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PUBLIC ADDRESS SYSTEMS

by

ROBERT EDGAR

BERNARDS RADIO MANUALS

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CONTENTS

PREFACE

It needed a major war to arouse the public interest in Sound Reinforcement. The first demand was for systems over which orders could be passed for the control of personnel during air attack. It was essential that the workers in the offices and shops of our war industries were marshalled promptly and dispersed to the shelters, and order-passing equipment was developed for this purpose.

There followed the period known as the 'phony' war when warnings, after the first alarms, were practically unknown. But the loudspeakers remained, waiting for the day of their justification. The microphones and equipment were ready, as were the control operators. It was inevitable that this potential would be used for more peaceful purposes, such as calling staff who had wandered from their telephone extension areas. It soon became known as 'staff-calling' or 'paging' and these systems are now in common use in most of our big industrial concerns. It meant an end to the peculiar form of frustration that resulted from long distance (and local) calls being wasted owing to the difficulty of finding the person under call. Nowadays, if the telephonist cannot contact the person, the microphone key is operated and the individual paged. He is then able to pick up the nearest telephone. contact the exchange, and answer the incoming call. It is necessary to limit the paging list; otherwise the operator might easily be overwhelmed.

In some cases 'music while you work' was adopted and 'staff-calling' followed, but the end result was the same. The equipment was there and intelligent minds were quick to avail themselves of this new medium.

Factory hooters were not allowed in war-time; that shattering roar that hastened the feet of the laggard and sent them home again in the evening.

Time signals over the sound alarm came into being and finally, in peace time, Fire Alarms.

So, from simple beginnings we developed into the present, with Fire, Time, 'Staff-calling' and Music replacing the grim warning of the approach of hostile aircraft. A new industry was born.

SOUND AMPLIFICATION

Although Sound Reinforcement is now a part of our daily life, there are still many who know very little of the problems behind a successful system. We intend to review these problems and to discuss them in non-technical language in an endeavour to make things easier for those who either possess a system or who are contemplating this investment; or for the engineer who contemplates an approach to this new line.

Public Address can be classified, quite simply, under two headings. Sound Reproduction and Sound Reinforcement. The latter can be said to have evolved from the former, and it is in this field that most of our problems lie. As its name implies, it is a strengthening of an already audible sound, so we have two factors to consider; the source of sound and the amplified sound.

For the purpose of simplicity the sound will be referred to as the voice, as it is the voice that offers the greatest problem in terms of intelligibility. This presents two problems:—

(a) To give the necessary sense of realism, the sound must appear to emanate from the person speaking, and it must be in the form of "lift" rather than a highly amplified voice. If the latter occurs, then we have left the realms of Reinforcement and gone back to Reproduction.

(b) There must be no discernible time lag between voice and loudspeaker. If there is, then there will be an unpleasing sense of "woolliness" in the reinforced sound.

Sound travels slowly, 1,100 feet per second. A sound, bat striking ball for example, would therefore have a time lag of one second before reaching a spectator 370 yards away.

If a microphone were placed near the batsman, the amplified sound reproduced over a loudspeaker adjacent to the spectator would be, for the purposes of this very simple analogy, instantaneous. There would therefore be two distinct sounds, separated by one second of time—and a second is quite a long interval in this case.

Returning to our first problem (a), we have to consider the acoustics of the building, and the purpose of the building. We might, for instance, be considering the reinforced voice from the Pulpit or the Altar; or again, it might be the conventional Stage, with all the aids of proscenium arch, etc.

Indeed, there are so many variations that one is forced to consider each installation as an individual problem and proceed from there.

SOUND REPRODUCTION

It is obvious that the main problems are under the heading "Reinforcement", but before we discuss these in detail a few words are necessary on "Reproduction". This is generally understood to refer to systems where the niceties and technical refinements are not so necessary. The originator of the sound in this case is only concerned with projecting the voice—often outdoors and sometimes to distant locations or overflow meetings. There is no great need to preserve the illusion of the source of sound, nor does the question of time lag enter into it. Sound Reproduction over a Sports Ground or Stadium is largely a question of projection far enough and deep enough to reach the covered stands, for example.

It is not quite true to say that time lag does not enter into it. It does but overlap is of far less importance when a powerful amplified voice is in use; intelligible often up to a quarter of a mile and audible, but not wholly intelligible over a much greater distance.

It is, however, advisable to have the amplified sound emanating from one central source; a tower, for example, from which sound is radiated.

A grandstand at a Sports Ground can effect good coverage by using the roof and by aligning the loudspeakers on to strategic listening points.

Loudspeakers mounted in a chain away from the central point are rarely successful, the last in the chain being obviously out of phase due to time lag.

Echo, too, is a fact to be considered when projecting the voice outdoors, where houses, etc., bar the way and give rise to a whole series of echoes.

Finally, there is far less danger of acoustic feedback so that the full gain and power output of the amplifier is available. Acoustic feedback will be discussed fully under the heading "Sound Reinforcement".

SOUND REINFORCEMENT

Acoustic Feedback

This is perhaps the greatest enemy of all acoustic engineers, the more so as it is a fundamental for which there is no cure—only careful compromise. It is always a possible danger when microphone and loudspeaker are used in the same confined area.

Should the gain of the system be high enough any note from the loudspeaker may be collected by the microphone and re-introduced into the circuit, building up into that distressing thing "howl-back".

Fortunately, this state of affairs is presaged by a slight ringing note and the operator usually has time to reduce the gain of the system.

This means that the effective gain of the system is limited by this feedback point. This limitation cannot be overstressed. It is as if you, in your home, had to listen to your radio at some barely audible volume, knowing that the threshold of feedback is the limiting factor and not the available power of your set.

A further analogy in terms of frustration is that of the owner of a powerful car being condemned to drive some low-powered and possibly ancient model and to watch the speedometer trembling at 40 while the sole of his shoe remains firmly pressed as far as the boards.

It is possible to reduce this effect by using highly directional microphones and by the utmost care in the choice and positioning of the loudspeakers in relation to the microphone. This, of course, is a question of experience, and here again experience cannot be overstressed in this class of installation where so many factors have to be considered, and where there is so much individuality in each job.

Experience, often gained the hard way, will help in the estimation of a Cathedral, a church or similar edifice. Theatres too, have a general problem, varying often in size but acoustically similar. Troubles experienced in one class of installation will inevitably help in a similar job, but the answer to all, where feedback is a fundamental, is intelligent compromise.

Finally, there is the condition where no compromise is possible and the adjacent loudspeaker has to be switched out of circuit when the microphone is in use. In these systems the disconnection of the loudspeaker should be automatic whenever the microphone is selected.

A further cause of feedback may be due to the use of a microphone having an unequal response, i.e. a peak output at some point in the audio range. This may mean that the gain over the whole of the audio range suffers and has to be reduced to a level, where this peak point can no longer trigger-off this oscillatory condition. A considerable loss of energy can result.

In this question of feedback alone, there is a strong case for the use of the best available equipment — microphones, amplifiers and loudspeakers. Any two of these may be nullified by the employment of an indifferent third.

Time Lag

Time lag has been mentioned, very briefly, in the opening remarks. We have taken as our example a nice round figure of one second; a considerable time lag and a considerable distance (370 yards). This, of course, is an extreme case; more applicable to Sound Reproduction. In Sound Reinforcement our limit can be considered as 100 feet, or approximately 1/10th of a second. This may not seem much but when clarity and intelligibility are necessary 100 milli-seconds is considered to be a dangerous time lag, 50 or 60 milli-seconds being permissible.

The governing factor in all such cases is the intensity of the initial sound. Can it be clearly heard from a distance of 100 feet? (to continue with our original figure). Is it intended to be heard, for example! Consideration of this point alone will help one to understand the complexities of designing a system.

For instance, the system might be for use in a church, and one microphone might be adjacent to the High Altar. The delivery from this point would be quite different to that from the Pulpit or Lectern.

In the first case the congregation would not expect to hear much, in the second it should be heard by all. In the first case, it would not matter if the time lag was excessive as the sound origin would be inaudible at that distance and no clash would ensue.

To avoid excessive time lag it is therefore necessary to revert to the problem of loudspeaker coverage.

We have already mentioned the desirability of creating the illusion of voice and reinforced sound as coming from the same point, but we know this to be impossible, as microphone and loudspeaker in such close proximity would result in acoustic feedback.

FIG. 1

This shows a conventional three-channel mixer circuit. It will be seen that the switches are back-loaded with a resistance equivalent to the microphone impedance to maintain a constant input impedance. The three components, microphone, loading resistance and potentiometer are therefore of a similar impedance and the amplifier should be chosen to accept this. Similarly the joint impedance of the three loudspeakers should be approximately that of the amplifier output.

Mis-matching will not prevent the system working but will result in a loss of gain which may or may not be important. Severe mismatching should not be tolerated.

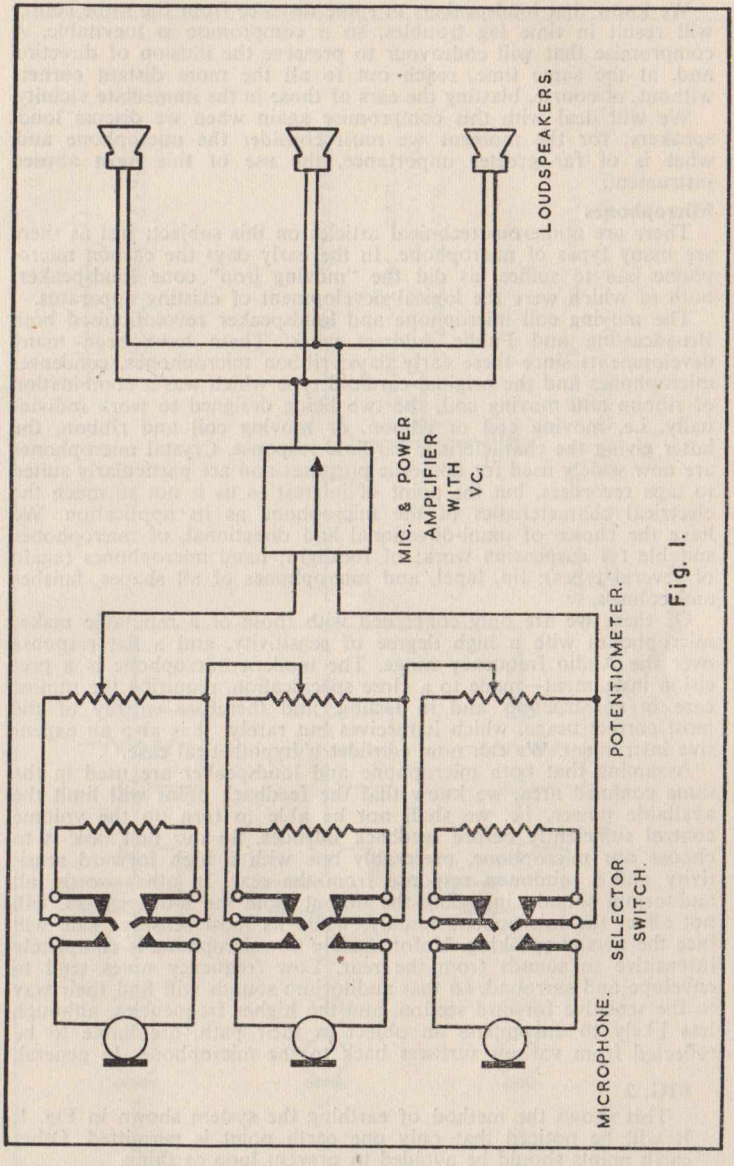

LOUDSPEAKERS.
MIC. & POWER AMPLIFIER WITH VC.
POTENTIOMETER.
SELECTOR SWITCH.
MICROPHONE.

Fig. 1.

We know that loudspeakers at some distance from the same source will result in time lag troubles, so a compromise is inevitable. A compromise that will endeavour to preserve the illusion of direction and, at the same time, reach out to all the more distant corners without, of course, blasting the ears of those in the immediate vicinity.

We will deal with this compromise again when we discuss loudspeakers; for the moment we must consider the microphone and, what is of far greater importance, the use of this most abused instrument.

Microphones

There are numerous technical articles on this subject: just as there are many types of microphone. In the early days the carbon microphone had to suffice, as did the "moving iron" cone loudspeaker; both of which were the logical development of existing apparatus.

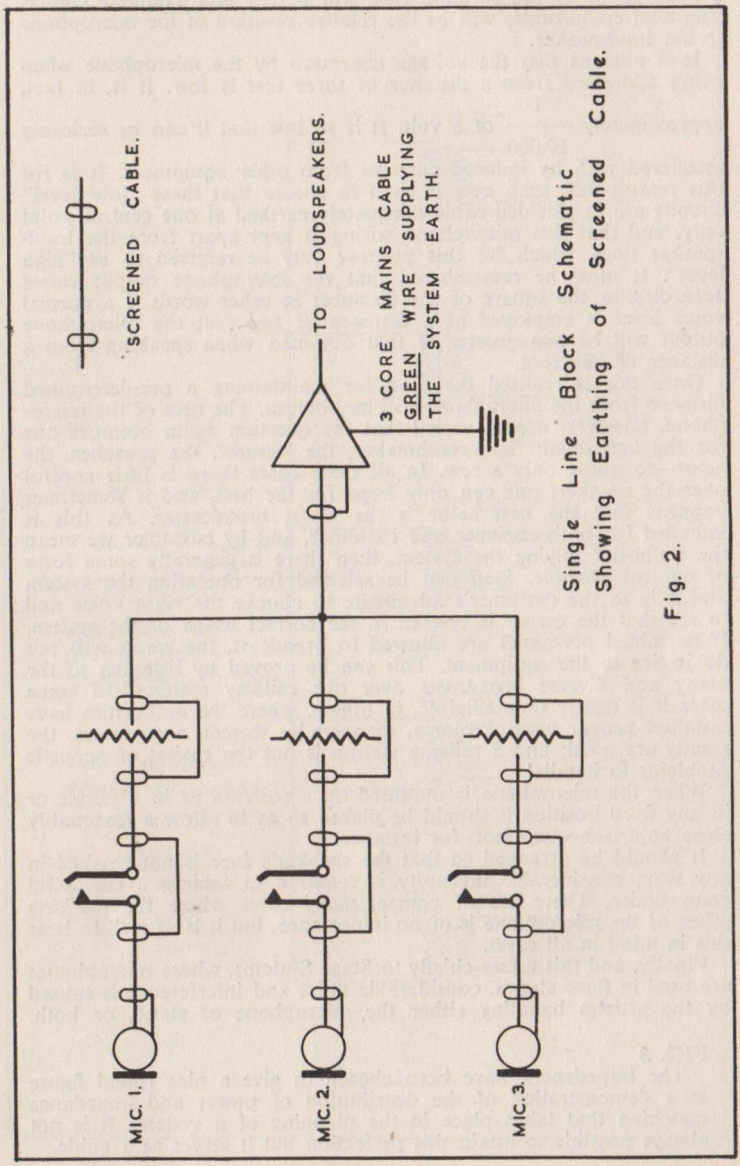
The moving coil microphone and loudspeaker revolutionised both Broadcasting and Public Address work. There have been many developments since these early days; ribbon microphones, condenser microphones and the original cardioid type which was a combination of ribbon and moving coil, the two being designed to work individually, i.e. moving coil or ribbon, or moving coil and ribbon, the latter giving the characteristic cardioid response. Crystal microphones are now widely used for domestic purposes and are particularly suited to tape recorders, but the point of interest to us is not so much the electrical characteristics of the microphone as its application. We have the choice of omni-directional and directional, of microphones suitable for suspension work; of footlight; hand microphones (again of several types); lip, lapel, and microphones of all shapes, finishes and colours.

Of these we are only concerned with those of a reputable make; microphones with a high degree of sensitivity, and a flat response over the Audio frequency range. The modern microphone is a precision instrument—made to a close specification, requiring the utmost care in construction and in testing, and therefore worthy of the most correct usage, which it receives but rarely. It is also an expensive instrument. We can now consider a hypothetical case.

Assuming that both microphone and loudspeaker are used in the same confined area, we know that the feedback point will limit the available power, i.e. we shall not be able to turn up the volume control sufficiently before feedback intrudes. So our first task is to choose our microphone, preferably one with a high forward sensitivity and a minimum response from the rear. In other words, all auditorium sounds, including the output from the loudspeakers, will not affect the microphone unduly, while its most sensitive side will face the person speaking. Unfortunately no microphone is completely insensitive to sounds from the rear. Low frequency notes tend to envelope and surround, so that auditorium sounds will find their way to the sensitive forward section, and the higher frequencies, although less likely to encompass an object in their path, are liable to be reflected from various surfaces back to the microphone. In general,

FIG. 2

This shows the method of earthing the system shown in Fig. 1. It will be noticed that only one earth point is permitted. Other earth points should be avoided to prevent loop earthing.



Single Line Block Schematic
Showing Earthing of Screened Cable.

Fig. 2.

a microphone of the cardioid type will be the best available choice. The final compromise will be the relative position of the microphone to the loudspeaker.

It is obvious that the voltage generated by the microphone when being addressed from a distance of three feet is low. It is, in fact, approximately $\frac{1}{10{,}000}$ of a volt. It is so low that it can be seriously interfered with by induced currents from other equipment. It is for this reason that such care is used to ensure that these "low level" circuits are in shielded cable adequately earthed at one central point only, and that this microphone wiring is kept apart from the loudspeaker lines, which for this purpose may be referred to as "high level". It must be remembered that the microphone output varies according to the square of the distance; in other words if a normal voice level is employed at a distance of **two** feet the microphone output will be **one quarter** of that obtained when speaking from a distance of **one** foot.

Once this is realised the need for maintaining a pre-determined distance from the microphone will be obvious. The uses of the microphone, however, are so varied that the question again becomes one for the individual: the speechmaker, the lecturer, the preacher, the actor—to quote only a few. In all these cases there is little control over the speaker; one can only hope for the best, and it sometimes happens that the best actor is the worst broadcaster. As this is intended for both engineer and customer, and by customer we mean the authority buying the system, then there is generally some form of control possible. Staff can be selected for operating the system and it is to the customer's advantage to choose the right voice and to see that the owner is briefed in the correct usage of the system. If untrained personnel are allowed to broadcast, the result will not do justice to the equipment. This can be proved by listening to the many and diverse broadcasts over our railway systems. In some cases it is nearly unintelligible, in others, where the authorities have installed proper control rooms, manned by women announcers, the results are good: and a railway station is not the easiest of acoustic problems to handle!

When the microphone is mounted on a rostrum or in a pulpit or in any fixed position it should be placed so as to allow a reasonably close approach—two feet, for instance.

It should be arranged so that the speaker's face is not masked in any way; considerable ingenuity is required to achieve a successful compromise. There are of course, many cases where the masking effect of the microphone is of no importance, but it is as well to bear this in mind in all cases.

Finally, and this refers chiefly to Stage Systems, where microphones are used in floor stands, considerable noise and interference is caused by the artistes handling either the microphone or stand, or both.

FIG. 3

The impedances have been chosen to give a nice round figure as a demonstration of the distribution of power and impedance matching that takes place in the planning of a system. It is not always possible to attain this perfection but it serves as a guide.

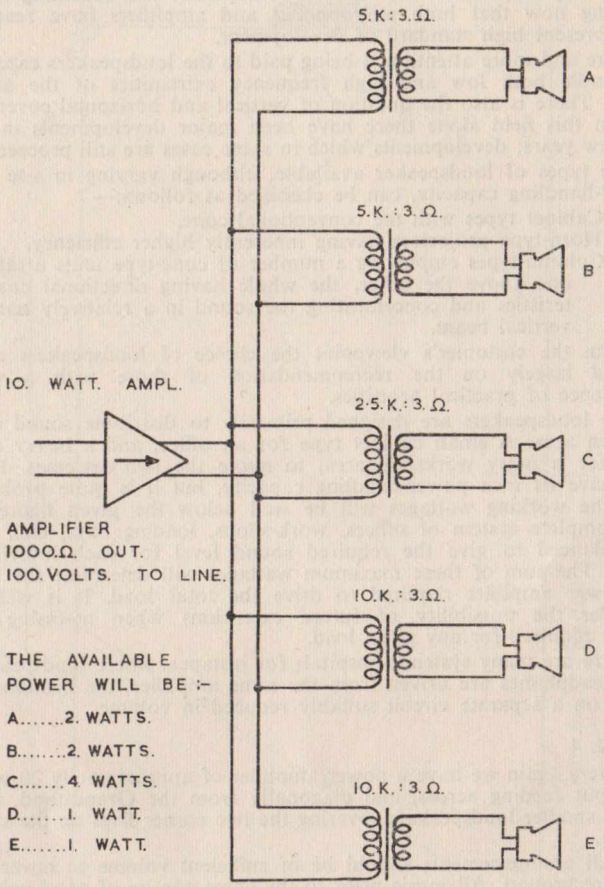

5.K:3.Ω.
A
5.K.:3.Ω.
B
10. WATT. AMPL.
2·5.K.:3.Ω.
C
AMPLIFIER
1000.Ω. OUT.
100. VOLTS. TO LINE.
10.K.:3.Ω.
D
THE AVAILABLE
POWER WILL BE :-
A.....2. WATTS.
B.....2. WATTS.
C.....4. WATTS.
D.....1. WATT.
E.....1. WATT.
10.K.:3.Ω.
E

Fig. 3.

This does not affect the working if the microphone has not been switched into circuit; but once this has been done it is advisable to refrain from handling it, as this is transferred in terms of noise over the loudspeakers.

The requirements of the modern loudspeaker are becoming more exacting now that both microphones and amplifiers have reached their present high standard of development.

More and more attention is being paid to the loudspeakers capacity to handle both low and high frequency extremities of the audio range. There is also the question of vertical and horizontal coverage, and in this field alone there have been major developments in the last few years; developments which in some cases are still proceeding.

The types of loudspeaker available, although varying in size and power-handling capacity, can be classified as follows:—

(a) Cabinet types with the conventional cone.
(b) Horn-type projectors having inherently higher efficiency.
(c) Column-types employing a number of cone-type units arranged one above the other, the whole having directional characteristics and concentrating the sound in a relatively narrow vertical beam.

From the customer's viewpoint the choice of loudspeakers must depend largely on the recommendation of those with a wide experience of practical acoustics.

The loudspeakers are designed primarily to distribute sound over a given area. A small cabinet type for an office, and a heavy duty type for a noisy workshop area, to quote the two extremes. Each will have its own power-handling capacity, but it is quite probable that the working wattages will be well below the given figure, as the complete system of offices, work-shops, loading bays, etc., will be balanced to give the required sound level for each individual point. The sum of these maximum wattages will determine the type of power amplifier required to drive the total load. It is well to consider the possibility of future extensions when assessing the power required for any given load.

There are many systems, hospitals for instance, where loudspeakers and headphones are driven from the same amplifier, the headphones being on a separate circuit suitably reduced in volume.

FIG. 4

Here again we have a power amplifier of approximately 20 watts output feeding across, and diagonally from the Grandstand, with two smaller loudspeakers covering the two corner flags on the stand side.

All announcements should be of sufficient volume to cover the entire ground. All music prior to the game can be of good volume and of a welcoming nature; lively marches etcetera.

At the interval the music should be a pleasing background and chosen to pour oil on the troubled waters. Finally the spectators should be given a loud and defiant farewell as they troupe home to their warm firesides.

In the larger grounds loudspeakers can be included to cover the offices and the dressing rooms, and in some cases, the entrance gates.

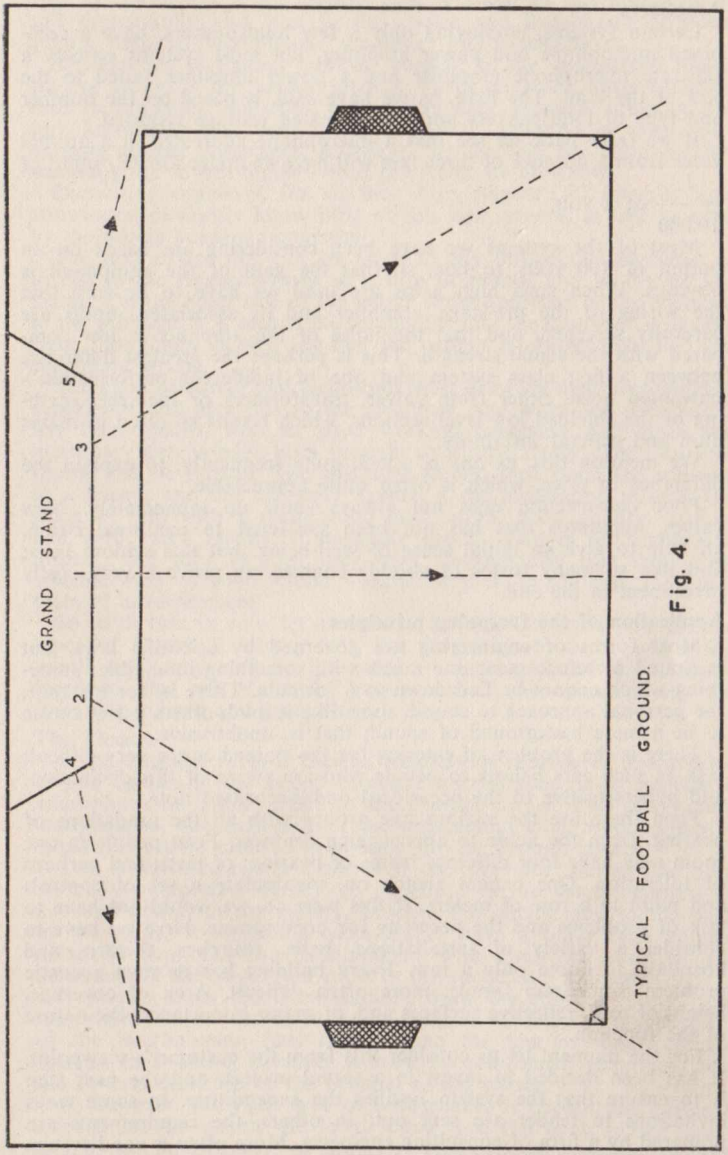


Fig. 4.

Amplifiers

Certain systems, employing only a few loudspeakers, have a combined microphone and power amplifier, but most systems employ a separate microphone amplifier and a power amplifier suited to the size of the load. The load, as we have said, is based on the number and type of loudspeakers and the estimated wattage required.

If we refer back we see that a microphone addressed in a normal voice from a distance of three feet will have an approximate output of $\frac{1}{10.000}$ of a volt.

Most of the systems we have been considering are based on an output of 100 volts to line, so that the gain of the equipment is obvious. When such high gains are used we have to be sure that the wiring of the pre-stage amplifier and its associated inputs are carefully screened, and that the noise of the amplifier is low compared with the signal strength. This is perhaps the greatest difference between a first class system and one of indifferent performance—unwanted noise either from valves, transformers or incorrect earthing of the shielded low-level sections, which results so often in mains hum and general instability.

We mention this, as one is asked, quite frequently, to explain the difference in price, which is often quite appreciable.

Poor construction does not always show up immediately. New valves, apparatus that has not been subjected to continual strain, all help to give an initial sense of well-being, but this seldom lasts; and like so many forms of shoddy engineering prove a very costly investment in the end.

Application of the foregoing principles

Most forms of engineering are governed by scientific laws, but in Sound Reinforcement one meets with something intangible; something which cannot be tied down to a formula. There is, for instance, the personal approach to sound; some like it loud, others prefer music to be a mere background of sound; that is, unobtrusive.

There is the problem of catering for the trained ear; a very difficult task as such ears belong to people who are aware of this distinction, and hypersensitive to the occasional odd discordant note.

Then there are the various age groups with all the gradations of hearing, from the acute to approaching deafness. Four people in one room may have four different forms of hearing; of taste, and perhaps of toleration. One cannot switch on, manipulate a set of controls and point to a row of meters. If this were so, we would not have to talk of problems and the necessity for compromise. Here we have to consider a variety of installations, halls, churches, theatres and hospitals, to quote only a few. Every building has its own acoustic problem, sometimes simple, more often difficult. Area of coverage, height of roof, reflective surfaces and, of major importance, the nature of the function.

For the moment let us consider this from the customer's viewpoint. It has been decided to invest in a sound project, and the next step is to ensure that the system justifies the expenditure. In some cases invitations to tender are sent out; in others, the requirements are prepared by a firm of consulting engineers. More often a good system sells itself. The latter is obviously the target to aim at, and this can

only be successful if the utmost care is taken in the initial study and preparation, and later in the choice and installation of good quality material-microphones, amplifiers and loudspeakers.

Applications to tender, however popular to the commercial mind, are not always in the general interest. Firms tendering waste valuable time in preparing estimates, engineering data, etcetera, often in the sure knowledge that their quality standard, reflected in price, will mitigate against acceptance. Railways, for example, are notorious for accepting the lowest tender—with the result we all know.

Consulting engineers, for all their high standard of integrity and knowledge, obviously know little of this new science, as can be seen by the purely academic approach.

The best advice that can be given to any prospective customer is to call in the representatives of a firm of repute, and to discuss the matter. On the other side of the ledger is the approach of the engineer to the problem. It is said, quite frequently, that the customer is always right. One might as well say that the patient is always right and the consultant wrong.

The good salesman and technician must draw on their accumulated experience and give this to the customer, and when the installation has been handed over in good working condition, and when the mercenary details have been brought to a satisfactory close, the link should not be broken. The customer should look upon the supplier as a friend; and this can only happen if the installation justifies the price. A firm with a really good installation; good quality. that is, and with every facility, is naturally proud. Visitors are invited to inspect, and they in turn may wish (presumably) that their own systems were as good. Good workmanship is, in the end, the finest form of advertisement.

So, with that in view let us pass to an examination of the various types of Sound Reinforcement, not forgetting those in which the 'small man' may well be interested — dances, church halls, sports meetings, etc.; all of which, however small, are governed by the foregoing axioms and generalities.

The Theatre

In its simplest form a theatre installation consists of from three to five (generally the latter) footlight microphones, with perhaps a microphone on a floor stand in the Prompt corner. Two heavy duty loudspeakers, one each side of the proscenium arch, with perhaps a monitor, suitable reduced in volume, in the Prompt corner.

The disadvantages are obvious if the previous matter has been correctly interpreted. Firstly, to penetrate to the distant corners of the auditorium, to the gallery, beneath the circles, and to the back of the stalls, it would be necessary to have a fairly high volume of sound from the two loudspeakers, with disastrous effect on the occupants of the boxes and stalls in the immediate vicinity.

It would, under the circumstances, draw the attention away from the original sound source to points roughly 45 degrees on both sides of the microphones, thus contravening the first of our laws; the illusion that sound, however it may be reinforced, emanates from the general direction of the original sound source.

If, however, the right type of loudspeaker is chosen and carefully aligned on the target. the lower circle and the back of the stalls; and if two loudspeakers of the more conventional type are mounted

well forward of the proscenium arch, a degree of reinforcement is possible without it over-riding the original sound source.

It is necessary at this point to re-assert that for these notes we are assuming the source of sound to be the human voice. We have referred above to the 'right type' of loudspeaker, and by this we mean something similar to the column-type loudspeakers now coming into prominence. We have described these in our comments on loudspeakers in a previous chapter.

The choice of microphone is also very important. It should be of the directional type, having a high forward sensitivity and a very poor response to auditorium noise—that, of course, includes the output from the loudspeakers. Should this not be so, then feedback will intrude and limit the working gain of the system.

The larger theatres have now concentrated on 'front of the house control' and this usually consists of a console capable of accepting a number of microphone points and mixing them into a general input to the amplifier by means of the selection keys and potentiometers associated with each channel. Tone control and an overall gain control are often supplied in this position, so that the operator has the whole of the Sound Reinforcement system at his fingertips. All, that is, save the stage manager's control for paging the dressing rooms and the other ancilliary systems attendant on a large production. As if this were not enough there is often a 'front of the house' system, controlled from there and installed to give interval warnings to the various bars, lounges and foyers into which people throng during the interval period.

To complete the picture there is the necessity for a gramophone point, with suitable cue-attachment for providing sound, either for 'effects' or for interval music when no orchestra is present. The pick-up output is usually reduced to microphone level and impedance can therefore be accepted by the normal fader system.

The Small Hall

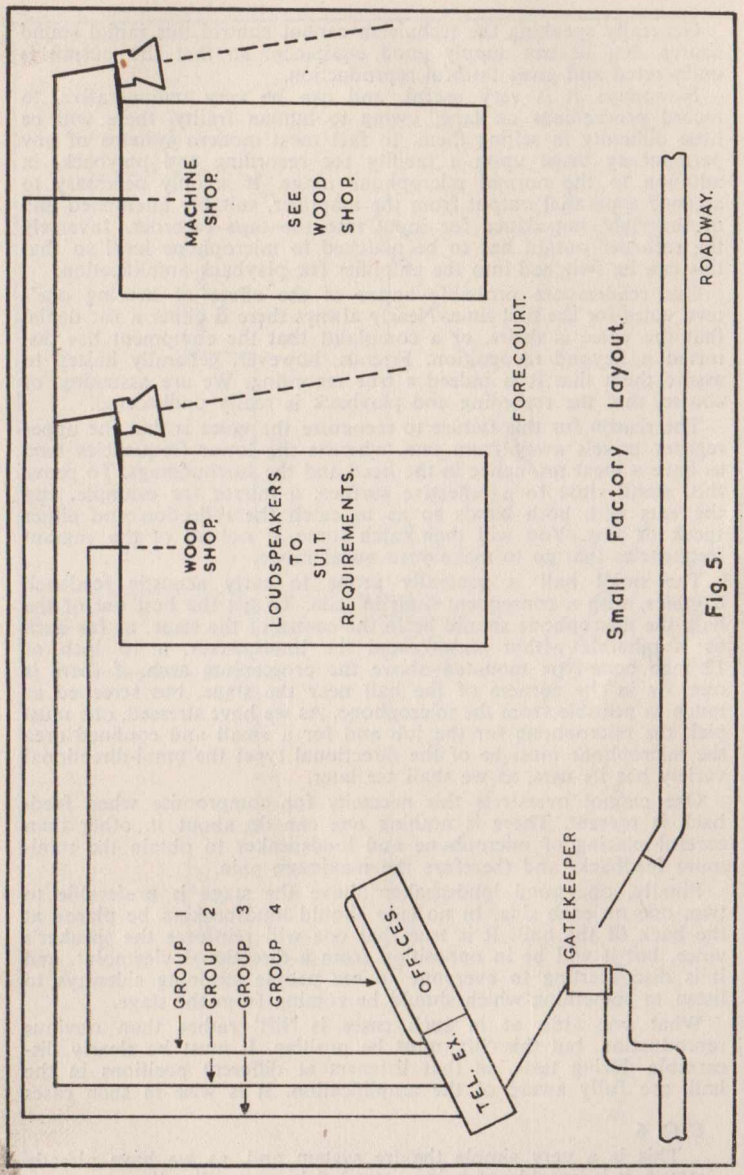
We have mentioned quite briefly, the sort of thing that can grow out of a simple system, but the fact remains that there are countless halls and meeting places up and down the country that are catered for by the local trader and often by the amateur.

For the latter we recommend our opening remarks on the principles to be aimed at, and with this in mind we visualise many such functions where speech, or singing, either solo or choir, are catered for by a single microphone. It is worth while spending a little extra on a good microphone, as it is trite but true to say that one gets out of a system what one puts in. A bad voice (and all voices are not necessarily good microphone voices) will also sound bad when reinforced.

Most people, however, are firmly convinced that their voice is **the** microphone voice. The writer has yet to meet the person who thinks otherwise.

FIG. 5

This shows a normal small factory system covering offices at a low volume level and capable of being switched out of circuit if not required, and a higher level for shops and runways. This, of course can be extended to cover a much greater area and might easily comprise such input sources as Time Signals, Music, Fire Warnings and the usual limited Staff calling.



Small Factory Layout.

Fig. 5.

Generally speaking the technician cannot control this initial sound source, but he can supply good equipment so that the output is undistorted and gives faithful reproduction.

Nowadays it is very useful, and can be very remunerative, to record proceedings on tape; owing to human frailty, there will be little difficulty in selling them. In fact most modern systems of any permanency insist upon a facility for recording and playback, in addition to the normal microphone usage. It is only necessary to arrange a parallel output from the amplifier, suitably attenuated and of the right impedance for input into the tape recorder. Inversely the recorder output has to be matched to microphone level so that this can be switched into the amplifier for playback amplification.

Our readers are probably aware of the effect of hearing one's own voice for the first time. Nearly always there is either a flat denial that the voice is theirs, or a complaint that the equipment has distorted it beyond recognition. Friends, however, generally hasten to assure them that it is indeed a true recording. We are assuming, of course, that the recording and playback is really undistorted.

The reason for this failure to recognize the voice is that the upper register travels away from one, whereas the lower frequencies tend to have a local resonance in the head and the surroundings. To prove this, stand close to a reflective surface, a mirror for example, cup the ears with both hands so as to catch the reflection and either speak or sing. You will then catch some, if not all of the vagrant frequencies that go to make your vocal range.

The small hall is generally prone to early acoustic feedback troubles, with a consequent limit in gain. To get the best out of the hall, the microphone should be in the centre of the stage, as far back as is possible within reason, and the loudspeaker, a 10 inch or 12 inch cone-type mounted above the proscenium arch, if there is one, or in the corners of the hall near the stage, but screened as much as possible from the microphone. As we have stressed, one must pick the microphone for the job and for a small and confined area the microphone must be of the directional type; the omni-directional variety has its uses, as we shall see later.

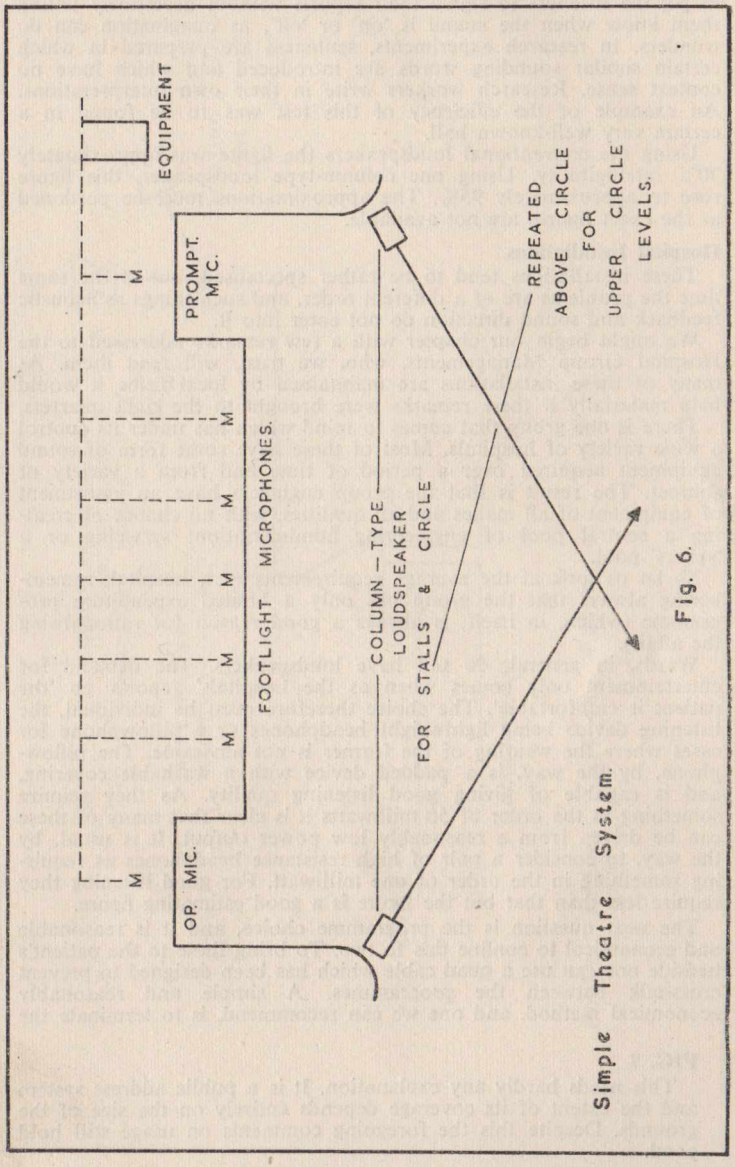
One cannot overstress this necessity for compromise when feedback is present. There is nothing one can do about it, other than careful placing of microphone and loudspeaker to obtain the minimum feedback, and therefore the maximum gain.

Finally, one good loudspeaker above the stage is preferable to two, one on each side. In no case should loudspeakers be placed at the back of the hall. It is true that one will reinforce the speaker's voice, but it will be in opposition from a directional viewpoint, and it is disconcerting to everyone to see people straining sideways to listen to something which should be coming from the stage.

What one aims at in such cases is 'lift' rather than obvious reproduction, but this 'lift' must be positive. It must be clearly discernible during tests, so that listeners at different positions in the hall, are fully aware of the amplification. It is wise in such cases

FIG. 6

This is a very simple theatre system and, as we have already stated, it is capable of being extended in many directions.



Simple Theatre System.

Fig. 6.

to get the listeners to signal their reports without necessarily letting them know when the sound is 'on' or 'off', as imagination can do wonders. In research experiments, sentences are prepared in which certain similar sounding words are introduced and which have no context sense. Research workers write in their own interpretations. An example of the efficiency of this test was to be found in a certain very well-known hall.

Using the conventional loudspeakers the figure was approximately 70% intelligibility. Using one column-type loudspeaker, this figure rose to approximately 95%. The approximations must be pardoned as the exact figures are not available.

Hospital Installations

These installations tend to be rather specialised, but at the same time the problems are of a different order, and such things as acoustic feedback and sound direction do not enter into it.

We might begin our chapter with a few remarks addressed to the Hospital Group Managements, who, we trust, will read them. As many of these installations are maintained by local firms it would help materially if these remarks were brought to the right quarters.

There is one group that comes to mind which has under its control a wide variety of hospitals. Most of these have some form of sound equipment acquired over a period of time and from a variety of sources. The result is that the group engineers have an assortment of equipment of all makes and all qualities, with no chance of creating a central pool of engineering administration; servicing or a 'spares' pool.

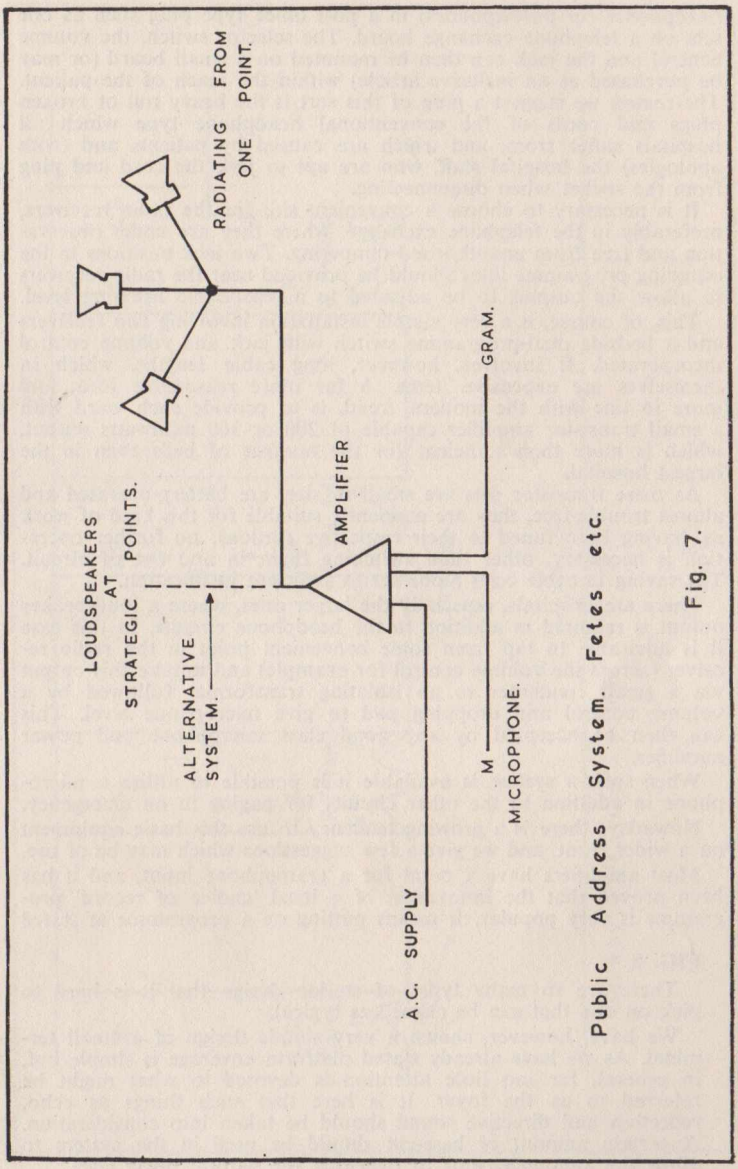
So let us look at the average requirements of a hospital, remembering always that the group has only a limited expenditure programme (which, in itself, is always a good reason for rationalising the affair).

Wards, in general, do not have loudspeakers. The demand for entertainment only comes when as the hospitals' reports go 'the patient is comfortable'. The choice therefore must be individual, the listening device being lightweight headphones or a pillowphone for cases where the wearing of the former is not advisable. The pillowphone, by the way, is a padded device with a washable covering, and is capable of giving good listening quality. As they require something in the order of 50 milliwatts it is clear that many of these can be driven from a reasonably low power output. It is usual, by the way, to consider a pair of high resistance headphones as requiring something in the order of one milliwatt. For good listening they require less than that but the figure is a good estimating figure.

The next question is the programme choice, and it is reasonable and economical to confine this to two. To bring these to the patient's bedside one can use a quad cable which has been designed to prevent cross-talk between the programmes. A simple and reasonably economical method, and one we can recommend, is to terminate the

FIG. 7

This needs hardly any explanation. It is a public address system and the extent of its coverage depends entirely on the size of the grounds. Despite this the foregoing comments on usage still hold good.



Public Address System. Fetes etc.

Fig. 7.

headphones (or pillowphones) in a post office type plug such as one sees on a telephone exchange board. The selector switch, the volume control and the jack can then be mounted on a small board (or may be purchased as an inclusive article) within the reach of the patient. The reason we suggest a plug of this sort is the heavy toll of broken plugs and cords of the conventional headphone type which all hospitals suffer from, and which are caused by patients and (with apologies) the hospital staff, who are apt to jerk the cord and plug from the socket when disconnecting.

It is necessary to choose a convenient site for the radio receivers, preferably in the telephone exchange. where they are under observation and free from unauthorised tampering. Two jack positions in the outgoing programme lines should be provided near the radio receivers to allow the outputs to be adjusted to a reasonable listening level.

This, of course, is a very simple installation involving two receivers and a bedside dual-programme switch with jack and volume control incorporated. It involves, however, long cable lengths, which in themselves are expensive items. A far more reasonable idea, and more in line with the modern trend, is to provide each ward with a small transistor amplifier capable of 200 or 300 milliwatts output, which is more than sufficient for the number of beds even in the largest hospital.

As these transistor sets are small in size, are battery-operated and almost trouble-free, they are eminently suitable for this kind of work as, having been tuned to their respective stations, no further operation is necessary, other than switching them in and out of circuit. The saving in cable costs alone seems sufficient justification.

There are hospitals, especially the larger ones, where a loudspeaker output is required in addition to the headphone circuits. In this case it is advisable to tap from some convenient point in the radio receiver (across the volume control for example) and to take this output via a small condenser to an isolating transformer followed by a volume control and dropping pad to give microphone level. This can then be accepted by any good class microphone and power amplifier.

When such a system is available it is possible to utilise a microphone in addition to the other circuits for paging in an emergency.

Nowadays there is a growing tendency to use this basic equipment on a wider front, and we give a few suggestions which may be of use.

Most amplifiers have a point for a gramophone input, and it has been proved that the innovation of a local 'choice of record' programme is very popular. It means putting on a programme at stated

FIG. 8

There are so many types of station design that it is hard to pick on one that can be classed as typical.

We have, however, shown a very simple design of a small terminal. As we have already stated platform coverage is simple but, in general, far too little attention is devoted to what might be referred to as the foyer. It is here that such things as echo, reflection and directive sound should be taken into consideration. A certain amount of bass-cut should be used in the system to allow the announcements to over-ride the natural noise level.

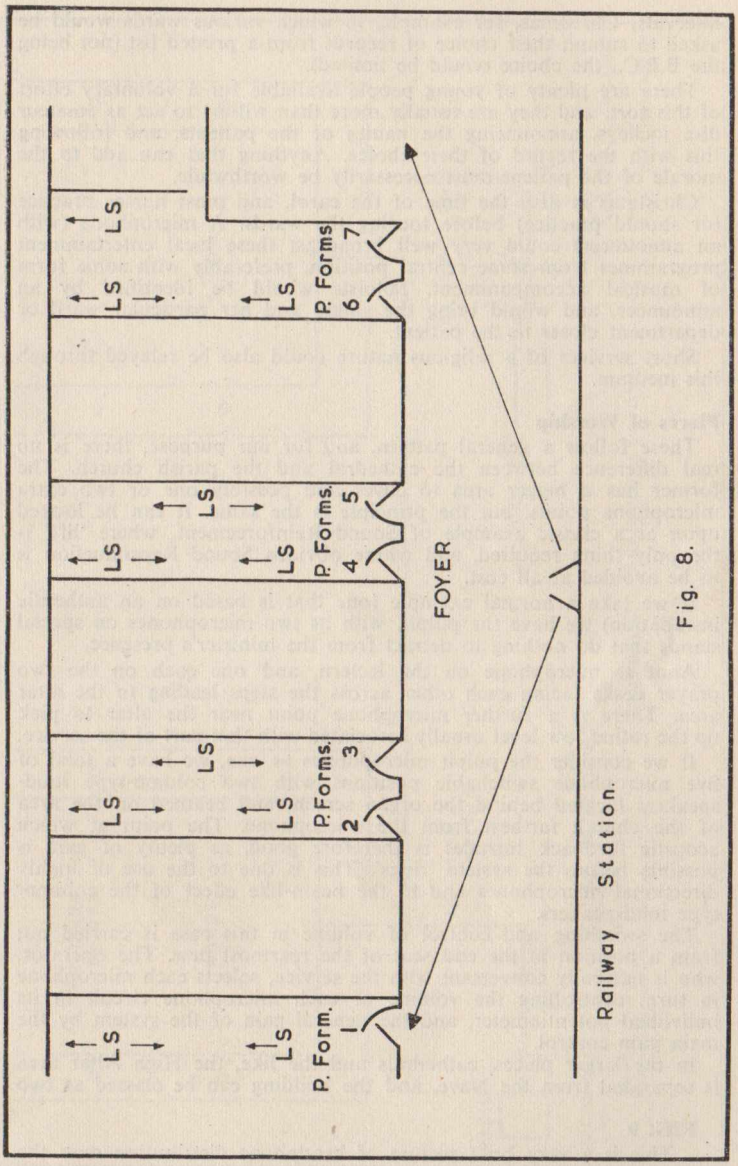


Fig. 8.

intervals, Christmas, for example, in which various wards would be asked to submit their choice of records from a printed list (not being the B.B.C., the choice would be limited).

There are plenty of young people available for a voluntary effort of this sort, and they are usually more than willing to act as amateur disc jockeys, announcing the names of the patients, and following this with the record of their choice. Anything that can add to the morale of the patient must necessarily be worthwhile.

Christmas is also the time of the carol, and most nurses practice (or should practice) before touring the wards. A microphone (with an announcer) could very well broadcast these local entertainment programmes from some central position, preferably with some form of musical accompaniment. Soloists would be identified by an announcer, and would bring the singer and her particular ward or department closer to the patient.

Short services of a religious nature could also be relayed through this medium.

Places of Worship

These follow a general pattern, and for our purpose, there is no real difference between the cathedral and the parish church. The former has a bigger area to cover and possibly one or two extra microphone points, but the principle is the same. It can be looked upon as a classic example of Sound Reinforcement, where 'lift' is the only thing required, and where obvious Sound Reproduction is to be avoided at all cost.

If we take a normal example (one that is based on an authentic installation) we have the pulpit, with its two microphones on special stands that do nothing to detract from the minister's presence.

Another microphone on the lectern, and one each on the two prayer desks facing each other across the steps leading to the altar area. There is a further microphone point near the altar to pick up the rather low level usually associated with that part of the service.

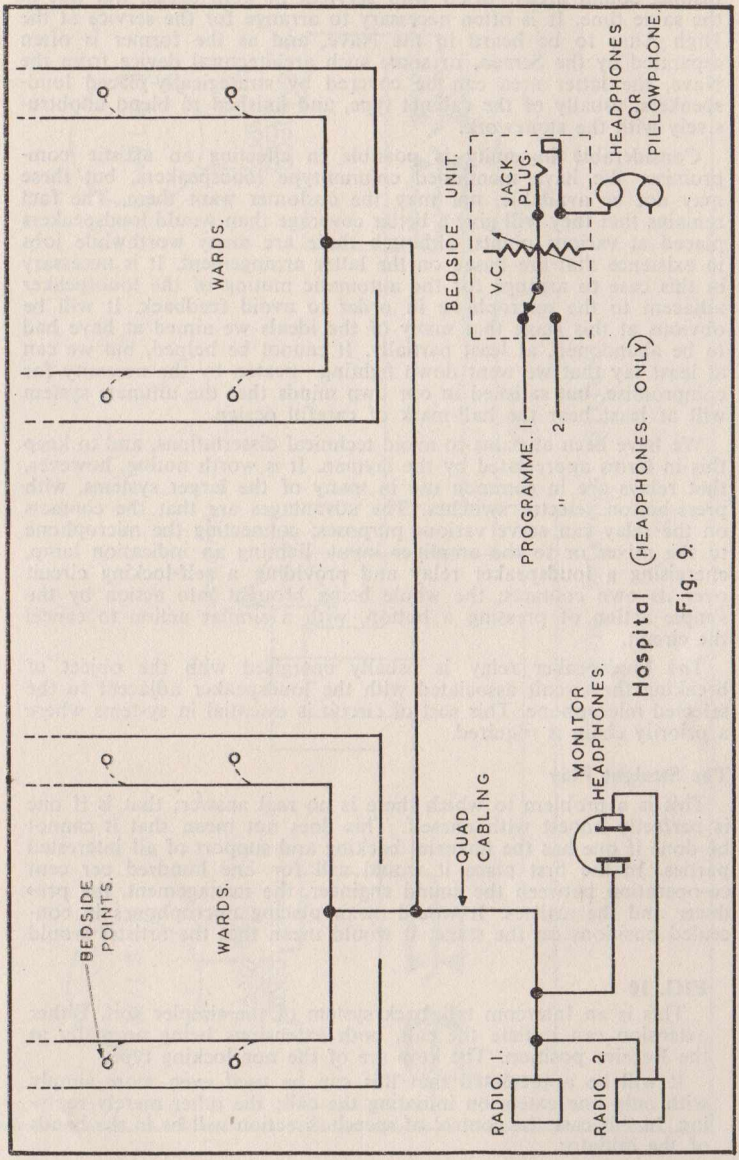
If we consider the pulpit microphones as one, we have a total of five microphone switchable positions with two column-type loudspeakers located behind the organ screen, and beamed on the area of the church farthest from the microphone. The point at which acoustic feedback intrudes is therefore good, as plenty of gain is possible before the system 'rings'. This is due to the use of highly directional microphones and to the beam-like effect of the column-type loudspeakers.

The switching and control of volume in this case is carried out from a position in the end seat of the rearmost pew. The operator, who is naturally conversant with the service, selects each microphone in turn, controlling the volume of each microphone circuit in its individual potentiometer, and the general gain of the system by the main gain control.

In the larger places, cathedrals and the like, the High Altar area is separated from the Nave, and the building can be classed as two

FIG. 9

This is a very brief picture of headphone distribution over the wards; only two being shown, and in these, only four bed positions.



Hospital (HEADPHONES. ONLY)

Fig. 9.

distinct sound areas; often with services in both areas, but not at the same time. It is often necessary to arrange for the service at the High Altar to be heard in the Nave, and as the former is often separated by the Screen, or some such architectural device from the Nave, the latter area can be covered by strategically-placed loudspeakers, usually of the cabinet type, and finished to blend unobtrusively with the stonework.

Considerable ingenuity is possible in effecting an artistic compromise. We have mentioned column-type loudspeakers, but these may not be available, nor may the customer want them. The fact remains that they will give a better coverage than would loudspeakers placed at various points, although there are many worthwhile jobs in existence that are based on the latter arrangement. It is necessary in this case to arrange for the automatic muting of the loudspeaker adjacent to the microphone in order to avoid feedback. It will be obvious at this stage that many of the ideals we aimed at have had to be abandoned, at least partially. It cannot be helped, but we can at least say that we went down fighting—beaten by the necessity for compromise, but satisfied in our own minds that the ultimate system will at least bear the hall-mark of careful design.

We have been at pains to avoid technical dissertations, and to keep this in terms appreciated by the layman. It is worth noting, however, that relays are in common use in many of the larger systems, with press-button selector switches. The advantages are that the contacts on the relay can serve various purposes; connecting the microphone to the mixer or to the amplifier input lighting an indication lamp, energising a loudspeaker relay and providing a self-locking circuit over its own contacts; the whole being brought into action by the simple action of pressing a button, with a similar action to cancel the circuit.

The loudspeaker relay is usually energised with the object of breaking the circuit associated with the loudspeaker adjacent to the selected microphone. This sort of circuit is essential in systems where a priority chain is required.

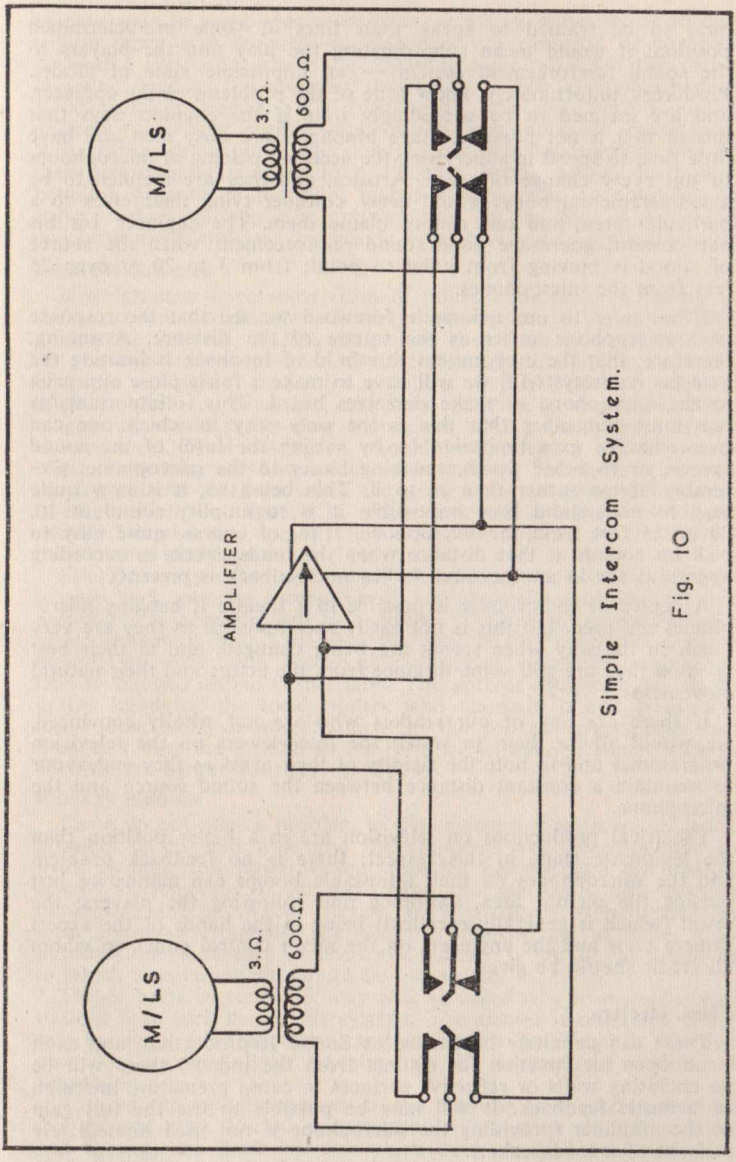
The Straight Play

This is a problem to which there is no real answer; that is if one is perfectly honest with oneself. This does not mean that it cannot be done if one has the financial backing and support of all interested parties. In the first place it would call for one hundred per cent co-operation between the sound engineer, the management, the producer and the artistes. It would mean placing microphones in concealed positions on the stage; it would mean that the artistes would

FIG. 10

This is an Intercom talk-back system of the simpler sort. Either extension can initiate the call, both extensions being normally at the Receive position. The keys are of the non-locking type.

It will be appreciated that this can be used even more simply with only one extension initiating the call; the other merely replying. In this case the control of speech direction will be in the hands of the initiator.



Simple Intercom System.

Fig. 10

have to be trained to speak their lines at some pre-determined position; it would mean subordinating the play and the players to the sound reinforcement system — an impossible state of affairs. Producers, unfortunately, know little of the problems of the engineer, and are inclined to be exceedingly irate if the engineer says that this or that is not possible. Stage Managers are busy men and have little time to spend in supervising the accurate placing of microphones to suit every change of scene. Artistes, and they are inclined to be a temperamental body, would never consider tying themselves to a particular area, and one cannot blame them. The engineer, for his part, cannot guarantee good sound reinforcement when the source of sound is moving from point to point; from 3 to 20 or even 25 feet from the microphones.

If we refer to our axiomatic foreword we see that the response of a microphone varies as the square of the distance. Assuming, therefore, that the ever-present threshold of feedback is limiting the gain (as it always will) we will have to make a fairly close approach to the microphone to make ourselves heard. This is important, as one must remember that this is the **only** way in which one can overcome the gain limitation — by raising the level of the sound source, or in other words, speaking closer to the microphone, preferably across rather than in to it. This being so, it is now quite easy to understand how impossible it is to amplify sound at 10, 20 or 25 feet from the microphone. It is, of course, quite easy to pick up sounds at that distance when the loudspeakers or recording apparatus are in another area (when no feedback is present).

A degree of compromise is possible in a theatre if hanging microphones are used, but this is not easily accomplished as they are very much in the way when scenes are being changed, and at their best position they are still some distance from the actors and their natural movements.

If there are any of our readers who are not wholly convinced, we would advise them to watch the interviewers on the television programmes and to note the rigidity of their arms as they endeavour to maintain a constant distance between the sound source and the microphone.

Theatrical productions on television are in a better position than the legitimate stage in this respect; there is no feedback problem and the microphones on their adjustable booms can manœuvre just outside the picture area, swooping and following the players; the result (which is generally excellent) being in the hands of the expert camera crew and the engineers on the mixer control panel, to whom all credit should be given.

Fêtes, etcetera

These can definitely be classed as Sound Reproduction, and as it is an open air function (as distinct from the indoor) there will be no enclosing walls or reflective surfaces to cause premature intrusion of acoustic feedback. It will now be possible to use the full gain of the amplifier (providing the microphone is not used immediately in front of a loudspeaker).

Here, again, there are two courses open to us; to contain our

loudspeakers in some central position, radiating outwards or to distribute them over an area—in marquees, for example, or covering the walks and odd corners. The latter is quite usual but can result in sound overlap, remembering that sound travels at approximately 1,100 feet per second. In a function of this sort, with a public unlikely to be over critical, such overlap is of no great importance. It is customary to use some form of horn-type loudspeaker, and as these are usually coupled to a 15 ohm pressure unit the power handling capacity is naturally higher and requires an amplifier of corresponding wattage. The pressure unit, by the way, is a moving coil instrument, coil and diaphragm being enclosed in a metal casing.

Football Grounds

Most grounds have some form of public address for speaking to the customers and for broadcasting music prior to the match and during the interval. If they have not, then here is a fine chance for the local trader or amateur. Unfortunately, the upkeep and use of these equipments is carried out in a very half-hearted manner; music is often too loud and extremely irritating to the crowd, who, in general, would rather hear themselves talking about the referee's shortcomings. Music therefore, should be limited to a background effect, something soothing rather than martial, for there is enough of that on the sidelines while the game is in progress. The music is often ill-chosen. Speech is often distorted and hard to follow, usually because the speaker has not been briefed in the correct microphone technique.

Feedback may exist to some slight extent if the sound is allowed to seep back into the control room, but, generally speaking, the full output of the amplifier will be available. The area to be covered will be as shown in Fig. 4 namely the roof of the centre to a point directly opposite, with loudspeakers beamed diagonally across the field to the two distant corner flags. This sort of equipment is usually in the hands of the local traders who maintain it and frequently have some form of advertisement in the printed programmes and broadcast over the ground in the form of an announcement such as 'records are by the courtesy of Messrs. ————————'.

Railway Stations

These do not offer a problem to the engineer; there is no feedback problem to contend with and the amplifiers are therefore able to work at their full power output. Cowled loudspeakers are usually spaced at intervals of 30 feet along the platforms, the cowling minimising the inevitable overlap from platform to platform. As most announcers mention the platform number and as there is an unmistakable difference in level, the listener is left in no doubt as to which announcement should be listened to.

Things being so simple, it may well be asked why so many railway stations have such deplorable systems. The answer is contained under two headings, false economy, and indifferent handling. In the first place, the quality is poor because only the lower-priced tenders are acceptable.

The second, equally serious, is the drafting of platform staff to microphone duty. Verbal instructions for travellers should be clear and concise, and those stations which have changed over to female announcers are proof of this.

A section of a large railway terminus that deserves much more attention than it gets is the area surrounding the platform heads, where the ticket collectors gather in their cloaks of cynical gloom. There is one large terminus where the column-type loudspeakers were demonstrated with great success—a great improvement on the old system. Nohing more was heard of this. There are others where the sound from the ancient loudspeakers has to be heard to be believed, being almost unintelligible and filling the place with reflected echoes.

A railway station is not an easy place to cover, acoustics were not considered when the plans were drawn, and one has to compete (if steam engines are being used) with a whole variety of dreadful sounds.

Then there is the vast echoing roof and reflected pillars; but these after all are but a challenge to the sound engineer.

Rather a gloomy outlook; but railway stations, especially those of the last century are themselves gloomy, full of that 'parting that is such sweet sorrow' atmosphere, so that it becomes an additional reason for a bright female voice to guide us on our way, in place of the gibberish, mains hum, key clicks, etc., which we so often hear.

Choice of Amplifiers

We have already mentioned the amplifier, and our purpose now is to decide on the type, in terms of power output, for our individual systems.

To some, this will be common knowledge, and again to others—to the small trader doing this sort of thing as a sideline, or the amateur—it may prove to be of some use.

Firstly, the amplifier should be of reputable make, capable of giving the output claimed — undistorted. That is, five per cent harmonic distortion or less. There are certain models on the market with rather extravagant claims, and these should be avoided. Five per cent is considered rather high these days, but this amount of distortion is neither visible on an average oscilloscope nor is it audible.

Seven per cent can both be seen and heard when testing at 1,000 cycles. So keep below 5 per cent and obtain some information from the supplier as to the amplifier's performance over the audio frequency range. It should have almost a flat response between 50 cycles and 8 Kc/s. A drop of a decibel or two at either end will not matter, although when studio requirements are called for, both distortion limits and the response curves are much more strict. The price also rises considerably.

When choosing an amplifier (either a combined microphone and power amplifier or two separate units) make enquiries as to signal-to-noise ratio, that is the output when the amplifier control is at maximum, with the input either short-circuited or terminated in a resistance. If the noise level is high it may be made up of mains hum plus the inherent noise of the amplifier, valve hiss, etc., and whatever the test figure the noise should be inaudible, and if the model is only reasonably quiet when securely tied down to earth then, in our opinion it is not much good, as earthing is problem enough without having an unstable amplifier as well.

We will now give, in general terms, some idea of the wattage required for the various systems, bearing in mind that a cone-type

loudspeaker is unlikely to require more than one or two watts, and a pressure unit, anything up to eight watts.

We must say here, quite frankly, that there exists quite a lot of confused thinking, and often a difference of opinion on such matters. We have been approached by laymen who are not satisfied with an offer of a twenty watt amplifier, as they are in possession of four twenty watt loudspeakers. The figure of twenty watts in this case was hopelessly inaccurate and misleading, as the client was under the impression that he would need at least 80 watts from his amplifier. One can visualise the cone assembly disintegrating at such a figure, besides being quite useless for the average system where, if such a power was necessary one would choose a more robust type such as the moving coil pressure unit with some form of horn.

Bearing in mind our previous remarks, oft repeated, that indoor systems are limited by the feedback point, it can be said that the power required per cone unit in a church, at a banquet or any such function is less than a watt, possibly less than half a watt. A large theatre can function very well on a 40 watt output or even a 30 watt, providing these figures are genuine undistorted output figures. A small hall employing one or more loudspeakers will work admirably on 6 watts, and will work just as well on a higher powered amplifier, although in this case a certain amount of the available power will be unused.

For anyone engaged on hire work; that is installation and operation of fêtes etc., a medium powered amplifier is advisable as it can cover so many varied functions; whereas a lower power output will at times be found insufficient. The difference is more in design than in price, a fact worth noting.

For a factory of any size the wattage will be much higher, a very rough estimate being 1 watt per cone type and 3 to 4 watts for the outdoor-types which may be installed in noisy machine shops or in roadways or loading bays.

It is usual to arrive at an approximation of the estimated power required, and then to install an amplifier of reputable make with a power margin to cover a possible extension of the system at a later date.

In these larger installations, especially factories, it is customary to carry out the control from some form of panel, sometimes in the office block and sometimes in the gatekeeper's office. It is sometimes deemed advisable to duplicate the control, working it in the telephonist's area in the daytime and from the gate at night. These, however, are domestic matters such as crop up with every new client.

Earthing of Systems

This is of supreme importance, and to achieve a stable and trouble-free system it is necessary to proceed as follows.

It will be appreciated that the output of a microphone is extremely low, no higher than many stray currents from many sources, all of which may be induced into the system unless the low levels are adequately screened and earthed. It is necessary to use a screened pair cable from microphone to amplifier or from microphone to ampifier via the fader, as shown in Fig. 2, and it is essential that this low level cabling is kept well apart from the high level or loudspeaker cabling, as too close coupling of these widely different

levels will result in instability, and may result in high frequency oscillation.

It is important that only one earth point is used. If more than one is used it will result in a loop earth condition which may be extremely dangerous and cause instability.

Impedance Matching

To avoid loss it is essential that both the input and the output of the amplifier are correctly matched. For instance a 50 ohm microphone should work into an amplifier designed to accept this impedance. As regard the output it is customary to supply a line transformer with each loudspeaker and to use the tappings on the line side to effect a match.

Assuming the tappings are 2,500, 5,000 and 10,000 ohms, it will be possible to select so that the joint impedance of the total is approximately that of the amplifier output. This is not always possible, so one is on the safe side in leaving the amplifier working **up** into a higher impedance rather than into a lower. This is very important if the amplifier has a class B push-pull output stage. These tappings are also available to decide the amount of applied power available for each unit (see Fig. 3).

Many amplifiers have the secondary of their output transformers in two halves. When these two halves are in series the impedance will be, for example, 600 ohms but when they are parallelled it will be only 150 ohms. This gives, in addition to the previous range of selected tappings, a fair chance to arrive at a compromised matching.

Before concluding, here are a few relevant remarks of a general nature. A cone-type loudspeaker makes a good utility microphone with quite a substantial output. It can be used for Intercom. systems, the unit then becoming alternately a transmitter and receiver. This sensitivity makes it ideal for picking up such sounds as bird song for recording, or for intercom. work, but it has no direct use in an area where feedback limits its use, especially as it has an omni-directional characteristic. It is necessary to use a line transformer having a similar line impedance to the amplifier, for example, 600 ohms, so that input or output matching is equal.

Another point worth remembering is that a considerable length of microphone cable (four to five hundred yards) has no ill effect upon reproduction providing it is normally robust, is correctly screened and earthed to the amplifier end. There is also apprehension at times when loudspeaker lines are rather long. Here again there will be no appreciable loss if loudspeaker cabling is in 3x.029 or its equivalent.

Another point is at all times to avoid close-coupling between microphone (low level) and loudspeaker (high level). Close-coupling in this case is unlikely to occur other than in the vicinity of the amplifier, although there are cases where both levels are taken to some distant point. In this case they should be in separate conduit runs, properly earthed, and at a safe distance of about one foot from each other.

Gramophone pick-up outputs, unless built in an equipment rack, should have the matching pads and transformers (if any) in the **amplifier end** of the lead, and the leads should be reasonably short.

It is important to watch this carefully, as inefficient earthing may result in the hum from the 'gram motor going out over the system: and here are a few things to remember:—

If you are on the stage, don't stand there listening to yourself. If you cannot hear your amplified voice, so much the better, providing, that is, that your listener can. If you insist, as some artistes do, on hearing a large volume of sound from the loudspeakers, then someone is being deafened, and you might as well be in a fair ground.

Don't blow into the microphone or tap it with your finger nail. It's like doing your swimming in the shallow end (with one foot on the bottom). If you have so little confidence and require reassurance then rub the ball of the thumb across the microphone and be prepared to receive the engineer's thumbs up sign.

Above all, maintain your speaking distance from the microphone whenever possible. Don't shout into the microphone.

Finally, here are some do's. Treat a system as you would your first new car, that is, don't overload it, keep it clean, and remember at all times that it cannot think for itself—and you can.

No. 158 RADIO, TELEVISION, INDUSTRIAL TUBE, TRANSISTOR AND DIODE EQUIVALENTS HANDBOOK by B. B. Babani **9/6**

Size 7½" x 5" 208 pages Plexilaminated washable cover

This is the latest of our famous equivalents books and is the only complete list of its kind in the world. For the first time, equivalents are included of every type of transistor and diode as well as for the vast number of old and modern valves.

No. 159 REALISTIC HIGH FIDELITY by H. A. Hartley **5/–**

Size 7¼" x 4¼" 96 pages 36 diagrams

H. A. Hartley, the well known Hi-Fi authority, covers the field, in this book, from the point of view of achieving the maximum realism. As this hinges mainly on the actual sound producing mechanism, the loudspeaker, its enclosure and position is considered in considerable detail. As Mr. Hartley was engaged in speaker and enclosure design for many years he knows exactly what he is talking about and his great ability as an author makes his book both enjoyable to read and easy to understand.

No. 160 COIL DESIGN AND CONSTRUCTION MANUAL 5/–

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No. 162 HIGH FIDELITY STEREO GRAMOPHONE

by D. W. Easterling **5/-**

Size 7½" x 5" 96 pages 33 illustrations

Using the new E.M.I. record turntable and pickup arm, this book describes the construction of a complete unit for playing stereophonic records with absolute fidelity. The constructional information is provided in the minutest detail so as to be suitable for even those without previous constructional experience. Large wiring diagrams and chassis bending and cutting diagrams are provided together with photographs of the completed equipment.

No. 163 TRANSISTOR CIRCUITS MANUAL No. 2

by Clive Sinclair **2/6**

Size 7¼" x 5" 44 pages 20 diagrams

This is the second of the transistor circuits manual series and, like the first, it provides circuit details and constructional data for a large number of transistorised units. As this book deals with some slightly more advanced projects than Book 1, technical descriptions of the mode of operation of the circuits are included, as well as the purely constructional details. The common denominator of the circuits is originality so that the purchaser is bound to find a lot in it which he has never seen before. The units described are: 1, Single transistor metal detector; 2, Subminiature power amplifier; 3, Broadcast band receiver booster; 4, Simple Electronic organ; 5, Two transistor pocket radio with speaker; 6, Transistor F.M. tuner; 7, 1 watt hi-fi amplifier; 8, Subminiature pocket transmitter; 9, Subminiature shortwave receiver; 10, Shortwave frequency changer; 11, 30 mc/s voice modulated transmitter; 12, 10-30 mc/s superregenerative receiver; 13, Subminiature hearing aid.

No. 164 HIGH FIDELITY TAPE RECORDER

by Clive Sinclair **2/6**

Size 10" x 7½" 24 pages 15 illustrations

This book describes the construction of an elegant and high performance tape recorder with a frequency response of from 30 c/s to 12,000 c/s. The recorder uses the well known Monarch deck and a modified version of the Mullard amplifier on a T.C.C. printed circuit board. All the parts, including a suitable case, are on the market in kit form and this kit is now available from your local dealer.

BERNARDS RADIO BOOKS

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56.	Radio Aerial Handbook	2/6
57.	Ultra-Shortwave Handbook	2/6
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