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THE B.B.C. TELEVISION CENTRE AND ITS TECHNICAL FACILITIES

By

F. C. McLEAN, C.B.E., B.Sc., H. W. BAKER, O.B.E., and C. H. COLBORN, B.Sc., Members

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SUMMARY

The B.B.C. Television Centre is the first television headquarters and programme production centre built by the B.B.C. and one of the few buildings in the world constructed expressly for television programme origination. The Centre is at present equipped for producing about twenty hours of programme per week from four production studios and their ancillary areas, and for maintaining continuity of the network programme as a whole. The Centre is principally intended for the production of live programmes but has considerable facilities for the production and reproduction of programmes in recorded form. When completed the Centre will have some ten or eleven studios and will be capable of originating and handling programmes for two programme chains. The Centre includes facilities for all phases of work concerned with programme origination, including recording and standards conversion. It is initially equipped for black-and-white operation on 405-line standards, but has been designed so as to be ready for conversion to the requirements of other television standards and for colour.

Arising from the large power requirement of television production, the Television Centre also contains a large amount of heavy power equipment.

(1) ORIGIN OF PROJECT

In November, 1936, the first public high-definition television service in the world was started by the British Broadcasting Corporation from two small studios at Alexandra Palace.[1] In 1939, the service closed down at the outbreak of war, but well before this the studios had proved inadequate to meet the expanding requirements and plans for expansion at Alexandra Palace were under consideration. In addition, the Corporation was looking for a site in London for a new permanent television headquarters to accommodate new studios and their ancillary services, together with direction, administration and allied activities. The site was to be of a size adequate to meet the long-term development of the service and to be convenient of access for artists and staff. Alexandra Palace had been chosen in 1935 as its elevated and central geographical position made it very suitable as a transmitting site—it was then essential, before long-line vision transmission had been developed, that the vision origination source should be located as close as possible to the transmitter.

The two prototype television studios at Alexandra Palace and their equipment occupy a unique place in the history of television, and have provided a first-class training ground in the television broadcasting art for programme and technical staff.

(1.1) Urgent Need for Studio Expansion

The television service was resumed in June, 1946, from Alexandra Palace with the two studios and two outside broadcast units. With the increasing public interest in television, the need for expansion on the studio side soon became urgent, while a new permanent headquarters and studio centre was still an essential main requirement. The search for a suitable site was continued, but it was realized that, even after a site had been obtained, a working headquarters could not be achieved for several years. In the meantime, to provide the urgently needed studio accommodation, the Rank Film Studios at Lime Grove, Shepherds Bush, were purchased, and during the years 1950–53 four of the original film studios were converted to television studios. Later, other studios were constructed in buildings adapted for the purpose in Hammersmith and Shepherds Bush.

(1.2) Permanent Television Headquarters Site

The first positive step towards the attainment of a permanent television headquarters and studio centre in London was made in 1949, when the B.B.C. acquired thirteen acres of the site of the Franco-British Exhibition of 1908 at White City, Shepherds Bush, W.12. Though barely adequate in area, a more convenient site, near to the centre of London, with good public transport facilities, could hardly have been chosen.

The schedule of accommodation requirements which had been prepared covered a very wide range of items including seven studios and ancillary accommodation; scenery design, construction and storage space; restaurant and offices. The architect's interpretation of the schedule in relation to the available site—shown in the site plan (Fig. 1)—was accepted in March, 1950. It was an imaginative approach and provided a functional architectural solution to the special problems imposed by the

The authors are with the British Broadcasting Corporation.

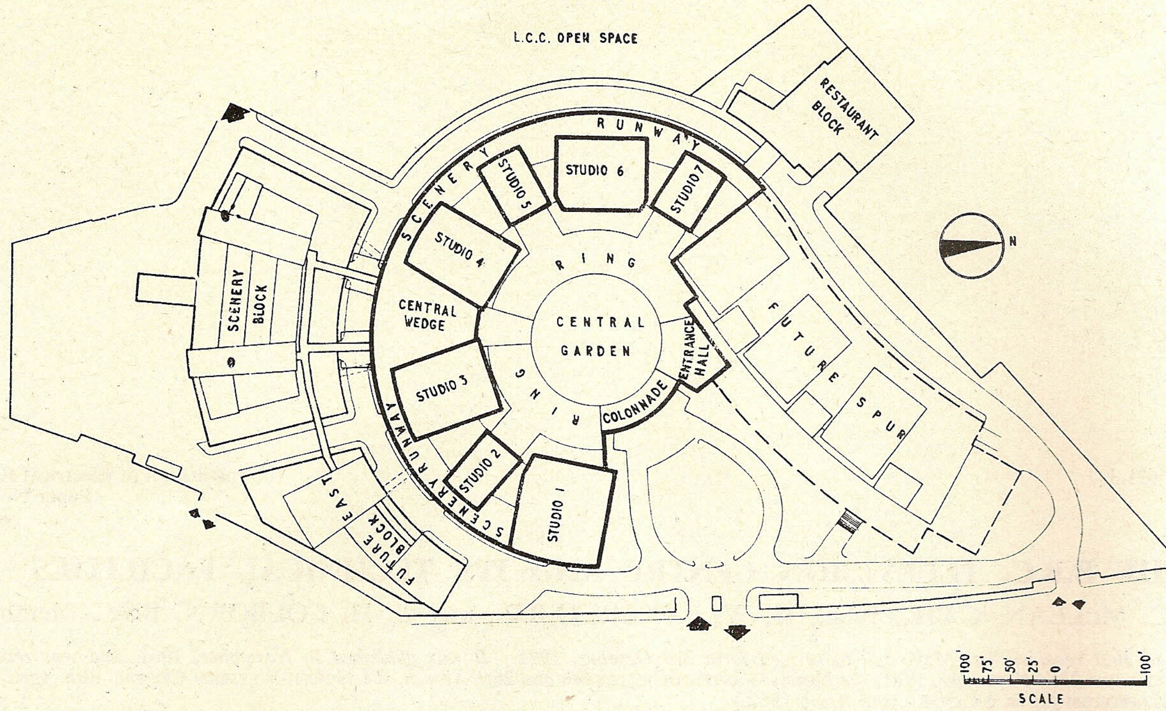

Fig. 1.—Layout of the Television Centre.

location and triangular shape of the site and the requirements of access and circulation. It also took advantage of the open park space which adjoins the site, and part of the attractiveness of the whole is derived from the excellent use which the London County Council have made of this park.

The circular arrangement of television studios in which scenery is fed in from the outer periphery, with access for artists and staff from the inner ring, had in fact already been suggested as a most convenient and efficient operational layout by the late Peter Bax, of the B.B.C. Television Design Department, in about 1942. Further study confirmed the soundness of this proposal, and while the circular arrangement has brought problems in layout and installation, in fact the wedge-shaped spaces between the studios have proved remarkably useful.

(1.3) Planning

Planning of the project went ahead during 1950 and 1951, and by April, 1951, the master plan had been approved in principle. The main development was then delayed by the Government restrictions on capital expenditure. However, the scenery block was started and completed in 1953. Scenery design and supply activities were then transferred there from Alexandra Palace.

In July, 1953, it was known that the restrictions on capital expenditure imposed in 1951 would be relaxed and active planning was resumed. The delay in the building of the main block had had one very important advantage in giving an opportunity to review the 1951 plans in the light of experience gained in the larger studios at Lime Grove, particularly with regard to studio shapes and sizes. As the result, appreciable changes in studio dimensions were made and studios were to be more nearly square in shape. Detailed planning of the main block was restarted early in 1954, and after approval by the L.C.C., building work was started in mid-1955.

In planning the Centre, two basic concepts had been adopted: first, provision for the eventual introduction of a second B.B.C. television programme; second, provision for the eventual introduction of colour. Space has been allowed in the technical apparatus areas for the future introduction of colour, although black-and-white equipment will be installed in the first instance. In this connection it can be broadly stated that colour equipment requires about one and a half times the space of black-and-white. The greatly increased level of studio lighting required for colour has been taken into consideration in the planning of power supplies and ventilation plant capacity.

The planning of the technical area layouts and facilities at the Television Centre has been governed to a large extent by the valuable experience gained in the Lime Grove studios and also in the two converted film studios at Hammersmith (Riverside), which were taken into service in 1956.[2]

In the Riverside Studios different layouts were provided in the two production control rooms to resolve the question of front or side viewing into the studio. Different methods of production lighting control and patching systems were provided in the two studios. This has influenced the choice for the Television Centre, where auto-transformer dimmers with manual patching have been installed.

To achieve closer co-operation between the lighting and vision control staff, in one studio the lighting console was installed in the vision apparatus room in front of the camera control units.

As a result of a prolonged investigation, improved camera channel stability was obtained and more efficient methods of lining up Image Orthicon channels were evolved. Both of these simplified vision control. Various devices to improve camera channel stability and layouts to facilitate camera and studio operation were tried out on an experimental basis leading to one-man vision control and the arrangements described in Section 6.3.

(2) OUTLINE DESCRIPTION OF THE CENTRE AND ITS TECHNICAL FACILITIES

(2.1) Building Development

The overall building development is shown in the layout plan (Fig. 1), and the development so far completed is shown in

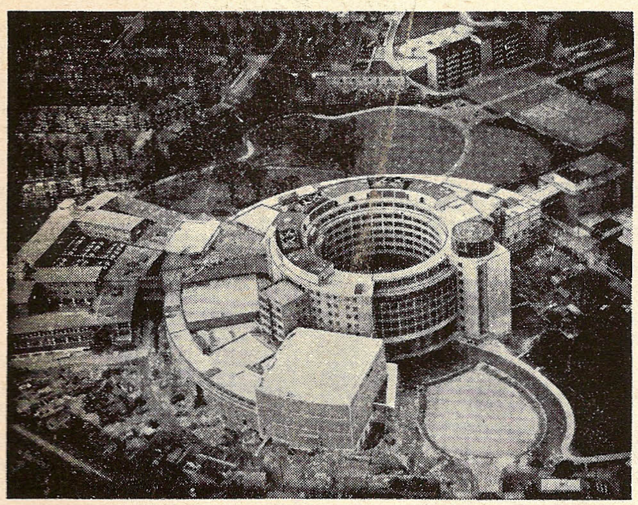

Fig. 2.—The building as seen from the air.

Fig. 2. The conception of the Centre is functional, consisting of a multi-storey circular main block around a central garden, with the studios and a central wedge radiating from it. A covered scenery runway surrounds the outer ring of the studios. This in turn is encircled by a ring road, which provides access to the inner face of the scenery block (opposite to the central wedge on the south side of the main block) and the restaurant block on the north-west side. The total floor space of all of the ancillary areas, both technical and production, is about 300 000 ft^2. The office accommodation is about 100 000 ft^2.

Future planned development on the site includes the east block, to be started in late 1961, on the undeveloped ground east of the scenery block. This will be a building of about 1 500 000 ft^3 and will contain electrical, mechanical and building maintenance workshops; stores for valuable and bulky equipment, pianos and studio audience seating; film dubbing and review theatres; cutting rooms and offices.

The final development of the site will take the form of a 'tail-piece', or 'spur', to the main block, for which 2¼ acres is available. This will contain additional studios and offices.

The various buildings and their functions are briefly described below in order of completion.

(2.2) Scenery Block

This building, completed in 1953, covers approximately one acre and has a volume of 2 500 000 ft^3. On the ground floor are workshops for carpenters, property-makers and others engaged in the making of scenery, and a scenery artists' studio (20 ft × 70 ft × 65 ft high) for painting large backcloths. Also provided at this level is a large and lofty setting space where scenery is assembled and dispatched to the studios, through the scenery runway on trailers hauled by electrically driven trucks.

The basement contains an area of about 50 000 ft^2, for the storage of scenery, which is connected by a large lift to the ground floor; a large property store; the main intake electrical supply substation and the boiler house. Two tunnels connect the east and west ends of the basement with the main block.

Offices for set designers, caption artists and others are provided on the second, third and fourth floors.

(2.3) Restaurant Block

This building covers a quarter of an acre and has a volume of about 500 000 ft^3. It was completed and brought into service early in 1960. On its three floors it can cater for 750 persons at one sitting and for three sittings in sequence. It may be added that the estimated maximum daily population of the centre when all seven studios are available is 2 500.

(2.4) Main Block

This building, which covers 3½ acres and has a total volume of 10 000 000 ft^3, consists of a seven-storey inner ring around a central garden court 150 ft in diameter, seven production studios with their ancillary and technical areas, and a four-storey central wedge housing the main central technical facilities. A basement extends over the whole area. The principal accommodation on the various floors is as follows:

Basement.—Video-tape telerecording suite (under the central garden), artists' dressing rooms, make-up rooms, telephone exchange, stores and locker rooms and ventilation plant rooms.

Ground Floor.—North hall entrance, which is the main entry and control point for staff, artists and visitors; production studios and ancillary accommodation; and star dressing rooms.

First Floor.—Studio technical control and apparatus suites, studio lighting dimmer rooms and power distribution switch rooms.

Second Floor.—Electronic maintenance and test rooms, technical stores, camera tube and valve stores and engineering offices, electrical power supply substations above the scenery runway, and ventilation plant rooms in the wedges between studios. Bridges connect this floor to the scenery block and restaurant block.

Third Floor.—Music and gramophone libraries, wardrobe work rooms, stores, launderettes and offices.

Fourth, Fifth, Sixth and Seventh Floors.—These are almost entirely allocated for offices.

(2.5) Production Studios

Around the inner ring and radiating from it are the seven production studios. Of these, four (Nos. 3, 4, 2 and 5) have been equipped and brought into service. Nos. 1, 6 and 7 have been constructed in shell form and will be gradually equipped and brought into service during 1963 and 1964. The dimensions of the studios and other details are tabulated below:

Studio No.	Type	Dimensions (length × breadth × height)	Area	Volume	Measured reverberation time
		ft	ft^2	ft^3	sec
1	I	108 × 100 × 54	10 800	583 200	—
2	III	70 × 50 × 34	3 500	115 500	0·7
3	II	100 × 80 × 44	8 000	357 000	0·8
4	II	100 × 80 × 44	8 000	357 000	1·0
5	III	70 × 50 × 34	3 500	115 500	0·7
6	II	100 × 80 × 44	8 000	357 000	—
7	III	70 × 50 × 34	3 500	115 500	—

Height dimensions are from floor to ceiling. Reverberation times are for acoustically treated empty studios. A pit has been provided in the floor of studio No. 1 (50 ft × 30 ft × 7 ft 6 in deep), which will have a movable floor that can be raised and lowered in sections for production purposes.

The importance of the studio dimensions is explained and the constructional details are described in Section 6.1.

(2.6) Studio Ancillary Accommodation

Experience had shown the need of local storage space for each studio, directly accessible from the studio floor, and this has been provided in the wedges between the studios. Valuable properties, pianos, etc., and transportable technical equipment—cameras and dollies, microphone booms and lamps—can be safely kept in these stores during periods of setting and striking scenery in the studio. The wedges also provide quick-change dressing rooms and make-up rooms at studio floor level.

Artists' dressing rooms are arranged in three groups around the inner ring, in the basement under the small studios, and at ground-floor level. On the two levels there are 120 dressing rooms of various sizes, of which 34 at ground level are for important and star artists. These have been planned for quick access by artists to the ground-floor assembly areas associated

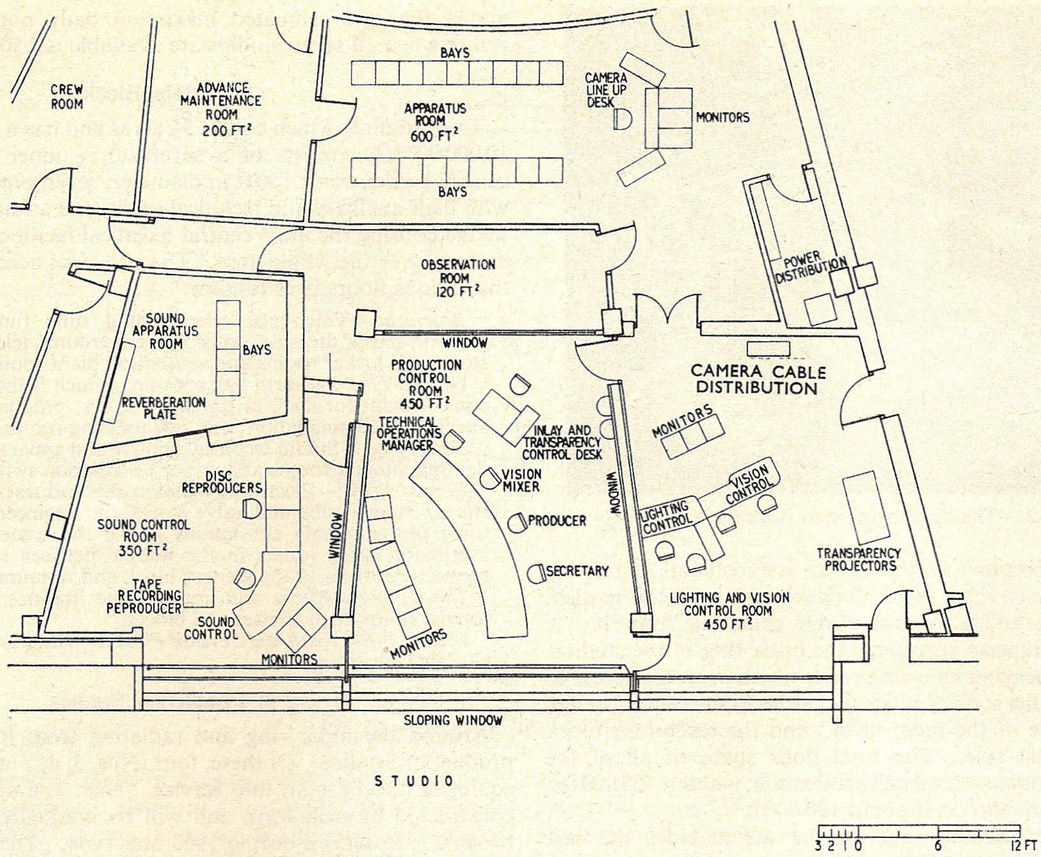

Fig. 3.—Studio (type II) technical suite.

with the three groups of studios. Each assembly area has a green room, refreshment point, telephone booth, etc., so that artists can rest and be on immediate call close to their studios. Make-up rooms are provided at both floor levels, and wardrobe accommodation is on the third floor.

(2.7) Studio Technical Areas

Each studio is operated as an independent unit with its own self-contained technical control and apparatus suite formed at first-floor level at the inner-ring end of the studio. Spacious accommodation is provided in three separate areas for production control, lighting and vision control and sound control, each area giving a direct view into the studio. Separate vision and sound apparatus rooms, a first-line maintenance room and a visitors' observation room are also provided in the suite. The layout is shown in Fig. 3, and Fig. 4 gives a view of the lighting and vision control room. Lighting dimmer and switch rooms are provided at first-floor level in the wedges between the studios. They are accessible from the studio floor or from the lighting gallery which surrounds the studio. The main electronic maintenance and test rooms are located in the inner ring at second-floor level immediately above the vision apparatus rooms; again, ready accessibility has been the aim.

(2.8) Studio Technical Facilities

Cameras supplied by two manufacturers but designed to a common specification and using $4\frac{1}{2}$ in Image Orthicon tubes are used in all production studios. A maximum of six cameras are operationally available in the large studios and four in the small. The cameras provided by the two manufacturers differ somewhat in design but the most important operating features are similar in both.

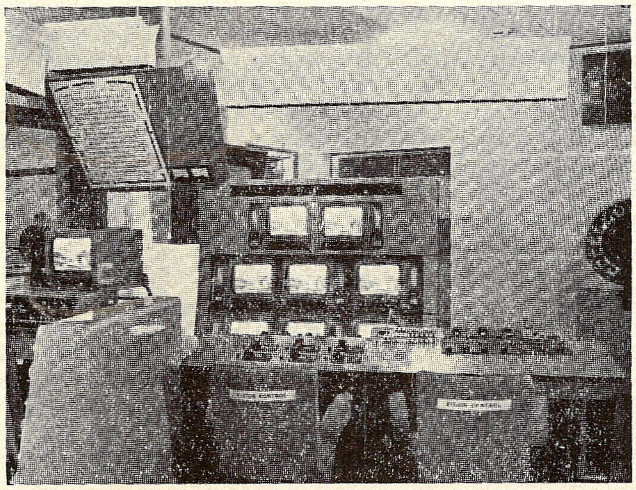

Fig. 4.—Lighting and vision control room (studio No. 4).

An important feature is the provision of remote vision control facilities at a desk which is situated alongside the production lighting control console in the lighting and vision control room; thus the two very important operational functions, on which picture quality depends, are closely integrated. This advance in operational technique is dealt with in more detail in Section 6.

Modern lighting installations with dimmers and electric hoist suspension are provided in all studios (see Section 6.4).

(2.9) Central Wedge

This four-storey building, situated between studios 3 and 4, almost centrally positioned in relation to the seven studios, has been designed to accommodate the central technical services. The ground floor forms the south entrance to the main block and is mainly used for incoming and outgoing goods traffic. The first floor has been allocated for future telecine development.

(2.10) **Telecine Suite**

This is formed on the second floor and space is available for a total of eleven telecines for 16 mm and 35 mm working, although only six have been installed at present.

(2.11) **Central Apparatus Room**

This occupies the greater part of the third floor. Its functions include: generation and distribution of synchronizing and timing pulses to all local studios and telecines; reception, measurement and distribution of all vision and sound signals from local and external programme sources; termination and distribution of all internal and external communicating circuits; monitoring of main electrical supply intake to the site, and control of its local distribution by remote operation of the 11 kV and 415 V switchgear.

Two standards conversion equipments[3] are also accommodated on this floor. These are normally used in conjunction with multi-standard video-tape equipment for the conversion of highly topical programme material to and from North America and elsewhere. Each channel is capable of converting any one of four input standards, i.e. 405, 525, 625 or 819 lines, to any of three output standards, i.e. 405, 525, or 625 lines.

(2.12) **Presentation Suite**

Two almost identical presentation suites, of which only one is as yet equipped, have been formed on the fourth floor of the central wedge. The suite includes the central control room, which is the continuity centre for the national network. The layout is shown in Fig. 5, and Fig. 6 gives a general view of the presentation studio and control room.

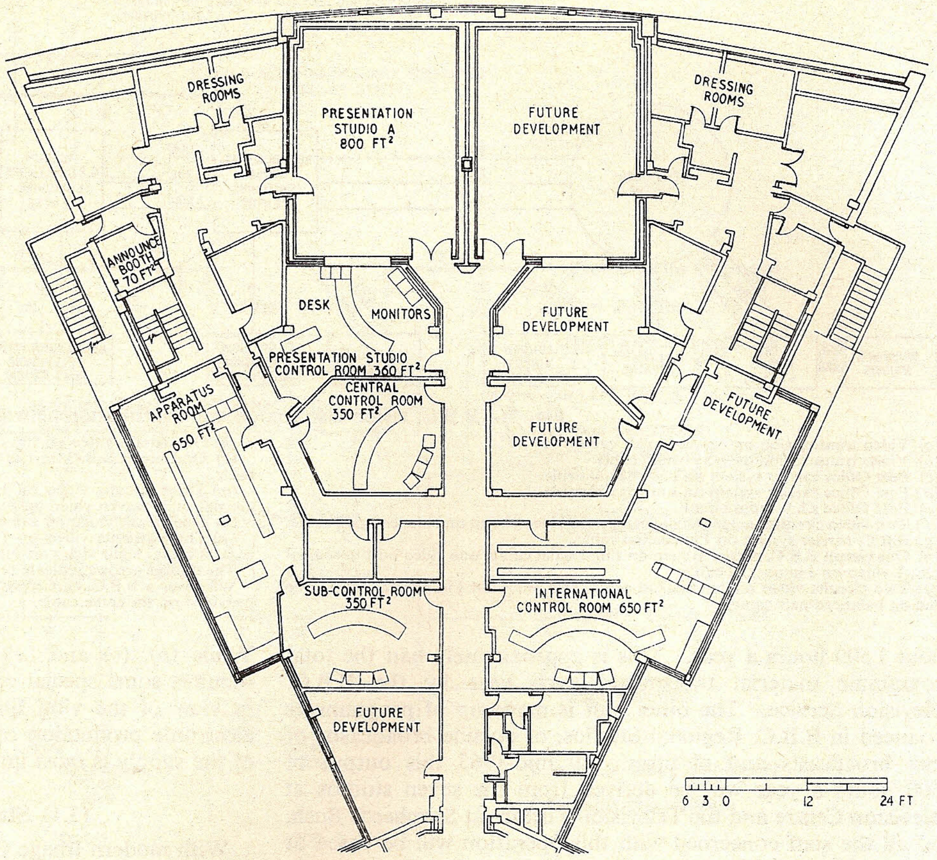

Fig. 5.—Presentation suites.

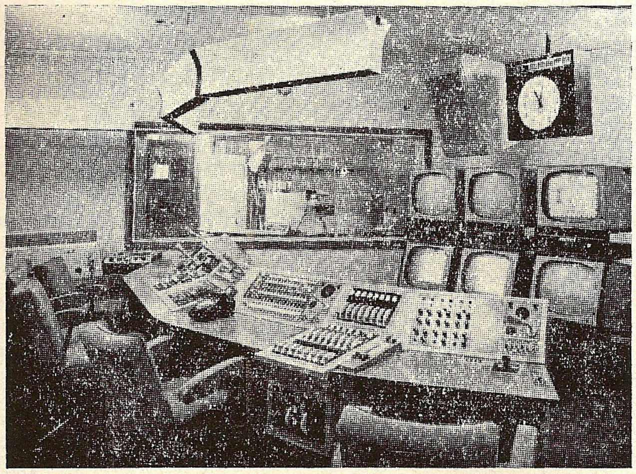

Fig. 6.—Presentation suite: control room and studio.

(2.13) **Other Programme-Origination Facilities**

The relationship of the Centre to the external programme-origination facilities in London and the regions and the distribution network is shown in the simplified network diagram, Fig. 7. The external studio facilities in London include three production studios at Lime Grove, a Television Theatre, a Television News Centre at Alexandra Palace and small News/Interview Studios at All Souls' Langham Place, St. Stephen's, Westminster, and London Airport. The three studios at Lime Grove are to be replaced by studios Nos. 1, 6 and 7 at Television Centre during 1964 and 1965. In addition, four mobile television broadcast units with ancillary radio-link equipments, based at Wembley, are available in London for covering national and sporting events and other outside broadcasts. Film production facilities are provided at the B.B.C. Television Film Studios at Ealing in West London. These include three large film stages, caption rooms, dubbing and review theatres and cutting rooms, and a large number of film vaults for the storage of films for archival purposes. An important part of the output from these studios is the production of film sequences for insertion into television studio productions.

(2.14) **Programme Output**

At present, the total electronic programme output from the seven production studios and Television Theatre in London is

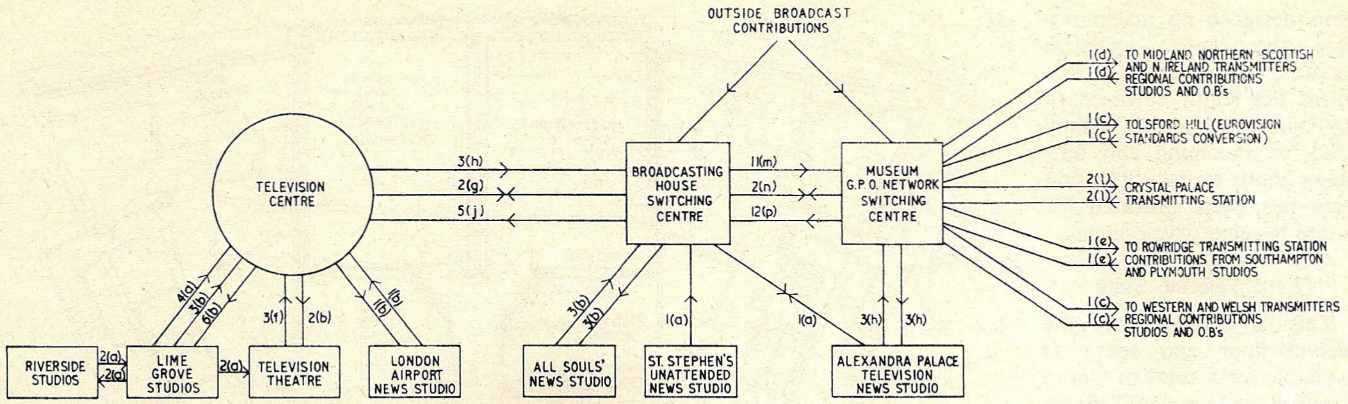

Fig. 7.—B.B.C. vision distribution and contribution network.

(*a*) Video transmission on balanced-pair cable
(*b*) Video transmission on $\frac{3}{8}$ in coaxial cable.
(*c*) Post Office carrier system on $\frac{3}{8}$ in coaxial cable.
(*d*) Post Office carrier system on 1 in coaxial cable.
(*e*) Post Office s.h.f. radio circuit.
(*f*) Two video circuits on $\frac{3}{8}$ in coaxial cable; one video circuit on balanced-pair cable.
(*g*) B.B.C. carrier system on 1 in coaxial cable.
(*h*) One circuit B.B.C. carrier system on 1 in coaxial cable; one video on 1 in coaxial cable; 1 video on $\frac{3}{8}$ in coaxial cable.
(*j*) Two circuits video on 1 in coaxial cable; two video on $\frac{3}{8}$ in coaxial cable; one video on balanced-pair cable.
(*k*) One circuit video on 1 in coaxial cable; two circuits video on $\frac{3}{8}$ in coaxial cable.
(*l*) One circuit B.B.C. carrier system on 1 in coaxial cable; one video on 1 in coaxial cable.
(*m*) Three circuits video on 1 in coaxial cable; one B.B.C. carrier system on 1 in coaxial cable; seven video on $\frac{3}{8}$ in coaxial cable.
(*n*) One circuit video on 1 in coaxial cable; one video on $\frac{3}{8}$ in coaxial cable.
(*p*) Three circuits video on 1 in coaxial cable; one B.B.C. carrier system on 1 in coaxial cable; eight video on $\frac{3}{8}$ in coaxial cable.
The double arrows indicate reversible circuits.
Wherever a B.B.C. carrier system is used on a 1 in coaxial cable, a video circuit is provided on the same cable.

about 1 500 hours a year. This is approximately half the total programme material transmitted each year by the B.B.C. Television Service. The other half is made up of programmes produced in B.B.C. Regional Studios, of outside broadcasts, of news broadcasts and of films. By mid-1965 this output of 1 500 hours a year will be derived from the seven studios at Television Centre and the Television Theatre at Shepherds Bush, and all the staff concerned with this operation will be based at the Centre.

(2.15) Staff

The total staff required to maintain the service, excluding news, outside broadcasts and film production studios, in London on a seven full-day per week basis, is 2 650. This figure can be roughly broken down as follows:

Direction and administration	160
Programme services:	
Programme production and planning	595
Artists' bookings	35
Scenery design and construction	300
Production and management (scenery handling, etc.)	275
Wardrobe and make-up	160
Engineering:	
Engineering headquarters staff	35
Studio electronic and mechanical maintenance	140
Central operations and maintenance	50
Studio technical operation	275
Telecine and telerecording	100
Studio electricians—operation and maintenance	100
Riggers	5
House engineering services (electrical and mechanical)	120
Central services	300

Of this total, rather less than half are normally based in offices.

(3) ELECTRICAL POWER ARRANGEMENTS, BUILDING CONSTRUCTION AND GENERAL SERVICES

The power facilities for such a Television Centre must provide for:

(*a*) The special requirements of production lighting for television studios.
(*b*) Supplies for television technical plant for studios and other technical areas.
(*c*) Supplies for ventilation plant.
(*d*) Supplies as normally required for a large office building, i.e. for lighting, catering, lifts, miscellaneous domestic services, etc.

While (*b*), (*c*) and (*d*) present no unusual requirements, (*a*) requires some special consideration as described below. Also, in view of the vital function of the Television Centre in the electronic production of programmes, the maximum reliability of the supply is most important.

(3.1) Studio Production Lighting

With modern Image Orthicon cameras, it has been found that the maximum lighting load for a studio for black-and-white operation represents approximately 25 W/ft^2. This is appreciably less than the figure which had been reached on some previous installations, the reduction arising from more efficient luminaires and from light control in the camera by remotely controlled iris adjustment.

On the basis of this figure the maximum loads required for the three types of studios for black-and-white operation became

	kW
Type I	300
Type II	200
Type III	90

These supplies are made available to the studios as single-phase a.c. for black-and-white operation. If any studio is subsequently converted to colour operation the short-duration load may be as much as three times the black-and-white figures, and in these conditions it will be necessary to operate from a 3-phase supply. The power supply arrangements are designed to facilitate this change.

It was decided to adopt a lighting voltage of 240 V a.c. instead of 110 V as used in previous installations, to keep down the size of cables and to come into line with the more general practice in this country and in Europe.

(3.2) Maximum Demand

Stage II of the project included two type II studios and two type III studios. To determine the probable maximum demand for these four studios taken together, a long series of readings was made of the actual demands of four production studios then in use (1957). From these it was found that the overall diversity factor for a number of studios with respect to the sum of their maximum estimated loads was usually well below 50%

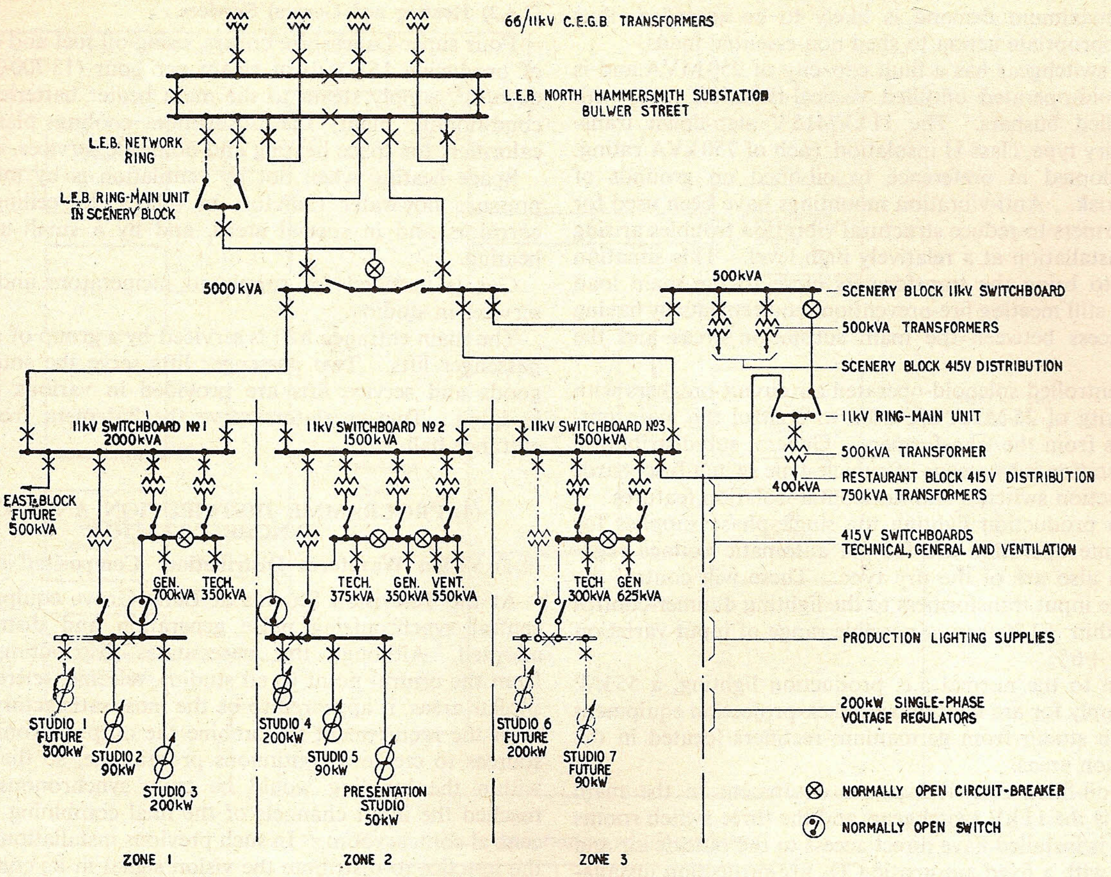

Fig. 8.—Power supply arrangements.

and only occasionally and for short periods reached 75%. This information was used in estimating the maximum demand for the premises as a whole and for estimating the total amount of refrigeration required for air conditioning in the studios.

The diversity applying to all other loads in the building was estimated from experience gained in previous premises. From these considerations it was estimated that when stage III is complete, with seven studios in regular use and with the telecine and telerecording areas fully equipped, the maximum demand for the whole premises on a black-and-white basis will be between 3 000 and 3 500 kVA. When the site is completed with the additional accommodation in the spur, this figure may rise to something between 4 000 and 5 000 kVA for an all black-and-white service. For the condition in which 50% of the studio output is in colour the total is likely to rise by a further 800–1 000 kVA, making a probable total demand of about 6 000 kVA.

(3.3) Detailed Power Supply Arrangements

Supplies to the site are taken at 11 kV from the London Electricity Board. In the interest of maximum security, the supplies are normally taken from two underground cable trunk feeders direct from the Electricity Board's 66 kV/11 kV bulk-supply substation approximately half a mile away. These two feeders, each of which is capable of supplying 5 000 kVA, are operated as a closed ring to supply three 11 kV substations situated around the periphery of the main studio block above the scenery runway. Balanced pilot feeder protection is provided on all the 11 kV cables forming the ring, including the two trunk feeders from the Electricity Board's substation. As each of these cables is capable of carrying the full load of the site, continuity of supply is assured at each of the main block sub-stations in the event of an 11 kV cable fault.

Fig. 8 is a simplified block schematic of the power supply arrangements. To permit the operation of the two 11 kV trunk feeders as a closed ring, it is necessary that both shall be fed from a single section of the Electricity Board's substation. To guard against a long-term failure of supply to the site should a fault cause simultaneous failure of both normal supplies, a third 11 kV supply is available. This emergency supply is taken from a portion of the Electricity Board's 11 kV network fed from another section of their substation. The load that can be taken from this supply will be dependent on the loading of the Board's network at the time, but it will normally be adequate to maintain full programme service at the site.

It was considered impracticable and unnecessary to provide a standby power supply on a sufficiently large scale to cover possible periods when all the incoming supplies might be interrupted. However, when the east block is equipped it will contain a 100 kVA Diesel-alternator set which will provide sufficient power for speech announcements and the operation of one telecine machine and sufficient equipment to enable a programme to be routed through the Television Centre, if necessary. All other forms of local programme origination in the Television Centre would be suspended if this condition arose. There are, in addition, emergency lighting batteries, which will maintain the lighting in stairways, corridors and similar areas.

The control of all the 11 kV switchgear on the site is from a remote control board situated in the central apparatus room area. A summation maximum-demand meter mounted on this board records the half-hourly maximum demand to the whole site. The meter incorporates a device to give warning if the estimated

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operational maximum demand is likely to be exceeded, thus instigating appropriate action to shed non-essential loads.

The 11 kV switchgear has a fault capacity of 250 MVA and is of the solenoid-operated oil-filled vertical-isolation type, with compound-filled busbars. The 11 kV/415 V step-down transformers are dry type, class H insulation, each of 750 kVA rating, and were adopted in preference to oil-filled on grounds of reduced fire risk. Anti-vibration mountings have been used for these transformers to reduce structural vibration troubles arising from their installation at a relatively high level. This situation was chosen to bring the transformers close to the main load centres while still meeting fire-prevention requirements by having no direct access between the main substation areas and the studio areas.

Remote-controlled solenoid-operated air circuit-breakers with a fault capacity of 25 MVA are used to control the main outgoing circuits from the transformers. General sub-distribution from the substation is by means of cubicle-type switch-fuseboards with rotary-action switches and horizontal-isolation features.

For studio production lighting the single-phase supplies for black-and-white operation are fed via automatic voltage regulators, which also are of the dry type. These will control the voltage on the input transformers to the lighting dimmer-control boards to within $\pm 1\%$ from a possible range of input variation of -12% to $+6\%$.

In addition to the normal a.c. production lighting, a 55 kW 110 V d.c. supply for arc lighting and back-projection equipment is fed to each studio from germanium rectifiers located in the main substation areas.

The only oil-filled electrical power equipment in the main studio block is the 11 kV switchgear, and the three switch rooms in which this is installed have direct access to the outside air and are provided with a fixed automatic CO_2 fire-protection installation giving remote warning in the fire duty officer's room.

The remaining main substation areas have a low fire risk and are provided with rate-of-temperature-rise detector warning systems.

The larger motors associated with the ventilating plant have been provided with individual power-factor correction capacitors.

Fluorescent lighting has been adopted universally for office and general areas, corridors, etc., and in most of the technical operating and plant areas.

(3.4) Building, Ventilation and General Services

(3.4.1) Construction.

The form of construction adopted is basically steel framework with reinforced-concrete foundations and floors, and brick panel walling. The foundations are designed to keep ground loading constant as far as possible. Variations do occur, and the main structural joints, which extend through the building and the foundations, enable some differential settlement to take place without damage. This also applies to the ground slab, which covers the whole area under the building—some 3½ acres.

The large mass of the main block consists of several structural subdivisions. These provide for physical separation of structural units of the same pattern and also for separation of units of different function, height and loading. The structural joints, besides allowing for differential settlement, are arranged to reduce the effects of thermal movement and shrinkage. The joints are also arranged so as to form suitable locations for dividing the building into fire cells, and in some cases to form barriers to the transmission of structurally borne sounds. The walls and floors of each of the fire cells are capable of resisting fire for four hours. Openings through the walls are fitted with double doors or shutters which close automatically in the event of fire.

(3.4.2) Heating and General Services.

Four super-Lancashire boilers, using oil fuel and each capable of producing 15 000 lb of steam per hour (13 700 000 Btu/h) at 60 lb/in^2, supply steam to the main heater batteries of the air-conditioning plant, the absorption cooling plant, and the calorifiers for space heating and domestic services, etc.

Space heating when not by ventilation is by means of low-pressure hot-water radiators in offices, by ceiling heating in corridors and in special areas, and by a small area of floor heating.

Gas is installed for supply to incinerators and production services in studios.

The main entrance hall is serviced by a group of four gearless passenger lifts. Two passenger lifts serve the south hall, and goods and service lifts are provided in various parts of the building. Two escalators serve the basement from the main entrance hall.

(4) PROGRAMME DISTRIBUTION AND SOURCE SYNCHRONIZATION

(4.1) Vision Waveform Distribution: Composite/Non-Composite

At the Television Studios at Lime Grove equipped in 1953, central synchronizing pulse generation and distribution was adopted. Although this necessitates distributing the pulses from the central point to all studios, telecine, telerecording and similar areas, it appeared to be the most satisfactory solution to meet the requirement to combine the outputs from the various sources to create a continuous programme, so that all sources within the building would be truly synchronous when they reached the input channels of the final combining mixer in the central control room. In such previous installations it had been the practice to distribute the vision signal in its composite form (i.e. the full waveform including the synchronizing signals) for all purposes. In the planning of the Centre the merits of composite and non-composite distribution were considered. It was initially decided to route all sources (telecine, etc.) in their non-composite form into the studio mixers and to provide cutting facilities only for asynchronous contributions. This system had the advantage of simplifying the design of the studio mixer, since no clamping, synchronizing signal removal and reinsertion would have been necessary as part of the mixing process.

Much later, with the introduction of video-tape recording, it became apparent that reproductions from video tape would in time become frequent sources of contributions to studios and that such reproductions would be, in effect, asynchronous. This so increased the proportion of asynchronous sources forming part of a studio programme that it was decided in those circumstances to abandon the scheme for non-composite working and to revert to composite distribution universally. Thus, the design of the studio mixer had to be adapted to enable it to deal with asynchronous sources; this gave a fade-to-black facility for all sources, remote or local. Further reference to mixer design is made in Section 6.3.2.

(4.2) General Routing and Switching Arrangements

The vision distribution system was planned to provide technical flexibility and ease of operation while retaining a relatively simple transmission chain. To achieve this the following techniques were developed: remotely controlled vision switching; and the use of a fixed gain distribution system. The remotely controlled vision switching (and the associated sound switching) serve to route the vision and sound signals within the premises. In this scheme the central apparatus room forms a focal point, and all circuits from sources and destinations terminate there and are available for interconnection. Thus the outputs from studios,

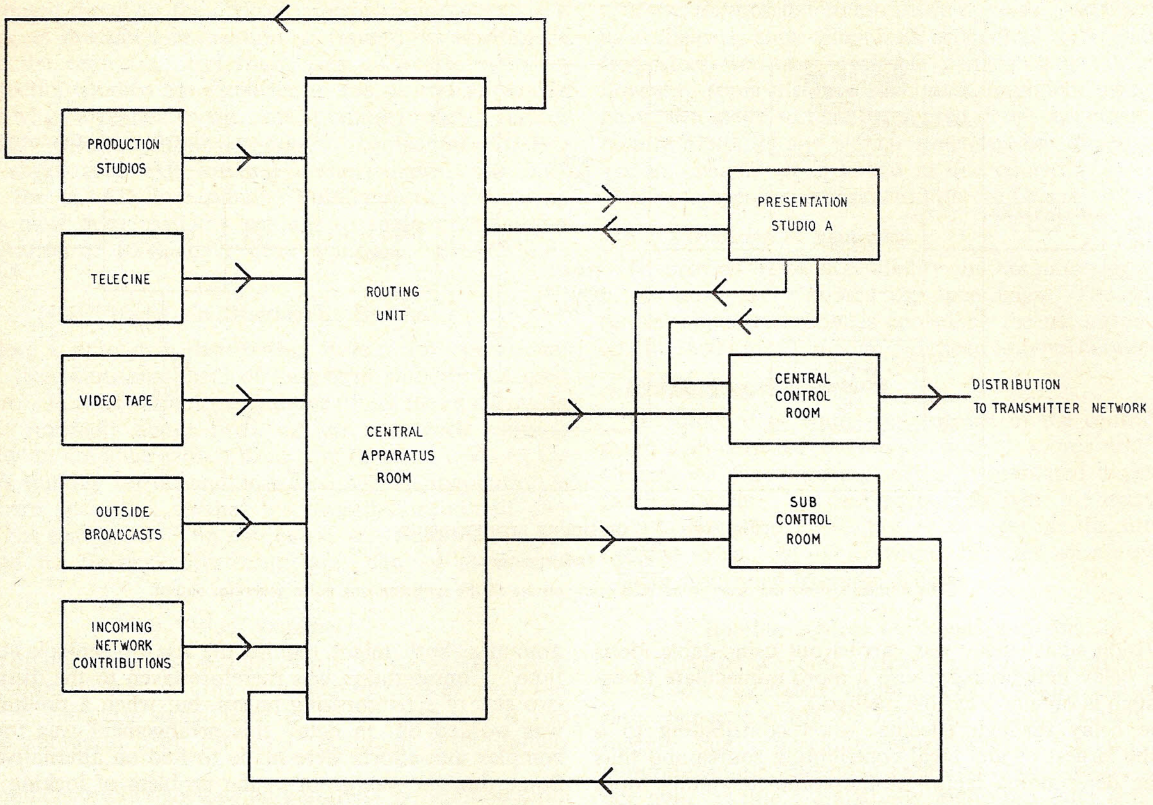

Fig. 9.—Basic programme routing system.

Sources		Destinations	
Telecine	12	Studio lines	36
Miscellaneous	7	Central control room }	2
External	14	Sub-control room 1 }	
Video tape	12	External and miscellaneous	32
Studio	7		
	52		70

from telecine and video-tape machines and from incoming outside broadcast and network circuits appear as sources, and circuits to the production studios (for contributions to a studio programme) and to the central control room mixer appear as destinations.

Fig. 9 shows the basic routing system. Each vision source and each destination is allocated a remotely controlled selector switch, and normally at a given time, only one source can be connected to any one destination. The routing is effected from an operating panel located in the main control desk in the central apparatus room. Display panels indicate the routing that has been established. The manner in which the switching of the sound, control and signalling circuits is related to the switching of the vision circuits is described in Section 4.7.

(4.2.1) **Switches.**

For the switching of the vision circuits a motorized type of rotary switch was selected after very comprehensive tests. Two types are used, one with 11 and the other with 23 outlets. The tests, which included life tests and measurements of resistance and capacitance, gave very satisfactory results. The capacitance, which is of the order of 0·5 pF, is considerably less than is normally obtained with relays used for a similar purpose. The contact resistance is less than 4 mΩ.

(4.2.2) **Vision Cable.**

To simplify equalization and timing problems a special multi-circuit coaxial cable, having 14 cables in one sheath, was developed and is used for runs from the central apparatus room to studios, telecine areas, etc. The cable is of high grade, has an impedance of 75 Ω ± 2% and a loss at 3 Mc/s of 0·45 dB per 100 ft.

(4.3) Vision Timing and Source Synchronization

It is necessary as part of programme requirements to mix and superimpose sources in the production studios and also in the central control room from a large number of sources both within and outside the Centre (Fig. 7). In order that this can be satisfactorily carried out, it is essential to meet these requirements:

(i) *Vision Timing.*—All signal sources must have a relative timing accuracy of not more than 50 ns at the various mixing points.

(ii) *Source Synchronization.*—External programme sources, e.g. outside broadcasts and regional studios, etc., must be synchronized with the controlling station. This is normally carried out using the method of genlock.[4]

(4.3.1) **Vision Timing.**

The vision timing arrangements (Fig. 10) are essentially very simple, all cable runs between the studios and central apparatus room being of identical length (500 ft), and the timing delays through all studios being made the same. To keep a timing error not greater than 50 ns at the various mixing points it was decided to use cable loops for vision delay and networks for

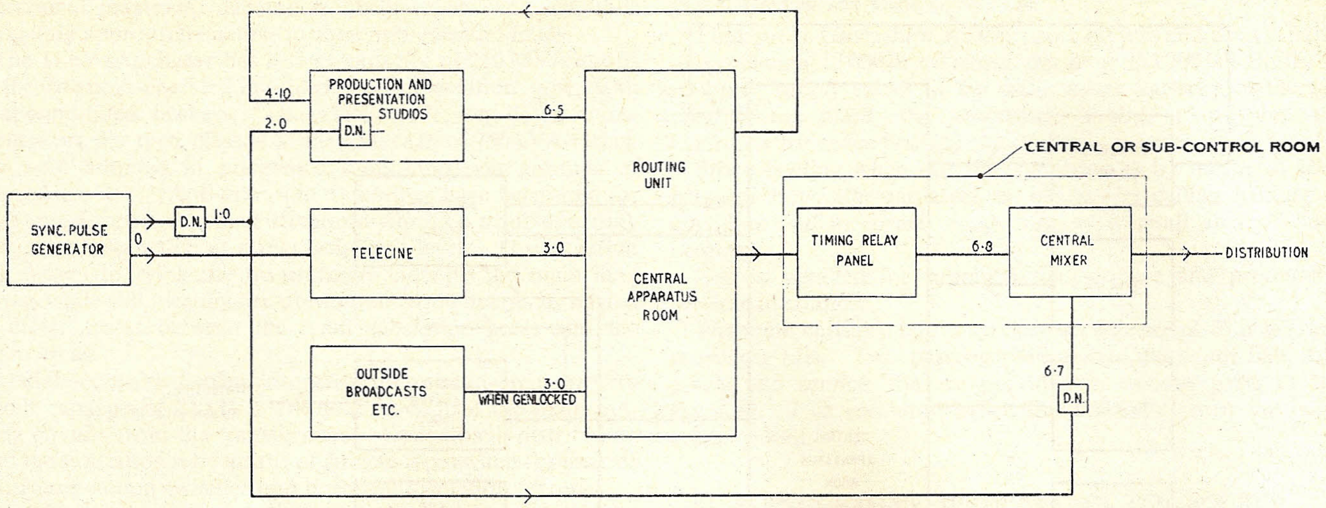

Fig. 10.—Vision timing arrangements.

D.N. Delay network.

The numerals show the delay in microseconds relative to the synchronizing pulse generator output.

pulses. (Vision signal delay was carried out using cable loops rather than delay networks, because a more immaculate transmission system is obtained by this method.)

The time delay through telecine, when contributing to a studio, is the largest of any local contributing source and thus becomes the determining factor of the complete timing loop. All telecine machine outputs arrive in the central apparatus room 3 μs late when compared with the synchronizing waveform from the pulse generators. Thus, external sources, when genlocked, are adjusted to be at the same point in time as telecine. These groups of signals are then routed via the switching system to studios and central control.

The pulse feeds to the studio cameras are delayed using lumped networks to ensure that the camera output is coincident in time with the contributions from telecine and genlocked remote sources.

When central control select a programme source, switching information is automatically passed to the timing relay panel. If the source is a telecine or remote, a cable loop together with equalization is inserted in the programme chain for the chosen input to the vision mixer. The delay in this loop (approximately 2 500 ft) is equivalent to that which would result if the source had been routed via a production studio.

In the event of other studios being built on the spur, the timing problem could be solved either by providing a separate synchronizing pulse generator in a sub-central apparatus room in the spur which could be slave-locked to the master synchronizing pulse generator in the central apparatus room, or by inserting loops of cable in the appropriate points of the programme chain. No decision has yet been made as to the method to be adopted.

(4.3.2) **Source Synchronization.**

The method of genlock is widely used where items originating externally to the Centre are required to be mixed with or superimposed on a programme being produced within the Centre. It takes the form of controlling the Centre pulse generator from the synchronizing pulses derived from the asynchronous source being used.

It was a requirement for the Television Centre that it should, in due course, be capable of producing two separate continuous television programmes. Since genlock is frequently used for one programme, it was apparent that, if there were to be two programmes, both might require the use of genlock at the same time. Consideration was therefore given to the distribution of two sets of synchronizing pulses, but when a preliminary plan was worked out in detail this arrangement was found to be complex and efforts were made to find an alternative solution. Some thought was given to the problem of locking all contributing sources to the Television Centre waveform generator. It appeared practicable to do this for permanent sources within the London area, but no satisfactory solution appeared feasible for distant sources.

Thus, no universal solution could be seen in terms of locking synchronizing pulse generators to each other. In the absence of such a solution it was considered that standards conversion equipment could be used as an additional means of deriving a synchronous signal from an incoming asynchronous signal.

It was decided, therefore, to plan on the following basis:

(*a*) To install one central synchronizing pulse generator in the Television Centre and to distribute its pulses to all internal sources (as already described).

(*b*) To provide genlock equipment so that the central generator could be genlocked to any one external source at a time.

(*c*) If, when genlock is already in use, it is required to accept another asynchronous source for mixing, etc., a synchronous signal should be derived from it by the use of standards conversion equipment.

This plan will still be effective if, at some later date, the television service signals are independent of the mains.

(4.4) Equalization of Vision Programme Circuits

The sources appearing in the central apparatus room for switching can be divided into two main groups: circuits from telecine, video-tape machines, outside broadcasts, etc.; and circuits from production studios. The signals from the first group are fed into the vision switching system, and it has been arranged that each source passes via 400 ft of coaxial cable (400 ft being the distance from the furthest internal source to the central apparatus room). If one of these sources is then routed to a studio it will traverse a further 500 ft *en route*. The object of making these path lengths the same is to ensure that all sources, when fed to a studio, traverse the same route (approximately 900 ft), and identical equalization is applied to them all.

When routed direct to the central control room mixer via a cable loop, as described in relation to timing, equalization is effected in the central control room area. Circuits returning from production studios are equalized in the central apparatus room, and when extended to the central control room a further small amount of equalization is added to compensate for this relatively short run. All internal circuits have been fully equalized for a 625-line signal. Pulse-and-bar measuring techniques have been used for setting up these circuits and pulse/bar ratios of 100% have been achieved on a 625-line 1T pulse.[5, 6]

(4.5) Fixed-Gain Distribution System

To achieve a unity-gain distribution system, for operational simplicity, fixed-gain amplifiers of long-term stability are used throughout. For the various programme routes the equalization required is normally about 13 dB or less, and each route is followed by an amplifier with a fixed gain of 15 dB. When the circuits are initially set up and equalized a little attenuation is added, where necessary, so that the overall link, circuit plus amplifier, has zero gain. This can be set very accurately at the outset, and no further adjustments are required in normal operation.

(4.6) Vision Amplifiers

A range of amplifiers has been developed for use in the routing and distribution system. At the outset careful consideration was given to the standard signal level to be adopted and it was decided to standardize on the level previously used, namely 1 V p–p.

The amplifiers are designed as plug-in units to facilitate rapid replacement, and to enable servicing and repairs to be carried out away from the main equipment racks. They have fixed gain and a high input impedance. Further, to limit the effect of failure of any one amplifier and to make for operational simplicity, each amplifier has its mains power supply incorporated in it.

The complexity of the overall routing makes it inevitable that in many cases several vision amplifiers are effectively in tandem between the picture source and the final output from the Television Centre. For this reason a very stringent specification of performance was adopted. It is not practicable, in this brief survey, to give the full specification for each type of amplifier, but the stringency of the specification may be judged by the requirement to achieve a K-factor*[5,6] rating of better than 1% for any main programme route with a vision bandwidth of 5 Mc/s.

The amplifiers can, in fact, handle satisfactorily a 405-line or a 625-line black-and-white signal or a colour signal of the N.T.S.C. type on either standard. The basis of the design of all the vision amplifiers is a 3-stage negative-feedback triple, the output being taken from the cathode of the last valve. The gain is determined wholly by two high-stability resistors, and careful control of the characteristics of the gain loop of the amplifiers has enabled the transmission performance over the whole working bandwidth to be set by the adjustment of one variable element. The types of amplifiers in use are:

(*a*) A vision distribution amplifier of unity gain; three outputs.
(*b*) A vision distribution amplifier of 3 dB gain; three outputs.
(*c*) A vision amplifier of 15 dB gain; one output.

All the above amplifiers deliver 1 V p–p into a 75 Ω load with an ample reserve of power.

(*d*) A vision amplifier of 12 dB gain delivering 4 V p–p into a 75Ω load. This is used for feeding programme to an outgoing ⅜ in coaxial-cable circuit.
(*e*) A pulse distribution amplifier of unity gain; four outputs.

It was not possible to introduce transistor amplifiers generally, as at the early stage when bulk orders had to be placed, suitable transistors were not available commercially. More recently, however, some vision distribution amplifiers using transistors have been made and are being used in the equipment for feeding picture monitors and similar functions not directly in the programme chain. It is hoped in due course to introduce more transistor-operated equipment into the Centre.

(4.6.1) Ventilation of Equipment.

To provide quick accessibility the amplifiers and other electronic units are mounted on open bays. The whole of the central apparatus room is cooled by the natural circulation of conditioned air fed in from overhead louvres between the racks.

(4.6.2) Running of Cables.

The amount of equipment located in the central apparatus room area and the interconnection of source and destination circuits via the switching system necessitated a very extensive cabling system. To deal adequately with the mass of cabling and to have the possibility of changes in the future, it was decided to run the cables within the area on an overhead-tray system suspended from the ceiling.

(4.7) Routing System for Sound and Ancillary Circuits

A separate switching system is provided for the routing of the sound and associated circuits. This provides source-to-destination connections for the following circuits: sound programme output; cue programme feed; talkback; loudspeaker intercommunication; telephone communication; 'sound-on' facilities; cue light facilities; availability indication; and lamp indication of routing. These facilities are available for all the Television Centre and Lime Grove sources.

All the above connections are available on jack-fields in the central apparatus room for test and emergency interconnection purposes. Motor-uniselector switches with 52 outlets and 16 levels are used, there being one switch per destination, directly controlled by the corresponding switches in the vision routing system. This method of control is very simple and enables direct indication of the source selected to be made available to the destination, even though the vision signal may have been routed via, say, standards conversion equipment or a combining unit before reaching its destination.

(4.8) Telecine Ancillary Switching System

Remote control of telecine machines can be exercised from production studio control rooms and necessitates a minimum of six source-to-destination connections, which are provided by an additional motor-uniselector switch of the same type for each telecine source. These switches are controlled by means of a connection through the basic switching system just as the basic switches are controlled by the vision switching system.

(4.9) Remote-Control Facilities between Television Centre and Television Switching Centre

The main simultaneous-broadcast network circuits throughout the country terminate in the Television Switching Centre at Broadcasting House in Central London, and a limited number of tie lines is available to extend these circuits as required to the Television Centre (Fig. 7). Some types of programme involve contributions from different Regional Centres following each other in quick succession, and to avoid the need for the manual switching of these tie lines, rotary switches of the type already described are fitted in the Television Switching Centre and are operated from the central desk in the central apparatus room at Television Centre by remote control.

(5) CAMERA TUBES, CHANNELS, CAMERA OPERATION, ETC.

(5.1) Choice of Camera Tube

This was most thoroughly examined, as shown below.

(5.1.1) Technical Performance.

A series of tests[7] was conducted to determine the following properties of the various camera tubes available:

Signal/noise (both noise/power and noise/frequency spectrum).
Sensitivity.
Resolution.
Transfer characteristic.
Contrast range.
Freedom from lag and associated effects such as memory.
Background.
Freedom from spurious effects.
Stability (i.e. constancy of black level, sensitivity, etc.).
Colour response.

All the tubes considered in the tests were low-velocity tubes (see Section 5.1.2) and included:

3 in Image Orthicon (for various target-mesh spacings).
4½ in Image Orthicon (also for various target-mesh spacings).
C.P.S. Emitron (Orthicon).
Vidicon.

The tests showed that the Vidicon was unsuitable for general production studio use owing to its sensitivity/lag characteristics and it was therefore discarded. Of the other tubes, the 4½ in Image Orthicon was shown to be definitely superior to the 3 in Image Orthicon for resolution, grey scale and signal/noise ratio, whilst the Image Orthicons were both superior to the C.P.S. Emitron in sensitivity and in contrast-handling capacity.

The final result of the tests was that the medium-target-capacity 4½ in Image Orthicon had a lead over the other tubes, but the choice was not finally made until all the factors enumerated in the following paragraphs had also been very carefully considered.

(5.1.2) Ease of Operation.

For this, a tube with a low-velocity scanning beam was imperative. Of the low-velocity tubes available, the simplest to operate were the simplest tubes, namely the C.P.S. Emitron and the Vidicon. A study in 1957 of the 4½ in Image Orthicon showed, however, that its operation was capable of considerable simplification, and thus in this respect there was inherently little to choose between the various types.

(5.1.3) Ease of Maintenance.

Again, the simpler types of camera tube scored over those that were more complex, and the C.P.S. Emitron and the Vidicon showed advantages. Average tube life was included under this heading.

(5.1.4) Availability.

Image Orthicon tubes and Vidicons were available from more than one source in the United Kingdom.

(5.1.5) Tube Costs.

Both the costs at that time and the trends in cost predicted by the tube manufacturers were considered. The Vidicon was by far the best tube in this respect.

(5.1.6) Cost of Lighting.

Using the sensitivity figure obtained from tests in the research department, together with summarized operational experience, an estimate was made of the capital and running costs of the lighting of the first four studios to be equipped. In this assessment, the Image Orthicon tubes were definitely superior.

(5.1.7) Optical Considerations.

An important factor in the choice of a camera tube is the size of the optical image required on its photocathode. The depth of field observed by a camera is a function, amongst other things, of relative aperture and is inversely proportional to the linear dimension of the image. A camera with a photocathode diagonal of 2·16 in (C.P.S. Emitron) has the same depth of field at a relative aperture of f8 as a camera with a 1·6 in diagonal (Image Orthicon) at f5·8 or a camera with 0·63 in diagonal (Vidicon) at f2·32. Thus tubes with very large photocathodes are at a disadvantage through the necessity to use their lenses at comparatively large relative aperture numbers, thus effectively reducing the camera sensitivity, whilst those with very small photocathodes require lenses operating at very small relative aperture numbers, which are more difficult to produce. Further, satisfactory designs of zoom lenses are available only for image sizes of diagonal 0·54 in (13·5 mm), 0·63 in (16 mm), 1·12–1·26 in (28–31·5 mm) and 1·6 in.

The choice therefore tends towards tubes with photocathode diagonals in the range 0·54–1·6 in, with a preference for those of 1 in or more. Thus, of the camera tubes under consideration—Vidicon 0·63 in, Image Orthicon 1·6 in and C.P.S. Emitron 2·16 in—the Image Orthicon is the most suitable.

(5.1.8) Summary of Points on Camera Tube Selection.

Consideration of the foregoing shows that the 4½ in Image Orthicon must be the choice, since it is the only camera tube that either satisfies or goes a reasonable way towards satisfying all the criteria. The B.B.C. was in fact the first broadcasting authority to order camera channels designed for use with 4½ in Image Orthicon tubes. In recent years, this tube is being increasingly used by other broadcasting organizations.

(5.1.9) Lighting Power Required.

When the decision was made to standardize on the 4½ in Image Orthicon, the Corporation had already considerable operating experience with these tubes. From this it was known that, to obtain a satisfactory depth of field for normal working, the cameras should operate with a lens aperture not less than f5·6. Making allowance for the effective increase in sensitivity to be derived from the use of remote iris control (Section 5.2.4), this would require a normal lighting intensity on the sets of 50 lm/ft^2. To obtain this intensity with the more efficient luminaires to be used (Section 6.4), the lighting power required in a studio averages 25 W per square foot of total floor area. As already noted, this determined the total lighting power.

(5.2) Specification of Camera Channel

(5.2.1) Stability.

To obtain ease of operation, it was desirable that the channel should be so stable that, once the controls had been set up, adjustment in operation could be limited to light input (iris) control, lift and selection of contrast law.

With a high target-mesh potential (about 3 V) and exposure at about ½ stop over the 'knee', redistribution is negligible and the black level is stable. If the exposure is increased, redistribution of the electrons causes the black level of the picture to be dependent on scene content, a most undesirable condition.

For operation in the proposed manner, it was essential that all the tubes in use should have a similar performance within close limits. To ensure this, a considerable amount of work has been done in recent years by the Corporation in association with manufacturers to devise a satisfactory test specification.

The foregoing requirements having been established, a series of operational tests showed that it was quite possible for one man to operate a number of camera channels, and a method of operation was developed which is more fully described in Section 6.

(5.2.2) **Camera Channel Controls.**

To achieve the system of operation just described, it was required that all the controls used for setting up or for operation should be passive elements suitable for remote operation. A system was designed in which the controls fall basically into two groups:

(*a*) All the controls required for setting up the camera were contained on a panel in the vision apparatus room (see Section 6). These are checked daily and normally are not touched during operation.

(*b*) The controls required for operation were mounted on panels in the vision control room at a console position adjacent to the lighting supervisor (see Section 6).

(5.2.3) **Contrast Law Correction.**

To obtain a satisfactory picture from a tube exposed as suggested, contrast correction is necessary.[8] To achieve this without introducing any controls requiring continuous operation, the operator has been given the choice between a selected number of overall transfer characteristics which have been previously adjusted to suit the circumstances.

(5.2.4) **The Camera.**

Some of the special features of the camera are as follows:

Servo-Control of Lens Iris.—If light control is achieved by the use of variable neutral density filters, it is necessary to pre-set the lens iris to a value such that in the darkest scene there is still some density in hand to allow for operational adjustments during transmission. The light loss from this cause is generally at least one stop, which means that for the same depth of field an increase of lighting intensity of at least 2 : 1 is required, and this represents a considerable increase in the cost for both power and ventilating capacity. It was therefore decided to adopt the method of remote control of the iris as the means of light control; this gives no inherent loss and automatically gives the maximum depth of field for a given lighting intensity.

Slow-Motion Control of Focus.—A capstan control, situated towards the rear of the right-hand side of the camera body, and needing two complete turns to cover the whole range, was adopted.

(5.3) **Technical Clauses of Specification**

In drafting the technical clauses, an attempt was made to prescribe the tolerance limits in terms related to the actual effect on the picture, whereas in previous practice the limits had frequently been defined in terms of traditional methods of measurement. Some of the principal clauses are outlined below.

(5.3.1) **Random Fluctuation Noise.**

One of the most important features of any television picture is noise,[9] particularly the peak signal/noise power or peak signal/r.m.s. noise voltage, and the distribution of noise energy over the frequency spectrum as shown by the signal/noise curve. In assessing the importance of noise, the distribution is weighted because noise per unit bandwidth is less important at the upper end of the frequency spectrum than at the lower. Nevertheless, for the purpose of specification, the severe limits required for lower-frequency noise were applied to upper-frequency noise, to safeguard against the translation of noise in the frequency spectrum by non-linear effects.

(5.3.2) **Resolution (Horizontal).**

The resolution expected of the camera tube is described, in order that the design of the deflection and focusing yoke may be

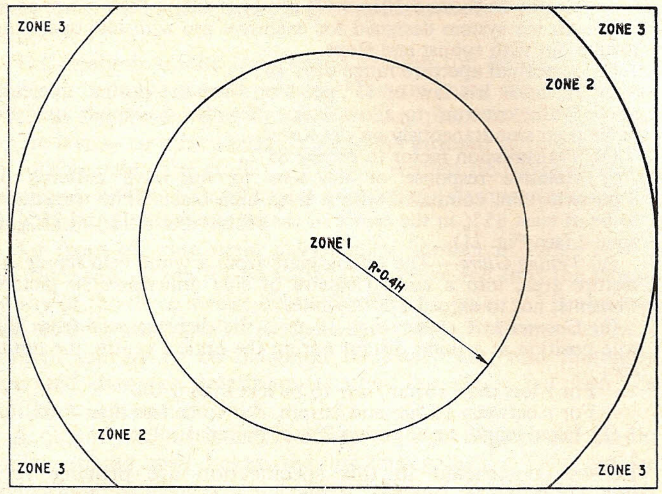

Fig. 11.—Division of picture into zones.

determined. The picture is divided into zones of importance and the limits are related to the zones (Fig. 11). A test pattern with bars of a sinusoidal transmission characteristic is used for the measurement. A suitable test chart (B.B.C. No. 51) was developed for this purpose and has been fully described elsewhere.[10]

(5.3.3) **Geometry and Scan Linearity.**

The limits applied here are the derivative of the positional error. Thus, if a positional error h accumulates in a distance r, the parameter h/r is a difference function that tends towards the true derivative as h and r tend to zero. It is specified that for values of r equivalent to or greater than 25 lines (i.e. 25/377 times picture height) h/r shall not exceed 0·02, but for smaller values of r a progressively increasing value of h/r is permitted.

The virtue of this method of specification lies in the fact that it covers positional errors in all directions, including those such as 'line ragging' that lie at right angles to the direction of measurement. In addition, a limit is placed on signal variation caused by changes in scanning velocity, and, most important of all, the parameter specified also appears to be one very closely related to the subjective disturbance caused by positional errors. Acceptance of equipment using this method of measurement has also been simple, straightforward and unambiguous.

(5.3.4) **Frequency and Phase Characteristics.**

As the relation between amplitude and phase frequency characteristics cannot be readily related to subjective appreciation, the sine-squared pulse-and-bar method of testing, which gives a realistic assessment, was adopted. A series of tests was conducted and it was found that amplifiers for camera equipment could be tested very effectively and quickly by this method, but that much tighter limits would be required than those used for long-line testing.

The specification eventually asked for an undistorted 2T-pulse and allowed limits of distortion for the 1T-pulse that would not appreciably add to those already imposed by the inclusion of a bandwidth filter in the channel.

(5.3.5) **Specification of Lenses.**

The mechanical and optical properties of lenses for use with 4½ in Image Orthicons (photocathode diagonal, 1·6 in) were covered by a separate specification,[11] thus ensuring freedom of choice of lenses, irrespective of the make of camera equipment. Some interesting requirements from the specification are:

(*a*) Ability to focus a 10 in × 7½ in object filling the picture area.

(*b*) An iris system designed for extensive use with low operating torque but with robust end stops.

(*c*) A normal aperture range of *f*4 to *f*16.

(*d*) A linear iris law of 13° per stop over the normal aperture range, with 'overrun' to allow lenses of wider maximum aperture to be used simultaneously on the turret.

(*e*) Transmission factor to exceed 85%.

(*f*) Relative response of the lens to sine-wave patterns of 8 patterns/mm, compared with a large-area black-white transition, to be at least 85% in the centre of the picture (zone 1) and 75% in zone 2 (see Fig. 11).

(*g*) *Veiling Glare.*—The veiling glare from a white field filling the picture area, into a central square of side dimension 30 picture elements, not to exceed 1% of white.

(*h*) *Geometrical Distortion.*—If dr is the displacement from the true position at a point distant r from the optical centre, the limits are:

For r less than 16 mm, dr/r to be less than 0·01.
For r between 16 mm and 20 mm, dr/r to be less than 0·05.

(*i*) Focal length to be within 2% of nominal value.

Lenses constructed to this specification are proving very satisfactory. The most commonly used lenses are those with focal lengths of 2, 3, 5 and 8 in (giving horizontal angles of 35°, 24°, 14° and 9°); focal lengths of 12 in (6°) and 1½ in (46°) are occasionally used.

In addition to fixed-focus lenses, a limited number of zoom lenses are in use, the usual complement being two per studio. The technical performance of these particular zoom lenses is extremely good.

(5.4) Presentation Studio Cameras

In the presentation studio the operating conditions differ in many ways from those in production studios. The live programme material is of a very simple nature, mainly announcements, etc., interspersed with considerable material from captions and film. Thus, there is no really rapid movement and the cameras are focused on the announcer for considerable periods. In these circumstances, a Vidicon-type camera is quite suitable, and in addition to its other merits, has the advantage of freedom from sticking. Initially, the Vidicon cameras are being manually operated, but it may later be decided to adapt them for a considerable degree of remote control (of focus, zoom, pan and tilt).

To produce satisfactory results with these cameras, the production lighting level is about four times that in the production studios using Image Orthicon cameras, but as the area of the studio is small and the studio is in use for relatively short periods, this is not a serious matter.

(6) STUDIOS, CONSTRUCTION, EQUIPMENT AND OPERATION

(6.1) Construction

The studio dimensions are made to meet the requirements for different types of television productions in the expectation that in general each studio will be used for a particular type of production. Experience has shown that a narrow rectangular studio is restrictive and that a more nearly square shape is better suited to the free movement of mobile equipment, such as camera dollies, microphone booms, etc., and ensures that each studio in itself is as adaptable as possible to programme needs. The height of the studio must be such as to provide working room for high- and low-angle camera shots and for flying of scenery, to take into account the acoustic requirements, and to give reasonable acoustic conditions.

The studios are independently built from foundations to roof to prevent structure-borne noises from reaching them. Airborne noise from trains on the nearby viaduct and from aircraft is kept out by the provision of massive walls, doors and roofs. The walls, 2 ft 3 in thick, have reinforced-concrete beams and columns, with brick panels constructed so as to form ducts for ventilation and other services. The roofs are of reinforced concrete surmounted by 6 in aerated screed, surfaced with asbestos tiles.

The concrete roofs are carried on welded-steel trusses, which also support a high-level system of walkways and the grids for lighting and scenery. Allowance is made for the considerable individual loads which occur during the setting of various productions. The trusses are fire protected by being covered with sprayed-on asbestos fibre.

The grid, supported by the roof trusses, mounts the electrically operated lighting hoists, and the lighting gallery which runs around all studios is itself supported along its outer edge from the main roof trusses.

The roof trusses also support seven rolled-steel joists provided for the suspension of scenery and running the length of the studio. Further scenery suspension is provided from the overhead grid by a number of electrically operated hoists.

The studio floor is of reinforced concrete designed to support a load of 220 lb/ft^2, including a knife-edge load of 1300 lb per linear foot. Bolt holes for staywires, etc., are embedded 10 ft apart in each direction. The floor finish, of heavy linoleum on asphalt, has been laid to a fine tolerance, to provide a flat surface for fast-moving camera dollies; the permitted error is less than $\frac{1}{32}$ in over a length of 10 ft.

General service points recessed into the acoustic treatment are provided around the studio, each containing gas and water supplies and drainage. A centrally situated point on each of the studio walls provides drinking water. Each studio is provided with a hot-water supply, and compressed air or steam can be made available to fixed points as required. Further fixings for staywires, etc., are provided on each of the long walls of the studio.

(6.1.1) Acoustics.

Specialized acoustic treatment is provided in the studios and their associated control suites, reverberation times and types of finish being dictated by the operational purpose of each area.

Studios 2 and 5 originate talks, interviews, small music items, etc., and their reverberation time must be a compromise taking account of both speech and music. Light entertainment programmes from studio 4 contain roughly equal amounts of voice and music from comparatively large orchestras for which perceptible reverberation is desirable. Studio 3 is used mainly for drama productions, for which a relatively 'dead' studio is essential.

An analysis of the characteristics of earlier B.B.C. television studios was used as a basis for deciding the reverberation times shown in the Table in Section 2.5. The treatment provided is designed to produce a durable and flush fitting surface on the ceiling and all walls.

Basically, two types of treatment are used:

(i) Membrane absorbers, consisting of 6 in deep boxes with a hardboard/roofing-felt membrane on the face side and the whole covered with rockwool.

(ii) Wide-band absorbers consisting of Therblock rockwool covering a 6½ in deep partitioned air space.

The membrane absorber has a resonant frequency of about 90 c/s. As it is covered with rockwool it also absorbs well at middle and high frequencies, but there is a dip in the absorption curve between 100 and 300 c/s. However, the wide-band absorber behaves particularly well between 100 and 300 c/s and also at middle and high frequencies. Thus, a judicious combination of both types provides a fairly evenly balanced absorption

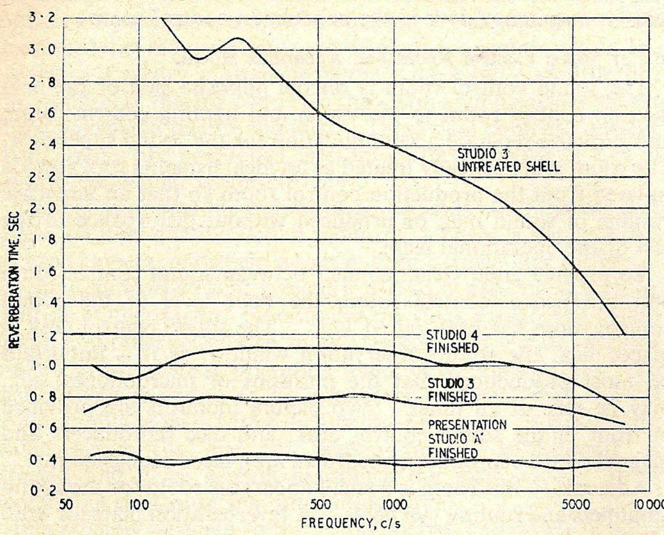

Fig. 12.—Studio reverberation times.

curve, as is shown in the results for studio 3 in Fig. 12. Controllable artificial reverberation is also available if required.

Production control rooms have a low reverberation time, and the adjacent sound control rooms a certain amount of 'liveness' to provide for high-quality monitoring. Control room wall coverings consist of 16% slotted steel sheet. The areas are carpeted throughout.

(6.1.2) Studio Ventilation.

The general arrangement of the air-conditioning plant is shown in Fig. 13. Each studio and associated control suite is air conditioned, and the associated plant is designed to deal with a continuous lighting load of up to 300 kW in the large studio, while higher lighting loads—which may be encountered for short periods in colour television—will cause a few degrees rise above the normal operating temperature on the studio floor of about 73° F.

The fresh-air intake is arranged around the perimeter of the building over the scenery runway, the air being drawn through ducts in the structure to the conditioning plant in the basement, where it may be mixed with a controlled amount of recirculation air drawn from the studio. The air is then delivered through felt filters, cooler, battery heater and control dampers to supply a ring main under the studio.

Air from the ring main passes up a number of risers within the thickness of the studio walls and can be fed into the studio at any of the three levels: below the lighting gallery, 7 ft above it and at near roof level. Electrically operated volume dampers control the air to be delivered by each riser, and manually operated dampers determine whether the air is fed into the studio at low or high level.

A quantity of air is extracted through gratings in the studio walls situated well below the lighting gallery. This can be recirculated as above, or may be discharged to the atmosphere. The remainder of the air, approximately 50% of the total, rises to the roof of the studio, where it is extracted through high-level ducting and discharged to the atmosphere.

The temperature and volume of air are balanced automatically. When a temperature of 70° F is reached, the chilled-water battery coils come into operation. The chilled water is supplied from an absorption-type refrigeration plant, in which lithium bromide is used as the absorbent. Waste heat is dissipated through induced-draught condenser water-coolers on the roof.

Considerable thought was given to the means of dealing with the varying loads and distribution requirements imposed on the air-conditioning plant by changing studio operations. To provide maximum flexibility the air distribution in each studio can be set up from a damper control panel situated on the lighting gallery, and the supply of chilled water to various plants can be controlled from the house engineering control room in the basement. Also, in extreme cases, flexible trunking can be used to feed air to any point in the studio as required.

The air conditioning installation of a type II studio (8 000 ft²)

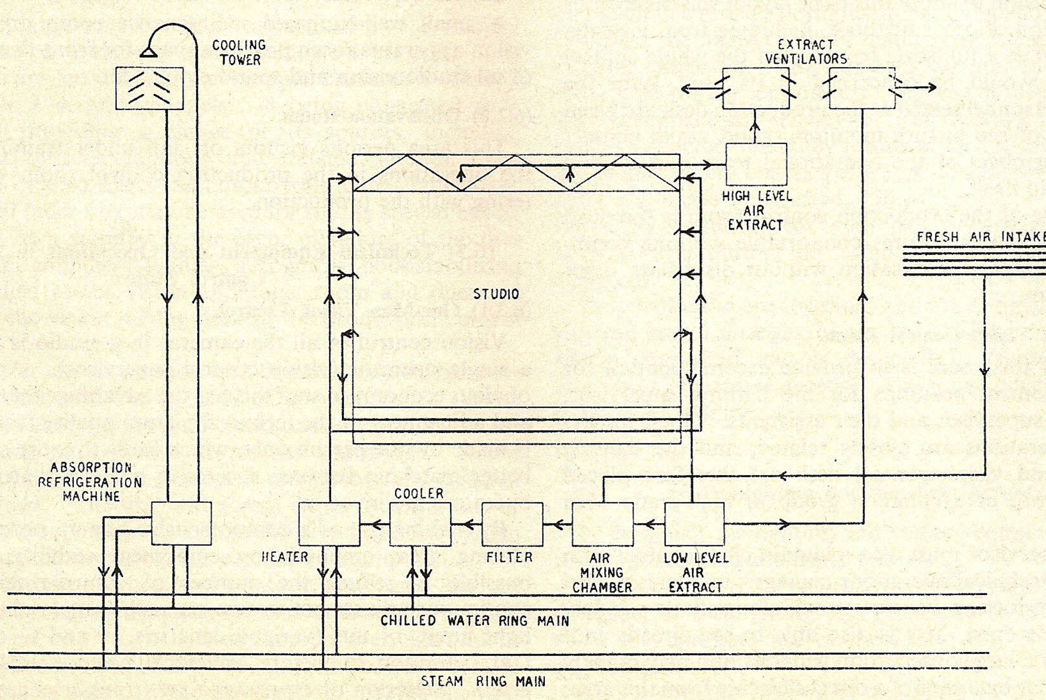

Fig. 13.—Studio air-conditioning system.

is capable of maintaining the following conditions within 8 ft of studio floor level:

(*a*) An average temperature of 73° F and a relative humidity not in excess of 55% under conditions of maximum internal loading (300 kW and 400 persons) and maximum outside temperature (87° F, dry bulb; 70° F, wet bulb).

(*b*) An average temperature of 65° F under minimum outside weather conditions (30° F, saturated).

(*c*) Temperature of between 65° and 68° F under normal external conditions, only rising to 73° F under conditions of maximum internal loading noted in (*a*) above.

The average temperature in a studio at any time is indicated by the temperature of the air in the suction side of its low-level extract fan. Under normal operating conditions air is circulated at the rate of 29 000 ft^3/min, which represents approximately five air changes per hour in the studio. The total electrical power used for air conditioning a type II studio is 31·5 kW, plus 152 kW required for the absorption refrigerator unit, which can supply cooling for three studios.

(6.2) Equipment and Operation

(6.2.1) Production Control Room.

This room, placed centrally in the suite, contains the production desk providing operational positions for the producer, his secretary, the technical operations manager and the vision mixer. The use of a curved desk improves the visual contact between the key operational staff, who sit at its convex edge. Seating space is available behind the desk for set designer, make-up and costume supervisors, and other personnel concerned with the production.

Placed centrally in front of the desk is a bank of nine 21 in picture monitors, which display all contributory picture sources involved in the production and the final 'transmission' picture output from the studio. An operational position is also provided for the inlay and transparency equipment used for special effects and titling purposes.

It will be seen (Fig. 3) that the production desk is placed sideways to the studio observation window and diagonally inclined to face it. The decision to adopt this basic layout was taken after careful consideration of other methods, including front viewing, and after appraisal of a full-scale mock-up of the whole control suite by all who would be concerned in its use. With the adopted layout, personnel seated at the production desk are given an excellent view of the picture monitors, good visual contact with other key members of the operational team and a good view into the studio itself.

A special feature of the production control room is the dead acoustic treatment, which ensures comfortable working conditions and permits local conversation without disturbing other sections of the team.

6.2.2) Lighting and Vision Control Room.

The function of this room is to provide accommodation for the operational control positions for the lighting supervisor, the vision control supervisor and their assistants. Their important technical operations are closely related, and the lighting control console and vision control desk are therefore placed side by side in front of a common group of high-grade 14 in picture monitors.

The lighting supervisor must also maintain close contact with the producer and technical operations manager, and he is placed nearest to the production control room alongside a window which he may slide open. He is also able to see directly into the studio through a large observation window, and may quickly reach the studio floor by means of a direct staircase from this area.

The transparency projector equipment is installed in this room but is controlled together with the inlay equipment from the inlay transparency desk in the production control room.

(6.2.3) Sound Control Room and Apparatus Room.

The sound control room is on the opposite side of the production control room to the vision and lighting control room, and provides separate accommodation for the sound supervisor. The room is acoustically treated as an ideal listening room and is isolated from the production control room so that an adequate volume of sound may be produced without disturbance to the rest of the operational team.

To provide good visual contact between sound control room and production control room, the floor level of the sound control room has been raised 12 in. The sound control desk is placed near the studio observation window, as it is important on most productions that the positions of microphones, etc., may be seen at all times. Two picture monitors are provided in front of the sound control desk, and disc reproducers and magnetic-tape reproducers/recorders are placed alongside it.

Adjacent to this room is a small apparatus room for the sound amplifiers and routing jackfields. A reverberation plate for echo effects is also installed in this room.

(6.2.4) Vision Apparatus Room.

The bay-mounted vision equipment, including the camera control units, vision mixing equipment and distribution and switching equipment, power units, etc., associated with the routing of pictures throughout the studio, is housed in the vision apparatus room behind the control rooms and opening directly off the lighting and vision control room. A desk is provided in this room for the testing and precise line-up of cameras and other vision equipment before rehearsal and transmission by the duty maintenance engineer. A mimic power-control panel is also installed in this room from which basic power supplies for the studio lighting, technical and ventilation plants may be remotely switched. The location of this apparatus in a separate room facilitates maintenance and adjustment work without interference with the production staff.

(6.2.5) Advance Maintenance Room.

A small well-equipped maintenance room opening off the vision apparatus room provides space for front-line maintenance of all studio vision and sound equipment.

(6.2.6) Observation Room.

This area permits visitors or staff under training to observe the operations in the production control room without interfering with the production.

(6.3) Technical Equipment and Operations in the Studio Control Suite

(6.3.1) One-Man Vision Control.

Vision control of all the cameras in a studio is performed by a single operator (vision control supervisor). Apart from the obvious economy in staff this has the advantage that the judgment and adjustment of the technical picture quality from all cameras is made by one person only, which leads to more consistent and better matching between successive pictures than when several operators are involved.

By making use of a comprehensive line-up procedure and by placing great emphasis on equipment stability, it has been possible to reduce the number of controls requiring semi-continuous adjustment to two on each camera channel, namely light input, or IRIS (variable lens iris, + and − one stop) and LIFT (variation of picture waveform position relative to black level). Selection of CONTRAST LAW (transfer characteristic) and adjustment of GAIN are also occasionally necessary, and controls are provided. For operational convenience the iris and lift controls of each camera are combined in one device such that a quadrant-type movement to and from the operator alters the iris whilst a rotary movement of the same knob alters the lift. The position of this iris control is shown on an indicator adjacent to the associated picture monitor. These dual controls, one for each camera, are positioned in front of the operator in a convenient rectangular pattern (Fig. 4).

The operator sees the output of all cameras continuously displayed on high-quality picture monitors. There is one monitor for each camera, and their layout pattern corresponds to that of the dual controls so that a picture is readily associated with its control. Other picture monitors in the stack display the studio output and other selected pictures. Beside each picture monitor is a waveform display providing quantitative information. To enable these monitors to be accurately matched, they can all be fed simultaneously with a picture line-up signal. An assistant, seated beside the operator, makes various adjustments as directed and gives general assistance but exercises no direct operational control of the transmitted signal.

Immediately adjacent to the vision control desk is the lighting console, the operating point for the lighting supervisor and his assistant. The lighting supervisor and the vision control supervisor maintain close liaison as their work is complementary and complete co-operation is essential. On the lighting console are switches and dimmer controls for all the lamps in use in the studio, and these are adjusted and balanced by the lighting supervisor so as to produce the optimum technical and artistic quality (see Section 6.4).

During the initial rehearsals of a production the minimum of vision control is performed and the cameras are effectively used as photometers registering the brightness of each point in the scene, thus greatly facilitating the adjustment of lighting levels. During later rehearsals and transmission, full vision control takes place and fine but important adjustments are made to the dual controls from moment to moment throughout the production so as to achieve the optimum quality.

(6.3.2) Vision Mixing Equipment.

The vision mixing unit consists basically of two 8-channel fader units and a 2-channel group change-over unit. The 8-channel units are fed with identical inputs, channels 1–4 being tied to cameras 1–4, and channels 5–8 being connected to a switching unit providing a choice of 10 sources, including telecine, special effects, captions and outside sources. The group mixer is used to select the output from either fader unit. Thus the second fader unit may be used for setting special effects but also serves as a standby in the event of failure of the first unit. The mixer amplifiers, switches and synchronous stabilizing units are installed in the vision apparatus room and operated remotely from the vision mixing desk in the production control room.

The basic mixer circuit consists of a crystal-diode bridge connected between the grid and cathode of a mixer valve. When the bridge is balanced equal signal amplitudes are applied to the grid and cathode and no output reaches the anode. If the channel is cut or faded up, the bridge is unbalanced and a signal output is obtained. The unit will accept either synchronous or asynchronous vision sources, a comprehensive interlock system ensuring that asynchronous signals are not superimposed.

Existing synchronizing signals of constant amplitude, derived from either the station distribution systems or from the original signals in the case of an asynchronous source, are reintroduced to the output vision signal. This system introduces no distortion to a colour burst or other colour information, making the unit potentially suitable for colour television if required.

(6.3.3) Picture Monitors.

Each of the picture monitors in the main bank, all of which have 21 in screens, is normally associated with one of the eight mixer channels, a separate monitor being provided for the studio output picture. Their specification includes 'back porch clamping' and a high performance in resolution, l.f. response and stability. Full d.c. restoration is employed. Remote control of contrast and brightness for all monitors has been fitted at the production desk, and the monitors are all set up (using a special line-up signal simultaneously fed to each monitor) prior to each period of use. The technical operations manager is provided with an $8\frac{1}{2}$ in picture monitor built into his desk position so that he can check any source without distracting the remainder of the operational team.

It was decided to use high-quality 14 in picture monitors in all the technical areas, namely studio lighting and vision control room, apparatus room, central apparatus room, for detailed technical appraisal, and to use good-quality 21 in monitors in production areas, including studio production control rooms, where the technical performance is not of the first importance.

(6.3.4) Inlay Transparency Equipment.

The equipment for special effects, comprising inlay and overlay, which is now closely linked operationally with a new display apparatus for captions and still photographs in transparency form, is mounted at a separate desk behind the production desk. The facilities provided by inlay and overlay, whereby any shape may be cut out of a picture from one source and filled by a picture from another, are well known,[12] but in this case a Vidicon camera channel replaces the flying-spot channel used in previous installations for producing the silhouette. The camera has been designed specially for this purpose and is capable of a wide range of scanning alterations. The use of a Vidicon camera gives a choice of operating window size, and as the camera can be quickly replaced the reliability of the system is considerably enhanced.

Inlay facilities are closely integrated with the display of captions produced as photographic transparencies. This medium permits much greater flexibility in handling and makes it possible to obtain the highest picture quality consistent with the camera channel employed. Still captions are mounted in 2 in × 2 in slides, and rolling captions are prepared as strips of 35 mm film. The equipment for display of transparencies comprises three special projectors linked by means of an optical multiplexer with a Vidicon camera channel of a type identical with that used for inlay silhouette generation. Each projector is fitted with a vane-type shutter in the light path, operated by means of a fader, thus permitting any combination of picture sources to be displayed.

Two projectors are for slides and are designed to permit rapid and automatic changes of up to 30 slides. The third is for 35 mm film strip and is designed to transport the film at accurately repeatable speeds. The range covers speeds of 2–30 pictures per minute.

(6.4) Lighting and Scenery Arrangements

In designing the lighting and scenery equipment and facilities two important requirements were:

(*a*) To cut the time required for setting, rigging and subsequent derigging of the lighting and scenery to a minimum, so as to make the optimum use of the studio for rehearsal and transmission purposes.

(*b*) To provide maximum flexibility in the lighting control system, as the 'one-man vision control technique', already described, places considerable responsibility for picture quality with the lighting supervisor.

(6.4.1) **Lighting.**

After careful consideration of various methods of lighting suspension it was decided to utilize electrically hoisted lighting bars (in a manner similar to that previously used at the Riverside Studios[2]), as this system was considered to combine maximum flexibility with speed of rigging.[13] Bars 9 ft long are spaced 5 ft 4 in apart down the length of the studio, with 2 ft spacing between adjacent rows. Each bar has four 2 kW socket-outlets fed by means of preformed rubber-moulded self-coiling cable. The bars can be raised or lowered, singly or in groups, from a control panel on the studio floor, at a speed of 30 ft/min. This system has the advantage that all the rigging and derigging of luminaires can be done from the floor.

All the studio lighting circuits are routed into a patching panel in the dimmer room, so that the circuits may be connected to the dimmers in any arrangement to suit the production. This gives extremely good flexibility.

The dimmers are of the electro-mechanical servo-controlled variable auto-transformer type. This system was chosen in preference to any of the all-electric dimmers such as thyratrons, magnetic amplifiers or silicon-controlled rectifiers, because once the dimmer is driven to a given position its control line can be disconnected and yet the level of light remains controlled, whereas with the all-electric dimmers the control must be continuously maintained for all levels, except 'black-out'. This considerably simplifies the design of the control console. The auto-transformer type also has the advantage that when in the undimmed condition it delivers the full voltage; with the alternative systems there is always some residual loss of voltage, the amount usually varying with the load.

The dimmer controls are all mounted on a console located in the lighting and vision control room. Immediately above the console is a mimic diagram, in the form of a plan of the studio, which shows the condition of all the lighting circuits in use. Each dimmer channel has two potentiometers permitting two independent lighting levels to be stored, and in addition there are 20 memories available which can recall all the channels in any combination.

Apart from a very limited number of arcs, tungsten lighting is used throughout. No fluorescent lighting is used.

The following improved types of luminaire were specially developed for this project: spot-lights in which the beam spread has been increased to give a maximum angle of flood of 55°; soft lights comprising ten 200 W internally-silvered reflector spot lamps housed in a fibre-glass container; and special cyclorama lights consisting of an aluminium reflector housing a 500 or 1 000 W tubular filament lamp. The use of these latter for lighting cycloramas has reduced the total power required for this purpose by one-third.

All luminaires are adapted for pole operation of pan, tilt and focus; this further reduces the time required for rigging.

The following Table gives the normal complement of hoists and luminaries for a type II studio (e.g. studio 3 or 4).

Type II Studio: Lighting Equipment

Lighting hoists	104	2 kW switched-only channels	10
2 kW studio outlets (240 V)	490	500 W spotlights	80
5 kW studio outlets (240 V)	20	2 kW spotlights	80
*250 A d.c. studio outlets (110 V)	12	5 kW spotlights	12
2·5 kW auto-transformer dimmers	120	2 kW soft lights	50
5 kW auto-transformer dimmers	18	Cyclorama lights	110

* For back-projection arcs, and large spotlights.

(6.4.2) **Scenery.**

Considerable attention was directed to the general problem of the expeditious handling and erection of scenery. Taking first the erection of scenery in the studio, it was considered worth while to provide electrically-operated hoists. These are mounted on the overhead steelwork and located between the lighting hoists. Each hoist is mounted on a trolley which can be moved laterally over a distance of 10 ft, and by this means loads can be lifted at a very large number of points within the studio, the operation of the hoists being controlled from a panel on the studio floor. Each hoist can lift a load of 250 lb at a speed of 30 ft/min. This facility has proved extremely valuable in practice and has greatly reduced the necessity for *ad hoc* rope installations.

In addition, a triple cyclorama track has been installed on all four walls of each studio, and sections of this track can be lifted by electric hoists and lowered on to special vehicles used to transport the cycloramas and curtains. Thus a backcloth can be fitted with all its bobbins, preassembled on to a portion of track in the storage area and rapidly erected in the studio. To facilitate the transport of scenery and backcloths a number of battery-operated electric tractors and trailer vehicles have been provided.

(6.4.3) **Audience Seating.**

The erection of temporary seating for studio audiences has, in the past, been a laborious and time-consuming process. It was therefore decided to develop a unit system of seating to meet this particular requirement. The seats are permanently fixed on a series of horizontal rows, all contained in one complete unit, but adapted to fold down when not in use, so that the assembly of rows can be telescoped into a rectangular block for transport and storage. A unit block, containing 11 vertical rows and a total of 66 seats, when collapsed into the storage condition forms a rectangle measuring 10 ft 8 in × 4 ft × 7 ft high and weighing 3 tons. The unit is towed into the studio on road wheels; hydraulic jacks are then lowered, the road wheels are removed, and by means of a handle fitted to the front, eleven shelves are wound out one by one; the overall length is then 34 ft. With this system four men can assemble seating for an audience of 400 in about 2½ hours. This system has been made to conform to the very strict requirements of the local authority and it represents a great improvement on previous methods.

The ability to install audience seating, as required, in this expeditious manner renders it unnecessary to provide any permanent built-in seating, and when necessary, the whole of the floor area of all the studios is available for production purposes.

(7) PRESENTATION SUITE

The presentation suite at Television Centre, which includes the central control room, is the continuity centre for the B.B.C. national network. All network contributions, which include local studios, telecine, satellite London studios, outside broadcasts and regions are passed through the presentation area prior to their distribution to transmitters throughout the United Kingdom. The layout of the technical areas is shown in Fig. 5.

Presentation studio A is used for continuity announcements, programme trails and small productions of the interview type. The associated studio control room has operational positions for presentation assistant and vision and sound control staff. 'Sound only' announcements originate from a separate announcer's booth.

The central control room is the focal point for the monitoring and switching of all programme contributions from local and external sources. It contains positions for the senior presentation assistant and technical staff, who work in close liaison with the adjacent presentation studio control room staff.

The sub-control room, providing similar facilities to the central control room, is used for the rehearsal of composite programmes involving the mixing of contributions of local and outside sources.

The second presentation suite will be brought into service when a second programme starts.

The international control room, also located on this floor, is provided for the control and monitoring of all television programmes which are sent and received over the Eurovision link.

(7.1) Technical Facilities

(7.1.1) Presentation Studio, Control and Apparatus Room.

The studio is equipped with three cameras of the Vidicon type which are complete with lenses providing horizontal viewing angles over the range 9°–35°. Essential camera control facilities are remotely operated from the production desk in the control room, situated adjacent to the 24-dimmer lighting control system, which gives dimming and switching of studio lighting.

Vision mixing equipment consists of an 8-channel unit, similar to one bank of the production studio mixer. The studio cameras and caption-effects sources are tied permanently to five of the mixer inputs, the remaining three channels being available for telecine and outside-broadcast inserts. Six 21 in picture monitors are stacked in two rows in front of the control desk.

The caption equipment employs a Vidicon camera associated with an optical multiplexing unit, two slide projectors and one film projector. A second camera is used for the display of a clock and occasional opacities. Caption controls are operated remotely and are normally under the control of presentation staff.

Essential operational sound controls are grouped at the sound operator's position on the production desk. The sound mixing equipment comprises eight quadrant faders and an independent channel which by-passes the main control. These will normally be allocated to three studio microphones, disc and tape reproducer and 'sound only' announcement booth, etc.

(7.1.2) Central Control Room.

The vision-sound mixing panel utilizes five pairs of quadrant faders, each pair comprising one sound and one vision fader. One pair is normally tied to the presentation studio output, the remaining channels being switchable to any of 46 programme sources which are routed by the central apparatus room. In addition, two independent sound channels are available for Big Ben, tape machine, etc. All four switchable channels will accept synchronous or asynchronous sources for cutting and fading to black operation. The sound and vision inputs to these channels can be selected from the mixer position, together with talkback, signalling, studio loudspeaker, intercommunication, etc.

Six 21 in picture monitors are installed, one showing the network output and five displaying the various programme sources. Similar technical facilities are provided in the sub-control room.

(7.1.3) International Control Room.

Sound and vision mixing facilities will be available for programmes requiring multi-lingual commentaries and comprehensive control line switching facilities. Six 21 in picture monitors and extensive sound and vision monitoring equipment will also be installed.

(8) TELECINE AND TELERECORDING

(8.1) General

At the time of the original planning, in the early 1950s, film was the only medium available for the recording of television programmes. Thus, at that time, provision was made for a telecine suite to include several telecine machines for the reproduction from film of all kinds and for a telerecording suite to contain several sets of equipment for recording on film.

Later in the 1950s, however, it became apparent that video-tape equipment would be widely used for telerecording and for subsequent reproduction. The use of video tape increased so rapidly that it became necessary to allocate the area originally planned for telerecording to video-tape telerecording only, and to provide an additional area (the basement area below studio 6) for film telerecording equipment.

Although, in these later conditions, it was apparent that considerable programme material would be transmitted from video tape, it was estimated that the amount which would still be derived from film would not decrease appreciably, and it was therefore decided to develop the telecine suite on the lines of the original plan and not to reduce the amount of equipment to be installed.

The following Sections describe the telecine suite and the video-tape recording suite.

(8.2) Telecine Suite

The telecine suite is on the second floor of the central wedge. The layout of the area is shown in Fig. 14, from which it will be

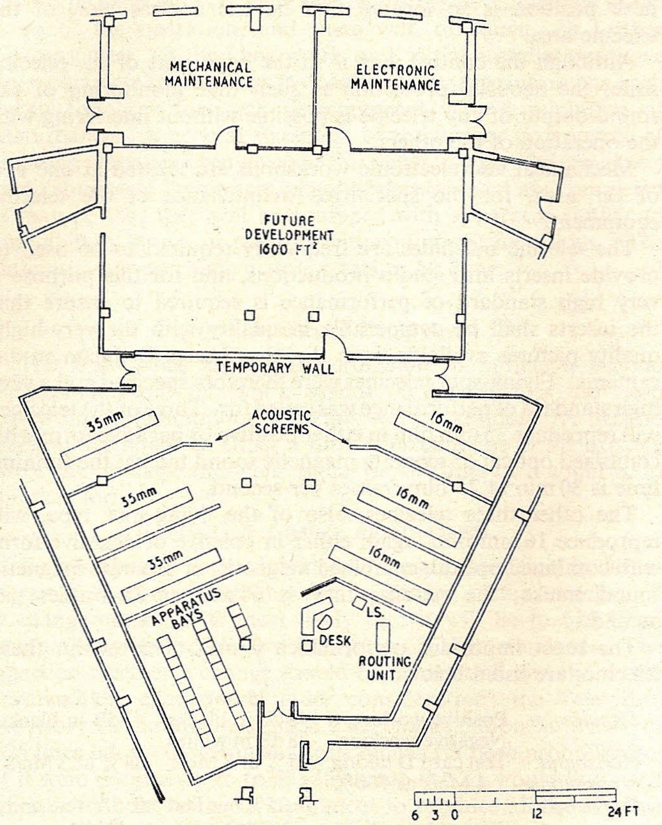

Fig. 14.—Telecine suite.

seen that six telecines have been installed, with provision for an additional five or six machines. The six telecines and the central control equipment have been installed in one common, open area. Even so, the acoustic separation between any two telecines is better than 20 dB. This is due partly to the acoustic screens between machines and partly to the precise location of the individual machines and their associated loudspeakers. In addition, all walls and ceilings have been treated with sound-absorbing materials. Thus, simultaneous use of a number of manned telecines, all on different programmes, is possible.

The intention is to make the operation of the telecines as automatic as possible. Already it is possible to start, stop and rewind them remotely from studio production control rooms and the presentation suite. Additional remote and automatic controls are envisaged which should make it unnecessary to man individual telecines except, perhaps, for some of the more topical productions which use large quantities of film and where last-minute changes are common. When this stage has been reached, only a small staff will be needed in the telecine area to load and unload the machines, to monitor their performance, to switch the machines to their appropriate destinations and to deal with emergencies. This method of working was much in mind when deciding on the open-plan arrangement. Most of the internal acoustic screens in the area have been so constructed that they can be removed easily if this is thought to be desirable to simplify monitoring and supervision of the equipment when completely automatic operation becomes possible.

In the control area, the telecine supervisor can monitor the vision and sound outputs from any telecine. He can also make the necessary connections for duplex operation of any pairs of machines and for switching the telecines to any destination. His desk position is so located that he has a clear view of the telecine area.

Although the control area is in the open part of the telecine suite, the acoustic protection is such that monitoring of the sound output of any telecine is possible without interfering with the operation of the others.

Mechanical and electronic workshops are located at one end of the area, for the specialized maintenance of the telecine equipment.

The telecine machines are frequently required to be used to provide inserts into studio productions, and for this purpose a very high standard of performance is required to ensure that the inserts shall be comparable in quality with the very-high-quality pictures available from the 4½ in Image Orthicon studio cameras. Flying-spot telecines were therefore specified and a very high standard of performance was called for. Three of the telecines will reproduce 35 mm film in either positive or negative form with combined optical or separate magnetic sound tracks; the running time is 30 min at 25 film frames per second.

The other three telecines, also of the flying-spot type, will reproduce 16 mm film, again either in positive or negative form with combined optical, combined magnetic, or separate magnetic sound tracks; the running time is 64 min at 25 frames per second.

The most important performance figures achieved on these telecines are listed below:

		35 mm	*16 mm*
Signal/noise	Positive working	48 dB in blacks	42 dB in blacks
	Negative working	38 dB in whites	
Horizontal resolution	Test card D taking 1 Mc/s as 100%	95% at 3 Mc/s	84% at 3 Mc/s
Geometry		0·25% line and frame	0·5% line and frame
Gamma	0·5	Constant over 100 : 1	Constant over 100 : 1
Unsteadiness		0·15% vertical and horizontal	1 line vertically 0·15% horizontally.

(8.3) Video-Tape Recording Suite

The video-tape recording suite is located in the basement under the central garden. The plan of this area is shown in Fig. 15. In the first instance, five video-type recorders, all of the Ampex type, are being provided.

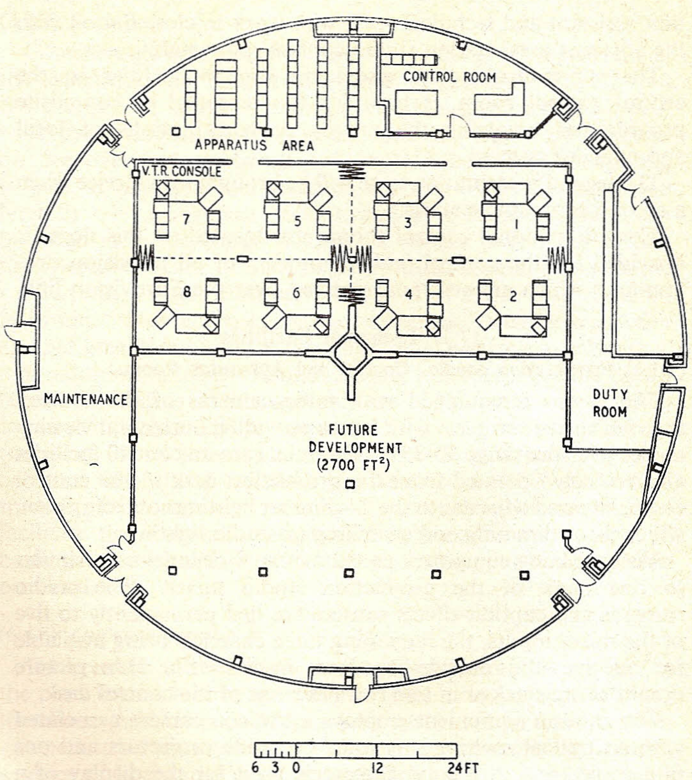

Fig. 15.—Video-tape recording suite.
The numbers 1–8 indicate the recorder positions.

As in the telecine suite, internal partitions have been reduced to a minimum and are readily removable should this prove desirable at a later date. The machines themselves are being installed in the arrangement best designed to achieve acoustic protection between adjacent machines with the minimum of partitioning. In this area it may be necessary to use machines singly, e.g. for editing, previewing or transmission; or in duplicate when recording or transmitting important programmes; or even in groups of three or four when compiling a single programme from a number of tapes. The machines have been laid out as shown in Fig. 15 with all these various requirements in mind, and considerable use has been made of simple plastic folding screens to provide sufficient acoustic protection to enable machines to be used singly when necessary.

Control and apparatus rooms form part of the area. Facilities in the control room permit the vision and sound monitoring of any programme during recording or reproduction, and the routing of programmes to and from the various video-type recorders. Ancillary areas are provided for maintenance, tape handling, tape storage, etc.

The video-tape recorders in this area are being used for all purposes, namely for recording and reproducing short inserts into studio productions, recording and transmitting complete programmes, for tape editing, and for transfers of programmes from video tape to film. As mentioned above, five machines are being installed in the first instance, but there will be space for fourteen or sixteen in this area.

Five video-tape recorders are already in use in Television Centre. These are capable of operating on either the 405/50 standard or the 625/50 and 525/60 standards used respectively in Europe and North America, to enable them to record or reproduce programmes on any of these standards in conjunction with the standards convertors in the central apparatus area.

It is early yet to talk about the complete automation of video-tape equipment, and it will certainly be a year or two before it is possible to introduce as much unmanned operation as is already possible with telecines; even so, the necessary circuits have been installed to permit remote start, stop and rewind of the video-tape machines and the problems of automatic working are being investigated.

(9) COMMUNICATION

(9.1) Requirements

The communication needs of the Television Centre, while not requiring the high electrical performance of the vision network, are, in fact, much more extensive and complex; they may be summarized as follows:

(*a*) Telephone and loudspeaker intercommunication immediately available between all the operational areas associated with each programme.

(*b*) Communication between all technical areas and the central apparatus room for engineering purposes.

(*c*) Facilities for the extension of outside-source control lines to any internal destination and subsequently rerouting lines as required.

(*d*) Immediate communication between all maintenance areas without impeding operational communications.

(*e*) A telephone panel in each studio to accommodate varying telephone circuits.

(9.2) Facilities

These requirements were met by the adoption of the systems described below. In addition, a 3000-line p.a.b.x. serves the premises.

An *operational system* of loudspeaker intercommunication is provided. At any one position, it consists of a number of 'fixed' stations which are always available and of routed stations which appear only for the duration of a particular operation, e.g. a telecine source contributing to a studio.

The principle of routing intercommunication stations is particularly advantageous in the central control room, where the source keys are reduced to only one for each of the mixer channels. Direct communication between central control room and an internal source exists only if that particular source is selected to one of the mixer channels via the main sound routing system, when circuits for programme sound, 'cue programme' back to source, talkback from source, loudspeaker intercommunication, telephone and availability buzzer, and 'on air' cues are completed. Thus, communication is restricted to sources concerned with the immediate programme changes. When a source-to-mixer channel selection is changed, all communication facilities are transferred to the new source, although the control keys and lamp indicators remain unchanged.

An *engineering manual exchange* (e.m.x.) provides telephone facilities between the central apparatus room and key technical points throughout the Television Centre and the remainder of the B.B.C. television network. The equipment, based on the use of motor-uniselectors, provides facilities for 200 subscribers and 6 tie circuits. Calls may be originated, answered and routed, conference linking facilities are provided, jackfield plugging facilities for long-period routings enable tie circuits to be kept free for normal operations, and comprehensive lamp indication shows exactly which facilities are in use.

A *control line routing system*, again employing motor-uniselectors and operated from the central apparatus room, permits the routing of up to 24 engineering and production control lines associated with outside broadcasts, regional contributions, etc., to a maximum of 100 subscribers. (The 24 lines also appear on the e.m.x. so that calls may be answered prior to the actual routing of the circuit.) Access is always available to any line, so that, if, for example, a production control line to a studio is faulty, the engineering control line can be routed to the studio immediately from the appropriate main desk control panel.

A *maintenance system* of loudspeaker intercommunication provides full inter-calling between all base maintenance and studio maintenance areas. 'Listen-before-speak' facilities are incorporated and provide a conference facility when required.

Studio telephone panel.—Each studio production control room desk is provided with a pushbutton switching panel, equipped to accept 15 control lines extended from the main sound switching system, control line routing system and e.m.x., so that calls can be answered directly and/or routed to a number of local studio operational positions.

(10) FUTURE DEVELOPMENTS

The major development will be to complete the Television Centre on the lines already envisaged, subject to any change of plan as the need for additional facilities develops.

The type of operation now being carried out at Television Centre differs very appreciably from that visualized at the time when the project was first conceived, but the basic design was sufficiently sound for these new methods and facilities to be incorporated without difficulty. Before the project is completed, it is to be expected that there will be further developments in the form of the operation, and there will, of course, be further changes after the building work and initial installations have been completed. As far as is possible, every precaution has been taken to allow for such developments with a minimum of disturbance. A general statement of the further programme of building work has been given in this paper. When the remaining three studios of the present phase of development are completed it may be that they will be equipped with apparatus similar to that already in use, or possibly with equipment for colour. The design is, however, adequate for this to be done.

(10.1) A Second Programme

The B.B.C. has asked for permission to radiate a Second Programme, and the whole layout of the facilities has been based on the assumption that this will be granted. A Second Programme could be either a further programme in the existing form with a black-and-white signal on 405 lines or it could be in another form.

(10.2) A Change of Standards

As has already been explained, the equipment has, as far as possible, been made suitable for facilitating such a change. If a change comes, it is most likely that it will be to 625 lines, compatible with the Western European C.C.I.R. standards. The question whether a change should be made at all and the actual form of the change are under consideration; the Television Advisory Committee has made a recommendation in favour of 625 lines but no Government decision has yet been promulgated. If it were decided to go to 625 lines, the B.B.C. would find itself initially without sufficient equipment to produce all the 625-line programmes that would be required; and, conversely, it would find that some items that it would produce on 625 lines would also be wanted for its 405-line operation. It is to be expected that there might be an appreciable increase in the demands for standards conversion equipment for which space is available. This could lead to the introduction of appreciable quantities of equipment on the memory-storage principle as at present used, but the requirement would also lead to the intensification of the present search for better methods of standards conversion.

(10.3) Programme Interchange

Interchange of television programmes with other countries was virtually unknown at the time the Television Centre was planned, but it now exists on a wide scale and every year it goes on over greater distances. There is no doubt that this tendency will increase: more of the programmes radiated in the United Kingdom will originate overseas, and more United Kingdom programmes will be sent abroad. The adoption of a 625-line standard would facilitate this process very considerably, as no standards conversion would be required over a large part of the world. The adoption of 625 lines could also possibly facilitate the interchange of programmes with the United States without standards conversion, should it prove possible to radiate pictures over the United Kingdom network on either 625 lines, 50 fields, or 525 lines, 60 fields, the line frequencies for which are virtually identical. Failing this, however, the increase in the facilities for converting between 50- and 60-field systems will be necessary.

(10.4) Asynchronous Operation

It is hoped, fairly early in the life of the Television Centre, that it will be possible to introduce fixed line and field frequency operation, i.e. that the field synchronizing signal will be independent of mains frequency. This would be of advantage in programme interchange and also of great assistance for colour, while it also has very appreciable advantages for the maximum efficiency of the transmitting network. All the equipment at the Television Centre has been designed with this requirement in view.

(10.5) Colour

As has been explained, all the design of the equipment has, as far as possible, catered for the addition of colour facilities to the Television Centre. Whether colour, if introduced at all, will be on 405 lines in the existing programme or whether it will be on 625 lines is a matter for Government decision. In either case, the facility will require appreciable additions to the lighting and to the amount of equipment installed in the apparatus rooms, but the power supplies, ventilation and control room layouts have all been provided. Colour could therefore be introduced into the Television Centre with a minimum of difficulty. The rate at which colour will be introduced is hard to say, and it is improbable that, at any time, all studios would be equipped for colour operation. As things stand, however, all could be so equipped.

(10.6) Recording

One of the biggest changes in television in the ten years since the inception of the work at the Television Centre has been in the development of television recording. Ten years ago, television recording virtually did not exist and the only medium for recording programme was the conventional cinematograph film. Since that date, however, enormous strides have been made in the recording of television pictures, both on photographic film and on magnetic tape. Judged by the parallel of developments in sound broadcasting, the use of such recording facilities will increase very considerably, but it is difficult to say where the balance will lie between film, tape and other forms of television recording. Film recording has the advantage that it is relatively simple and cheap, and can be easily edited. It is also easy to make a large number of copies. The probability is, therefore, that this type will remain for a long period and the development will be a gradual loss of the high-quality market in the 35 mm film to the rather lower-quality that is possible on 16 mm, while the high-quality material will be distributed on tape or other means.

Recording for black-and-white sequences on tape, already at a very high level of perfection, will no doubt improve, and in its use for domestic programmes, the cost of operation is not too serious. For many stations abroad, however, it looks as though tape will be too expensive for many years and reliance will continue to be placed on film. Tape also has considerable advantages in the recording of colour, which, so far, is very difficult to do on film. It may be, however, that some of the new suggested forms of recording, and particularly the so-called thermoplastic form, may prove to have very great advantages. Great fluidity will have to be maintained in the allocation of facilities for programme recording, and it is thought that the present layout contains adequate space for this.

(10.7) Apparatus

There is no doubt that automation of the equipment will continue to progress and that, because of developments in this field, there will be a fairly high rate of obsolescence. Camera equipment, too, is liable to a high rate of obsolescence, dependent on the development of new types of camera tube. A relatively small improvement in the performance of the photoconductive type of tube could provide a reason for the obsolescence of a large part of the photo-emissive types of tube at present used.

(10.8) Transistors

Transistors are used to a very minor extent in the Television Centre, and even then not in the direct programme chain. It is to be expected, however, that the fairly near future will see a very rapid increase in the amount of transistor equipment with a consequent gain in space and saving in power.

(10.9) News

Up to the present day, it has not been possible to integrate the B.B.C. Television News activities fully with the television service, and even in stage III of the Television Centre project, there is no provision for this.

In the further development of the Television Centre, when the spur is added, it is hoped that it will be possible for the Television News to be adequately housed, in which case it will be possible to integrate the technical facilities for Television News much more fully with the regular programmes and to make more facilities available to Television News. This should be particularly helpful in the way of provision, not only of important facilities in the Television Centre, but of more ready access to outside sources of programme from Europe and elsewhere.

(11) ACKNOWLEDGMENTS

The authors wish to thank the Director of Engineering of the B.B.C. for permission to present the paper. They also wish to recognize the very effective co-operation between the engineers of the industry and of the B.B.C. in realizing this project; and to express their gratitude for the help they have received from so many of their colleagues in the preparation of the paper.

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DISCUSSION BEFORE THE INSTITUTION, 23RD NOVEMBER, 1961

Sir Harold Bishop: My comments will be somewhat coloured by inside information, but I shall keep them as unprejudiced as I can. The first question that anyone asks about the Television Centre is, Is it a success? As one who has watched it being built and seen it in operation I can give an unqualified Yes to that question from every point of view. The artistes, the programme and engineering staffs, the scenery makers, the administrators—all have had good words to say of the building and its equipment.

I want first to pay a tribute to the architect, Mr. Graham Dawbarn, who was the originator of the circular design, and perhaps more particularly to Mr. M. T. Tudsbery, who recently retired from the post of Civil Engineer to the B.B.C. He had much to do with the working out of that design with Mr. Dawbarn and making it a practical possibility.

Of course there were criticisms of the design. The installation, it was said, would be more expensive and it would be difficult to fit equipment into rooms which had not parallel walls. I think it is fair to say, but I should like the authors to comment, that it did, in fact, make the installation a little more difficult than it would otherwise have been. But, as is made clear in the paper, there was no possible alternative design. In other countries a rectangular type of design has been successfully adopted, but the space required is much more than is available at Television Centre. In my opinion, therefore, the circular design has fully justified itself.

Problems arise because of the long time required to build and equip a studio and get it into service. First of all, it is necessary to build it as an ordinary building operation, but it takes two years to transform it from carcass form into an operating unit. The difficulty is, as with all long-term electrical projects, that while the job is being done, particularly in a field which changes so quickly as broadcasting, new ideas come along and it is found that something should have been done in a different way. As somebody said about computers, 'If it works, it's obsolete'.

The second problem is line standard. Are we going to stay on 405 or change to 625 lines? What equipment provision should be made for this uncertainty? Perhaps the authors will say more about this. The third problem is colour. We do not know what we are going to be permitted to do, and when. Clearly the specification must cover all reasonable possibilities. Fourthly, we do not know what is going to be the effect on studio usage of the development of recording, and particularly magnetic recording.

So far as the number of studios is concerned, it seems to me that for two programmes each of, say, 50 hours a week we shall want about a dozen studios. At the moment we have eight in use—four in the Centre, three at Lime Grove, and the television theatre. These, together with our facilities in the provinces, are pretty well full up in providing one programme. That is why for two programmes we may want up to 12 studios. The statement in Section 2.14 may be a little optimistic; the authors speak of 1 500 hours a year from seven studios, four hours per studio per week. There are so many uncertainties, but it is clear that to produce two nation-wide simultaneous programmes it will be necessary to retain for a long time the studios we have at Lime Grove and Riverside.

The authors say that the equipment has been designed throughout to allow a change of line standard fairly easily. We are all waiting for the Pilkington Report, which we understand will be submitted to the Postmaster General in the spring of next year. The Government will then no doubt decide what is to be done about line standard, colour, additional programmes and so on. I should like the authors to say more about this matter. If we were told to radiate a programme on 625 lines, what changes would have to be made to the equipment at the Television Centre to allow this to be done and possibly to allow the use of old and new standards simultaneously?

The authors also say that there will be no difficulties in introducing colour. That seems to me rather a rash statement. We know a little about colour; we have been experimenting with it for the last six years. We know a lot about problems of lighting and heat dissipation and that sort of thing; but the techniques are still largely unknown, and until we have to produce colour programmes as a routine operation we shall not know the difficulties we shall be up against.

An important question is the possibility of further automation to save manpower. A good deal has already been achieved.

We have visitors of all kinds from all over the world to Television Centre. It has created a great deal of interest. The majority are deeply impressed but of course there have been criticisms. Anyway, it has made people talk and so we learn for the future.

Mr. B. N. MacLarty: The successful completion of this great project reflects the greatest credit on all concerned; I say this with some feeling, because for 21 years I was engaged on the co-ordination of B.B.C. projects and, although I have been away from this work for 13 years, I still have vivid memories of all that it entails.

It is not always appreciated by those outside the B.B.C. that the design, direction of installation and setting to work of a project of this magnitude is undertaken almost entirely by the engineering staff of the B.B.C. and that few consultants are employed in connection with the radio, television and power sides of the projects. In this instance the television-camera equipment was specified to the various contractors and designed by them, but the majority of the studio control room equipment was designed by the B.B.C. engineers.

Perhaps the acknowledgement to what the authors term 'industry' is a little restrained, having regard to the fact that the development of high-definition television was due to the foresight and skill of the industry.

When viewing the television and electrical installation in this building, one wonders what proportion of the total cost is in respect of television and sound equipment. One feels that a high proportion of the total must be absorbed in lighting fittings, power plant, etc. Could the authors give a rough indication of the percentage spent on television equipment, excluding, of course, the cost of the building, heating and other services?

Television technique is still developing rapidly, and I imagine as time goes on it will be necessary to economize in the space taken up by technical equipment, which will be possible when the fullest use is made of transistors and a reasonable degree of miniaturization.

Mr. B. Marsden: There have been many important developments in television techniques, and I should have liked to see more detailed information on the technical facilities. We must offer our congratulations on the building layout adopted. The circular layout with the flow line around the studios is exactly right, although I must agree with the authors that such a layout is very costly. We are finding in our organization that it is wise to invest money to reduce on labour costs in later years.

As for the acoustics of the studios, the curves are quite remarkable—the reverberation times are extremely short for the size of the studio and remarkably flat. We have adopted an artifice by which we increase the reverberation time deliberately at speech frequencies, and this effects an improvement, especially in drama presentation. We also deliberately distort the frequency response of audio equipment and use limiting and compressing amplifiers. Used with discretion such distortion can greatly enhance intelligibility and general quality of a programme.

I see from Fig. 5 that there is duplication of presentation facilities. This is to enable the B.B.C. to put out a second television service, but the layout presupposes that the B.B.C. does not have to put out commercials to pay for this second service. I suggest that, if commercials are to be broadcast upon the B.B.C.'s second service, modifications to the layout may be quite considerable.

I am most disappointed to see that transistors are not used very greatly. Transistorized video amplifiers are now available and it is possible to achieve a performance adequate for colour and more than adequate for black and white. We have completely transistorized our pulse generator, picture and sync distribution and can already report on the reliability and higher efficiency of this technique.

Dr. K. R. Sturley: As the one responsible for the technical training of staff required to operate the Television Centre, I have naturally been kept fully informed of the various developments as they have occurred. This does have some disadvantages since it tends to give a series of isolated snapshots without an overall view. The great value of the paper is that it places the whole development in proper perspective.

It is interesting to note that, though the Television Centre represents an appreciable advance on Lime Grove in more economical use of manpower and a better grouping of operational positions, its effect on the training syllabuses has been marginal. The problems of fault location and maintenance have not been appreciably changed, and the greater stability of the equipment has simply allowed the operator to assume responsibility for a greater number of equipments. The one-man vision control is an example, and this brings me to my first question. Figs. 3 and 4 suggest that the one-man control is in fact two-man control. Why is this?

The authors have indicated that the financial frustrations they suffered have been turned to good account since they allowed later developments to be incorporated. Transistors were not sufficiently developed for use when they finalized their schemes. Do they feel able as yet to indicate the probable effect of the use of transistors? Would it appreciably reduce maintenance and save valuable space?

The paper encourages a peep into the future. Is it possible that we may see remotely-operated cameras with built-in transistorized radio transmitters allowing them to be tracked unattended anywhere over the studio floor?

Dr. A. M. Spooner: The authors give a figure of 1 500 hours a year for the total electronic programme output from the seven production studios and the television theatre, and a figure of 2 650 for the staff required for this. It is interesting to divide one by the other, which gives 0·57 programme-hour per man per annum. Comparable Associated-Rediffusion figures (but including programme-hours from outside broadcasts and from films made and transmitted by Associated-Rediffusion, and also staff for originating those kinds of programme) are: output, 870 hours; staff, 1 269. This gives a ratio of 0·68, which may be compared with the B.B.C. figure of 0·57.

At Wembley, Associated-Rediffusion have a large studio which can be divided into two by acoustically insulated partitions—this is found to be an economic and convenient arrangement. I understand that the B.B.C. were considering such a scheme, but decided against it. Was this because they feared there might be insufficient acoustic isolation between the two halves of the studio, or was there some economic reason against it?

The reverberation curves which the authors give are excellent. Can they tell us whether the reverberation time changes materially for different kinds of scenery owing to reflection from hard surfaces or absorption from soft drapes, and so on?

Mr. S. N. Watson: The distribution system by means of which signals are sent to, and assembled from, the various programme-originating areas is inevitably a large part of the total technical installation.

It is a feature of the distribution system, which we regard as beginning at the input to the picture mixers, that all the individual items of equipment are designed to work at fixed gain so as to eliminate the regular checking of levels and setting of gain controls. Experience has shown that these latter procedures not only consume a great deal of skilled operational effort, but also, unless great care is exercised, usually result in an inaccurate signal level. Fixed-gain working is only practicable with individual units having extremely stable gain, since some of the routes can contain many individual items of equipment. The following figures were obtained on measurements of 15 typical routes of a complex nature, one of which contained as many as 22 individual items, including two picture mixers. Of the 15 routes, two had an insertion gain which was not measurably different from unity, four were within 0·1 dB, a further five were within 0·2 dB, two others within 0·3 dB, and the final two within 0·4 dB. So far as the transmission quality of these routes is concerned, all had a *k*-rating for the 405-line system of better than 1%. For the 625-line system, of the 15 routes, ten had ratings better than 1%, one was $1\frac{1}{2}$%, and the remainder better than 2%.

The line-time non-linearity distortion, which was measured with a 10-step staircase, was 6% for the most complex chain with the exception of the last step to white level, where, owing to the setting of peak limiters, the distortion was 20%. The distortion is expressed as the ratio of the difference between the amplitudes of the largest and smallest steps with respect of the amplitude of the largest step.

At the sub-carrier frequency of the 405-line N.T.S.C.-type colour system, i.e. 2·7 Mc/s, differential phase was ± 2°, which was greatly in excess of the expected amount of distortion. The cause of this has been traced to one individual item of equipment which is receiving attention.

No measurements have yet been made at the colour sub-carrier frequency, i.e. 4·4 Mc/s, of the 625-line N.T.S.C.-type colour system.

Mr. V. J. Cooper: The first subject with which I wish to deal is automatic switching. The B.B.C. seem to be lagging somewhat behind others in the use of automatic programme switching, and I should like to ask whether this is a matter of policy or due to some lack of courage.

With regard to studios, an ingenious arrangement has been used for stacking the audience seats in the studio, and I wonder whether similar ingenuity has been shown in dealing with the awful business of trailing cables over the studio floor. I have visions of all the cables being carried overhead on universally jointed booms, which would give complete flexibility, keep the floor clear and make studios look tidier than they do today.

Finally, a year or two ago I and a number of others shed a sympathetic tear at the early demise of a young lady called Vera—video-electronic recording apparatus. She was a fast young thing with a number of useful attributes, but the absence of any reference to her in the paper suggests that she is not only dead but buried. Is there not a small corner somewhere in the new large centre for housing her?

Mr. R. G. Mitchell (*communicated*): The B.B.C. is to be congratulated on a very good engineering feat. I would like to point out, however, that the Television Centre in Rome has also been built specially for television and there may be other installations in Europe by now. Many other countries are planning such centres, including Czechoslovakia where a new Television Centre is being built just outside Prague; it is due to come into operation in 1963.

I was a little worried by the proposal to use a standards convertor to lock an outside signal to the Centre when the local synchronizing generator is already genlocked to another outside source. Has this system been proved, and what deterioration, if any, is due to the standards convertor?

I was surprised to see that station timing has been achieved by using equal line lengths from all sources with, presumably, the resultant problem of frequency equalizing on each line. There are lumped-circuit delay lines suitable for video circuits now available, which have been used successfully in other installations. The lumped-circuit delay line has many advantages over cable: there is considerable saving in space, and when high-quality cable, such as is installed in the Television Centre, is used the delay line is cheaper. The fact that the delay line does not require equalizing and has less attenuation than cable saves amplification through the system.

I was intrigued by Dr. Sturley's remark about a studio roving-eye camera. This was suggested some years ago, and since then has become a much more practical idea with the advent of transistors and modern u.h.f. techniques. An all-battery-operated camera, mounted on an electric truck, is quite practical, while line and field drive could be sent to the camera via the camera operator's system of intercommunication. The vision signal could be transmitted at 1 000 Mc/s outside bands 4 and 5, using frequency modulation to reduce reflection troubles. It should be possible to design the receiver to receive six channels which could be demodulated and sent to the vision mixer in the normal way.

There are a number of advantages to be obtained from this suggestion. There would be no long cables dragging around the studio floor, the timing and equalizing problem would be eased, while rapid movement of the camera from one part of the studio to another, and between studios, is possible.

I noticed that film telerecording is still retained and the authors feel that there is room for both tape and film recording in a modern television system. While I agree in principle with these statements, I would like to point out that new fast-processing machines have made it possible to produce film ready for re-transmission within a matter of minutes. The actual time of the film in the processing machine is one minute, and the film runs through at the standard projector speed of 35 ft/min.

Transfer of tape to film is already being used by some operators, and when it is necessary to convert from 525 lines 60 c/s, to 405 lines 50 c/s, it may be better to transfer from tape to film than to transfer from tape to tape via a standards convertor.

THE AUTHORS' REPLY TO THE ABOVE DISCUSSION

Messrs. F. C. McLean, H. W. Baker, and C. H. Colborn (*in reply*): The following comments are in reply to individual speakers.

To Sir Harold Bishop.—The circular shape of the building and the resulting non-rectangular areas had the effect that some additional effort was required for both the planning and the installation work. The advantages gained, however, more than outweighed this effort. Most of the main technical areas are fairly large and with the exercise of some ingenuity it proved possible to devise quite satisfactory layouts (see Figs. 3, 5 and 14). In some of the smaller areas, e.g. small distribution switch rooms, some difficulty in planning was experienced. Similarly, in the office and corridor areas difficulties were sometimes experienced in obtaining the optimum position for lighting fittings. No significant difficulties arose in the actual installation of the technical equipment once the layout had been settled, and, in general, wiring runs were not unduly difficult, as in most cases the radius of curvature is very large. Slight difficulty was experienced in lighting the face of the inner court with tubular fittings, as in this case the radius of curvature is not so large.

In order to provide for a possible change to 625 lines, all the picture-originating equipment, including studio cameras, picture monitors, telecines and video-tape equipment, must be made to be switchable to either standard. The present position is that all the (existing) studio-camera equipment could be converted to operate on 625 lines in addition to 405 lines in a period of two to three weeks. The central sync-pulse generators at present installed can be switched to generate master pulses for 405/50, 625/50 or 525/60 standards as required. The vision-distribution system is designed to work on either standard. Five video-tape recorders are of the multi-standard type, but more telecine equipment capable of operating on 625 lines would be required. The camera equipment, telecines, etc., to be installed in Studios 1, 6 and 7 will all be of the multi-standard type (405, 625 and 525/60). Provision for multi-standard pulse distribution is also being made.

While the colour situation remains undecided, it was clearly impossible to invest any appreciable amount of money in provision for colour. Nevertheless, some provision has been made and it will be possible, with additional equipment, to originate colour signals from any studio.

To Mr. B. N. MacLarty.—The cost of the television and sound equipment, together with those portions of the power and wiring specifically relevant to it, represents approximately 20% of the total capital cost of the project, including building.

To Mr. B. Marsden.—It has been the policy for many years past to invest in plant in order to reduce labour costs and this policy will be continued.

Some transistorized equipment has been in use since the Centre was first commissioned and, in addition, a transistorized central sync-pulse generator was installed before the end of 1961. Further transistorized equipment will be installed in due course.

To Dr. K. R. Sturley.—Figs. 3 and 4 show two duty positions at the vision-control desk. The vision-control supervisor occupies the main vision-control position (left) and has control of up to six studio-camera channels. The vision-control assistant occupies the right-hand position; his function is to make occasional adjustments to contrast gradient (when instructed) and picture monitors, and to answer telephone calls, etc., but he does not exercise control over the video signals. Experience with one-man vision-control operation over the past year or so indicates that the vision-control assistant is unnecessary. Future vision-control desks will be designed with one operational position only.

The use of transistors on a large scale should result in savings in space, power consumption and ventilation capacity. Its effect, however, on maintenance effort and space is as yet unknown, as none of the existing video- or audio-transmission equipment is transistorized. New equipment to be provided for Studios 1, 6 and 7 will be largely transistorized and it is likely that some economies in maintenance effort and space will result, but it is doubtful whether they will be very significant.

Unattended remotely-operated mobile studio cameras with built-in radio transmitters might well be technically feasible in the not too distant future. It is doubtful, however, whether unmanned cameras would be practicable in a production studio, where six mobile cameras are frequently deployed and often have to manoeuvre in very confined spaces.

To Dr. A. M. Spooner.—Some years ago, in the early planning of the Centre, the B.B.C. considered a scheme for dividing one of the Type II studios (8 000 ft^2) into two small studios, when required, by the provision of a movable partition which would provide the necessary acoustic isolation. It was finally decided that the requirement of the service was for a large studio and that the very occasional need for small studios, in addition to the three already provided, would not justify the cost.

The studio reverberation times as shown in the curves will be modified to some small extent by scenery, flats, drapes, etc., but the effect of these is not as great as might be expected owing to the random distribution of the acoustic treatment—both l.f. membrane absorbers and wide-band absorbers—on the walls of the studios. Controllable artificial reverberation in the form of reverberation plates and echo rooms is also available if required.

To Mr. V. J. Cooper.—B.B.C. network operations deliberately do not run to a strict timetable, and so far as switching between individual programme items is concerned, they allow for a measure of flexibility in presentation and timing. The need for fully automatic programme switching does not therefore arise. There is as yet no proposal for resuscitating Vera.

To Mr. R. G. Mitchell.—The use of the standards convertor as an alternative method to genlock of source synchronization is immaculate from the synchronization point of view, but some slight deterioration in picture quality results, which is inevitable in the present state of the art. In fact, this method is rarely used in practice.

At the time at which it was decided to use lengths of continuous cable for achieving delay equalization, there was no doubt that a more precise result could be achieved by this means than by the use of lumped delay lines, when it is taken into account that delays of the order of 3μs are required. Even at the present time, some years later, when the fixed lumped delay network has a better performance, it is still, in our view, possible to achieve a more precise result with a continuous cable than with lumped delay networks. It must be remembered that we are talking about very precise requirements indeed. Moreover, on a cost basis the advantage also still lies with the lengths of continuous cable; for the delay of 3μs the total cost of providing a cable and equipment is of the order of £60 and precision lumped delay would undoubtedly be more expensive. So far as space for the cable is concerned, there is no problem at the Centre, where adequate space in wiring ducts is available.

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