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ACOUSTICS OF THE FINE ARTS AUDITORIUM OF THE UNIVERSITY OF OKLAHOMA

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Many auditoriums, chapels and lecture rooms have been noted for their acoustical peculiarities but it was not until Wallace C. Sabine* of Harvard University undertook the problem in 1895, that "Acoustics of Auditoriums" was changed from guess-work to a science. He developed the reverberation formula, and then determined the relations which give optimum results. He found that air currents cause only negligible acoustical effects, but that irregularities in temperature may result in marked and, in general, unfavorable accoustical effects. He also showed the uselessness of wires for improving the acoustics of an auditorium and the meager advantages derived from sounding boards.

The acoustical properties of the Fine Arts Auditorium of the University of Oklahoma are very unsatisfactory. Even those sitting comparatively close to the front have difficulty in understanding a speaker unless the auditorium contains a large audience. This condition is due to two causes, excessive reverberation and extraneous noise.

REVERBERATIONS

Sound, produced in a confined space, will continue until it is either transmitted by the boundary walls, or is transformed into some other

*Wallace Clement Sabine, Collected Papers on Acoustics, 1920.

kind of energy, generally heat. This process of decreasing the sound intensity in an enclosure is called "absorption." The continuation of the sound in an enclosure after the source has stopped is called "reverberation."

Whenever sound is reflected by a surface, part of the energy is absorbed while the rest of the energy is reflected back into the room. Upon each reflection, from a given surface, the sound intensity is decreased by a constant fraction, called the coefficient of absorption. Since the velocity of sound is comparatively high, the time required for it to travel across the average auditorium is so short that each reflection is not distinguishable by the ear. Instead a jumbled-up effect is observed, i. e., the auditorium reverberates. The time required for the intensity of a sound to decrease to 10^{-6} of its original intensity, is defined as the "toime of reverberation." If very loud sounds are used, this time of reverberation may be measured by means of a stop watch.

W. S. Sabine arrived at an empirical formula for determining the reverberation time "T" in terms of the absorbing power "A" and volume "V" of the auditorium or room.

$$T = kV/A \qquad (1)$$

Where $A = \sum_{i=1}^{n} a_i S_i$, and a_i =, coefficient of absorption for the surface of area S_i. The constant k was determined from data obtained by examining a large number of auditoriums and rooms, and is equal to 0.05 sec/foot or 0.164 sec/meter.

Carl F. Eyring** recently has derived a formula which holds for dead rooms such as those used for radio broadcasting and sound picture production.

$$T = -kV/S \; [\log_e (1-A/S)] \qquad (2)$$

Since equation (1) is sufficiently accurate for practical work in auditoriums designed for music and speaking, it will be used in all the calculations below.

The "Optimum Time of Reverberation" is defined as the time for which the best acoustical results are obtained. This varies somewhat with the volume of the auditorium.

By calculating the volume and the absorbing power of the Fine Arts Auditorium from the dimensions, we found the time of reverberation to be 5.4 seconds. According to Knudsen,*** the optimum time of reverberation for an auditorium of this size is 1.25 seconds.

Since the absorbing power of a person is approximately 4.7 square feet (i. e., equivalent to 4.7 square feet of open window) the time of reverberation is reduced to 0.95 seconds for a capacity audience, 1,800. If it were not for the extra noise and confusion introduced by so many people, a speaker would have little difficulty in making himself heard in all parts of the auditorium.

**Carl F. Eyring, Jr. Acous. Soc. Amer., 1, 217 (1930).

***V. O. Knudsen, Jr. Acoustical Soc. Amer. 1, 56 (1929).

Of course it is seldom that the auditorium is filled. Therefore it is desirable to correct the auditorium so that it will have satisfactory acoustical properties when smaller audiences are present. For a one-third audience (600 people) the time of reverberation is 2.13 seconds, while for an audience of 300 people the reverberation time is 3 seconds. To give optimum results with a one-third audience it would be necessary to add 3,148 square feet of absorbing power; for an audience of 300 it would be necessary to add 4,473 square feet of absorbing power.

The installing of upholstered seats is a very common way of adding absorbing power. The advantage in upholstered seats is that the time of reverberation does not change so rapidly with the number of people present. If the 941 seats on the first floor were replaced by upholstered seats the time of reverberation for no audience would be 2.1 seconds and for a one-third audience, occupying 600 seats, 1.7 seconds, which is still considerably above optimum; in fact the auditorium would be classed only "fair."

There are 5,077 square feet of plastered walls, which could be covered without any great difficulty with some form of sound absorbing material. There are many different kinds of sound absorbing plasters, tiles, and fiber boards on the market at the present time, which may be procured at reasonable prices. Below are listed some of the better known absorbing materials with their absorption coefficients, for a frequency of 512 cycles per second.

Acoustic-celotex (felted bagasse fibers)	0.25 — 0.70
Nashkote (Asbestos-akoustikes felt)	0.31 — 0.41
Akoustek (Tile)	0.37
Akoustolith (Tile)	0.12
Corkoustic (Cork)	0.30 — 0.35
Acoustotone (Tile)	0.17 — 0.59
Sabinite (Plaster)	0.21

If the 5,077 square feet of plastered walls were covered with some type of absorbing material with an average absorption coefficient of 0.40, in addition to installing the upholstered seats, the optimum condition would be obtained for a one-third audience.

There are also 6,064 square feet of plastered ceilings on the undersides of the balcony and the gallery. If these surfaces and the 5,077 square feet of plastered walls were covered with some type of absorbing material with an average absorption coefficient of 0.18, in addition to the upholstered seats, the optimum condition would be realized for 600 people. With no audience the reverberation time would be 1.44, which is still considered in the range of good acoustics. If the seats remain as they are and if the walls and ceilings, just mentioned, are covered with a material having a coefficient of absorption of 0.23, the reverberation time would be the optimum if an audience of 600 were present.

EXTRANEOUS NOISE

The greatest source of noise inside the auditorium is caused by the grating of feet on the floors. The floors of the balcony and the gallery are of concrete while the lower floor is covered with wooden flooring. If the concrete were painted with the proper heavy paint, and the wood well oiled a large part of this noise would be stopped at its source. Of course more efficient methods could be used, but they would entail a much greater expense.

A corridor having a concrete floor encircles the entire auditorium. This forms a most efficient source of noise when people are passing through it. Since the plastered walls are very good reflectors of sound, this noise is carried into the auditorium to such an extent that it is noticeable in all parts of the auditorium and makes audition nearly impossible near the entrances when even only a few people are arriving or departing. This noise could be reduced by placing rubber runners in the entrance and in the corridors. If the walls and ceiling were covered with some sound absorbing material, the unavoidable noise would be largely absorbed before it could get into the auditorium.