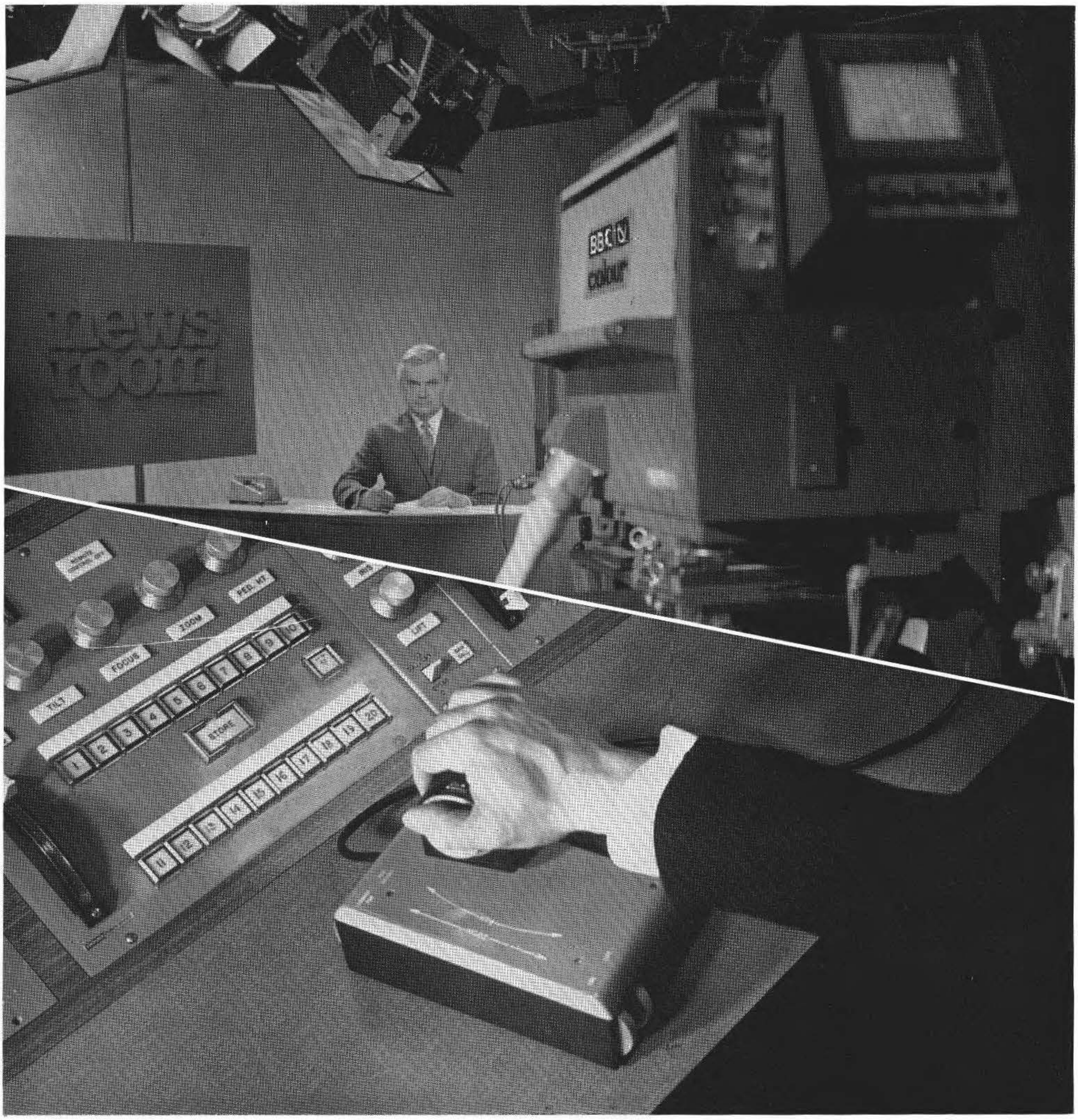
BBC ENGINEERING

Number 81 January 1970



Number 81 January 1970

BBC Engineering

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Contents

The upper portion of the composite cover photograph shows newsreader Kenneth Kendall in Studio N2 at the Television Centre Spur, while the lower portion shows one of the remote control units in the production control room from which the pan, tilt, focus, zoom, iris, pedestal height, and electrical lift of a camera channel can be controlled when manual remote control is in use.

Introducing BBC Engineering

The BBC has now been publishing the Engineering Monograph series for fourteen years. These monographs have proved a valuable medium for making the results of work done in the BBC Engineering Division available for engineers engaged in the field of broadcasting and telecommunications generally but it has become increasingly clear that their scope has been limited by the very fact – which is implicit in the name given to the series – that each issue has been restricted to a single paper conforming approximately to a standard length.

This limitation has now been avoided by shortening the title to BBC ENGINEERING and thus making it possible to include a number of articles, papers, or announcements covering a wide range of BBC engineering developments and operational experience in both television and radio. It is hoped that, in addition to papers of the type that have appeared in the monographs, some of the contributions in BBC ENGINEERING will appeal to readers who are interested in broadcast engineering generally, although not professionally engaged in this field.

There will be an average of four issues per year and the total amount of material published each year will be at least equal to the average contents of a year's issues of monographs.

The annual subscription to BBC ENGINEERING is 30s. (£1.50) or $4.00, post free. Single copies and back numbers cost 8s. (40p.) or $1.00, post free. Orders can be placed with newsagents and booksellers or BBC Publications, 35 Marylebone High Street, London, W1M 4AA.

A list of BBC Engineering Monographs still available is on the inside back cover.

Editorial

Colour on three channels

The start on 15 November 1969 of colour transmissions on all three of the national networks was a landmark in the history of British broadcasting. It was the culmination of experimental work extending over more than sixteen years.

BBC-2 has been transmitted almost entirely in colour for more than two years. The quality of the colour pictures has been widely acclaimed and has fully justified the care that was taken in preparing for the colour service. Before it started, some fundamental decisions were made: that the PAL system should be used: that colour should not be restricted to spectacular programmes but that virtually the whole output should be in colour from the start, and that the utmost care should be taken to ensure the highest quality of reception on colour receivers (and of black-and-white reception for the majority of viewers still using monochrome receivers). Experience has shown that these decisions were right, and the British radio industry has made great efforts to ensure that colour receivers are efficient and reliable, and that adequate facilities exist for servicing them.

This experience (which is reviewed from the studio operating point of view in an article in this issue) laid the foundations for the extension of colour to BBC-1 and to the ITA network.

All three colour programmes are transmitted in colour on the 625-line standard and on uhf. This has several advantages: interference is far less troublesome on uhf than on vhf and the new transmissions can all be received on a single-standard receiver, whether black-and-white or colour, which needs only one comparatively small aerial and is simpler, cheaper, and more reliable than the dual-standard receivers that have hitherto been necessary for receiving all three programmes. The introduction of colour has not caused any noticeable deterioration in the quality of the pictures received in black-and-white and indeed the quality of a colour transmission, when viewed on a monochrome receiver, tends to be subtly better than a monochrome transmission viewed on the same receiver – perhaps because of the more precise control of grey-scale tracking that has to be exercised during a colour transmission.

All the BBC and ITA uhf transmitters are co-sited and share a common mast, and the transmitter networks are being rapidly extended towards national coverage. We believe that the availability of all three programmes in colour will certainly arouse the enthusiasm of viewers and will, despite the present economic conditions, encourage them to obtain receivers that will enable them to see the world of art and nature in its true colours.

Experience in the Operation of Colour Studios

C. R. Longman*

Early experiments

The colour television service on the BBC-2 network has been in existence for over two years. It was officially opened on 2 December 1967 after a colour-launching period which started with the Wimbledon Lawn Tennis Championships in July 1967.

The start of the service was preceded by trials and experiments in existing television studios at Alexandra Palace and Lime Grove, covering a period of approximately eleven years. The purpose of these tests was to provide critical assessment of the quality of colour transmissions received in the viewer's home using all known colour transmission systems and operating on the various line standards. These tests usually consisted of small studio operations using different types of electronic colour cameras and film equipment. Such experiments continued at the Television Centre where the studios had been designed from their inception with colour in mind.

Early experimental colour transmissions employed three-tube 3-in. image orthicon cameras which required continuous adjustments to the various controls on the camera control units and a very high lighting level. In fact, incident lighting of the order of 4,500 lux was required for correct operation, and the cameras – because of the use of the I.O. tube – were large and heavy. This considerably restricted normal type of camera work and hampered freedom of movement, thus precluding the sophisticated shots and camera work normally required by producers and directors. The high light levels required (more than five times those used with monochrome cameras) produced studio ventilation problems, restricted the size of production sets, and resulted in unsatisfactory working conditions for the operational staff on the studio floor and for the artists.

Advantages of lead-oxide photoconductive tubes

With the introduction of colour cameras using lead-oxide photoconductive tubes, with their improved sensitivity, electrical stability, linear transfer characteristics, and negligible dark current, most of these problems were overcome. Tests immediately revealed that such a camera, when correctly aligned, required relatively little adjustment to obtain correct exposure and accurate colour-matching between shots. The lighting level required was only about one-third that needed for the I.O. cameras and little more than that needed by monochrome cameras. In view of the stability, a method of operating was devised using one-man vision control, this being the current practice in monochrome studios. Experience of this mode, which had been gained over a number of years, could be applied to colour operations. It was quickly established that close co-ordination between the lighting director (the technical manager in BBC studios) and the vision control operator was necessary to produce good results and, by concentrating all operational controls in a single desk and using shared monitoring facilities between lighting and vision control (Fig. 1), a high standard of picture quality could be achieved under controlled conditions.

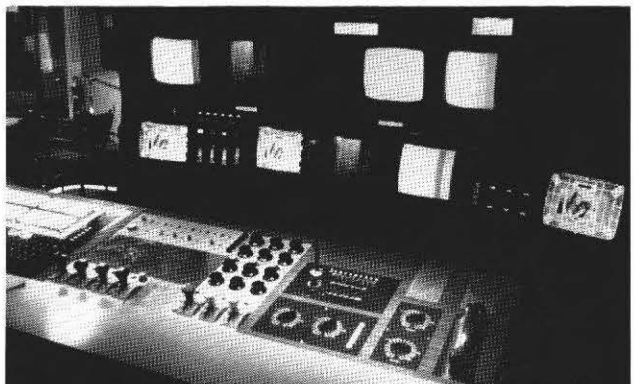

Fig. 1 Lighting and vision control desk, showing monitor layout and one-man vision control knobs

Colour studio lighting

The next stage was to consider the design and operating philosophy to be applied to BBC colour studio operations and to determine the required number of studios. To aid this decision the BBC planning group responsible for colour had established the following principles:

(*a*) The colour picture must be of the highest quality.

(*b*) Reproduction of the colour transmissions by monochrome receivers in viewers' homes must be as good as for monochrome transmission.

(*c*) The operating efficiency of all equipment in the colour studios must be as high as previously achieved in monochrome studios.

Obviously the first two principles are extremely important but the third principle is also vital to maintain the productivity previously achieved in BBC monochrome studios. Normally

* Head of Engineering (Television Studios).

the studios – unless they are undergoing maintenance work – are in use twenty-four hours per day. During the night a finished production is 'struck' and the scenery and lighting are rigged for the next production. The following day is occupied by rehearsals with transmission or recording during the evening. To achieve the same productivity in colour there were considerable equipment and organisational difficulties to overcome; in particular the striking of scenery and the positioning of lighting equipment must be completed in minimum time. A considerable investment in mechanical handling equipment could be justified if it increased the production capacity. The colour studios were, therefore, re-equipped with a new form of semi-saturated lighting installation designed by the BBC, which uses a large number of 4-ft (1·2m) lighting bars, fitted with electric hoists and evenly spaced over the studio area. Fig. 2 shows some of the methods of suspension used for luminaires and other pieces of equipment which are

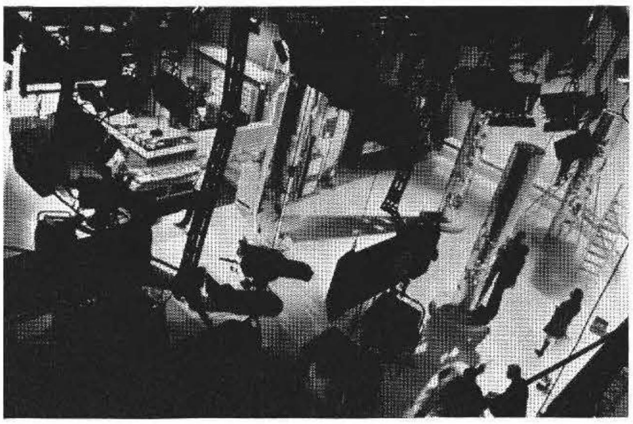

Fig. 2 Studio floor viewed from the lighting gallery

normally suspended from the lighting grid. With dual-source luminaires on each bar it was possible to reduce the rigging time previously required. These new luminaires have a spotlight on one side which is capable of operating at 2·5 or 5kW and a soft light on the other side containing four 1·25-kW lamps which can also be switched to operate at 2·5 or 5kW. With such an arrangement it is possible to restrict the range of dimming which would otherwise be necessary to achieve the required incident light level and to avoid unacceptable changes in colour temperature.

Lighting, of course, plays an important part in producing high-quality colour pictures, and considerable thought has been applied to the requirements for large and complex productions. It has proved to be extremely useful to have equipment which can store the dimmer settings of each lamp, particularly where more than one scene takes place in the same area. Fears that colour might change as a result of changes in the operating temperature of lamps have proved to be unfounded provided that such changes are kept within defined limits. A tolerance of $\pm 150^\circ$K in colour temperature about a mean line-up level of 2900°K with an incident light level of 1600 lux is acceptable for face tones and this gives a dimming range of approximately ± 25 per cent in light output. Clearly the range of control on backgrounds can be much greater and the full range can be used on cross fades. A more serious deterioration of picture quality can occur as a result of over- or under-exposure and to avoid this the lighting must be controlled to keep the contrast range in the picture within 30:1. Pictures with contrast ratios in excess of this will be marred by camera tube lag. Scenic design and costume should be within 20:1 contrast range to enable dramatic emphasis to be given to different scenes by lighting according to the atmosphere and mood required. The plumbicon camera tube has a straight-line characteristic and thus accurately reproduces the scene being viewed: if the maximum permitted contrast range is exceeded the exposure must be chosen to neglect one end of the scale. Usually the high-light end of the range is favoured to avoid crushing and consequent incorrect reproduction of facial tones. Experience has shown that costume and scenic designers must accept these limitations in contrast ratio: the lighting director can then concentrate on the artistic aspects of the picture.

The production of coloured light by using colour filters over the lamps is becoming increasingly important. Such filters are available in a wide range of hues but, if realism is to be maintained, the hue of any strong coloured light must be selected with great care, especially if the picture contains flesh tones. It is possible to use coloured light to add interesting colours and patterns to scenic design and under controlled conditions to correct unsatisfactory hues in the scenery.

With the introduction of colour, new lighting control systems became available which take advantage of computer technology and provide larger capacities for information storage. Some of the new colour studios have been equipped with these systems, which contain approximately 300 dimmer channels capable of storing information of any intensity level on any or all of 100 files (or memories). The individual control of intensity is carried out by calling up the required channel on a decimal-coded-selection panel: the level is then indicated and can be adjusted as required. Adding, subtracting, or cross-fading from file to file is possible. Intensity adjustments can be made to the channel and the new information then be re-filed. The flexibility of such lighting equipment has proved to be popular with lighting directors working on complex productions and the system is, in fact, most versatile on any studio operations.

The adoption of one-man vision and lighting control led to improved results and experience has shown that the lighting should be so controlled that the vision operator need not vary the iris over a range of more than plus or minus half a stop. Exposure for colour should be accurate to one-eighth of a stop to achieve good matching during cutting between close-ups in the same scene. Generally the cameras work at about F.4. The vision operator also has controls enabling him to match film sequences with the output of the studio colour cameras. The unit used for this purpose is known as TARIF (Technical Apparatus for the Rectification of Indifferent Film) and it permits correction of the gain and gamma of the colour separation signals, to compensate for any tracking errors which would otherwise cause colour casts in the high- and low-light areas of the reproduced pictures.

Camera line-up and checking

The operational line-up of the colour cameras is carried out by studio engineers attached to each colour studio. To avoid wasting valuable studio rehearsal and recording time, line-up is arranged wherever possible to coincide with meal breaks for the operational crew. Before each camera is lined up and put into operational use, the camera tubes are checked in a test channel against performance specifications previously agreed with the manufacturers. The parameters tested are sensitivity, resolution, transfer characteristics, linearity, lag, microphony, background (spots, blemishes, shading), geometry, etc. An important characteristic of the plumbicon tube is its lag and to check this, before the subjective effect on rehearsal pictures is examined, the tube is tested by exposing it to a pulse of light one field in duration. The resultant signal is viewed on a waveform monitor which also displays the following eleven fields. The decay time of the resulting signal is then checked to see if it is within critical tolerances. During operational line-up the cameras are exposed and focused on to a registration chart and the beam currents, focus, alignment, scan adjustments, and zoom tracking checks are carried out. Next, the picture registration is checked by comparing the red, blue, and luminance pictures with the green signal: any small errors are minimised by fine scan adjustments. The camera is then focused on a 30:1 logarithmic grey-scale chart illuminated with an incident light level of 1600 lux at a colour temperature of 2900°K. The chart also contains a super-black for setting up flare-correction circuits. Overall colour balance is obtained by a twitter method of displaying each signal waveform in turn against the luminance signal. This is achieved by the use of an electronic switch operating at 12·5 Hz and switching between the luminance, red, green, and blue waveforms. Any inequalities of signal amplitude or tracking are corrected by adjustments of individual lift and gain control.

Final colour balance and camera matching is obtained by a subjective assessment of the facial skin tones of an artist or a colour model girl, if one is available (Fig. 3). Wherever possible all cameras are set up on a similar medium close-up shot with the subject seated in a part of the studio set which is an average representation of the scenic design and background used in the production. This area is carefully checked for lighting intensity and colour temperature before the final colour balance takes place.

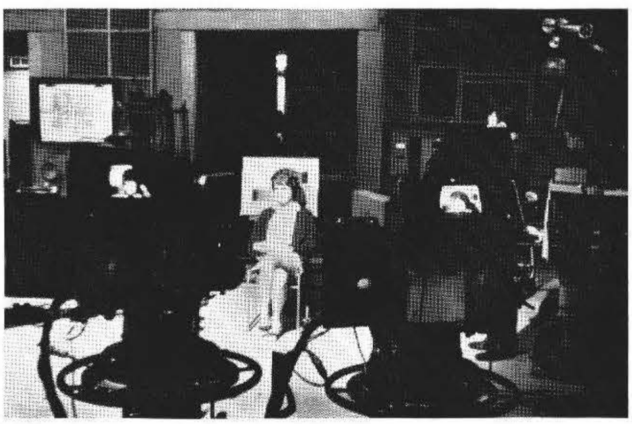

Fig. 3 Checking grey scale and colour balance during line-up period

Production planning

High-quality colour pictures, particularly for complex productions, can be achieved only by careful planning from the starting point. For major productions, all factors affecting the colours of scenery and costumes must be considered in advance. The choice of lighting depends upon considerations of camera techniques, artists' movements, and sound pick-up. Planning meetings well in advance of a production are attended by the director, designer, lighting director, costume supervisor and sound supervisor, and there is frequent communication between these experts throughout the preparatory stages. Costume and scenery colours must be in harmony and within a contrast range of 20:1 – minimum reflectance 3 per cent (black), maximum reflectance 60 per cent (white), Munsell value 2:8. During the planning stages the planning team consider such details as:

(*a*) the camera techniques to be used;
(*b*) the pattern of artists' movements and their close-up positions;
(*c*) the explicit requirement of the script, e.g. whether the scenes are interior or exterior, whether the time is day or night. For many situations the lighting requirements are well known;
(*d*) the implicit requirements of the script, e.g. the mood or artistic impression including the general atmosphere required by the director;
(*e*) the sound pick-up problems which are often aggravated by the choice of camera angles and split sound perspective;
(*f*) the overall visual presentation of the production including lighting, scenic design, costume, make-up, etc.

Usually on major productions the same team attends the outside rehearsal with the director and artists to finalise studio requirements well before the technical rehearsal is mounted in the studio. With such a close control of the operation, valuable studio rehearsal time may be used to maximum advantage.

Studio layout

The staff employed in colour studios are required to work at high studio productivity and work a shift day of at least twelve hours, possibly on two- or three-day productions. The environmental conditions for staff working under such pressure are of increasing importance. Not only must thought be given to the ergonomics of the layouts of desks and their controls but adequate room ventilation must be available to provide satisfactory working conditions.

Three main areas are used to house the sound equipment, production control room, and vision/lighting control room. There is also an apparatus room to house camera control, vision mixing, and distribution equipment, and some studios have a common caption room in which caption equipment is capable of being routed as a synchronous source to the vision mixer of a selected studio. This area contains vidicon monochrome transparency scanners and 60-slide flying-spot colour-transparency scanners. The monochrome equipment is coupled with a colour synthesiser, the remote control of which may be routed to each of the studios as required. In this way a choice of colour backgrounds and lettering may be produced from monochrome slides. An important factor in control-room layout is communication between the various personnel and it is essential that production and operational staff should be able to hear and at the same time see each other under certain operating conditions. Visual contact is maintained by windows between the production control, vision control, and sound control rooms. In addition, intercommunication sound systems are provided so that staff can speak to each other or receive instructions.

Monitor placing is important and should be such that staff can see them easily. A suitable viewing distance for a 19-in. colour monitor is 4 to 5 ft (1·2–1·5 m). Sound is also important and in all three control rooms there is a high-quality loudspeaker and the listening levels are adjusted so that artistic changes of sound balance or extraneous noises within or outside the studio are immediately detected. To this end the control room walls and ceilings are acoustically treated and the floors are carpeted. Each of the three control rooms has an observation window which provides a good view of the studio floor. These windows are double-glazed and have a cyan coating on one face and a magenta coating on the other. The resulting blue shade has the effect of raising the apparent colour temperature of the studio lighting to the operating colour temperature of the colour monitors in the control rooms. All colour monitors must be adjusted to give an illuminant 6500°K white-point at a brightness level of approximately 20 ft-lamberts. To assist with monitor alignment all areas are equipped with a white reference light box fitted with neutral density grey scale. An electronic wedge on the picture monitor is made to match this peak white, mid-grey, and black by progressive manipulation of slope, background, and R, G, B video gains. Considerable thought has been given to the local ambient lighting conditions and to effects of light shining from the studio and adjacent control areas through observation windows. A local ambient light level of 4 to 8 ft-lamberts, with a colour temperature of approximately 6500°K, offers the best compromise between comfortable and critical viewing conditions. All the colour monitors used are capable of good convergence, geometry, and grey-scale tracking and they achieve stability within about thirty minutes.

Programme chain

In the programme chain, all local and remote coded sources are fed via distribution amplifiers to switching matrices for selection by the vision mixer or to the various preview monitors. The coders for the monitors located in the control rooms are centralised in the Common Apparatus Room along with the vision mixing equipment and camera control units. In this way easy access is available for alignment.

A solid-state vision mixer consisting of two groups of 8-channel units is provided, each group being fed into two group cut/fader units which have electronic wipe control facilities. The first four inputs to the group mixers are tied to the local studio cameras and the next four fed via a selection unit which has access to all remote sources such as telecine, video tape, O.B.s, etc. These remote sources are routed to the mixer through the automatic phase comparator and return circuits provide error signal correction to the phase of the originating source sub-carrier.* The overall timing with this system is within ±25 ns and the phase of the sub-carrier is adjusted to be within two degrees. Central pulse generation is used at the Television Centre to feed all studios and in addition to the line trigger, field trigger, mixed blanking and mixed synchronising pulses already distributed, PAL colour working requires axis switching, sub-carrier and burst/gating pulses. These seven feeds together with test card F are distributed to all studios and picture sources from a main central apparatus room in the network areas. Locally-generated test signals in the studios include colour bars, saw tooth, step wedge, black-level, and picture line-up signals.

* In O.B.s, however, extra equipment either Natlock or Genlock is employed to achieve synchronous working.

Colour separation overlay

Experiments with a new form of colour separation overlay have in recent months been most successful and this new technique is rapidly being applied to studio operations and is being made an integral part of the vision mixing equipment. Overlay is a television process which enables a plain background against which an artist is being shot to be replaced by a scene provided by another camera, slide-transparency scanner, telecine or any other synchronous source. To do this a high-speed electronic switch operates on the change in the vision signal from the foreground camera when its scan passes from the artist to background and vice versa, in other words on a keying pulse at the boundaries of the artist's silhouette.

In monochrome this keying signal can be derived only as a result of a difference in tonal contrast between artist and background. In practice it is difficult to arrange for the necessary tonal values in the foreground artist picture to be distinct from those of the background. Shadows can for instance cause the newly-inserted background to appear in unwanted areas.

The colour television system, however, provides a simple means for deriving the keying pulses from the colour camera which has, of course, separate camera tubes for red, green, and blue signals. The studio arrangement is that the foreground object (which is to be inlayed into another background picture source) is placed in front of a plain background which is usually saturated blue. Strictly the background could be any primary colour but blue is normally chosen because the foreground object is generally a performer and flesh tones have little blue content.

The blue camera tube responds to all that is blue in the viewed scene. Because there is little or no blue in the foreground object and a considerable amount in the background, there is a significant change in signal output from the blue tube at the boundaries of the foreground object. This signal transition is shaped into a switching pulse which is used to actuate an electronic switch. As the foreground camera is applied to one input of the switch and the background camera to the other input the overlay process takes place, placing the foreground object effectively into the chosen background. The equipment being provided in colour studios uses the (B – Y) output from the camera and not the direct output from the blue tube. This makes use of the luminance difference (as well as the colour difference) between the foreground object and the saturated blue background and also ensures that the electronic switch does not operate on the blue content of a foreground white.

There is little doubt that this new process will have a big impact on BBC productions not only by providing a substitute for expensive scenic backgrounds but also by giving a considerable variety of visual effects and illusions. It is already being used with advantage in the field of Current Affairs, News, and Light Entertainment.

Results achieved

The installation of all this new colour equipment has required considerable further training for engineers and technical operators. Colour training is being carried out at the BBC Engineering Training Centre where engineers are given special colour courses. Following such courses they are given practical training in colour studios before they are required to work on colour equipment. Vision and lighting staff have also received courses and practical training in colour lighting techniques and vision control.

Experience has shown that studio staff have taken on the challenge of colour and quickly mastered its complexity. The size of this achievement can be measured against the fact that the expected productivity of a monochrome studio is between six and six and a half days a week producing approximately thirty minutes a day of programme material. For colour studios a six and a half day week is now expected, with half a day for maintenance, and even with extended colour line-up periods the same productivity has been achieved.

The success of the colour operation in the studios has been the result of team work between the technical operators, the studio engineers, and their colleagues in the specialist departments, as well as the programme production staff.

It may not be immediately obvious that the choice of colour system would affect studio operations, but experience has established the operational convenience of the PAL system. In particular its insensitivity to phase errors has enabled special effects such as split screen, inlay and overlay to be used successfully on the coded signal, and pictures from remote sources can be accepted as if they were locally generated.

Having contributed to the success of BBC-2 in colour, Television Studios Department are now engaged with the increasing challenge of introducing colour into the BBC-1 network.

BBC Television News—Alexandra Palace and the Television Centre Spur

H. C. J. Tarner*

Summary: The aim of Part 1 of this article is to outline the history of Television News Engineering and give an account of the engineering problems of News presentation. Part 2 describes the technical facilities for News presentation in the new building extension at Television Centre, known as the Spur, which was brought into service last September.

CONTENTS

PART 1 ALEXANDRA PALACE

1.1 Introduction to Television News Engineering

The principal aim of the television news service is to get news stories to the public. Television News engineers are responsible for the operation and maintenance of the technical facilities required to do this. The engineers must strive to maintain the highest possible technical standards but must be prepared to compromise if the picture or sound material is of low quality but of high news value. An important point is that World News is the only programme which can be daily compared on BBC and ITV transmissions. The public are quick to criticise if a network does not cover a major event or local news that they expect to see in a bulletin.

News engineering is concerned with news gathering and news transmissions. The latter are very concentrated, have little rehearsal, and may contain the results of hours of recording and video-tape editing. The technical services must therefore be able to provide the equipment and expertise necessary to enable the news material to be gathered, edited, and transmitted in the shortest possible time. For this reason, news engineering cannot queue up for shared facilities and must have its own equipment. The engineering staff must be flexible in outlook and be able to appreciate editorial problems. Experience has shown that engineer/operator staff are best suited to the technical duties and short-duration high-intensity transmissions inherent in a news service.

1.2 History of News Engineering at Alexandra Palace

It was decided in 1954 that live news bulletins should be broadcast regularly on BBC TV and that these would replace the Newsreel type of programme then being broadcast which used film presentation exclusively, based on cinema techniques.

A modest start was made in July 1954 in Studio A at Alexandra Palace (the original high definition electronic studio), using Standard Emitron cameras, and in June 1955, Studio B (the original Baird mechanical system studio) was brought into use using P.E.S. Photicon (image iconoscope) cameras. The film was reproduced on telecine machines consisting of industrial vidicon channels with 16-mm and 35-mm pro-

* Head of Engineering (Television News).

jectors. In June 1961 the high-velocity studio cameras were replaced by broadcast-quality vidicon cameras but the significant point about this installation was that the cameras were remotely controlled. Pan, tilt, zoom, focus, and iris for four operational cameras could be controlled by two engineers in the control room. In addition a supplementary close-up lens could be switched into each camera channel.

A news studio was set up at Broadcasting House and in October 1957 another for use by Parliamentary correspondents was formed in St Stephen's House on the Embankment. The latter studio had an industrial-type camera channel which was remotely switched on from the news headquarters at Alexandra Palace. When this studio was transferred to College Mews it was modified to have full remote control from Alexandra Palace, twelve miles away. Later a 'Telephone Dialling Control' system was installed which enabled up to ten electronic parameters of the camera channel to be controlled from Alexandra Palace in addition to the movements of the camera. Interview facilities were also installed in the Queens Building at London Airport.

Between 1958 and 1962 Regional news studios were set up at Bristol, Birmingham, Cardiff, Glasgow, Manchester, Belfast, Plymouth, Southampton, Norwich, Newcastle, and Aberdeen. Each of these studios was equipped with electronic and film cameras, vidicon telecines and film processing equipment. The outputs from these centres included local regional news and items injected into the main national news programmes. Regional contributions could be recorded at Alexandra Palace by a simple system consisting of a standard 16-mm film camera, shutter-phased, focused on a high-grade picture monitor. Later a quick-pull-down full-information professional film-recording system was installed and this in turn was replaced by video-tape equipment. The news headquarters also helped the regions by injecting programme material from the London area into their local programmes.

It is often necessary in news presentation to transmit photographs. Large photographs could be displayed direct to the studio cameras but for small photographs and facsimiles from a picture service, special equipment was developed. This had two ports with optical multiplexing to give mixing, fading, cutting, and soft wiping of the images which were directed via two optical paths into a vidicon channel. Each port was capable of holding at least twelve photographs each mounted in a sandwich of plastic and the transmission sequence could readily be altered. This equipment could also reproduce captions and animations and thus was a very useful tool in news presentation.

At this time, film was processed at Alexandra Palace and transmitted in negative form, phase-reversal being achieved electronically in the telecine channels; most of the film used was 16-mm but some 35-mm was received from such sources as libraries and members of the public sometimes offered hot news stories on 8-mm film. No professional 8-mm telecine channel was available and one was constructed using a projector and an industrial vidicon channel. This proved very useful and many scoops were transmitted directly from this telecine or via another recording medium such as video tape. Subsequently a more professional installation was made which multi-plexed into a standard 16-mm telecine.

The sound-on-film technique changed very early in BBC news operations from optical to a combined magnetic track using a stripe of magnetic material on the edge of the film. The 16-mm film cameras were modified in BBC workshops to record on this magnetic stripe and to work from a 12-volt battery. This eliminated the need for mains power and gave camera crews more mobility.

As part of the news-gathering technique, the daily Eurovision news exchange was developed and films and tapes made available via the Eurovision network. In this way international news was available in picture form at Alexandra Palace with negligible time delay: the need for aeroplane journeys and possible customs delays was thus avoided.

The need was felt for a film-exchange information system across the Atlantic to the North American continent, and BBC Design and Research Departments developed a system of transmitting 16-mm film frames using a slow scanning speed. The transmitter worked as a flying-spot telecine and the receiver as a flying-spot printer. This system became known as Cablefilm and enabled video information to be contained within an audio bandwidth and transmitted across conventional Post Office transatlantic sound circuits.

This new system was first used when H.M. the Queen opened the St Lawrence Seaway on 18 June 1959. The equipment was then transferred to the NBC building in New York and exchanges were carried out between NBC and the BBC in either direction for important news stories. It tended to be used more for transmitting to the USA because the time difference is in their favour by six hours. The main difficulty of this system was its slowness, because the effective bandwidth was achieved by increasing the scanning time by a factor of 100. Thus film occuping one minute at normal projection speed took approximately 100 minutes to transmit even though only every other frame was transmitted. The receiving equipment restored the normal number of frames by producing two images for every one frame of incoming information. Sound was transmitted separately and precautions were necessary to secure synchronisation with the picture.

Specially-designed news equipment included a 16-mm mobile telecine, a mobile processing vehicle, and mobile editing apparatus. These were housed in three 30-cwt vans and operated at conventions, London Airport, etc. An outside broadcast (O.B.) unit was required, and two 4½-in. image orthicon cameras were therefore installed in a similar van. The size of the vehicle was kept small to enable news events in the Greater London area to be covered without the disturbance that the large O.B. type of scanner causes to traffic.

1.3 BBC Network 2

The introduction of the second BBC channel on 20 April 1964 posed new problems because of the 625-line standard. This meant that line standards in the studios had to be changed for different programmes but the biggest problem was that video tape recordings were required on both 405 and 625 lines. Moreover some regions were capable of working on the 405-line standard only. Thus a considerable amount of standards conversion was inevitable and it was quite normal for stories to suffer two standards conversions before transmission; these were usually carried out on optical converters.

The problems for engineers with the constantly-changing news demands were considerable. One optical converter was available at Alexandra Palace but more sophisticated electronic converters became available later at the Television Centre and traffic into and out of the Centre for conversion became continuous. This problem diminished as more picture origination on 625-lines for internal use took place. The News programmes were some of the first to originate on 625 lines and be down-converted to 405 lines on a regular basis.

Another problem stemming from the second network was that stories needed to be treated in greater depth for the longer News bulletins on BBC-2. This necessitated making prints from all the original negative cine film material before it was edited. The prints were then available for BBC-2, the original negative being kept for BBC-1.

To produce the positives, two printers were installed. These were capable of producing from a commag* negative either a commag positive or a mute print and a separate magnetic track. As equipment to do this could not be bought from one manufacturer, the sound section was bought from one and the picture section from another, and the two parts were 'married' together by the BBC's Planning and Installation Department.

An interesting problem was the provision of sub-titles for the 'News Review for the Deaf' programme which reviews the week's news and adds captions line by line to provide a summary of the news in the sound channel.

This was solved by employing a standard electric typewriter which used silver ribbon and black paper. The paper was then transferred to a matched electric typewriter carriage which supplied the traction to move the paper from a feed roller through a "letterbox" slit. The opening was viewed by a vidicon camera in the small objects (micro) caption scanner and the output inserted into the main vision feed with a black edge electronically framed around the letters.

1.4 Colour

The next major development was the introduction of regular colour programming on 2 December 1967. This required new equipment but the amount to be installed at Alexandra Palace was kept to a minimum because a large new installation for news was being built in the Spur at Television Centre.

It was decided to standardise on 16-mm Kodak E.F. 7242 reversal film which is designed for exposure in artificial light with a colour temperature of 3200°K. This film has the required high emulsion speed and has been proved in operational use in North America. It is possible to under-expose this film by 1, 2, or even 3 stops corresponding to speeds of 250, 500, and 1000 A.S.A. and to compensate in the ME-4 processing. If the film is exposed in daylight, correcting filters can be used and the loss in speed is not too serious. Courses were organised to train camera crews in the use of colour film and the rushes were scrutinised until the techniques were fully mastered.

For years BBC News had used a commag negative film but it was necessary to switch to a commag reversal system. This required the production of monochrome negative copies for BBC-1 and duplicate colour positives for use on 'News Review' and other programmes where considerable editing was needed, such as the late News summaries. To cope with this, the monochrome printers had to be modified to give colour facilities, and to allow for the increased thickness and reduced resolution of the colour film, tolerances on the film camera lenses were carefully checked and traction mechanisms adjusted.

Colour captions are usually in the form of 35-mm transparencies and equipment was developed to allow slides and opacities to be multiplexed into a common optical path to enable a colour camera to view them. In addition, equipment using commercially-available slide projectors was manufactured to enable images to be projected behind the newsreading positions.

To add to the complications of colour it was decided that the main news on BBC-2 should be brought forward from the late evening to 7.30 p.m. This meant a considerable reduction in the time available for the preparation of film and film processing.

An additional difficulty was that the provincial centres which could supply local film were not colour capable and an aircraft had to be chartered to bring the film to Alexandra Palace for processing and transmission.

Much training was necessary to prepare staff for colour operations but generally speaking the introduction of colour news on 5 February 1968 was a great success and viewers were impressed by the increased information available in coloured pictures. BBC News has the task of telling news in the shortest possible time and in a condensed form: it is easier to convey this information if colour is available.

PART 2 THE SPUR: TELEVISION CENTRE

2.1 Introduction

The Television Centre Spur has been designed for Television News. Initially the Spur was planned for one network: later it was modified for two monochrome networks and finally for two colour networks. Although primarily built for News, the Spur also contains one production studio, T.C.8.

2.2 Brief description of technical facilities

The News installation includes studios, telecine and video tape areas, a film processing section, film workshops, cutting rooms and, of course, Newsrooms, offices, etc. The basement contains an underground car park for news operational vehicles.

The installation is primarily for the 625-line 50-field PAL colour standard but pictures can be originated on NTSC 525-line 60-field standards directly or via a converter. Experience gained from the news operation has been incorporated into the planning and future requirements have been anticipated as far as possible, although operating techniques in colour are still being developed.

2.3 Detailed description of technical facilities

2.3.1 Basement

The basement contains a large garage primarily intended for film camera cars but with facilities for parking the News O.B. unit. There is a small workshop to service this unit and also space for storing equipment, film, chemicals, and stationery.

* A picture film with a combined magnetic sound track.

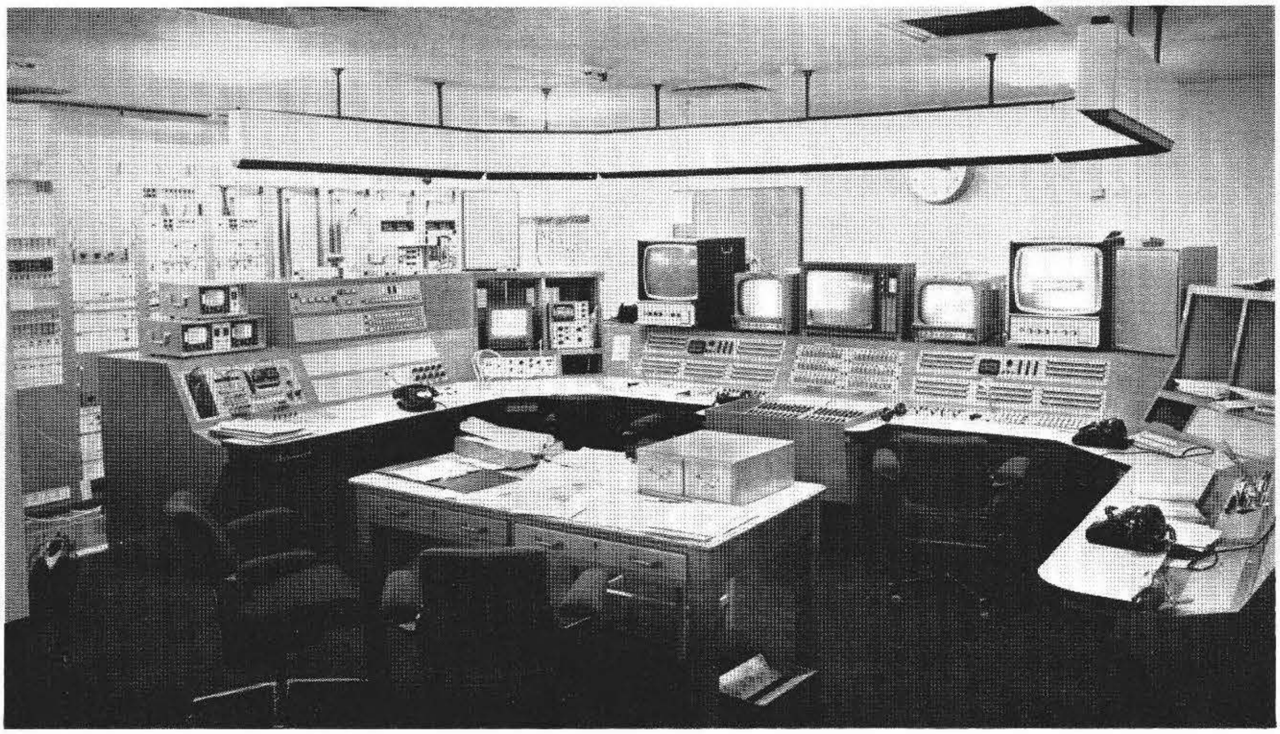

Fig. 1 Control positions in sub-central apparatus room

2.3.2 Ground floor

This floor is occupied by Studio T.C.8 and by News film despatch rooms. An interesting feature is that in addition to the normal passenger and goods lifts there are two film hoists, one for transporting film to the processing area on the third floor, and one for transporting the processed film to the telecine area on the fourth floor.

2.3.3 First floor

This floor contains the sub-central apparatus room (sub C.A.R.) in which the many communications facilities required by the News Service are controlled. The sub-C.A.R. has its own genlocking equipment and pulse generators as well as feeds from the main Television Centre pulse chains. It also supplies all technical areas in the Spur with sound, vision, pulses, and communications facilities. The sub-C.A.R. also co-ordinates the output of news sources in the Spur with other areas in the Television Centre and with the external switching centres of the simultaneous broadcast network. The main sound routing system in the sub-C.A.R. has 100 sources, each of which can be connected to any of sixty destinations. Fig. 1 shows the control desk in the sub-C.A.R.

Facilities also exist for remote control of the camera at the Parliamentary Studio. The sub-C.A.R. has on-air programme switching facilities which permit two or more sources to be combined without the need for manning a studio control room. There are also facilities for comprehensive video and audio checking and for controlling the main power switching into the Spur. The sub-C.A.R. and other operational areas in the Spur are interconnected by an elaborate engineering, production, and editorial intercommunication system with about ninety subscribers. The number of subscribers at any one station has been predetermined according to their operational requirements. The sub-C.A.R. also has a 100-way engineering telephone routing panel and normal talkback facilities. The switching systems in the sub-C.A.R. can be 'overplugged' to give maximum flexibility.

2.3.4 Second floor

This floor contains a sound studio and audio tape editing rooms for the television service.

2.3.5 Third floor

This floor contains video-tape and film processing areas and the senior engineering offices. The video-tape and film processing areas are adjacent because at the time of the original plan, film was the main recording medium and it was logical to have the processing facilities next to it.

a Video-tape area

This section has four Ampex 1200B colour video-tape recorders with space for more if required. The machines are housed in separate cubicles but sliding partitions enable them to operate in groups if required. At the centre of this area there are two quality check rooms. These enable the senior engineer to monitor the quality of the recordings and also enable programme staff to cue other recording channels during multiple long-term recordings. Normally the editorial staff concerned with a video-tape recording would be with the engineers in the cubicles. The machines have facilities for selecting any programme source for recording. Moreover multi-V.T.R. replays can be switched to common destination lines into the news studios and sub-C.A.R.

b Film processing

This area is equipped with three large Photomec colour processing machines (Fig. 2) operating on the Kodak M.E.4 process, a Lawley Unicon machine, and two black-and-white processing machines.

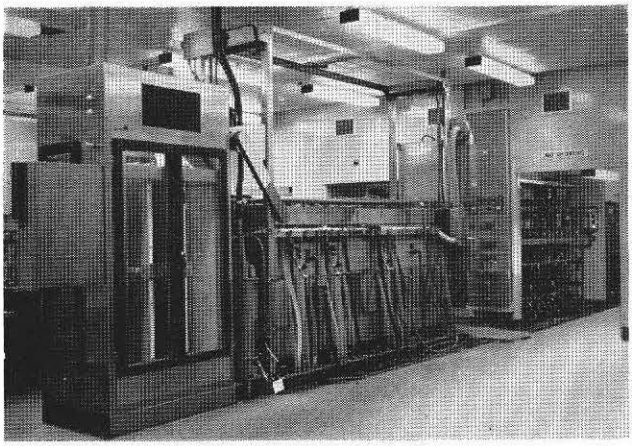

Fig. 2 Photomec colour film processing machine

Silver recovery units are coupled into the fixer circulating systems of the Photomec machines and silver is also recovered from the fixer effluents of all the machines.

A large additive printing machine with A and B facilities for making fades is installed. In addition two sets of printing equipment, already modified for colour work, were transferred from Alexandra Palace, together with a new subtractive printer of this type. This area also contains rooms for sensitometry, densitometry, chemical mixing, and print grading.

2.3.6 Fourth floor

This floor contains a large Telecine area equipped with nine 16-mm colour machines, two of which are multiplexed to deal with 8-mm and super 8-mm film. There are also two 16-mm monochrome telecines.

Additional facilities on the fourth floor include three review theatres, seventeen cutting rooms, a library cutting room, three film make-up rooms, sound track-laying rooms, optical and electrical workshops, foreign news communication equipment, and facilities for dubbing.

a Telecine section

i *General* The two monochrome machines were designed by the BBC's Designs Department. Seven of the Plumbicon three-camera-tube colour telecines were developed from these machines by Philips/Peto Scott and use the same type of Siemens Bauer double band projector.* The other two colour telecines are made by Pye and have four Plumbicon camera tubes and Philips' projectors. These can operate on 625-lines 50-fields and 525-lines 60-fields: they can also operate with 8-mm and super 8-mm film in addition to 16-mm. Sound for these two telecines is reproduced from conventional sepmag tape machines.

* This projector includes provision for a film carrying a sepmag sound track in addition to the picture film.

ii *Philips/Peto Scott Telecine* As mentioned, the majority of machines are of this type and, therefore, the projector facilities and signal control system that they use are described in more detail. These facilities are also common to the monochrome telecines.

The Bauer Projector main motor is driven in synchronism with field pulses. The machine can accept 730 m of film (giving over one hour's total running time) and a sepmag track film can be loaded on to the integral system or laced on a separate sound reproducer locked to the projector by a selsyn system. Two separate tracks can be interlocked using these facilities; comopt and commag sound can be handled in the normal way. Three machines have additional equipment to provide commag and internal sepmag sound recording facilities.

The projectors can run up to operating speed and be braked very quickly; this is important for telecines required to reproduce a number of short inserts into a closely-timed News Bulletin. The traction system of the projector can also be reversed.

An automatic light control system compares the video output with a reference potential which is determined by the setting of the light control, and uses the resulting error signal to control a motor-driven light valve in the projector. The time constants for 'increase' and 'decrease' correction of the output signal are different.

The optical coupling system between the projector and the camera lenses is of the telecentric type.

iii *Telecine Programme Control* The telecine machines are set up using special maintenance and colour test trolleys after which the machines are controlled at four desks, the following three being in the telecine area:

Desk 1: handles up to six telecine machines and is primarily used for BBC Network 1.

Desk 2: is identical and primarily used for BBC Network 2.

Desk 3: can also handle up to six machines and is used to feed BBC regional centres and areas outside the main news complex with film inserts. Its main purpose is, however, to feed two electronic film-viewing theatres adjacent to the telecine. Desk 2 is shown in Fig. 3.

Fig. 3 Telecine control desk, showing six telecine control positions and one supervisory position

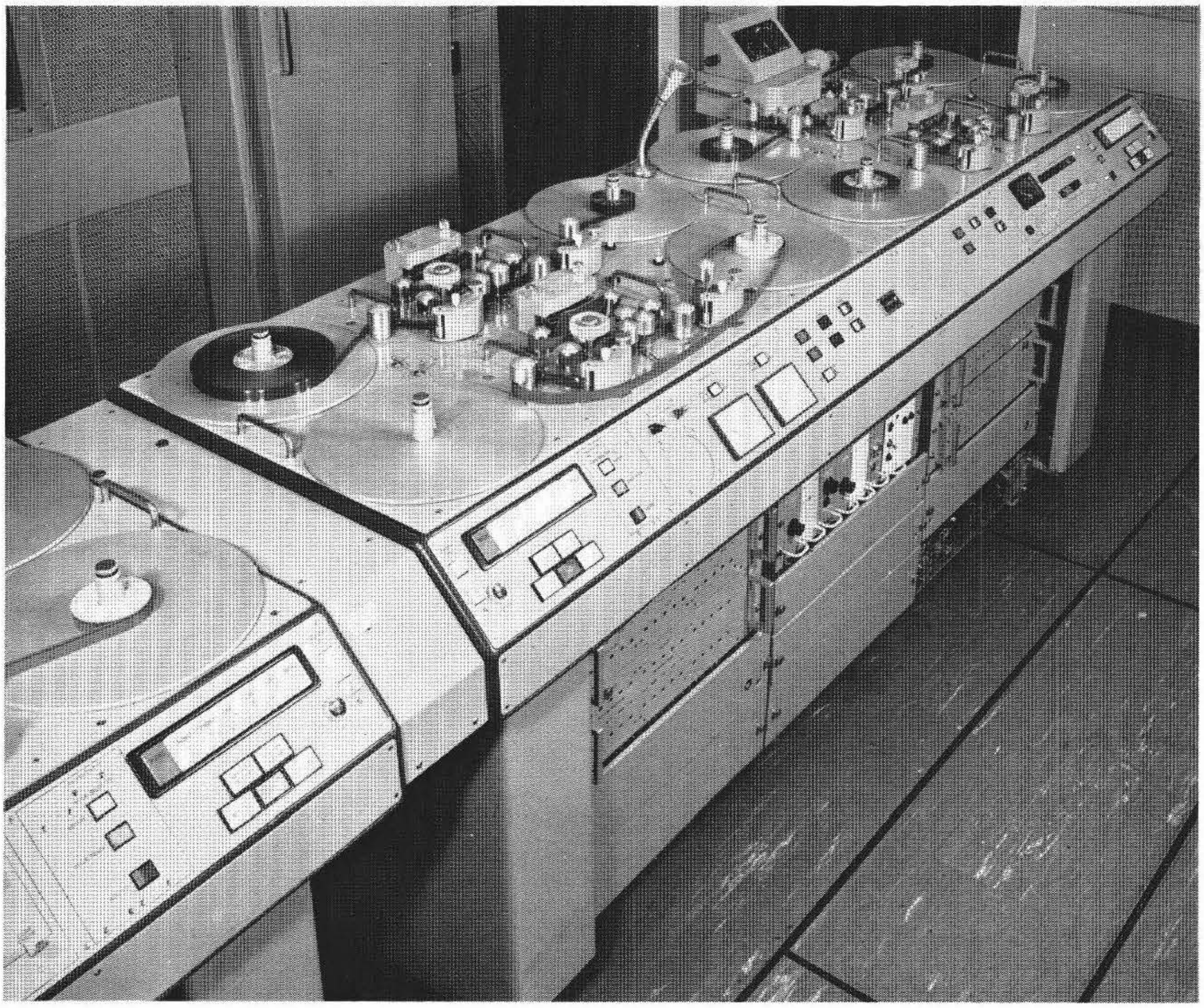

Fig. 4 Keller film dubbing machines

In addition to the main telecine desk-controlled switched feeds there are auxiliary parallel feeds from the main outgoing vision and sound lines. For example, the electronic viewing theatres, in addition to their own selectable feeds, can display the telecine output on the main transmission lines into the studios. The system is flexible and any telecine positions on the three desks can feed any of the nine main lines although usually the desks are locked to their three normal destination lines for a particular transmission. For colour reproduction the telecine machines are automatically phased with the central mixing point when selected.

iv *Telecine Film Review* The electronic method of reviewing film was chosen because:

1 The film is viewed via the medium for which it was intended.
2 It is seen at the same size and under approximately the same conditions as in the viewer's home.
3 It can be seen after electronic corrections have been applied.
4 The signal can be phase-reversed if necessary.
5 The film can be distributed on internal viewing systems to offices if senior editorial decisions are required and to any other staff who may need to see it. The numbers are not limited to those in the viewing theatre.
6 Electronic viewing theatres are cheap and easy to construct. The associated telecine facilities will normally be provided by the operational machines.

b Dubbing section

The Keller machines (Fig. 4) used for dubbing have facilities for reproducing film audio tracks of all standards and recording them on a master track, the picture being displayed by a vidicon system. The sound being recorded is controlled from a small desk in the Keller machine room or a larger sound desk in the sound and vision dubbing control room. This area is also equipped for dubbing on to video-tape machines and has a vision mixing desk complete with colour monitor displays and a control position. This position is in fact the fourth desk already mentioned as associated with the telecine area. This desk can control remotely up to six video-tape machines or telecines but only two of the inputs have TARIF* facilities. Associated with the control room there is a dubbing studio for

* Technical Apparatus for the Rectification of Indifferent Film.

Fig. 5 Plan of the sixth floor of the Spur, Television Centre

commentary purposes with gramophone and tape facilities and film-to-film and film-to-tape transfer equipment.

Next to the dubbing suite is a recording and sound transfer room. This contains two 16-mm sepmag machines with tape interlock facilities, disc reproducers, and audio tape machines for transfer work, and communication channels for receiving correspondents' despatches. For simple transfer and effects work a Keller machine is provided in a separate room. The rest of the floor is devoted to offices and the photographic library.

2.3.7 Fifth floor

This mezzanine floor contains a few News offices.

2.3.8 Sixth floor

A plan of the sixth floor, which can be described as the output floor, is given in Fig. 5. In addition to a large Newsroom it has two studios each 110 m² in area and equipped with four remotely-controlled Marconi colour cameras.

a Studios

The studio lighting grid is made up of tracks with turntables at each end. The dual-source lanterns* are on rolling pantographs. There are two large control rooms, one for each studio, and separated from the studio by a glass partition.

* These lanterns are widely used in BBC Television studios. One source gives a hard light and the other a more diffuse light.

The control rooms are divided into raised islands, one of which is for the sound mixer and his disc and tape machines. This island is partially screened by glass which gives some acoustic isolation but enables the sound mixer to keep in touch with control-room operations, an essential requirement in constantly-changing News programmes. Another island supports the editorial desk and on the floor level

Fig. 6 Control console for lighting and camera positioning

is the production section containing vision mixer, production assistant, senior television engineer, and secretarial positions. The remaining island houses the vision control and lighting console (Fig. 6). The vision control positions have full remote control of the studio cameras (Fig. 7). There are in each studio four panels each enabling up to twenty pre-set

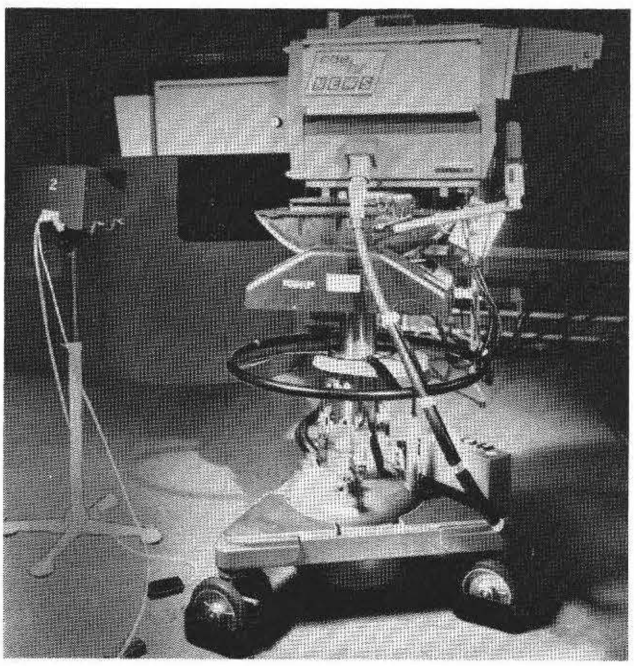

Fig. 7 Remotely-controlled studio camera

camera shots to be adjusted after which information on these shots can be fed into a ferrite-core memory store in the vision apparatus room. For each of the twenty shots per camera, information is stored on the position of pan, tilt, zoom, focus, iris, and master lift. For four of the eight cameras information on camera pedestal height can also be stored.

The analogue voltages corresponding to these control functions are transformed into a digital code for storage. When the appropriate shot-selection button is pressed, the stored information is reconverted into a control voltage and fed to the appropriate motor.

The information is retained in the store until fresh information is substituted from the positional controls and the store selection button is pressed. These controls enable a shot to be trimmed and do not alter the stored information if the store button has not been operated.

The twenty shots per camera are conveniently laid out so that ten are on Bank A and ten are on Bank B and a change between a position on one Bank to another on the other Bank is possible using a 'shot' fader. Direct shot-position cutting is also possible. In addition a manual control box can be substituted for the memory store. It is also possible to disconnect the remote control system and use operators on the camera dollies who can then operate the zoom and focus servos locally. A magnetic store was chosen for holding the information representing camera settings because this greatly reduces the number of controls and associated panel space needed. In the Alexandra Palace system the information was stored in the settings of the control potentiometers, so that the storing of five camera functions for each of six shots needed thirty controls for each camera channel. In the Spur, seven camera functions can be stored for each of the twenty shots. This would require 140 controls for each camera channel with the Alexandra Palace system, whereas the magnetic store enables one set of seven camera function controls to be used for setting up all twenty shots – i.e. seven controls only for each camera channel. In addition to the camera positioning panels, RGB, lift, and gain controls are provided for colour matching on each channel.

The engineers function as camera position controllers and vision control operators. The monitor configuration is laid out with these two functions in mind and the monitor screens are arranged to be close to the engineers to enable them to adjust camera focus accurately.

b Vision apparatus room

The camera control units and ancillary apparatus for these two studios and other areas on the sixth floor are housed in a central vision apparatus room. The vision mixing equipment is of the conventional A/B type with wiping and colour separation overlay (Chroma-key) facilities.

c Conference room

A conference room of area 56 m² capable of originating small programmes has been constructed on this floor and up to two colour cameras can be moved to this room from the news studios.

d Conference control room

A small control room built adjacent to this conference room has conventional control-room positions and two remote camera control panels which use the memory store in the vision apparatus room.

e Central Newsroom

The large Newsroom has communication facilities, teleprinters, and a permanently installed monochrome camera. In addition two colour cameras, one on remote control, can be installed in the Newsroom if required. Operation of these colour cameras is from the small control room mentioned above.

f Caption and inlay room

Captions, either opacity or transparency, are originated in a special control room equipped with a monochrome micro scanner. This is used for inlaying the sub-titles in the 'News Review for the Deaf' programme (see 1.3), and includes a colour synthesiser enabling a two-tone monochrome caption to be reproduced in two colours. Two single-port opacity, two 2-port, and two single-port transparency flying-spot caption scanners are also installed. Some of these have an optical offset facility to improve picture composition when colour separation overlay (Chroma-key) inserts are made in the newsreader presentation shots. A control desk with TARIF facilities is provided in this caption area.

g Auxiliary areas

Auxiliary areas on this floor are an unattended sound studio, an electronic workshop, a small catering area, graphic artists' room, offices, and a photographic processing suite. This contains rooms and equipment for negative developing, copying, enlarging, and print developing both for monochrome and colour stills as well as transparencies.

2.3.9 Seventh floor

This floor contains conference rooms, one equipped for inter-station conferences. There are observation rooms for viewing the News studio operations.

PART 3 CONCLUSION

The last News transmission took place from Alexandra Palace late on Friday, 19 September 1969. Overnight all the equipment needed in the new headquarters, including colour cameras, Keller dubbing equipment, libraries, and filing systems were transferred by a fleet of vehicles to Television Centre Spur.

The co-ordination of this move required comprehensive labelling and colour coding to ensure that equipment arrived in the correct room in the required order of priority. To ease removal of equipment from Alexandra Palace a hoist was built externally to the fifth storey of the main tower and flood lighting installed. The entire move covered two days but the essential equipment was in place by the next morning.

The News operation went into action according to a normal Saturday schedule on 20 September, the first transmission being an insert into *Grandstand* at lunchtime. Routine colour and monochrome programmes were transmitted in the evening. This was the biggest move that the BBC has ever made but it went well and there was negligible damage or loss of equipment.

The Spur has now been in operation for four months and, although the installation is not quite complete, no major operational or engineering troubles have been experienced. The increased facilities are being successfully incorporated into the programmes and the flexibility of the installation is appreciated by staff.

Twelve Years of Video-tape

John Nash*

Video-tape recording has been used by the BBC since 1958. Although few people foresaw its potential importance when it was introduced, the fact that more than half of all BBC television programmes are now recorded on video-tape or have used the system at some point in their preparation does not provoke any surprise nowadays.

During the early years of television after the war, machines were developed to record television pictures and sound on photographic film: such telerecordings were greatly used at this time and provided a valuable means of programme storage. Both engineers and producers, however, felt the need for a recording system which could be replayed immediately, like sound recordings on magnetic tape. Attempts were made to develop tape recorders in which the bandwidth needed for a video signal was obtained by passing a magnetic tape over a fixed recording head at about 200 in. per second, but the first equipment to promise any real success was the Ampex VR1000, in which the quadruplex transverse-track recording technique appeared for the first time. In this system the essential high head-to-tape speed is obtained from an assembly carrying four recording heads and rotating at about 15,000 r.p.m. on an axis parallel to the length of a 2 in. wide magnetic tape which moves at a relatively modest 15 in. per second. The video information is thus recorded in a series of parallel tracks nearly perpendicular to the length of the tape.

Beginnings of the Video-tape Section

This system seemed likely to gain world-wide acceptance, and accordingly two of the American machines were bought by the BBC, the first being eventually installed at the Lime Grove television studios. After investigations by the Research and Designs departments had been completed, two engineers in the television studios were given the task of mastering what must have seemed a formidable piece of electronic equipment.

Official transmissions began on 1 October 1958 with a three-minute trailer for *A Tale of Two Cities*. Very soon, more ambitious projects were being covered, including complete schools programmes and various sporting items. In January 1959, the second machine was installed, an operator shift system was started, and it could truly be said that BBC's Video-tape Section had been launched.

These early efforts indicated a tentative approach which seems quaint judged against today's streamlined arrangements. Each recording was booked by separate memo and transmission was frequently backed by a film telerecording as a safety measure. Clearance of programmes for tape erasing was a particular problem; with a total of only a few dozen tapes available for use, there was no chance of storage for the future.

The first machines were equipped with basic necessities only: there were no such extravagances as tape-timers or rewind facilities. If, for example, the 'Grandstand' director asked the video-tape operator to replay the last one minute and forty-two seconds of the game up to a particular goal, the operator had to find the point where the ball entered the net, carefully lift both spools, and interchange them. After relacing, he ran the machine forward and used the wall clock to time the reversed tape back to the required starting point. This cumbersome procedure took several minutes and has, needless to say, been superseded. Present-day machines can be run backwards and the tape can be timed in either direction (remotely if need be) from digital-reading timers.

Another rather surprising omission was the absence of a machine erase head. Bulk erasure was the only method of removing previously recorded signals. This meant that, even in an emergency, it was not possible to go back and record over a part of the tape that had just been used. If there was insufficient tape to re-record part of a programme, the only alternative was to use a fresh tape: because of the limited supplies available the decision to change tapes was not one to be taken lightly.

Expansion of video-tape facilities

With the opening of the Television Centre in 1960 came two more machines which were initially operated in what is now part of the Presentation Studio complex, but were later moved down to VT's present home in the Centre basement. Subsequently, a further four machines with various design improvements were installed in this area. Counting the two early machines at Lime Grove, the section now had a total of eight operational machines. Additional units incorporated in the new recorders made it possible for them to be fed to studio mixers as synchronous sources. These developments established video-tape recording as an important part of the television scene. Up to this time, the video-tape machine servo mechanisms (for controlling longitudinal tape movement and rotational position of the four-head drum) had been effective only in maintaining adequate continuity of video signal. Now, however, with these improved mechanisms, tighter control was exercised and the output sync-pulse timing variations

* Technical Author, Technical Publications Section.

were reduced to within the limits required for synchronous replay. Admittedly, it was with bated breath that the operator waited, first for studio cue and then for the machine to run into synchronism.

One of the early problems facing the crews as they sought to establish their claim for serious consideration was the annoying presence of tape 'drop-out', which gave tell-tale white flashes on the screen. Prevention rather than cure was first thought to be the answer. All new tapes were initially polished by passing them through a recorder fitted with a special headless drum; the tapes were then inspected for remaining drop-out by recording a blank-screen signal (constant black level) throughout the tape length, and subsequently watching for white flashes during playback: for sheer tedium this task had no equal. Various methods of automatic drop-out measurement have since been developed but the modern practice is to accept the fault as an almost natural hazard, and to compensate for it electronically during playback.

The deluge

Transistorised equipment came next. Four RCA TR22 recorders arrived, and with them an unexpected inundation; a deluge not of extra bookings but, strictly according to the dictionary definition, of water!

It happened one Saturday just as operators were preparing for the evening's work. Someone heard a dripping sound, which bore no relation to any of the programmes showing on neighbouring monitors. Water was seen cascading down a wall and gathering on the ceiling above; the staff quickly realised that the pool over their heads (with Ariel resplendent above, and round which the Centre building arc curves) was leaking and that it held a lot of water! The drips became a steady stream. Doors were hastily detached from bays and positioned to direct the water from live apparatus. The door into a temporary test room was broken open to reveal one of the precious new machines receiving an unscheduled wash; cables leading to it were uncoupled or simply cut through so that the machines could be removed from the shower and, finally, plastic sheets were found to cover up any remaining equipment which could not be moved. Bookings were speedily rearranged (the crews are still most adept at this art of instant rearrangement) and work in the rest of the area went on normally. The whole of that night was spent in mopping up and the next day all except one of the machines affected worked perfectly. Paradoxically, the fault on this particular machine was subsequently traced to a 'dry' joint!

625-line working

The four new equipments were installed, ceased to be regarded as nine-day wonders, and joined the older types in time for the beginning of BBC-2 and 625-line working. By now, the operating staff had been increased to about 30 engineers arranged in two shifts.

Sports coverage

More members joined the section in readiness for expansion and in particular for the World Cup programmes in 1966. This proved to be the biggest enterprise in concentrated effort; it was nothing out of the ordinary during those hectic days to wander through the cubicles and count upwards of 60 monitors showing matches being recorded, dubbed, edited or transmitted. The place echoed to the roar of a hundred thousand voices in acclamation of numerous goals – and also, it seemed, to as many multilingual commentaries!

The coverage of this series showed a remarkable degree of liaison between the Sports Department and Video-tape Section. Even so, it represented only a normal Saturday afternoon's 'Grandstand' multiplied several times. The facility of quick turn-round between recording and replay was like the breath of life to sports programme directors, and they were among the first to make full use of the operators' increasing skills in this and many other facets of video-tape use; over the years, they have become almost as eager to accomplish the impossible as the directors are to ask for it. There is no doubt, too, that sports programmes are more hungry for tape than any other type of broadcast. During a typical Wimbledon fortnight, for instance, at least 130 tapes are used; at 90min. per reel, this represents about 200 hours of recorded material.

Clogging

An operational problem which became evident at this time was that known as 'clogging'. The four video heads, sliding across the tape at about 100 m.p.h., tend to pick up minute particles of the oxide coating. These particles build up into an appreciable layer on the head tips and increase the effective distance between tape and head with a consequent reduction in recorded or reproduced signal level. If only one head is affected, the result is several horizontal bands of 'noisy' picture, each containing some 15 scanning lines; severe clogging can result in complete loss of video information.

The problem has become worse in recent years, possibly due to the finer oxides employed by manufacturers as they strive to accommodate the ever-higher recording frequencies being used. A satisfactory answer has yet to be found, although repeated cleaning of the heads and tape guides does help to reduce the number of occurrences to a minimum.

Colour

When BBC-2 started colour transmissions in 1967, the Video-tape Section was ready to meet the fresh demands with seven machines capable of handling the composite colour signal. The necessarily greater degree of signal-timing stability meant that the tape movement and relative head-drum position control arrangements had to be more strict, and thus more complicated in instrumentation. A special problem in colour video-tape recording is, in fact, concerned mainly with the requirement that correct relative head-to-tape-track position and speed is consistently and precisely maintained between recording and playback. Subjectively, any departure from the ideal appears as changes in hue and/or saturation in bands across the pictures and is therefore known as 'colour banding'. Additional units in the machine signal circuits decrease this banding by compensating for the more predictable forms of timing error, while care in preparation of the machine (mechanical and signal-circuit adjustment) before both recording and replay can further reduce it to an acceptable level. Generally, however, because many of the requirements for satisfactory signal transfer are conflicting, compromises are necessary and even the near-ideal is reached only by experience.

Fig. 1 Editing video-tape by splicing

Electronic editing

The new recorders are also equipped with electronic editing units. Instead of physically cutting and joining the tape (this process, shown in Fig. 1, is not only wasteful but somewhat clumsy, even though expert operators have made minor miracles quite commonplace), electronic counting circuits arrange that the machine is automatically switched from replay to record at the end of one section of previously recorded programme so that there is no loss of continuity in the video, sound, or control signals on the tape. On replay the transition appears as a studio camera cut. When a section of the programme already on the tape is to be replaced with material from another source, the same mechanism can subsequently produce a timed switch back to the replay mode so that the result appears as a cut into and out of the other material. All this is accomplished without any visible mark being made on the tape. A further advantage of this form of editing is that it can be carried out during the recording session; thus, because the actual timing of the cut can be controlled from the gallery, the programme director or producer is closely involved in the process which has hitherto been regarded as an engineering activity.

Other aspects of video-tape operations

The Video-tape Section at Television Centre maintains a programme tape store of nearly 12,000 separate items, and mounts some 400 recording, playback, or editing sessions each week. The non-engineering staff are responsible for organising bookings, maintaining the supply of new tapes, and looking after the store of recorded programmes. The Television Centre is not the only place where video-tape recordings are carried out: there are also regional video-tape sections whose task differs only in scale from that of their colleagues in London.

The future

The present machines, which might be considered the second generation, show a remarkable improvement over the first. There would seem to be little room for further development, but a third and subsequent generations are almost inevitable. Further borrowings from computer and allied techniques could reduce the inherent system-timing instability to such a degree as to make additional error-correction units unnecessary. There would, in fact, be no need for the current methods of successive approximation to the ideal. Beyond these changes could well be reduction in the size of the machines and, more importantly (for economic reasons concerning transport and storage of tape), the recording medium itself.

Progress in the Use of Pulse-code Modulation for High-quality Sound Links

D. E. L. Shorter*

Summary: The feasibility of p.c.m. as a means of distributing high-quality sound signals has now been established and one application – the incorporation of the sound signal within the video waveform on the link between studio and transmitter – has already been practically demonstrated. The possibility is now being explored of using multichannel p.c.m. systems to distribute monophonic or stereophonic sound signals together with various ancillary services. Some technical problems peculiar to this use of p.c.m. are discussed with reference to the results of recent investigations.

Present stage of development

Pulse-code modulation (p.c.m.), by reason of its inherently stable characteristics and its high degree of immunity from distortion and noise on the transmission channel, is a very attractive method of distributing sound programmes over a nation-wide network. A BBC monograph[1] published in December 1968 described a theoretical and experimental study carried out by the BBC to assess the feasibility of this application of p.c.m.; the present article gives an outline of some subsequent developments.

In the publication referred to above, the possibility of distributing the sound signal associated with a television programme in the form of p.c.m. signals incorporated within the video waveform was considered, and brief reference made to a system in which the time interval within the line synchronising pulse was utilised for that purpose. Experimental apparatus[2] working on this principle has now completed a series of service trials (believed to be the first operational application of p.c.m. to high-quality sound signals) over the vision link from London to Kirk o'Shotts in Scotland, and has been demonstrated on the Eurovision network between London and Copenhagen; the system, now known as 'Sound-in-syncs', has reached the advanced design stage and is expected to come into service during 1970.

As the next logical step in the application of p.c.m. to the distribution of sound signals, further attention is being given to the requirements of the home radio programmes, both on mf and vhf as well as those of the overseas services. Here, in the absence of various constraints which operate in the case of 'Sound-in-syncs', a variety of possibilities are open.

Requirements for vhf radio

The most stringent technical requirements are those imposed by the vhf radio service, in which a high signal-to-noise ratio is required. If quantising noise could be assumed to take the form of a smooth hiss, a 12-digit code would be adequate[1] even in the absence of the various known noise-reducing artifices. This assumption, however, is not justified at very low levels for which the signal excursion is no longer large compared with the magnitude of a quantising step; in these circumstances, audible distortion of the signal – known in p.c.m. telephone systems as 'granular effect' – appears. In designing a p.c.m. distribution system for the vhf broadcasting service, the granular effect has to be taken into account because of the wide dynamic range of the signal and the possibility that some listeners may reproduce sound at so high an average volume that in quiet passages distortion components comparable in level to the system noise may still be audible. Recent subjective tests indicate that with a linear analogue-to-digital conversion, a 14-bit p.c.m. code would be required to remove the last trace of granular effect on critical programme material.

The granular effect in quantised sound signals corresponds to the production of spurious contours in quantised television signals. In the latter case a known remedial measure[3] is to add a small amount of random noise to the signal before coding, to produce the effect of interpolation between quantising levels. Alternatively, the interpolating waveform may consist of a single component locked to half-sampling frequency and having a peak-to-peak amplitude equal to half the interval between quantising levels; this component, being outside the transmitted band, is automatically removed by the filtering at the receiving terminal. Both these artifices are applicable to sound signals, and by the combination of the two it has been found possible, with a 13-bit code, to satisfy the requirements for both distortion and signal-to-noise ratio, while leaving a safety margin sufficient to allow several p.c.m. systems to be connected in tandem.

Requirements for stereophony

A distribution system for sound programmes must make provision for stereophony. If the stereophonic signal were applied to the p.c.m. system in the coded multiplex form in which it is required at the transmitter input, it would be unnecessary to have a stereo coder at each transmitter. In the case of the 'Zenith-G.E.' system, however, the spectrum of

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the multiplex stereophonic signals extends to 53 kHz and it would be a formidable task to design a p.c.m. system to accept the composite signal while meeting the requirements for signal-to-noise ratio; even if this were done, such an arrangement would not allow the information capacity of the channel to be fully utilised, if necessary, for other purposes. A more flexible arrangement can be achieved by transmitting the left- and right-hand signals over separate p.c.m. channels, each of which may then be utilised independently when required.

In the zenith-G.E. stereophonic system, the composite signal required to modulate the transmitter can be generated (apart from the pilot tone itself) by switching alternately between the signals in the left- and right-hand channels at the rate of 38 kHz.[4] In a p.c.m. system each of these channels is represented by the output of a digital-to-analogue converter which is initially in sample-held form and has to be filtered to remove components above the audio-frequency range. If the sampling frequency of the p.c.m. system were made equal to 38 kHz, the left-right switching could be carried out on the audio-frequency signals in their sample-held form; a single filter would then suffice to remove components above 53 kHz. This artifice avoids the need for a separate stereophonic coder at each transmitter; against that advantage must however be set a loss of some 12 per cent in channel capacity incurred by sampling at 38 kHz when, for an audio-frequency bandwidth of 15 kHz, a sampling rate of about 33·5 kHz would otherwise be adequate.

Application of compandors

Reference was made in the monograph previously cited[1] to the use of a syllabic compandor operating on the audio-frequency signal to increase the effective signal-to-noise ratio of a p.c.m. system. However, such a device, even if satisfactory for a single channel, is not suitable for stereophony unless its overall gain is independent of signal level under dynamic as well as static conditions. Directional effects in stereophony are determined to a great extent during transients in the signal,[5] and it is therefore important that these transients should not be accompanied by momentary changes in the relative gain of the left- and right-hand channels. Serious anomalies have been observed when on the onset of a signal the expander in one channel of a stereophonic system was a few milliseconds late in restoring the gain reduction produced by the corresponding compressor; only the more sophisticated types of compandor are capable of meeting the requirements. In deciding the basic parameters of the p.c.m. system, therefore, the cost of compandors must be weighed against that of the additional information capacity, in the form of extra digits in the p.c.m. code, required to make such expedients unnecessary.

Requirements of a.d.c.s and d.a.c.s

In the evolution of the 'Sound-in-syncs' system, experimental analogue-to-digital and digital-to-analogue converters of the ramp-counter type, with a sampling frequency of 31·25 kHz, were constructed; these were capable of operating with up to 11 binary digits per word, although a 10-digit system was eventually used. For the later investigation, however, it was necessary to consider the possibility of the more stringent requirements referred to above, and for experimental purposes a 14-digit a.d.c. and d.a.c., capable of sampling at 38 kHz, were therefore developed. These operate on a double-ramp principle in which the counting is carried out first in groups and then in units, an artifice which allows conversion to be effected with a counting rate of only 15 MHz, compared with 800 MHz which would otherwise be necessary.

Minimising the effect of momentary faults

Although wide-band communication systems are in general reliable, occasional momentary loss of signal, for example, through abnormalities in the radio transmission path of an s.h.f. link, must be allowed for. In the case of p.c.m., a fault condition lasting long enough to produce an error in a single digit will falsify the complete digital word of which that digit forms a part; in a binary coded system an error in the most significant digit can produce a loud click, while an error in even the seventh digit could still be audible in a quiet passage of programme. Parity digits can be added to the code to provide error detection so that the decoded signal may be inhibited for the duration of the fault. The proportion of errors detected increases with the number of parity digits, and at first sight it would therefore appear preferable to use the maximum number available to protect all the channels in the system at once rather than to associate a much smaller number of parity digits with each individual channel. With this arrangement, however, a fault affecting any one channel will cause the output from all channels to be inhibited; a more elaborate system is therefore required to reduce the total number of audible faults to a minimum. Where the decoded signal has to be momentarily suppressed, this operation must be carried out as unobtrusively as possible, and artifices such as switching on the zero crossings of each audio signal may be necessary to minimise discontinuities in the waveform.

Parameters of the distribution system

From the foregoing, it is now possible to consider the form which a p.c.m. distribution system of the future might take. As one example out of many possibilities, let it be assumed that a bandwidth of 8 MHz is available and that 8×10^6 pulses of $(\text{cosine})^2$ form are transmitted per second. Assuming further that stereophonic multiplexing equipment is already provided at transmitters, sampling could be done at 33·5 kHz, so that a complete p.c.m. frame could contain 234 digits. With a 13-digit binary code, eighteen high-quality sound channels could in theory be obtained, but in practice the equivalent capacity of two channels would probably have to be utilised for error detection and synchronising signals, giving sixteen useful channels.

Flexibility

To illustrate the flexibility of a p.c.m. system it may be noted that for any one of the 15-kHz high-quality channels we could substitute three 5-kHz channels for narrow-band programme material, or six communication channels, each having likewise a 5-kHz bandwidth but with fewer digits and thus a lower signal-to-noise ratio. Again, any one of these six communication channels could be replaced with 180 telegraph channels working at 300 bands or 1,170 channels at 50 bauds (these figures include an allowance for extra synchronising signals which would probably be required in practice).

Conclusion

It is clear from the foregoing that a p.c.m. system is in principle capable of satisfying all the known requirements of a high-quality sound signal distribution network.

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Contributors to this issue

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John Nash joined the BBC in 1951, having been educated for a commercial career at Clark's College, Guildford. He served as an army Staff Band musician during the war, and then returned to civilian life for further education at Guildford Technical College.

After five years in the BBC Research Department, he moved first to the Transcription Recording Unit, working on sound programmes, and then to the Television Service as a video-tape engineer and editor. In 1964 he accepted an attachment to the Engineering Training Department to assist in writing descriptions of the Television Centre installation. After a second period in video-tape operations, Mr Nash transferred permanently to BBC Technical Publications Section, where he is now concerned in preparing instructions with subjects ranging over all types of broadcasting equipment.

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Henry Tarner has been with the BBC since 1944, apart from a wartime period of service with the Signals Branch of the RAF. In 1949 he transferred from radio to the television service at Alexandra Palace, which then housed the whole of the BBC's television studio and broadcasting transmitter facilities. After working at the Lime Grove television studios from 1951, Mr Tarner returned to Alexandra Palace in 1956 to join the expanding Television News Service, and became Head of Engineering, Television News, in 1967. He has been intimately associated with the planning of the new Television Centre Spur.

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