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ARCHITECTURAL USES OF THE CRITICAL DISTANCE CONCEPT

by
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When the opportunity presents itself to work with the architect at the conceptual design stage of a building project, the architectural acoustics problem may be approached from either of two fundamental standpoints.

1. A loudspeaker array may be chosen for its esthetic applicability to the architectural desires. (The architect may decide he wishes to use a small loudspeaker such as the 9844A, thus choosing to restrict the architectural parameters to its coverage, throw, and acoustic gain requirements.)

2. The architectural configuration and material chosen for a particular space may be inviolable and the sound system must be designed solely in terms of the acoustic conditions as found. (For example, monumental and religious spaces where traditional and psychological considerations require that transmission of speech be sublimated to the required visual impact.)

Designing the Room to Fit the Loudspeaker

If the architect were to choose a loudspeaker system first and were to consult with you as to the limiting parameters controlling the acoustics of the space to be designed, you would have the following problems to solve:

Given a room with a desired internal volume, boundary surface area, and a desired D_2 distance plus a loudspeaker with a specified Q, what would be the

Minimum $\bar{a}$ allowable
Minimum R allowable
Maximum RT_{60} allowable

in order that $D_2 \leqq 4D_c$:

Given:

$V = 500{,}000 \text{ ft}^3$

$S = 42{,}500 \text{ ft}^2$

$D_2 = 150 \text{ ft.}$

$Q = 10$

Find:

Minimum $\bar{a}$
Minimum R
Maximum RT_{60}

$$R = \frac{(0.25D_2)^2}{0.019881Q}$$

$$R = \frac{1406.25}{0.19881} = 7073.336$$

$$\bar{a} = \frac{R}{R + S}$$

$$\bar{a} = \frac{7073.336}{49573.336} = 0.143$$

$$RT_{60} = \frac{0.049V}{-S \log_e (1-\bar{a})}$$

$$RT_{60} = \frac{24500}{6558.488} = 3.74 \text{ sec}$$

Litho in USA CP-372-2.5K

We can therefore tell the architect that, in addition to giving us a location for the chosen loudspeaker that allows even coverage and sufficient acoustic gain, he must not:

Allow the $\bar{a}$ to go below 0.143

Allow the room constant R to go below 7073.336

Allow the RT_{60} to go above 3.74 sec

These are extremely useful acoustic limits and are those the architect is traditionally familiar with from years of dealing with acoustical consultants and acoustic material suppliers.

Designing the Loudspeaker to Fit the Room

In existing construction situations, it is usual to accept the acoustic parameters of the room as they are and attempt to minimize their effect on the intelligibility of speech through careful sound system design practices. Where this is the case, one of the most useful "first calculations" is to see what minimum value of Q would allow the use of a single source.

Given:

$$V = 500{,}000 \text{ ft}^3$$

$$S = 100{,}000 \text{ ft}^2$$

$$RT_{60} = 9.6 \text{ sec}$$

$$D_2 = 150 \text{ ft}$$

What would be the minimum acceptable Q that would allow $D_2 \leqq 4D_c$?

$$Q = \frac{(0.25D_2)^2}{0.019881R}$$

To solve the above equation we must first solve for $\bar{a}$ and then R.

$$\bar{a} = 1 - e^{-\left(\frac{0.049V}{S \cdot RT_{60}}\right)}$$

$$\bar{a} = 1 - 2.718281828^{-\left(\frac{24500}{960{,}000}\right)} = 0.025$$

$$R = \frac{S\bar{a}}{1-\bar{a}}$$

$$R = \frac{2500}{0.975} = 2564.013$$

We can now solve the original equation given above:

$$Q = \frac{(0.25D_2)^2}{0.019881R}$$

$$Q = \frac{1406.25}{50.975} = 27.59$$

A Q value this high could only be met at mid frequencies by a very large Extenda-Voice* system.

*Patent applied for.

Obviously, it is also possible to change V, S, or D_2 to fit the other parameters.

Useful formulas for these preliminary room and system calculations are:

$$D_c = 0.141\sqrt{QR}$$

$$S\bar{a} = R(1-\bar{a})$$

$$S = \frac{R}{\bar{a}} - R$$

$$S = \frac{0.049V}{-RT_{60}\log_e(1-\bar{a})}$$

$$V = \frac{-S\log_e(1-\bar{a})\,RT_{60}}{0.049}$$

$$\bar{a} = 1 - e^{-\left(\frac{0.049V}{S \cdot RT_{60}}\right)}$$

$$\bar{a} = \frac{R}{R+S}$$

$$R = \frac{S\bar{a}}{1-\bar{a}}$$

$$Q = \frac{(D_c)^2}{0.019881R}$$

$$R = \frac{(D_c)^2}{0.019881Q}$$

$$RT_{60} = \frac{0.049V}{-S\log_e(1-\bar{a})}$$

By using these formulas singly and in combination, it is possible to calculate the effect of any change in the basic parameters of the room's acoustic properties. When used in conjunction with the NAG and PAG formulas and when even distribution is achieved, high intelligibility is the reward. Naturally, you can use the reciprocal of any multiple of D_c to adjust the factor used with D_2. For example, if you desire $D_2 = 2D_c$ then you use $(0.5D_2)^2$ in the formula given.

Continued reporting by Altec sound contractors of the correlation between calculated and measured results from these formulas continues to help in their development.