CHIMNEY SWIFT 'THUNDER'

BY A. D. MOORE

GROSKIN, in the Auk for July, 1945 (Auk, 62: 361–372), has a very interesting account of large numbers of Chimney Swifts roosting in a large chimney at Ardmore, Pa. As Groskin states, Audubon and others have reported that when swifts enter or leave a hollow tree or chimney, a noise resembling distant thunder may be heard. Sutton mentions " . . . the thunderous booming of their wings as they sought new perches farther down." However, neither Groskin nor another observer (Mohr) detected any undue noise at the Ardmore chimney, although they were specifically listening for it. After discussing the flying-space limitations imposed on the birds by typical openings, Groskin concludes that "this limitation makes it highly improbable that they could produce a very loud noise with their vibrating wings."

Such a conclusion implies that Audubon, Maynard, Howell, and Sutton were not good observers; and, unwittingly, it also implies that pipe organs do not exist. The Ardmore chimney is 83 feet high. Little, if any of its resonance effects would be within the audible limits of the human ear. Groskin had the bad luck to listen for 'thunder' in a case that would yield little or no audible thunder. But there is no justification for generalizing from one case and, by ignoring resonance, denying the existence of 'thunder' in other cases.

Everyone is familiar with resonance in one way or another. When we shout into a cistern or an empty barrel, some of our tones are amplified to what may become a deafening roar. A cavity or pipe can resonate at a lowest (the fundamental) frequency, and at overtones (multiples) of that frequency. Overtones are also called harmonics. Quoting from Lemon and Ference ['Analytical Experimental Physics' (Univ. of Chicago Press)]: "Whenever an open or closed pipe is subjected even to an *entirely irregular* jumble of air pulses, those which happen to occur at intervals that exactly correspond to the fundamental frequency (or that of any of the pipe's harmonics) are amplified . . . ."

When swifts enter or leave a chimney at changing rates of, say, from five to 20 birds per second, and at random spacings, they are furnishing an irregular jumble of air pulses, and resonance is bound to occur. As will be seen later, they may also produce regular air pulses, leading to increased resonance effects.

This is not the place to expand on the theory of resonance. Any good physics textbook will cover the more usual parts of the theory. All we need do here is to make clear some of the possibilities as applied to swifts and their roosting places.

As a familiar basis for discussion, let us consider the lowest three octaves of the 88-key piano. The lowest string is usually tuned to have a fundamental frequency of around 27 cycles per second. This same string also produces overtones of frequencies 54, 81, 108, 135, 162, and so on. Going up the scale by octaves, we find strings with fundamental frequencies of 54, 108, 216, approximately (exact values depending on actual pitch used in tuning). If the keys within this range of three octaves are rapidly and irregularly fingered, noise like thunder is produced. Most of the sounds of distant thunder are found within this range.

An 'open' pipe is one that is open at both ends. The discussion will be strictly confined to this type of pipe, for the time being. A pipe having a length of about 21 feet will resonate at a fundamental frequency of 27, like the piano's lowest string; and, like that string, it will also resonate at the overtone frequencies of 54, 81, 108, 135, and so on. Swifts flying into the top of a 21-foot chimney would produce *irregular* air pulses, some of which would agree with these frequencies, and such tones would be amplified by resonance.

Regularity of air pulses from wing-beats would also be present. The frequency of the swift's wing-beat is sure to be somewhat variable, and it is probably somewhere between 10 and 20 beats per second. A wing-beat of 13.5 per second would produce a complex sound wave having a fundamental of 13.5, with overtones of 27, 40.5, 54, and so on. Thus, some of the overtones would be amplified by resonance in a 21-foot pipe.

Any pipe length can be studied by use of the formula, $N = c/(2L)$, where N is the pipe's fundamental resonant frequency; c is the velocity of sound—about 1,128 feet per second; and L is the approximate pipe length in feet. Assuming the Ardmore chimney to be an open pipe, we can very easily find that the frequencies of its fundamental and first several overtones would be approximately 7, 14, 21, and 28.

The lowest frequency typically heard by the human ear is about 20, and even this may not be heard unless the intensity is high. Thus, only the overtones of frequencies 28 and higher could be heard at the Ardmore chimney. Moreover, the rough general rule is that the higher the overtone, either in the source of the sound or of the resonant effects of a pipe, the weaker is the volume of that overtone. Still another effect comes in: the Ardmore chimney measures 3 by 4 feet in section, which means that a swift is small in comparison—thereby being relatively ineffective in inducing resonance in the first place. Groskin is a good observer; he should not have heard any loud noises at the Ardmore chimney.

The Ardmore chimney, in the part used for roosting, actually is a ventilator. As such, the lower end may well continue to a total length far beyond 83 feet, by virtue of connection to a duct. All of the frequencies would then be still lower, and still farther below the audible range.

The 'closed' pipe (closed at one end) is next considered. Some chimneys are closed pipes, being blocked at the bottom by dampers, fall of soot, and so on. A hollow tree need not have a bottom opening. Dr. Dow V. Baxter of our School of Forestry and Conservation assures me that certain fungi can cause disintegration of the tree interior if the top only is open.

To find N for a closed pipe, use $(4L)$ in the formula instead of $(2L)$. For the same lengths, the closed pipe frequencies are half those of the open pipe. Thus, if the Ardmore chimney happened to be dampered off, its fundamental would be 3.5 instead of 7, and any possibility of hearing it resonate would be still farther removed. Incidentally, the closed pipe does *not* resonate in the overtones of frequencies that are even multiples of the fundamental. The resonant frequencies of a 42-foot pipe are 27, 81, 135, etc.

The discussion has had a musical basis, and it might lead one to think that Sutton, for instance, should have heard rich organ tones—especially in view of the fact that he listened to a church chimney! Actually, the noise of "distant thunder" is to be expected in these cases, rather than music. Numerous factors enter in as causes, only some of which need be mentioned. Swifts enter irregularly, thereby setting up rapid volume fluctuations. Some wing-beats will produce frequencies a little different from the exact resonant frequencies of the 'pipe'; these will be amplified somewhat, but they will produce discords. The resonant frequencies themselves will change somewhat during the flights of the birds; when enough of the opening is taken up by bodies to be appreciably blocked, these frequencies will change. Probably the greatest cause of volume fluctuation will be due to the random way in which several pairs of wings may beat in or out of phase with each other; when they happen to change from helter-skelter to approximate unison of group wing-beats, in successive groups, very large changes in sound volume would certainly result.

By using the above formula on a few cases, it will readily be seen that most chimneys and many hollow trees offer rich possibilities for the production of chimney swift "thunder." Audubon was right!

August 4, 1945
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Ann Arbor, Michigan