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PRINCIPLES OF RAKE DESIGN

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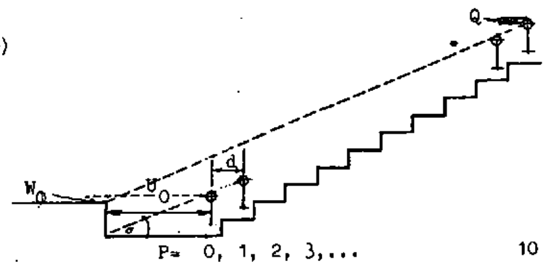
1. INTRODUCTION

Clear vision of the stage from any seat in an auditorium is normally established by means of rake generating algorithms. One normally attempts to achieve two goals in rake design: 1) clear vision from every seat; 2) a rake which is as shallow as possible. Both of these conditions will be satisfied if the envelope of clear vision of each seat is uniform in size and coincident in location with the stage. All rake formulae contain some implicit assumptions about the stage or platform, and about the observer. Very often rake formulae are not applied successfully, because these assumptions are false in the circumstances or due to conflicts with concomitant design problems involving circulation and space organization or row and stage geometries. The purpose of this paper is to outline these as well as the algorithms themselves.

2. THE STRAIGHT RAKE

The angle of rake is determined by the difference in elevation between the two rearmost rows necessary for the last row to have clear vision of a reference point on the stage. This reference point is generally located on the major axis of the auditoria at the front of the stage, preferably at stage height. Less stringent reference points may be located further back and/or at eye height above the stage floor.

$$\sigma = \tan^{-1}\left(\frac{PQ + W_o}{U_o} + \frac{Q}{d}\right)$$



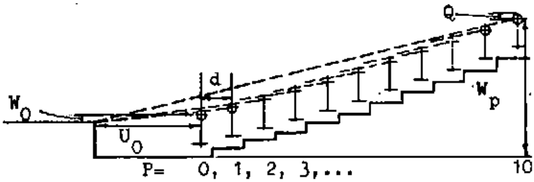
From the equation it is obvious that the important criteria are the "starting point" (location of the first row, P = 0, eye level relative to the reference point horizontal distance = U_o, vertical distance = W_o), the number of rows (P), the "clearance", (Q), and the row spacing, d. (It is assumed that the starting point is chosen with due regard to intervening balcony parapets or other physical obstructions.) Generally the rake increases as PQ and W_o are increased and U_o and d are decreased. The straight rake is not very efficient if P is large, since the clear viewing envelope at the front of the auditorium becomes excessively large in order to gain sufficient clearance at the rear. Graphs of a wide range of straight rake angles in terms of P, U_o and W_o are given in Andreas (1977). It appears that with a typical starting point, 10 to 12 rows can be accommodated in one straight rake without becoming excessively steep or developing a great disparity in viewing envelopes.

3. RUSSEL's 'ISACOUSTIC' RAKE

This curved rake is currently preferred for many auditoria since, in theory, it generates sight lines that are coincident at the reference point. The angle of rake becomes steeper at every successive row and the eye level height above the reference point of any row (W_p) is given by:

$$W_p = U_p\left(\frac{W_o}{U_o} + Q \sum_{i=0}^{p-1} \frac{1}{U_i}\right)$$

where $U_p = U_o + Pd$



Thus the height of any row is a function of the height of the first row, the clearance, the number of rows and their spacing. The relative height of any row in an isacoustic rake, compared to its counterpart in a straight rake is lower. As the number of rows is increased the disparity increases.

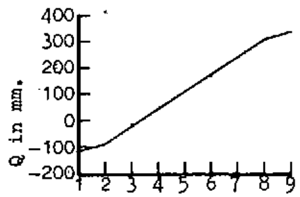
4. APPLICATIONS

It is often suggested (see Ham (1972) for instance) that isadomal rakes may be "straightened" to overcome the inherent problems of a continuously varying floor slope. This idea ignores the basic characteristic of the isacoustic rake, that it is not only the amount of rake which is important but where it occurs. In general, a steeper rake is required further away from the stage reference point. It is the difference in elevation between consecutive rows rather than the first and last rows which is critical. The effect of straightening an isacoustic rake, maintaining the first and last row elevations and any small number of points in between is to increase the probability of seeing from the first row towards the middle of the set of rows and to decrease the probability of seeing from the middle towards the last row. This is a serious liability when P is large and especially when the low values for Q currently recommended are used. If it is not feasible to adopt a true isacoustic rake, the best policy is to use several short, true, straight rakes in order to keep the probability of clear vision high. If a series of short straight rakes are used it is generally best to have longer ones near the front and shorter ones towards the rear.

Of the variables contained in the two equations, the starting point W_o/U_o, and the clearance value, Q, require further elaboration. If it is assumed that the reference point is at stage floor level, it is obvious that it is best if W_o/U_o

is positive in order that all observers may view the stage floor. One pays heavily for a high value of W_o/U_o however, with a steep rake. Potential steep rakes are often dealt with by reducing the value of Q, in variants of either formula which provide what is known as "alternate-row" vision. Here one attempts to offset seats in adjacent rows so that the centre line of any seat is coincident with the edge of two seats in the preceding row, so that the observer views the stage through the slot between the two observers in front of him. The clearance value can then be reduced by ½ (or d can be doubled). Two problems exist with the alternate-row vision: 1) to achieve this perfect offset it is necessary to use seats of various widths, especially with the long rows of continental-type seating; 2) it is not obvious that the entire stage width will be visible within each "slot" especially towards the front of the auditorium. Finally, the method implicitly considers the audience members as static observers who do not need to adjust their positions significantly in their seats to remain comfortable, an arguable assumption. An unusual suggestion for achieving a low rake has been suggested by Cramer (1968). Called a "cheat-rows" method by its author, it ignores the first one or two rows of the auditorium and starts the rake beyond this. The principal effect is to reduce the value of W_o/U_o which pays off in a lower rake and deficiencies in clear vision from the first rows. One may feel that there is an adequate justification for this when the front rows are often replaced by a stage extension or orchestra.

The value of the clearance, Q, is of critical importance in any rake algorithm. In general this value has been slowly depreciating from Russel's 305-457 mm (1841) to Ham's 100 mm (1972). Far more significantly, it appears to mark the degeneration of the designer's "model" of the audience member. Russel on the one hand wished to accommodate normal position shifting of the audience and normal variations in human dimensions. More recent authors regard the audience as a number of static points of uniform dimension. In the latter case, the value for Q is equal to a notional distance between the eye and the top of the head. Frink (1968) has suggested a method of describing Q in terms of probability of seeing. The main problem with his technique is its basis on the assumption the eyeheight h_e and total height h_t are a normally distributed population. A normal mixed population (number of males = number of females) is definitely non-Gaussian. The following values for Q are based on a method for dealing with bimodal distributions of h_e and h_t described in Andreas (1977). It differs from this earlier paper solely in being based on better anthropometric data; that available for seated males and females in Murrell (1971).



at 1 less than 1% of population may see reference point

at 5 approximately 50% of population may see reference point

at 9 over 99% of population may see reference point

It is apparent that a value for Q of 150 mm-200 mm for every row vision would yield a high probability of clear vision.

PRINCIPLES OF RAKE DESIGN

It is normally accepted that generation of a rake in a bilaterally symmetrical auditorium should be considered along its major axis, however, this may not often be the most critical sightline test. Depending on the shape of the stage front and the shape of the rows, a great deal of disparity in clear vision envelopes may occur. It has been suggested (Ham, 1972) that other (unspecified) sections should be checked. In fact for a given row and stage shape it is possible to predict the most critical section for clear vision. These have been described for twelve common row and stage combinations in Andreas (1977). In general the critical section may be determined from the seat in the first row that is closest to the stage edge (where U_o is smallest). A line through this point normal to the row (making d smallest) demarcates the critical section and the location in plan of the reference point on stage. It is obvious that the most efficient rake occurs in those plans where U_o is the same for every seat in the first row. The disparity will be greatest when rows are long and there is a wide variation in U_o. Where a geometric affinity cannot be achieved (ie circular stage front + circular rows with a common focus), the disparity can be reduced by "approximating" the row shape to the shape of the stage. In this way the disparity is not cumulative across the auditorium.

5. CONCLUSIONS

Throughout this paper it has been assumed that one of the ideals of rake design is a very efficient envelope of clear vision. It should now be clear that the alternatives to this are either a relatively low rake with complete clear vision of the stage from only part of the auditorium or a relatively steep rake with complete clear vision of the stage but implying that, at least in part, the stage and seating could have been brought closer together, paying off in closer contact between the patrons and the performers. It is not argued that this ideal should always be adhered to. Where extreme uniformity in clear vision is not relevant it is still desirable to make informed decisions about the alternatives based on an understanding of the principles involved, decisions which may be accurately reflected in seat pricing for example. In general it may be said that two alternative strategies to rake design may be taken. The first is characterized by the auditorium having an isacoustic rake, continental seating with affine row and stage edge shapes, offering uniform clear vision from all seats. The alternative would consist of series of straight rakes and broken row shapes reflecting the stage profile. The obvious advantage of the second approach is the greater flexibility it offers the designer.

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