thirds the ratio is about 70 percent provided that the total length of the baffles does not exceed 12 ft. Pressure drops through silencers should be calculated as accurately as possible and the approximation factors outlined here used as checking factors.

IV Mechanical Considerations

Silencers that are acoustically and aerodynamically correct must also be structurally sound and provide useful life commensurate with permissible depreciation or obsolescent rates.

On gas turbine installations where the silencers will be 8 and 10 ft or more in any one cross-sectional dimension, the bodies are generally fabricated of not less than $^3/_{16}$-in.-thick steel plate to provide both structural strength and attenuation. Where exhaust silencers become a part of the exhaust stack and must support a substantial weight of stack above the silencer section, the weight of the plate should be increased in accordance with requirements for stacks established by codes and good engineering practice. Perimeter edges should be flanged to provide bending resistance and a means of securing silencer sections together and to adjacent duct work.

Since the silencers are of plate construction and are generally of substantial size, the plate thickness itself will provide appreciable resistance to corrosion if properly painted prior to installation and if the exterior surfaces are periodically painted. Exhaust gas silencers usually run at such high temperatures that any internal painting other than with a high temperature aluminum paint has little value. The exterior surfaces of exhaust mufflers similarly can be painted only with a high temperature paint such as aluminum and as often as maintenance conditions require.

Baffles for inlet silencers should be of all welded construction so there are no mechanical components that can become loose due to vibrations or fatigue and be ingested into the turbine. On large gas turbine installations it is generally accepted practice to use 16 gauge steel for the framing and perforated facings. This material adapts itself well to welding. Some turbine manufacturers specify that silencers shall be fabricated with galvanized steel which presents problems in making good welds. Since good welding is more essential than the corrosion resistance of a galvanized steel sheet, the use of cold rolled carbon steels which may be painted with corrosion resisting paint, except at spots or areas where welding is required, is preferred. The completed units should be painted with corrosion resisting paint with care being exercised not to coat the sound absorbing insulation beneath the perforations. The sound absorbing material in inlet baffles is generally preformed mineral wool insulating board of 4 or more pcf density completely enveloped in fibrous glass cloth having low flow resistance properties. Since perforations may have a tendency to be rough on one side, corrosion resisting screen wire of 18/14 aluminum or bronze mesh is generally placed between the perforated metal and the fibrous glass cloth enveloping the sound absorbing material.

Baffles for exhaust silencers are generally fabricated with 10 gauge steel framing members and 10 gauge perforated steel facings. This gauge of metal is amply heavy for all types of welding operations and provides great structural strength and allowance for corrosion over a substantial period of time. The sound absorbing materials in the exhaust baffles are generally preformed mineral wool of densities of 6 to 8 pcf with a capacity to resist breakdown of the fibers at temperatures up to 1200 deg F. Since most gas turbine exhausts operate between 800 and 900 deg, the 1200-deg melting point for the fibers is no more than adequate. The binders that are used in forming this material into sheets ultimately deteriorate at the exhaust temperatures. The insulating material is wrapped in fibrous glass cloth, the surface of which is separated from the perforated facings with a stainless-steel screen wire of 18/14 mesh 0.011 or heavier wire. The surfaces of the exhaust panels are generally superficially painted with high temperature aluminum paint to provide some protection to the metal surface but primarily for appearance prior to installation.

Acceptable gas velocities through sound treatment in exhaust mufflers is generally limited to 150 fps. Actually the mass flow of gas is the determining factor in building up a velocity head. Exhaust gases traveling 100 fps and intake gases traveling 60 fps have about the same velocity head. If velocities in excess of 150 fps will be encountered, erosion of the acoustical insulation material should be prevented by the introduction of high velocity subfacings beneath the outer perforated facing. An acceptable subfacing is a corrugated perforated steel which reduces the erosive effect of air currents in the perforations directly adjacent to the sound absorbing insulation.

V What About Standards?

As yet no standards have been established either for the acoustical or aerodynamic performance or construction of gas turbine silencers. NEMA's proposed Standard on gas turbine silencing should be a progressive step to promote uniform performance standards. It is possible that this Standard may also delve into structural qualities of the silencers.

Since the number of different sizes of gas turbines that will be used on industrial power installations will be limited, it is possible that the fabricators of silencers could establish certain silencer sizes for the turbines of various capacities. Furthermore, these silencers could be made in modules which would have specific attenuating and aerodynamic characteristics. Different combinations of these modules could be assembled to meet a wide variety of attenuation requirements without the necessity for having to engineer or design a silencer every time that one is required.

References

1 National Electrical Manufacturers Association's proposed Standard SM 32-1961, WEH-7/3/62-lm, p. 11.

2 B. G. Watters, S. Labate, and L. L. Beranek, "Acoustical Behavior of Some Engine Test Cell Structures," *The Journal of the Acoustical Society of America*, vol. 27, no. 3, May, 1955, p. 450.

3 L. L. Beranek, "Noise Reduction," McGraw-Hill Book Company, Inc., New York, N. Y. 1960, chap. 17, p. 454.

4 Ibid., chap. 8, p. 188–191.

5 Bolt Beranek and Newman Inc., Report No. 490, WADC TR 58-202 (2).

6 L. L. Beranek, "Noise Reduction," McGraw-Hill Book Company, Inc., New York, N. Y., 1960, chap. 17, pp. 437, 438, 449.

7 Ibid., chap. 17, pp. 449, 454.

8 Heating Ventilating Air Conditioning Guide 1960, American Society of Heating, Refrigerating and Air Conditioning Engineers, Inc., New York, N. Y., 1960, chap. 21, p. 293–302.

9 C. N. Deverall and E. T. Nichols, "Fans, Ducts and Filters," Air Conditioning Refrigeration Data Book 1955–56, The American Society of Refrigerating Engineers, New York, N. Y., ninth edition, 1955, Sec. 24, p. 10–13.

DISCUSSION

Richard R. Audette[2]

This paper is excellent and very timely due to the recent widespread application of peaking gas turbine package electric power plants. As a discusser, I am adding some supplemental information which I believe will be of benefit. To expand on Part II-1 (Sources of Noise) Fig. 10 is given. This figure gives the sound pressure levels (db) for a General Electric 11,250 kw gas turbine package power plant at 200 ft, with standard silencing on the gas turbine inlet and exhaust, the generator inlet and exhaust, and an acoustical enclosure for the entire package. No silencers were provided for the fin-fan. A close study of this figure shows that the fin-fan exhaust and the generator are the major sound producers at 200 ft rather than the gas turbine. Thus, for a lower sound pressure level package more sound reduction must be provided for the generator and a silencer added to the fin-fan exhaust.

One item not covered by Mr. Eckel is the silencing and the air

[2] Acoustical Engineer, General Electric Company, Schenectady, N. Y.

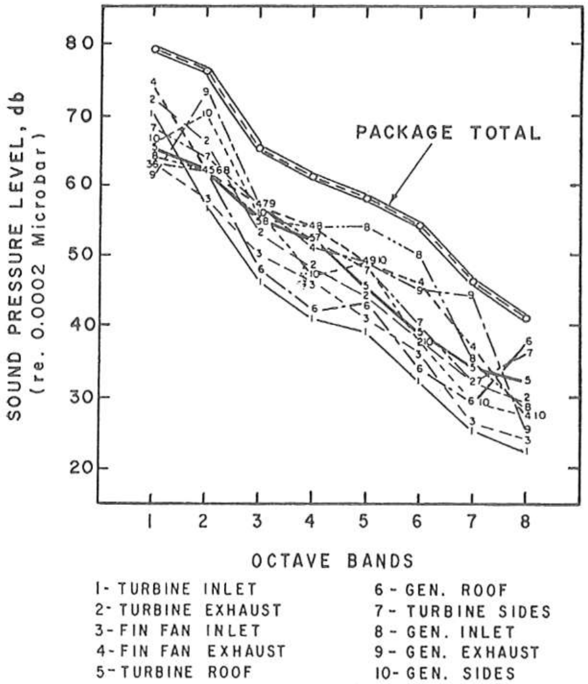

Fig. 10 Sound pressure levels (db) for a General Electric 11,250 kw gas turbine package power plant at 200 ft with standard silencing

circuit exits "self-noise." Self-noise is the sound generated by the air traveling through the silencer and the sound generated at the exit. These sounds are generated because of the air turbulence due to rough surfaces, obstructions within the silencer, and the mixing action at the exit. Where high sound levels are permitted this presents no problem, however, where a high degree of silencing and high-velocity flow are combined this combination might create self-noise which could cancel out some of the silencer effectiveness. Fig. 11 shows that a high turbulence air flow with a velocity of 150 fps emitting from a 12 ft dia vertical stack would give an overall sound pressure level of 91 db at 200 ft due to exit self-noise. This level of 91 db would exist regardless of how effective the silencer. This self-noise is very important at high exit velocities because under these conditions the sound produced has nearly equal sound pressure levels in all octave bands thus producing unwanted high frequency sounds.

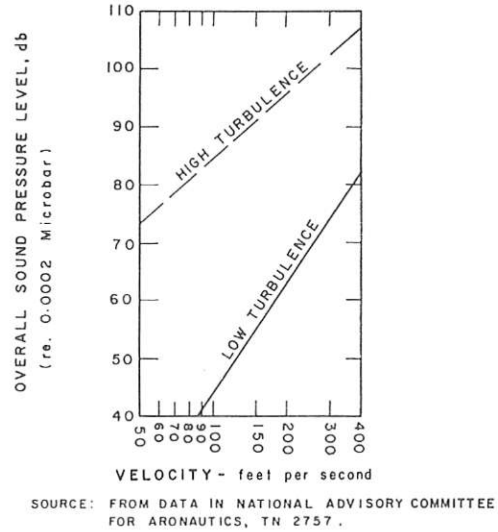

Fig. 11 Effect of exit velocity on the overall sound pressure levels (db) from a 12 ft-dia air jet measured at 90 deg to jet axis and 200 ft away

Author's Closure

Mr. Audette's discussion has effectively shown the need for a complete analysis of the sound sources on gas turbine installations, particularly where used for packaged power.

Self-noise generated by exhaust gases leaving a silencer can be avoided by designing the silencer with adequate open area so the exit gas velocities and the velocity through the silencer passages do not generate noise levels that exceed the limits imposed by the acoustical criteria. Some of the gas turbine manufacturers are now specifying maximum gas velocities through the silencer passages and at exit to atmosphere. Lower velocities through the silencer passages and at the exit will not only contribute to lower noise levels but will improve the efficiency of the turbine by reducing back pressure in the silencer. One large manufacturer of turbines already specifies maximum velocities through exhaust silencer passages of 150 fps and exit velocities not exceeding 80 fps. At these velocities a high temperature gas of relatively low density will not generate unwanted noise and will not build up undesirable back pressure.