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The Broadcasting of Music in Television

Part I
Introduction
by R. F. A. POTTINGER
(Assistant Head of Technical Operations, BBC Television Service)

Part II
Sound and Vision
by LIONEL SALTER, M.A., MUS.B., L.R.A.M.
(Head of Music Productions, BBC Television Service)

Part III
Operational Technique
by E. G. M. ALKIN
(Senior Sound Supervisor, BBC Television Service)

Part IV
Acoustic Treatment of Television Studios
by C. L. S. GILFORD, M.SC., A.M.I.E.E., F.INST.P.
(Research Department, BBC Engineering Division)

BRITISH BROADCASTING CORPORATION

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ACOUSTIC TREATMENT OF TELEVISION STUDIOS

by

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BRITISH BROADCASTING CORPORATION

FOREWORD

THIS is one of a series of Engineering Monographs published by the British Broadcasting Corporation. About six are produced every year, each dealing with a technical subject within the field of television and sound broadcasting. Each Monograph describes work that has been done by the Engineering Division of the BBC and includes, where appropriate, a survey of earlier work on the same subject. From time to time the series may include selected reprints of articles by BBC authors that have appeared in technical journals. Papers dealing with general engineering developments in broadcasting may also be included occasionally.

This series should be of interest and value to engineers engaged in the fields of broadcasting and of telecommunications generally.

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THE BROADCASTING OF MUSIC IN TELEVISION

SUMMARY

The problems involved in broadcasting music in television are discussed by different members of the BBC staff from the programme, engineering, and operational standpoints.

Part I is an introduction which outlines the special problems of both the aural and visual components of a musical programme, including the conflicting requirements of sound and vision perspective, and the difficulty of making a singer's words understandable without impairing the balance between voice and orchestra.

Part II pays particular attention to the artistic aspects, and quotes examples of situations which necessitate co-operation between producer and sound supervisor at the planning stage.

Part III discusses operational technique in more detail, and explains how the subjective effects of sound and vision—especially in relation to musical balance—make it essential to regard the two components as being of equal importance. Different forms of artificial reverberation are described, and the special techniques involved in different types of musical programme are discussed.

Part IV deals with studio acoustics for television musical programmes, and describes the work done in determining a range of reverberation times which can give, in studios of different sizes, the best compromise between the acoustical requirements of musical programmes and programmes of other types.

PART I: INTRODUCTION

by R. F. A. POTTINGER

(Assistant Head of Technical Operations, BBC Television Service)

1.1 *Evolution of Television Studio Technique*

When the BBC Television Service began in 1936 sound broadcasting was already well established and the techniques of sound production were associated with accepted working conventions in the use of technical facilities. Those conventions have naturally been influenced by subsequent developments, but the foundations had been laid. It might, therefore, be assumed that sound in the new television service presented no problem, as the techniques and equipment evolved for sound broadcasting were already available.

This might have been the case if visual techniques were based on the supposition that cameras should be used simply to show the listener what he was listening to; the television camera being placed, so to speak, next to the microphone to provide a window for the listener to see through. Such an arrangement could have been the basis of television production technique if the sense of hearing were physiologically dominant, with sight a subordinate faculty. The reverse is the case, however, and in consequence television production techniques developed with the producer's attention directed primarily to the picture, with sound adapting itself to suit.

The electronic television cameras, with which the service began, were highly sophisticated even when they first emerged from laboratory development. Most of the signal processing equipment was installed in an apparatus room adjacent to the production studio, while lenses, pick-up tube, scanning coils, signal amplifier, and viewfinder were combined in a compact and light-weight box, connected to the apparatus-room equipment by a flexible multi-cored cable.

It was possible to mount the camera on a panning head and dolly, like a film camera, and the pioneer producers quickly appreciated the manœuvrability which this form of mounting gave them. They saw that they could move both artist and camera within the scenic area. This influenced their choice of material for television programmes and the shaping of production technique. In turn, it was necessary for the microphone to be mobile, and again film-studio equipment was used by adopting the microphone boom. On these lines a combination of the elements of film studio and sound broadcasting practices was evolved and led to television working out its own rules for sound and its own types of equipment.

Some of the rules imposed difficulties which led to very poor results. For example, at one time it was believed that technical equipment must never be allowed to appear in the picture for fear of spoiling the illusion of the scene being transmitted. It was, therefore, considered wrong to show a microphone in shot, and often the result was that dialogue was indistinct, or a singer completely overwhelmed by musical accompaniment, because the microphone was moved farther and farther away from the artist while the camera tracked back to a long-shot. Now, it is accepted that the microphone may be seen in some kinds of programme provided it is small enough to be unobtrusive.

1.2 *Special Problems of Musical Programmes*

Programmes featuring music usually pose difficult and interesting problems. While it would be rash to suggest that there are no problems unsolved in the sound component of non-music programmes, it is true to say that for plays, interviews, quiz programmes, and so on, certain techniques have become normal; but for broadcasting music in television ideas are still very fluid and there is plenty of room for argument and development. The important point to be made here is that television sound cannot develop in itself separated from consideration of the picture. The producer must decide the character of sound he wants, bearing in mind that the viewer does not watch without listening, or listen without looking at the picture —he takes in both picture and sound. This leads to the important factor of perspectives. Although it has become rather unfashionable to speak of 'sound perspective' in television the fact remains that when picture and sound perspectives match they combine to give an illusion of reality which often has a vital subjective effect.

In the presentation of singers the relationship of voice and picture achieves one aspect of the illusion created by good choice of perspective, and the relationship of voice and accompaniment another. These relationships are affected by the placing of the singer's microphone and the mixture of its output with the output of orchestral microphones. They are also affected by the style of the orchestration and the treatment it demands in microphone balance and mixing. Thus, the final result is not entirely in the hands of the sound operator, for his work will be affected by the individual approach of the musician or composer responsible for the orchestration.

In the presentation of instrumentalists there are two schools of thought: one says a good 'normal' sound balance should be achieved, leaving the producer free to take close-ups of solo instruments whenever he chooses; the other says close picture should be matched by close sound, and therefore the producer should only take close shots of instruments when they are musically dominant.

Questions of this sort are important from a technical point of view, because a development in ideas of presentation will lead to a change in operational technique, which in turn might require new technical equipment.

Another important factor is the character of studio acoustics. Whereas in the BBC sound services it is customary to provide some studios acoustically treated for speech and others for music, in the television service it has not yet been practicable to provide special studios for music. This has led to a compromise in acoustic terms, and all television studios are provided with 'general-purpose' acoustic treatment so that they are acceptable on the one hand for speech in outdoor scenes and on the other for musical performance. The desired characteristic for general-purpose acoustics was found by experiment.

The development of production ideas for presenting music in television programmes had led to a great deal of discussion and experiment in the BBC. Operational techniques, equipment, and acoustic treatment have been developed accordingly, and it can be expected that the interrelated process will continue. Some aspects of these developments are described in the succeeding sections of this monograph.

PART II: SOUND AND VISION

by LIONEL SALTER, M.A., Mus.B., L.R.A.M.
(Head of Music Productions, BBC Television Service)

2.1 *The Artistic Aspects*

Not so many years ago, a television producer rehearsing a musical show in the studio startled his colleagues with the command, 'Fade all cameras and bring up sound!' 'Whatever for?' he was asked. 'I want to listen to the orchestra properly for a moment,' he replied. The looks of blank astonishment on all sides brought it home to him how unusual was his request. Dazzled with the myriad possibilities of the exciting new visual medium, television folk have often tended—and occasionally are still apt—to accept that it consists of sight *and* sound, but to treat the latter as a poor relation doomed to snatch what little consideration, facilities, and rehearsal time his all too demanding cousin is pleased to cede him. Such an attitude, of course, is not sense, particularly in musical programmes; for without the finest obtainable musical quality the whole *raison d'être* of such a programme is lost. The sound supervisor in television has, in any case, a considerably more difficult task than his opposite number in sound broadcasting. To start with, the studios in which he works, instead of being specifically designed for certain well-defined types of sound programmes, are far more general in purpose; and every scenic layout (which, naturally, will be different for each programme) will change the acoustics in some new, and unpredictable, way.

His first consideration must be to secure an acceptable sound for transmission, if necessary calling into play echo chambers, reverberation plates, or other devices; but an intelligent sound man will realize that no musician can give of his best if he feels the *ambiance* unresponsive. Not only solo instrumentalists and singers, but orchestras, are extremely sensitive to their acoustic surroundings—it will be remembered how ill at ease orchestras were at first in what seemed to them the unsympathetic dryness of the Royal Festival Hall—and need to have responsive conditions created for them.

At production conferences the sound supervisor needs to have a say in the general planning, since otherwise a camera script may create virtually insoluble problems for him. In the case of 'straight' concerts or recitals, the placing of microphones does not usually cause insuperable difficulties unless the producer insists on camera moves which result in 'masking' effects; but in operas or light musical productions, where microphones must be invisible, all kinds of complexities may arise. Microphones mounted on adjustable telescopic booms must follow singers wherever they move in the studio, but must constantly be ready to lift out of sight if a wide-angle shot is taken; and a producer's desire to take a panoramic tower shot of, say, a crowd scene may make even this impossible.

Pre-recording techniques, sometimes used in light entertainment programmes if artists' unions' regulations permit, may ease the task of artists, sound staff, and producer alike; but no such loophole exists, or would be artistically desirable, for opera (though the 'playback' method of miming to a previously made recording is common in various European countries). It is not that fairly exact synchronization of lip movements to the sound-track cannot be obtained by careful rehearsal; but the whole comportment, breathing, etc., of a miming actor rarely sustain the illusion that he is actually singing; and therefore this technique merely adds a further unreality to an art already dependent on the acceptance of a number of unrealistic conventions. With 'live' studio productions of opera, solo singers and chorus alike must be adequately covered for sound, and their voices (for all that some may be picked up on different microphones from the others) balanced in proper perspective in relation to each other as well as to the orchestra, which is nearly always in an entirely separate studio—not only so as to obtain better sound quality but so as to leave precious floor space clear for sets, actors, and cameras. Since, however, intelligibility of words is a prime consideration in television opera (for opera is drama, not merely a series of vocal set-pieces), the level of the voices may sometimes need to be discreetly 'assisted', though without noticeably reducing the rich orchestral sonority on which, say, a late Verdi opera so much depends. This calls for the exercise of the nicest judgement on the part of the sound supervisor, who, obviously for musical programmes, generally needs to have had a good deal of musical training and experience.[1,2,3]

Some knotty problems of perspective can arise in orchestral concerts on television. If the camera approaches an orchestral player—still more if it comes into close-up—an immediate contradiction of sight and sound is precipitated if the part he is playing cannot be easily distinguished by the ear; yet at the same time it would clearly be physically almost impossible, and artistically quite intolerable, if the sound perspective were constantly to be changed. The onus here must rest on the producer, who should avoid close-ups unless they are musically motivated, i.e. unless the instrument concerned has a real solo. Experiments in stereophony may suggest other solutions, but there is a difficulty which seems insuperable at present. The wide screen of the cinema does not seem likely to be practicable for domestic television within the foreseeable future, and with the usual spacing of five to ten feet between loudspeakers in a domestic stereophonic system, the sound source is too wide for the size of the picture, and the result can be most unrealistic.

2.2 *Conclusion*

In television musical programmes, sight and sound are of equal importance, and must always be treated as such. In order to avoid conflict between the aural and visual requirements when planning a production, the producer and sound supervisor must co-operate closely. For the sound component, the primary need is that the transmitted sound should be acceptable, but if this is to be achieved it is also important that the performers should feel their surroundings to be acoustically responsive. For this reason, it is not usually sufficient to add artificial reverberation to the transmitted sound only.

In television opera, miming to pre-recorded singing is not generally acceptable, and a separate studio is nearly always used for the orchestra. The balance between voice and orchestra is made very critical by the need to achieve intelligibility of words without noticeable disturbance of the musical balance.

In orchestral concerts, close-ups of individual players should be avoided unless the instruments concerned have real solos which justify them.

PART III: OPERATIONAL TECHNIQUE

by E. G. M. ALKIN

(Senior Sound Supervisor, BBC Television Service)

3.1 *The Importance of Sound in Television*

The operational aspect of broadcasting music on television is so much a hybrid of programme and engineering techniques that it is very difficult to define, and this is probably the reason why this important subject tends to be disregarded in both musical and technical literature. It is hoped that this section of the monograph may go some way towards rectifying this omission.

The techniques of music recording and sound broadcasting are so well established and have achieved such a high standard that it is easy to assume that all the problems of sound reproduction have already been solved, and to dismiss the sound element in television as relatively simple and perhaps even a little old-fashioned. In reality, television sound technique is new and still in process of evolution, because the possibilities of sound and its importance in relation to the picture are becoming increasingly realized and exploited while, at the same time, the broadening scope of pictorial presentation creates greater practical difficulties.

This suggestion that sound is simple has long been one of the major barriers to progress in the standard of television sound, because the problems of sound are all too seldom sufficiently appreciated in advance to enable them to be fully overcome, although they are often among the most difficult encountered in the technical planning of a production. It has always been difficult for people who have not had actual experience with microphones to appreciate the niceties or even the necessity of microphone technique, and the presence of a picture complicates the issue still further. The layman is quite capable of assuming that, because he can see something apparently at close quarters, he will automatically hear it, and he will certainly expect to do so. Although long-focus lenses can make it easy to take a close-up picture from a considerable distance, picking up the corresponding sound can be quite a different matter.

Television is generally thought of as a purely visual medium and it is often suggested that television sound is relatively unimportant and that a low standard is acceptable because the picture distracts the attention, or because it supplies most of the information. These assertions are based on half-truths which can be very misleading, and it would be interesting to know if the people who make them have tried the simple experiment of watching television for a lengthy period without the sound.

Certainly the picture commands the attention, but it will not hold it for long if the aural sense is not suitably occupied. It is also true that sight can be a more efficient method of imparting information than sound, but an evening spent looking without listening will provide comparatively few pictures that are self-explanatory and, perhaps surprisingly, will illustrate that, generally speaking, the more informative a programme the more the information is contained in the sound. Also, since the majority of television production stems from either a script or a score, the most common function of the picture is to illustrate what it is important to hear and, unless each item portrayed is, in fact, clearly audible, the picture will only increase the frustration through drawing attention to the discrepancy.

Just as television pictures are not intended to be watched without sound, so television sound is not complete without the pictures. For, in addition to its function of imparting information, sound has a very important role to underline the realism of the picture by suggesting third-dimensional perspective and a sense of movement, by enhancing the realism of the settings with complementary acoustics and sound effects, and by heightening visual impact with music and dynamic contrast. In drama at least, the sound and pictures should be so married as not merely to add together but multiply to produce another dimension.

3.2 *Music*

A high proportion of television programme time is given over to productions in which music supplies the basic ingredient of the programme. In such cases, the role of sound is obvious, but what is less obvious is the impact of the picture in determining the desirable characteristics of the sound, and the problems it creates in its achievement.

It might at first be thought that television sound technique is analogous to the making of films, because pictures and movement are involved, but the film-makers long ago discovered the impracticability of balancing music and taking pictures at the same time and they almost invariably pre-record the music, post-synchronize the pictures, and do a great deal of tidying-up in the cutting room and dubbing theatre.

The television sound man is faced with all the problems associated with movement and the picture and, at the same time, has to contend with continuous-take production as well as the immediacy and inevitability of sound broadcasting. His efforts, moreover, will inevitably be compared with the latter, since the result reaches the listener's home in much the same way—although the sound quality produced by a television receiver is usually inferior to that of most table model sound receivers.

Unfortunately, from this point of view, there has always been a tendency on the part of television set manufacturers to make economies on the sound side, and now, with the advent of the wide-angle tube, the position is getting worse instead of better. As tubes have become shorter, so manufacturers have been able to make economies in the size of the cabinets; loudspeakers and baffle area have got smaller —and, worse still, the loudspeaker is often relegated to the side of the set so that the high frequencies are greatly attenuated and people in close-up sound as though they were talking out of one ear. The buying public naturally appreciates the neater and more elegant appearance of the sets in the shops and cannot be expected to understand that the price of neatness is loss of entertainment value (particularly in the case of music), due to degradation of the sound quality. They often attribute this to the transmission.

Of course, these remarks are equally true of sound broadcasting listeners with poor apparatus, but the important distinction is that, whereas the serious music listener would not rely on a pocket transistor radio for such programmes, serious music on television (including symphony concerts and opera) reaches a wider and ever-increasing audience, many of whom might never listen to it on sound broadcasting and probably none of whom bought a television set with this purpose in mind. Although there are signs of a general awakening to the problem, there would seem to be little hope of much improvement in the immediate future and it is as well to face the fact squarely, even sometimes to the extent of subtly modifying balance technique accordingly.

This may at first seem a heretical doctrine because the policy of the BBC has always been that the transmission standards should cater for the highest quality listening conditions, and that it is the listener's own affair whether he takes advantage of these standards. This must be true of television also as far as the frequency characteristic and distortion content are concerned, and it will be assumed throughout that the quality of the microphones and associated apparatus is of the highest order and that the transmission frequency response is sensibly flat throughout the audio range of the system.

Balance technique, however, is a different matter, and here it is important to distinguish between technical quality and balance (i.e. character) of the sound. It can be shown that, within the range in which a balance can be said to be a matter of opinion, there are a number of styles and some are much more adversely affected by poor quality reproduction than others. Generally speaking, the answer is to err on the side of clarity, for the finer and more complicated the texture of the sound, the less satisfactory will be the result. For this reason, some orchestral balances of a distant ethereal character, which are most pleasing when listened to at loud volume on high-fidelity equipment, are most unsuitable for television, and conversely this is the reason why small, intimate orchestral combinations usually broadcast well.

On the other side of the coin is the fact that the medium of transmission is VHF and, as the service area is usually determined more by picture than by sound limitations, the problem of signal/noise ratio is less acute than it sometimes is in sound broadcasting.

3.3 *Orchestral Balance Technique*

In order to understand the particular problems of music balance for television, it is necessary to analyse the technique of sound broadcasting.

It is convenient, first of all, to consider the factors involved in broadcasting the symphony orchestra, because the instrumentation of the orchestra and the music they play are usually balanced internally (i.e. there is the correct weight of strings to balance the woodwind, brass, and percussion, etc.) and it is intended to be heard in a concert hall at some distance. The technique is therefore fairly straightforward and in a good concert hall or studio it is generally possible to broadcast the entire orchestra on one microphone. The choice of microphone and its position in the hall are determined by three basic factors:

(*a*) BALANCE between the sections of the orchestra.

(*b*) PERSPECTIVE. No section or instrument should sound incongruously close or distant.

(*c*) ACOUSTIC QUALITY. The best compromise between direct and reverberant sound (clarity and warmth of tone) commensurate with the character of the music being played.

It is a criterion of a good hall or studio that the areas satisfying each of these conflicting requirements will overlap to some extent, giving an area in which the microphone can be placed without unpleasant acoustic coloration or other unclean effects being introduced.

Assuming that the layout of the orchestra is satisfactory and that a position has been found for the microphone which gives a good general balance, it then remains to follow the rehearsals with a score so as to be able to point out to the conductor any detailed discrepancies of balance that may occur. Even the greatest conductors expect this sort of guidance from sound supervisors, as they are well aware of their inability to judge balance from their position critically enough for broadcast purposes. This applies to anybody listening to the orchestra directly, because his binaural sense gives him discriminatory powers which are denied a person listening to a monophonic broadcast, and the balance of the broadcast reproduction is made still more critical by the fact that its volume level must be a small fraction of the original.

For this reason, as well as the more obvious technical ones, a degree of volume compression must be applied in a subtle manner and without detriment to the apparent dynamics of the music. This is achieved by intelligent anticipation with the aid of a score.

The technique of broadcasting or recording a symphony orchestra could thus be summarized as the reproduction (within the limitations of low-volume monophonic listening) of the sound that would reach a listener sitting in a favourable position in the concert hall.

3.4 *Television Concerts*

When a symphony orchestra is televised, even assuming that the broadcast is from a hall or studio with suitable acoustics, further complications are introduced by the visual requirements. It may be necessary for the orchestral layout to be arranged for visual rather than for balance purposes, and this often means spacing out the musicians to a greater extent than is desirable. A compact layout that would be most suitable for sound balance would look a jumbled-up mass on the screen. This is particularly true when long-focus lenses are used from a distance in order to achieve quick cutting between close-ups and wide-angle long-shots. The resultant foreshortening can make the musicians look as though they are sitting in each other's laps. For the same reason it is often necessary to space the soloists of the orchestra from the players immediately behind them (usually in the vertical plane) in order that their close-up shots will not give exaggerated emphasis to the latter's feet. A great deal of careful thought must go into designing orchestral layouts and rostrum levels, etc., that provide clean lines and good pictures without impairing the musicians' ability to play in concert and balance with each other. Figs. 1 and 2 show the difference between the orchestral layout for a sound broadcast and a spaced layout used in a television broadcast.

In order to give visual impact to the production, and because the long-shot of a large orchestra is somewhat indistinct on the small screen, a large proportion of the time is taken up with close-up shots of individual instruments or sections. The sound mixer is at once faced with a dilemma. If he takes no notice of the picture and maintains the normal distant, flat perspective, the close-up pictures will appear most incongruous with the sound, whereas any serious attempt to match sound with picture would result in a disturbance of the perspective relationships within the orchestra that could be disastrous to the music.

The choice is clear—music must be the first consideration and any adjustments occasioned by the presence of the picture must not detract from the music in any way. But when close-up shots of soloists and sections are shown, it is essential that they are clearly audible and the balance becomes even more critical.

Fig. 1 — Typical layout for a studio sound broadcast of a symphony orchestra

Fig. 2 — Spaced layout used in a studio television broadcast of a large orchestra

This point about vision imposing the need for greater care on sound is very important and requires careful definition, as it is the reverse of normal experience, where often the ability to see assists the faculty of hearing. It is all too easy to assume that the presence of a picture provides an alibi for television sound, when usually the reverse is true. For example, the listener in the concert hall can often overcome a poor balance by looking at the orchestral instruments and thereby use his binaural sense to discriminate in favour of the required source. This ability is denied the listener to a monophonic broadcast, who is presented with a single source of sound, so that if the balance is not to his liking, there is nothing he can do about it. It is also true that speech is often made clearer by the ability to see the mouth of the speaker, but this is because of the ability to lip-read, which most people acquire in varying degrees through natural experience. In fact, it is possible to become so proficient at lip-reading that speech can be understood without any sound, but it would be an expert indeed who could hear all the notes by merely looking at the instruments.

If the solo, or important part, is submerged or indistinct, a close-up picture will not make it any clearer but will merely increase the viewer's frustration. So it emerges that a television presentation requires a sound balance that is immaculate and clear, for which it usually becomes necessary to depart from single-microphone technique and employ a degree of mixing. This must, however, be done with great subtlety in order that the instruments portrayed become clear without unduly altering in perspective, for this is the key to the situation. The concert-goer uses his eyes to select the important instrument and in so doing he hears it more clearly, but he does not leave his seat and move over to where it is, so that for him its sound perspective remains unchanged.

The requirement as far as television is concerned, therefore, is that the sound in general should have slightly more 'presence' than is usual for sound broadcasting. This does not mean that the sound should be lacking in reverberation, but rather that the direct sound should precede the indirect in a manner that provides a clear attack for each note. This is a subtle distinction, but a very important one. In a hall with live acoustics this effect can be obtained by employing a mixture of microphones that are respectively too close and too distant for single-microphone technique.

3.5 *Artificial Reverberation*

Most television music is, however, broadcast from television studios rather than concert halls, and here the question of acoustics raises a further complication. All BBC television studios so far have compromise acoustics because they may be used for anything from recitals to drama. The overhead costs of television studios are such that it has not as yet been possible to set aside a large one for music only and even then there would be conflicting acoustic requirements because only in the case of concerts and recitals would a really live acoustic be satisfactory. This is because of the problem of separation, which will be discussed later.

If a studio is to be used for the spoken word, and particularly for drama (where it may be necessary to represent the effect of an open-air scene), the acoustics must be very dead by musical standards. In television it is seldom possible to get the microphone sufficiently near to the artist (because it must be kept out of shot), and this also calls for dead acoustics. In effecting the acoustic compromise it is necessary to err on the side of being too dead for music rather than too live for drama. This is because it is impossible to subtract the effect of reverberation where too much exists, but it is possible, within certain limitations, to add reverberation by artificial means. Normally all music that is broadcast from television studios involves the use of artificial reverberation in some form or other. Because artificial reverberation plays such an important role in television and because it must be used to simulate natural acoustics—not just for special effects—the design of echo rooms and other reverberation devices assumes considerable importance. Furthermore, owing to the variety of types of music involved and the variation in studio acoustic conditions (due to changes of scenery, etc.) to which the artificial reverberation is to be added, it is necessary to have a range of different reverberation times available. For this reason each studio at the Television Centre is equipped with a continuously variable plate reverberator as well as having access to three echo rooms each with different reverberation times.

3.5.1 *The Echo Room*

The echo room consists of a reverberant room containing a loudspeaker and microphone. The input to the loudspeaker can be fed with a proportion of each output of various microphones placed about the orchestra. The degree of mixture is selected according to the requirements of each instrumental section. This technique of employing selective echo has been developed for the broadcasting of dance bands and light orchestras, where it is normal to employ graded amounts to the strings, brass, and woodwind and none to the rhythm section, but it also has an application in the televising of symphony concerts, to overcome the problem of incongruity between sound and pictures when close-up shots of the musicians are taken. By employing a separate microphone, the instrument seen in close-up can be slightly accentuated, and at the same time the proportion of its output fed to the echo room can be made larger than that of the other microphones. In this way it is possible effectively to increase the tone of the instrument without changing its perspective. The output of the echo room is then fed in desired proportion with the direct output of the main orchestral microphone.

In recent years attention has been given to adjusting the acoustics of the echo room to obtain the best results, but when it is in use the listener's ear soon recognizes the low- and middle-frequency resonances which are characteristic of a small room. The device of using a large studio as an echo room has been tried on special occasions and found to give better results, but it is obvious on economic grounds that this cannot often be used.

3.5.2 *Magnetic Reverberation*

In the search for an improvement on a small echo room, two basically different approaches have been used. In the first approach, reflections of the original sound are generated within the system just as reflections of the direct sound are produced by the walls of the studio. The BBC magnetic reverberation system[4] was of this type. In principle, the original sound was recorded on a revolving drum coated with magnetic recording medium and played back from seven heads distributed at irregular intervals around the drum. The last playback head was connected to the recording head, thus producing a continuous repetition of the seven reflections. An attenuator in the feedback circuit enabled the successive repetitions to die away at any desired rate.

Trials with this equipment showed it to be very satisfactory in supplementing the natural reverberation of the general-purpose studios, the single frequency coloration due to the regular repetitions not being serious. When used with very dead studios, however, the colorations were more obvious and, when impulsive sounds such as those of some percussion instruments were reproduced, the separate repetitions from the seven playback heads could be heard as a rapid flutter. Auxiliary apparatus was introduced to reduce this effect, but it could not be entirely eliminated, being inherent in the mode of action of the equipment.

3.5.3 *Reverberation Plate*

The place of the magnetic equipment has been taken recently by another variant of the first approach, which originated in Germany[5] and which consists essentially of a steel sheet approximately 3 ft by 6 ft, suspended vertically by its corners in a steel frame which is resiliently mounted inside a wooden box. Also mounted on the frame is a rigid porous sheet of equal size, made of resin-bonded glass wool, with suitable apparatus to enable its proximity to the steel sheet to be varied while remaining perfectly parallel to it.

Sound waves are induced into the steel plate by a moving coil exciter element welded to it at a critical point and the complex flexural vibrations induced in the plate, which give the effect of reverberation, are picked up by a crystal contact microphone welded at another carefully selected point on the sheet. The reverberation time is controlled by the damping effect of the porous plate and can be varied between one and five seconds by altering the two plates by means of a calibrated hand wheel projecting from the top of the box. This equipment is in use both in the television and sound services of the BBC. It produces impulsive sound better than the magnetic equipment, but tends to add a characteristic metallic-sounding coloration. Its low-frequency reverberation is generally less acceptable than that of a good echo room.

3.5.4 *Limitations of Artificial Reverberation*

It is clear that no source of artificial reverberation is a complete substitute for a natural acoustic and most systems introduce a considerable degree of coloration. For this reason several different sources are sometimes mixed together or used in series so that their respective colorations tend to become less distinctive. It is also common practice to use separate sources of reverberation of different time-lengths for singers and orchestras.

These stratagems, skilfully applied, can result in a tolerable broadcast, even under the most unsuitable acoustic conditions, but there still remains the problem of the effect on the performer, and really dead acoustics can have a very serious effect on performance. String players particularly are affected by lack of reverberation and often tend to force their own tone in an effort to hear themselves; this results in a harsh quality and poor ensemble and internal balance, some instruments tending to 'stick out' above the others. Careful consideration must be given to this, especially in the design of sets, so that the orchestra, and particularly the string players, are surrounded by sound-reflecting settings. Sometimes artificial roofs are also used.

The whole concept must be carefully planned from the acoustics point of view with due regard to requirements of balance and ensemble, and this is one reason for the attendance of the sound supervisor at the earliest planning stage of the production. The technique of acoustic set design should not be confused with the old 'band-shell' principle, in which the whole orchestra was placed in a reflective shell. This seldom proved satisfactory because the shell had most effect on those instruments at the back of the orchestra which were the most deeply contained within it, and it thus favoured the sections such as brass and percussion, that are most able to look after themselves, and the whole perspective of the orchestra was reversed.

Although careful design of reflective settings can provide a few early reflections which do much for the comfort and encouragement of the performers, it is not usually possible to introduce sufficient reflective material into the studio to have much effect on the reverberation time.

3.5.5 *Ambiophony*

Clearly, the ideal would be to have studios with variable acoustics that could be adjusted to meet the changing circumstances of production. Such methods as revolving reversible panels or louvres are not practicable in television studios because so much of the wall space is taken up with apparatus and most of it is usually covered with scenery anyway. Experiments have been proceeding over the past five years with a basically different approach to the problem of artificial reverberation, in which the aim is to develop an electronic system which enlivens the acoustics of the studio itself (instead of being applied only to the sound signal emanating from the studio) so that the artists get the benefit as well as the viewers. Originally simple fold-back systems were used, in which the sounds created by the performers were relayed back to them via a number of loudspeakers placed around the studio walls. Although the result was far from providing a natural effect, it did provide considerable encouragement to the artists, especially in the case of singers and choruses. The experiments were then enlarged during the course of the first series of 'International Concert Hall' programmes, using more and more loudspeakers of various types, and later a set of multi-delay equipment was obtained in conjunction with sixty-five loudspeakers placed around the walls of Studio 'G', Lime Grove, to provide the system which is now called ambiophony.[6,7]

Ambiophony is a method of creating variable acoustics in a dead studio by electro-acoustic means. The method is to employ a large number of loudspeakers, placed around the walls of the studio and fed with the orchestral sound through a multiple time-delay device. The loudspeakers are intended to re-radiate the orchestral sound in much the same way that the studio walls would do were they reflective instead of absorbent, so that the musicians are presented with a more suitable acoustic environment and can adjust their performance accordingly. They cannot do this if the reverberation is merely added afterwards.

Time delays are introduced into the loudspeaker circuits, so that the output of each loudspeaker is delayed by roughly the time that the sound of the orchestra would take to reach its position in the hall. Use is thus made of the Haas[8] effect by which sounds which are more than about 10 ms apart appear to emanate from the direction of the first one received, the later sounds influencing only the impressions of loudness and quality without spoiling the sense of direction.

As the time delays can be arranged to make the loudspeakers sound like natural reflections from the walls, it follows that by increasing the time delays beyond that calculated from their respective distances, the walls can be made to appear to recede and the studio to assume bigger proportions or a different shape. This can be a useful feature, as the optimum size of a symphony orchestra studio is much larger than the average television studio. In practice, although a large number of loudspeakers is employed, they represent only a very tiny fraction of the normal sources of natural reflections, so that the amount by which the apparent size can be increased without the loudspeakers becoming obvious as point sources is clearly limited and, even so, every effort has to be made to obtain a diffuse effect.

The present delay equipment now installed in Television Centre consists of a tape loop with eight reproducing heads which can be moved to alter the delays and coupled together in various ways to deliver four outputs. Normally the first and last heads are used singly to supply the loudspeakers nearest and farthest from the orchestra respectively and the other two outputs consist of mixtures of three reproducing heads each. To increase the random effect further, the loudspeakers are not connected strictly according to the delay appropriate to their position, but are mixed in such a way that the general trend is correct. The apparent reverberation time can be increased by introducing echo into the microphone output feeding the device, or by creating regeneration within it by feeding some of the output of the last reproducing head back into the record head.

The system has also a natural regeneration because a proportion of the output of the loudspeakers is picked up by the microphone supplying their input and a major problem is to achieve sufficient output from the loudspeakers to be evident in spite of the loudness of the orchestra without the system becoming unstable and developing into howl-round. In the BBC experiments, this has been largely overcome by employing two completely separate microphone systems, one for broadcast and one to feed the ambiophony only, the latter being much closer and designed to favour those sections of the orchestra (usually strings and woodwind) most affected by the deficiency of the studio acoustics.

The most obvious use for ambiophony is in the televising of symphony concerts, when its application is reasonably straightforward, but investigations are proceeding into the possibilities of its use for other types of music production.

It is obvious that, as soon as vocalists' microphones are employed, and especially if they are moving around on booms, there will be considerable complication due to pick-up of the loudspeaker output on the booms. As the ambiophony delay system is designed to create a natural effect from the position of the orchestra, it follows that there could be positions in the studio where the effect might be most unnatural.

3.6 *The Problem of Separation*

There is also the problem of separation. This could be termed the major problem of television sound. It stems from the fact that, in order to keep the vocalist's microphone out of the picture, it is usually too far away from the vocalist, with the result that it picks up much too great a proportion of the accompaniment. Even if this does not result in the vocalist being swamped by the accompaniment, it means that the balance of the orchestra is spoiled, as the microphone is usually far from being in the correct position for a good orchestral balance.

3.7 *Televised Opera*

This problem of separation is particularly acute in the televising of opera, where a large orchestra is usually employed and where the production often calls for wide-angle long-shots for spectacular effect. In fact, the problem of obtaining good operatic sound and at the same time suitable pictures is so difficult that most of the world's broadcasting organizations do not attempt it, preferring to adopt the 'playback' technique.

There are two basic forms of playback; one in which the parts are played by actors miming to singers' voices, usually pre-recorded, and the other in which the singers mime to their own pre-recorded voices. The first method has the obvious advantage that actors can usually be found who are more suitable visually than some singers, but very extensive rehearsal is required for actors to learn the libretto with sufficient accuracy for mime purposes and, even then, difference in comportment and phrasing make the mime all too obvious in close-up. The second method is, therefore, usually more successful, but when a singer mimes to his own voice it is difficult to resist the temptation to concentrate too much on appearances and the whole thing has an unreal quality.

The BBC has shown that, provided the technical problems can be overcome, live opera is much more satisfactory than any form of mime. This fact was clearly demonstrated at the UNESCO Congress on Opera and Ballet in Television, held in Salzburg in 1959.[9] Of the very large number of operas presented from all over the world, only those from the BBC, NBC, and CBC were produced 'live', and it was generally agreed that they had a spontaneity and conviction lacking in those made to 'playback'.

3.7.1 *Remote Orchestra Technique*

Unless the opera is very small and intimate in character, the first essential, if good sound and freedom of visual presentation are to be obtained, is to employ a separate studio for the orchestra. This provides the double advantage of increasing studio space and reducing the problems of separation. Ideally, the remote orchestra studio should, for reasons of convenience, be located on the same premises, but very successful results have been obtained using concert halls separated from the vision studio by several miles. It is, of course, essential that close contact is maintained between singers and orchestra throughout the action, and this is achieved in the following ways:

The singers hear the orchestra by means of directional loudspeakers mounted on the microphone booms and tracked about the studio to follow the action. Six-foot column loudspeakers are used mounted vertically on the boom prams so that their output is directed towards the action and on the dead side of the unidirectional microphone. In this way the amount of orchestral sound fed into the vision studio is minimized and localized, and this helps to enable the boom microphones to work at greater distances from the singers and also prevents the vision studio from becoming a vast 'echo room' to the detriment of the orchestral sound. It is also necessary for the conductor to hear the singers. It would be a simple matter just to provide him with a pair of headphones, but it is extremely difficult for a conductor to control a large orchestra through a complicated score with his head buried in headphones. To obviate this problem, and at the same time provide full two-way sound relay between the studios without howlback, two special types of loudspeaker have been devised by the BBC Engineering Division.

(*a*) *The Hood Loudspeaker*

The first is the hood loudspeaker, which consists of a special baffle forming a pyramid 4 ft square by 2 ft high, containing an 8-in. loudspeaker, mounted on an inner baffle, the space between which and the outer shell being packed with fibre glass. The hood is suspended over the conductor, inclined slightly to the rear, so as not to interfere with his hands and in such a manner that the sound from the singers' remote studio is relayed to him and, to a lesser extent, to the orchestra, while sufficiently shielding it from the orchestral microphone to prevent a howl-round taking place.

This device, which was first used for the opera *Salome*, has proved very successful in practice and has resulted in clear and easy loudspeaker communications between orchestra and singers, even when the microphones are at considerable distances. Whenever possible, the mixing of singers with orchestra should be done in the orchestral studio, the sound mixer in the vision studio selecting and mixing the vocal microphones so as to present the orchestral sound mixer with one vocal source. This is because it is not possible to balance an accompaniment satisfactorily unless the vocal part is taken into account. The remote studio thus becomes the master from the sound point of view. There is, however, sometimes a requirement for the conductor to be seen in shot and, as the hood loudspeaker would look ugly, a special loudspeaker mounting has been made for use in shot.

(*b*) *The Music Stand Loudspeaker*

This consists of a wooden top fitting on a music stand and incorporating a slit covered with expanded metal, below which are mounted three 3-in. eliptical loudspeakers to form a line source, which beams the sound towards the conductor's head. Apart from its use in shot, the device can be used to assist in the elimination of time-lag, when the vocalist is in the same studio but a long way away, or as a standby for the hood in remote operation.

3.7.2 *The Conductor's Camera*

To overcome the problem of the occasions, which are quite frequent in opera, when the singers require a lead from the conductor, a television camera is used in the orchestral studio to relay a picture of him on a closed circuit to monitor screens arranged around the action studio (usually over the top of the sets). A *repetiteur* is then employed to stand beside the cameras in the television studio and relay the conductor's beat while watching the screens.

Fig. 3 shows both the above-mentioned types of loudspeaker, as well as the working and standby closed-circuit cameras, in a remote-orchestra operatic broadcast.

By these means, perfect synchronism can be achieved between orchestra and artists, regardless of their movement, and the risk of serious time-lag, which is almost inevitable if the orchestra is at the other end of the same studio, is eliminated. At the same time, the use of remote orchestra technique results in considerable improvement in orchestral balance and, above all, greater freedom of presentation. Yet another advantage is the ability to divide the studios and rehearse separately when required, thereby making more efficient use of the rehearsal time. It follows that there should be a general maxim for television music production that, in most cases when the orchestra is not required to be seen in shot, it should be in a separate studio from the action.

3.7.3 *Pre-recorded Sequences*

Some of the more ambitious opera productions have sequences which, for reasons of size, complexity or convenience of scene changing, etc., require to be filmed or pre-recorded in advance. To pre-record the music would be prohibitively expensive, so the orchestra has to be added 'live' at the time of transmission. The problem of synchronizing the live music with the recorded material is over-

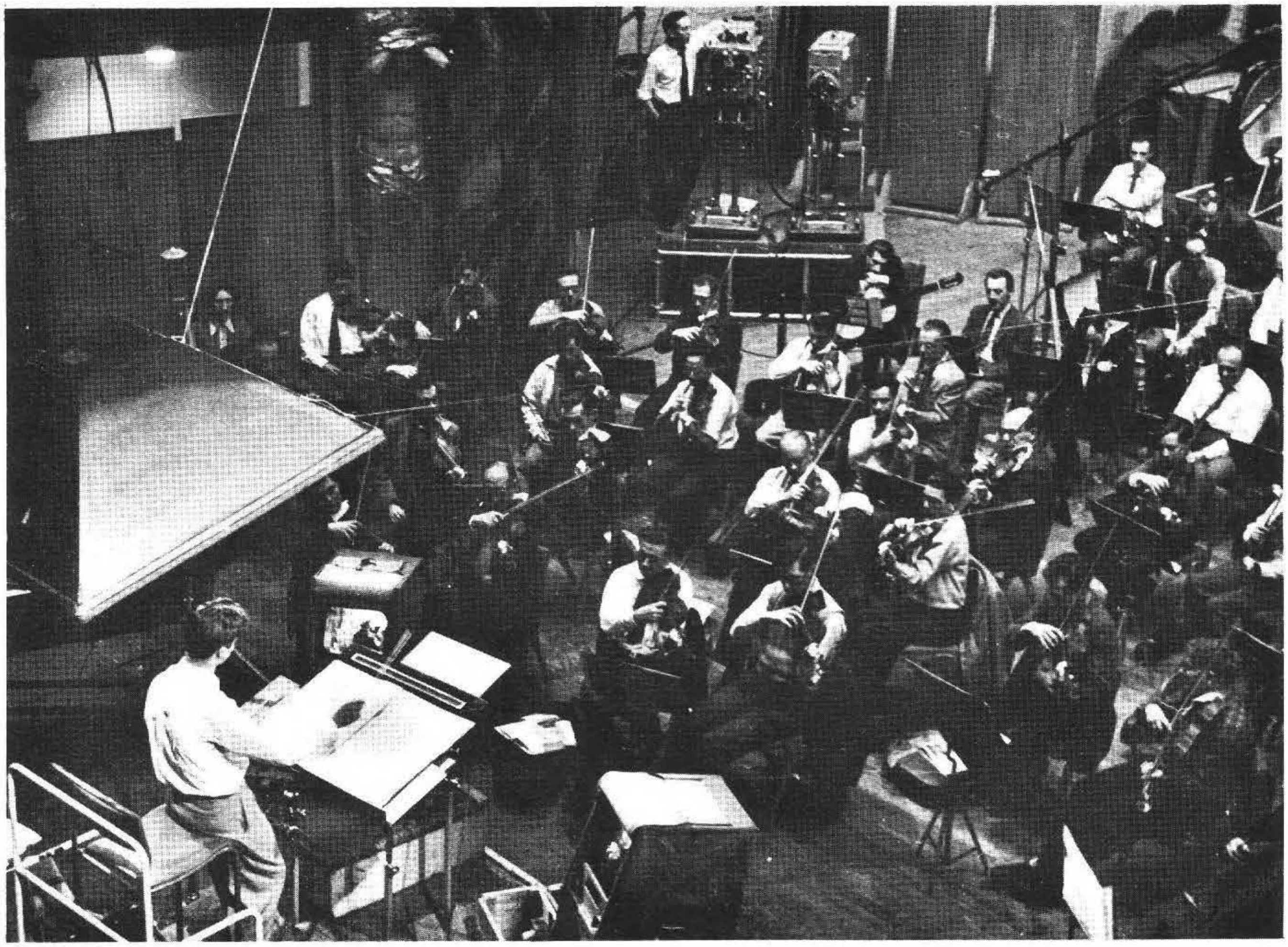

Fig. 3 — The hood and music-stand loudspeakers in use in a remote-orchestra operatic broadcast. The television cameras in the background provide a view of the conductor on monitors in the television studio, linked by closed circuit

come by recording a special guide track to which the film or telerecording is made and which is fed to the conductor's headphones only. The guide track usually consists of a piano version of the score, accompanied by spoken bar counts and any instructions or warning of tempo changes, etc., that the conductor might require. It is often necessary to record vocal sound on these pre-recordings and this part of the sound track must be broadcast. In these cases, the conductor's guide is limited to a few seconds to establish tempo prior to the vocal entry and a silent bar is provided in which the sound mixer must fade up the recorded sound to transmission. Any subsequent breaks in the vocal part are dealt with by interposing a further section of guide track with a silent bar at each end in which to fade out and in. This is naturally a somewhat risky practice and, whenever possible, use should be made of twin-track recording in order to keep the guide track and transmission track separate. One method with film is to employ a combined optical track for guide purposes and a synchronized separate magnetic track for transmission. It is sometimes desirable to pre-record voices in sound only, so that use can be made of mime technique to overcome particularly difficult situations created, for example, by exceptionally long shots. Again, a vocal and a guide track are required, and this is the principal reason why all quarter-inch tape machines for BBC television are to be standardized as twin-track.

3.7.4 *The Incompatibility of Televised Opera*

Having overcome the practical problems of opera production on television, there remains the problem of adaptation. Most operas, and particularly the larger classical ones, are written for a grand, and sometimes gargantuan, theatrical effect. It matters little if the libretto is indistinct (in fact, sometimes several different languages have been used at the same time), or if the situation makes sense. The whole presentation is separated from reality by the proscenium arch and the footlights. Opera in the theatre is a spectacle of colour and a satisfying blend of vocal and orchestral tone. Television opera presentation, on the other hand, tends to take the form of a music drama; the proscenium is forgotten and the action shot in close-up with realistic settings. Moreover, it is projected into the sober atmosphere of the home fireside, where it is seen by a great many people who are not opera fans and who do not know the plot or understand the conventions. (A televised opera can play to an audience of four or five millions.)

Under these conditions, a conventional opera balance can be most incongruous, and an artist seen in close-up made to look ridiculous mouthing inaudible, or at least indistinct, words. Yet if the accompaniment is sufficiently suppressed to enable the words to be clearly heard, all musical perspective is lost and it ceases to be opera. Here again, the television sound mixer is faced with a dilemma, caught between two diametrically opposed requirements. All that can be done is to adopt a technique of weaving the two sources together through every bar of the music so as to make the utmost of each; a process that demands considerable skill and sensitivity, particularly as it must be carried out without detriment to the artist's intended dynamics.

3.7.5 *The Question of Vocal Dynamics*

Part of an artist's musical interpretation is bound up with the dynamics that he applies to the score. When broadcasting or recording under static conditions, the vocalist-microphone distance remains constant and it follows that the microphone output level will follow the artist's intentions. In television, however, it is necessary to move the microphone continuously and sometimes to switch between a succession of fixed microphones while the artist is singing, in order to accommodate his movement about the set or to clear camera shots of varying lengths. Under these conditions, the output from the microphones will be continually varying, and these variations may bear no relation to the artist's intended dynamics whatsoever. It is, therefore, necessary for the sound mixer to be thoroughly conversant with the work and the artist's interpretation in order to be able, not merely to 'iron out' the variations, but to re-interpret his dynamics for him. This is a factor that concerns not only opera but all television music where movement is involved.

3.8 *Ballet*

The problems of television ballet from the sound point of view are somewhat similar to those of opera in as much as a large orchestra is usually employed and it is, therefore, not possible to accommodate it and the large sets needed for the action in the same studio. It is, therefore, necessary to employ another studio for the orchestra, and advantage is usually taken of the more suitable acoustics of one of the sound broadcasting studios for the purpose. A further complication is introduced, however, over the question of rehearsals. For economic reasons, it is necessary to cut orchestral rehearsal time to that required for rehearsing the music, and rehearsals conducted on this basis are of little value to a producer wishing to rehearse camera shots of the dancers. Therefore, ballet music is usually pre-recorded in advance, but the recording is not used for rehearsal as the extra performance fees which would then be involved would increase the cost. This makes it necessary to take elaborate precautions to ensure that the recorded tempi are correct (often the principal dancers attend the recording) and later a piano transcription is made, the pianist listening to the orchestral recording while he records the piano version. Even the final run-through has to be conducted in this way, and, as the dancers do not hear the orchestral recording until the transmission, great care must be taken over the balance and the positioning of the loudspeakers in the action studio so as to ensure that every item in the score is clearly audible, otherwise an important cue could be missed. Normally, a combination of high-quality floor-standing loudspeakers and slung column loudspeakers is used, positioned according to the action.

It has been discovered that if the sound is limited entirely to that of the orchestra, the production has an unreal quality. To give conviction to the pictures, effects microphones are employed in a subtle manner to introduce noises from the dancers' feet and rustle of costumes, etc., particularly when in close-up.

Sometimes in ballet, the dancers start before the music, and the conductor is responsible for giving the down-beat precisely on cue. When the music has been pre-recorded, the onus falls on the tape operator to start his machine with similar precision.

3.9 *Light Music*

The sound technique associated with so-called 'straight music', complicated as it is, is simple compared with that involved in the televising of modern light music (which forms the bulk of the output). The basic problem stems from the fact that modern orchestras and orchestrations have developed alongside the microphone, and dance bands in particular rely heavily on the use of microphone technique to achieve balance, even in the dance hall or theatre.

For broadcast or recording purposes, an accepted microphone technique has evolved and the musical arrangers have become accustomed to writing their scores with little thought of internal balance on the assumption that the sound balancer will sort it out for them. In recent years, this technique has been taken a step further and arrangers and sound engineers have co-operated to produce new and more exciting musical effects. Nowadays the vast majority of star performers in the light entertainment field are recording artists, and many have built their reputation on a particular sound 'gimmick' devised by their recording company. A typical example is the exaggerated use of echo in association with very close microphone technique, which can give the effect of great power to a very small voice. When these artists appear on television, their admirers naturally expect them to sound as they do on their records, despite the fact that the necessary conditions in the recording studio cannot possibly be reproduced for most television productions. In recording, singers are often completely separated from the orchestra in a soundproof booth, or their voices are recorded at a separate session.

In television, orchestral layouts are often designed for visual rather than balance purposes, studio acoustics are usually unsatisfactory, and the artists move about or work too far away from the microphone to achieve adequate separation. The sound balancer, therefore, has to reorientate his mixing technique and make continuous adjustments not only to balance the orchestration, but also to compensate for the varying orchestral sound picked up on the moving microphones.

There are encouraging signs that musical arrangers are becoming aware of the particular nature of the television medium and writing for it. This does not imply that it is necessary to restrict artistic creativeness, but that, as in the case of nearly all television sound problems, the solution lies in intelligent anticipation at the earliest stage.

3.10 *Conclusion*

Sound is a vital and integral part of any television production. The desirable aesthetic standard of sound is not diminished by the presence of the visual aspect, although the problems in its achievement (particularly in the case of music) are usually greatly increased by it. The picture should often supply the reason for a particular quality of sound. It should never supply the excuse for it.

The home listener has become accustomed to accept as normal a very high standard of sound quality and operation in sound broadcasts and recordings. He cannot be expected to make allowance for problems that he probably does not understand and often it is the artist's reputation that is at stake.

It would be a comparatively simple matter to achieve high-quality sound at all times by imposing serious restrictions upon the scope of visual presentation, but such a policy is considered unlikely to be in the general interests of the service.

Television sound is thus presented with the interesting challenge to produce results comparable with the best recordings, sound broadcasts, and films under conditions that would be considered unacceptable to these media. This challenge is being met by the use of all existing sound techniques and by a continuous search for new equipment and methods appropriate to the particular problems of television. There is still considerable scope for the design of new apparatus such as microphone booms, radio microphones, and control equipment, and for the development of narrow acceptance-angle microphones, etc. Continued improvement in standards can be expected from the furtherance of good co-operation and mutual understanding of the problems between programme and engineering personnel.

PART IV: ACOUSTIC TREATMENT OF TELEVISION STUDIOS

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4.1 *Necessity for General-purpose Studios*

One of the most important factors which create special problems in television broadcasting of music, as opposed to sound broadcasting, is that the studios must in general be suitable for other types of programme, whereas with sound studios this is not in general required. Compared with a sound studio for a similar purpose a television studio will generally be larger and more expensively equipped. There must be room for a cyclorama, scenery, and the movement of cameras and microphone booms. The ceiling must be higher to allow lighting grids and scenery hoists to be accommodated, and the various surfaces must carry cables, winches, and large ventilation trunking. Thus, while it has been possible to achieve a great deal of specialization in the use of sound studios, the comparatively small number of television studios must be used for the production of almost any type of programme.

A single studio will therefore have to be used for drama, discussion or panel programmes, light entertainment or music. The acoustic treatment of studios tends to be more appropriate to speech than to music, partly because musical programmes are in a minority but also because this leads to a more practical compromise.

The acoustic requirements for the two types of programme conflict quite seriously. Those for speech are determined by the fact that most scenes are shot from short distances varying from a few feet with individual speakers to several yards in typical dramatic situations. The microphone must be kept out of shot and is often necessarily farther from the speaker than is desirable. The correct acoustic perspective can be obtained in such circumstances only in a studio of extremely short reverberation time in relation to the volume.

With symphonic music, on the other hand, a comparatively long reverberation time is required to give acceptable quality. The acoustic treatment of a studio to be used for all types of programme must be a matter of very careful compromise, and the possibility always remains that for certain programmes the acoustics of the studio will have to be disguised or enhanced by various devices. The following sections describe the experiments carried out during the last twelve years to establish the best compromise treatment.

4.2 *Early Work on the Television Broadcasting of Music*

In the years immediately following the reopening of the Television Service after the war, the only studios were the two at Alexandra Palace. They were small and too reverberant in the bass. Though there were some successful transmissions of music, large orchestras could not be accommodated, while the quality of orchestral music accompanying ballet or variety was impaired by the cramped conditions, extraneous noise, and difficult microphone and monitoring conditions.

When the Lime Grove studios became available, conditions were completely changed. The studios were large and very heavily damped with 4 in. (10 cm) of rockwool over most of the walls and ceiling. Fig. 4, for example, shows the reverberation characteristic of Studio D, Lime Grove, in its original condition. The optimum reverberation time for music in a studio of the same volume, 134,000 cu. ft (3800 m^3), would be about 1·4 sec at low and middle frequencies and the first experimental rehearsals of music gave quite unacceptable results; piano tone was wooden and lifeless and orchestral tone was thin and badly blended, with noticeable diversity of opinion between the players as to exactly when each note should begin and end.

Attempts were made to obtain fuller tone from a solo piano by the use of local reflection and to improve tone and co-ordination between orchestral players by the construction of a reflecting enclosure or 'band shell' around them.

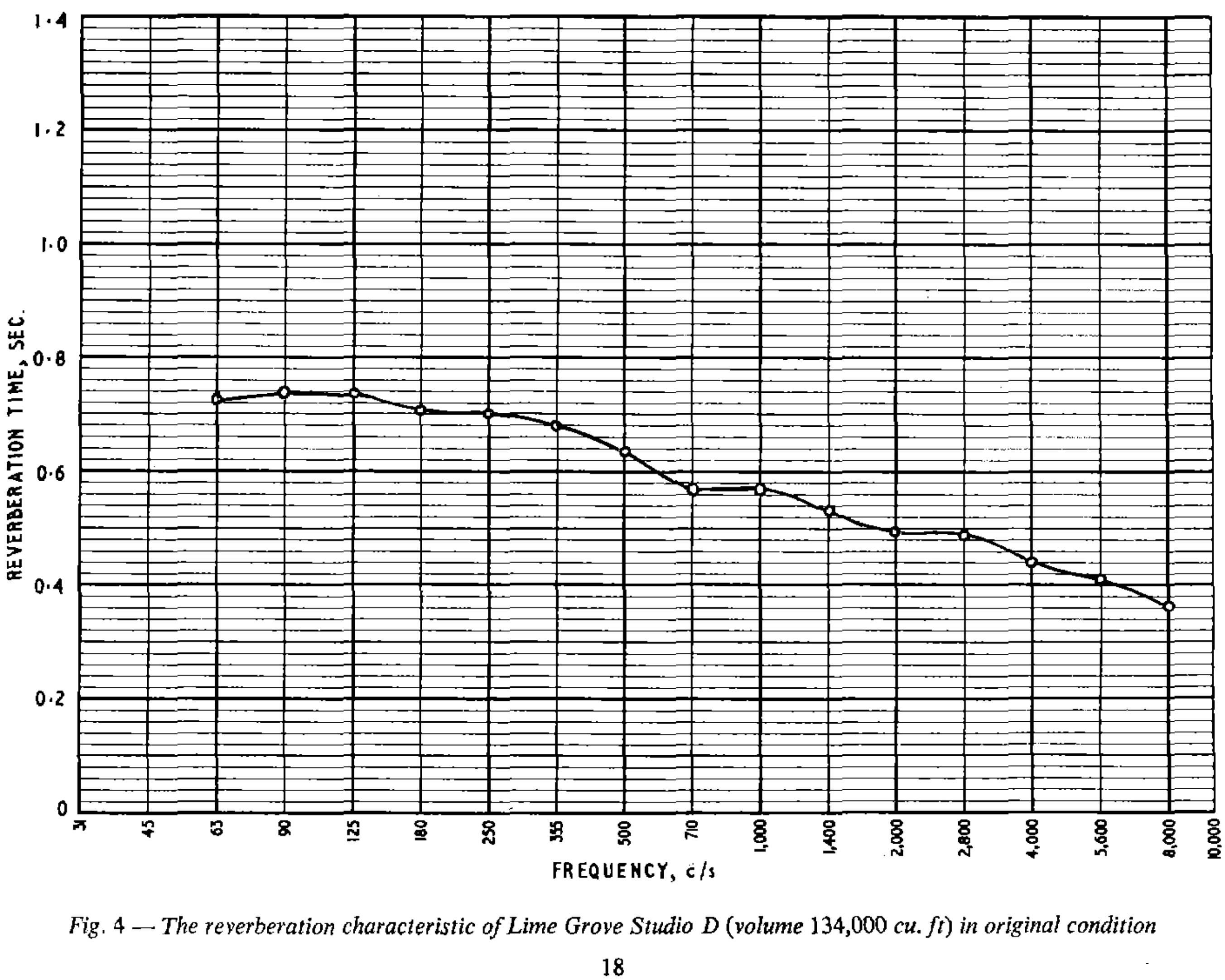

Fig. 4 — The reverberation characteristic of Lime Grove Studio D (volume 134,000 *cu. ft) in original condition*

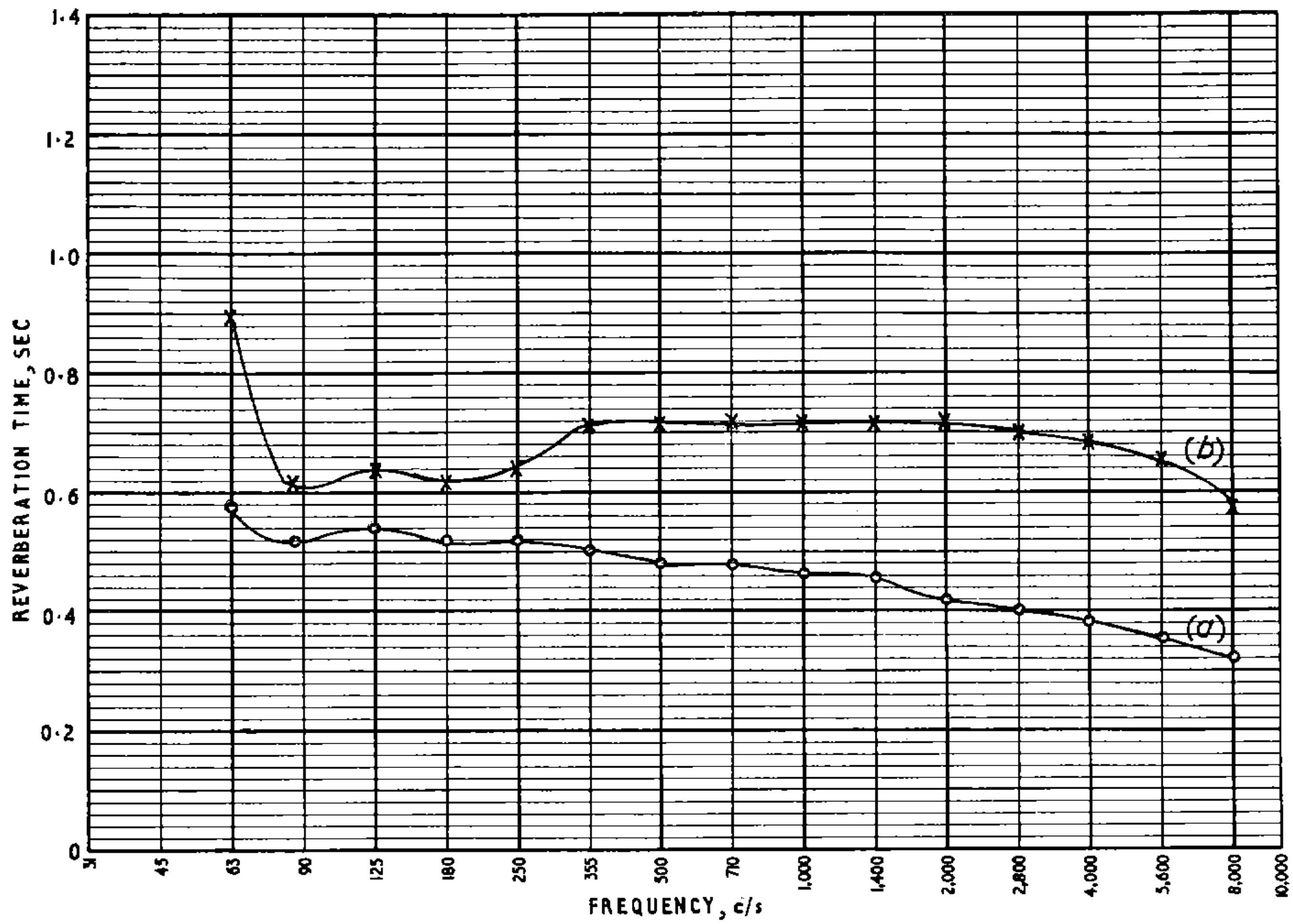

Fig. 5 — Reverberation characteristics of Lime Grove Studio E (volume 113,000 *cu. ft)*

(*a*) *Original condition* (*b*) *After alteration*

The piano experiment was partly successful but those with the orchestra produced no worth-while improvement. Slightly better results could be obtained by mixing the output of a very distant microphone with that from the main microphones, and a combination of the two methods was used for the first transmissions of purely orchestral programmes.

While it was still not possible to reserve a studio exclusively for musical programmes, the acquisition of the four large studios in Lime Grove permitted some variation in treatment between one studio and another, thus providing a series of studios which would allow some choice of acoustics whilst allowing all studios to be kept fully in use.

4.3 *Experiments in 'Compromise' Acoustics*

Experiments were therefore started to find the shortest reverberation time which would give acceptable results for small musical combinations without rendering it unsuitable for the majority of speech programmes. Some areas of rockwool were removed from Studio H and hinged plasterboard shutters constructed by which other areas could be obscured at will. Tests with this studio led the way to a full-scale re-treatment of Studio E. The outer 2-in. (5 cm) rockwool blanket was removed from large areas of the walls and ceiling, the remaining 2 in. then being covered with plasterboard. This alteration raised the reverberation time considerably at middle and high frequencies but only slightly in the bass since the plasterboard with the rockwool behind it formed sound-absorbing panels which were moderately effective at low frequencies only. The resulting reverberation characteristic was more level and generally higher than before. Fig. 5 (a) and (b) shows the extent of this change.

It was found that, although the studio was still far too dead for good musical quality, it was now possible to obtain very satisfactory results with the aid of an echo room to supplement the natural reverberation of the studio. Alterations of the same kind but of varying degree were carried out on the other studios. Studio D was modified slightly to reduce the low-frequency and raise the high-frequency reverberation, thus producing a flatter curve and a mean liveness more suited to the production of drama. Studio G, which is larger than these two, was made generally more reverberant in two stages and became the principal studio for musical programmes of all kinds.

When the two large studios at Riverside were added, it was decided to prepare for programmes with large symphony orchestras, and more ambitious ballet and opera. These former film stages were too dead, except in the bass where there was excessive reverberation due to the absence of any low-frequency sound absorption other than that due to vibration of the breeze-block wall linings. These defects were remedied by removing some areas of rockwool, mostly in positions where the wall spaces were required for the installation of cables and ventilation ducts, and by adding low-frequency absorbers similar in construction to the roofing-felt membrane absorbers used in many sound studios[10] but double-sided. Fig. 6 is a diagram showing the construction of one of these units.

The reverberation time at mid-frequencies of Riverside, Studio 1, was raised in this manner from 0·78 sec to 0·90 sec, while that of Studio 2, which is smaller, was raised by only 0·05 sec to 0·83 sec.

These six studios, together with the Television Theatre, which was replaced for a period during alterations by the King's Theatre, Hammersmith, provided a useful range of general-purpose studios which could be used for most types of programmes. It should be emphasized that satisfactory musical quality was still not obtained without the addition by some means of extra reverberation. The device

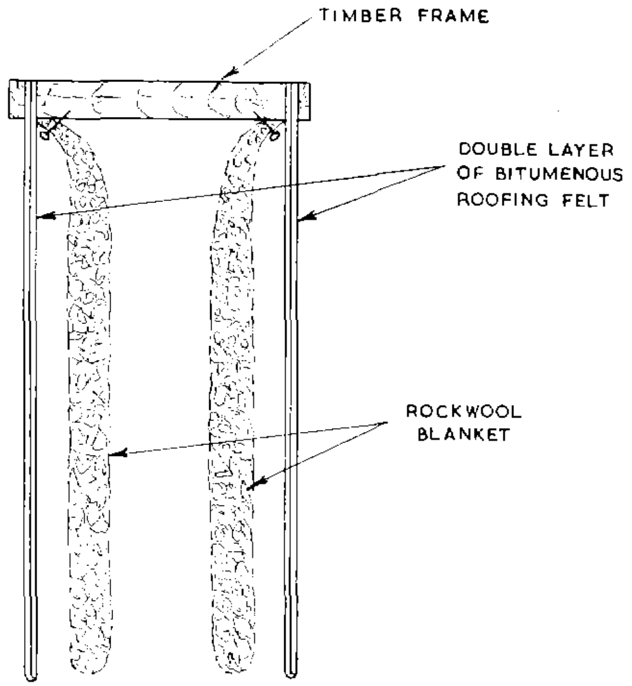

Fig. 6 — Section through part of double-sided membrane sound absorber

employed for this purpose was to mix with the electrical output of the studio microphones a proportion which had been passed either through a small, highly reverberant room or artificial reverberation equipment such as the BBC's magnetic apparatus or the more recent reverberation plate. These methods are described in Part III of this monograph.

For the transmission of purely orchestral programmes where the only scenery requirements are a pleasant background and the concealment of lighting and camera arrangements, the most satisfactory method was, and still is, to use a good sound studio and microphone arrangements similar to those found best for sound broadcasting. Thus, the Sunday afternoon symphony concerts generally came from the large orchestral sound studio in Maida Vale and there have been many highly successful television transmissions from good concert halls. However, the layouts found necessary for the visual presentation of a large orchestra often make it impossible to use the microphone techniques required for the best orchestral sound.

Nevertheless, it was decided that as long as general-purpose studios were necessary their design could be based on the experiences described above, and stock was duly taken of the results. A point which has been omitted from the foregoing is that the reverberation time required in a studio to give a certain subjective impression of liveness increases with the volume of the studio. For instance, a studio of 50,000 cu. ft (1,420 m^3) requires a reverberation time of about 1·2 sec for orchestral music. A concert hall of ten times the volume having the same reverberation time would sound impossibly dead, and a time of about 2 sec would be about right.

4.4 *Relationship between Optimum Reverberation Time and Volume*

To assess the results of the experiments on general-purpose television studios, therefore, the reverberation times were plotted graphically against their volumes. As the reverberation characteristics are never absolutely level, the figure used for the graph was the mean reverberation time between 500 c/s and 2,000 c/s since this frequency region is largely effective in determining the subjective impression of reverberation.

Fig. 7 shows the result of this process applied to the studios referred to above, other studios completed before 1958, and the small London studios used for news and announcements only. A square represents a studio considered too reverberant, a cross one which is too dead, and a solid dot is used for those which are regarded as correct. A line (a) is drawn representing the best division between the too-reverberant and too-dead studios, and lines (b) and (c) enclosing the area around this line within which conditions are satisfactory generally. The figure shows also at (d) the currently accepted curve for sound studios used entirely for music.

4.5 *Present-day Practice*

This graph has been used as a basis for the design of all studios since the beginning of 1958, culminating in Tele-

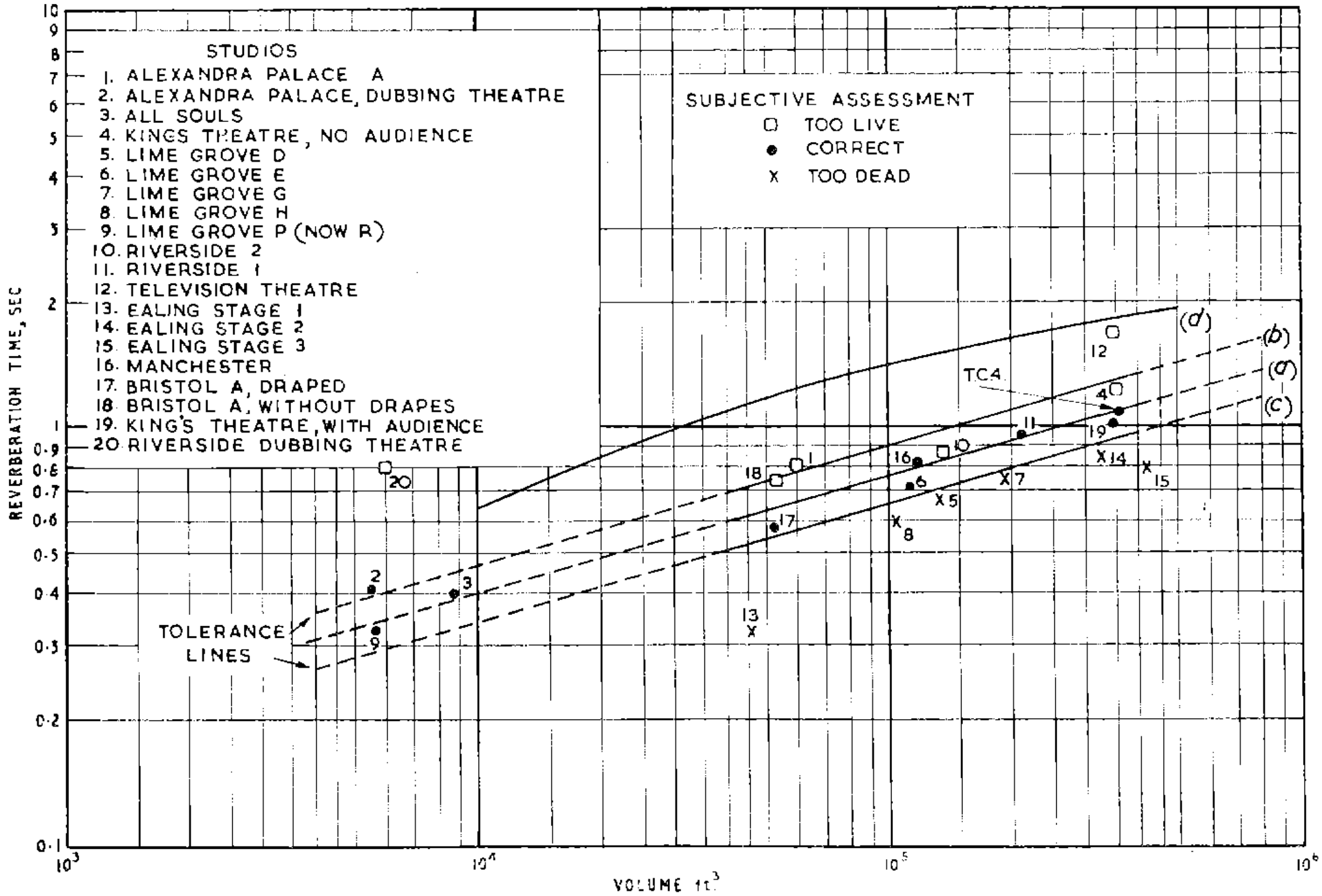

Fig. 7 — Optimum reverberation time for BBC studios

(*a*) *Optimum*
(*b*) *Upper limit* } *General-purpose television studios*
(*c*) *Lower limit*
(*d*) *Music studios in the sound service*

(The curves are based on information previous to the building of Television Centre. The point for Television Centre Studio 4 *is added for the purpose of this monograph)*

vision Centre Studio 5 which came into service in August 1961. Studio 4, which came into service some months earlier, is very much larger than those in Lime Grove, and is intended mainly for light entertainment. A reverberation time of slightly less than 1·1 sec was chosen in this case, corresponding to the volume of 360,000 cu. ft (10,200 m³), and Fig. 8 shows that this figure has been fairly accurately achieved.

The acoustic treatment in this studio is of two kinds. The low-frequency sound absorbers are of an inexpensive type developed by the BBC Engineering Division.* The energy-dissipating element is a layer of roofing felt firmly stuck to the rough side of a sheet of hardboard, the other side of which faces out into the studio. This combination forms the front of a closed air space between 2 in. and 8 in. (5 cm and 20 cm) deep and constitutes a resonating system with the compressibility of the air within. The frequency of resonance, and therefore of most efficient sound absorption, is determined by the depth of the air space. Fig. 9 (a) and (b) shows typical curves of absorption coefficient against frequency.

Wideband middle- and upper-frequency absorption was supplied by 2 in. of very dense rockwool over an air space 6 in. deep which was partitioned by hardboard divisions into cells measuring 1 ft (30·4 cm) square. Partitioning of this sort improves the absorption at low frequencies at the expense of high-frequency performance. The smaller the dimensions of the cells the more prominent is this effect, and the dimensions were therefore chosen to give the best balance between the two ends of the scale, remembering that at high frequencies sound is increasingly absorbed by

* British Patent No. 860682.

its passage through the air irrespective of absorption at the wall surfaces. Fig. 9 (c) is the absorption characteristic of this construction.

In the interests of fire prevention, rockwool of a lighter density enclosed in steel mesh was hung in front of the low-frequency absorbers. Unfortunately, the effects of two absorbers, one in front of the other, are not necessarily additive; in this instance the combined absorption curve had a deep dip at 300 c/s due to an anti-resonance effect which was largely compensated by a peak at the same frequency in the wideband absorbers.

As the number of studios available to the Television Service increases, the tendency may well be towards greater specialization in studio design. Indeed, it is possible that there may eventually be a television studio particularly designed for music and used for nothing else. With the present high demands on the existing studios, however, there seems little immediate prospect of this.

4.6 *The Addition of Reverberation*

It has been made clear by the foregoing section that the main defect in the acoustics of existing television studios for music is the deadness, or lack of adequate reverberation. This affects transmission in several ways. Firstly, the quality of the sound is poor and unsatisfying; secondly, slight mistakes, irregularities, or deficiencies in tone by individual players are more obvious to the listener; thirdly, the quality of the performance suffers because the players fail to hear each other well enough to keep perfectly in time and balance with one another.

The first two of these defects can be ameliorated in many cases by mixing in the output from distant microphones which receive a greater proportion of reverberant to direct sound, or by the use of artificial reverberation. The third can be tackled only by changes in the studio. The various methods of adding artificial reverberation have been described in Part III of this monograph.

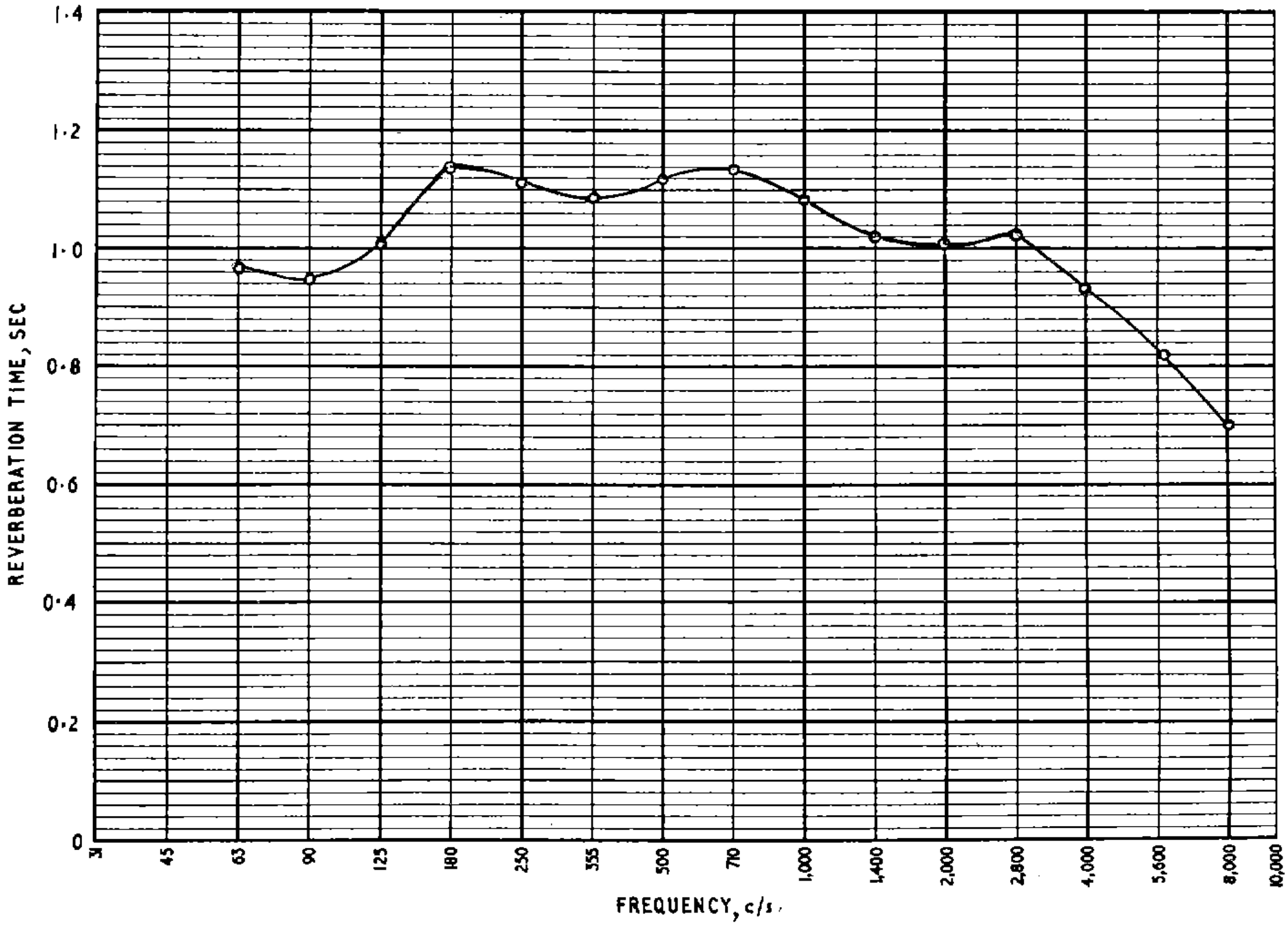

Fig. 8 — Reverberation characteristic of Television Centre Studio 4 (volume 360,000 cu. ft)

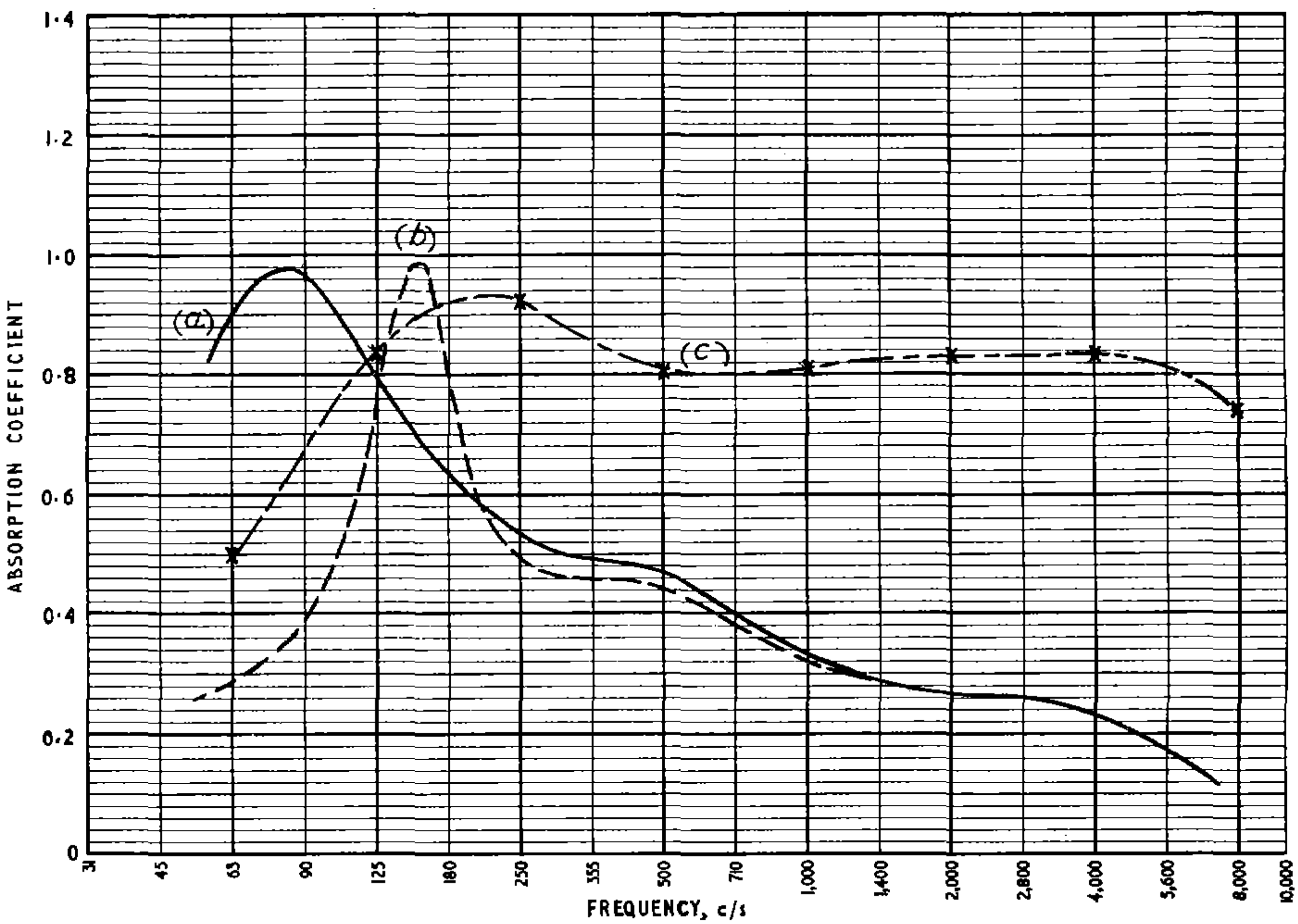

Fig. 9 — Absorption characteristics of sound absorbers used in Television Centre studios

(*a*) *Low-frequency resonant absorber, depth* 6 *in.* (15 *cm*)
(*b*) *Low-frequency resonant absorber, depth* 3 *in.* (7·5 *cm*)
(*c*) *Broad-band partitioned absorber*

4.7 *Conclusion*

The requirement that the design of every television studio should make it suitable to a greater or less degree for all types of programme makes the satisfactory broadcasting of orchestral sound practically impossible to achieve.

Experiments during the past ten years have resulted in a curve relating the optimum reverberation time of a general-purpose television studio with its volume. A studio designed with reference to this curve will be too dead for music broadcasting, but will nevertheless be reverberant enough to produce acceptable quality by the use of an echo room or the addition of some form of artificial reverberation.

For really satisfactory broadcast sound, it is necessary to use a good sound studio or concert hall and it is to be hoped that when the remaining studios at Television Centre are built the total number available will make it possible to adapt one studio particularly for musical programmes.

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CORRECTIONS TO ENGINEERING MONOGRAPH NO. 39 (TWENTY-FIVE YEARS OF BBC TELEVISION)

The following errors have been noted in the above monograph, and copies should be amended as indicated:

Page	*Section*	*Column*	*Paragraph*	*Line*	*Amendment*
12	3.12	*Right-hand*	*1st*	3	*Reference* '10' *should read reference* '15'
13	3.15 (*c*)	*Right-hand*	*5th*	4	'6·75 *Mc/s*' *should read* '6·75 *kc/s*'
18	4.7	*Right-hand*	*7th*	*8th from foot of page*	'24 *r.p.sec.*' *should read* '240 *r.p.sec.*'
25	..	..	*Caption to Plate* 12	.. .. ..	'*transmissions*' *should read* '*transmission*'
25	..	..	*Caption to Plate* 13	.. .. ..	'*Studios*' *should read* '*Studio*'

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