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THE HALL OF THE UNIVERSITY OF WARWICK

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INTRODUCTION

On 26 January 1982 the opening concert in the Hall of the University of Warwick Arts Centre brought to fruition a scheme to provide a multipurpose hall suitable for orchestral concerts to complement the existing facilities of the Arts Centre. Compared with current projects of a similar size the budget for this new 1300-seat hall was very modest, as can be judged from the contract sum of £988,804. Inevitably there was a natural desire by the client to include in the design brief all possible activities from music-making to wrestling; of necessity an order of priorities was established:

(1) music of all periods and forces (saleable seats 1300)
(2) conferences, lectures (occasional cine and still projection)
(3) rock concerts, discos, dances
(4) exhibitions, University examinations and spectator sports

For many functions a relatively large flat floor of at least $500m^2$ was required; for concerts much of this would have to be raked using retractable bleacher seating. With orchestral music as the first priority, it was decided to aim for a final mid-frequency RT as high as possible in the range 1.5 to 2.0 seconds in the fully occupied hall. To this end a volume of $13000m^3$, i.e. $10m^3$/person, was recommended with all absorption except the seating reduced to a practicable minimum. The decision already taken by the architects to omit a ceiling and leave the roof structure and ventilation ducts exposed was confirmed.

ACOUSTIC DESIGN FOR THE AUDIENCE

In the event, the free volume in the concert configuration (bleacher seating out) turned out to be $12100m^3$, that is $9.3m^3$ per seat. Because of uncertainties in the bleacher absorption, Beranek's 1960 (1) audience absorption data were used in preference to his 1969 data. The former gives higher absorption particularly at low frequencies. Steps to minimise absorption included plastering the forticrete block walls and substitution of painted Durox planks for pre-screeded woodwool in the exposed roof. The final shape of the hall is shown in Figure 1. It includes a wall behind the orchestra platform which extends towards the rear of the hall on each side of the main seating rake. This wall was made as high as possible so that it could be used to provide lateral reflections to the main seating area. The location of audience and choir seating above and behind this wall on all three sides was thought to be beneficial in several respects. A nagging uncertainty was the extent to which the open lattice roof trusses, the circular section ventilation ducts and the roof shape would provide sound scattering and adequate diffusion in the hall. In the absence of model tests, a judgment was made that the general geometry of the hall in conjunction with the scattering elements would be adequate.

ACOUSTIC DESIGN FOR THE MUSICIANS

Depite work by Marshall et al (2) an authenticated rationale for orchestra stage acoustic design or even the means for developing it, did not exist in 1980, though recent work by Meyer and de Serra (3) is promising. The Warwick design was therefore based on a hypothetical but plausible psychoacoustic analysis combined with a brief empirical study of existing orchestra stages of good and poor reputation.

The design included reflecting elements at a height of approximately 7.5m above the stage (see Figures 1 and 2). Roughly speaking, the curved surface (1) provides reflections between the choir seats and the orchestra platform and vice versa; the annular reflector (2) gives reflections back into the orchestra from all four sides of the platform, and the central "inverted trough" (3) provides cross-stage reflections by virtue of double reflections from its internal right angle. These elements were intended primarily to provide reflections between one player and another to assist ensemble but it was recognised that they would also give reflections back to the sound source in certain cases. In order to increase the number of these latter reflections some "pyramids" (5) were hung above the platform. These were also recommended above the choir but were omitted. Each consists of three mutually perpendicular planes which have the property that sound making specular reflections from each of the three internal surfaces in turn emerges parallel to the incoming sound and thus returns to the source for all angles of incidence within certain limits. In principle these elements are very efficient because each pyramid can provide one reflection of his own sound back to each player; the number of reflections equals the number of pyramids.

ASSESSMENT

No systematic subjective assessment has been made, though in initial comments by listeners there was general agreement that the sound was clear, intimate, reasonably well balanced and free from serious faults. Comments by musicians have been very enthusiastic.

The measured RT (100% occupancy) shows good agreement with the calculated values (Figure 3) and measurements of the EDT generally show no wide discrepancies between the EDT and RT. Measurements of the mean 80ms early-to-late energy ratio (4) were -0.4dB and -0.8dB for a source in the stage and choir seating respectively, and were within 0.5dB of the theoretical value. The measured mean values of the 80ms early lateral energy fraction over the octave bands 125Hz to 1000Hz were 0.21 and 0.23 for the stage and choir source positions respectively. The range was approximately ± 0.1 in each case. By and large these results are consistent with the generally satisfactory subjective comments and with data from other halls of good reputation.

Measurements of the steady state sound level were particularly favourable to the Warwick Hall, giving as they did a small range ± 1.5dB and fairly high mean values of -2dB and -4dB for stage and choir source positions respectively relative to the theoretical value. These results are consistent with the overall impression of loudness upon which some listeners have commented.

Finally, in the absence of any physical criterion for assessing the stage acoustic conditions, measurements were made across the stage and across the stalls of the ratio of early-to-direct sound R_1 where

$$R_1 = 10 \log \left\{ \int_{5}^{\infty} p^2(t)\,dt \Big/ \int_{0}^{5} p^2(t)\,dt \right\} \quad dB$$

Average values for R_1 in the 500 and 1000Hz octave bands were:

across stage $R_1 = 4.5$dB
across stalls $R_1 = 2.5$dB

These measurements show that early reflections on the stage contribute nearly three times as much energy as the direct sound, but in the stalls barely twice as much as the direct sound. It would be interesting to know if R_1 has much smaller values for poor performing areas. The measurement of the reflected sound energy which returns to the source presents practical problems and was not attempted.

ACKNOWLEDGMENTS
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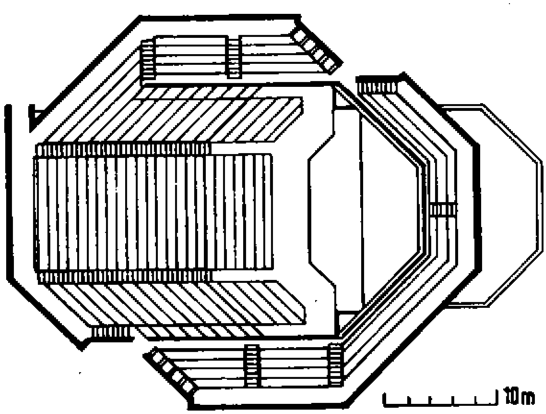
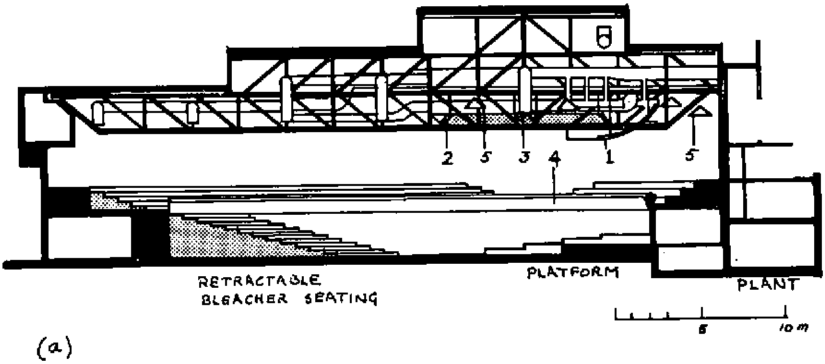
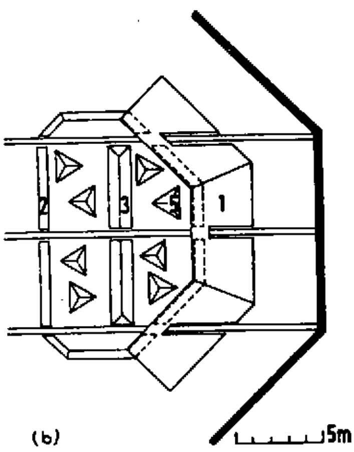


Figure 1: PLAN OF THE HALL





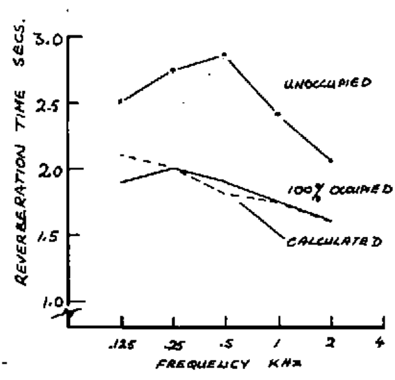


Figure 2: LONG SECTION (a) AND PLAN (b) OVER THE ORCHESTRA PLATFORM

Figure 3: CALCULATED AND MEASURED REVERBERATION TIMES