THE UNIVERSITY OF MICHIGAN
COLLEGE OF ENGINEERING
Department of Mechanical Engineering

Progress Report

QUIETING SINGLE-CYLINDER ENGINES

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ABSTRACT

Reduction of sound levels in lawnmowers using a four-cycle engine can be accomplished with a good muffler and isolation of the engine by enclosing it in a container. With a properly designed fan blade and housing, the noise level can be so reduced that a nearly normal conversation may be carried on with the lawnmower operator. Mowers incorporating these ideas have immediate commercial possibilities as a premium product at a reasonable increase in cost, although about 10% less power can be expected in a silenced engine over an engine operating without a muffler. Currently standard mufflers result in a 6% loss.

Reduction of noise in the two-cycle engines can be accomplished in the same manner as the four-cycle engines, but with the two-cycle engine the problem of back pressure created by a muffler is more serious. A considerably larger muffler is needed with the two-cycle engine for comparative results with the four-cycle engine. A rough comparison of equally sized mufflers shows that there is a 25% hp loss with a two-cycle and a 10% loss with a four-cycle engine.

With the two-cycle engine, the mower base itself should make up the muffler body, using as large a space as possible without interfering with the contour of the blade scroll.

I. INTRODUCTION

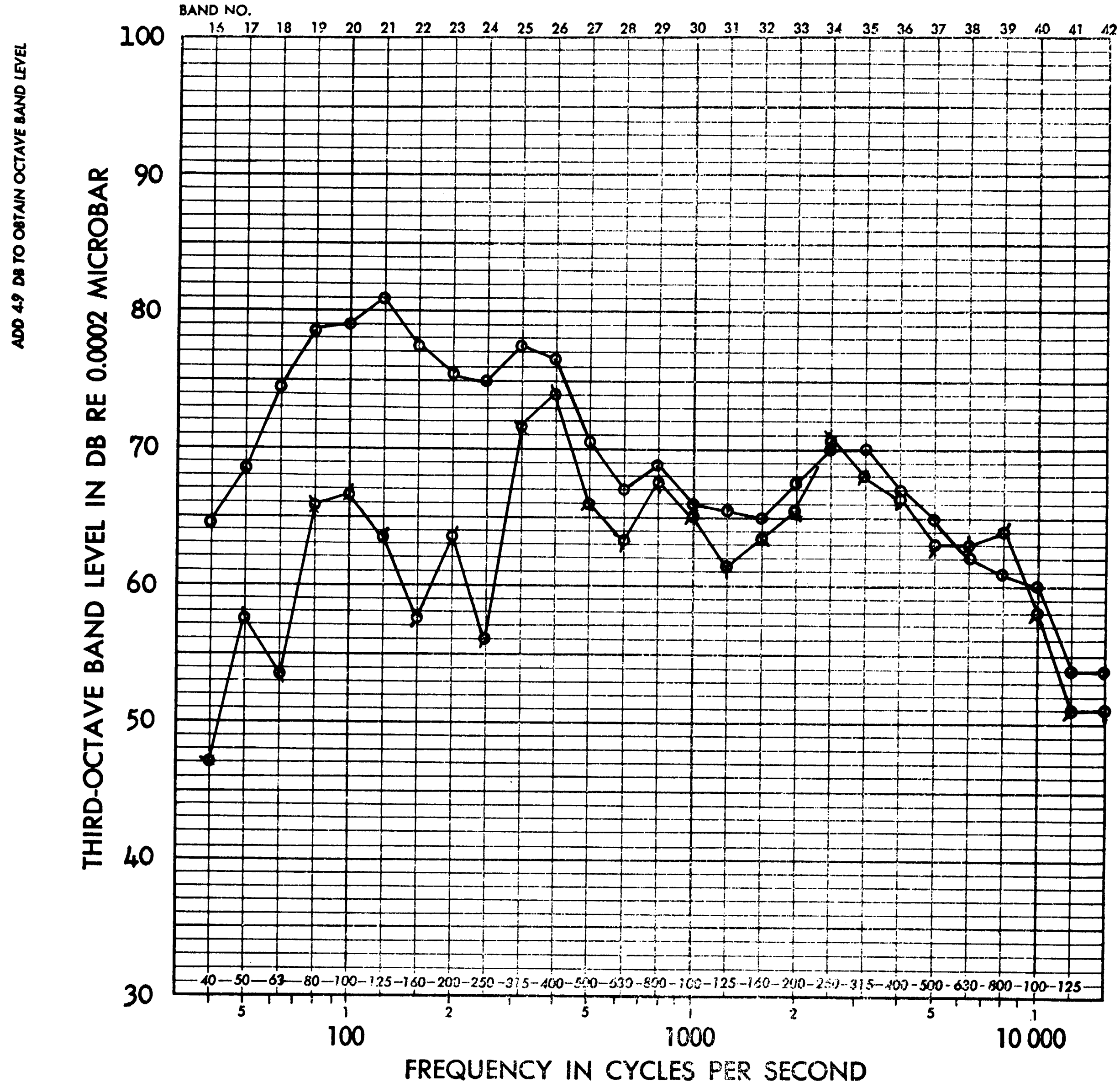
Sound investigations made of the Lauson 2-1/2-hp engine running at full throttle on an eddy current dynamometer indicated that much of the low-frequency noise generated by the engine could be reduced with an effective muffler. Figure 1 shows this reduction when the exhaust noise is piped away in a flexible metal tube. The frequencies above 400 cps remained unchanged, indicating that these are radiated at sources other than, or in addition to, the exhaust.

Intake noise also contributes to the low-frequency level but compared to the high-energy levels of the exhaust system, the intake-noise problem is unimportant until the exhaust-noise level is brought down to a comparative level and then both systems must be considered. Figure 2 indicates that muffler silencing is again the most important factor in the low-frequency spectrum; the silencing of the intake air is not noticeable until effective exhaust silencing is used.

Test runs were made involving tappets, camshaft, fan, and shrouding; no noticeable results were recorded. To observers, however, removal of the tappets on a driven engine was quite apparent. This difference is probably due to the nature of the noise which radiates high-energy levels for only very short periods of time. The ear can detect these pulses but the instruments tend to average them over a longer period, making them insensitive to pulsating types of noises. It was concluded from these tests that a good muffler must be designed to reduce low-frequency noise. These tests also confirmed the original sound analysis (Report 2481-115-P) that the reduction of exhaust-pulse noise left the irritating portion of the noise from the engine and mower blade unchecked. These noises must be dealt with separately.

Engine noise other than exhaust noise can be overcome by eliminating or reducing the noise sources or by isolating these sources from the listener. In the reduction-of-noise approach to the problem, each item contributing to the total noise must be reduced to a satisfactory level. Reducing any one item will do little in reducing the overall level unless some distinct tone or noise is being generated by that item. Some possibilities along this line may be in the use of nylon lifters and timing gears. Other such noise sources as valves closing on their seats, cylinder and crankcase deflections, piston slap, etc., have no simple solutions. Thus because of the many difficulties inherent in the reduction of noise energy, the method of noise isolation appeared to be the better of the two.

Noise isolation, to be effective, must include isolation of noise through the air and through solid materials. An airtight container around the engine

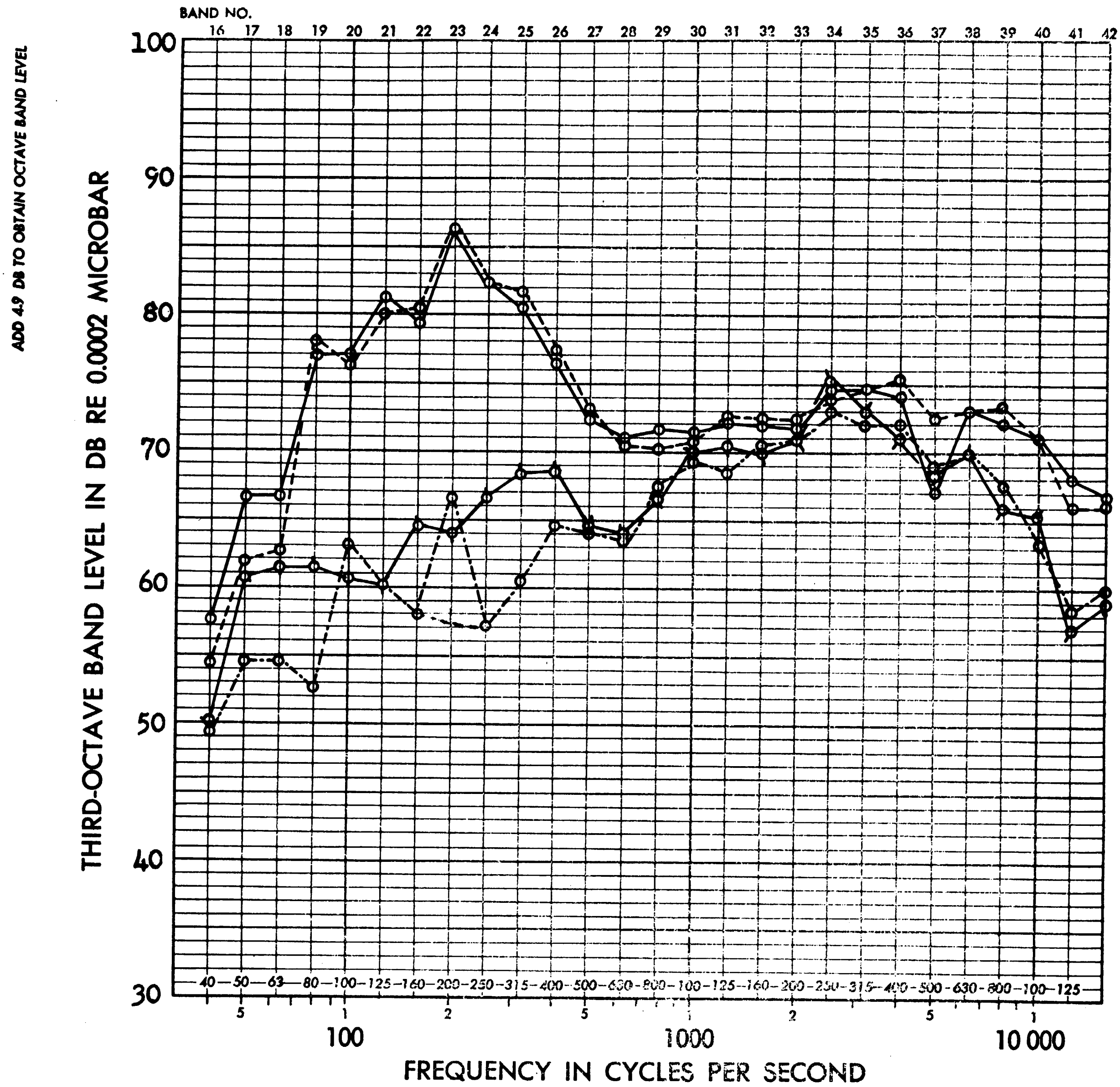


———o——— Muffler on, facing mike at 10 ft.

———ó——— Exhaust piped out a flex tube.

2-1/2-hp Lauson driving an eddy current dynamometer. Full throttle, 3300 rpm, outdoor field conditions.

Fig. 1. Effects of exhaust noise on the sound spectrum.



———o——— Normal operation, air cleaner and muffler on.
———ó——— Air cleaner on, exhaust piped out a flex tube.
-----o----- Intake piped out a flex tube, muffler on.
—·—·—o—·—·— Intake and exhaust piped out.

2-1/2-hp Lauson engine driving an electric motor. Full throttle, 3460 rpm, indoor run.

Fig. 2. Effects of exhaust and intake noise on the sound spectrum.

with mechanical separation of the container from the engine is the ideal answer to this problem. However, the engine must be mounted, and it must receive and eliminate air for cooling and combustion. This makes an airtight container impossible. The next best thing is a chamber which has airtight openings as far as the sound is concerned. This is possible with sound filters attached to the openings.

Mechanical isolation is possible with the proper rubber mountings. A doughnut mounting is ideal for this purpose. A simple schematic of the solution is shown in Fig. 3.

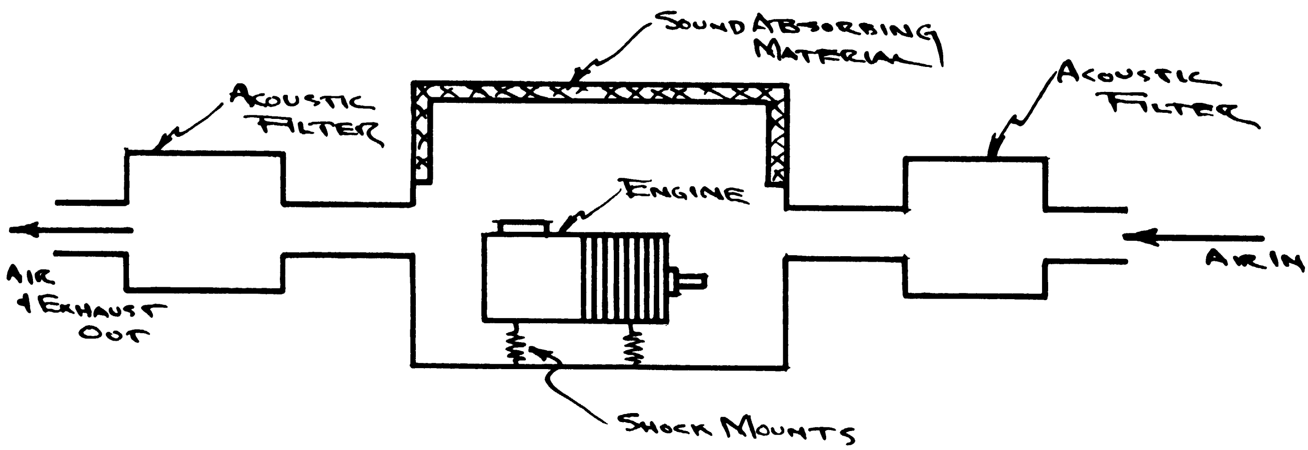


Fig. 3. Principle of noise isolation with an enclosed engine.

The problem now is to incorporate these features into a mower with an acceptable appearance at a reasonable cost.

II. PROPOSED DESIGN (FOUR-CYCLE ENGINE)

A. EXPERIMENTAL MODEL AND RESULTS

The first and only experimental model built proved the feasibility of engine isolation possibilities, and with a few modifications can solve all the problems. The design is illustrated with some simple sketches of the construction of the model (Fig. 4) and photographs (Fig. 5).

Results of tests of this design were very satisfactory in all important respects. Demonstrations of actual grass cutting were the most effective; the mower sounded much like an electric model. The mower blade was the major noise source. The noise resembled that of an aircraft propeller and was not objectionable during normal grass-cutting operations. However, the noise did become objectionable at speeds of 3400-4000 rpm.

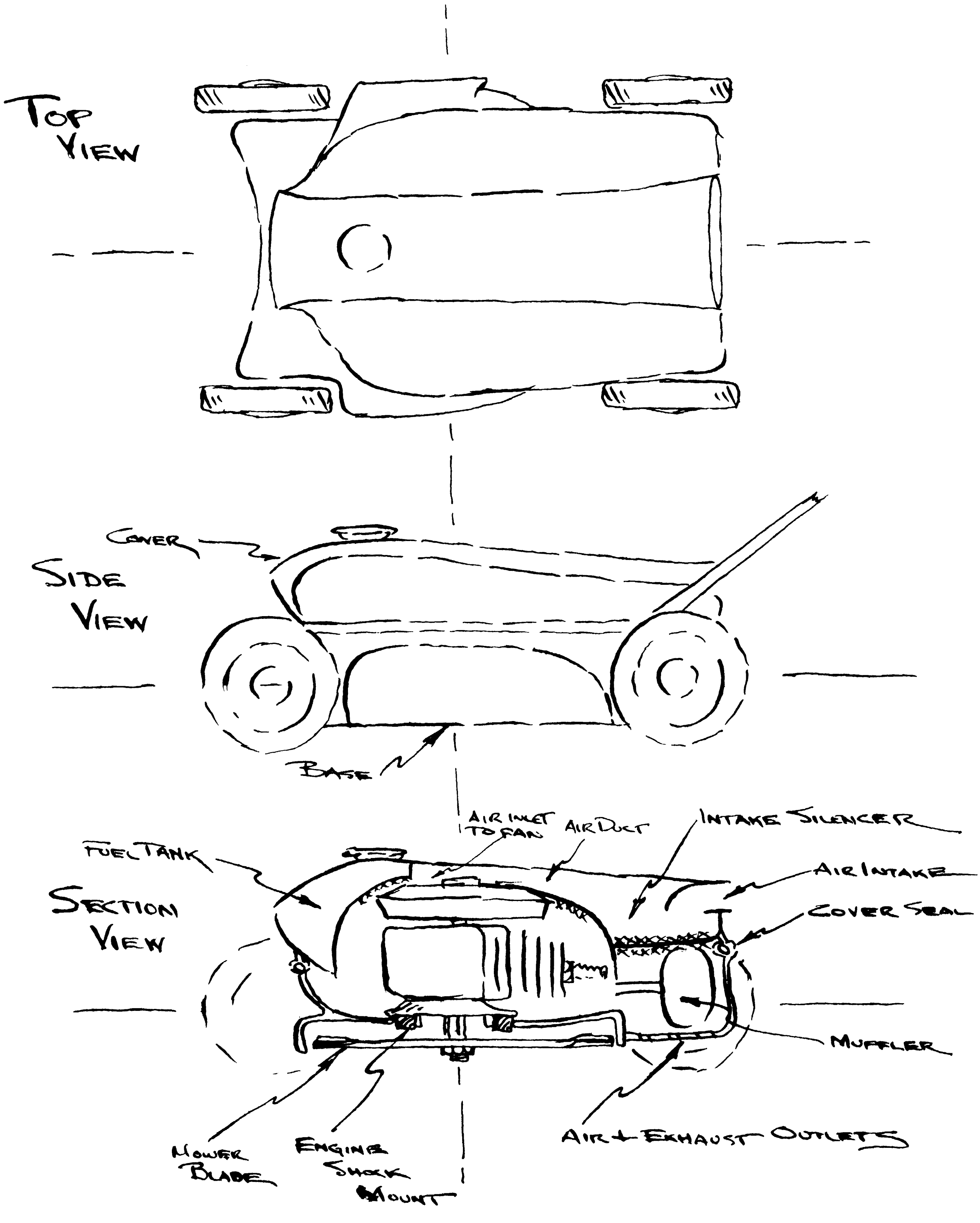


Fig 4. Sketch of experimental enclosed engine lawnmower.

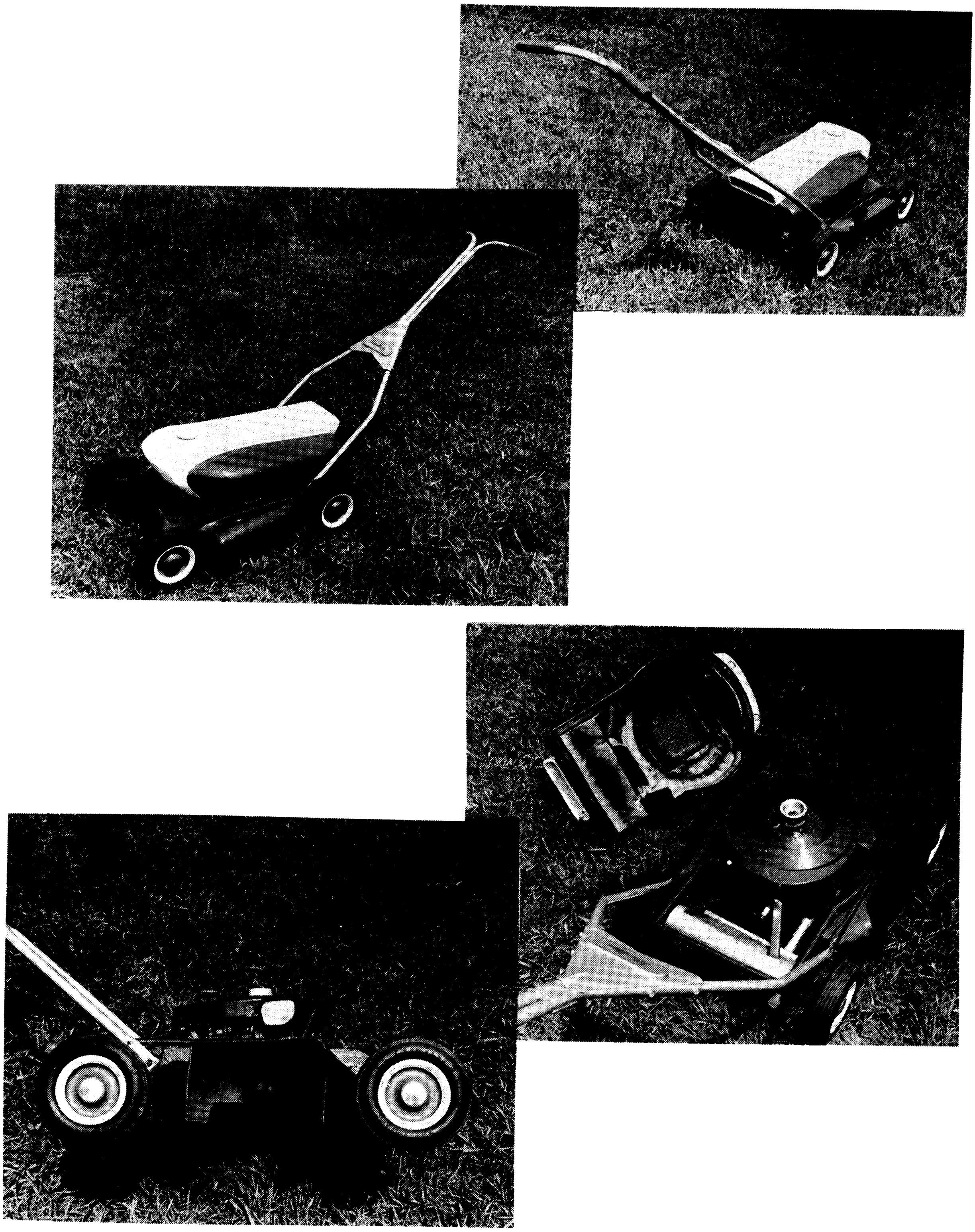


Fig. 5. Experimental enclosed lawnmower.

Four items on this particular mower need to be improved:

(1) Air flow should be greater around the crankcase;
(2) The inlet air should be rerouted to reduce heat pickup;
(3) Isolation between the muffler and the engine should be greater; and
(4) The inlet-air area should be increased.

These are discussed below.

(1) The oil temperature on dynamometer test at full throttle ran as high as 370°F. Head temperatures leveled off at 390°. The oil temperature can be reduced in several ways, one of which is increasing the air flow around the crankcase. This can be done simply by enlarging the exit part of the fan so that more air will flow around the crankcase. It is also possible to locate the cooling-air exit so that it is aided by the fan action of the mower blade. Increased radiation can be obtained on the lower crankcase section by the addition of cooling fins. This last method may be feasible if production warrants it, and if the method of shock-mounting the engine is incorporated in the casting at the same time.

(2) Rerouting the inlet air is an absolute necessity. With 60°F ambient air temperature, the air picked up an additional 40°F before entering the carburetor. Power runs of the entire mower assembly showed a power decrease in the same ratio as the temperature rise or $520/(460+T) = 520/560 = .93$. From these results it also seemed apparent that the larger fan was not using any more horsepower than the standard fan.

(3) Isolation of the muffler from the engine will no doubt reduce the other heat problems. The muffler chamber can provide more effective isolation and for best results should be completely out of the mower housing.

(4) Increasing the inlet-air area is necessary if the inlet air is to be filtered. Since the engine air must be filtered, it seems logical that an oversize filter could be used which would also keep the entire engine compartment free of dirt and grass. This could be an easily accessible filter mounted in the cover and visible to the operator for checking and maintenance. Such a filter could be paper and would snap into position in the cover. Dirt and grass could be removed simply by removing the filter and tapping it on some object.

Power and torque curves of the test engine are shown in Fig. 6. These are a comparison of the engine with a standard fan, etc.; without muffler, with a Sears muffler, and with the experimental muffler. Curves for the enclosed lawnmower are identical to the experimental muffler curves but lowered to 93% of the experimental muffler values because of the increased air temperature.

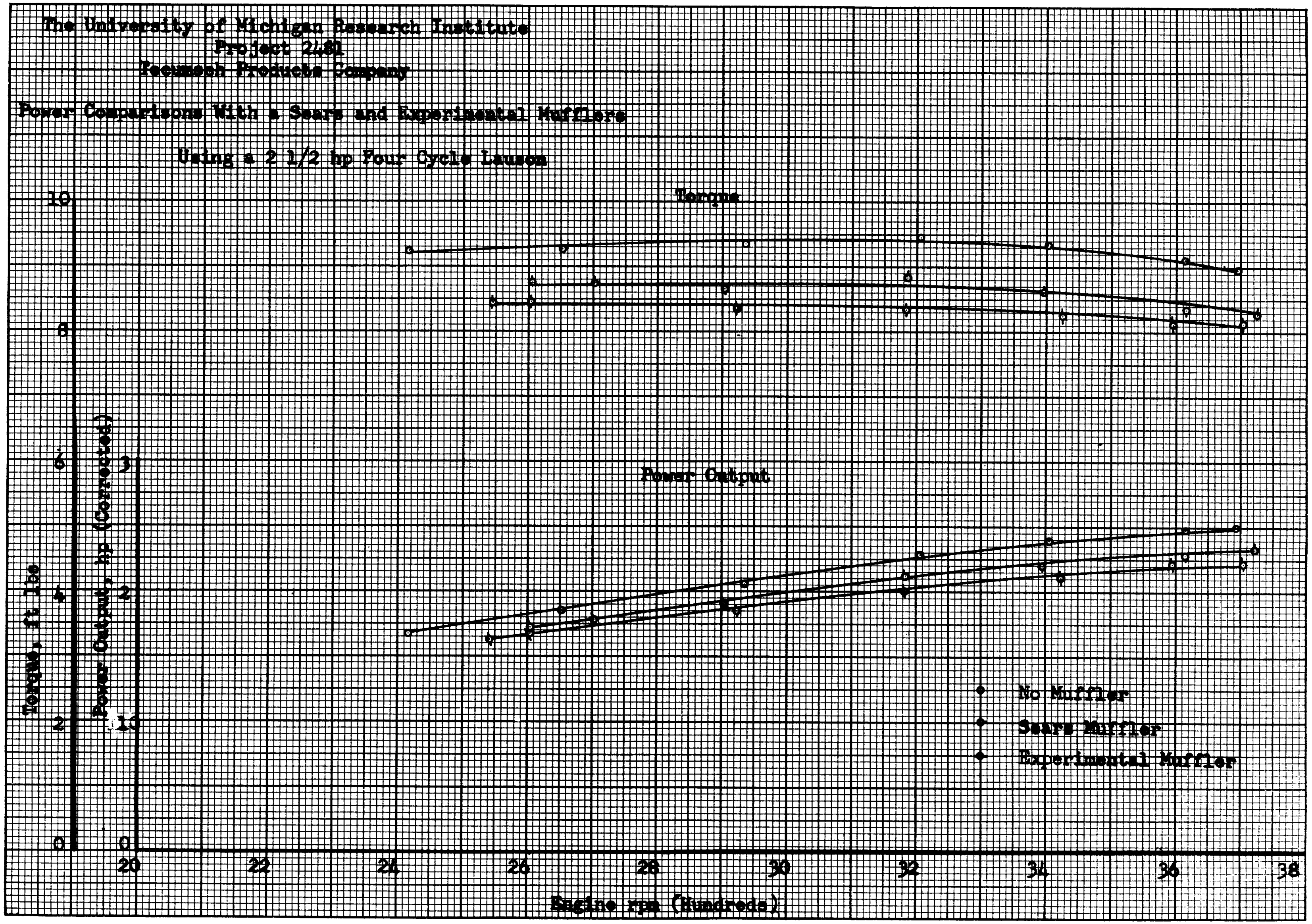

The University of Michigan Research Institute
Project 2481
Tecumseh Products Company
Power Comparisons With a Sears and Experimental Mufflers
Using a 2 1/2 hp Four Cycle Lauson
Torque
Power Output
Torque, ft lbs
Power Output, hp (Corrected)
0
2
4
6
8
10
1
3
20
22
24
26
28
30
32
34
36
38
Engine rpm (Hundreds)
No Muffler
Sears Muffler
Experimental Muffler

Fig. 6

The results of the sound tests are shown in Fig. 7. This is a comparison of the experimental lawnmower with a Sears 20-in. Craftsman in an open field test. The surprising results of this test are the complete reduction in noise at the high-frequency end of the band. Apparently the blade noise has been reduced as well as the engine noise. An attempt was made during construction of the underbody of the mower to provide a smooth unbroken scroll for the blade to reduce turbulence of the air, and this seems to have been effective.

B. PROPOSED PRODUCTION MODEL

A successful production design should have all the features of the experimental model plus modifications which will eliminate the four problems mentioned previously.

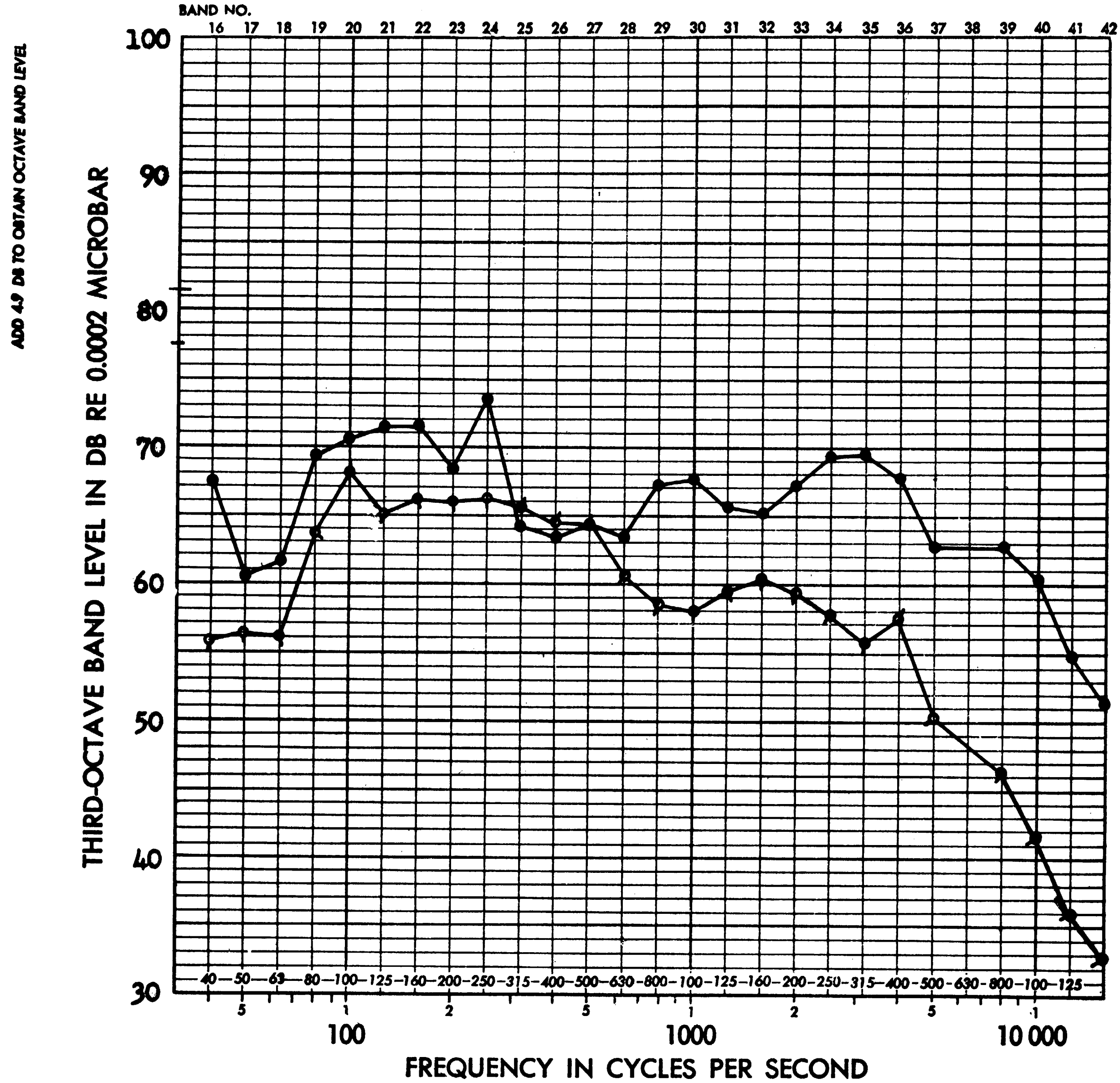
For reasonable costs the lower section of the mower or base can be a one-piece-die casting. This requires no more effort on the part of the mower manufacturer than previously. A small amount of additional aluminum will be necessary for the buildup of the mower base to match the cover for sealing purposes. The die can be a simple single-draw die as before.

The top cover of the mower is merely a modification of the present gas tank-shroud combination now being produced.

Additional material, indicating greater costs than present manufacturing costs, are as follows:

1. Small amount of additional aluminum in base die casting;
2. Larger gas tank to act as cover;
3. Gasoline-resistant rubber seal between base and cover;
4. Fiberglas sound material such as is used in automobile manufacture or spray-type deadener materials;
5. A locking device to hold cover down;
6. More steel in muffler (manufacturing operations are similar to present construction); and
7. Torsion-ring mounting device.

The torsion-ring mounting device, to be effectively used as an engine mount, should have certain design features. The rubber should have a low spring constant, which would require a rubber of low durometer. The engine, when mounted, should move quite easily in torsion about the crankshaft. Lateral movements will be stiffer as this puts the rubber in compression and is a desirable characteristic of this type of mounting. A proper rubber and mounting will be obtained when the engine can be twisted and released and will oscillate at a low frequency, that is, below its lowest idle frequency. This provides good isolation between engine and mounting at all running speeds.



——o—— 2-1/2-hp Standard Sears Craftsman 20 in. mower (cutting blade installed).

——ø—— 2-1/2-hp experimental enclosed mower (cutting blade installed).

Outside field conditions. Average of four readings.
Speed: 2600 rpm, part throttle.

Fig. 7. Comparison of sound levels of a standard vs. the experimental lawnmower.

To prevent damage in the event the engine is suddenly stopped by the mower blade, mechanical stops should be provided on the mounting ring which will prevent too great an engine displacement.

A proposed model, shown in Fig. 8, incorporates two basic changes from the experimental. First, the muffler is outside the engine compartment and is isolated from it by the wall of the mower base. In such an open position it can radiate the heat away from the mower and also be aided by natural air convection. It is also removed from the intake air to prevent pre-heating. Secondly, the air-intake area has been increased. The increase need be only to increase the filter surface. Inside the filter the duct could be reduced to as little as 14 sq. in. of cross-sectional area. Figure 9 shows a possible base die casting suitable for an enclosed engine.

As many designs of an enclosed engine mower can be had as there are manufacturers. Fulfilling the requirements of a basic chamber and openings for the engine, the mower manufacturer can have individual designs to suit his requirements.

The blade housing should be considered in the design. The housing should be smooth and free of cavities and sharp edges. Any cavity or edge creates turbulence and produces noise. For best results the base casting should be designed for a smooth scroll, and irregularities which this may cause in the appearance from the top view should be remedied by the cover design.

A suitable muffler is shown in Fig. 10. This type appears to be satisfactory for any four-cycle engine and is simple in construction. A larger engine would require a larger volume proportional to the increased displacement.

Muffling, using a gas-flow method of analysis, is dependent on the muffler chamber volumes and restriction of the gas in the flow from the engine to the exit of the muffler. Small openings (high restriction) and large volumes reduce the noise level. Small openings increase the power loss while large volumes reduce it. Therefore, for an engine to have a good muffler without undue power loss, muffler volume must be larger than that of those presently installed on engines.

An acoustic method of analysis is also possible (a good deal of additional experimentation and design is involved), which yields similar results.

The muffler structure should be made as stiff as possible to prevent flexing of the muffler and creating noise at the surfaces. Sheet steel of 16 or 20 gage is satisfactory. Construction may be of thinner material if two layers are used with, perhaps, asbestos material between. The layer method provides friction at the surfaces and prevents resonant conditions of the muffler walls.

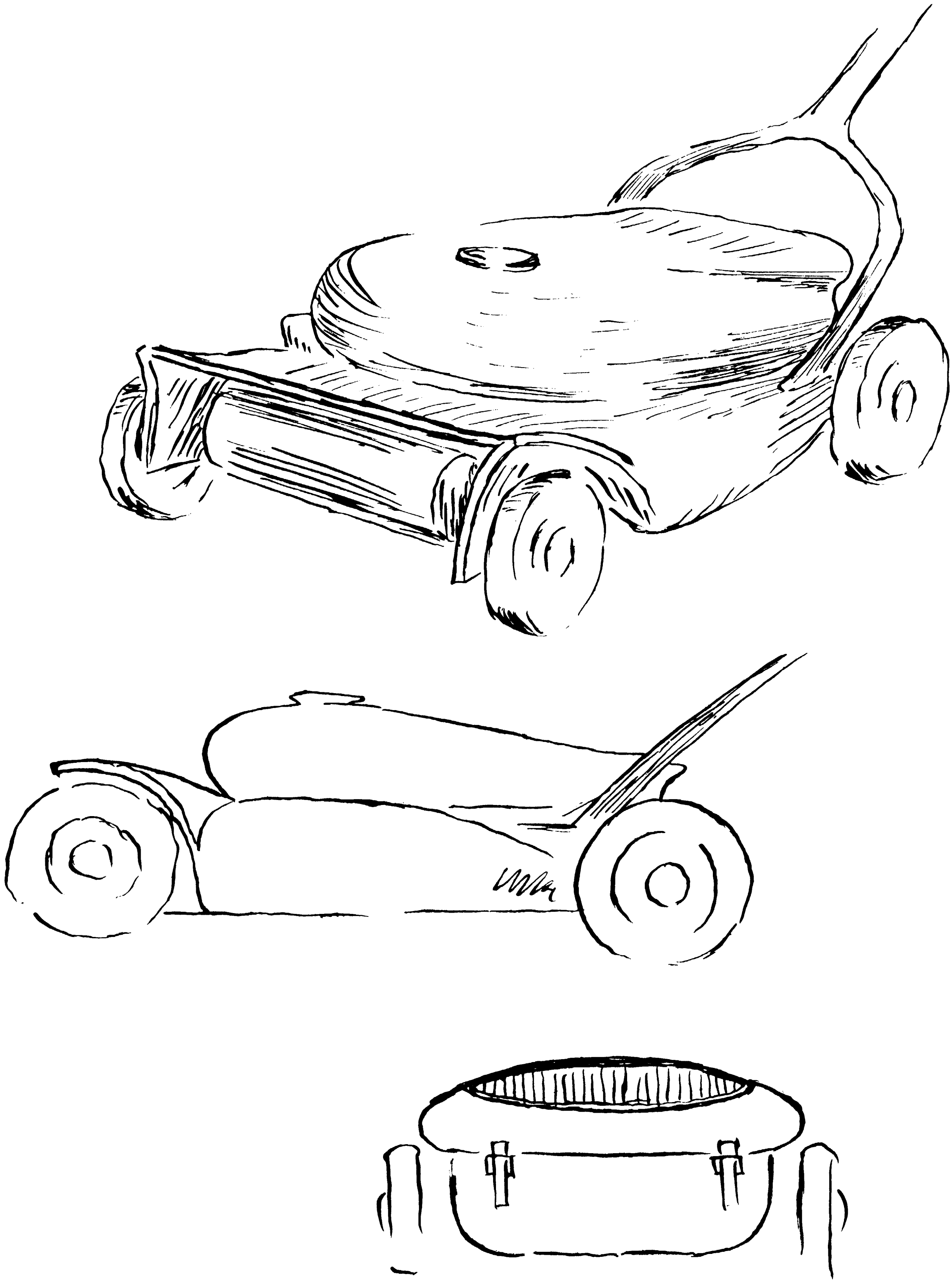


Fig. 8. Position of muffler and air intake in an enclosed design.

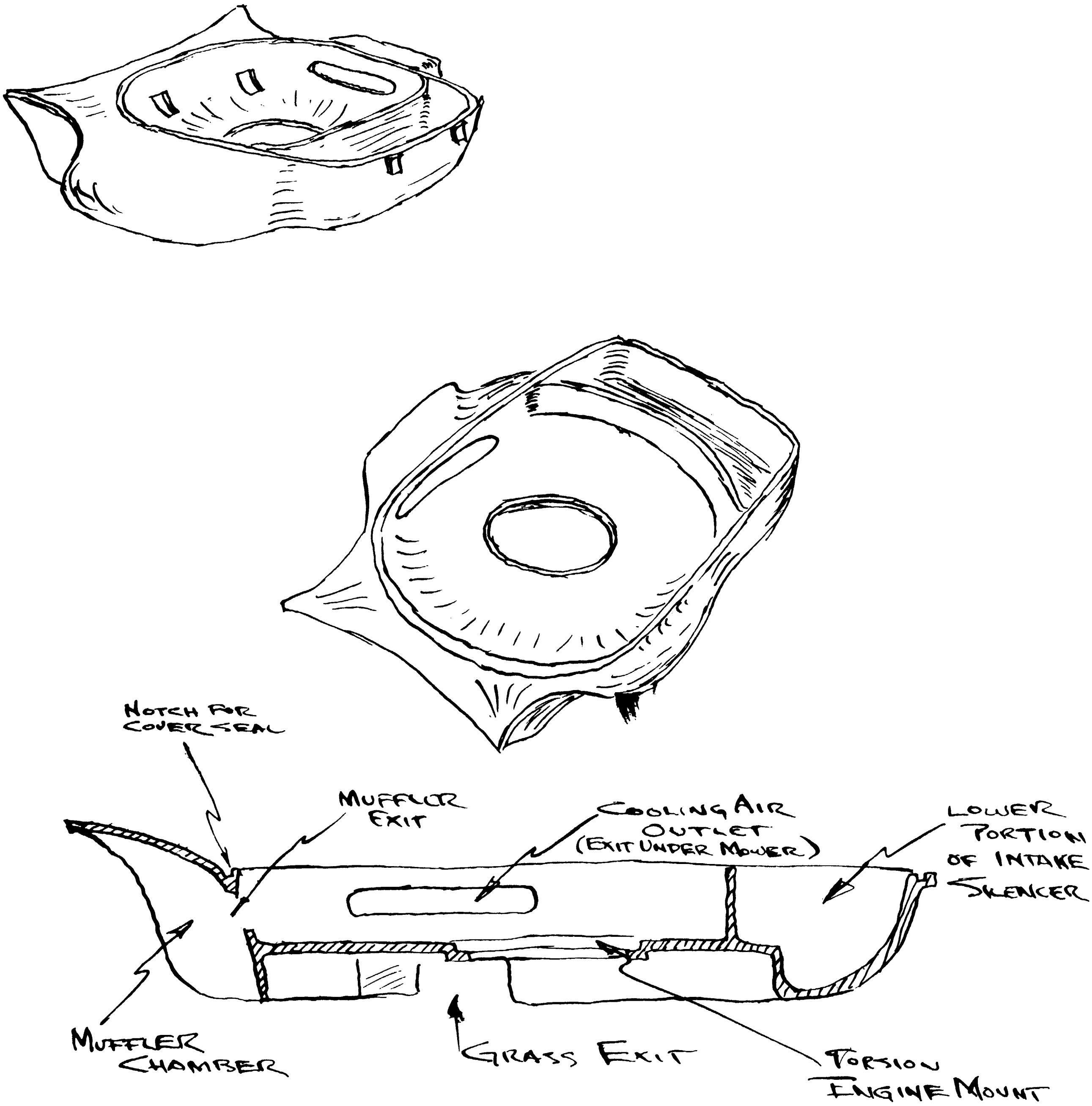


Fig. 9. Possible die-cast base for an enclosed engine.

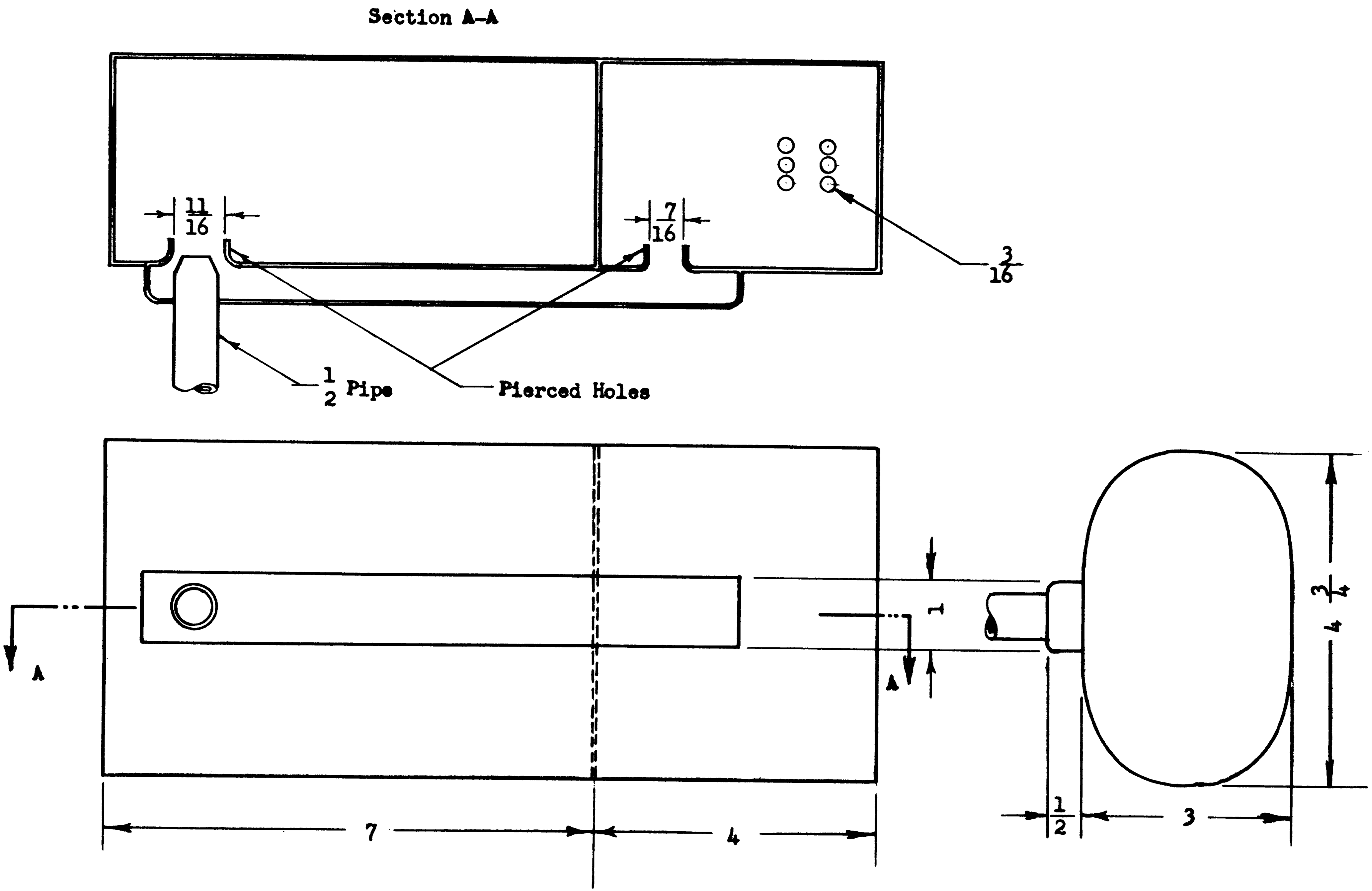


Fig. 10. Two-stage muffler.

III. PROPOSED DESIGN (TWO-CYCLE ENGINE)

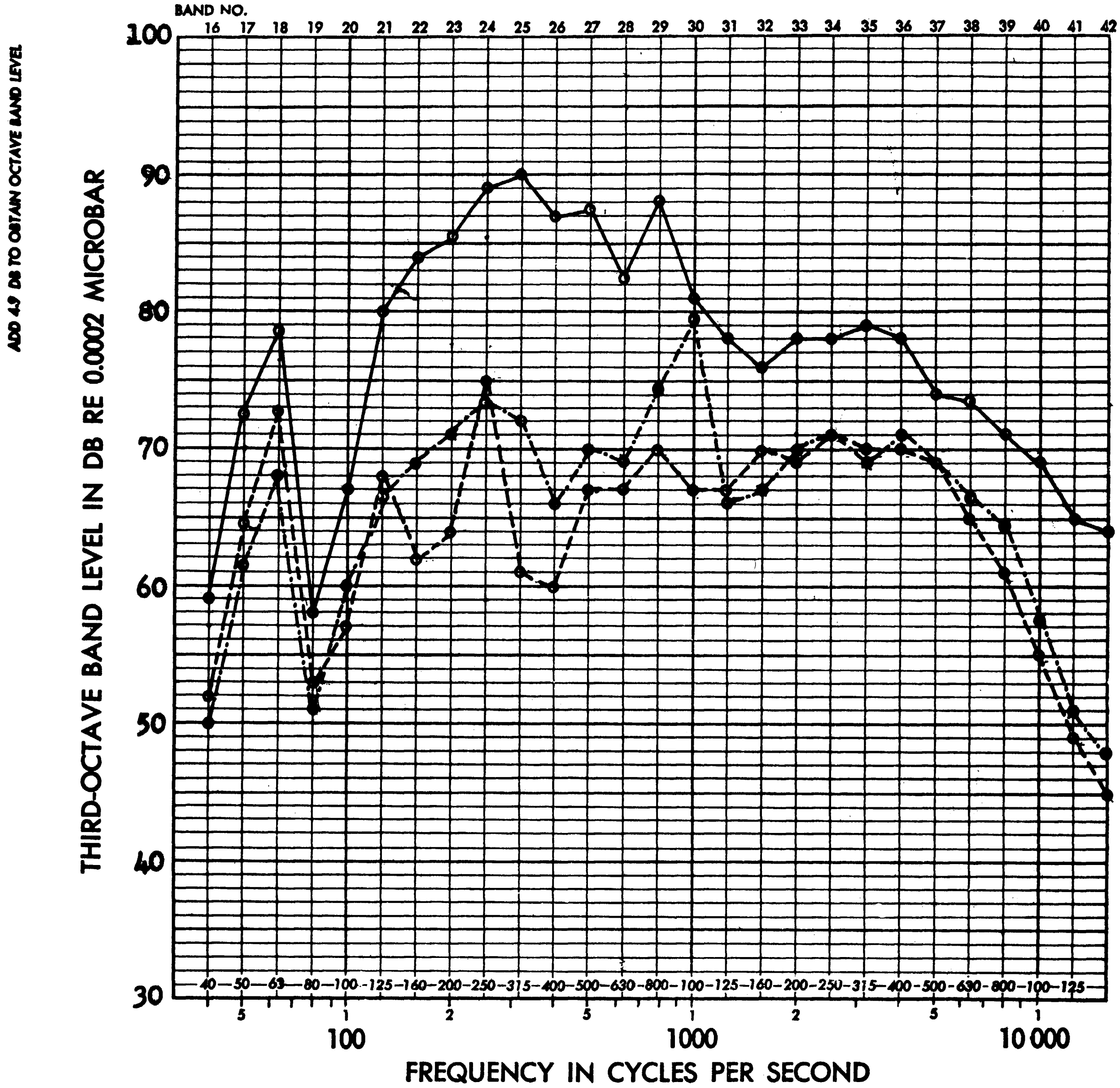
The two-cycle engines have all the basic problems of the four-cycle engines. No tappet or valve noises are encountered and the basic firing frequency is twice that of the four-cycle, but the same solutions are satisfactory for either type of engine.

The effect of back pressure on horsepower is much more critical in the two-cycle than in the four-cycle. The ability of the engine to breathe is dependent on unrestricted flow of gas from the exhaust port. To attain this along with quieting involves large mufflers.

Figure 11 shows some sound runs with mufflers on a two-cycle Power Products engine. The experimental muffler in this case was similar in construction to that in Fig. 10 with slightly more volume. Considerable reduction in noise was accomplished. The circular muffler is a presently available Power Products muffler and is the best of the commercial mufflers tested. Sound reduction was nearly as good as with the experimental muffler with an equal power loss (Fig. 12). A small can type of muffler dropped the noise level just slightly below the unmuffled condition and resulted in a large decrease in power at high speeds. Both sound and power curves were run with an 8-in. connecting pipe between the engine and muffler to permit mounting the engine on the dynamometer. This additional volume tends to lower the noise levels and increase the power output shown in the figures, but the results are comparative. The various mufflers are shown in Fig. 13.

Because of the critical back-pressure demands, it seems advisable to use the mower base to obtain an economically large muffler. The front or rear of the base could be enclosed to form one or two chambers which could serve as the muffler. The principles illustrated in Fig. 10 would provide satisfactory results.

If a completely enclosed engine is desired, the problem of heat transfer from the muffler chamber back to the engine compartment must be considered. To avoid the heat problem under these conditions, isolation of the components in the initial design and then adequate insulation between the muffler and engine will be necessary. Flexible mountings would also be advisable to reduce noise transfer from the engine to the base. This would then complicate the connection of a rigid muffler to a flexible engine.



———o——— Without muffler
—.—.—o—.—.— With circular muffler
-----o----- With experimental muffler

2.2-hp Power Products engine driving an eddy current dynamometer, full throttle, 3600 rpm, indoor run.

Fig. 11. Effects of mufflers on the noise spectrum of a two-cycle engine.

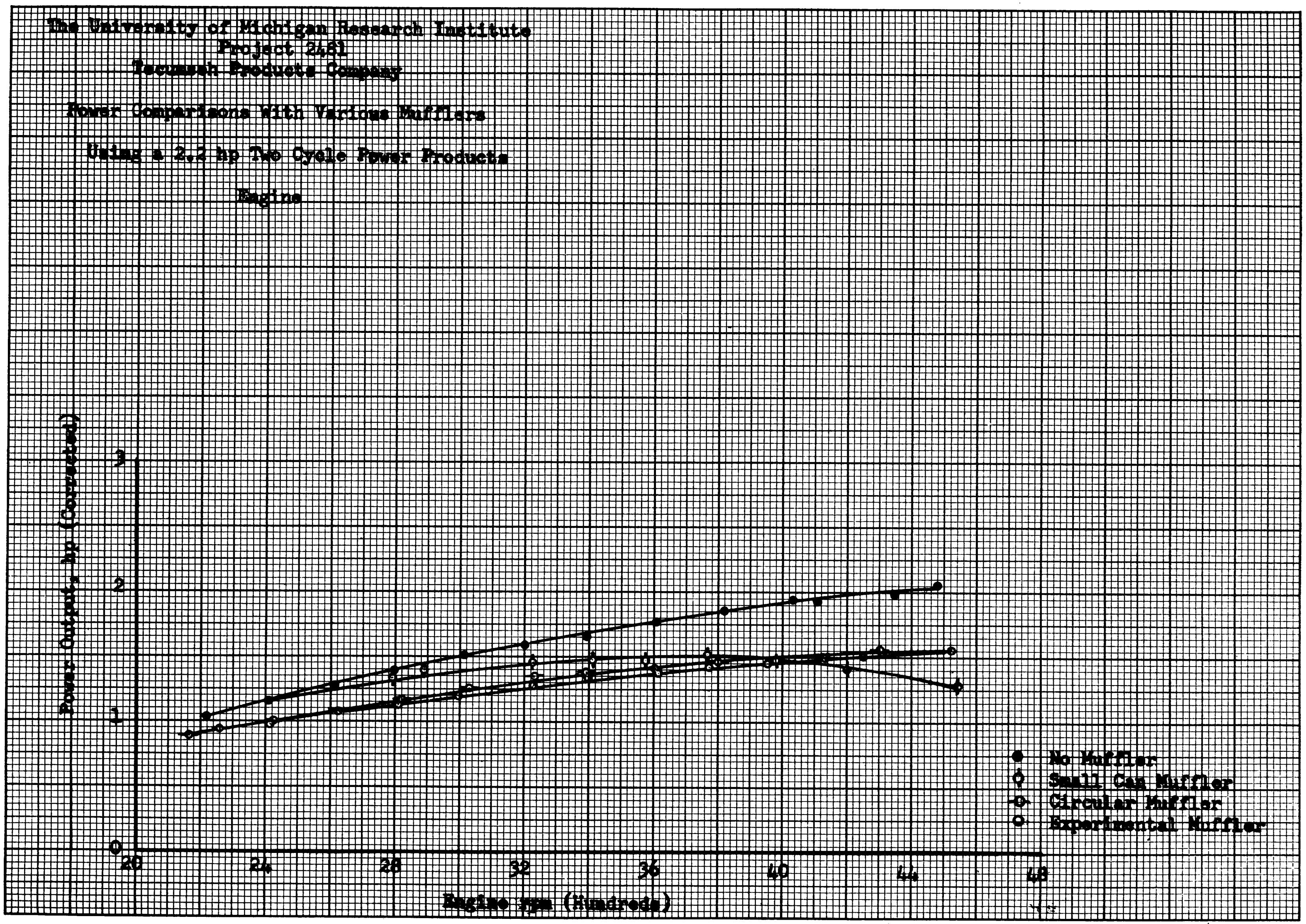
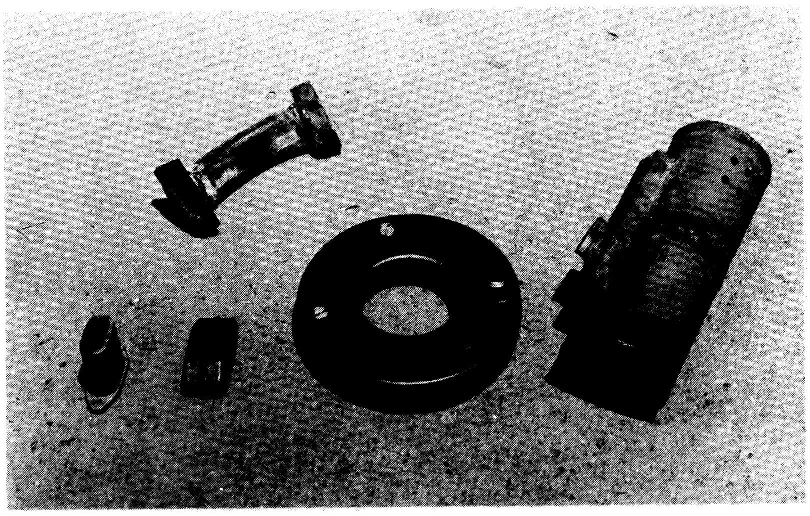


Fig. 12. Power losses of a two-cycle engine with mufflers.



From left to right: 1. simple exhaust port extension; 2. small can type of muffler; 3. circular muffler; 4. experimental muffler. The pipe shown in the upper left-hand corner is the exhaust extension used during dynamometer testing.

Fig. 13. Two-cycle mufflers.