OLYMPIA CENTRAL CLUSTER

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INTRODUCTION

Olympia Exhibition Centre is a major exhibition venue situated in the West of London. The complex comprises, The Grand Hall, National Hall, Olympia 2 and Olympia 2 Exhibition Centre.

The space in question is the Grand Hall.

The Grand Hall is a glass and steel construction with a long reverberation time providing a quite difficult acoustic environment. (Fig. 1 shows the empty reverberation time of the space.)

In 1982 one of the first central clusters to be used in the UK was installed in the Grand Hall at Olympia.

The original cluster comprised constant-directivity horns with the usual low frequency compliment.

This cluster was used in both the nearby Earls Court Arena and Olympia. The cluster was a success in both venues and within two years a second cluster (based on the design of the first) was permanently installed in Olympia. The original remained in Earls Court.

PA REFURBISHMENT

In 1990 AMS Acoustics was commissioned to upgrade the existing sound system in the Olympia complex.

Phase 1 addressed the National Hall and Phase 2 is concerned with the Grand.

It was a pre-condition of the Local Authority that the new system was compliant with BS 7443: Sound Systems for Emergency Purposes.

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Grand Hall
The Grand Hall is used for a variety of purposes from exhibitions and meetings, Arena events (including boxing) and also pop concerts.

Criteria
The primary criteria is BS 7443 which in terms of performance, specifies an STI of ≥0.5. The Olympia management, mindful of the importance of acceptable audio, required rather a better specification and a target in excess of STI = 0.65 was proposed. Two primary factors make this target difficult:

1. Long reverberation time.

2. High sound levels in the case of boxing and other arena events.

Options
There are two basic options:

1. Distributed.

2. Central Array.

For reasons beyond the scope of this Paper it was decided to pursue the central array option.

ACHIEVABLE INTELLIGIBILITY

The achievable intelligibility will depend upon , amongst other features, direct-to-reverberant ratio.

We considered the central cluster as a point radiating sound over a prescribed area from which it is possible to estimate the directivity of the source necessary. This represents the very best case as it assumes perfect radiation.

By comparing the angle subtended by the audience surfaces and 4π steradians it is possible to estimate the theoretical minimum directivity Q.

We determined that Q was in the region 3 to 3.5.

Hence we are able to predict the minimum theoretical direct-to-reverberant ratio at selected target points.

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Listening positions varied in distance from the source and the table below gives theoretical maximum direct-to-reverberant ratio.

Distance from Source (m)	Max. attainable direct-to-reverberant ratio dB
40	1k 0 2k +1
60	1k -4 2k -3

From our experience we deduced that whilst we could not expect to improve on these figures, in practice we would expect the results to be worse and hence it was important to try and reduce any unwanted effects.

INVESTIGATIONS

We carried out four sets of tests to evaluate the problem as follows:

1. Measurement of direct-to-reverberant ratio of single units at Olympia.
2. Mathematical investigation of the polar plots.
3. Front-to-back sound power measurements.
4. Effect of cladding the loudspeakers.

Test 1 - Hall Measurements

Using the constant-directivity horns proposed for the cluster we measured the fall-off with increasing distance and compared that with our theoretical model of the Hall. Fig. 2 shows the results of our tests compared with those obtained theoretically.

Test 2 - Mathematical Models

This involved setting up a spreadsheet to evaluate the front-to-back ratio of the loudspeakers based on manufacturers data.

The routine is simple and not worthy of expansion here but in essence it integrates using standard procedures the sound pressure level over given solid radiation angles.

The routine was carried out on a complete family of constant-directivity horns but the results presented here are for 40° x 20° and 60° x 40° devices only.

The results are presented as two values. Firstly, the ratio of the power radiated within its specified radiation angle to the power radiated from the whole less the specified radiation angle. Secondly, by taking the forward facing radiation angle as 90° x 90°.

Forward Angle	Front-to-Back Ratio (dB) @ 1kHz		Front-to-Back Ratio (dB) @ 2kHz	
	40° x 20°	60° x 40°	40° x 20°	60° x 40°
As specified	-4	+2	-4	0.3
90° x 90°	+9	+9	14	8

Test 3 - PWL Measurements
The power output of the family of CD horns was measured using normal reverberation chamber PWL determination methods.

The horns were arranged as shown in fig.3. In this way we are able to determine the ratio of power radiated through the mouth of the horn and the power radiated through the horn casing.

The results are as follows:

Horn	Forward-to-Rear PWL Ratios	
	1kHz	2kHz
40° x 20°	+24	+27
60° x 40°	+20	+21

Discussion of Tests 1, 2 and 3
From our Hall tests it can be seen that the units behave within experimental error as one would predict using normal acoustical methods. It also confirmed our fears regarding the direct-to-reverberant ratio.

Comparing the results of tests 2 and 3 we are able to determine that much of the energy measured under anechoic conditions at the rear of the device originated at the front and further that the rear radiation through the case is a minor effect. Although this is not altogether surprising it is useful to quantify the effect.

We therefore needed to attempt to reduce the reverberant effects.

Test 4 - Effect of Cladding Horns
We decided to evaluate the effects of cladding the horns in a variety of ways. Tests were carried out to determine the polar plots of 60° x 40° device.

The following tests were made:

(1) Basic horn.

(2) Horn in complete enclosure.

(3) Horn in enclosure with 75mm open area.

(4) As (3) but horn set back 50mm into box.

(5) Horn in enclosure with 150mm open area.

(6) As (5) but horn set back 50mm into box.

Fig. 4 shows the cladding methods.

Results of Test 4
The results of the horn cladding are shown in figs. 5 & 6.

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The front-to-back ratio was determined from the polar plots obtained using our mathematical model. The table below shows the results based on a 'front' angle of $90^{o} \times 90^{o}$.

Table of front-to-back ratios

Condition	1kHz	2kHz	4kHz
Basic horn	1.7	5.1	10.6
Complete enclosure	2.7	5.0	9.6
Small box	2.6	5.7	10.6
Small box, loudspeaker set back	2.2	8.1	13.7
Large box	3.6	6.6	11.5
Large box, loudspeaker set back	4.4	8.9	13.2

Firstly, it should be noted that there is very little difference between the basic horn and with a horn with complete cladding. This seems to corroborate the evidence of tests 2 & 3.

The boxes with an open front however, showed a marked improvement at high frequencies. In the case of the enclosure with 75cm opening, the front-to-back improvement at 2kHz is in the region of 4dB.

CONCLUSIONS

From the measurements made, we are able to conclude that a considerable advantage will be gained by enclosing the horn units. The horns are in the process of being enclosed with 150mm open area set 50mm back into the box.

PRACTICAL REALISATION

The central cluster for Olympia is due to be hoisted into position on 16th November.

It comprises Electro-Voice MH6040 horns complete with co-axial high frequency unit together with 4 No. Electro-Voice HP4020 horns. Low frequency units are also included.

Due to weight restrictions the cluster has to be split into two, each half rigged to a main truss.

Each semi-cluster is housed on a framework approximately 5m by 4m and each weighs approximately 2000Kg.

The cluster will be used for the first time for the Olympia 'Horse of the Year' show early December 1992.

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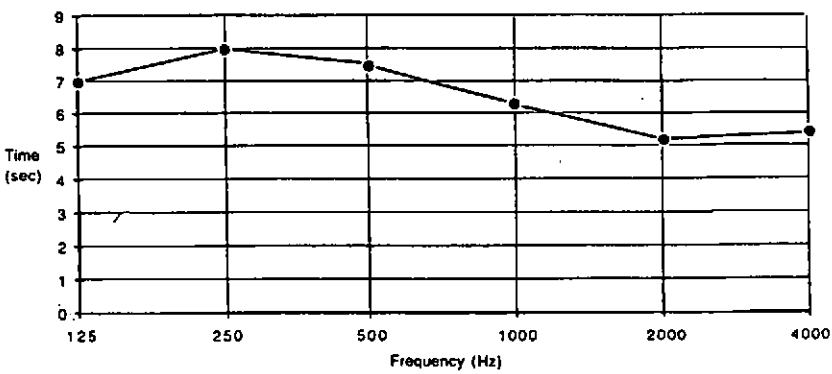
Figure 1 - Reverberation Time of Olympia Grand Hall



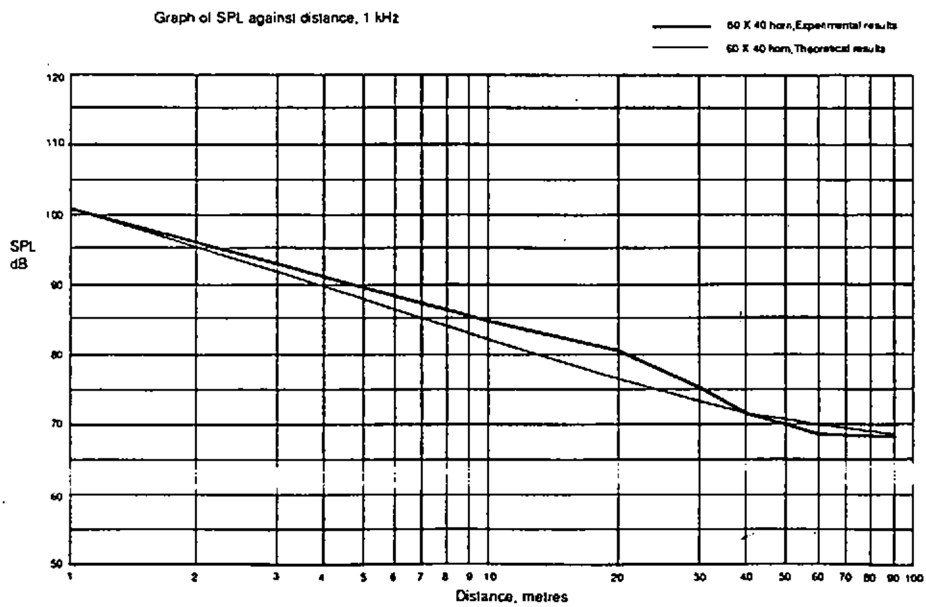


Figure 2

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Figure 3 - Test Arrangement for PWL measurements

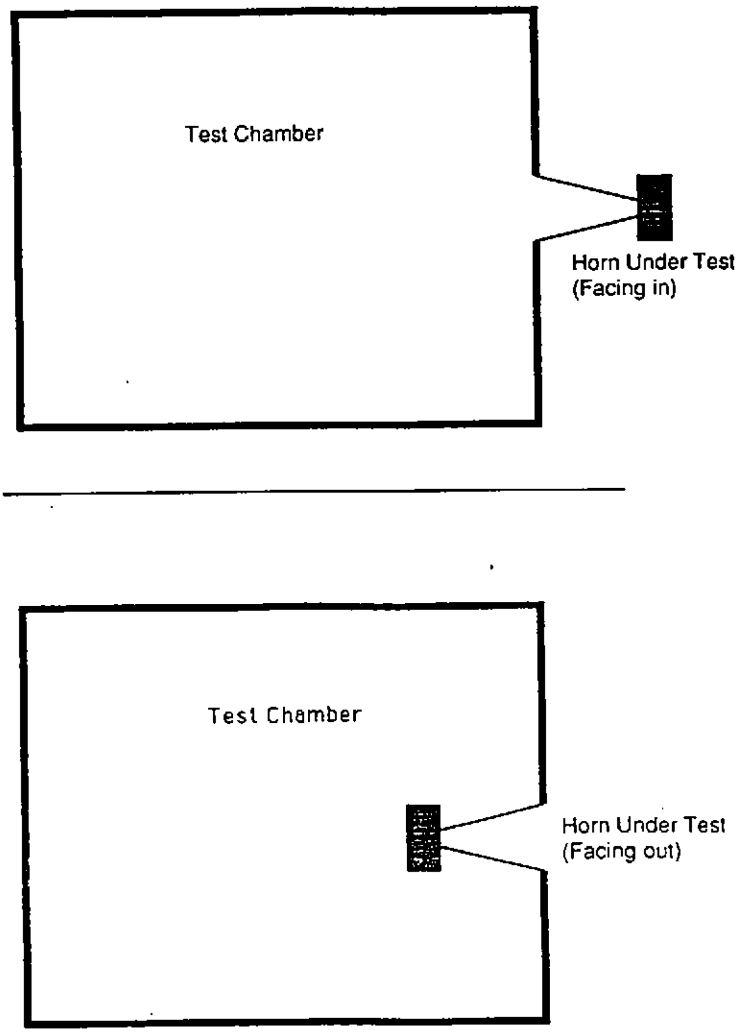
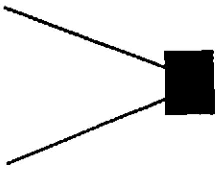
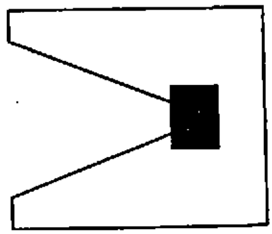


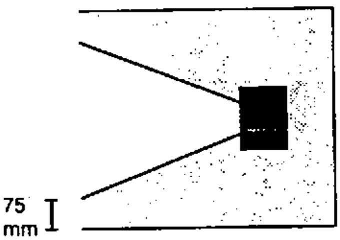
Figure 4 - Enclosure test Arrangements for 60 X 40 horn



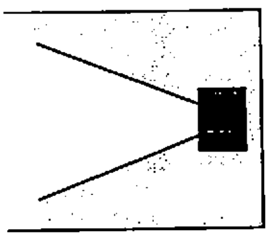
1. Basic Horn



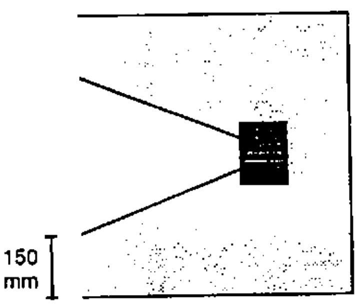
2. Horn in Complete Enclosure



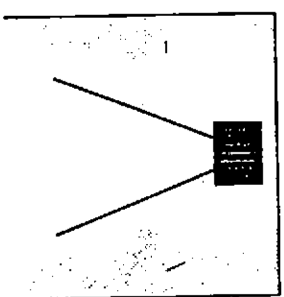
3. Horn in enclosure with 75 mm open area



4. As (3) but horn set back 50 mm into box



5. Horn in enclosure with 150 mm open area



6. As (5) but horn set back 50 mm into box

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Effect of lined enclosures on directivity, 2kHz, at 1.5 m.

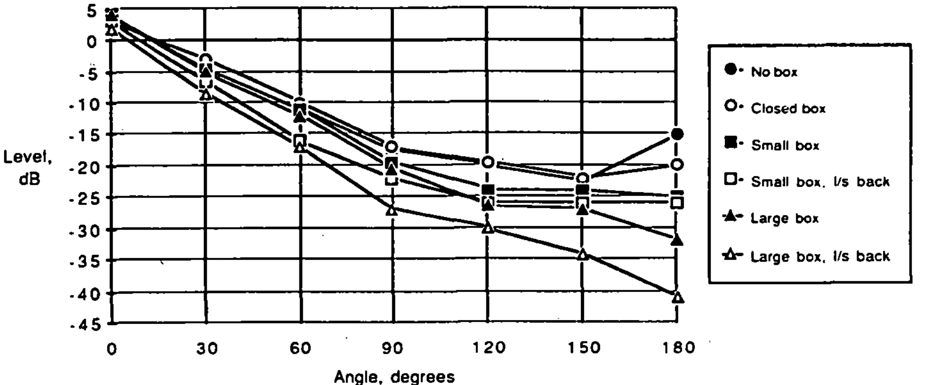

Figure 5

Effect of lined enclosures on directivity, 1kHz, at 1.5 m.

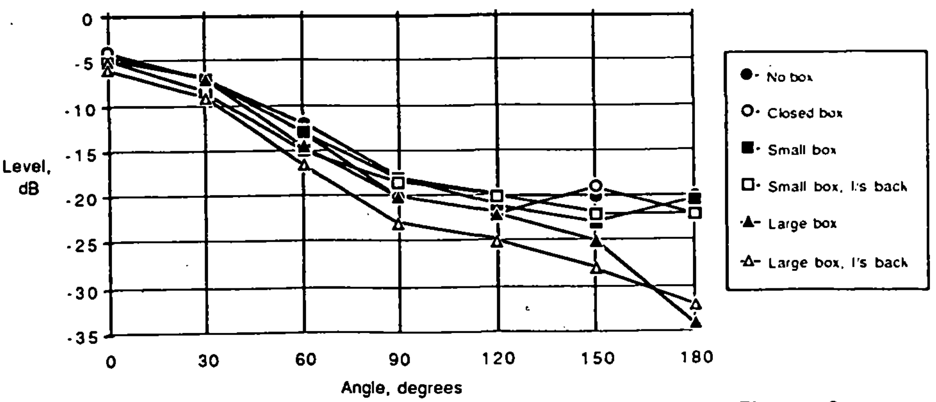

Figure 6