed with standard lagging mounted on " crinolines."

The multi-jet blastpipe is as before, but a new pattern of chimney has been provided, and altogether, a considerable change has been made to the general appearance of the engine; in fact L.B.S.C. might find it does not deserve the title " spam-can " any more.