live TV is not very popular with actors and actresses. In the half-hour and hour presentations in the live form, all sorts of tensions, frantic costume changes and scene changes are, of course, necessary and, as a result, many actors and actresses refuse to appear on live TV. Of course, the tension arises from the fact that a fluffed line is going to be heard by the entire audience, or some disarray in the dress of a male actor who has just made a quick change may be evident. So, even without any further perfection in the technique of splicing, isn't recording in segments — starting with a fade-in and ending with a fade-out — possible, so that an hour's show can be leisurely performed in front of television cameras, together with a video-tape recorder, in perhaps the space of 6 or 7 hours preceding the broadcast. Then everybody can go home, relax and look at the show on the air and it will, essentially, be a live show. In this way your video tape will enhance the ease of presentation of live TV and render film shows less necessary as time goes on.

Mr. Harmon: One thing that would bother me about this, in what you say, in going to "black" as we call it, in television, this is fine, but suppose you have a fluff in the middle of a television field, how do you splice this?

Mr. Solow: Do it over again. Do it in easy segments.

Mr. Harmon: But you're still going to have to go back to a vertical period somewhere to make the splice?

Mr. Solow: That's right. You'd divide an hour's show perhaps into six 10-min segments.

Mr. Harmon: I thought you might be suggesting to the Ampex gentlemen that here's a neater way to splice, just go to black for a couple of dozen fields and cut anywhere you want and let your picture roll.

Mr. Solow: No, construct the script originally in the form of segments that would start with a fade-in and end with a fade-out, so that each segment is successively put in the can. You could then splice without worrying about revealing the scan lines, and just play the whole show. Of course, as more machines are delivered to the networks, I can also foresee, with added horror, that each television camera can have its own tape recorder connected to it, and then after all of the performance has been completed, the show can be played back over several monitors in the manner that live TV is played back, and a technical director can then punch one tape in following the other, and make lap dissolves and fades and that sort of thing. I suppose that is in the offing, too. So it's a dim future.

Mr. Miner: I think the general area that you're discussing resolves itself, in great measure, to the operating agility of the people who are using the equipment rather than the actual abilities of the equipment itself.

Interchangeability of Videotape Recorders

By CHARLES P. GINSBURG

New requirements are placed on video-tape recorders when tapes are to be recorded on one machine and reproduced on another. The nature and extent of these requirements are discussed for both monochrome and color.

Some of the greatest problems involved in the interchangeability of video tapes, whether in monochrome or color, come from the fact that the pictures from the tape are segmented. An average of a little more than 16 picture lines is read out as each head describes an arc of 90° across the tape. There are 16 of these picture line groups in a field. Because of the segmentation, small variations from one band to another in noise, in frequency response or in time position will be visible and objectionable. If we make the reasonable assumption that the response characteristics of the four r-f electronics channels which carry the signals to and from the heads are matched, the variations mentioned above can be discussed in terms of electrical and magnetic behavior and mechanical positioning of the heads.

Noise Banding and Frequency Banding as a Function of Variations in Head Performance

Let us say that the process of recording a signal on tape and then recovering it constitutes a transmission channel. On the VR-1000 Videotape Recorder, we have four such head-tape transmission channels. These channels vary among themselves in two ways of special interest to the interchangeability problem:

(1) Slight variations exist in the impedance frequency characteristics of the several channels. This is due to very small differences in head circuit resonant frequency, including variations in the source impedance of the amplifier circuits driving the heads during recording, as well as loading impedances presented to the heads during playback.

(2) Attenuation characteristics due to magnetic losses and to gap effect vary slightly from one head to the next. Since we are working with magnetic gaps whose dimensions approach the shortest wavelengths which are recorded on the tape, there may be variations in attenuation resulting from an inability to hold the gaps to exactly equal values for all heads.

Consequently, in comparing the transmission characteristics of the four channels, we will find:

(1) Differences in the amplitude vs. frequency characteristics accompanied by differences in delay distortion. This would be the case for variations caused by differences in the resonant frequencies.

(2) Differences in the amplitude versus frequency characteristics not accompanied by differences in delay distortion. This would be the case for variations caused by differences in the size of the magnetic gaps.

The tendency toward noise banding and frequency banding will increase somewhat when tapes are to be played back interchangeably. The optimizing of the recording current for a given head is, by definition, a process by which the best possible picture is obtained, and results in the best possible current setting in view of the playback as well as the record characteristics of that particular head. Theoretically, there are several reasons why an optimum recording current setting for a given head will not necessarily be the best setting if a different head assembly is to play back the same tape. Fortunately, in practice, this matter is of secondary importance.

The azimuth alignment requirement for the head gaps, i.e. perpendicularity with respect to the transverse magnetic tracks, is considerably tighter for interchangeability than it is for an operation in which a tape is to be played back only with the same head assembly with which it was recorded. Within extremely wide limits of azimuth errors, there is essentilly no decrease in head resolution or head output in the latter case, since the control system is so designed that each of the four heads will play back the particular set of magnetic tracks which it recorded. However, if the azimuth is different in playback than in record,

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Presented on April 24, 1958, at the Society's Convention in Los Angeles by Charles P. Ginsburg, Ampex Corp., 934 Charter St., Redwood City, Calif.
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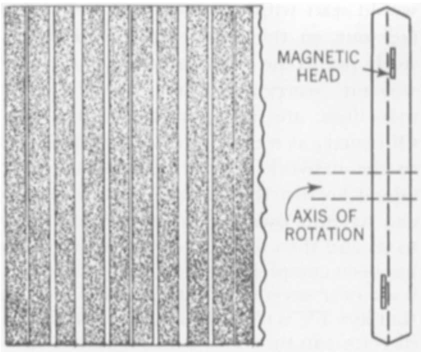

Fig. 1. Irregular track spacing.

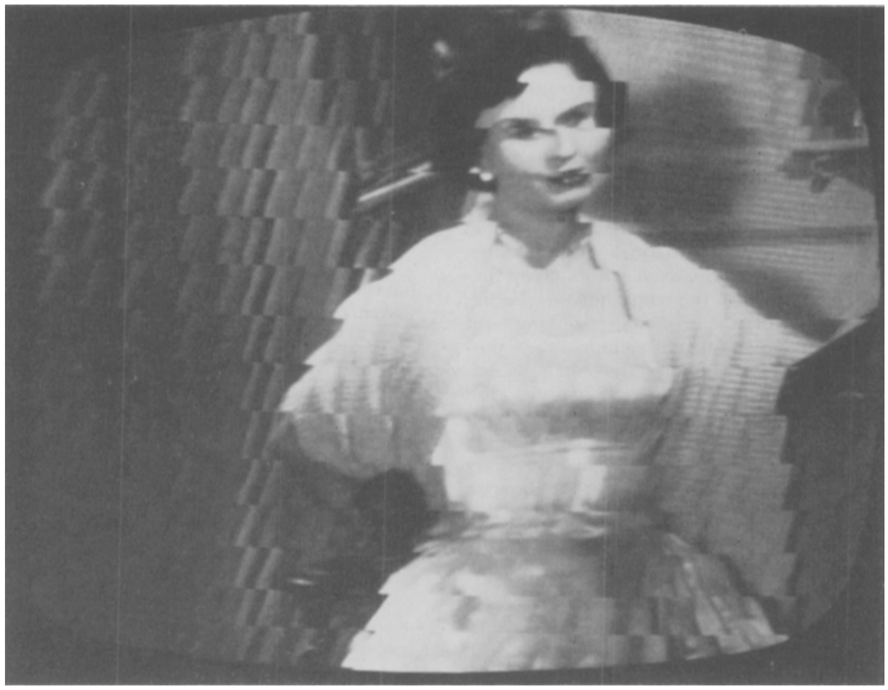

Fig. 2. Playback result when female guide is farther from drum than when recording was made.

which would be the case in interchanging tapes, there will be a loss in playback voltage increasing at the shorter wavelengths and causing a decrease in signal-to-noise ratio even for small azimuth errors. Since we are concerned with wavelengths as short as 200 μin., the numerical value of the azimuth tolerance might be very difficult to meet were it not for the fact that the tracks in the Videotape Recorder are only 0.01 in. wide. The displacement of the axis of the gap with respect to the axis of the recorded signal must be kept small with respect to the shortest wavelength which is to be reproduced. It is obvious that this same tolerance can be met at a larger angular difference as the track width is decreased.

Because of the several sources of variation in transmission characteristics from one channel to the next, it might seem desirable to have independent control of the r-f playback response of each of the four channels. However, from an operational standpoint, it is highly desirable to be able to play back a tape recorded on a different machine without adjusting the channel response characteristics. The heads have been sufficiently well controlled in performance to permit the interchange of monochrome tapes without playback equalizing controls, but because the high-frequency components of the NTSC color signal are more important than they are in monochrome such adjustments are usually necessary when interchanging color recordings.

Another source of degradation of signal-to-noise ratio peculiar to the interchangeable use of video-tape recordings lies in the mechanical tolerances affecting the pattern written on the magnetic tape. As shown in Fig. 1, errors in track spacing can be caused by faults in positioning the heads in the axial direction. Somewhat similar troubles can be caused by excessive wobble of the rotating head drum, or by asymmetry with respect to the center line of the tape as the tape is guided from the supply reel to the head drum and then to the take-up reel.

When a tape is played back on the same machine and with the same head assembly with which it was recorded, these track spacing and track curvature problems are of little or no importance, since eccentricities in recording will be followed by the same eccentricities in playback.

For operations in which tapes are used interchangeably, however, a misregistration of as little as 0.002 in. during part or all of the sweep of a given head across the tape will result in a decrease of the amplitude of the recovered modulated wave, a consequent decrease in signal-to-noise ratio for the corresponding portion of the reproduced picture, and an increase in banding noise.

In short, slight tracking errors will merely result in an overall decrease of the signal-to-noise ratio for the non-interchanged tape playback; but these same slight tracking errors will cause banding noise in the tape interchange case if track spacing or track curvature errors exist. For an overall signal-to-noise ratio of 36 db, for example, a difference of 2 db from one band to the next will be more objectionable than an overall degradation of 2 db.

Time-Base Banding

If the timing variations in the reproduced picture which may occur as a result of variations in the rotational motion of the drum are disregarded, the factors which play a role in the variations in time position of the information coming from the rotating heads can then be classified as:

(1) Factors relating to the positioning of the head tips around the circumference of the drum. This positioning is referred to as rotational alignment, or angularity, or quadrature relationship.

(2) Factors involved in the configuration of the drum and the female guide.

Angularity

If the time base of the reproduced information experiences a discontinuity in the transition from the output of one head to the output of the next, there will be a corresponding step in the picture information which appears on the monitor. Figure 2 shows such discontinuities generated when the female guide in playback is farther from the drum than it was when the recording was made. Figure 3 illustrates what happens when a tape is recorded by heads in proper rotational alignment but which is being played back by heads which are not in quadrature.

Although the FCC standards of good engineering practice imply that such discontinuities must not amount to more than 0.5% of the line period, or about 0.3 μsec, an error this large repeated every 16 picture lines is intolerable to the observer. To hold these displacements to an acceptable value, each head gap should be positioned to within one-half the distance on the drum circumference corresponding to 0.05 μsec, since the error will be cumulative when the tapes are used interchangeably. In linear distance on the drum, this amounts to about 38 μin.

Since it would have been impractical to use optical means for rotational alignment of the heads on the periphery of the drum, it was initially planned to use delay lines to compensate for errors

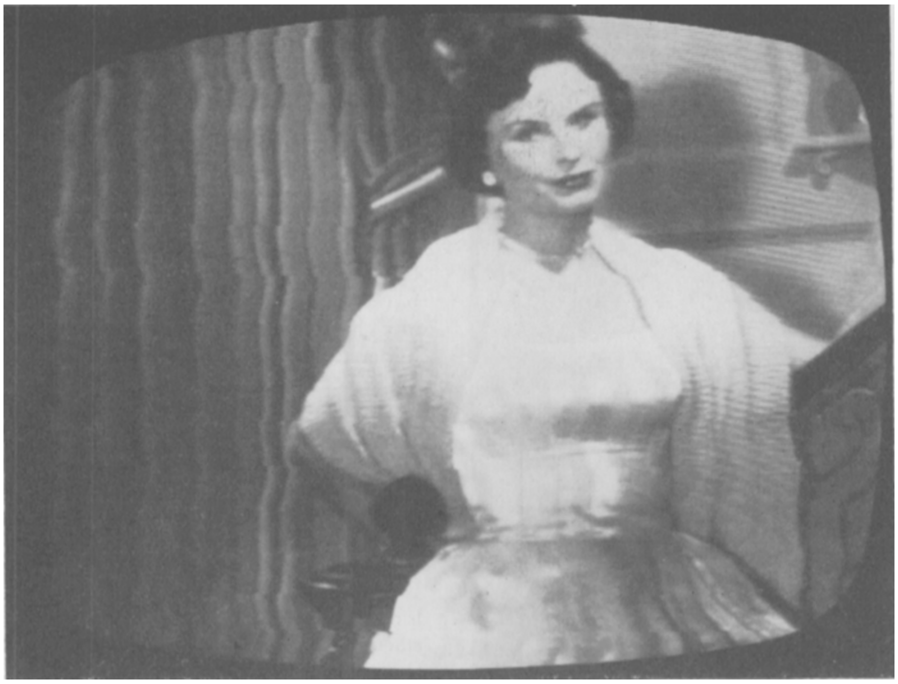

Fig. 3. Result of poor quadrature alignment.

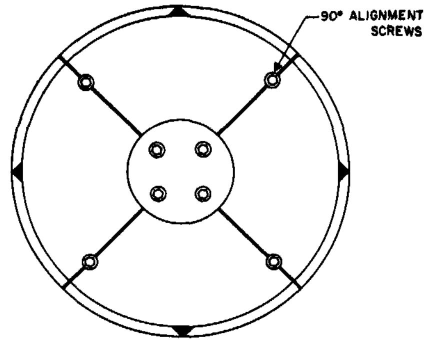

Fig. 4. Arrangement of alignment screws.

in angularity. However, because of problems resulting from interchannel cross-talk during both record and playback, and also because of some possible operational complications, it was decided instead to use an approach in which the heads are first aligned on the drum to within 1 μsec, and are then brought into effectively perfect angularity by means shown in Fig. 4. The tapered alignment screws are used as vernier angular adjustments of the pie-shaped segments of the drum, and angularity of the head gaps can thus be set to a very precise degree.

Head Wear, Tape Stretch, and Nonconcentricity

For color as well as for monochrome, we are concerned with changes which occur as the pole tips of the rotating heads wear down due to abrasion by the tape. The nominal setting of the female guide for a new head drum assembly is approximately that setting which establishes concentricity of guide profile and drum (Fig. 5).

There is sufficient tension exerted on the tape from both lateral directions so that the rotating head tips which project from the periphery of the drum into the slot in the female guide actually stretch the tape temporarily in the region of head contact. It is obvious that as the guide is moved closer to the drum, the extent to which the tape is stretched at any given point in the sweep is increased in accordance with the movement.

Assuming that a recording has been made and then put on the shelf while the heads are worn down 0.001 in. through usage, what happens when an attempt is made to play back the old recording?

Having a smaller sweep radius, each head gap will now describe a shorter path per unit angle of sweep. On the other hand, the tape is now being stretched less, and thus the information that was recorded per microsecond will tend to have a shorter path during the playback process than it occupied during the original recording process. In practice this compensating action is about 90% effective, which means that for 1 mil of tip wear the guide must be backed 0.1 mil away from the drum.

Although there are means by which

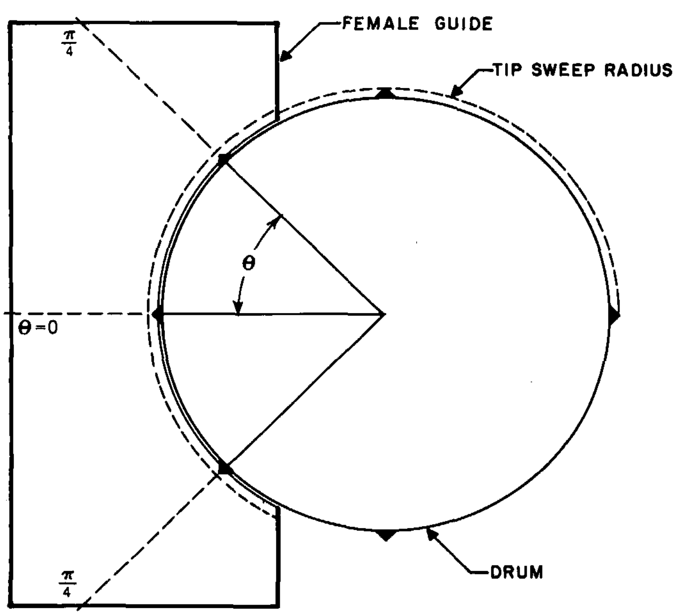

Fig. 5. Profile of drum and guide.

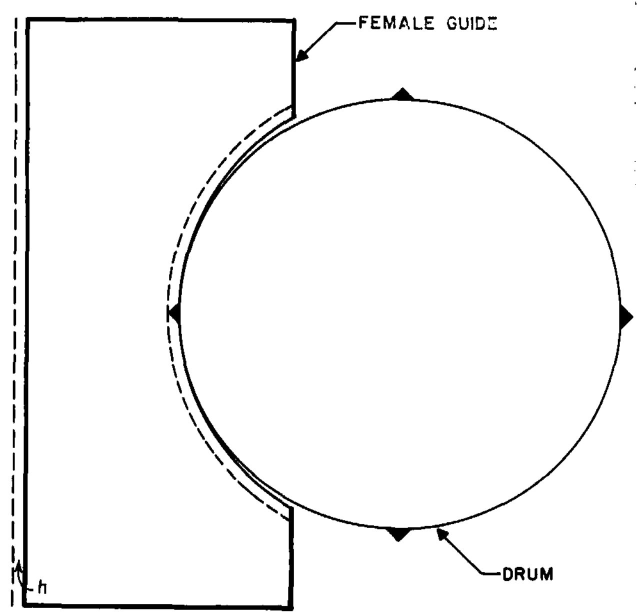

Fig. 6. Nonconcentricity due to movement of guide toward drum.

Fig. 7. Scalloping distortion resulting from vertical misadjustment of the guide.

this percentage of compensation might be increased to the point where no adjustment of the guide would be needed, there are other considerations which require that a compensating means be available by which to alter the time base of the playback signal. For example, the temperature and humidity coefficients of the tape itself are large enough to necessitate time-base adjustment even under fairly limited ranges of ambient conditions. The range of compensating movement of the female guide may be expected to be greater under conditions of interchanging tapes from one recorder to another than it would be in the case of recording and playing back on the same machine.

Since the curvature of the guide and the arc of the rotating heads can be concentric at only one horizontal position of the guide with respect to the drum, it is apparent that the geometry will generally display some small nonconcentricities (Fig. 6). Consequently, we can expect variations in the extent to which the tips protrude into the guide slot, with accompanying changes in tape stretching, as a function of the instantaneous angular position of a given head. Therefore, it becomes necessary to ascertain:

(1) What effect on raster structure is generated by these variations?

(2) What effect on color signals is created by these nonconcentricities?

Some simplifications can be effected by assuming that perfect recordings have been made in every case and that any changes in position or dimension are understood to prevail only during playback. Let ΔP be the change in protrusion of the head tips into the guide slot, and consequently into the tape, as a result of a change in the guide position with respect to the drum. Θ is the angle which a given head makes with respect to a horizontal line directed from the drum center toward the guide. The heads sweep down across the tape so that Θ for the active part of the head sweep starts off at $-\pi/4$, progresses to zero and then to $\pi/4$. For a horizontal movement, h, of the guide toward the drum, $\Delta P = h \cos \Theta$.

Let us define a function ΔS as the proportional difference between playback time base and record time base. This might best be explained by the following example: If a given amount of picture information took 10 μsec to record, and then, because of a horizontal movement of the guide, takes 10.5 μsec to play back, ΔS will be equal to 0.05. This means that the playback time base will have a proportional difference of 0.05 with respect to the record time base. Thus ΔS is dimensionless and is merely a correction factor to apply in the case of a misadjustment, misalignment or compensating movement.

We can now set

$$\Delta S = \frac{Kh \cos \Theta}{r}$$

where r is the tip sweep radius and K is the numerical value of the compensating action referred to earlier; i.e., small tip radius changes are 90% compensated for by a decrease in tape stretch.

If we define ϵ as the total accumulated error in time base as the head describes an arc between two values of Θ, then

$$\epsilon = \int_{\theta_1}^{\theta_2} \Delta S d\Theta = \frac{Kh}{r} \int_{\theta_1}^{\theta_2} \cos \Theta d\Theta$$

If we want to predict the extent of the discontinuity generated by moving the guide 1 mil closer to the drum, we have merely to integrate ϵ over the limits of $\pi/4$ to $-\pi/4$. Thus,

$$\epsilon = \frac{Kh}{r} \int_{-\pi/4}^{\pi/4} \cos \Theta d\Theta$$
$$= \frac{0.9 \times 0.001 \times 1.414}{1.036}$$
$$= 1.23 \times 10^{-3}$$

Therefore, the amount of information recovered by a head during its 90° arc is less than it should be by a factor of

Fig. 8. An example of successful interchangeability, when components are properly adjusted.

1.23×10^{-3}. Since it takes 1/960th of a second for a head to describe a 90° arc, the accumulated time-base error during the sweep amounts to $1/960 \times 1.23 \times 10^{-3}$ seconds which equals approximately 1.3 μsec.

The type of scalloping distortion shown in Fig. 7 is the result of vertical misadjustment of the guide. The fact that such distortion is accompanied by negligible displacement at the transition points can be shown by integrating the cumulative error e over the range defined by the active portion of the head sweep. For a vertical guide misalignment v, $\Delta S = \frac{Kv}{r} \sin \Theta$, and therefore:

$$e = \frac{Kv}{r} \int_{-\pi/4}^{\pi/4} \sin \Theta d\Theta = 0$$

Thus the total amount of information played back under conditions of vertical mispositioning of the guide is correct, although time-base errors within each head sweep may easily reach an objectionable value. If we define scalloping as the accumulated time error between $\Theta = 0$ and $\Theta = \pi/4$, then scalloping equals:

$$\frac{1}{2 \times 960} \int_0^{\pi/4} \Delta S d\Theta = \frac{Kv}{1920} \int_0^{\pi/4} \sin \Theta d\Theta$$

For a vertical misalignment $v = 0.1$ mil, the scalloping will thus amount to less than 0.015 μsec within each band. The maximum tolerable amount of scalloping, from the standpoint of subjective picture quality, may be considered to be 0.1 μsec or less. Proper adjustment of vertical positioning of the guide prior to recording can be made by use of a standard alignment tape.

Finally, let us consider the effects, on a color picture, of the nonlinear characteristic induced in the time base by the nonconcentricity which results from guide movement. Since the color system is one in which phase locking is effected at the beginning of each picture line, our principal concern is the extent to which phase shift occurs at the 3.58 mc subcarrier frequency during a single line. We have considered time-base errors caused by nonconcentricity to be sinusoidal. Vertical misalignment of the guide with respect to the drum will cause an expansion of the time base at one extreme of the sweep and a contraction of the time base at the other extreme. This will be accompanied by a maximum rate of change of the time base occurring during that television picture line which is read out at the center of the sweep. A horizontal mispositioning of the guide will result in a maximum stretch error at the center of the sweep and a maximum rate of change of time-base error during the first and last lines of each sweep. The extent of the time-base rate errors will directly determine the amount of hue shift in a burst locked color Videotape Recorder system. Taking into account all of the variables involved in a given playback operation, and even allowing a reasonable degree of operational or setup error, the worst case of phase change within one line will be undetectable to the eye.

Since time-base distortions of the type we have been discussing can be closely controlled, especially as operating and maintenance characteristics of the machines continually become better understood by the users, it seems rather doubtful that these phase changes will ever become objectionable. However, if the expanded use of color video-tape recorders on an interchangeable basis, involving sequential duplication operations, presents detectable hue shift in the picture, the problem can be readily solved by the use of a pilot carrier system of the type which has been developed in the laboratory and which grants complete freedom from the type of defects discussed. The conversion of color machines from burst locked to pilot carrier operation would be a comparatively simple matter. Unless we find that eventual usage warrants the transition to a pilot carrier system, it is best to reserve that portion of the video-tape spectrum for other possible uses.

Discussion of Video-Tape Recorder Operations

Seven speakers presented these subjects at the Society's Convention in Los Angeles on April 24, 1958:

"Magnetic Tape for Video Recording" by Robert A. von Behren, Minnesota Mining and Mfg. Co., 900 Bush St., St. Paul 6, Minn.

"Engineering Planning in the Evolutionary Development of the Video-Tape Recorder" by John M. Leslie, Jr., Ampex Corp., 934 Charter St., Redwood City, Calif.

"Electronic Marking and Control for Rapid Location of Vertical Blanking Area for Editing Video-Tape Recordings" by Joseph Roizen, Ampex Corp., 934 Charter St., Redwood City, Calif.

"Electronic Convention to Color Recording With the Ampex VR-1000 Video-Tape Recorder" by Charles E. Anderson, Ampex Corp., 934 Charter St., Redwood City, Calif.

"Timing and Frequency Requirements for Color Video-Tape Recording" by Earl Roger Hibbard, Ampex Corp., 934 Charter St., Redwood City, Calif.

"Interchangeability of Color Video-Tape Recordings" by Charles P. Ginsburg, Ampex Corp., Redwood City, Calif.

"Magnetic-Tape Recording of Color Television Signals" by Jerome L. Grever, Radio Corp. of America, Camden, N.J.

Other participants in the discussion which followed the group of papers were:

Ralph E. Lovell (Session Chairman), National Broadcasting Co., 3000 West Alameda Ave., Burbank, Calif.

George Lewin, Army Pictorial Center, 35-11 35th Ave., Long Island City, 1, N.Y.

J. Barry Watkinson, Cascade Broadcasting Co., P.O. Box 702, Yakima, Wash.

Ralph R. Wells, Columbia Pictures Corp., 1438 N. Gower St., Hollywood.

Walter Bach, Berndt-Bach Inc., 6900 Romaine St., Hollywood 38.

Ralph Dodds, Creative Productions, P.O. Box 765, Burbank, Calif.

Rolf A. Seitle, KQED, 525 Fourth St., San Francisco, Calif.

Helmer W. Andersen, CBS Television, 6121 Sunset Blvd., Los Angeles.

David S. Horsley, 3929 Kentucky Dr., Hollywood 28.

Robert G. Neuhauser, Radio Corp. of America, Lancaster, Pa.

Mr. Lewin: Is there any hope of interchangeability between the RCA and Ampex recording?

Mr. Ginsburg: Ampex and RCA recognize the importance to the industry of establishing interchangeability between the video-tape recorders of both companies. Steps are being taken to agree on various system parameters so that such interchangeability can be brought about.

Mr. Lewin: In view of the rather high cost of the video tape, is there any hope of re-using the tape once it's been spliced?

Mr. Roizen: Yes, although it requires a little skill to splice together two tapes from different machines so that they will go through without showing any discontinuity in either the sync or video information. If you record over the splice you wouldn't even know it went through the machine. In other words, if you erase the tape and re-