THE LONDON TELEVISION SERVICE

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SUMMARY

This paper describes a television broadcasting station recently built by the British Broadcasting Corporation in a part of the Alexandra Palace, London, N. The development of the television service in this country is traced from the early attempts to promote an experimental service of transmissions on low standards of definition to the establishment of a high-definition public service.

The paper is divided into six parts.

Part 1 touches briefly upon the history of television development in this country, and describes in some detail the transmission of low-definition pictures from B.B.C. stations during the years 1929 to 1935.

Part 2 deals with the recommendation of the Television Committee that a station for transmitting high-definition television should be established, and it discusses various factors upon which the subsequently appointed Television Advisory Committee based its decisions regarding the choice of the Alexandra Palace site, the operating wavelengths, and standards of definition.

Part 3 describes the arrangement of studios and apparatus rooms at the Alexandra Palace station. The problems of studio acoustics, production lighting, and the provision of essential supplies, are also dealt with.

Part 4 describes the layout and arrangement of the control room and transmitter equipment installed for the vision and accompanying sound transmissions.

Part 5 is concerned with the plant developed to enable current events and other programme items taking place at some distance from the Alexandra Palace to be televised. Some account is given of the use of land lines to carry television signals.

Part 6 is a brief consideration of the reception results of signals from the Alexandra Palace since the beginning of the service, and embodies the result of signal-strength surveys made in the vicinity of, and at distances from, the station.

Finally, the various types of television receivers and aerials are discussed.

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INTRODUCTION

This paper gives a general description of the London Television Station and touches upon past experience with experimental 30-line transmissions. It discusses the circumstances influencing the Television Advisory Committee's recommendations regarding the establishment of a high-definition service, and the subsequent factors governing the choice of operating wavelengths, standards of definition, and the Alexandra Palace site.

Following upon the recommendations of the Television Advisory Committee, the British Broadcasting Corporation has acquired on lease a portion of the Alexandra Palace premises in North London which, with slight modifications, were arranged to accommodate two complete television systems of the Marconi-E.M.I. and Baird companies respectively, each system having its own studio premises and vision radio-transmitter. A third radio transmitter is provided to broadcast at will the sound accompanying the vision of either system. Two aerial systems are provided, the one interchangeable between the two vision transmitters, and the other permanently connected to the sound transmitter.

In addition to the premises set apart for present technical requirements, the British Broadcasting Corporation has also leased the Alexandra Palace Theatre, which it is anticipated will provide additional studio accommodation in due course. Certain other areas have been converted into offices for the technical and production staffs.

In the course of the paper the arrangement of the areas referred to above is described and illustrated by means of plans, followed by descriptions of the apparatus installed. The acoustic treatment of the studios and the arrangement of production lighting are described, together with a reference to conditions of working during the production of studio scenes.

An account is given of the equipment developed for television outside broadcasts and of the problems associated with the transmission of television signals over land lines.

The final part of the paper gives an account of the general performance of the station, in so far as this has been ascertained since the inception of the service.

PART 1

EARLY TELEVISION AND THE 30-LINE EXPERIMENTAL SERVICE

(a) Brief Historical Survey of Early Television Activities

Although usually considered to be a modern art which has made accelerated progress in recent years, television has its beginnings deeply rooted in the past. In the case of other similar achievements it is often found that early scientific discoveries have been made for which no immediate practical use could be found, but television differs in that, long before it was contemplated, an accidental scientific discovery clearly indicated the possibility of seeing at a distance.

In 1817 the metal selenium was discovered by Berzelios, and 56 years later an operator named May, working at the terminal of the Atlantic cable at Valencia on the southwest coast of Ireland, discovered that the behaviour of some selenium resistances in use at the station varied according to the amount of light shining upon them through the window. It was, of course, realized that, just as the transmission of sound to a distance by cable necessitates the creation of an electric current which faithfully represents it, so, in order to see at a distance, we must have some means of controlling a current by means of light; and this discovery by May, quickly confirmed by W. Smith and W. G. Adams, created immense interest and may be said to have been the true beginnings of television.

It was clear that television, in common with other methods of transmitting a picture to a distance such as phototelegraphy, required a solution to the problem that the communication channel can be said to have only two dimensions whereas the picture to be transmitted has three. Consequently some means of reducing the three dimensions of the picture to two only were required before television in a practical form could be realized. This was, and still is, accomplished by splitting up the picture into elements which are transmitted successively, and in 1884 the Polish scientist Nipkow invented his famous disc, which is still in use in certain systems of television to-day. Meanwhile other discoveries destined to contribute to the success of television were being made. Faraday in 1845, and Kerr in 1877, had demonstrated the effect of magnetic and electrostatic fields on polarized light. It was not, however, possible to achieve television, as no means of amplifying the very small currents available had yet been found, and therefore a special interest attaches to a description by A. A. Campbell Swinton in *Nature* in 1908 of a device which was the forerunner of the " Emitron " used to-day at the London Television Station. This apparatus fundamentally possesses a comparatively high sensitivity, owing to an inherent electrical storage effect.

During the years 1923 to 1928, experiments carried out by J. L. Baird finally resulted in the completion of a television system which gave tolerably faithful reproduction of an object transmitted through the medium of a line connection between transmitter and receiver.

It was realized that the range of frequencies necessary for the elementary degree of definition then used was only a little greater than was required for the faithful transmission of sound, and it was considered that it might be possible to transmit such pictures over the normal sound-broadcasting system.

(b) The First Regular Transmissions of Television of Low Definition

In 1929, arrangements were made between the British Broadcasting Corporation and Baird Television, Ltd., for the regular broadcasting of television from the B.B.C.'s London station, which was then a 2-kW transmitter situated in Oxford Street. In the system then in use the transformation of the picture into a succession of elements, or " scanning," was accomplished by dividing the picture into 30 vertical strips, or lines, each line being explored in succession by a square aperture, whose width and height were each equal to the width of one line. The number of pictures transmitted per second was $12\frac{1}{2}$, this being achieved by repeating the scanning cyclicly at this frequency. These transmissions, which were unaccompanied by sound, lasted for $\frac{1}{2}$ hour and took place daily except on Saturdays and Sundays, the studio being situated at the laboratories of the Baird Co. in Long Acre.

In October, 1929, these transmissions were transferred to the B.B.C.'s station at Brookman's Park. As this station is equipped with two separate transmitters, one for the National and one for the London Regional programme, it became possible to transmit the sound associated with the television programme, and this was started on the 14th April, 1930.

(c) The Equipment of a Television Studio at Broadcasting House

The British Broadcasting Corporation watched very closely the results of these early experimental transmissions and the progress which was being made at the same time in the laboratories of the Baird Co., and it was decided in 1932 to equip one of the studios in the basement at Broadcasting House with the latest 30-line television apparatus designed by the Baird Co., and to take over the responsibility for originating the transmissions, as by this means more direct experience would be gained of the problems entailed in the production of suitable television programmes.

A studio was therefore set apart in the sub-basement of Broadcasting House, with a small adjoining room having an intercommunicating window between it and the studio. The television scanning apparatus was installed in the adjoining room and operated through the window.

The installation of the apparatus was commenced in July, 1932, and the first programme was transmitted on the 22nd August. The vision signals were still radiated from London National, but the sound signals were radiated from Midland Regional instead of London Regional from this date.

Fig. 1 shows the layout of the control-room apparatus, from which the various parts of the equipment can be located as described.

The apparatus comprised the following sections:—

(1) The scanning-beam projector for generating the spot of light which is required for the spotlight system.
(2) The photocells.
(3) The amplifiers and mixers.
(4) The caption scanner.
(5) The sound apparatus.

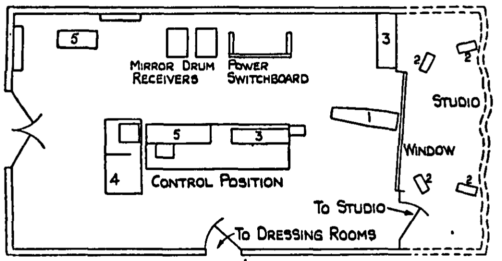

Fig. 1

(1) A schematic drawing of the optical system of the projector is shown in Fig. 2. An arc lamp at B, having its positive carbon horizontal, irradiated an aperture A situated about $\frac{1}{2}$ in. from the positive crater and consisting of a hole 0·125 in. square in a plate of metal.

The light passed to the convex lens L, having a focal length of 22 in., which focused an image of the illuminated square aperture on the artist, via the optical path AL, LP, PM, and MI. P was a plane mirror which reflected the beam on to the mirror drum situated at M. The drum consisted of a metal cylinder having 30 milled surfaces to which were fixed mirrors radially spaced evenly round the drum.

In order to bring the spot into focus on the artist the arc lamp could be moved towards or away from the lens by means of a hand-wheel. The scanning of a very close-up view could not be accomplished by this, however, and when such a view was wanted, the scanned area was reduced in size by an auxiliary long-focus convex lens which could be swung into the optical path in front of the drum, and which is shown at L2.

The projector could be swung horizontally about a fulcrum to follow sideways movements of an artist, and a mask could be raised or lowered to vary the sector of light taken from the drum upwards and downwards to follow the corresponding movements in the studio. Forward and backward movements were followed, as has been explained, by the arc adjustment. The drum was driven by a synchronous motor situated inside it and running at 750 r.p.m. from 50-cycle a.c. mains at 110 volts.

At the end of each line it was necessary to transmit a synchronizing signal, taking the form of a pulse of absolute black which was generated by a mask on the mirror drum which allowed a specific interval at the end of each line. In this interval the photocells received no light, and an electrical black pulse was generated.

(2) The studio was equipped with nine large gas-filled caesium photo-electric cells, and two further banks of four smaller cells per bank. This number of photocells was greatly in excess of that required purely for reasons of sensitivity, but since the photocells must be regarded as light sources from the point of view of illumination of the picture, it was necessary to fit a number to obtain lighting of some artistic merit.

(3) The photocells were connected together to form four groups, and each of these outputs was then applied to its own " A " amplifier, and the outputs of each of these amplifiers were led to a desk, at which an engineer could mix them in desired proportions. It is interesting to note that the operation of these mixing controls had, of course, the effect of varying the intensity and apparent direction of the lighting of the scene.

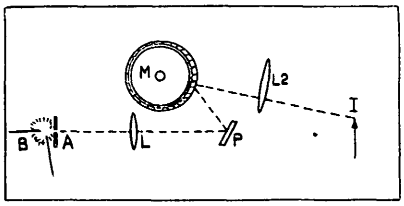

Fig. 2

After passing through the main volume control the signals were further amplified in a " B " amplifier, and thence passed to a pair of " C " amplifiers. One of the " C " amplifiers fed the signals to the main control room at Broadcasting House, from which they were passed by land line to the London National transmitter. The other " C " amplifier supplied a local picture monitor.

(4) In order to be able to transmit titles, tuning signals, and other matter which could conveniently be drawn on a small card, an additional scanner was provided. In this apparatus a spotlight method was again used, light from a 900-watt lamp being distributed by a Nipkow disc on to the card, which was viewed by two photocells. The card was held in place on one of the sides of a dodecahedron made of wood, so that 12 cards could be prepared and brought into position one by one. This subsidiary apparatus had its own individual amplifiers and mixers.

(5) The sound part of the transmissions was picked up by three microphones. The outputs of these were led to mixers, followed by " A " amplifiers. The signals were then sent to the Broadcasting House Control room, from which they were connected by line to the Midland Regional transmitter at Daventry.

Programmes were given four times a week for $\frac{1}{2}$ hour from the above studio, and transmissions included items of varied type, such as variety, ballet, exhibitions of pottery and pictures, and animals from the Zoo.

At the beginning of 1934, as the development of studio technique progressed, it was realized that it would be desirable to have the use of a larger studio. A new studio was accordingly prepared at 16, Portland Place, which adjoined Broadcasting House and was the property of the B.B.C., and on the 16th February, 1934, the transmissions were suspended for 10 days so that the television apparatus could be moved over to the new studio. The programmes were recommenced on the 26th February.

(d) The Cessation of the Experimental Service

Meanwhile, improved systems of television having greater definition and less flicker were being developed, and it was evident that the time was not far distant when the 30-line transmissions would be discontinued. As a preliminary to their discontinuance, the number of transmissions per week (then four) was reduced as from the 31st March, 1934, to two, the length of each transmission, as before, being ½ hour. After a time, however, it was found difficult to produce a balanced programme of general interest in half an hour, and from the 13th October, 1934, these transmissions were lengthened to ¾ hour. They continued in this form for almost another year, after which they were finally discontinued on the 11th September, 1935, in view of the impending high-definition service.

PART 2

EVENTS LEADING TO THE ESTABLISHMENT OF THE ALEXANDRA PALACE STATION

(a) The Television Committee's Recommendations

In order to understand the technical decisions, it is necessary to discuss the circumstances leading to the establishment of the Alexandra Palace station.

Having regard to the rapid strides which had been made in the technique of television, His Majesty's Postmaster-General in May, 1934, appointed a Committee under the Chairmanship of Lord Selsdon to consider the development of television and to advise him on the relative merits of the several systems and on the conditions under which any public service of television should be provided.

Having examined all the different systems of television in this and certain other countries this Committee reported in January, 1935, that the art of high-definition television had reached such a standard of development as to justify the first steps being taken towards the early establishment of a public television service of this type.

In view of the close relationship which clearly must exist between sound and vision broadcasting, the Committee recommended that the authority which is responsible for sound broadcasting—the British Broadcasting Corporation—should also be entrusted with the inauguration of the television service under the guidance of an Advisory Committee to be appointed. Consequent upon the result of its investigations the Television Committee further recommended that there should be an extended trial of two systems under strictly comparable conditions, by installing them side by side at a station in London where they should be used alternately and not simultaneously, for a public service.

The two systems in question were those of Baird Television, Ltd., and Marconi-E.M.I. Television Co., Ltd., both of which were in a relatively advanced stage of development and had already been operated experimentally over wireless channels with satisfactory results. The two companies were therefore to be given an opportunity to supply to the British Broadcasting Corporation the necessary apparatus to operate their systems.

The Committee stipulated that a standard of not less than 240 lines and 25 frames per sec. should be used, as this was considered to represent the minimum definition acceptable for the purposes of a public service.

The Television Committee further recommended that an Advisory Committee be appointed on which the Post Office, the Department of Scientific and Industrial Research, and the British Broadcasting Corporation, should be represented. This Committee was duly appointed and, in turn, deputed a number of its members to form a sub-committee to deal with exclusively technical matters.

(b) The Choice of Standards of Definition and Operating Wavelengths

The respective companies were invited to submit their views regarding the standard of definition which they would prefer to adopt.

Baird Television, Ltd., expressed their preference for the minimum standard acceptable to the Television Committee, viz. 240 lines and 25 frames per sec. sequentially scanned.

For 240 lines and 25 frames per sec. the effective upper limit of frequency generated by scanning was said to be about 1·5 Mc./sec., and it was suggested that any further increase in this frequency band resultant upon an increase in the number of lines or frames was not warranted, on the grounds that the cost and complication of the receiver would be unduly increased. The Marconi-E.M.I. Co. on the other hand desired to use 405 lines and 50 frames per second, interlaced to give 25 complete pictures per sec. They laid stress on the advantages of interlaced scanning on the grounds that it has the apparent effect of increasing the picture-repetition frequency to 50 per sec. at which no flicker is perceptible to the eye. This is achieved, however, without extending the band of frequencies beyond that which would be generated by 25 frames sequential scanning.

The greater number of lines proposed by the Marconi-E.M.I. Co. would of course increase the frequency band, but this, they maintained, would be justifiable in view of probable improvement in receiver technique in the future, which would permit the higher degree of definition transmitted to be effectively reproduced. The upper limit of frequency generated by this method of scanning was said to be approximately 2 Mc./sec.

The Advisory Committee gave the matter of standards close attention, but their efforts to arrive at a compromise in the form of a common standard of definition mutually acceptable to both companies were unsuccessful, chiefly owing to the advanced state of development which had been reached by the companies using their respective standards of definition.

In consequence the Advisory Committee decided that transmissions should take place on both standards of definition alternately. That is to say, during the period of transmission by the Baird system 240 lines and 25 frames per sec. would be used, while during the Marconi-E.M.I. transmission period the alternative standard of 405 lines and 50 frames per sec. interlaced would be employed.

Before reaching this decision the Advisory Committee assured itself that the two proposed standards of transmission could be received on a single receiver by means of a simple switching operation without unduly complicating or increasing the cost of the receiver.

It was hoped that a single radio vision transmitter might be constructed which would be suitable for both systems, but this was found not to be practicable, as the characteristics required by the two systems were so diverse as not to permit of the use of common apparatus other than the aerial and high-frequency feeder line.

Choice of Wavelengths.

The choice of a working wavelength for the vision transmitter was largely dictated by the very wide band of frequencies to be transmitted, as it would clearly be impossible to modulate any but an ultra-short wavelength with such a band of frequencies.

In general it is not practicable to operate a radio transmitter if the ratio of the carrier-wave fundamental frequency to the modulating frequency is much less than 20/1, otherwise the problem of ensuring adequate response at the side-band frequencies becomes too complicated.

This being so, a carrier wave frequency of 40 to 50 Mc./sec. is required for high-definition television, as it is called upon to accommodate modulation frequencies having an upper limit of about 2 Mc./sec.

Above 30 Mc./sec. there are no internationally-agreed wave-band allocations. The Post Office allocated the band between 40·5 and 52·5 Mc./sec. for the purposes of television, and the Television Advisory Committee decided that the London station should radiate vision on a frequency of 45 Mc./sec.

The accompanying sound could, of course from the technical point of view, be transmitted on any wavelength in the short, medium, or long bands, but owing to the congestion which exists, some difficulty would have been experienced in finding a channel for this transmitter, let alone any future transmitter of the same type. Moreover, in the interests of simplicity it is desirable that television receivers should be capable of picking up both sound and vision on one and the same aerial. For these reasons, therefore, the Advisory Committee decided that the sound should be broadcast on an ultra-short wavelength also, as close in frequency to the vision transmission as might be practicable, and a frequency of 41·5 Mc./sec. was chosen for this purpose.

This provided a separation of 3·5 Mc./sec., which was considered to be sufficient to prevent side-band interference between the two signals without encroaching more than was essential on the total wave-band available.

By such a disposition of frequencies, space is left at the higher end of the band for one more clear channel which will serve in the event of the erection of another station. It is believed that in the case of a third station situated more remotely from London, the original London sound and vision frequencies could be used without interference; while in the case of a fourth station, the same frequencies might be employed as for the second station, and so on, allotting the frequencies on a staggered basis. Whether this will be possible is not yet known, as insufficient data have yet been compiled regarding the area of interference caused by the London Television Station under all conditions of ionization of the upper atmosphere. Evidence at present makes it clear that reflection phenomena at 45 Mc./sec. exist, but their full significance is not entirely understood at present. Part 6, Section (*b*), deals with this aspect of the matter.

(c) The Choice of a Site

The choice of a site suitable for the London station presented a number of problems, and it was not an easy matter to find a situation where all the various requirements were adequately fulfilled.

In the first place it was necessary to use ultra-short waves for transmission, for reasons previously outlined. The effective range of ultra-short waves of this order of wavelength is known to be comparatively small—at one time it was thought not to extend beyond the optical range determined by the curvature of the earth's surface, although this has since been disproved. In consequence it is clear that the station must be situated as nearly as possible at the centre of the area of population which it is intended to serve.

Secondly, as is well known, the height of the transmitting aerial above surrounding territory is of cardinal importance in the service area of an ultra short-wave station, so that a most important requirement of the site was that it should stand on high ground and, further, that there should be no restrictions to the erection of a high mast to give a satisfactory elevation to the aerial.

Thirdly, a large area was necessary to accommodate the studios and rooms for the scanning and transmitting apparatus required for the operation of the two systems.

The first and most obvious site for the station is in the centre of the city, but, apart from the fact that no very high ground exists in the centre of London, this situation could not be contemplated, as it would not be permissible to erect a high mast and also the cost of acquiring a sufficient area for the needs of the station would be prohibitive.

Attention was therefore turned to high ground lying some distance from the centre, and a careful study was made of those parts sufficiently elevated to be of interest.

Hampstead and Highgate appeared to offer promise, but it was found that the acquisition of an area sufficient for the purpose in these districts would have been very costly, and severe restrictions existed regarding the erection of high masts.

High ground in the South of London, notably near the Crystal Palace, was considered, but in this case it was felt that the greater part of the service area of the station would be too much displaced in a southerly direction. Such places as Shooter's Hill were ruled out, on the grounds that they were too far from the central residential districts.

The Alexandra Palace site, however, appeared to possess outstanding advantages in that the ground-level was satisfactorily high, being 306 ft. above sea-level. There was a great deal of available space in the building, and Governmental permission to erect a sufficiently high mast was obtainable.

Another factor which weighed in favour of the Alexandra Palace site lay in the fact that the Palace stands on the top of an eminence so that the ground falls away very rapidly in all directions, and is comparatively low-lying all round, particularly in the direction of the centre of London. It was thought likely that this fact would give very low local attenuation, and some experimental evidence bearing upon this assumption is referred to in Part 5, Section (*c*). A 6 in. to the mile relief contour map of Greater London was constructed, and from this it was clear that with this site for the transmitter the number of areas in which weak signals would be likely to be encountered, owing to the overshadowing effect of high ground, would be a minimum over the whole of Greater London.

The Alexandra Palace site was accordingly chosen, and subsequent experience has confirmed the wisdom of the choice. This, however, will be dealt with later in the paper.

(d) The Beginning of the Service, and the Adoption of a Single Standard of Definition

The first transmissions from Alexandra Palace on both systems took place early in August, 1936, and demonstrations were given at the Radio Exhibition at Olympia between the 26th August and 5th September of that year. A period of " trial programmes " followed, and the television service was formally opened by the Postmaster-General on the 2nd November.

It was found that in practice the use of two standards of definition involved many disadvantages, from the point of view both of the manufacture and of the operation of receivers. In response to strong representations from many quarters, the Television Advisory Committee decided that it was essential in the interests of television, and to make possible the simplification and reduction of cost of receivers, to adopt a single standard of working.

It was further found that the impression of flicker associated with the use of 25 frames per sec. sequentially scanned gave rise to criticism on the grounds of eye strain, so that the superiority of interlaced scanning at 50 frames per second, giving 25 complete picture scans per sec., was clearly established.

In consequence the Television Advisory Committee decided that transmissions from Alexandra Palace should be carried out on a single standard of definition, viz. 405 lines and 50 frames interlaced, giving 25 complete picture scans per second. A public announcement to this effect was made on the 5th February, 1937.

PART 3

GENERAL DESIGN OF THE STATION

(a) General Plan of the Accommodation

The portion of the Alexandra Palace buildings taken over by the British Broadcasting Corporation consists of the S.E. tower with about 30 000 sq. ft. of adjacent premises in which the station proper is situated. The N.E. tower and theatre comprise a further superficial area of about 25 000 sq. ft.

The S.E. tower was converted to provide offices for the technical, production, and administrative staff, and it also serves as a base for the aerial mast. The existing pylon top and floors were removed, and fire-resisting floors and staircase were installed to provide five floors of offices above the ground floor.

The floors were carried by steel members, and the main brickwork of the tower, which is 85 ft. in height, was tied horizontally by steel ties at each floor, thus producing a structure of great solidity on which the mast could be erected. By means of these alterations the floor area available was increased by some 8 000 sq. ft.

With the exception of the structural modifications to the tower, the premises in general required little alteration from a structural point of view to adapt them for the equipment which they were to contain. Certain additional partitions were required, and it was necessary to segregate the premises from the remainder of the Palace buildings by means of a fireproof partition to fulfil the requirements of the local authorities.

Fig. 3 shows the layout of the S.E. premises. On the ground floor the base of the tower provides an entrance hall which forms the main entrance. Behind the tower is the local electricity substation and distribution switchgear room, the associated transformers being of the outdoor type and situated immediately outside the building.

The premises west of the tower provide two large halls each 70 ft. × 50 ft. to accommodate the Marconi-E.M.I. and Baird vision transmitters respectively, while in a central third hall 56 ft. × 24 ft. is situated the Marconi sound transmitter. Air-blast coolers for the water supply to the cooled-anode valves in all three transmitters are situated on the colonnade in front of the main premises, suitable chambers having been formed by bricking up the existing colonnade arches.

Behind the sound transmitter is a fully equipped theatre 40 ft. × 15 ft. for the projection of sound films, which is used by the productions staff for the selection and timing of excerpts from films which it is proposed to use for television purposes.

At the west end of the ground floor is a scenery-storage space 52 ft. × 22 ft. with a wide and lofty entrance from the terrace, into which large pieces of scenery and other bulky objects can easily be brought. This space can also be used as a temporary studio to televise objects whose weight or bulk precludes the possibility of their being taken to the studios on the first floor. A basement beneath accommodates the boiler for the heating system.

At the extreme rear of the premises is situated a restaurant for the staff, together with the necessary kitchens and storage rooms.

On the first floor there are two main studios each 70 ft. × 30 ft. and 27 ft. high, one for use with the Marconi-E.M.I. equipment, and the other originally used for the apparatus for the Baird intermediate film process and electron camera.

Between the two main studios are two control rooms, one associated with each system, a small studio and scanner room for the Baird spotlight scanning process and a room housing the Baird apparatus for film scanning by mechanical means.

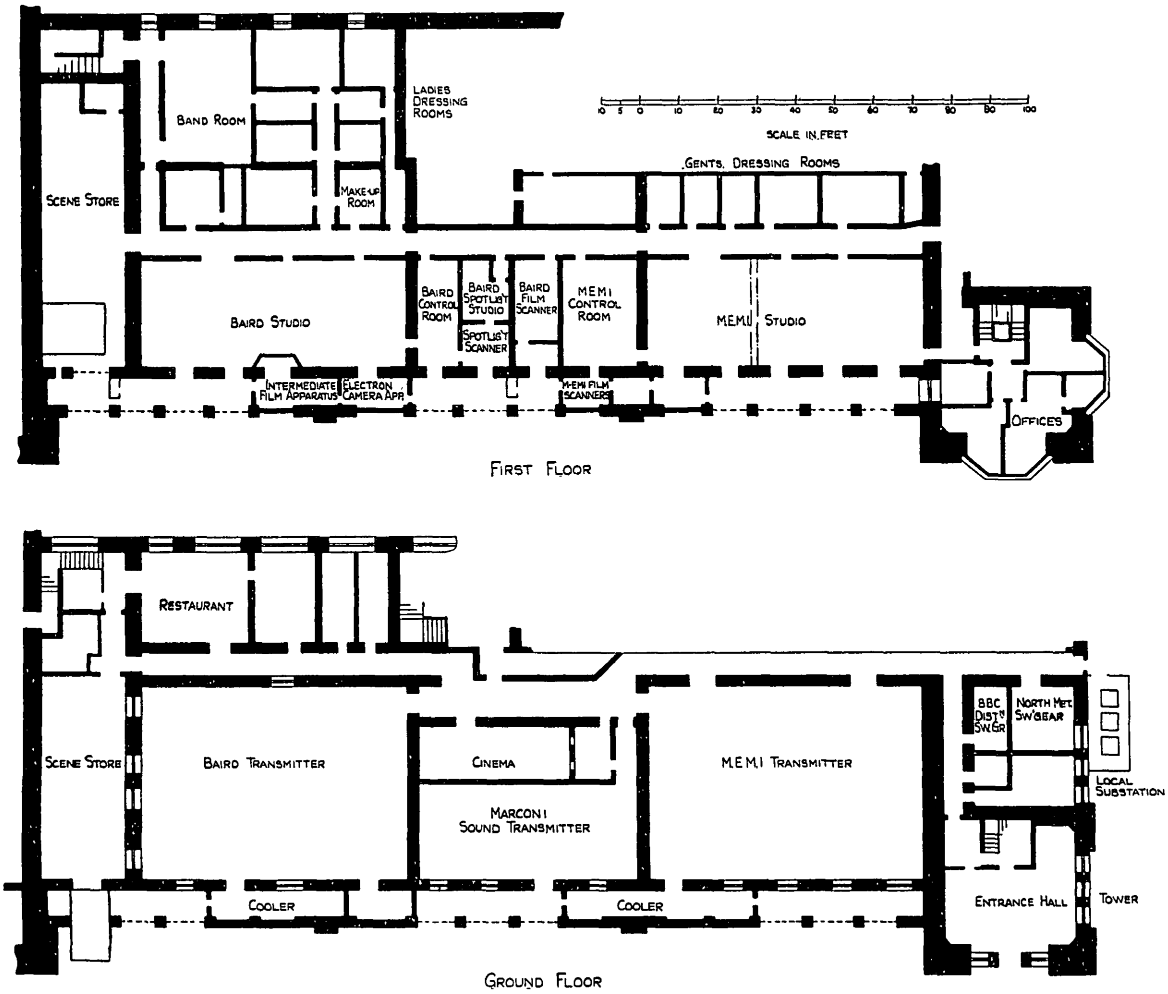

Fig. 3.—Plan of London Television Station.

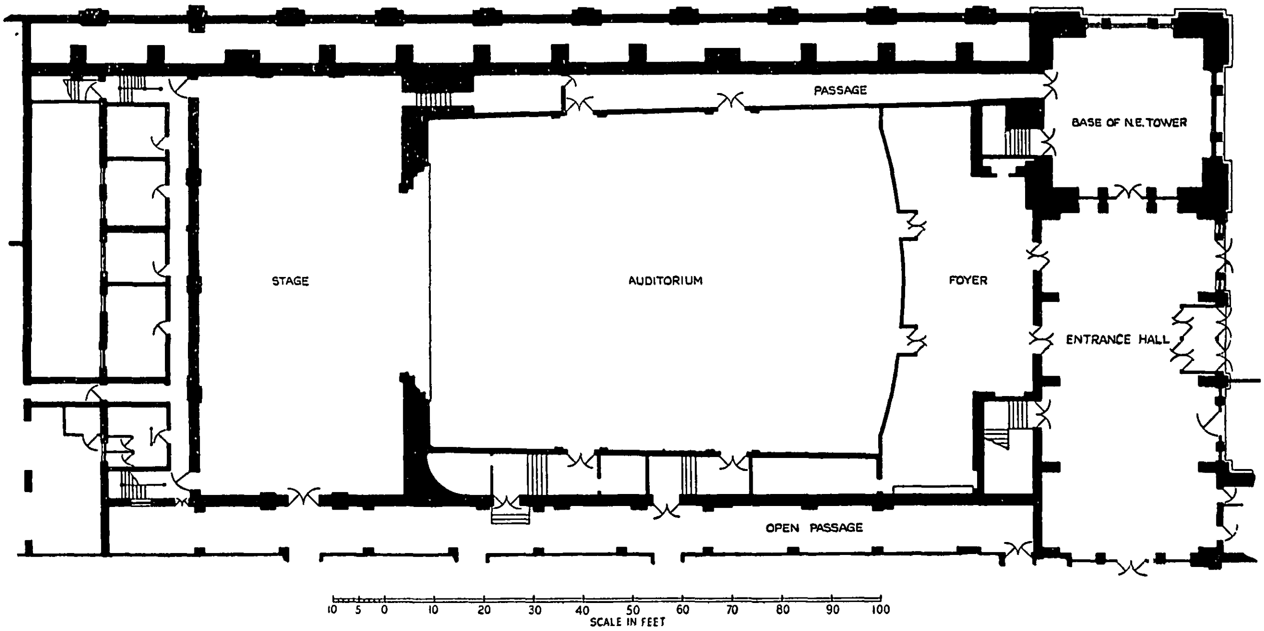

Fig. 4.—Plan of theatre area.

Film scanning by the Marconi-E.M.I. process is carried out in an annexe to the control room, built on the first-floor colonnade.

The rear portion of the premises is devoted to dressing rooms for male and female artists, a make-up room, and a band instrument room. The west end of the premises provides a second scenery store similar in dimensions to and immediately above the store on the ground floor, a floor trap and travelling gantry with block and tackle being provided to raise scenery from the ground floor to the first floor.

The scenery which is required for current productions only is stored in these spaces, the bulk of the scenery being at present stored in the north-east theatre premises.

Since the decision to adopt a single standard of definition, the Baird studio has been brought into use as additional production space for transmissions on 405 lines and 50 frames interlaced.

Fig. 4 depicts the theatre premises, and it will be observed that considerable space for possible future extension of studios exists in this area.

(b) Arrangement of Electrical Supply

The electricity supply for the Alexandra Palace installation is taken from the North Metropolitan Electric Supply Co.'s system. A ring main in the form of two feeders exists between the Alexandra Palace local substation and the Wood Green traction substation via the supply company's substation at Ringslade Road. The Wood Green substation in turn is fed by alternative routes from the supply company's power station at Brimsdown, and thus continuity of supply is amply assured. Supply is at 11 kV, 3-phase, 50 cycles per sec., and distribution is at 415 volts, 3-phase 4-wire, with earthed neutral.

(c) Acoustic Treatment of Studios

As has been stated, the two main studios are 70 ft. long, 30 ft. wide, and 27 ft. high, and their acoustic treatment has called for careful consideration.

It was considered that the acoustic properties desirable in a studio intended for television should differ from those sought after in a studio exclusively used for sound broadcasting.

In the latter case, the ear is the only criterion of the reproduced performance, and the effect produced can be materially enhanced by the artistic introduction of a certain degree of reverberation or echo. Such effects, however, require careful arrangement of the performers before the microphone so that a pleasing balance of sound is obtained. Moreover, the degree of reverberation which is acceptable varies widely with the type of performance —thus a studio suitable for a variety performance would not be suitable for a symphony orchestra, and, in general, different studios are used for different types of programmes. Above all, the placing of the performers from an appearance point of view is a matter of complete indifference in sound broadcasting, so long as a correct sound balance is maintained.

In the case of television, however, it is an entirely different matter, as the proper location of performers from the point of view of appearance is of paramount importance in the interests of artistic production, so that sound requirements must, of necessity, be subservient to this consideration. Added to this, it is not at present economically possible to provide a series of studios of divergent acoustic properties, each fully equipped with the manifold requirements of television.

Consequently, studios designed for general purposes were required, adapted for a wide range of scenic presentations varying from an intimate *tête-à-tête* to an elaborate and extensive production. In order that the sound accompanying scenes of such widely divergent character should be of uniformly good quality, and in the absence of much experience in television technique, it was thought desirable to design the acoustics of these studios on the basis of film-studio technique, that is to say, to make them as little reverberant as possible, and to allow the temporary sets built up as scenery to provide local reverberation for each particular scene. Film-studio practice is to cover as much as possible of the walls and ceiling with a highly absorbent material such as mineral wool. A convenient and less expensive alternative was found in the form of 2 ft. square slabs of asbestos felt about 1 in. thick. The original specification, therefore, was to cover the whole of the wall and ceiling surfaces with this material, stuck in contact with the plaster work. A form of sound-proof shutter was specified for the windows, consisting of a wooden framing, boarded on both sides, pugged with sawdust, and covered on both sides with canvas-covered acoustic quilt. The floor was to be untreated acoustically.

In practice, various modifications were made to this specification. One of the long walls of each studio, that on the north side, was found to be of lath-and-plaster construction unsuitable for direct application of asbestos felt, and it was necessary to support the slabs other than by sticking them to the plaster. To a height of 5 ft. from the floor the walls were close boarded before the application of the slabs. Above this height wooden battens were erected at 2 ft. centres, and the asbestos-felt slabs were nailed to these.

The original lath-and-plaster ceiling was demolished and $\frac{1}{2}$-in. building board was nailed directly to the existing joists. At a later stage, the asbestos felt was found to be easily damaged and it was therefore covered to a height of 10 ft. with a light scrim which appears to have negligible effect upon the sound-absorbent properties of the material beneath.

Fig. 5 is a curve showing reverberation time plotted against frequency for one of the main studios, taken with nothing in the studios but the main fixtures. There is but little difference between the two main studios from an acoustic point of view.

The measurements of reverberation time were taken by means of a piece of apparatus which enables the actual decay of sound to be accurately recorded on a logarithmic scale on a moving strip of wax paper.

In view of the complex nature of the acoustical treatment of the studios in their final form, it is difficult to interpret the curves in relation to the absorbing properties of the various materials employed. Fig. 6 shows the absorption/frequency characteristics, as measured in a reverberation chamber, of asbestos-felt slabs fixed directly to a hard surface and fixed to wooden battens respectively. On the basis of these measurements, reverberation curves rising very considerably for frequencies below 500 cycles per sec. would be expected. Whilst it is probable that for this, as for other materials, some modification has to be made to the absorption curves obtained in a small reverberation chamber in order to render them strictly applicable to a moderately large studio, such modifications would not be sufficient to account for the low reverberation time actually found at these frequencies in the completed studios. It is quite probable that both the lath-and-plaster north wall and the lightly-constructed building-board ceiling are providing considerable low-frequency absorption, while possibly the effect of the relatively large area of window shutters has also to be taken into account. No data are available to enable any analysis of these effects to be made.

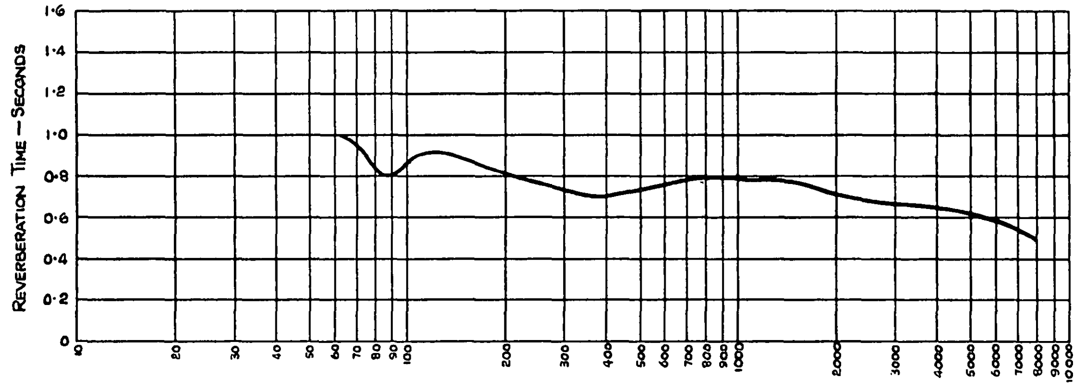

Fig. 5

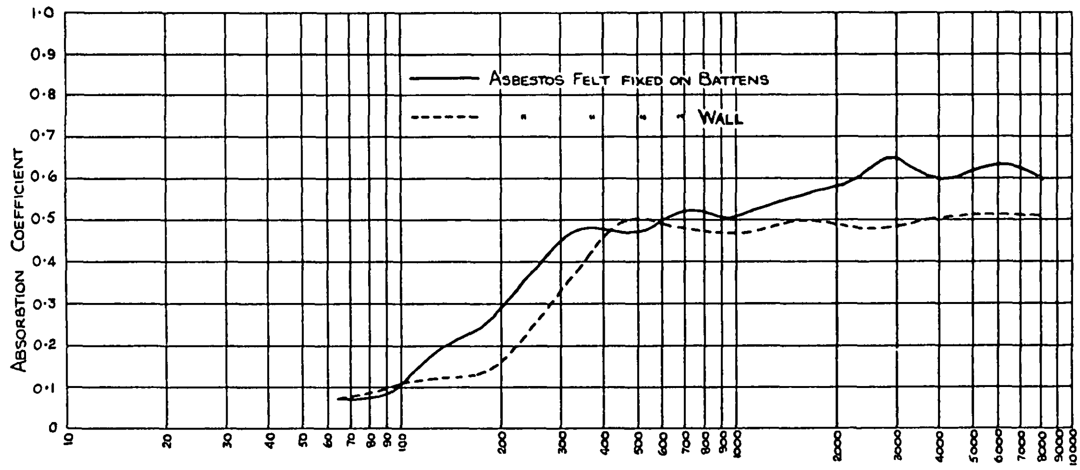

Fig. 6

As a result of the reverberation/frequency characteristics which have been obtained from the finished studio, the quality of the sound broadcast with the television is in general satisfactory over a large range of subjects.

(d) Production Lighting

The lighting of studio scenes for television presentation appears to demand the development of a technique which, while akin to both theatrical and film-production lighting technique and embodying something of both, nevertheless is not exactly similar to either in its entirety.

The reason for this lies in the fact that a television programme is in effect produced before an audience, just as is a stage production, and, consequently, equal continuity of action is necessary. The condition is therefore imposed that the production lighting must, in the main, be on continuously from start to finish, as in a stage presentation; and not intermittently as is usually the case in film studios, where isolated scenes are recorded and afterwards edited and knit together into a continuous whole.

This fact brings several difficulties in its train. First, all production lighting supply equipment must be rated to operate over comparatively long periods; secondly, the projectors and floodlights must themselves be capable of operating for a protracted period without overheating; and thirdly, the ventilation of the studio must be capable of dealing with the continuous dissipation of power involved in high-intensity lighting.

The first point means that it is not possible to economize by specifying a short-time rating for conversion plant and wiring, as is not uncommon in film-studio lighting installations, but rather implies that all lighting equipment must be continuously rated, as apart from the actual use of studios for transmission, a great deal of time is involved in fully lit rehearsals owing to the ever-changing nature of the productions necessary for a day-to-day television service.

The second point means that the design of projectors, spotlights, etc., must be carefully considered with a view to securing extra ventilation and means for conduction of heat generated, otherwise the wastage factor for lighting appliances is liable to be very high indeed.

The question of studio ventilation is covered in a later Section of the paper.

In general, the types of incandescent studio illuminator used for film-studio work have proved equally satisfactory for television, and lens and mirror spotlamps in powers of 500, 1 000, 2 000, and 5 000 watts, together with multiple lampfloods of from 3 000 to 15 000 watts, have all found their place in the television studio.

It has been necessary to modify to some extent the arrangements for ventilation in some types of lamps, as previously remarked, in order to cater for the longer periods of operation involved in television as against the use for which they were originally designed, viz. the film studio.

Arc-lamp illuminators have not been used to any great extent up to the present, chiefly on account of their tendency to give sudden fluctuations in the total amount of light falling on the scene, a feature which is very objectionable from the television point of view. In addition, the fumes from arcs are inconvenient if the latter have to be operated for lengthy periods in any but a very large studio, and arcs also require frequent attention during production.

The supply to all incandescent lamps has been standardized at 110 volts, being the voltage used by almost all film studios, and hence bulbs are readily obtainable in all wattages at this voltage.

The advantages which, in general, have led to the use of 110 volts instead of a higher voltage are manifold. Amongst other things the use of low-voltage high-current lamps has resulted in a smaller filament structure which is more rigid and hence less fragile, and also approximates more closely to a point source.

In order to reduce ventilating problems and give more comfortable working conditions for the artists, attention has been turned to lamps of the water-cooled gaseous-discharge type. Experiments will be carried out to determine the suitability of this type of illumination to television studios, and it is hoped that by a suitable combination of incandescent and gaseous-discharge lamps, the heating effect of close lighting can be materially reduced.

The actual arrangement of lighting units for any given scene in the studio approximates very closely to that adopted for a similar scene in a film studio.

A certain general level of lighting is attained by the use of floodlamps, after which the artists and scene to be televised are lit in detail by means of spotlamps, the exact arrangement and direction of lighting depending a good deal on the nature of the scene. High-angle lighting from the top, back, and sides, is used to give depth to the scene, and modelling achieved by the use of further spotlamps judiciously placed at floor-level. Delicate shading on the features of artists in close-up is achieved in general by the use of low-intensity diffused frontal lighting.

Lighting for television has something in common with lighting for the production of film by some colour processes, in that a fair amount of attention has to be paid to uniformity of illumination. This implies that a good deal of care has to be taken to avoid excessive overlapping of the illumination areas of several spotlamps, because departures from uniformity of illumination so caused while not perceptible to the eye, and often of not much significance when ordinary negative is being exposed, are readily discernible when the scene is viewed with a television camera, much in the same way as they are in the process of photographing colour film.

Studio scenes for television are normally illuminated with an average intensity of about 150 to 200 ft.-candles.

Alternating current is used for the Marconi-E.M.I. studio lighting at Alexandra Palace, and its use does not introduce any flicker into the televised picture, partly as a result of the thermal smoothing of the lamp filaments themselves, but largely because the 50-cycle frame frequency of scanning is so arranged as to be synchronized with the 50-cycle mains supply.

The Baird equipment, on the other hand, operating at a frame frequency of 25 cycles per sec., required the use of direct-current studio lighting for the intermediate film process and electron camera. The necessary supply was obtained from two motor-generators operated from the 415-volt supply mains, giving an output of 300 amperes each at 110 volts.

The detailed arrangement of production lighting equipment in the studios will now be considered.

The Marconi-E.M.I. Studio

The power supply is taken from the main distribution switchgear through a separate feeder and oil circuit-breaker to the primary of two 45-kVA 3-phase transformers, the secondaries of which are arranged for 110-volt 3-phase, 4-wire working. Both transformers are located in the Marconi-E.M.I. vision transmitter hall immediately beneath the studio.

The secondary side of one transformer is connected to a theatre-type lighting switchboard, which controls 24 separate circuits. The circuits are divided into three groups, each group being supplied by one phase and neutral from the transformer. Each circuit has a maximum load of 2 000 watts, and is provided with dimming and pre-selective black-out features.

Bank and differential dimming with any desired combination of circuits can be carried out, and any number of circuits can be pre-set so that they can be blacked out by means of a remote-operated contactor.

The output of the second transformer is taken to an adjacent remote-operated contactor board carrying nine single-pole contactors arranged in three groups of three, each group being connected to one phase and neutral of the transformer. Each circuit thus has a maximum loading of 5 000 watts and is controlled by a push-button switch on the lighting switchboard previously described.

No dimming or bank black-out features are provided in the case of these circuits.

All circuits are run to appropriate positions in the studio and terminate in sockets, to which illuminators may be connected by flexible cables fitted with plugs.

Plugs of different sizes are used for the 2 000- and 5 000-watt circuits so that there is no risk of overloading the former, while the latter can each be loaded to capacity either by the use of a single 5 000-watt illuminator, or by a number of lamps of lower power attached through the medium of multiple adaptors.

Fig. 7 shows the arrangement of the lighting appliances in this studio, from which it will be noted that the acting space is concentrated towards the eastern end. The area at the opposite end accommodates the orchestra and affords a certain amount of working space.

Extending around the three sides of the acting space bounded by studio walls is an erection of builders' steel scaffolding, which forms a lighting gallery at a height of 14 feet. This gallery is continued in the form of a bridge of steel-lattice construction, across the studio in front of the acting space.

The extreme flexibility of the steel-scaffolding construction is of manifest advantage, as extensions can be quickly fitted wherever necessary and illuminators clipped on by means of a fitting developed for the purpose at any height or angle to meet the requirements of some particular production.

The majority of the supply plugs are situated at lighting gallery level, as the bulk of the lighting power is concentrated in illuminators giving high-angle lighting. A number of overhead battens are provided, which can be lowered to floor-level for fitting up, and which serve to support the multiple-lamp floods used to afford the necessary diffused general lighting. These battens are provided with a number of circuits fed by flexible cables hanging from the ceiling and terminating in plugs on the battens themselves. Fig. 8 (see Plate 1, facing page 744) depicts a typical studio production scene.

The Baird Studio

The lighting arrangements in this studio are very similar to those in the other, and there again the system is divided into two parts. A theatre-type switchboard controlling 30 2 000-watt circuits is installed having identical facilities with that installed in the other studio, except that the supply is obtained from the two 300-ampere motor-generators previously described.

The second part of the system consists of a 45-kVA 3-phase transformer with 9-way remote-operated contactor board, situated in the Baird transmitter hall, feeding nine 5-kW distribution sockets in the studio, all arrangements being identical with those previously outlined for the similar portion of the equipment in the other studio.

The practice of mixing d.c. and a.c. studio lighting may, on first sight, appear unusual, but there is no valid reason why it should not be done, as the two parts of the system are entirely separate.

The layout of the studio differs but little from that depicted in Fig. 7, except that the lighting bridge traversing the studio is omitted. The arrangement of steel scaffolding for back and side lighting galleries is precisely similar in both cases.

(e) Studio Ventilation

The ventilation of a television studio is a matter which requires some consideration and, in general, involves problems which are not met with in the broadcasting studio and probably only to a lesser degree in the film studio.

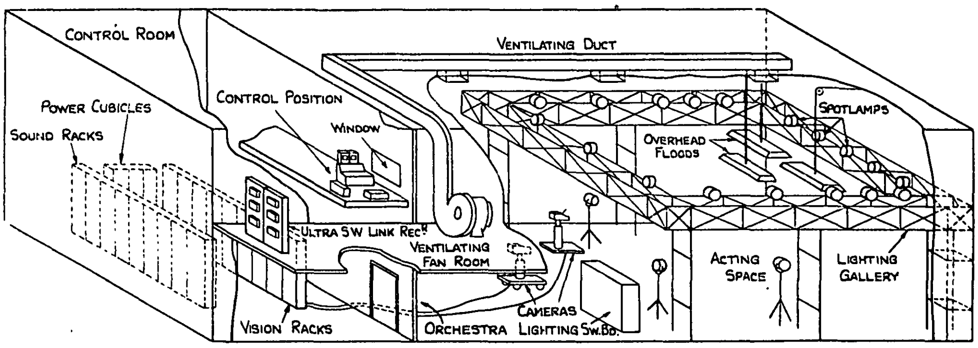

Fig. 7.—Diagrammatic layout of studio and control room, showing arrangement of production lighting.

In order to ensure adequate ventilation it is necessary to change the air in the studio with sufficient rapidity to carry away the heat due to production lighting without the introduction of noise from the ventilating machinery, which would be picked up by the studio microphones.

In the broadcasting studio the question of noise is of course equally important, but the absence of intense lighting, involving large dissipation of power, materially eases the problem, because the number of changes of air required per hour are very much fewer.

In the average film studio the ventilation problem is in general easier than in the present Alexandra Palace studios, because of the shorter times during which full lighting is in use, and also because of the greater volumetric contents of the average film stage. The particularly significant factor in this is the great height which is usually encountered, and which allows heated air from the lighting to rise to the top part of the chamber, where it accumulates during the shooting of a scene and is gradually removed by the ventilating fans during the subsequent period when no lighting is in operation.

In these circumstances the air at floor-level normally remains fairly cool, and continuously-operating ventilating machinery of moderate proportions proves quite adequate to exhaust the periodically replenished accumulation of heated air.

Ideally, of course, the studio should be provided with conditioning and refrigerating machinery in addition to the mechanism for changing the air, so that when the outside temperature is high in summer, the incoming air may be rendered quite clean and cool before its introduction into the studio. In the case of the Alexandra Palace installation no refrigerating machinery is provided, as it was felt that it was justifiable to dispense with it on economic grounds.

Each studio is provided with a separate ventilating system, the two equipments being similar in construction and disposition. Ventilation is effected by extracting the heated air from the upper part of the studio through three square grilled openings situated on the centre line of the ceiling and equally disposed along the length of the studio.

These outlets are connected by sheet-metal trunking, lined with acoustic board to minimize the transmission of noise, to a centrifugal fan capable of a maximum continuous duty of 10 000 cu. ft. of air per minute, giving approximately 12 changes of air per hour. The fan is driven by a 3-phase commutator motor with movable brushgear, giving a speed variation of 200 to 960 r.p.m.

The brushgear is controlled, through the medium of wire ropes running over pulleys, by means of a handwheel situated in the studio, and the speed variation so afforded gives adequate control of ventilation over a large range of lighting loads and conditions of outside temperature.

The incoming air to each studio is drawn from the colonnade through a series of specially constructed inlets, these taking the form of acoustic labyrinths designed to allow free passage of air while minimizing the ingress of sound from the outside.

The method of ventilation adopted differs from that used in the sound studios at Broadcasting House, as in this case conditioned air is introduced at the top of the studios and the displaced air allowed to escape through openings at the bottom. The object of this procedure is to avoid as far as possible the creation of draughts.

In the case of the Alexandra Palace studios, however, so much heat is generated by production lighting that it would not be satisfactory to oppose the resultant strong convection currents of heated air by artificially reversing the natural direction of air circulation.

(f) Studio Development

Some attempt will be made in this Section to forecast the general lines upon which the development of studios is likely to take place. It must be made clear that the following is based on proposals which are at present receiving consideration but in regard to which no definite decision has been made.

It is desirable when contemplating the extension of production facilities at Alexandra Palace to have continually in mind the requirements of extensions in the more distant as well as the immediate future. At present there are, as has been stated, two main studios of equal size, both equipped with comprehensive lighting systems, and under existing circumstances both these studios are operated from a single control room which provides facilities for the operation of four studio cameras and two film-scanning cameras simultaneously. The bulk of the production at present takes place in the east studio (the Marconi-E.M.I. studio) and the west studio (originally the Baird studio) is used as an annexe for further productions on occasions when requirements exceed the capacity of the east studio. Moreover, the control-room apparatus is so arranged that simultaneous working in both studios is not possible, and considerations of space in the existing control room preclude the possibility of extending the apparatus sufficiently to permit of this facility.

It is clear that only one actual transmission can be carried out at any one time owing to the existence of but one vision transmitter, but, nevertheless, it would be advantageous if a locally viewed televised rehearsal could be conducted in one studio while the other was on transmission, or, alternatively, simultaneous rehearsals conducted in both studios.

A further advantage would be gained by increasing the number of studios to three, and it is desirable that the third studio should be a good deal larger than those at present existing. The Alexandra Palace theatre has much to commend its use in this connection, as the available floor space is many times greater than that of the present studios, and experience has shown that the area of these is insufficient to permit of convenient working when productions of any magnitude are carried out.

The exact manner in which the studios would be arranged from the point of view of the television apparatus calls for very careful consideration, and it is essential that each should form part of a cognate scheme of working, which, although it might not be possible on economic grounds to complete it at one time, could be gradually built up as time went on.

Such a scheme has therefore been drawn up. It provides that each studio should be a complete unit with full production and rehearsal facilities, provision of film-scanning apparatus, and everything necessary for the production and monitoring of a televised performance or rehearsal, with accompanying sound.

The outputs from all studio units would then be brought into a central control room where facilities for pre-viewing the picture and pre-hearing the sound from each studio would be available, and a master-control position would be established. The master-control position would be provided with means for fading from one studio to another, both vision and sound as required, or making such superimpositions or dissolves as might be necessitated by the nature of the programme.

A further function of the proposed central control room would be to carry out the introduction into the radiated programme, at appropriate times, of television outside broadcasts coming from points remote from Alexandra Palace. The question of these outside broadcast transmissions is dealt with later in this paper.

In addition to the central control room, it is considered desirable that a centralized synchronizing signal-generating equipment should be provided, so that all sources of vision signal local to Alexandra Palace would be supplied with synchronizing impulses from a common source and superimposition of one upon the other could be carried out without difficulty.

PART 4

DESCRIPTION OF EQUIPMENT

(a) Marconi-E.M.I. Studio Equipment

This paper is not intended to include a detailed technical description of the apparatus; consequently, attention will be directed towards its operation rather than its principles of design.

The Marconi-E.M.I. system centres around the Emitron transmitting tube, which is a photo-electric device incorporating a light-sensitive mosaic scanned by means of an electron beam. Emitron tubes are built into portable cameras resembling, and used in a similar manner to, motion-picture cameras.

The Marconi-E.M.I. studio is equipped for the transmission of vision with four such cameras and their associated circuits. In addition, for the transmission of film which may either be required separately or as a composite part of studio production, there are two sets of film scanning apparatus in which the film is reproduced by a standard motion-picture head mechanism, the resultant image being projected through a suitable optical system directly on to the mosaic plate of an emitron tube, contained in a camera which in other respects is similar to those used for studio purposes. The sound is reproduced by means of a sound head of conventional design. A detailed description of this device is given in another paper.* There are, thus, in all six cameras, all of which are identical as regards their design and that of their auxiliary apparatus.

With each camera is associated a camera channel, which is a chain of apparatus enabling the control to be effected of all variables associated with each individual camera. These include the intensity and focus of the Emitron scanning beam, the width, height, and exact location of the scanned area, the tilt and bend waveforms which are injected for the correction of illumination errors, and the gain of each channel. There are also controls which take account of the finite time of transmission of the scanning wave-forms and vision signals along the camera cables, which transmission times will, of course, vary with the lengths of cables in use.

It is desired to be able to transmit any one of the pictures emanating from the six cameras, or in some cases more than one simultaneously, this being known as superimposition and being a favourite presentation device. It is a fundamental principle of presentation technique that more than one camera should be used in a studio production, the transmission being frequently changed from one camera to another in order to increase production facilities, and it is therefore desirable to be able simultaneously to observe the picture derived from any camera not on transmission so that all the necessary technical adjustments may be made before it is introduced into the transmission.

To accommodate these requirements of the London Television Station, three groups of apparatus known as " picture channels " are provided, which are linked with the six camera channels by means of an intermediate unit known as the " fading and monitoring mixer." By means of this unit the picture from one or more cameras may be introduced into the transmission and simultaneously observed upon a viewing monitor. At the same time the picture from any other camera may be connected to the second picture channel and a preview thereby obtained on a further viewing monitor associated with this channel. The third channel fulfils two functions. It enables the transmissions of film which are made every morning for the benefit of the radio industry to be carried out without interfering with a rehearsal which is proceeding at the same time, and which is using the other two picture channels. At other times it constitutes a spare channel.

The transmission of the sound associated with the programme is catered for by the provision of five moving-coil and three ribbon microphones in the studio. In addition there are, of course, the sound heads of the two telecinė projectors, and there are two gramophones by means of which interval music and effects may be introduced. Each of these 12 sources has its own pre-amplifier at the output of which the signals are in all cases approximately at zero level. After control at the sound-control desk, which will be described later, the signals pass into main amplifiers, and thence by distribution circuits to the transmitter and to subsidiary amplifiers for the operation of various monitoring loud-speakers.

This equipment, together with its associated H.T. and L.T. supply apparatus, is mounted in three rows of bays on the ground floor of the control room adjoining the studio, as shown in Fig. 9 (see Plate 2). The control room is 30 ft. long, 22 ft. wide, and 24 ft. high. At a distance of 15 ft. 6 in. from the ground a gallery is provided with a window looking into the studio. Behind this window are grouped a number of control positions from which the presentation of the programme can be handled. In the centre sits the producer and the senior studio engineer. In front of each is a microphone by means of which instructions may be given to the camera operators, the studio sound engineer, the electricians, and the studio manager, all of whom are provided with headphones. By means of a row of control keys such instructions can be given to any of the above engineers singly, or by depressing a master key to all those provided with headphones. Behind the producer sits the vision mixer, whose function is to introduce the various cameras into the transmission as required by the producer. In front of the producer is the sound-mixing desk, which receives the inputs from the 12 sound sources. The desk is operated by the sound mixer who, as in the case of the vision mixer, introduces the various sound sources whether they be microphones, gramophones, or film sound-tracks, into the transmission as directed by the producer. The sound-mixing desk is provided with separate balancing and fading controls. By means of the former the level of any sound source can be adjusted to the correct value, so that it can be rapidly introduced if required by operation of the fade control. Adjoining the sound-mixing desk is the sound-control position, at which the volume of the sound sent to the transmitter is manually adjusted. The control gallery also carries the gramophone position, so that its operator is in easy touch with the producer. There are also provided a pair of viewing monitors, one for the transmission and one for the preview circuit, and a loud-speaker so that the producer and all the engineers on the control gallery can

* C. O. Browne (see page 767).

see and hear what is being radiated and at the same time observe the studio through the window.

It will be seen that what might be termed the programme control is carried out from the gallery, whereas the more detailed adjustment of the vision and sound circuits is carried out by a group of engineers associated with the vision and sound racks on the ground floor. A signal system is fitted between the vision mixer and these racks so that he can call for any camera to be placed on the preview channel. A system of cue lights operated by push-buttons under the control of the producer is fitted to enable him to signal announcers and the conductor of the orchestra when to commence.

In the majority of productions the various vision and sound units will be distributed in the following manner. Camera No. 1 is usually in the centre of the studio on a mobile truck which enables " tracking " shots to be done. Cameras 2 and 3 may cover the main scene from alternative view points, or they may be set for smaller side sets. Camera 4 is usually reserved for announcers and captions. The sound from the main scene is covered by means of a moving-coil microphone suspended from a microphone boom, which enables it to follow the movements of artists. The orchestra, usually situated at the near end of the studio under the window, is taken on a ribbon microphone, and there will in general be one or two other microphones at suitable points in the studio, such as the side sets. A viewing monitor is also provided in the studio, so that, for such productions as dress shows, the announcer can give a commentary while observing the picture which is actually being radiated.

(b) Marconi-E.M.I. Vision Transmitter

This is situated in a large hall on the ground floor, as illustrated in Fig. 10 (see Plate 1).

The carrier frequency is originated by a master oscillator and doubler, the master oscillator operating at half the carrier frequency, or 22·5 Mc./sec. This is then amplified by six stages of amplification in cascade. The transmitter is contained in three cubicles, of which the first comprises the master oscillator doubler and the first four stages of amplification. The second cubicle contains the fifth amplifier, which delivers some 2 kW of radio-frequency power to the grids of the sixth amplifier; this is mounted in the third cubicle.

Mixed vision and synchronizing signals from the control room, having a picture/synchronizing ratio of 1/1, are fed to the modulator by means of concentric cable, and at its input they have an overall amplitude of some 10 volts. The modulator contains effectively four stages of amplification, between the first two and the last two of which are d.c. couplings. Between the second and third stages, however, the d.c. component is lost and is subsequently restored with a very great degree of perfection. At the output of the modulator the signals have an overall amplitude of some 2 000 volts, and the picture/synchronizing ratio is unchanged at 1/1. They are then applied to the grids of the sixth amplifier, and grid modulation is effected. Owing to the nature of the modulation characteristic of the sixth or modulated amplifier, the picture/synchronizing ratio becomes modified in the course of modulation to the desired ratio of 70/30.

The H.T. supply to the modulator valves is obtained from a motor-alternator set having an a.c. output of 500 volts and 50 kW at 500 cycles. Each of the four stages has its own H.T. rectifier, which, in the case of the first three stages, incorporates hard valves, but in the case of the last stage employs a mercury-pool rectifier. For the filament heating-current for the first three stages various supplies are used, including 500-cycle and 50-cycle alternating current; and direct current obtained by rectification from the 500-cycle supply. The two valves in the last or modulator stage have individual filament-current d.c. generators, that for the last stage being insulated from earth as the filament is at high potential.

Filament current for all radio-frequency valves other than the master oscillator is obtained from a motor-generator set which has an output of 400 amperes and 24 volts. The master oscillator filament is applied separately from the mains to a transformer and metal rectifier. High-tension supplies for the output stage at 6 000 volts are obtained from a hot-cathode mercury-vapour valve rectifier, and a second supply is similarly derived at 4 500 volts and feeds the third, fourth, and fifth amplifiers. A third supply for the remaining stages is provided from a metal rectifier.

The main controls are all grouped conveniently on one control desk, from which the switching operations are effected by remote control. A sequence starting-switch is provided to prevent damage to the transmitter by the application of power supplies in the wrong sequence, and the modulator is similarly protected by a system of interlocked push-buttons. All electrical apparatus is fully protected by interlocking circuits and water-flow monitoring devices, so that in the event of a failure of any supply the transmitter is automatically shut down and cannot be restarted until the deficiency is remedied.

The provisions for the protection of personnel are such that access cannot be obtained to any of the transmitter units until all dangerous supplies have been switched off and the apparatus earthed. No supply can then be reconnected to the transmitter until the gates of all the units have been closed and locked.

In the centre of the control desk is mounted a cathode-ray oscillograph, including an amplifier and the necessary time-base circuits. Switching arrangements are provided which enable the wave-form of the picture and synchronizing signals to be examined at the output of each stage of the modulator unit, and also the final wave-form at the output of the modulated amplifier.

The total input power from the mains to the vision transmitter is 95 kVA and its output power is 17 kW, corresponding to " full picture white." It is customary to rate the power of television transmitters in terms of peak, since it is not possible to use the normal method of rating in terms of " carrier wave power " as in the case of a sound transmitter, because a television transmitter does not radiate a steady " carrier wave."

(c) Baird Studio Equipment

The transmission of scenes from the Baird studio was effected by two methods: the intermediate film process, which was the first to be employed, and the electron camera, which was introduced subsequently. There was in addition a further small studio 30 ft. by 12 ft. intended for announcements, talks, and other similar purposes, and from which transmissions were made by the spotlight system. In a further room film transmission was carried out by means of two sets of teleciné apparatus. Each of these various sources of programme was regarded as a separate unit, whose output was passed to the main control room adjoining the large studio.

(1) The Intermediate Film Process.

The apparatus for television by this process was housed in an additional sub-control room at the side of the main studio and separated from it by a three-sided window. The scene, illuminated by the studio lighting-equipment described elsewhere, was photographed on to 17·5-mm. film. The film immediately passed in succession through developing, first-washing, fixing, and second-washing tanks. On emerging from the final tank the film was immediately scanned while wet. To effect this the film was passed through an underwater gate upon which was projected a beam of light from a 60-ampere arc. The light, having passed through the film, fell upon a scanning disc running at 6 000 r.p.m. and containing 60 equally-spaced holes arranged on the circumference of a circle. The horizontal scanning component was thus derived from rotation of the disc, while the vertical component was automatically provided by the continuously moving film. The disc was driven by a $\frac{1}{2}$-h.p. 3-phase motor, the disc and motor being enclosed in a chamber and running in a vacuum. This was necessary in order to prevent weaving of the disc due to air resistance, and also to avoid dust entering the small scanning holes. The motor required a supply of alternating current at 100 cycles per sec., which was generated by a separate motor-generator. The latter consisted of three machines in tandem: the 100-cycle alternator, a d.c. motor by means of which the generator and the scanning disc could be slowly run up together, and an a.c. motor which was cut in when the unit was up to speed, thus locking the set in synchronism with the mains.

The light from the scanning disc was arranged to influence a photo-electric cell of the multiplier type, the output of which was passed to a series of amplifiers and thence to the central control room. The line-synchronizing signals were simultaneously generated by the same disc by means of a further series of 60 apertures arranged on a circle within that containing the scanning apertures. These were illuminated by a slit of light, and a photocell situated behind the disc translated these light impulses into synchronizing signals of proper shape. They were then raised in level by an amplifier and passed to the central control room.

The time elapsing between the action in the studio and its appearance on the receiving screen, that is to say, the time required to process and scan the film, was 65 sec. It was, of course, necessary to apply a corresponding delay to the sound, and to effect this it was also recorded on the film by a recording head interposed between the camera and the developer tank. A corresponding reproducing head was fitted into which the film passed after having been scanned in the underwater gate. The film was finally reeled while wet and subsequently transferred to a large drying drum.

A picture monitor was provided in the sub-control room.

(2) Electron Camera.

The studio was equipped with two experimental electron cameras whose associated apparatus was housed in a further adjacently situated sub-control room. These electron cameras were of the type in which a phalanx of electrons emitted from a light-energized photo-cathode was bodily displaced, in the motions of frame and line scan, over an electrode having at its centre a small opening which constituted the scanning aperture. One of the cameras was mounted on a movable run truck, and the other on a tripod. The scanning currents and other supplies for these cameras were all generated in the sub-control room and sent to each camera by a composite cable. The camera outputs were amplified in head amplifiers, and the output passed back along a composite cable to the sub-control room. Inter-camera fading was carried out in this control room, and the single output passed to the central control room.

(3) The Spotlight Studio.

As its name implies, transmissions from this studio employed the spotlight system, in which the artist is kept in almost complete darkness and a spot of light of elemental size is distributed over him by means of a scanning device, the reflected light being picked up by photocells.

A disc scanner was used, running at 6 000 r.p.m. and having four spirals, each of 60 holes. Each spiral was brought into action in turn by means of a further shutter disc revolving at 1 500 r.p.m. The large disc, which was as usual enclosed in an evacuated chamber, was rotated by means of a $\frac{1}{2}$-h.p. 100-cycle 3-phase synchronous motor, deriving its power from a similar motor-generator unit to that described in connection with the intermediate film apparatus. The small disc was driven by a 1/20 h.p. 50-cycle 3-phase motor taking its power from the mains. The light source was a large arc consuming 120 amperes. Owing to the intense heat generated by an arc of this power, the scanning gate was water-cooled.

The reflected light was picked up by four large photocells of the multiplier type, whose positions in the studio were adjustable in order to obtain the correct lighting effects. The outputs of these were applied to an amplifier situated at the side of the studio, whose output was passed to the central control room.

A picture monitor was provided in the spotlight projection room.

(4) The Teleciné Equipment.

Two identical sets of teleciné equipment were installed. The film was driven under continuous motion by a modified standard film projector, and after illumination by a 60-ampere arc was scanned by a disc unit identical with that already described in the case of the intermediate film apparatus. The light from the disc was picked up by a lens system, and influenced a photocell, again of the multiplier type, whose output was fed to a series of amplifiers. The output from each set of teleciné apparatus was then fed to a common control amplifier which was provided with arrangements whereby a rapid change-over of both vision and sound could be made from one projector to the other. The output was then passed to the central control room. Individual picture monitors were provided for each machine.

(5) The Central Control Room.

The various vision and line-synchronizing inputs from the several sources were first passed to individual termination amplifiers in the central control room. From these they were fed to the main vision control desk, which contained arrangements for changing from one source to another and for monitoring the wave-form.

After further amplification the vision-synchronizing signals were passed to the transmitter via a concentric cable. Frame-synchronizing impulses were generated by apparatus which was common to all of the individual programme sources, comprising a disc rotated at 1 500 r.p.m. and containing one hole which was interposed as usual between a light source and a photocell. The necessary arrangements for mutually adjusting the phase of the various scanners and the central frame-synchronizing signal generator were provided. The frame- and line-synchronizing signals were mixed in an amplifier and passed to further synchronizing amplifiers, the output of which was fed to the transmitter via a further concentric cable.

(6) Sound Equipment.

The sound from the main studio was picked up by three condenser microphones. Associated with these were a control desk and a series of amplifiers in a sound sub-control room situated above the intermediate film sub-control room at the side of the studio. If the intermediate film process was being used, the sound, having been carefully controlled as regards volume, was passed in turn through a recording amplifier, the intermediate film apparatus, and a reproducing amplifier, and thence to the central control room. When the electron camera was used, the sound output was sent, of course, direct to the central control room.

The spotlight studio was also provided with a condenser microphone and its individual amplifying equipment. These two outputs, together with those from the sound heads of the teleciné apparatus, were selected as required from a sound-control desk adjacent to the vision-control desk in the central control room, at which position the main volume to the transmitter was also controlled. The signals then passed through further amplification, and were fed to the transmitter or to a monitoring loudspeaker as required.

The various vision sources were all connected to the central control room by the usual system of cue lights and interconnecting telephones.

(7) Power Supplies.

In the case of the vision apparatus, each stage of amplification had its own individual source of anode voltage, this taking the form of a mains rectifier. The filaments were heated by alternating current via transformers.

The sound-equipment H.T. supplies were derived in the normal manner from rectifiers, and the filaments again were heated from alternating current. The power supply for the arcs of the intermediate film and the two sets of teleciné apparatus were derived from three d.c. generators, each delivering 60 amperes at 110 volts. The power supply for the spotlight arc was derived from a further d.c. generator delivering 200 amperes at 110 volts. All these generators were situated in the transmitter hall.

(d) Baird Vision Transmitter

The Baird transmitter was housed in a hall on the ground floor beneath the Baird studio.

It consisted of five main units: (1) the master oscillator; (2) the intermediate amplifier; (3) the final amplifier; (4) the conditioner; (5) the synchronizing modulator; (6) the vision modulator; (7) the power supplies; and (8) the evacuation and water systems.

It is a feature of this transmitter that the picture and synchronizing signals are never mixed at vision frequency and each modulates a separate part of the radio-frequency chain. The synchronizing signals are applied to the intermediate amplifier, the output of which is raised in level at the final amplifier, and also modulated by the vision signals.

(1) The Master Oscillator.

The radio-frequency signal was originated at a frequency of 1·406 Mc./sec. by means of a crystal master oscillator which was temperature-controlled in an inner and an outer oven. This frequency was then applied to a number of multipliers and amplifiers in cascade, and the unit finally delivered 100 watts at the desired carrier frequency of 45 Mc./sec. It had its own mains-derived power supply.

(2) The Intermediate Amplifier.

This contained a pair of Metropolitan-Vickers demountable tetrodes, either of which could be associated by means of a change-over switch with a set of common radio-frequency circuits, the other tetrode at any time being held as a spare. The intermediate amplifier received the output from the master oscillator and raised it to a level of 1·2 kW at black level. Grid modulation of this amplifier by the synchronizing signals was effected by application of the output of the synchronizing modulator to the control grid of the demountable valve.

(3) The Final Amplifier.

This unit was of similar design to the intermediate amplifier. The final amplifier received the output of the intermediate amplifier and raised it to a level of 17 kW under white-picture conditions. It also received the output of the picture modulator, and grid modulation was again effected at the control grid.

(4) The Conditioner.

This unit was provided to carry out certain necessary conditioning of the demountable valves before they are once more put into service after having been taken down for repair. The process of conditioning consists in applying first of all to the control grid, then to the control and screen grids, and finally to the anode as well, alternating voltages capable of fine regulation. It was in this way possible to drive off the last traces of occluded gas, the

Plate 1

Fig. 8.—Studio scene during rehearsal.

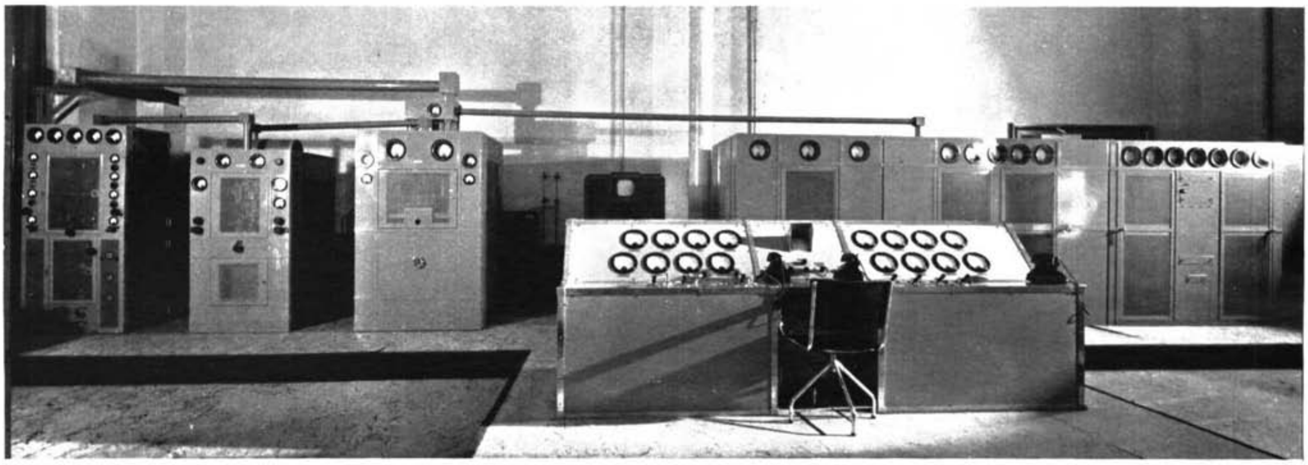

Fig. 10.—Vision transmitter.
Radio apparatus on left; modulator on right; control table in foreground.

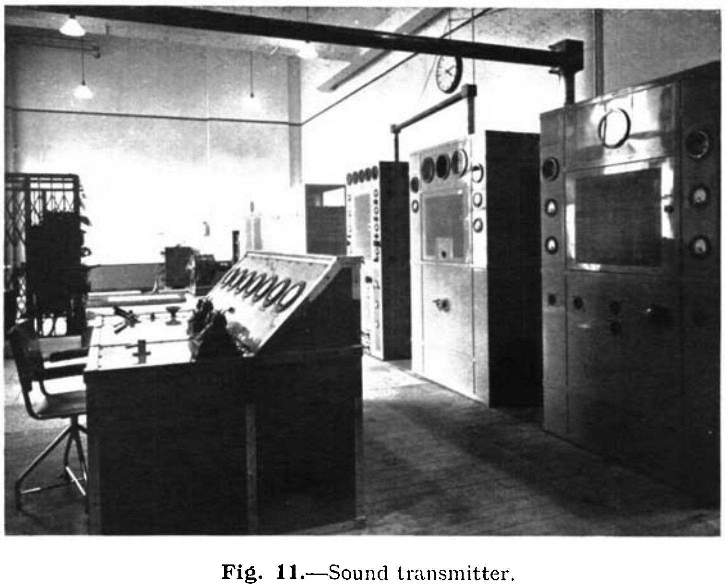

Fig. 11.—Sound transmitter.
Left foreground—Control table.
Centre background—Drive unit and low-power high-frequency stage.
Centre right—Final power amplifier.
Right-hand side—Modulator unit.
Left background—Power switchboard.

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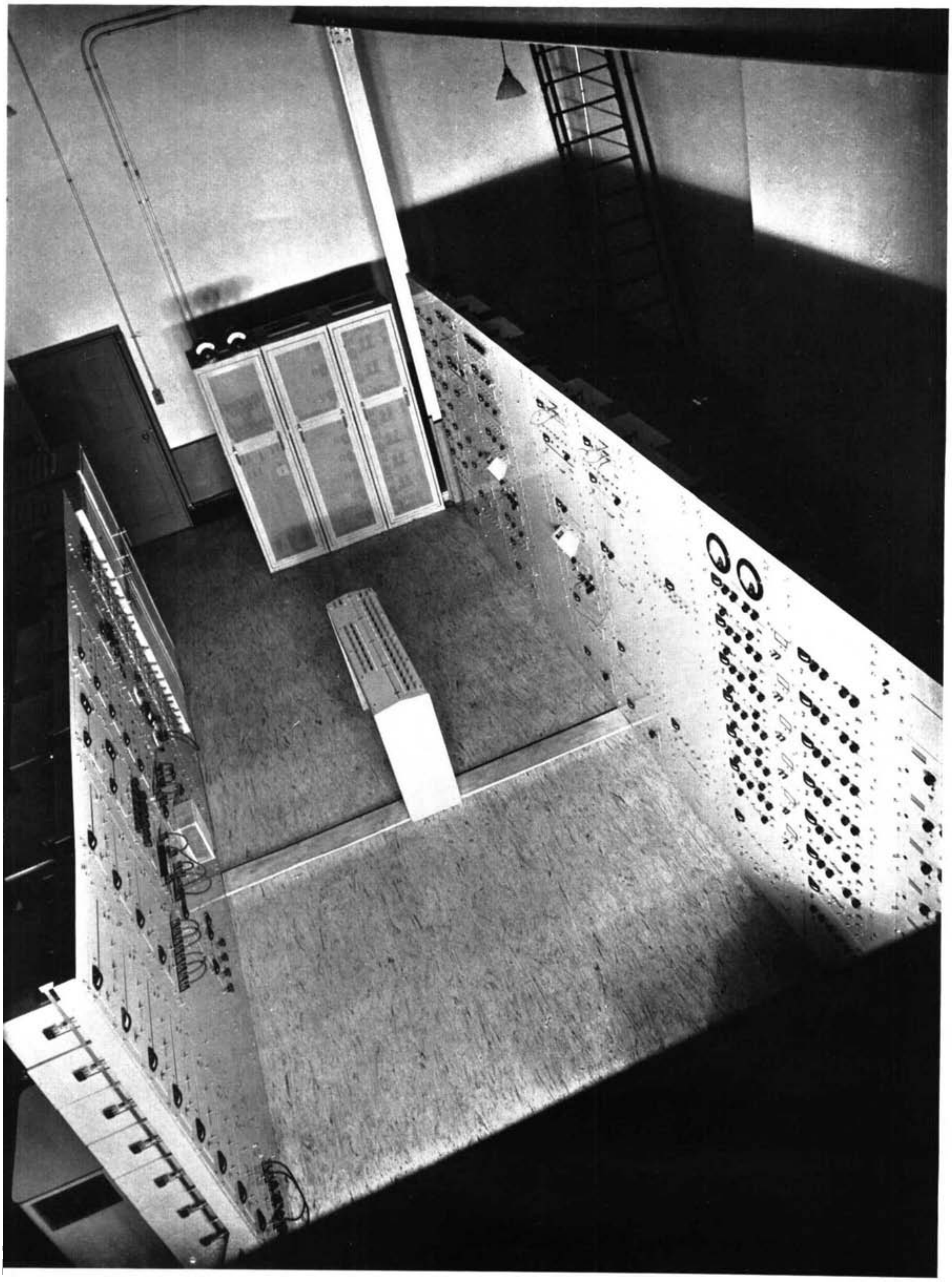

Fig. 9.—Control room of Marconi-E.M.I. system.

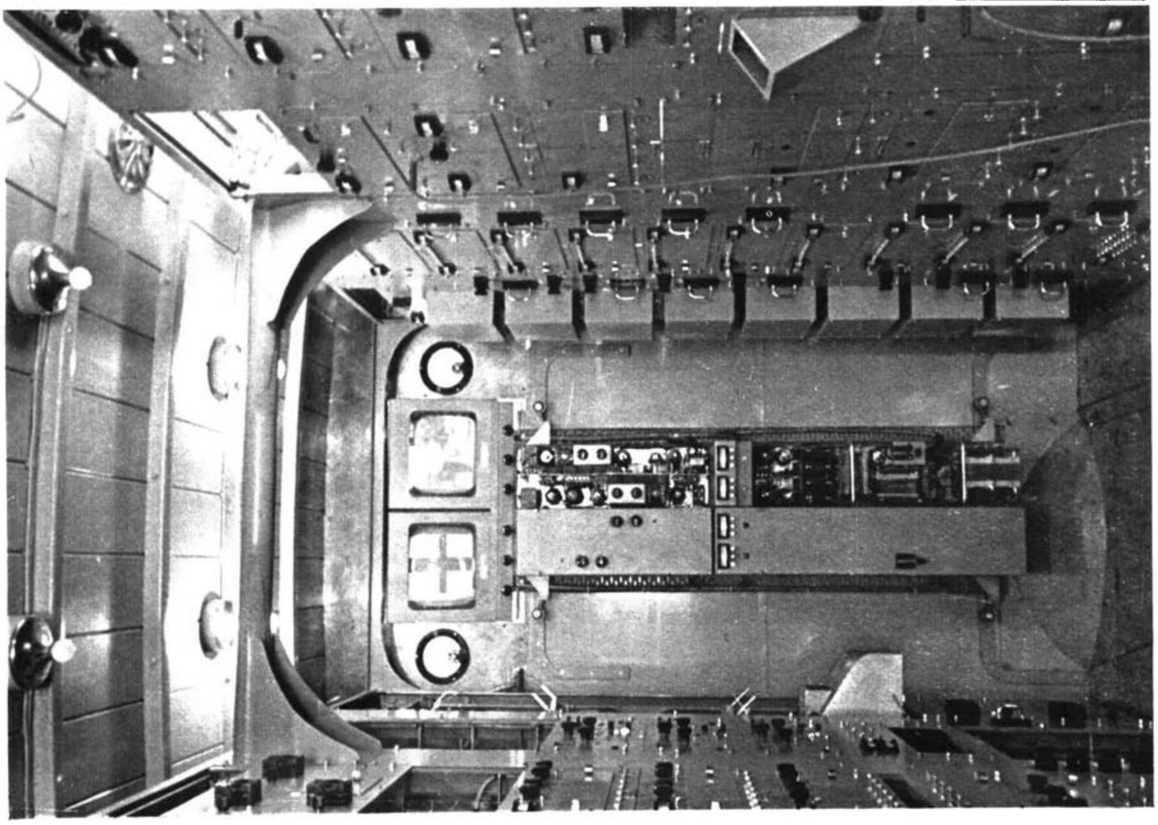

Fig. 12.—Mobile television control-room, showing picture monitors.
At right-hand side—Pulse generating equipment.
At left-hand side—Camera panels.

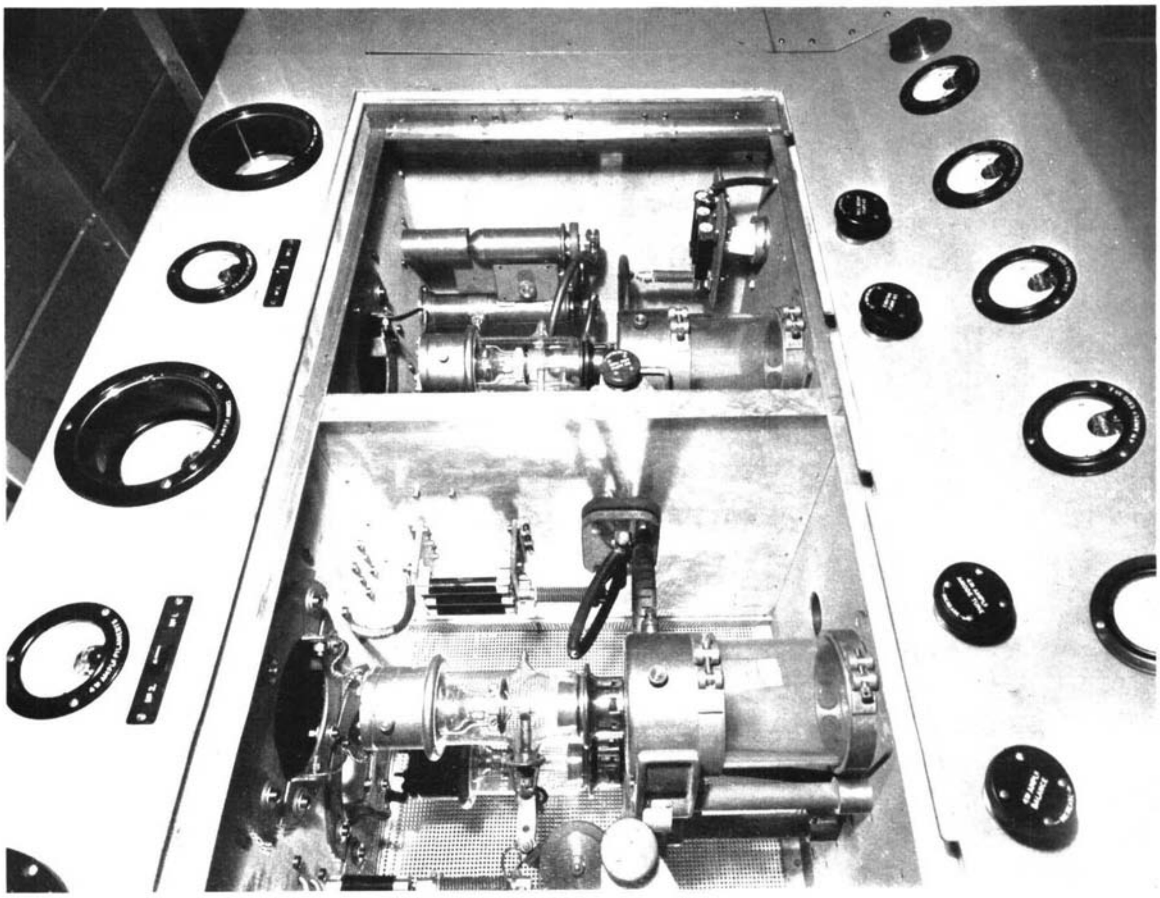

Fig. 14.—Mobile television unit: last two stages of the radio-link transmitter, showing the air-blast-cooled valves.

Plate 4

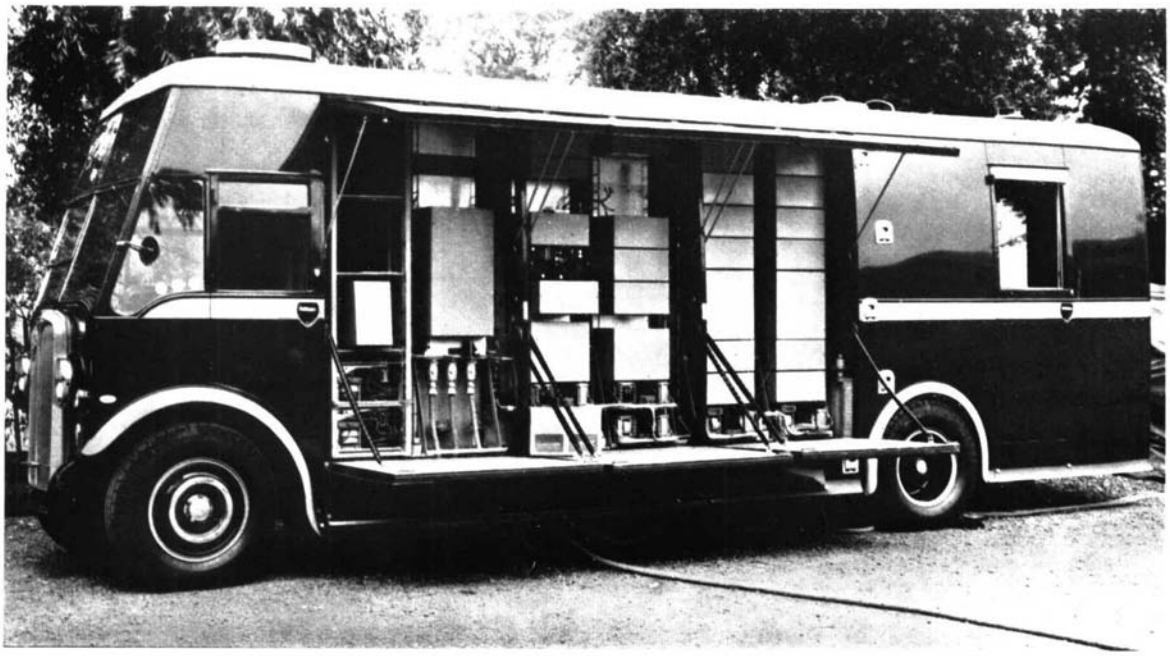

Fig. 13.—Mobile television unit: exterior of control-room vehicle with shutters opened to give access to rear of apparatus.
NOTE.—The camera cables can be seen underneath the vehicle.

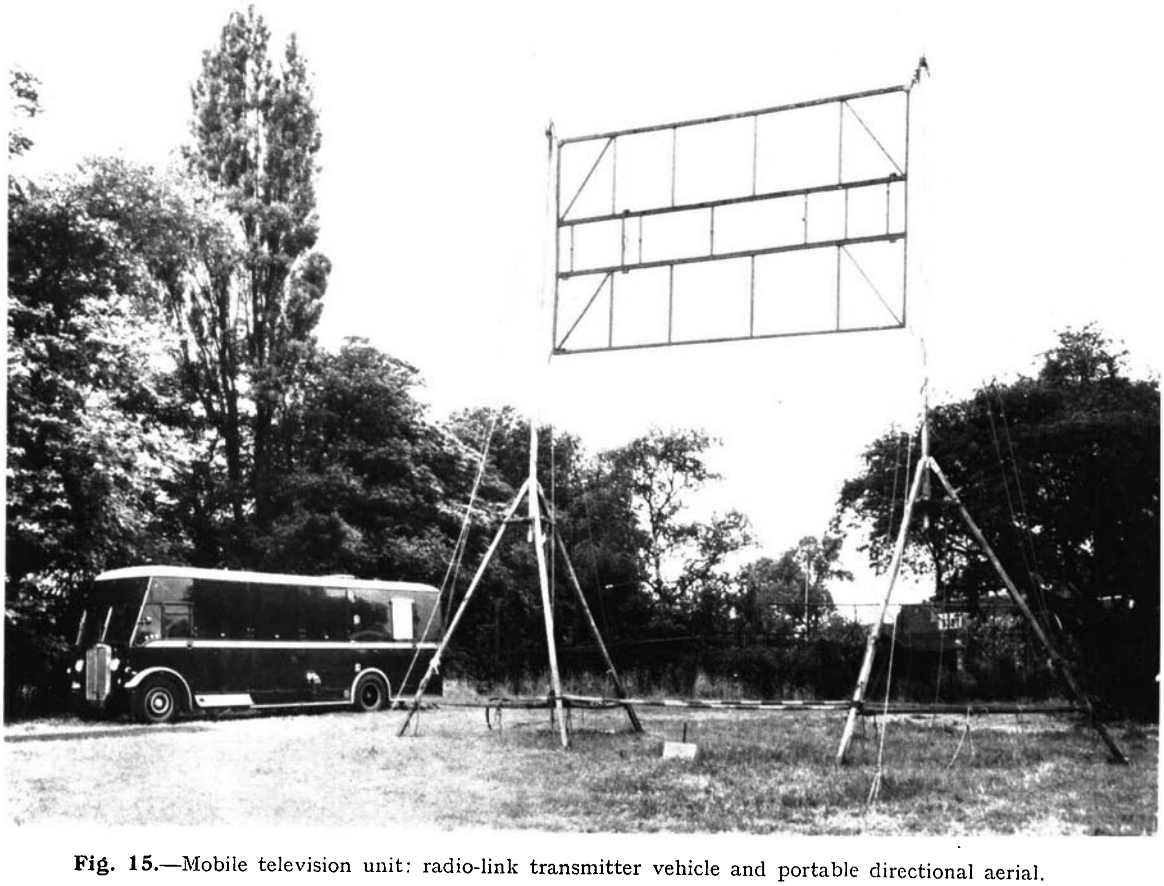

Fig. 15.—Mobile television unit: radio-link transmitter vehicle and portable directional aerial.

presence of which, without this precaution, would lead to the prevalence of frequent overloads upon the valves being returned to service.

(5) The Synchronizing Modulator.

This unit consisted of a 4-stage vision-frequency amplifier delivering a synchronous amplitude of 700 volts to the intermediate amplifier.

(6) The Vision Modulator.

This was a 7-stage vision-frequency amplifier receiving its input from the control room, and delivering picture signals of 1 000 volts amplitude between black and white to the final amplifier.

(7) Power Supplies.

The filament supplies for the final and intermediate amplifiers were each obtained from motor-generators delivering 200 amperes at 25 volts. The anode and screen supplies for the intermediate amplifier were obtained from a motor-generator delivering 14 kW at 7 000 volts for the anode, and 4 kW at 2 000 volts for the screen. The anode and screen supplies of the final amplifier were obtained from a motor-generator delivering 40 kW at 10 000 volts for the anode, and 2 kW at 2 000 volts for the screen. The anode voltage was in this case obtained from two machines connected in series but driven in tandem by a single motor. The modulator power supplies were obtained from rectifiers, and there was, in addition, a floating 2 800-volt 10-ampere-hour battery.

The control of the transmitter, as distinct from the modulator, was centralized at a control desk, on which was mounted an oscillograph for examining the radiated wave-form. Behind this was situated an additional panel for the centralized control of the modulators.

(8) Evacuation and Water Systems.

With each of the demountable valves was associated an evacuation system consisting of two oil condensation pumps in cascade and a rotary pump. This apparatus was entirely automatic, and created and maintained without attention an adequate vacuum in each of the valves. A complete water system was provided for cooling the anodes and heads of the valves and also the oil pumps. These were fully protected by water-flow relays, which would open the appropriate circuits in the event of a water failure.

As usual, complete protection was provided in all the apparatus so that personnel could not have access to dangerous voltages.

(e) Marconi Sound Transmitter

The transmission of sound from either of the two television systems is effected by means of one sound transmitter, which can be fed with the outputs from the control rooms of either system. This is situated on the ground floor of the Palace in a hall between the two vision transmitters, and is illustrated in Fig. 11 (see Plate 1). It normally operates upon a frequency of 41·5 Mc./sec., but is capable of working over a band of frequencies from 35 to 50 Mc./sec. It has an output power of 3 kW at 90 % peak modulation. The total input power from the mains is 78 kVA.

The transmitter is built in four separate units, each unit being housed in a metal cubicle. The carrier frequency is originated by a master oscillator and doubler, the master oscillator working at twice the carrier frequency and ensuring a stability of ± 1 part in 100 000. This is followed by five high-frequency amplifying stages. The master-oscillator doubler and the first four stages are all contained in one cubicle. A separate cubicle houses the fifth amplifier, at the anodes of which modulation is effected. A third cubicle houses a 3-stage modulator of conventional type. In the final high-frequency stage two C.A.T.9 water-cooled valves in push-pull are used, and in the main modulator stage three C.A.M.3 valves in parallel. The transmitter is designed to give high-quality sound reproduction, and enables advantage to be taken of the greater frequency band available at this short wavelength. The frequency response is flat to within 2 db. between 30 and 10 000 cycles per sec., and, in addition, the distortion factor of this transmitter is very low, the total harmonic content in the output low-frequency signal, expressed as an r.m.s. voltage sum, being 2 % at 90 % modulation.

All the valve filaments except that of the master oscillator are heated by direct current from a motor-generator having an output of 500 amperes at 24 volts. The master oscillator has its own supply from a rectifier.

The main H.T. supply at 6 000 volts (d.c.) for the fourth and fifth amplifiers and the modulator is obtained from a hot-cathode mercury-vapour-type rectifier associated with a transformer and induction regulator and appropriate smoothing circuits. Other auxiliary H.T. and grid-bias supplies are obtained from metal rectifiers. The whole of the H.T. and grid-bias supply equipment is housed in the fourth transmitter cubicle.

A control table is provided at which the essential operating controls are grouped, and the transmitter can be entirely controlled by one operator. The application of power supplies in the correct order is ensured by sequence starting arrangements, and a complete system of interlocks is installed for the protection of the apparatus and of personnel.

In an adjoining room are the necessary water pumps and air blowers for valve cooling

(f) Mast and Aerial System, and Feeding Arrangements

As previously stated, the transmitting mast is 300 ft. in height, and the ground itself is 306 ft. above sea-level, so that the total height of the mast is 606 ft. above sea-level.

Its design is intimately connected with that of the aerials themselves. Since two separate radiating systems are required, mechanical and electrical considerations both preclude the use of vertical dipoles situated one above the other. It was necessary in order to get uniform radiation in all directions to provide for each radiating system a number of aerials uniformly spaced around the mast. To facilitate this aerial design, therefore, the upper part of the mast structure which carries the aerials has been made octagonal in section and uniform in diameter. The height of this section is 97 ft. Below this the mast consists of a more orthodox tapering 4-sided structure having a height of 118 ft. 6 in. and base dimensions of 30 ft. by 30 ft. Each of the four corners of the base girders has been taken down through the structure of the building to within a few feet of the ground to obtain a secure anchorage.

The vision signals are radiated from the upper of the two aerial systems. This consists of eight push-pull end-fed dipoles uniformly spaced round the mast. Behind them are eight energized dipole reflectors. Each dipole consists of three wires situated at the corners of a triangle having a 15-in. base, in order to simulate a dipole of considerably greater diameter than that of a wire. All the eight aerial/reflector systems are joined in parallel. A number of concentric networks are provided in order to carry out the necessary transformations, which include rendering the aerial system asymmetrical so that it can be fed by the main feeder, which is of the concentric type, matching the impedance and maintaining a constant impedance over the required radio-frequency band width. In this connection it should be mentioned that the impedance is substantially constant over a band width of 2 Mc./sec. on either side of the carrier. The main feeder has a characteristic impedance of 78·5 ohms and is 5 in. in diameter. Electrical compensation is introduced at intervals in order to minimize the existence of reflected energy.

The sound aerials are situated underneath the vision aerials, and are substantially similar, differing only in their dimensions and in the absence of the elaborate networks necessary to accommodate the wide band-width occupied by the vision signals. They are connected to the transmitter by a feeder identical with that provided for the vision system.

PART 5

OUTSIDE BROADCASTS

(a) Programme Requirements

The televising of national ceremonies and open-air events of sporting and topical interest is perhaps one of the most useful functions which a television service can fulfil. Such events can be divided into two general classes:—

(a) Events which can be brought within close proximity to the television station proper but not actually into the studio itself.

(b) Events which by their very nature occur at some point remote from the transmitter.

The events classed under (a) are such things as demonstrations of horsemanship or golf, and displays of physical culture. These obviously cannot be done in the confines of a studio, but it can be arranged that they take place within a selected area close to the actual television site. Such events are classed as local outside broadcasts, and their televising can be accomplished by an extension of the internal studio facilities. That is to say, cameras can be taken to the scene of operation and directly connected back to the Alexandra Palace control room by means of a length of normal camera cable. In general it may be said that the maximum allowable length of camera cable which can be used without running into serious technical difficulties is approximately 1 000 ft.

Suitable provisions exist at the Alexandra Palace to facilitate such local outside broadcasts. Special cable ducts have been laid under the road flanking the B.B.C. premises, and camera cable can be run to any point in the grounds of the Palace within the limits of 1 000 ft. from the control room.

Similar provisions exist for the direct connection of sound equipment for picking up the sound accompanying the action being televised. Exactly similar technique to that adopted in the studios themselves is thus used for local outside broadcasts, with the exception that artificial lighting is in general unnecessary.

The events classed under (b) include such national occasions as a Coronation procession, the Wimbledon tennis tournaments, and the Armistice ceremony. Such events occur at places remote from the main station and it is therefore necessary to employ a different technique from that employed for local outside broadcasts.

In order that events of this type may be included in the television field a mobile television unit has been formed which in effect provides the same facilities for vision and sound as are available at the main station at Alexandra Palace, although of necessity somewhat limited in scope.

The function of this unit is to form a link between the remote outside-broadcast point and the main transmitter, and its requirements are that it shall be capable of conveying both vision and sound back to the main transmitter from any point within a given operating radius.

Every effort has been made to construct the mobile unit in the most transportable form possible, so that the minimum of time is required for moving it to site and setting it to work Rapid mobility is felt to be an essential of a unit of this type, as lacking this quality much of the topicality of the outside-broadcast transmissions will be inevitably lost, and their value thereby greatly reduced.

At present, setting up the equipment for an outside broadcast takes a comparatively long time, perhaps a day or even longer. This is considered to be far too long, and every effort is being made to arrive at a design of all equipment including the smallest accessories such that the process of setting up for transmission can be accomplished in an hour or even less.

Such an achievement clearly involves many difficulties, but it is considered that until it is possible to effect the setting-up in a time of this order, complete flexibility will not have been reached.

(b) Travelling-Studio Equipment

The travelling control room, which, as has been stated, is brought into use in cases where it is required to televise events taking place at points remote from Alexandra Palace, consists of a large motor vehicle, 27 ft. 6 in. long, 7 ft. 6 in. wide, and 10 ft. 8 in. in height, fitted with a closed body of special design.

Inside the vehicle body is mounted all the apparatus required to operate three Emitron cameras and six microphones. The cameras, which when the vehicle is in motion are carried in specially sprung cradles to protect the fragile tubes from the effect of road shocks, are in all respects similar to those used for studio purposes.

When the vehicle reaches the site of the broadcast the cameras are taken out to appropriate positions, being connected to the apparatus by multi-core cables similar to those used in the studio and each of a total length of 1 000 ft.

Provision is made on the vehicle for carrying 600 ft. of this cable on drums which are lowered through the rear doors of the body by means of a winch mechanism which enables them to be deposited on a hand-truck and so easily transported to the required point. After use, the drums are raised into the vehicle by reversing the operation of the winch.

The apparatus contained in the vehicle consists of all essential portions of the control-room scanning and amplifying equipment described in Part 4(*a*) of the paper, and includes duplicate sets of pulse-generating equipment either of which can be brought into action in the event of failure of the other.

Provision is made for fading from any one camera to another, or for the superimposition of the outputs from two or all three cameras. Two cathode-ray vision monitors are provided, one for the purpose of viewing the transmission actually taking place, and the other for previewing the picture emanating from the camera to which it is next proposed to fade.

The outputs of the six microphones are connected to a six-way fading mixer, so that any microphone or combination of microphones may be chosen as dictated by the requirements of the programme being transmitted. Duplicate speech amplifiers are provided and are equipped with a logarithmic volume indicator and a monitoring loud-speaker. The speech amplifiers are designed to deliver to a Post Office land line a signal of appropriate level for transmission to Alexandra Palace.

The whole of the equipment is made up in the form of flat-fronted panel units mounted in 7-ft. racks which extend down both sides of the body, with a central gangway for the operating personnel, as shown in Fig. 12 (see Plate 3).

The racks themselves are securely bolted together at the top and bottom and at several intermediate points, and the foot-plates of each set are bolted securely to a rigid frame which, in turn, is supported through the medium of resilient indiarubber insulated bushings, upon a series of transverse bearers carried by the chassis frame.

The two sets of racks are linked across the top at four points by strong tubular members heavily braced in two planes by means of welded radius plates.

The whole of the rackwork thus comprises a very rigid structure, carried on rubber-insulated mountings and entirely unconnected with the bodywork of the vehicle, and in consequence of its mass and the method of mounting it is not susceptible to the effect of road shocks.

In practice this method of construction has proved highly successful, and a minimum number of faults due to the disturbance of the equipment by vibration have occurred.

The rear of the racks is not accessible from the interior of the body, and to overcome the resultant difficulty of access to apparatus a particular form of body construction has been adopted, as illustrated in Fig. 13 (see Plate 4). The sides of the body have been made to open over the greater part of the length in the form of flaps. The top half of the bodywork is formed of flaps opening upwards and the lower half of flaps opening downwards. The lower flaps are retained in the horizontal position by means of chains, and they form platforms on which those manipulating the apparatus from the rear may stand at a convenient height. The upper flaps are supported by rods engaging in sockets in the bodywork and serve as a roof to ward off falling rain.

All the equipment is mains-operated, consuming a total of about 5 kW, and is adopted to operate from either single-phase or 3-phase 50-cycle supply mains over the range of voltages normally encountered.

In the absence of supply mains the mobile control room unit may be operated from a petrol-driven generator, details of which are given in the succeeding Section.

The chassis is of the 4-wheel 45-h.p. 6-cylinder petrol-driven type, and in the fully loaded condition weighs approximately 9 tons.

(c) Travelling Vision-Transmitter and Power Unit

The preceding Section described the mobile control-room apparatus for generating and monitoring vision and sound at an outside-broadcast point remote from Alexandra Palace. Both sound and vision must clearly be conveyed to Alexandra Palace in some manner so that they may be broadcast from the normal aerials to be received in the ordinary manner on viewers' receiving sets.

Conveying the sound signals to Alexandra Palace presents no difficulties, as use can be made of Post Office line circuits in the usual manner, but the vision signals present a serious problem. At the present moment it is not possible successfully to transmit television signals through the medium of ordinary land-line circuits of appreciable length, and while special television circuits exist, as will be described in a later section, their scope is limited at present, and many events of interest take place in localities far removed from these special circuits.

In circumstances such as these, other means for linking the mobile control room with Alexandra Palace must be adopted, and to this end a second mobile unit comprising an ultra-short-wave radio transmitter has been constructed.

This unit is mounted in a second vehicle of precisely similar construction to that used for the mobile control room, as previously described.

The transmitter is built into two sheet-steel cubicles, which are disposed either side of the centre line of the vehicle body and are carried by means of resilient bushings upon transverse bearers affixed to the main chassis members of the vehicle.

The transmitter is designed to operate at a frequency in the region of 64 Mc./sec. and delivers to the aerial a power of 1 000 watts at peak picture-white modulation.

The radio-frequency portion of the installation consists of a valve master oscillator operating at 32 Mc./sec., having a frequency stability of 1 part in 5 000. This is followed by one doubler stage, and five stages of neutralized push-pull radio-frequency amplification, modulation being by grid control on the final stage, depicted in Fig. 14 (see Plate 3).

All valves are of the air-cooled type throughout, and in the case of the final and penultimate stages consist of small water-cooled valves designed for working at these frequencies, modified for air cooling by having intimately affixed to their anodes a type of copper honeycomb, through the cells of which air is rapidly forced. Heat generated by the dissipation of energy in the valves is thus removed, without the use of cooling water, the presence of which would be inconvenient in a mobile vehicle.

The modulating equipment is designed on the same lines as that installed as part of the Alexandra Palace vision transmitter, but of course on a reduced scale, air-cooled valves being used throughout. The whole equipment is designed to pass, with a minimum of loss at the high frequencies, the wide frequency band required, and to transmit a signal having the same general form as that radiated from the main vision transmitter.

The output of the transmitter is adapted to feed the aerial either through a balanced open-wire feeder of about 500 ohms characteristic impedance, or, alternatively, by means of a coaxial high-frequency cable of 110 ohms characteristic impedance.

The first type of aerial used consisted of a two-stacked balanced series phase array adapted to emit a vertically polarized wave and having marked directional properties. This aerial was constructed on a Jarrahwood frame, approximately 18 ft. long by 12 ft. high, which was slung between two 30-ft. transportable wooden masts with tripod bases, both the masts and the aerial frame being capable of being dismantled into component parts of such size as to make transport possible. The vehicle and masts, as set up at the All-England Tennis Club at Wimbledon, are shown in Fig. 15 (see Plate 4).

It will be noted that in the interests of portability the height of the transmitting aerial was kept low, an action which was held to be justifiable on the following grounds.

Evidence showed that good-reception conditions could be obtained using a high transmitting aerial in conjunction with a comparatively low receiving aerial, and it is generally conceded that the converse must in theory apply. Consequently it was felt that if a very high aerial could be installed at the receiving point, a comparatively low aerial could be used with the transmitter, with manifest advantages from the point of view of rapid erection and dismantling. An aerial, details of which are given in a later Section of the paper, was therefore installed at the top of the Alexandra Palace transmitting mast for purposes of reception.

It must be understood that a very limited time was available for experimental work on these aerials, as it was necessary to provide some form of equipment in order that the apparatus should be available for certain imminent outside broadcasts, notably the Coronation procession and the tennis championships at Wimbledon.

In practice, rather variable results were obtained with the low series phase aerial, as it was found that from some outside broadcast sites a good signal strength giving a satisfactory signal/noise ratio was received at Alexandra Palace, whereas from others the results were very poor. For example, from Wimbledon a field strength of approximately 2 mV/m. was obtained, whereas from Hatfield Aerodrome, whence an attempt was made to relay the start of the King's Cup Air Race, a very low signal strength of the order 250 μV per metre only was obtained, which gave an insufficiently good ratio of signal to noise to maintain synchronism of the picture. The actual length of the radio-link path was $11\frac{1}{2}$ miles in the case of Wimbledon, and 13 miles in the case of Hatfield, and there clearly is not sufficient difference in these distances to account for the widely divergent field strengths obtained.

Some attempt was made to determine the factor influencing this divergence, and inspection of the topographical features of the intervening country revealed that in the case of Wimbledon, while the actual height of the site above sea-level was not great, being of the order of 100 ft., the transmitting aerial stood effectively on the summit of the highest ground in the district and a very marked falling-away of the ground occurred immediately, there being no high ground in the path of the wave for a number of miles.

In the case of the Hatfield site, on the other hand, the transmitting aerial stood on fairly level ground, there being no falling-away in the direction of the receiving point. There was in fact a certain amount of rather higher ground between the transmitter and the receiver, fairly close to the transmitting aerial, and it could only be assumed that this had the effect of introducing local attenuation, which resulted in the weak signal strength to which previous reference has been made. It would therefore appear that one of the most important influences on the performance of a short-wave transmitting station of this type with a low aerial lies in the nature of the immediately surrounding country. That is to say, if the transmitting aerial stands at the top of a local eminence with the ground falling away in the direction of the receiving point, and no high ground exists in the path of the wave for a number of miles, the signal strength obtained at the receiving point is likely to be good, even though there is some high ground between the transmitting and receiving aerials to the exclusion of the possibility of an optical path, provided that the obstruction is at some considerable distance from the transmitter. On the other hand, if an appreciable tract of ground, higher than or even level with that on which the transmitting aerial stands, exists in the vicinity of the transmitting aerial and between it and the receiver, very severe local attenuation appears to occur.

At present no quantitative data are available regarding this point, but field-strength surveys tracing the attenuation of the wave under various conditions will be made as soon as equipment for this purpose is completed.

It is well known that the height of either the transmitting or the receiving aerial has a very marked influence upon the received signal; consequently, after the difficulties experienced at Hatfield, attention was turned to the possibility of using a higher transmitting aerial in order to obtain a better ratio of signal to noise in the received signal. At the Pinewood film studios, Buckinghamshire, whence television broadcasts depicting the making of a film were carried out, it was found that raising the series phase array some 50 ft. on to the roof of the studio gave a gain of some 10 db. in the received signal compared with that obtained with the aerial at ground-level.

Practical experience to date therefore indicated that the use of a higher transmitting aerial was eminently desirable, and as the series phase array mounted on a somewhat bulky frame was clearly not a very convenient form of aerial for mounting at greater heights, attention was turned to other and simpler forms of aerial array which should be lighter in weight and more easily supported on a higher mast.

Comparisons made between the series phase array and a single vertical centre-fed dipole aerial at the same height indicated that the gain due to the former was approximately 6 db. The addition of an unfed vertical dipole reflector resulted in a gain of 2 db., so that for practical purposes it may be said that the dipole with reflector gives approximately 4 db. less signal strength than the series phase array, if erected at the same height, but owing to the very much lighter nature of the former it is possible to erect it at a greater height with a corresponding increase in received field strength. In later outside broadcasts, therefore, a single dipole radiator with reflector has been used, erected on wooden poles fastened to existing buildings at heights from 80 ft. to 100 ft. above ground-level as found to be practicable, and giving received field strengths estimated to be from 12 to 15 db. above that given by the series phase array mounted on 30-ft. masts. Owing to pressure of time it was not possible to obtain exact quantitative results in all cases.

The raising of the transmitting aerial to these greater heights has brought in its train certain difficulties concerned with the feeding of the aerial. For example, the use of long open-wire feeders is extremely inconvenient, as they are fragile and difficult to transport and are also liable to become twisted unless considerable pains are taken with their erection. Further, if they come into close proximity with metal objects, such as roofs or drain pipes, serious losses are liable to occur.

It is clear that coaxial types of feeders if sufficiently robust and flexible represent a more convenient method of feeding the aerial, provided that the loss introduced thereby is not excessive. A type of lead-covered high-frequency feeder having spaced internal insulation of low power factor, and a characteristic impedance of 110 ohms, was used for several of the later outside broadcasts and gave a very good performance from the electrical point of view, in that the losses for the length required were extremely small. This feeder, however, was originally designed for permanent installation and not for continuous handling, and when used for the purpose described it was found to be too fragile to be really practicable. In consequence a high-frequency cable has been developed of similar design but having a copper-tape armouring in place of the lead covering, and experimental lengths which have been tested show considerable promise from the point of view of both electrical suitability and mechanical strength, while being much lighter than the lead-covered type. It may therefore be said that the problem of feeding high portable aerials has been largely overcome, as the new type of feeder can be treated as a flexible cable and repeatedly wound up on a drum without damage.

The question of a suitable support for a higher aerial has received a good deal of attention, and numerous proposals have been considered. The practice of lashing wooden poles to existing buildings is clearly of the nature of a makeshift, and it occupies far too much time to be admissible in a transportable equipment where rapidity of setting up is regarded as of cardinal importance.

The use of portable masts does not offer an entirely satisfactory solution to the problem, as wooden masts of sufficient height to be effective are largely impracticable, on the grounds of the time taken for their erection and difficulties which are frequently encountered as far as space is concerned. Steel portable masts are equally inconvenient, with the added disadvantages of greater weight and the bad influence which a metal mast with its stay wires is likely to have upon the radiating properties of the aerial system.

Attention was therefore turned to the fireman's ladder, a highly specialized and well-developed form of structure which is ideally suited to the purpose in view, in that it combines extreme portability with ease and rapidity of erection.

Designs have therefore been drawn up foı a lightened form of wooden extensible ladder carried on a motor chassis which will form a rigid base for the aerial mast when the latter is erected.

The ladder will be pivoted on a rigid frame at the rear of the chassis, so that when lowered it will lie along the roof of the closed body with which the vehicle will be fitted. Erection will be accomplished by means of power derived from the engine, and it is anticipated that the process of raising or lowering will occupy only 2 or 3 minutes.

The mast vehicle will also serve the dual purpose of a tender for the mobile control room and transmitter vehicles, carrying all necessary accessories such as drums of additional cable, spare parts, and the like.

Mobile Power Unit.

A third vehicle of similar construction to those containing the mobile control and transmitting apparatus houses a petrol-driven engine-generator set capable of supplying power for both the other units, thus making the mobile outside-broadcast equipment independent of supply mains in places where these are not available or are unsuitable.

The engine is of the 6-cylinder omnibus-propulsion type and develops 120 b.h.p. at 2 200 r.p.m. It is direct-coupled to a 3-phase 415-volt 50-cycle alternator operated at 1 000 r.p.m., at which speed the engine is adjusted to develop 50/55 b.h p., giving a maximum electrical output of approximately 30 kW.

The engine and alternator are carried on a fabricated bedplate which is rigidly secured to the main members of the chassis. The engine is covered by a bonnet at the front end of which is mounted a radiator for cooling purposes, through which a fan draws air from the interior of the body. The heated air is ejected through an aperture in the floor boards of the vehicle and, in consequence, the interior of the body is well ventilated and kept free from noxious vapours.

The engine is provided with a centrifugal governor operating on the throttle valve of the carburettor, designed to give an accuracy of speed control under widely varying load conditions of $\pm 2\frac{1}{2}$ %. Under the comparatively steady-load condition representing normal working, the speed remains sensibly constant. The output voltage of the alternator is controlled by an automatic voltage regulator of the carbon-pile type, the chief function of which is to protect the apparatus against dangerous voltage surges during the process of switching load on and off.

Owing to the fact that the engine is liberally rated and thus operated well below its maximum output power and speed, commendably steady and sweet running is obtained over long periods with a minimum of attention and without vibration and trouble.

(d) Radio-Link Receiver at Alexandra Palace

The receiving aerial is mounted on the extreme top of the Alexandra Palace mast and is designed for the reception of vertically-polarized waves, taking the form of an electrically cylindrical dipole mechanically simulated by a number of wires arranged in a circle. It is connected through a series of transformations of similar form to those used on the vision aerial, to a lead-covered air-spaced paper-insulated coaxial feeder of about $\frac{3}{4}$ in. diameter, terminating at the receiver adjacent to the control room.

The receiving aerial is, of course, tuned to 64 Mc./sec. and it so happens that, as a result of transformations and the attenuation of the feeder, the signal voltage produced across the terminals of the receiver is approximately equal to the field strength of the signal incoming to the aerial.

An unwanted signal of the order of 10 volts (r.m.s.) total at the terminals of the receiver is induced into the receiving aerial from the local sound and vision aerials, and high-pass filter circuits are incorporated giving a discrimination of some 70 db. in favour of the wanted signal without the introduction of significant phase distortion.

Assuming a field strength of 2 mV/m. from the distant station, it will be seen that the wanted signal and local interference appear sensibly equal at the input to the first stage of the receiver.

The remaining discrimination between wanted and unwanted is achieved by the use of a superheterodyne receiver with a first detector having linear characteristics over a wide range, so as to preclude the possibility of cross-modulation, and intermediate-frequency stages having suitable band-pass characteristics.

The receiver takes the form of a 10-stage superheterodyne using an intermediate frequency of 7 Mc./sec. and is provided with automatic volume control and indicating instruments, including an oscilloscope for observing the received signal wave-form. No amplification is used at the original frequency (prior to the frequency changer), but three stages of vision-frequency amplification are introduced after the second detector, arrangements being made that the output shall contain the full d.c. component of the signal.

The output is thus in the usual form of vision + synchronizing signals, which is applied to the vision transmitter without the introduction of any further impulses or signals. It is taken to a suitable point in the control room, where, by means of relays, the input to the vision transmitter can be rapidly changed over from the output of the local studio apparatus to the output of the receiver. A rapid change-over is essential, as it is necessary to change from locally-generated synchronizing signals to those coming by radio from the distant point, and a complete cessation of synchronizing impulses to the transmitter would cause serious overloads if maintained for an appreciable space of time.

(e) Television Transmission over Cables

Attention in this country, as well as in others, has for some time been directed towards the transmission of television signals through line circuits, not only for the purposes of linking up outside broadcast transmission but also to permit ultimately of a simultaneous broadcast of a television programme from a number of widely-separated radio stations. A detailed examination of results so far obtained falls rather outside the scope of the paper, but it is felt that some brief reference to the broad lines along which investigations are proceeding would not be out of place.

In general, the types of circuits under consideration have fallen into three main categories:—

(*a*) Unbalanced coaxial cables designed for multi-channel telephony and/or television.
(*b*) Balanced-pair low-capacitance cables primarily designed for television.
(*c*) Normal telephone circuits.

As regards (*a*), experiments are in progress by the Post Office Engineering Department to determine the requisite conditions for satisfactory operation on a long route of cable of this type, with particular reference to the coaxial circuits already existing between London, Birmingham, and Manchester, intended for multi-channel telephony.

As regards (*b*), a network of this type of cable, supplied by the Marconi-E.M.I. Television Co. to the Post Office, has been installed round the centre of London, following the route depicted in Fig. 16. As will be seen, this route embraces numerous points of interest, including the site of many national functions as well as places of entertainment such as theatres, etc., and proceeds via Broadcasting House to Alexandra Palace. Tapping points are provided at frequent intervals along the whole cable route.

All signals originating on this circuit are led into a repeater station at Broadcasting House, where equalization and phase correction take place, after which the signals are amplified and directed to Alexandra Palace, where further equalization and amplification is necessary before they are applied to the vision transmitter.

As regards (*c*), the British Broadcasting Corporation has carried out certain experiments on short lengths of ordinary telephone circuit with the particular object of using such circuits as extensions to the balanced television cable where distances of 1 or 2 miles only are involved. The use of such spur circuits would be invaluable in cases where the site of an outside broadcast is situated a mile or so from the main television-cable route.

Preliminary investigations on these lines have been made to determine the suitability of ordinary dry-core paper-insulated cables for the transmission of frequencies in the vision range. The primary constants vary, not only with the physical dimensions of the pair concerned, but also with its disposition relative to the other conductors in the cable. The iterative impedances of pairs measured vary between 75 and 140 ohms.

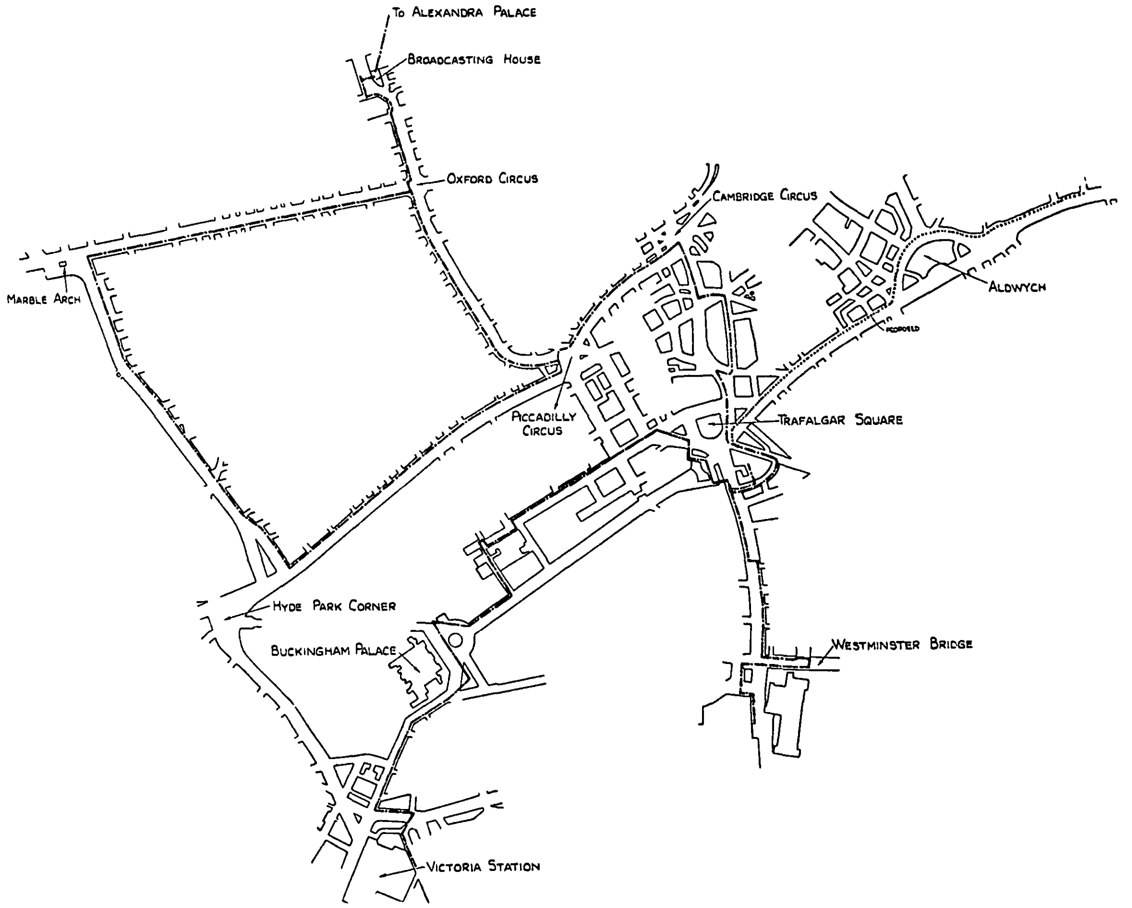

Fig. 16.—Balanced television cable route.

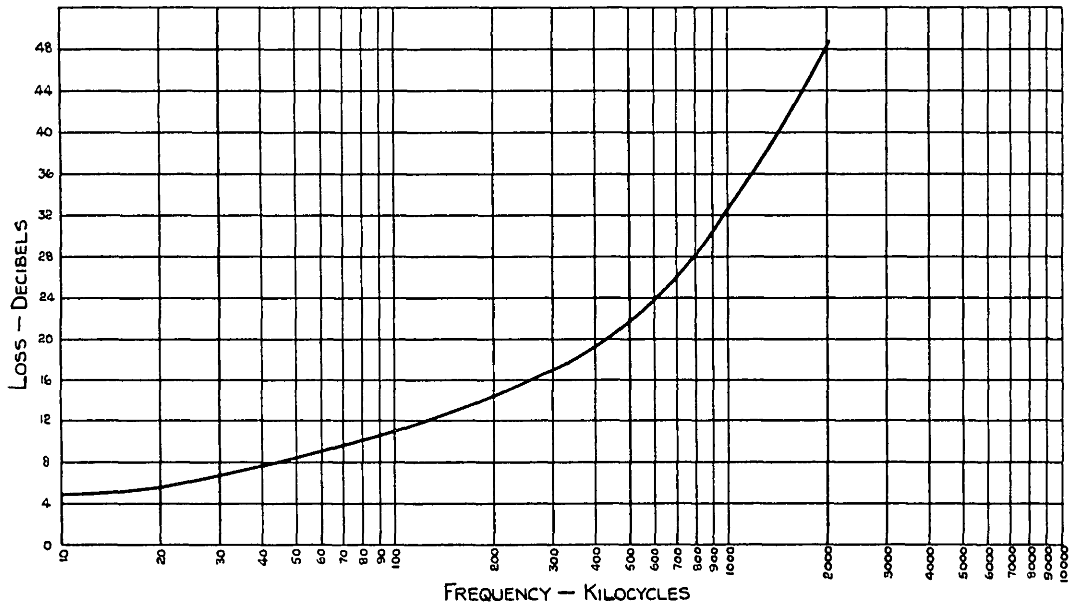

Fig. 17.—Insertion loss characteristic between 140-ohm resistances of 1·2 miles of 10-lb. paper-insulated cable.

Fig. 17 shows the insertion loss/frequency characteristic of 1·2 miles of 10-lb. twisted pair in a particular cable, measured between 140 ohms impedance. The shape of the characteristic is such that it can be equalized quite easily to within ± 1 db. over the whole frequency range by simple constant-resistance networks.

Measurements made on short lengths of cable indicate that where small-gauge conductors are concerned the high-frequency value of inductance is reached below 200 kc./sec., which means that at frequencies above this value the frequency/phase characteristic is linear, apart from a secondary effect of attenuation which becomes apparent at the higher frequencies. For the limiting lengths of circuit contemplated, it is possible to obtain the phase characteristic up to 200 kc./sec. by open-circuit and short-circuit impedance measurements. The phase distortion introduced by the attenuation-correcting networks has to be compensated, but as the required correction can be easily calculated this presents no difficulty.

A problem which requires special attention is the connection of the balanced circuit to an unbalanced amplifier at the low-level end of the circuit, as the longitudinal currents normally present in the cable pair must be much attenuated before they are effective in the unbalanced input of the amplifier. A specially-designed shielded repeating coil was included in a circuit of suitable constants, and was found to transmit frequencies in the range 50 cycles per sec. to 2·2 Mc./sec. with small attenuation and phase distortion.

With this arrangement of terminal apparatus, the noise level on the 1·2-mile section of cable referred to in Fig. 17 was better than 50 db. below the equalized signal. This method of transmission has not yet been used, and experimental work is still proceeding.

PART 6

PERFORMANCE OF THE STATION

(a) Field-Strength Measurements

A series of field-strength measurements have been taken on the television transmitters at Alexandra Palace, using for the most part the sound transmitter operating on 41·5 Mc/sec.

It has not been practicable to examine the field from the vision transmitter with the same detail as that of the sound transmitter, owing to the nature of its modulation, but comparison measurements of the relative value of field strength of the two transmitters have been made at numerous points, and it has been found that the average field strength due to the vision transmitter is 85 % of the sound-transmitter intensity.

This result is to be expected, as the vision transmitter radiated power varies from 17 kW at peak white to about 1·5 kW at black, with little radiation during synchronizing signals. The average radiated power is thus comparable with that of the sound transmitter which operates with a carrier-wave power of 3 kW.

Fig. 18 is a contour map of the field strength at ground level over the region within 25 miles of the transmitter.

The apparatus used for determination of the field strength was mounted in a vehicle, and consisted of a field-strength measuring receiver designed on the following lines.

The receiver took the form of a superheterodyne, using an intermediate frequency of 500 kc./sec., in which the input terminals were connected directly to the frequency-changer unit through an aperiodic coupling.

The efficiency of the frequency changer was shown to be independent of frequency, and consequently the received ultra-short wave signal could be measured by direct comparison with a locally generated medium-wave signal, the local-oscillator frequency being altered as required.

The efficiency of the aerial system at the required wavelength was determined by means of a loop radiator giving a calculable field, and once this had been evaluated it remained unchanged, provided that the operating wavelength was not altered.

In operation the receiver was set up and adjusted for the incoming ultra-short-wave signal, and the deflection produced by it on a galvanometer was noted. The medium-wave local-signal generator was then switched on and the frequency of the receiver local oscillator adjusted to an appropriate value. The voltage injected by the local-signal generator was then adjusted until the same reading on the galvanometer was obtained, and the voltage so injected determined by means of a thermal milliameter and calibrated attenuator. The value of voltage so obtained was then equal to the voltage due to the distant ultra-short-wave signal, and by applying a suitable factor (previously determined) for the aerial system, the actual field strength of the distant signal could be evaluated.

(b) Propagation over Long Distances

Field-strength measurements have been made at distances from 50 to 800 km. in an approximately straight line in a northerly direction to determine the behaviour of ultra-short-wave signals beyond the normal service area.

Fig. 19 shows the results, plotted in terms of Ed against distance, for day and night conditions.

It will be noted that these results appear to establish quite clearly the existence of a weak sky-wave at distances beyond about 150 km. under both day and night conditions, and this fact will have to be taken into account from the interference point of view in the consideration of the establishment of further stations.

(c) Reports of Reception and Interference Problems

Reports of reception of the Alexandra Palace television transmissions have in general been encouraging.

The range of the station was originally estimated to be approximately 25 miles, but in practice it has proved to be better than the value forecast, in that it is fairly safe to say that good reception can be obtained up to about 35 miles, except in cases where exceptionally bad interference is encountered.

Reports of vision reception have been received from places as far distant as Brighton, Southend, Cambridge, and Bedford, which are situated at distances of from 40 to 60 miles from the Alexandra Palace. Reception in these cases has been carried out under exceptionally favourable conditions, such as the receiving station being situated on high ground and some distance from sources of interference; consequently, these results cannot be regarded as entirely normal.

Reports of reception from even greater distances have been obtained, including such places as Rugby, which is approximately 70 miles from Alexandra Palace, and even latter case it must be assumed that reception was due to reflection phenomena.

The whole question of distant reception is, as usual,

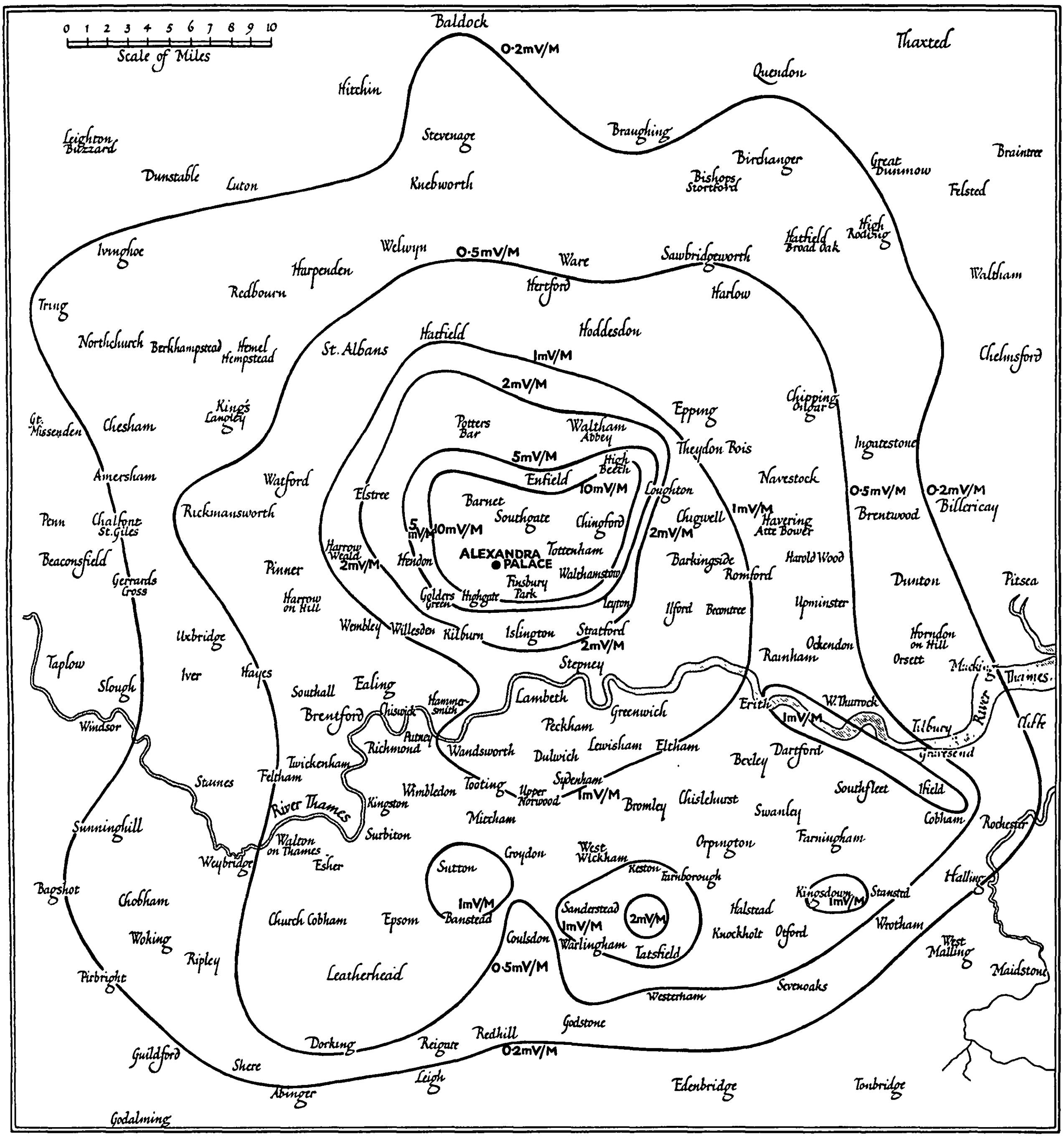

Fig. 18.—Field-strength map of London Television Station.

from a place in the vicinity of Manchester which is situated about 190 miles from Alexandra Palace.

In the case of the former, reception conditions were quite exceptional, the receiver being situated at the top of a 110-ft. concrete water tower standing in the middle of fields at a considerable distance from all roads. In the bound up with conditions of interference, and there seems little doubt that the limiting condition for reception lies in the ratio between the signal and the noise due to sources of interference extraneous to the receiver. It appears that in normal circumstances the condition is not reached where valve and other noises in the receiver itself introduced by the use of excessive gain form a limiting factor. It has been found that on the ultra-short wavelengths used for television the most serious forms of interference are due to two main causes. First there is the interference due to electro-medical apparatus used for high-frequency diathermy, of which two types are in general adopted. These may be generically described as " spark diathermy " and " valve diathermy."

The former usually consists of a multiple spark-gap

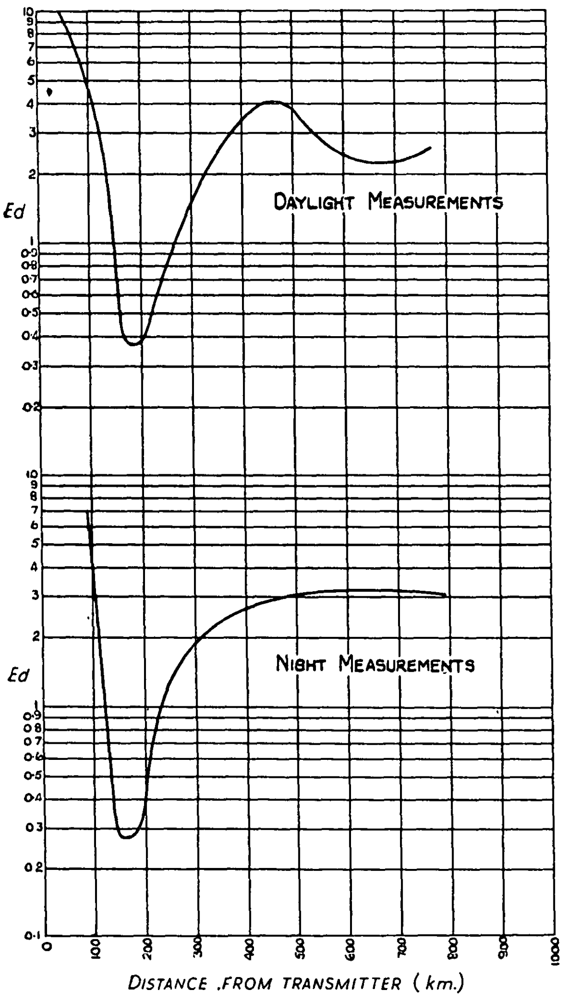

Fig. 19.—Measurements of peak field-strength values.

E = millivolts per metre.
d = distance in km.

supplied with alternating current at high voltage by means of a transformer operated from the supply mains. Associated with the spark-gap is a crude oscillatory circuit having much the same form as that used in early spark transmitting apparatus. Electrodes directly tapped across a part of this circuit are applied to the patient, and currents of the order of some amperes induced into the part under treatment, on wavelengths of from 3 to 10 metres, the actual wavelength being under the control of the operator. Such a machine radiates damped waves having a large band width and possessing great potentialities for interference, which, however, appears to be limited to a comparatively small range, as the radiated wave seems to be rapidly attenuated.

The valve type of machine has in the past consisted of one or more triodes connected to a self-oscillatory circuit, the H.T. supply being provided by self-rectification of the output of a step-up transformer connected to the supply mains. These machines are also capable of being operated from about 5 to 10 metres, and in some cases radiate enormously-strong undamped waves both on the fundamental and on numerous harmonic frequencies. The waves are heavily modulated with supply frequency, together with the many low-frequency harmonics introduced by rectification, and constitute interference of the worst possible type. Frequency-wandering and scintillation are usually present to a very great degree, and it is not uncommon for one of these machines to wander into the television band and obliterate television reception over a comparatively large area, as the undamped waves do not appear to be attenuated rapidly, and their effect is noticeable over surprisingly long distances. Later types of valve apparatus have been provided with high-tension rectifiers and smoothing circuits, which to some extent reduce the interference by confining it to a pure wave.

The suppression of interference from these causes is by no means an easy problem, as it is not sufficient merely to screen the apparatus itself and take adequate precautions to prevent the radio frequency being disseminated through the supply mains, since the greatest source of radiation is the patient himself and the leads connecting the machine to the electrodes applied to him. Further, the use of diathermy apparatus is not, in the case of most hospitals, limited to any one room which could be effectively screened, but rather it is the practice to transport the diathermy apparatus to all wards of the hospital, treating patients in their own beds wherever they may happen to be. The problem is thus materially complicated, as clearly it would be a task of great magnitude—if not impracticable—to screen the whole hospital with that meticulous care which experience has shown to be necessary in order effectively to suppress the interference.

One example of the efficiency of comparatively simple methods of screening a room has occurred in the case of a North London hospital situated about ½ mile from Alexandra Palace, where the use of a spark diathermy machine completely jammed the reception at Alexandra Palace of the 5-metre radio-link transmitter. The whole of the walls and ceiling of the room were covered with aluminium foil, 5 mils in thickness, applied with a paper backing after the fashion of ordinary wallpaper. The joints in the foil were of the butt type, a strip of aluminium foil being laid over the intersection and secured in position by means of a batten, so as to be in intimate contact with the foil on both sides of the joint. At one end of the room, which was open, a partition covered with ½-in. mesh chicken-wire was erected, good electrical connection being maintained between the aluminium foil on the ceiling and walls and the chicken-wire. Chicken-wire screens were placed over the window and laid on the floor underneath the usual rubber floor material. Stopper circuits in the form of radio-frequency chokes with condensers to earth were inserted in all electrical leads entering the room from outside, the chokes being placed in suitable screening boxes.

This treatment effected complete suppression of the interference, but the necessity for thorough measures was amply demonstrated by the fact that if the screened door in the partition was opened by only a few inches, the interference appeared at a level comparable with that experienced before the work of screening was carried out.

The existence of high-frequency diathermy apparatus is at present largely confined to the West End of London, where many physicians have their consulting rooms, and to a number of hospitals situated both centrally and in the suburbs. As a result of this the interference, while very violent, is not so widespread as the second form of interference previously referred to, viz. that due to the ignition systems of motor-cars.

Practically all types of motor vehicle, particularly those equipped with coil ignition, radiate more or less serious interference in the television band.

The actual carrying power of this interference is not great, being limited in most cases to a few hundred yards, but, nevertheless, the effect can be extremely serious in the case of the receivers where the aerial is situated in close proximity to a main thoroughfare where a large amount of vehicular traffic is constantly passing.

The two worst cases occur in the centre of the City, where, although the television signal is strong, traffic is particularly dense, and in places towards the fringe of the service area of the station where the television signal is weak and the receiver is situated in close proximity to a main road. The only slightly mitigating circumstance arises from the fact that in the outlying districts the volume of traffic is a good deal less, so that the degree of interference decreases at a rate which is somewhat commensurate with the reduction of signal strength. Even so, extremely bad cases occur in the vicinity of main arterial roads, and the only partial remedy which can be found lies in placing the receiving aerial as far as possible from the source of interference, e.g. at the end of a garden remote from the road, leading into the receiver through a suitably screened or balanced high-frequency cable. The use of directional aerial systems in these cases appears indicated, provided of course that the location of the interference sources does not lie in the same direction as the station.

A curious circumstance noticed is that motor-car interference shows a definite peak at about 125 cycles per sec., and, in fact, on listening it is possible to detect a hum of this frequency preponderating over the general indeterminate noise. It has been suggested that this peculiar frequency of the interference arises from the widespread use of 6-cylinder cars driven at a uniform 30 miles per hour in surrounding limited areas.

Assuming that the average circumference of a car wheel is 5 ft. 6 in. and the average back-axle ratio is 5 to 1, the engine speed would be approximately 40 revolutions per sec., which, for a 6-cylinder engine having a 120° crankshaft resulting in three sparks per revolution, should give a prime interference frequency of about 120 cycles per sec. On this basis, a 4-cylinder engine having two sparks per revolution with 180° crankshaft should give about 70 to 80 cycles per sec., and a certain peak of interference at about this frequency is to be noted, although it does not show up so prominently as the 125-cycle component. The above is mentioned merely as a matter of interest, and as being a possible explanation of a pronounced phenomenon for the existence of which no other convincing reason can at present be advanced.

It has been found possible in practice to suppress the effects of motor-car ignition interference by the inclusion of suitable suppressors in the form of resistances in series with the sparking plugs and distributor, or by completely screening the leads associated with the ignition system by means of an earthed metallic braid. A certain divergence of opinion exists as to whether the taking of these steps has any material influence upon the performance of an internal-combustion engine, but the whole matter is being carefully investigated by the Post Office and the Electrical Research Association with a view to drawing up a definite specification for the suppression of interference due to such causes as motor-cars, diathermy, etc.

(d) Types of Receivers and Receiving Aerials

A number of types of receivers have made their appearance on the market in various forms, but in general the cathode-ray tube appears to be used exclusively as the reproduction medium. The receivers divide themselves broadly into two classes, those using a straight radio-frequency amplification of the vision signal and others employing the superheterodyne principle. Of the latter type there is a further subdivision, viz. those receivers amplifying both sidebands of the transmission and those employing single-sideband operation.

In most cases the detector stage, or second detector in superheterodyne receivers, handles signals of fair amplitude and is equipped with two outputs. One output is usually taken to the control electrode of the cathode-ray tube, either direct or through a single vision-frequency amplification stage, which in some cases is a d.c. amplifier and in other cases is an a.c. amplifier having the d.c. component subsequently restored.

The second output from the detector is usually taken to some form of separator stage, which separates the synchronizing impulses from the vision signals and discriminates between line- and frame-synchronizing impulses. The resultant line- and frame-synchronizing impulses are then fed to the respective line- and frame-scanning oscillators, which are thus synchronized with the incoming signal and provide appropriate sawtooth wave-forms to produce the requisite scan.

The cathode-ray tubes vary in size from 9 in. to 15 in. screen diameter, giving picture dimensions varying from 8 in. × 6 in. to 12 in. × 8 in., and either electrostatic or magnetic focusing and scanning or a mixture of both is used. No definite evidence regarding the relative merits of these principles appears at present to exist. Larger cathode-ray tubes having screened diameters up to 24 in. have been made, but have not yet been generally adopted, as their construction presents rather severe problems, related to the effect of atmospheric pressure.

There appears to be a general tendency to standardize on tubes of 12-in. screen diameter, giving a picture approximately 10 in. × 8 in., although certain makers employ larger tubes and others smaller. The problem of accommodating a cathode-ray tube which may be between 2 ft. and 3 ft. in length in a cabinet of reasonable dimensions has given rise to the exercise of considerable ingenuity in design. The fashion in receivers appears to be fairly equally divided between those in which the cathode-ray tube screen is directly viewed, and those in which it is viewed by means of a mirror forming the top lid of the cabinet. It is generally conceded that the former method of viewing gives greater satisfaction to the viewer, but its use involves severe practical difficulty, necessitating as it does the mounting of the cathode-ray tube in a horizontal position, which in turn implies that the cabinet must be very deep, with the consequence that some difficulty is found in accommodating it in any but large rooms. If, on the other hand, a mirror is used, the cathode-ray tube may be mounted in a vertical position, which results in a cabinet of much more convenient shape. It is of course essential to use front-silvered mirrors to avoid the formation of double images.

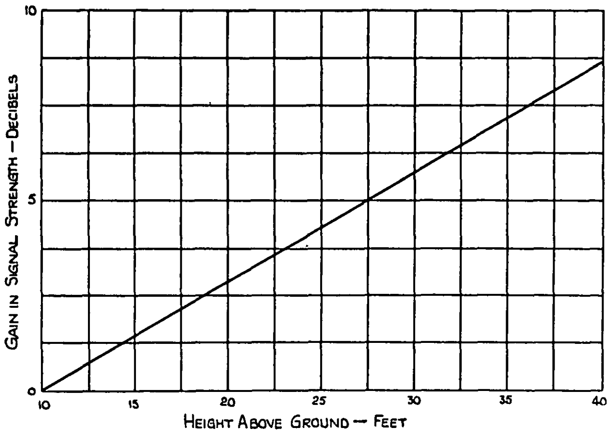

Fig. 20

The advent of television has led to the general use of certain specialized forms of aerials and the development of efficient but inexpensive feeder cables for use with them. The ordinary type of aerial used for sound broadcasting is of but little service for the reception of television, as not only does its response occur at a much higher wavelength, but any attempt to use it as an aperiodic aerial inevitably results in a very poor ratio of signal to interference.

It is the practice, therefore, to mount special types of aerials on the roofs of buildings, often by means of a short mast some 10 ft. or 15 ft. in height, the most general form of aerial to be used being the $\frac{1}{2}$-wave vertical-dipole aerial. This usually consists of a length of copper wire of large diameter, or of small copper tube which is either mounted at its centre so as to be self-supporting or mounted upon the wooden spar by means of stand-off insulators. In the majority of cases the dipole aerial is centre-fed by means of an interruption at its centre point. The two halves of the dipole are frequently connected to a balanced twin feeder having a characteristic impedance of about 120 ohms, so that very fair conditions of matching are obtained. This twin-wire feeder is constructed from two small-diameter copper conductors, embedded very close together in a tube of indiarubber (or gutta percha) and bituminous compound, and has comparatively low losses. It relies upon the proximity of conductors and the fact that it is balanced to ensure that interference due to fields which the cable may traverse cancels out.

An alternative method consists in transforming from a balanced aerial to an unbalanced feeder by means of a $\frac{1}{4}$-wave structure, the feeder in this case taking the form of a coaxial cable, consisting of a central copper conductor and an outside conductor of either lead or copper braid. The space between the conductors is filled up either with paper insulation designed to introduce the maximum of air space or by some low-loss rubber and bituminous compound.

The characteristic impedance of the resultant cable is about 120 ohms, and its losses are relatively low. It relies upon the shielding effect of the outer conductor, which is usually earthed at its lower end, to exclude interference.

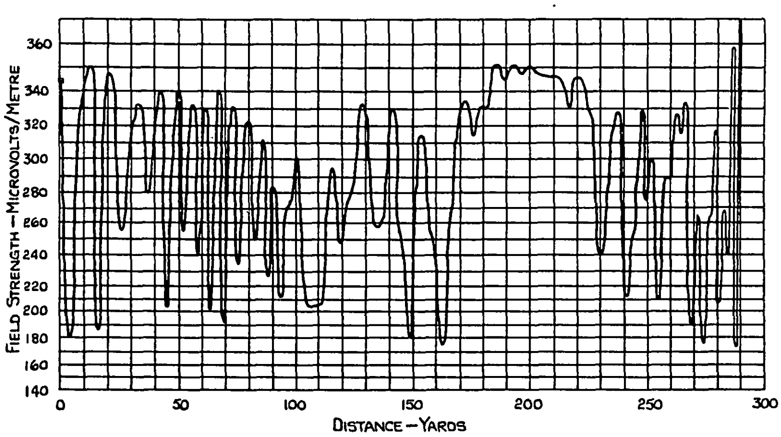

Fig. 21

Some attempts are made to introduce a measure of directivity into the receiving aerial by mounting a second unfed $\frac{1}{2}$-wave dipole at a distance of $\frac{1}{4}$-wave behind the receiving elements. A gain of from 2 to 3 db. in received signal strength has been recorded for this arrangement. Experiments have been carried out using more complex receiving arrays, including numbers of stack dipoles, inverted V aerials, and various others, but in general these have not as yet been applied to domestic receivers.

As has been previously stated, the effect of height is of great importance. This is illustrated by Fig. 20, showing the gain in field strength plotted against height in a receiving dipole.

Another problem which the receiving aerial brings in its train is the effect of standing waves due to the presence of metal roofs, drainpipes, neighbouring steel-frame buildings, etc. Fig. 21 shows typical effects upon the received field strength which may be encountered by moving the receiving aerial over distances of literally only a few yards. In some cases reflections are received of such delay as to introduce definite multiple images in the received picture, and cases have been recorded where reflections having an extremely long delay have resulted from the existence at some considerable distance of such objects as steel gasometers. Against this, however, it has happily proved to be the experience in general that if some little pains are taken to find a location for the receiving aerial where standing-wave conditions are at their best, and reflections at their minimum, a good result can be obtained in nearly every case.

Sound

Sound reception in practically all television receivers is by means of a separate superheterodyne, operating a loud-speaker suitably placed in the cabinet. In cases where the vision receiver also employs the superheterodyne principle it is not unusual to use a common frequency-changing oscillator for both vision and sound, arranging the intermediate frequency for the sound receiver to be $3\frac{1}{2}$ Mc./sec. lower in frequency than the vision intermediate-frequency.

Receiver Controls

In the case of receivers employing straight radio-frequency amplification of the vision signal, tuning is preset and the only tuning control provided is a trimmer on the frequency-changing oscillator of the sound receiver.

In the case of receivers using the superheterodyne principle for both vision and sound with a common oscillator, an adjustable trimming condenser is usually provided, by means of which the sound signal can be accurately tuned in, arrangements being made before the set leaves the factory that this position corresponds to the optimum tuning point for the vision also.

All types of receivers are provided with a brightness control, which usually varies the standing bias on the control electrode of the cathode-ray tube, and a contrast control which varies either the radio- or the intermediate-frequency amplifier gain or takes the form of a potentiometer across the vision-frequency output after the detector. Some receivers are provided with both of these latter controls, the gain control being used to compensate for variations in signal strength dependent upon the situation of the receiver, and thereafter left untouched. Adjustments to contrast are then made by means of the vision-frequency potentiometer in conjunction with the brightness control, and any desired value of picture contrast may thus be obtained. It is interesting to note that viewers almost invariably seek very "contrasty" pictures at first, but that after a time they tend to reduce the contrast to give a softer effect. The question of colour of the fluorescent screens is of course a matter of taste, and receivers having cathode-ray tubes giving every imaginable shade of green, blue, purple, and sepia, have from time to time made their appearance. While many of these tones are found attractive by some people, the more general taste is for a shade approaching black and white. The majority of receivers now being offered incorporate tubes in which the image is reproduced in a very good range of tones between black and white, with a commendable brightness in the high lights.

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Authors' Note.

Certain of the diagrams illustrating this paper have previously appeared in B.B.C. publications, but in the interests of completeness of this paper it is felt that it is not out of place to reproduce them.

[The discussion on this paper will be found on page 793.]