Proceedings of the Institute of Acoustics

CASE STUDY ON THE FIRST UK INSTALLATION OF THE ACS ENHANCED REVERBERATION SYSTEM

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1. INTRODUCTION

In June 1989 Spectrum Acoustic Consultants were appointed to advise on a complete refurbishment to the Gordon Craig Theatre, Stevenage. Spectrum's brief was first to assess the auditorium prior to refurbishment and specify suitable surface treatments to retain the excellent speech intelligibility of the theatre. A further objective was to investigate methods of improving the theatre acoustics for music performance.

This paper concentrates on the latter objective and presents a case study on the first UK installation of the ACS enhanced reverberation system. The theoretical principles behind ACS are not included in this paper but are covered in depth in refs. 1, 2 and 3.

2. THEATRE DESCRIPTION

Opened in 1975, The Gordon Craig Theatre is a 507 seat multi-purpose auditorium of fan shape with a single tier rake. The theatre stages a wide range of events, from symphony concerts, through legitimate theatre to business conferences.

The theatre acoustics prior to refurbishment were typical of many modern multi-purpose auditoria designed primarily for good speech intelligibility (RASTI values ranging from 0.61 to 0.74 for 70dB signal) with the consequent trade-off of insufficient warmth for music performance. (mid frequency RT of 1.1s).

The theatre management wanted to keep the good speech intelligibility for the drama and business conferences yet at the same time wanted to increase the number and quality of their music performances. With the refurbishment imminent the obvious solution was to specify materials to ensure that the good speech intelligibility was retained and also install some form of enhanced

reverberation system to improve the acoustics for music performance. After assessing all enhanced reverberation systems commercially available at the time, Spectrum specified the recent Dutch invention, ACS (Acoustic Control System).

3. A BRIEF DESCRIPTION OF ACS

The concept behind ACS is to try and simulate the reflection patterns of an ideal auditorium and then recreate these inside an existing auditorium. (see fig. 1).

The system samples the direct sound field emitted from the stage with an array of broad band directional microphones positioned above the stage area. The signals are then sent on to a signal processing rack consisting of a number of reflection simulation units. These units apply equalisation and signal delays to the sampled sound to simulate early reflections and reverberation. Finally, the modified signals are fed into the hall through an array of broad band loudspeakers distributed around the hall.

4. ACS IN THE GORDON CRAIG

The ACS configuration installed in the Gordon Craig is designed to provide early reflections and reverberation in the auditorium alone. Budget constraints meant that the stage modules were not included in the initial set-up, although they may be added at a later date.

There are 19 fine tuning parameters available with ACS, shown below

1-8	the individual RT values in the eight octave bands from 63Hz to 8KHz
9-16	the individual SPLs in the same octave bands
17	the scaling factor for all reverberation times
18	the input amplification of all microphones
19	the output amplification of all loudspeakers

Additionally the relative levels of different modules can be adjusted allowing fine tuning of the ratio of Early to Late energy.

ACS AT THE GORDON CRAIG THEATRE

Seven settings are programmed into the Gordon Craig system to cover the range of events staged in the theatre. The settings, together with mid-frequency RTs and performance guides, are given in table 1 below.

Setting	RT(s)	Performance Guide
0	1.1 (ACS off)	Normal acoustic for speech
1	1.3	Piano, Jazz, Ballet, Musicals
2	1.5	Chamber music, Recitals, Opera
3	1.7	Chamber and Baroque music
4	1.9	Symphonies
5	2.1	Symphonies
6	2.5	Choral music
7	3.0	Organ (dedicated setting)

All microphones are directional Senheiser MKH50's, with the stage microphones hung from a flybar at a height of 6m. The loudspeaker array is made up of a total of 33 cabinets distributed around the theatre, arranged in 3 groups.

Group 1:	Loudspeaker No.s 1 to 18	Reverberation speakers mounted on interior walls, directed at audience.
Group 2:	Loudspeaker No.s 19 to 27	Reverberation speakers mounted on lighting bridge directed at audience and stage.
Group 3:	Loudspeaker No.s 28 to 33	Early reflection speakers mounted to the sides of the proscenium.

The loudspeakers used for Groups 1 and 3 are Philips single 12" co-axial type 12202 drivers mounted in custom enclosures. Those used for group 2 are University Sound type LR2 SA line radiators.

The system was designed and manufactured in Holland by Birchwood Acoustics and installed by Shuttlesound Ltd, who are the UK distributor for ACS. The installation process took two men four working "days", although the work was carried out at night to avoid any disruption to the theatre schedule.

5. COMMISSIONING

The main commissioning and fine tuning process took 2 days and was carried out jointly by Spectrum and Birchwood Acoustics.

The quantative acoustic criteria was based on two parameters and is given below:

i.) Reverberation Time (RT)
The arithmetic average of the 500Hz and 1000Hz octave band RTs should be adjusted to the target RT's specified in table (1).

In addition the RT characteristic should be straight to within ± 10% in the frequency range 250Hz to 2kHz and drop to lower values at higher frequencies in a 'natural' way. (it has been shown at trials in the Delft University auditorium that this high-frequency reduction in RT is subjectively desirable).

ii.) Sound Pressure Level
With ACS on, the steady state reverberant sound pressure level increase (ref ACS off) should be in the region of 2 to 3dB.

In practice the settings which had been programmed during manufacture (based on plans of the Gordon Craig and Spectrum's acoustic data), were remarkably accurate and only small adjustments were necessary to meet the above criteria.

At the end of the two days and after subjective fine-tuning, the ACS reverberation characteristics were measured and are shown in appendix A.

A listening panel has been set up consisting of acousticians, musicians and regular concert-goers to provide longer term subjective feedback which may, if necessary, result in further fine-tuning sessions.

The response from musicians and audience since ACS has been installed has been extremely positive with the majority of the comments being on the natural, un-coloured nature of the ACS sound.

Inevitably there have also been areas where improvements are possible. Based on the experience of the Gordon Craig installation, there are a number of points (listed below) which will need considering in future installations.

i.) It is subjectively desirable to include audience noise/applause in with the sampled stage signal. Failure to do this means that the audience is placed in a noticeably different acoustic than the music. This can be disconcerting since the "big hall" illusion created by the ACS reverberation is shattered everytime the audience claps. This problem is solved simply by including extra microphones directed at the audience.

ii.) It is important to ensure that all the stage area is adequately covered by the microphones.

In the Gordon Craig the only acoustically viable microphone position that was also operationally acceptable to the theatre management, was suspension from a single fly-bar towards the front of the stage.

Subjective listening during a recent large scale symphonic concert suggests that there is insufficient coverage at the extreme edges of the stage. This is being further assessed by the listening panel to decide whether adjustment is necessary.

iii.) During the fine-tuning for settings 5 and 6, it was agreed to reduce low frequency RTs slightly relative to mid-frequencies to avoid picking up HVAC noise. However, during extended listening periods the emphasis on mid-frequency reverberation becomes noticeable. Again, the listening panel is assessing whether adjustment is desirable.

6. CONCLUSIONS

Before the installation of ACS, The Gordon Craig Theatre was typical of many multi-purpose auditoria throughout the UK - good speech intelligibility but depressing for music performance.

The introduction of ACS has been extremely successful both in terms of practical manufacture/installation and also in terms of the dramatically enhanced acoustics for all types of music performance.

Whilst ACS, and the other recently developed electro-acoustic systems, do not compete acoustically with the best designed concert halls, they can provide an enormous improvement in listening conditions in auditoria such as the Gordon Craig Theatre.

With the continuing economic pressure for auditoria to fulfil many roles, such systems offer a cost-effective solution to the acoustic problems inherent in multi-purpose auditoria.

References

1. Backgrounds and Principles of the Delft Acoustical Control System (ACS). D de Uries and A J Berkhout - Proc IOA vol.10 pt. 2.
2. A new direction in electro-acoustic reverberation control - A J Berkhout - AES, 82nd convention.
3. A Holographic approach to Acoustic Control - A J Berkhout - J Audio Eng. Soc. Vol. 36 No. 12.

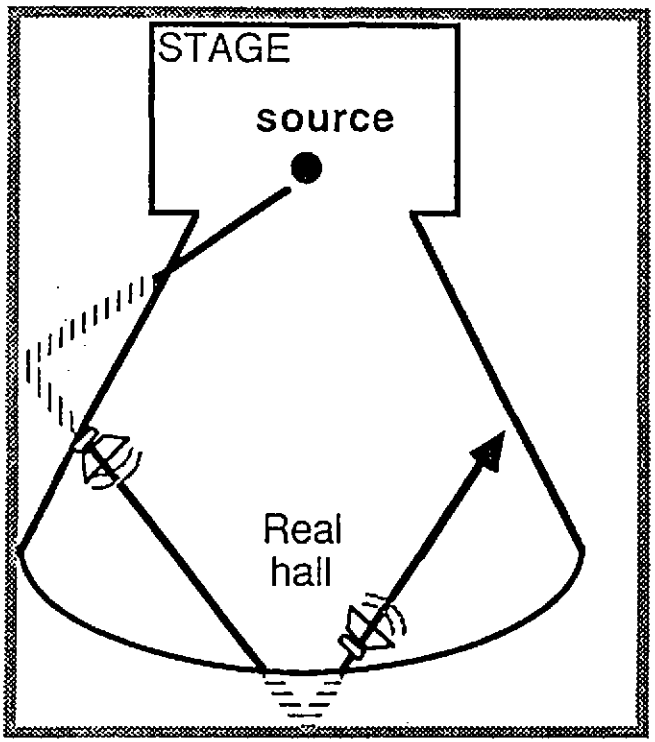
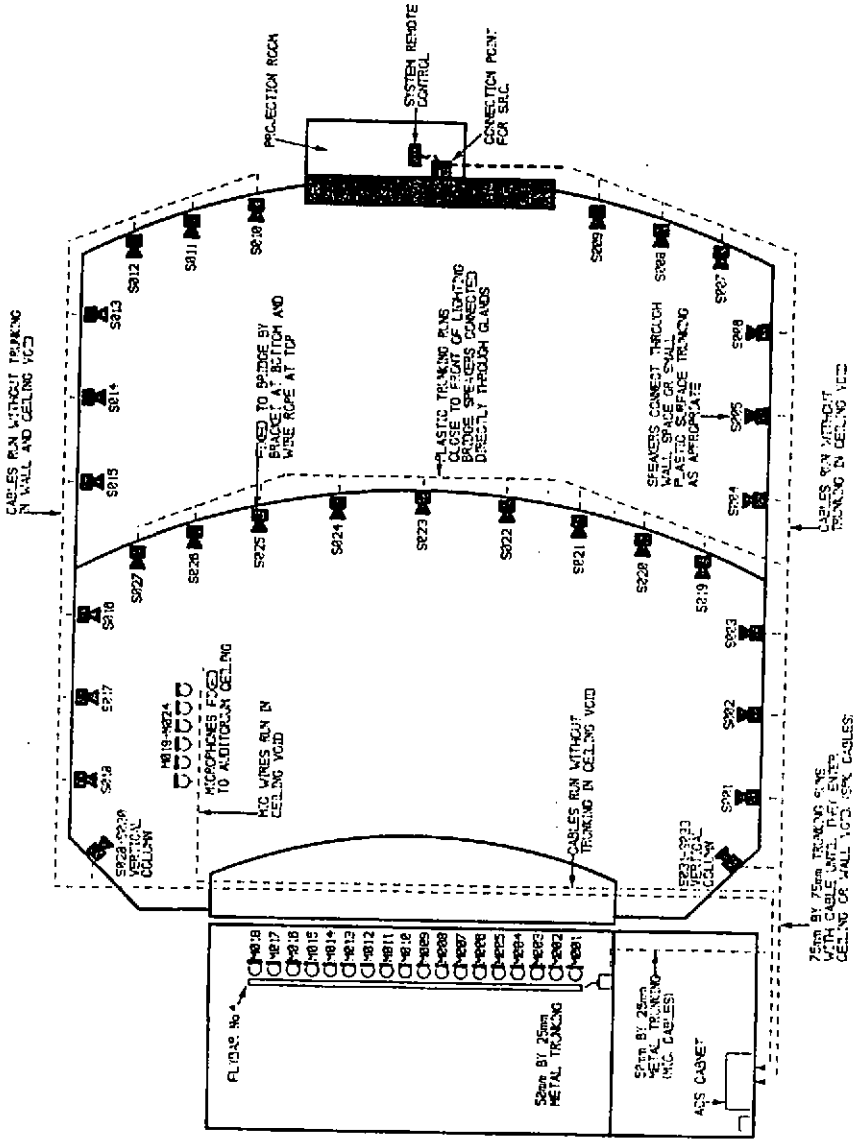
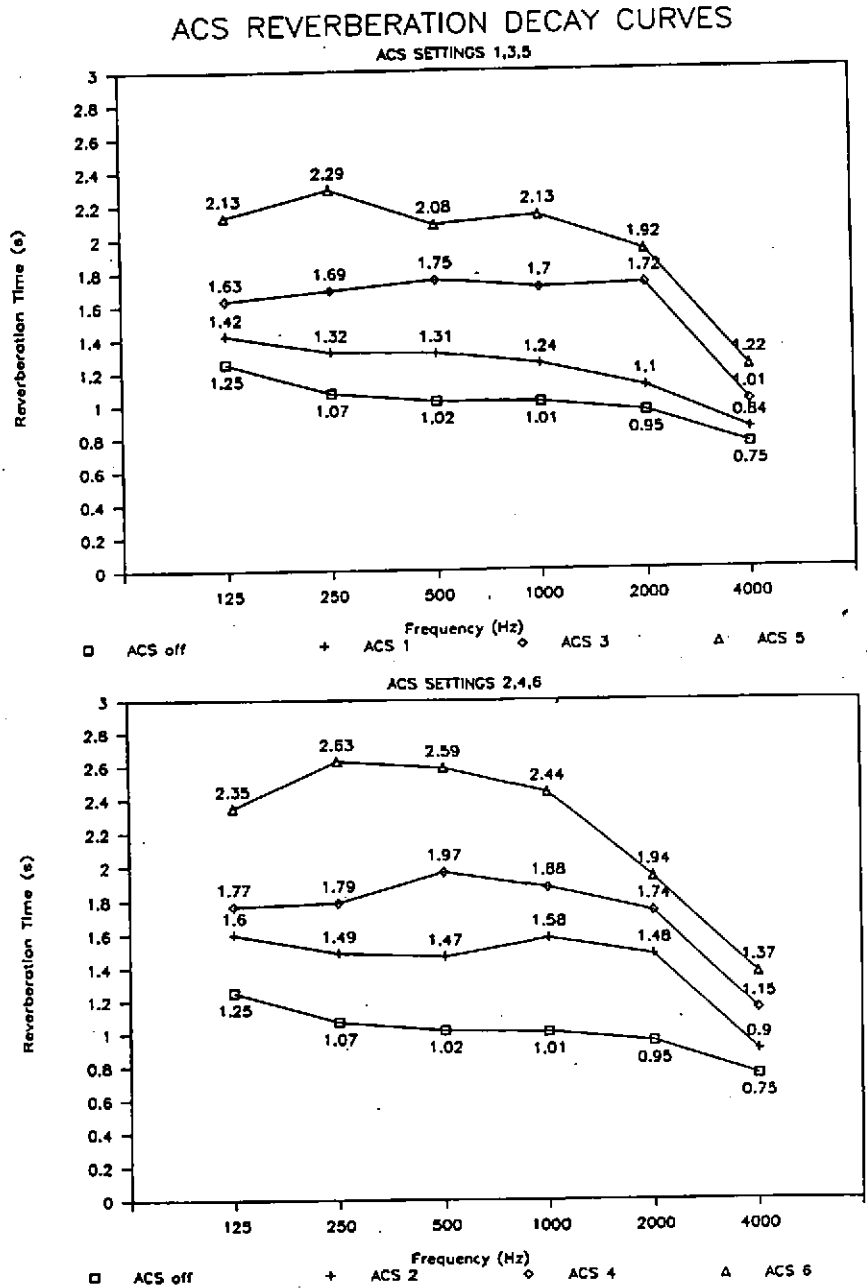


FIGURE 1 - The design concept behind ACS

ACS AT THE GORDON CRAIG THEATRE

FIGURE 2 - General layout diagram showing ACS component location




ACS REVERBERATION DECAY CURVES
ACS SETTINGS 1,3,5
Reverberation Time (s)
Frequency (Hz)
125
250
500
1000
2000
4000
2.13
2.29
2.08
2.13
1.92
1.22
1.63
1.69
1.75
1.7
1.72
1.01
1.42
1.32
1.31
1.24
1.1
0.84
1.25
1.07
1.02
1.01
0.95
0.75
ACS off
ACS 1
ACS 3
ACS 5
ACS SETTINGS 2,4,6
Reverberation Time (s)
Frequency (Hz)
2.35
2.63
2.59
2.44
1.94
1.37
1.77
1.79
1.97
1.88
1.74
1.15
1.6
1.49
1.47
1.58
1.48
0.9
1.25
1.07
1.02
1.01
0.95
0.75
ACS off
ACS 2
ACS 4
ACS 6