Southampton Mayflower

David Martin describes the installation of the new Sound System.

The sound reinforcement installation at the Mayflower Theatre required loudspeakers having wide dynamic range with a low visual footprint, appropriate to a 1920's theatre restored to its original splendour.

Sound system contractors are frequently called on to interpret tender document specifications in such a way as to satisfy the often diverse requirements of the architects, consultant, system operator and management. Their ability to interact successfully with all involved parties during the preliminary and on-site negotiations is paramount to the successful completion of a complex installation. Multi-purpose theatres, concert halls, conference centres, sports arenas and discotheques are some examples of installation customers who have specialised and often diverse needs for sound, video and lighting systems. The contractor who understands the artistic and aesthetic needs appropriate to a specific venue will be better prepared to specify and install equipment which will satisfy the customer than one who wishes to pass the buck to the architect or design consultant.

A contractor must wear many different hats: at times he will be called on to be a designer, an electrician, a painter, a negotiator, a bill collector, an acoustician and a co-ordinator. For a complex installation a contracting company must assemble a talented team who collectively have the broad spectrum of knowledge and experience essential to overcoming the many problems that will occur, and who will bring the project to a successful conclusion - on time.

History

The Mayflower Theatre, Southampton, was formerly known as the Gaumont Theatre. It was conceived during the 1920's and the building was completed in 1928. During the first few years of its operation, it was used exclusively for live theatrical preformances. In 1935 a projection system was installed and the Gaumont became a venue that could be used both for the screening of movies and for visiting artistes. Extensive use as a movie theatre continued right up and into the 1960's.

In 1950 the Gaumont was purchased by the Rank Organisation. The decline of the large movie theatre coincided with the arrival of rock 'n' roll: the Gaumont, with its large stage, played host to musical groups as diverse as Bill Haley, the Beatles, the Stones, Shirley Bassey and The Who. More recently, groups such as Queen, AC/DC, Status Quo and many others used the venue.

By the mid-80's the Gaumont was shabby but still in its original form. Rather than let it be sold for conversion to a supermarket or, worse, a bingo hall, Southampton City Council negotiated with Rank. The outcome was a plan to sell the building to Southampton City Council after it had been comprehensively restored and upgraded to suit modern theatrical and multi-media requirements.

Following a public competition, the Gaumont was renamed the Mayflower Theatre in June of 1986. It has a maximum seating capacity of 2,300, which reduces slightly if the orchestra pit is in use.

Preliminary Assessment

In mid-1985 we were approached by Rank Technical Services*. We made an initial site visit to assess possible loudspeaker positions, location of mixing console, control electronics and amplifier locations, and to gain a 'feel' for the acoustic environment. Just prior to Christmas 1985 we made a further site visit to demonstrate the proposed loudspeaker system. Rear reinforcement loudspeakers were temporarily installed forward of the first and second circles (see figure 3). A digital delay line was inserted between the source and these loudspeakers. Comprehensive speech articulation tests were conducted throughout the auditorium to the satisfaction of all assembled people, and much valuable data was collected: for instance, we proved that additional delayed loudspeakers feeding the second circle upper level were not really needed (reference to the sound control block diagram, fig.1 shows that we have made provision for second circle upper loudspeakers - this for a future enhancement of the system).

The Team

Whilst Martin Audio are primarily manufacturers, close co-operation exists with our dealers and distributors for the purpose of specifying loudspeaker systems used in installations. In addition, we maintain a direct involvement with selected clients. This enables the company to keep in close contact with end-user requirements, thereby acquiring the immediate experience needed to produce a superior product for the future.

Martin Audio has enjoyed a long-standing relationship with Quark Ltd., a specialist company formed in 1982 to handle professional sound installations, custom electronics design and manufacture, and service on all types of professional audio equipment. Peter Holmes, managing director of Quark, was therefore involved on this project from the beginning. The experience gained by the

* The project management team for the restoration and refit was provided by Rank Technical Services, a division of the Rank Organisation, and main contractor was Ernest Ireland. Client was Southampton City Leisure - a subsidiary of Southampton City Council.

two companies whilst working on the complex installation at St. David's Hall in Cardiff was to prove invaluable for this project.

The Tender

In an ideal world, every aspect and component of the sound system would be accurately identified and precisely specified: tenders would be invited, with the lowest bidder being awarded the contract. However, modern sound systems are complex and rapidly becoming even more so. Techniques for signal acquisition and processing are improving and expanding. Digital sound processing technology abounds, and is now finding its way into sound mixing consoles. Microphone technology has expanded to the point where there are over 600 different professional microphones to choose from, including many sophisticated radio microphone systems. An increasing range of loudspeakers and amplifiers makes the consultant's job more difficult: which combination is right? Producers, sound engineers and artistes have, in many cases, been exposed to both the technical complexity of the modern West End show, and have been involved with tour sound systems. In consequence, their expectations have been raised. The consultant who can accurately specify the sound system needs to be an expert and a specialist; such people do not exist, and one therefore must look to specalist companies who earn their living by designing, selling and installing the complete package. And these companies are rare.

The danger of an imprecise tender document is that the lowest bidder may put in a system which is not adequate. If, for instance, the signal cable specification is elaborate, then much of the budget can be spent with little left over for loudspeakers, mixing console and effects. The alternative approach (which we employed at The Mayflower) is to take the tender document as a guide to establishing and negotiating a budget that will ensure a satisfactory end result. This pre-supposes that the contract does not go out to open tender.

The sound and communications section of the schedule of refurbishment did in fact contain many intelligent suggestions; but much careful negotiation was needed to produce a well-balanced end result that would fit the budget.

Proscenium area. Loudspeakers can just be seen - lower columns are under temporary 'No Smoking' signs.

Feasibility and costing

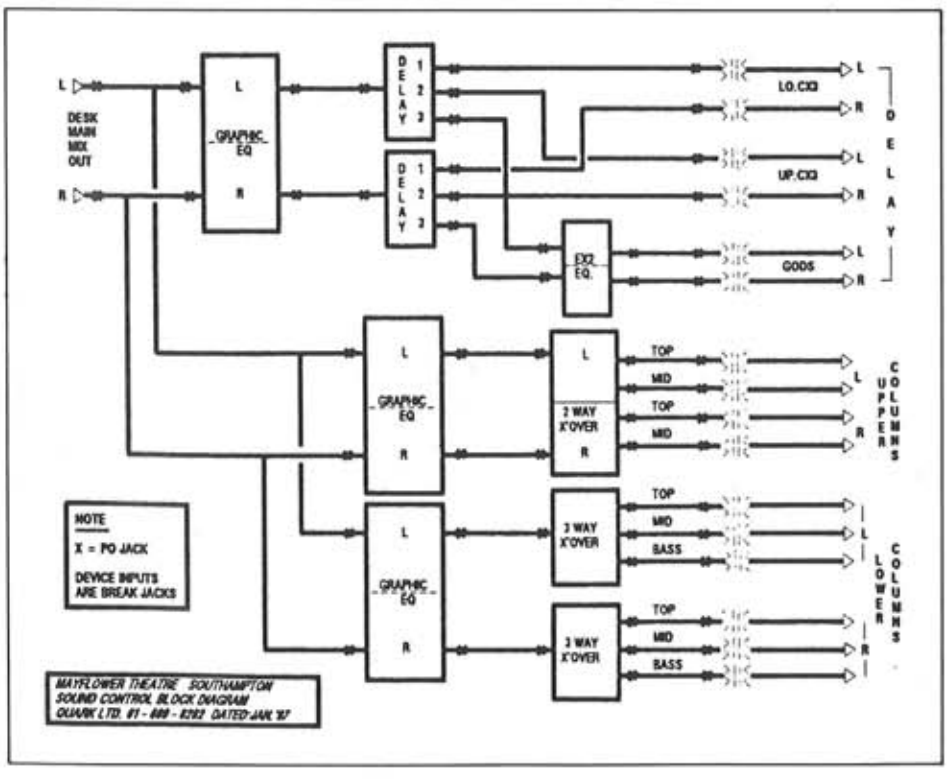
Following the demonstration at the Gaumont in December, we prepared an in-house feasibility and preliminary costing study which involved preparing a preliminary wiring diagram for the theatre and from which we could estimate the total number of man-hours required on-site. Together with a comprehensive breakdown of the equipment required, this enabled us to put a preliminary quote to Rank Technical Services, which was way over their budget!

In addition, a comprehensive report was prepared and sent to Rank for their comments. This report analysed and elaborated on every single item listed in the tender document. Many points required clarification - for instance, additional sound control positions were specified as being located on the left and right of the auditorium in the standing boxes, and had to be complete with its own jack field connected to the main jack field in the 'control room'. A quick analysis indicated that the cost of providing this facility would be prohibitive (later negotiations with the theatre consultant resulted in this requirement being deleted).

The tender document envisaged that the mixer and the associated electronic control equipment would be located at the rear of the first circle in a control room with "fully openable windows". This is an excerpt from our report:

> The mixing desk location is critical to the performance of the whole system and to the audience's enjoyment of the performance. Fundamental to the mixer location are the following requirements:
>
> a) It should be centrally located for proper control of the stereo image.
>
> b) It must be in the direct sound field of the primary loudspeakers, close enough to the stage for the mix engineer to observe every movement of the performers and every performer.
>
> c) It must not be in an area where the acoustic of that position in a room is different from the main body of the auditorium.

It therefore follows that an under-balcony location becomes more undesirable the further back under the balcony it is. It is also mandatory that there will be no acoustic obstructions, e.g. walls, either in



Close-up of actors' left CL1000 column and BSX sub bass.

front, to the sides, top or back of the chosen position.

It was eventually agreed that sound and lighting control would locate half-way back in the first circle, where it was originally.

Co-ordination

Our final quote was submitted and accepted. In addition to the system specification, we defined the parts of the installation that we were responsible for, and those of the client. For example, supply and installation of all cables would be done by the main electrical contractor to our specification. This enabled our complex system to fit the client's budget.

Quark would accept responsiblity for the wiring, on-site staff management and logistics, pre-testing of all electronics, installation, final testing and system documentation. Martin Audio would handle negotiations with the main contractor and sub-contractors, theatre consultant and architect, and would also be responsible for liaising with all other involved parties. In addition, Martin would handle finances, purchase and construction of all installation equipment.

Site Meetings

From the outset, and well before Quark could commence work on-site, I attended site meetings. These were of great importance because they ensured that the many decisions needed were made quickly, and with the full involvement of all appropriate people. At an early stage we prepared a spread sheet which listed all the stages of our installation, and displayed commencement and completion dates for each stage. As the contract progressed, this proved remarkably accurate - except that every stage commenced approximately one month after we had planned! However, our optimism in setting completion dates had allowed for a 4-week buffer period prior to Christmas 1986, so there were never any problems caused by the inevitable late start.

Signal Distribution System

For all microphone and line level signals, each feed originating from and going to the mix position was terminated at a star distribution point located in the amplifier room under the stage. At the mixer, each feed was terminated at the jack field, thence taken to its appropriate position. The signal distribution system can therefore be thought of as a signal bus system, with each point at the jack field terminating at the star distribution point, thence going to its destination. We built in considerable redundancy: each signal multiway has spare cables. Murphy's law of cable runs states that a problem in a signal cable will always occur in the least accessible part of the building (so far, we have had to swap only one cable).

Stage monitor loudspeakers are connected via a ring main, with multiple outlets. This helps keep cable losses low and enables a lighter gauge of cable to be used for long runs. Heavy gauge cable was used for the main and delayed loudspeakers, a good rule of thumb here being that cable resistance should **never** exceed 10% of the loudspeaker's rated impedance, and should be under 5%. 100-volt line distribution systems are avoided because they need very large, high quality transformers at each end. Wide bandwidth, 500W audio transformers are not a common item and add unnecessary complication and expense. The

View from centre stage showing 1st and 2nd circles. The photograph is deceptive: viewing angle from 2nd circle to stage front is 30° down.

complexity of the wiring may be judged from these facts:

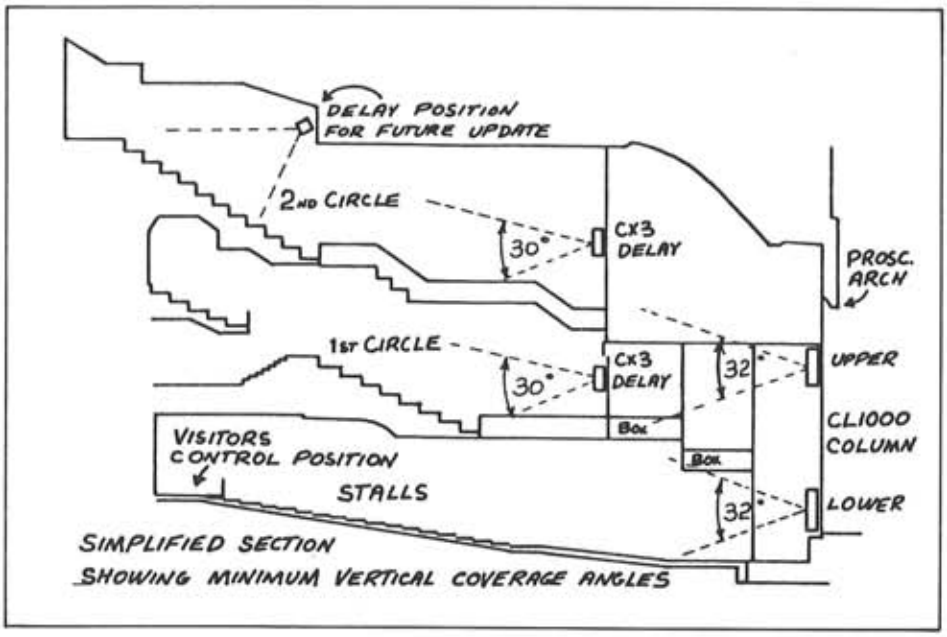
a) We estimate that there is over 16kms of twin screened cable installed.
b) There are over 1800 individual wire joints in the system.

Phase, Continuity and Testing

The importance of maintaining correct phase throughout the system cannot be overemphasized. It is common knowledge that all loudspeakers must be in phase; not so

CX3 co-axial delay loudspeaker and CL1000 columns, midway through painting.

Part-completed mixing console cable form.



well understood is the importance of microphone phase, especially for microphones in the footlights picking up distant performers. As each section of the wiring was completed, connections were verified and phase checks made, using walkie-talkies for communication. When the time came to connect the electronics, we were sure of the routing and phase of the 'wiring loom'.

It is also important to physically separate microphone and line cables from the loudspeaker cables, as otherwise with the very long cable runs which we employed, there would have been a real risk of inductive coupling, which can lead to instability. System instability may not be readily apparent - it can manifest itself only when the system is driven hard, and may take the form of an increase in distortion.

With the wiring loom in place, the system was connected. Working back from the loudspeakers, every step was verified until, at last, the console could be powered up. System verification now commenced in earnest, and the inevitable problems were identified and solved. Amplifier instability was traced to excessive input bandwidth; the addition of a 50KHz low-pass filter at all amplifier inputs effected an immediate cure.

More serious was system hum. Early production HH VX900 amplifiers were rapidly and efficiently modified by their technical staff. The Soundcraft 800 console exhibited low level hum pick-up, again solved efficiently by their technical staff who revised the internal grounding of the console on-site. In fairness, I should point out that we are operating in a low-noise theatre environment, and the hum problems that we experienced would certainly not be noticeable in rock 'n' roll or discotheque installations. Also, a high headroom 8000W sound system has a very wide dynamic range; it will magnify the slightest system hum or noise to a greater extent than will a system of limited acoustic output.

Final Test and Hand-over

Prior to Christmas 1986, we were able to demonstrate the nearly complete system using spoken voice and compact disc source. The system was 'tidied up' and all wiring documented in time for the official hand-over. The testing of a theatre sound system requires complete silence in the auditorium. The final test and de-bugging was therefore conducted late at night, after all other contractors had finished.

The official hand-over took place on January 14, and the theatre opened to the public on February 14.

The System In Use

Ironically, the new sound system was first used for a local rock band contest. It performed admirably at "near heavy metal" levels, and has subsequently been used for Peter Pan, Hans Anderson - The Musical, The Drifters and Des O'Connor.

Future acts booked to use the system include Val Doonican, John Williams, Foster Allen, and the autumn line-up includes Chorus Line, Desert Song, Camelot and Les Dawson's Christmas Pantomime. The Bournemouth Symphony Orchestra is intending to do a trial performance on the enlarged stage: without rear reflectors, will they need to mike up the percussion and horns? This is a tempting thought . . .

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CHOICE OF LOUDSPEAKERS

Several choices of loudspeakers presented themselves to us. We would have liked the opportunity to use a fully horn loaded system, recessed in the angled walls flanking each side of the proscenium arch, but the loudspeakers could not be recessed. The other option was to use column loudspeakers (this was the consultant's recommendation), but these needed to be of very slim profile, so as to be visually unobtrusive.

Column loudspeakers were once in widespread use but have declined in popularity. Poor vertical pattern control, limited acoustic output and dull sound caused by cheap transducers have contributed to their demise. However, when well designed, they have many advantages and were the logical choice for the Mayflower installation. Each column (as can be seen from the photograph) consists of a central high frequency horn, which is driven by a 2" exit compression driver. Arranged top and bottom are pairs of 30cm bass/mid drivers. These CL1000 columns may have their vertical coverage angle altered electrically: the medium throw position provides wide vertical coverage with a mid-band sensitivity of 104dB/1w/1m, while set up for long throw use (with narrow vertical coverage) sensitivity increases to 106dB/1w/1m.

The required minimum vertical coverage angles can be seen from fig. 2. It would have been possible to employ 4 CX2 loudspeakers in place of each CL1000 column; but 4 full range loudspeakers arranged vertically are very directional in the vertical plane - the directionality increasing with increase of frequency. For clean mid and high frequency control, an ideal column loudspeaker would vary its height inversely with frequency - as the wavelength decreased, it would shrink. The CL1000 columns (first used in St.David's Hall, Cardiff) approximate this condition through a careful choice of crossover points. At low frequencies, all four low frequency drivers are driven. Above 400Hz, only the inner paid radiate. The column is electronically crossed over at 1KHz, above which a 90° x 40° horn provides accurate pattern control to beyond 15KHz.

Each column can give a continuous output level of 130dB/1w/1m with considerably higher

Compact sound control area provides adequate space with no sightline obstruction.

'peak' sound levels (sensitivity figures on column loudspeakers are obtained by measuring in the far field, and referenced back to 1 metre distance using the inverse square law). The nominal lower limit for these columns is 60Hz: we therefore employed two BSX 2x18" subwoofers crossed over at 80Hz. These extend system response to 30Hz. Space and cost considerations precluded the installation of 4 BSX: this quantity would provide an ideal balance for high level use, e.g. rock 'n' roll. However, solid bass can be felt throughout the theatre, and the system's primary purpose is to provide high headroom - with consequent low distortion - for theatrical performance.

Delay loudspeakers are CX3's, using two 30cm low frequency drivers, one being a coaxial using a 1" exit titanium diaphragm driver for 30° clean vertical coverage. These units are passively crossed over, accept 500 watts of drive, and have a sensitivity of 101dB/1w/1m. Again the required vertical coverage precluded the use of stacked CX2 units with the consequent narrowing of vertical coverage.

For stage monitor loudspeakers we employed a mix of CX2 and CXW coaxials: their high efficiency and compact dimensions enable them to be hidden in a set. The coaxial design provides a true point source, with precise voice localisation, while their high acoustic output enables them to perform ideally for rock 'n' roll or star entertainer monitors.

DIGITALLY DELAYED LOUDSPEAKERS

From our initial tests, it was obvious that delayed sound to loudspeakers positioned as in fig. 2 considerably enhanced speech articulation in the first and second circle areas.

A pioneering paper published in Germany by Helmut Haas in 1947 provides guidelines for modern digitally delayed reinforcement loudspeakers. His findings as applied to the Mayflower Theatre may be summarised as follows:

a) An observer at B listening to loudspeakers C and D will perceive the sound as coming from C, provided that a packet of information sent to both arrives from C 5 milliseconds (ms) ahead of D. Under these circumstances D can be as much as 10dB louder than C before the observer perceives D to be equally loud.

b) For speech, a packet of information must arrive from D no later than 40ms after it arrives from C, or an echo will begin to be heard (absolute maximum delay delay 30ms. For music, longer delays are acceptable).

Set up procedure is simple: measuring distance from upper column (see fig. 2) we get:

BC minus BD = 31 feet (9.45m)

Speed of sound at sea level, 20°C = 1130 feet per sec. (344m/s)

Distance travelled in 1ms = 1.13 feet (0.344m)

Delayed arrival time from C is: 31/1.13 = 27.4ms

Delay setting for D is 27.4 + 5 = 32.4ms.

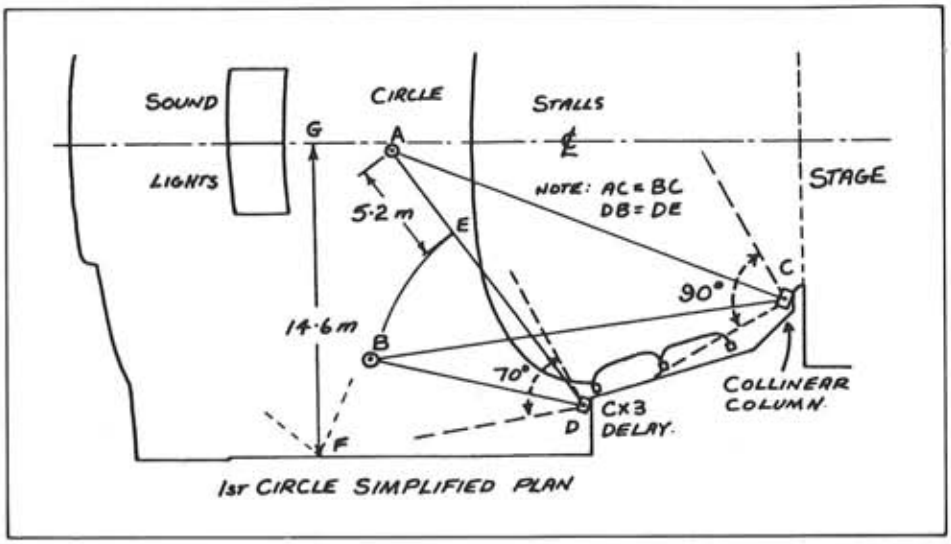
Check other positions, e.g. A for additional air delay to be sure that no echo will be heard:

$\frac{5.2m}{0.344}$ = 15.2ms + 5ms (initial delay at B)
= 20.12ms.

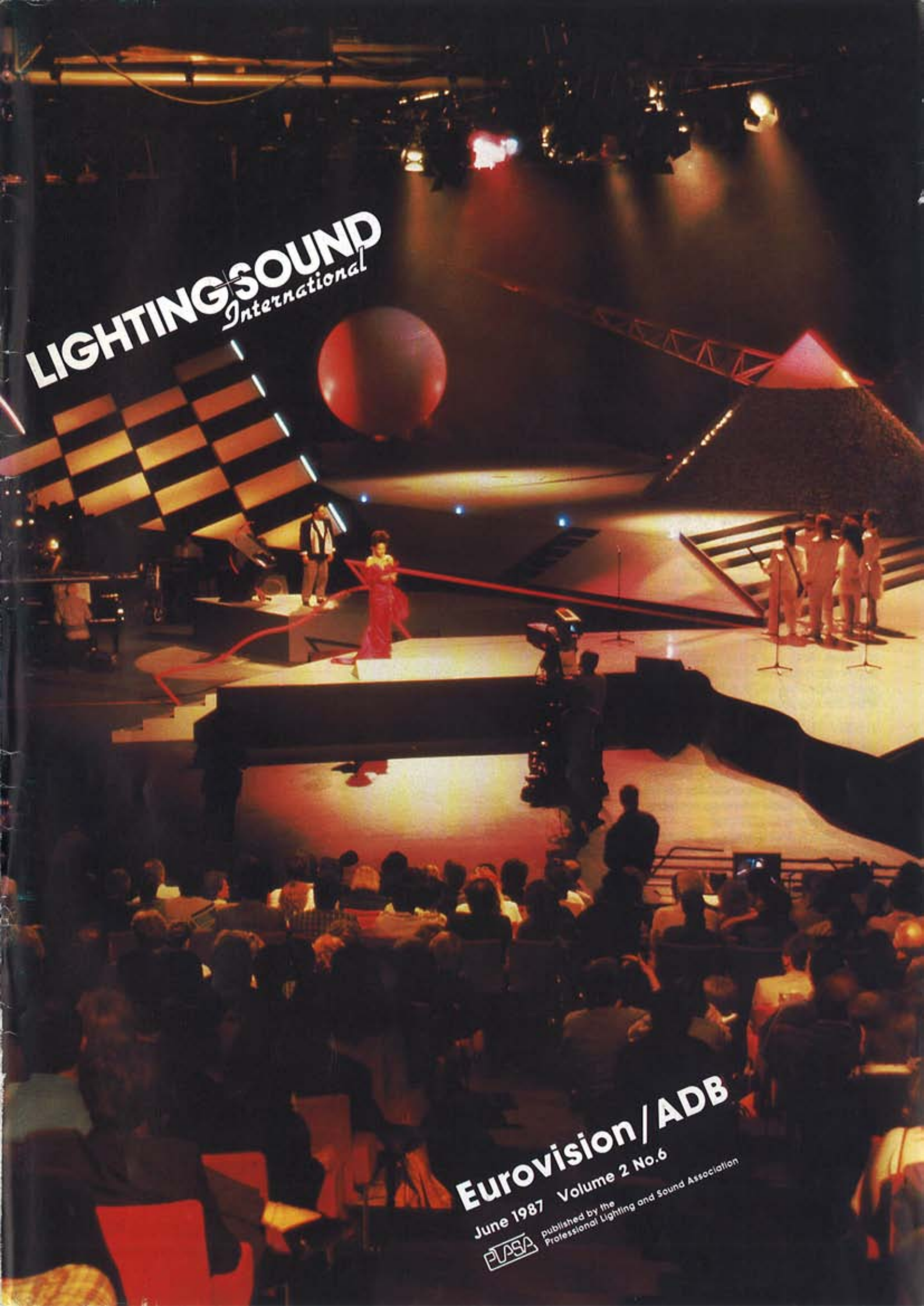
Highly satisfactory!

However, a loudspeaker positioned as at F can cause problems: it would delay sound at G by 44ms and will be worse at all positions forward of G: clearly it is important to position delay loudspeakers carefully.

Klark-Teknik DN716 delay lines were used on the delay loudspeakers: with 3 adjustable output delays, wide dynamic range and low distortion they were the logical choice.



1st CIRCLE SIMPLIFIED PLAN



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