perforated with many holes and have a diameter large enough so that the back pressure of the silencer is small. The length of the silencer should be at least 10 times the diameter of the inside tubing. The muffler can be strapped to the air hose supplying the tool.

o. Small Air Nozzles. The ejection of parts from a punch press is often accomplished by a blast of air. In other machining operations, an air blast may be used to blow away chips. Since both of these applications utilize the thrust of a moving stream of air, a silencer will not be a practical method for reducing the noise.

The design for an air nozzle shown in Figure 29 is about 10 db quieter than a straight piece of $^1/_4$-inch copper tubing even though both deliver the same

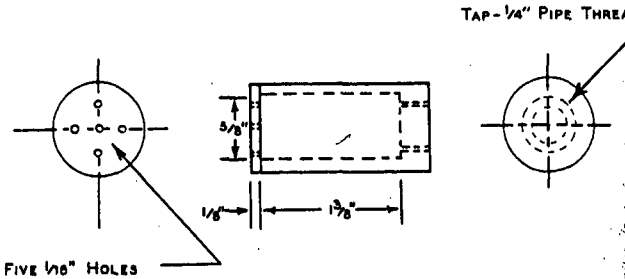


Figure 29. Design for air nozzle used to quiet air jets. The noise produced is about 10 db less than a straight piece of $^1/_4$-inch copper tubing that develops equivalent thrust. Almost any material may be used and only those dimensions shown are critical.

thrust. With the thrust delivered per unit area of opening held constant, less noise is produced when small holes are used. On the other hand, interaction between the streams from several holes causes the total thrust to be less than the sum of the thrusts from the individual holes. For the nozzle shown, holes with a diameter of $^1/_{16}$ inch seem to be optimum.

Quieting the nozzle of an air jet may be only part of the job. Sometimes considerable noise is produced when the air stream strikes an irregular object. Sharp corners, holes, and grooves should not be in the path of the air jet.

p. Air-Cylinder Exhausts. Quieting the exhaust of an air cylinder is a simple matter. Since the thrust developed by the escaping air is unused, a silencer may be attached without affecting the operation. Usually back pressure is unimportant and any commercially available silencer may be used. When back pressure is a consideration, commercial mufflers of the "straight-through" variety may be used. With such a simple solution to the problem available, there is little excuse for noisy exhausts on pneumatic equipment.

B. CONTROL OF NOISE BY ENCLOSURE

1. Fundamentals

The material presented in Section II makes it clear that a large reduction in noise can be achieved by complete enclosure of a noise source. However, Figure 10 shows that even small openings in the enclosure will cause large reductions in the effective transmission loss of the partition. Therefore, special attention should be paid to doors, windows, conduit and piping penetrations of the wall, and openings that are necessary for the feeding of material to and from the machine.

The examples discussed below are but a few of the industrial machines that can be quieted by enclosure.[31,32] The materials used in the construction of the enclosure depend upon the noise reduction that is desired. The approximate noise reduction of a particular wall construction can be found by use of the principles described in Section II.

The difficult part of the construction of such enclosures is the treatment of the openings that may allow noise to leak to the outside. Usually a duct with a small cross section and an inside surface lined with absorbing material is the treatment chosen for the openings necessary to the operation of the machine. Gaskets, caulking compound, and similar materials are applied to doors, windows, and cracks to eliminate all unnecessary openings.

Isolation of the machine from the floor may be necessary if appreciable vibration is transmitted to the rest of the building. Otherwise, vibration of the walls and floor may cause sound to be radiated into the room surrounding the quieted machine or to the room below the machine.[11,33]

The rules for enclosing a noisy machine can be summed up as follows: (*1*) Enclose as much of the machine as possible. (*2*) Provide adequate acoustical treatment for all doors and openings that are necessary to the operation of the enclosed machine. (*3*) Isolate the machine from the floor to minimize the transmission of vibration, if necessary.

2. Examples of the Control of Noise by Enclosure

a. Enclosure for a Wood Planer. A large wood planer used to surface rough lumber was operated steadily throughout each working day. Because of the severity of the operator's exposure to noise, an enclosure was constructed (Figure 30). The walls of this enclosure were made of heavy plywood covered on the inside with glass wool. The exposed surface of the glass wool was protected by a perforated facing. Openings in the enclosure were necessary at the

[31] R. Engstrom, Noise reduction by covers, *Noise Control*, **1**, 19 (March, 1955).

[32] R. T. Wells, Enclosures for noise reduction in the factory, *Am. Ind. Hyg. Assoc. Quart.*, **15**, 50 (1954).

[33] P. N. Hamme, *A Study of the Problem of Resilient Mounting Against a Non-rigid Foundation Structure*. Engineering Research Inst., Univ. of Mich., Ann Arbor, 1950.