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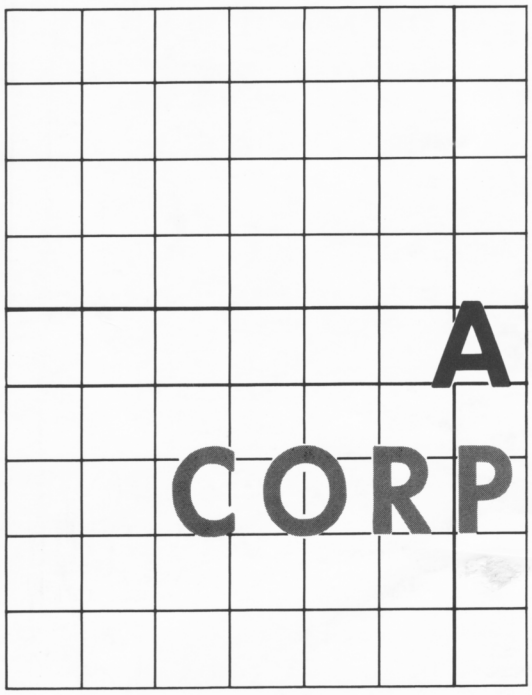

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TECHNICAL NOTES ON MULTI-CHANNEL RECORDING

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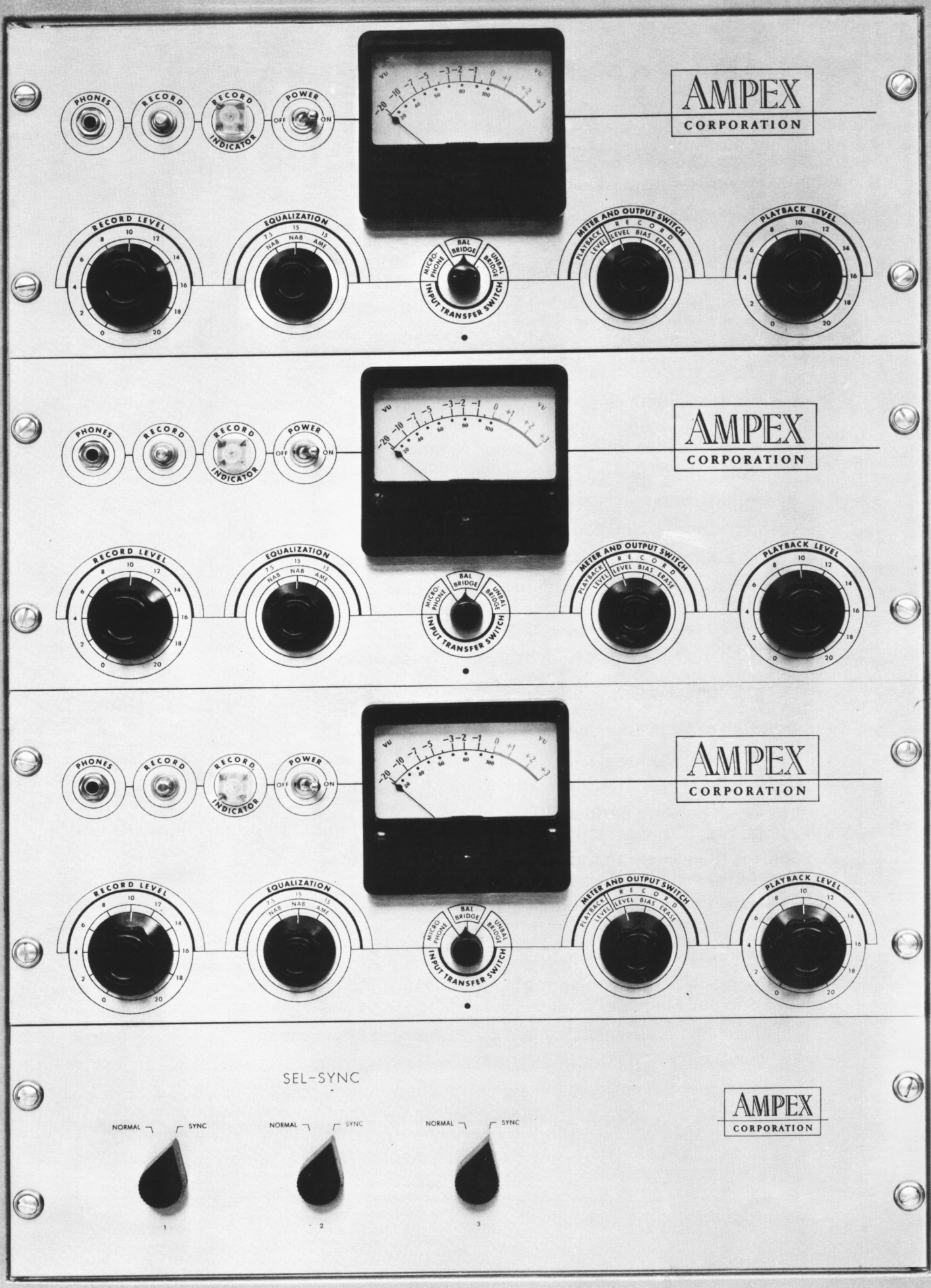
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TECHNICAL NOTES ON MULTI-CHANNEL RECORDING

I.

THE MULTI-CHANNEL RECORDER FOR MASTERING PURPOSES

The first experimental multi-channel magnetic tape recorders were developed by Ampex Corporation in 1949, using the Ampex Model 300. Early users of this equipment concentrated primarily on the development of stereophonic recording techniques, but it was soon apparent that multi-channel recorders were opening the way to a wide variety of other applications.

Probably the most important application of the multi-channel 300 was in instrumentation recording of data other than sound. It was soon in wide use for the testing of aircraft and guided missiles, geophysical recording, shock and vibration studies, and many other scientific and industrial applications.

As a result of the specialized attention given to multi-channel recording techniques, much valuable information was gained which benefited the audio field. Now recording studios are using units with more than two channels to great advantage. Not only are they applied to stereophonic recordings, but to the mastering of ultimate single-channel recordings of superior quality, produced with greater flexibility and economy.

A. THE STEREOPHONIC TECHNIQUE

In stereophonic recording, two or more microphones, each transmitting its signal independently, sample the complex wave-fronts of sound at separated points in an imaginary curtain between the performers and the intended audience. A microphone at the left of an orchestra picks up first and most strongly the instruments on the left. The right-hand microphone, then, picks up first and most strongly the instruments on the right. If three or more microphones and channels are used, each specializes on a given area of sound source.

In the reproduction, the listener is faced with two or more loudspeakers, each connected through time and space with the microphone corresponding. Each is located in about the same angular relation to him as the microphones were during recording. The speaker on the left reproduces first and most strongly the sounds which were nearest its microphone, while the speaker on the right does the converse.

A Minor Miracle

Mixture occurs only at the time of reproduction, and performs a sort of minor miracle of re-creation. Not only are the instruments on the left stronger from the left loudspeaker, but they are reproduced there momentarily earlier than they are heard, at a distance, in the right speaker. Since the reverse is going on between sounds at the right and their speaker, there results a melting of sound between them. With a strong sense of direction, the whole orchestra seems to be spread out before the audience, when the mixture is correct. There is no hole in the middle; indeed, in a perfectly microphoned and balanced presentation, a soloist can be made to appear exactly front and center, where there is no loudspeaker at all in a two-channel presentation.

It is curious that a certain amount of left-hand sound must be present in the right-hand speaker, subdued a little and delayed by distance, of course, if the effects of spread and realism are to be heard. When there is little or none of this mixing, we hear a kind of musical ping-pong, which certainly may be used synthetically by the director for good novelty effect, but is unsuitable for most musical reproduction.

Balancing Solo Sound

The balance of sound which places the soloist in the middle must be established at the time of the recording. It might be thought, at first, that errors in microphone placement might be compensated later in the dubbing studio by raising or lowering the strength of one signal in relation to the other. Within limits, where the error was only one of gain setting during the recording, it is true that this can be done. But after the recording is made it is not possible to vary individually the multitude of small variations in the delay of sound from each of many sound sources to each of the microphones, so good microphone placement at the time of recording is greatly to be desired.

B. THREE-CHANNEL STEREO

It might also be held that reliable "front and center" soloist location requires the use of three or more channels, so that one may con-

stantly serve a center loud-speaker. This attitude was taken by the motion picture industry a few years ago when stereophonic sound was decided upon for Cinerama, CinemaScope and Todd-AO productions.

Some thousands of theatres equipped themselves for three-channel magnetic CinemaScope sound, but more thousands did not. Some of these resorted to mixing the three tracks electrically, and presenting the mixture through their single stage speaker. Others reproduced the center channel only through their single speaker.

Eventually the picture producers were forced to release such films optionally with single-channel sound tracks of the old-fashioned photographic type. So the artists and engineers in the studios were forced for a variety of reasons to concentrate attention on the center-stage speaker.

Background vs. Narrative

In true stereophonic recording, background must actually be quite loud if it is to be heard softly behind narrative or dialogue, just as it may be quite loud in life in the opera or concert hall, without obscuring the soloist. This is because in the sound presentation the presence of real direction permits the listener to enjoy his normal power of selection among sounds he wishes to concentrate upon. But if a mixture of foreground and background sounds is presented in its normal real balance through a single-channel system, it is presented without real directionality, no matter how many speakers may simultaneously reproduce it, and the listener no longer can exercise his power of selection.

The background sounds uncomfortably loud compared to the foreground, and it becomes necessary in a single-channel transmission, if a pleasant reproduction is to be obtained, to reduce artificially the real relative level of the background sounds, whether background music or sound effects. Thus a stereophonic motion picture sound-track, complete with well-recorded stereo background music and sound effects and foreground dialogue, may sound very realistic, with a perfect balance of dialogue, music and effects, when heard through a high quality, well balanced, three-channel reproducer and loud-speaker installation.

Unbalanced When Mixed

If all three channels should be mixed electrically and presented through a single speaker, the background is much too loud in comparison with the dialogue, and intelligibility suffers. If the center channel should be the only one reproduced, then important dialogue or other sound on the right or left becomes subdued, and again intelligibility suffers. Since no studio has the unlimited time and money to produce one ideal stereophonic track and one ideal single-channel track for each picture, a compromise was drawn which, as time went on, more and more favored good single-channel intelligibility. It would, unfortunately, be true to say that there is next to no stereophonic sound in motion pictures, outside limited road-show releases.

A good case could be constructed for the proposition that the presence of a center channel in a stereo system tempts the recordist in haste to rely upon it so exclusively that there is soon very little stereo left in the production.

C. TWO-CHANNEL STEREO

True stereophonic sound is having a rebirth in tape for the home. This time, economy and precedent have caused release to be in two-channel form. This may be developing into a disguised blessing. When two-channel stereo is good, it is very good indeed; when it is bad it is obvious. Perhaps this is why so many commercially released tapes have been on the good side.

Every record company today is looking toward the time it will need a backlog of well-recorded stereophonic versions of its repertoire. Many have provided themselves with two-channel recorders, which have been used at most sessions to make a separately-microphoned stereophonic tape, simultaneous with the main effort at a satisfactory single-channel release for discs. Since the stereo is, in these efforts, secondary, such stereo masters have not always been successful.

One Channel from Two

Observing this, recordists have at some sessions concentrated upon getting a good two-channel stereo master, in the hope that a good single-channel master might be made by later mixing in the dubbing studio. But they experienced that inability to get good balance between foreground and background. Since the stereo front-and-center soloist effect occurs only with the directional presentations, it is lost when mixing occurs before reproduction. It appeared that mastering costs would rise, if two complete and separate technical crews,

with equipment, were to be needed for each recording session, one for stereo and one for single-channel.

D. MULTI-CHANNEL RECORDERS REDUCE COSTS

In some recording studios recorders of two, three, or more channels have been used for years solely as preparation for production of single-channel masters, for the purpose of reducing cost while expanding the opportunities for new sound effects.

The high cost of performer time in the mastering of a recording makes it advisable to keep rehearsals and repeats to a minimum, especially those which might be due solely to technicalities. It became, in these studios, common practice to isolate the soloist acoustically and to treat his channel separately for equalization, echo, or other special effects.

Many operations usually must be performed to get a perfect single-channel master. The string section of the orchestra is separately treated, perhaps, while the brass is usually miked close up. Balance for level must be optimized, also. If only a single channel recorder is available, all this technical modification of the recording must be carried out during the costly recording session. Should there be need for a single correction in any one of this multitude of operations, repeat of the whole performance is required.

Where a multi-channel recorder is available, however, the director may concentrate all his attention on the artist during the session, knowing that the mix, balance and technical treatment of soloist, strings and brass all may be handled after the session is over, in the dubbing studio. All that is required during the session is a good performance into well isolated microphones.

E. THREE CHANNELS (OR MORE) FOR MASTERING TWO-CHANNEL STEREO RELEASES

Tape recorders having three or more channels could also, of course, be used for stereophonic recording. Where the aim is ultimate release in two-channel form, extra channels are not at all superfluous. With a high quality three-channel machine the two outer channels are used for an overall pickup, optimized for stereophonic clarity without special regard for exact soloist centering.

On the center channel there can be recorded a close-up of the soloist. A recording thus is made which contains, in perfect synchronism, separate takes of background and foreground, which can be varied in relative level at will, *after* the recording is made. It was found that the front-and-center effect on two-channel reproduction could be obtained by feeding the close-up single channel of the soloist equally and identically to each of the two speakers.

Keeps Solo Front and Center

If this were all that were done, the two-channel stereo system would be in use merely to produce a good imitation of a single-channel recording. But when the stereo contents of the outer two channels on the three-channel original are independently dubbed to their respective places on the two-channel copy, while exactly equal proportions of the solo channel are mixed electrically onto each of these two channels, the result is a two-channel stereo reproduction with soloist front and center.

No elaborate precautions are necessary to preserve the center effect during the recording session. This procedure evolved, in one company, from the habit of a famous violinist, while playing before an orchestra, of turning from side to side as he played. With a stereophonic pair of microphones close enough to pick up both violin and orchestra, the result on replay was the appearance of a violinist racing from side to side of the stage throughout his performance.

A two-channel tape, dubbed from a three-channel original, in the newer manner, not only permitted the violinist to sway at liberty in playing, while staying front-and-center in the replay, but also permitted an overall orchestra pickup, no longer compromised to include soloist, which had much greater breadth and grandeur.

F. SUCCESSFUL RECORDING OF BOTH SINGLE AND TWO-CHANNEL MASTERS ON ONE MULTI-CHANNEL RECORDER

On further application of this three-channel mastering technique it became clear that, while all the attention might be upon preparing for a fine ultimate two-channel release, it was possible in most cases to derive a thoroughly satisfactory single-channel master for discs. On at least one occasion the single-channel recording, which was being prepared simultaneously, was muffed without being observed. The dam-

age was discovered after the musicians had disbanded, so it became necessary to construct a single-channel release from the three-channel stereo master.

Because background and foreground sounds were seperately recorded, a single-channel mixture was possible in which background was subdued to the ideal level, and the resulting single-channel master was preferred by the music director to the undamaged portion of the single-channel master originally intended for single-channel release.

G. IF THREE CHANNELS ARE GOOD, SIX OR EIGHT MAY BE BETTER

There appears to be no end to the usefulness of adding channels. One recording studio has acquired an eight-channel machine, with several other special features. It is used as a stereo mastering recorder, aimed at better two-channel stereo tape releases, in a manner which even further reduces demands upon the performers during the session.

Multiple microphone pickups are, of course, useful in stereo as well as in single-channel mastering. Multiple miking is more difficult in stereo, since the recordist must guard against left-hand confusions. Nevertheless, for good artistic effects a mixture of closeup, middle, and distant pickup is frequently useful.

The responsible director will experiment with such mixtures only when his monitor control-room is thoroughly isolated from the studio, and fitted with a stereo reproducing system which is adequate to represent the situation in which his stereo tapes will ultimately be played.

Follow Imaginary Lines

Very generally, and subject to wide variation for artistic purposes, in a multiple-mike two-channel stereo pickup a pair of imaginary lines is drawn from left center and right center of the performing group, so as to converge at a point well behind the intended audience. The microphones are placed in pairs along the lines, each equidistant from the performers, each aimed at its own segment of the sound source.

For stereo, all the microphones along one line are mixed into one channel. In elaborate setups, corresponding pairs of microphones are brought to ganged pairs of gain controls, so that gain is controlled simultaneously over each, while each feeds its own recording channel. The relation of direct and reverberant energy, upon which so much of the "depth" effect depends, is thus controlled without violence to stereophonic perspective. Adjustment of balance among near, middle and distant pairs is a delicate matter, and getting it right may consume considerable expensive performer time. Therefore, the eight-channel recorder.

Three Stereo Pairs

This machine has a stereo pair of channels, one for each near microphone, a pair for middle, and a pair for distant microphones. And it has channels for solo close-up. With its use, a relatively standard mike setup can be used session after session, a minimum of time used in setup and recording, and yet the most elaborate balancing and equalizing operations may be carried out later, in the dubbing studio, resulting in a two-channel stereo tape release of precisely controlled effect.

Of course, if both distant channels are mixed equally and brought to one gain control on the console, both middle channels equally mixed to another, the near pair to a third, and the solo channel brought to a fourth control, the result is the re-creation of a multiple-microphone single-channel session. With the four separate controls, a superior single-channel master can be created, with no fear of an error in the mix. Clearly a six-channel recorder would permit much the same operation, although on a lesser scale.

II.
OTHER APPLICATIONS FOR MULTI-CHANNEL MAGNETIC RECORDERS

While the multi-channel recorder has important uses in the preparation of masters, which eventually will see release in one or more single-channel forms, (tapes, discs, or film sound-tracks), it also has many uses outside of mastering. This is true especially of those newer multi-channel recorders which not only provide great accuracy in the synchronism of inter-channel playback but also have a high order of cross-talk rejection.

A. SOME MULTI-CHANNEL APPLICATIONS OUTSIDE OF MASTERING

Many examples may be given. Music and dialogue for an elaborate puppet-show have been recorded on one channel of a two-channel

recorder, while advance cues, and signals for entrances and effects have been recorded on the other channel. Since there is no possibility for one channel to get off synchronism from the other, every performance is letter perfect, every cue and every line on time.

Such an arrangement is also used for a well-known ice-skating show. On one channel is the music for the performance, played into the auditorium's sound system. Synchronized, on the other channel, are the backstage signals. Not only are the performer calls recorded here, but metronome ticks, in perfect synchronism with the music which will follow, permit all the performers to make their entrances, in perfect time with music which begins only when they are on stage.

B. RECONSTRUCTING HISTORIC OCCASIONS

The ability to record several different sound sources on tape, all simultaneous but unmixed, offers many other possibilities. Often tape recorders are used to record sounds which cannot be repeated, either because of cost or because of their unique character. An important occasion, perhaps an inauguration or conference, cannot be rehearsed or repeated. Yet a commentary on it, made simultaneously with the event, may be needed later to present a meaningful record. This, of course, may be recorded on a separate channel on the same tape as the recording of the event itself, when a multi-channel recorder is used.

Often on such occasions it is not possible to make a perfect "mix" of the several microphones which may be used. Yet a perfect recording can be obtained later if each of several microphones or groups of microphones are fed to individual channels for separation and mixing later at leisure in the studio, then to be dubbed to one-channel tape or disc.

C. SCIENTIFIC USES OF MULTI-CHANNEL SOUND RECORDERS

In science and industry it is useful sometimes to record simultaneously one or more sounds under study, or to present previously recorded sounds to separate locations repeatedly, always in synchronism, in exact time sequence. An effect may be recorded in one channel, while the operations producing that effect are described on another channel. Or, in a psychological experiment, entirely different stimuli may need to be presented simultaneously to different subjects. Multi-channel tape would enable the experimenter to be certain of exact repetition with each replay.

D. AN EDUCATIONAL APPLICATION FOR MULTI-TRACK RECORDERS

Both single-channel standard recorders and multi-channel machines have been used to improve the efficiency of language instruction. In one language department, for example, each student is provided with a standard tape recorder into which he plugs an earphone. All the recorders receive the output of a master tape in the control room, on which is a series of phrases or sentences spoken by an instructor, for students to imitate.

Because the instructor is on tape, his voice quality is the same throughout, and he never makes an error. Each student hears this example in his headphone as it is simultaneously recorded on his tape. With his own microphone the student then records his imitation after each of the instructor's examples. After the session, each student rewinds his tape and plays back the entire sequence of the instructor's voice followed by his own, in direct comparison. The tape can now be rewound and the lesson repeated, the master tape once again being fed to all students. While they record a new version the previous recording is automatically erased. Each successive attempt of the student is made more nearly correct by the experience of hearing himself as others do.

Use of Special Recorder

In a more refined version of this procedure, a special recorder is used. First, instruction tapes are prepared on a standard full-track recorder, so that the recording occupies the whole width of the tape. These are edited at leisure by cutting and splicing, so that only perfect examples are presented. After each example, a length of blank tape sufficient for imitation is left. The full-track tapes are then duplicated, so that each student may have a copy.

Each student uses a special recorder which is equipped with a standard half-track recording head, through which he can make his own recordings on the upper half of the tape, and a stacked pair of two-channel playback heads of high cross-talk rejection characteristics. Each of the two playback heads feeds its own individual amplifier, and each has its

own volume control, one marked "student" for the upper channel, and one "instructor" for the lower channel, which cannot be erased by the student. The separate playback amplifier outputs are mixed and fed to headphones.

Student Maintains Control

By manipulating the "student" and "instructor" knobs the student may, when playing the tape, hear either channel separately or both together. The circuit is arranged so that the "student" playback is cut off during recording.

In actual use, the student threads the full-track instructor tape on his machine, starts the tape to moving, switches on his recording button, and turns up the "instructor" volume control. He will hear the voice of the instructor in his headphone, from the lower playback head. Meanwhile, on this first play, he is erasing the upper half of the instructor tape, but leaving the lower half. He may now adjust his recording volume, and through his own microphone record, after the instructor, his own imitation of the example.

Study and Re-recording

He may stop the recorder, rewind, and then play back both the instructor and himself as many times as he likes before repeating the recording. Or he may go through the tape re-recording each example one at a time, and play back the entire recording later.

With such an arrangement this instructor tape can be issued to student after student, like textbooks. The tape is useful to all for as many repeats as desired, yet when the need arises to replace outdated instructions, the tapes can all be recalled, erased, full-track recorded anew, and be ready for another round of usefulness.

E. BINAURAL USE OF MULTI-CHANNEL RECORDERS

Stereophonic recording has received so much attention that the binaural technique seems to be somewhat neglected lately, and most multi-channel recorders are called "stereophonic" recorders. Fortunately, any good quality stereo machine of two or more channels will also serve well as a binaural recorder or reproducer.

The binaural technique implies the use of headphones or separate earpieces, which is usually impractical for commercial systems. Yet for special purposes this technique has its advantages. It might be said that stereophonic reproduction brings the scene of the sound to the listener, while binaural transmission takes the listener to the scene of the sound.

Sound Character Differs

The binaural method takes into account the fact that a substantial part of our human ability to sense the direction of sound results from small differences in its character at one ear, compared with its character at the other. A whistle at our left not only strikes our left ear first, but is much weaker at the right than the left because our head deflects and absorbs it. Lower pitched sounds on the left will reach the left ear first, but be about the same level, only later, at the right ear. In either case, experience has taught us how to interpret the result and to know where the sound is coming from. It is interesting to find that very low pitched hum, without harmonic overtones, is almost impossible to locate.

A binaural recorder uses two separate channels, one for each ear. Two microphones are used, each of which has as nearly as possible the same pickup characteristics as one ear. They are separated approximately the distance between our ears by an artificial head of much the same size and sound-absorption as a human head. This apparatus is then placed wherever we wish our eventual headphoned listener to seem to be when he plays back the binaural tape.

Use Pillow for Separation

In actual practice a matched pair of almost any professional quality cardioid or one-direction microphones serve well, separated by a small pillow, their diaphragms about six inches apart, facing opposite from one another and slightly forward. Each microphone then feeds its own channel on one track of the recorder. In playback, that track which carries the left ear impression is fed individually through amplifiers to the left headphone alone, the right track to the right headphone. The effect is as if the listener has been transported to the location of the microphones, so far as sound is concerned. Of course, if he turns, the sound scene will turn with him.

Aids Group Recordings

This arrangement has special usefulness in the recording of conferences, courtroom proceedings, debates or other gatherings where a

verbatim written transcription will be needed later. If a simple single-channel recorder were used, only the voice quality would identify the speaker, while with the binaural recording his location as well would be apparent. In a single-channel recording it is almost impossible to extract one voice from another when two or more speak at once, yet with the binaural playback we are able to exercise our normal power to select one at a time, then replay for each of the others.

III.
"SOUND ON SOUND" MASTERING

The phenomenal success of Les Paul and Mary Ford in their unique multi-voice records focused attention on the technique which they pioneered, and which has great usefulness for other purposes as well.

In the earliest days, "sound on sound" was accomplished with a single recorder, and a single-channel recorder at that, to produce those remarkable masters on which Les is heard accompanying himself, many times over, while Mary becomes a vocal soloist and all the members of the chorus behind her.

The machine was unusual in one way only: its heads were arranged in an unusual manner. In a normal machine the tape passes first an erase head, which removes all previous recording, then a recording head, which impresses a new recording, and then a playback head, which independently reproduces the newly recorded program. Les and Mary had a machine custom-built with the heads arranged Playback, Erase, and Record.

Records Solo First

Using this machine,Les would record first a solo version of his music. This would go on the tape through the recording head. He would then rewind the tape. The playback amplifier was then connected into the recording amplifier, while simultaneously being mixed with the output of Les' microphone preamplifier. He wore a pair of headphones which monitored the mixture going into the recording circuit. And then he would record an accompaniment to his own previously recorded solo, which he would hear in his headphones. The original solo would be copied along with the new part. Thus, the playback head would feed out the original solo line which would simultaneously be recorded with the new part a little further along the tape.

Passes Erase Head

The solo passage would then move past the erase head, leaving a clean tape for the record head to continue operation. The process would then be repeated, again and again, until all of Les' guitar parts and all of Mary's vocals had been collected. The difficulty with this arrangement was that a fluff anywhere along the line would make all of the previous work useless, and it would be necessary to start over again. Nevertheless, for many successful releases, this is how it was done.

A better solution was to use two normal recorders. In this case, the solo would start on one recorder. This would be rewound, the playback fed to the recording circuit of the second recorder, mixed with the output of the microphone. On the second recorder solo and first accompaniment would be recorded together, but the first tape was not erased, and errors in stage two would not affect it. The third part was added by playing the second tape back into the first machine, while adding part three, and so on.

Audible Degradation

But even this arrangement has its disadvantages. Fine as they are, magnetic recordings can be subjected only to a certain number of successive dubbings before audible degradation sets in. By the time the first voice on one of these tapes gets mixed onto the second tape it is a copy; when it gets to the third tape, it is a copy of a copy, until, if eighteen parts are added it is a long chain descendant of its original self.

Several things happen to the sound. If, for example, the original recordings were to deviate in frequency response only ±½ db from 30 to 15,000 cycles, thus, perhaps down ½ db at 30 and 15,000 cycles, then its copy on an equally flat recorder would be —1 at 30 and 15,000, —1½ in the third generation, and so on, until at eighteen generations the response would be —9 db at 30 and at 15,000 cycles. Any little bumps or hollows in the frequency response curve would similarly be exaggerated.

Accumulation of Noise

In well-designed recorders, whose noise depends solely on tape, noise also accumulates when generation after generation of copies are made. The noise increase, over the master recording, follows the "square root of the sum of the squares" law. This means that the S/N

ratio decrease is 3 db in the first copy, and that it will total 6 db at the 4th generation, 9 db at the eighth generation, and 12 db at the 16th generation. Thus it is desirable to begin with great S/N ratio in the original, if the final release is to be several generations removed.

Distortion collects, too, although luckily it is not the arithmetic sum of the distortions occurring with each successive generation, either. There is a limit to the dodges which can be employed to make each recording ten or more times better than it need be for single generation copies. It would be much better if most parts could be kept separate on their own original magnetic tracks, undiminished by multiple-generation copying, the ultimate number of generations being held to two or three.

A. "SEL-SYNC" (SELECTIVE SYNCHRONOUS) RE-RECORDING

It is possible to construct a multi-channel machine with separated erase heads, so that each can be activated individually and affect only its own track; and the record heads can likewise be separated so that any one or combination is activated independently. But this alone does not permit us to record first one channel, and then another below it, this time with no copying of the first, yet in perfect split-second synchronism.

The recording artist could, of course, listen to the playback of the first track while recording the next track down, but he would not be recording on the tape directly below the channel being heard, because the playback head is to the right (in advance, on the sound track) of the recording head. If he were later to wish to mix all the separately recorded parts in synchronism he would need a whole series of playback heads, stair-stepped and separated each from the next by precisely the distance between original recording and playback heads. This might have been possible, but there was a simpler solution.

Record Becomes Playback

While it is certainly true that the ideal recording head is different in many ways from the ideal playback head, and that any professional recorder should have separate units each designed to do its own job best, a good recording head can serve reasonably well as a playback head.

So a system was worked out for an eight-channel recorder, in which any recording head in the stack of eight could be switched to its channel's *playback* amplifier, without affecting the availability for recording of the other recording heads in the stack.

Recording Procedure

In use, the artist threads up his multi-channel separate erase recorder, and records part one on one channel only, leaving the others, for the moment, blank. He then rewinds, switches the head which recorded the first channel to its channel's playback amplifier, connects his headset to that amplifier, and records the second part on the next track on the same recording stack, thus directly in line with the first recording.

Of course what he hears in his headphones, when he uses a recording head for playback, is not the high quality signal he receives when he uses his regular playback head, but it is perfectly adequate for him to keep in time and tune, and it is thus possible to preserve synchronism on all his tracks, one after the other.

All Original Channels

With such a recorder, the artist can make as many parts as he has channels, and all will be originals. Two or three generations produce next to no detectable deterioration, however, and with such a machine the artist can produce a very large number of additional parts, none of them copied down more than a few generations. All eight originals may be mixed electrically and fed to an additional single-channel recorder, along with an additional part.

He now has a tape on which eight parts are copies, the ninth an original. Now *this* tape can be fed back to one channel of the multi-channel machine, along with a tenth part. This one channel now has eight parts which are second generation, one a copy, and one an original. Each of the remaining channels can now receive an added original part, all still synchronized. Playing back the eight-channel mixture, seventeen parts are obtained on a final single-channel copy, to which an eighteenth part can be added during the copying. No track is more than a third generation!

B. "SEL-SYNC" RE-RECORDING IN OTHER APPLICATIONS

By providing separate erase facility for each track of a multi-channel recorder, it becomes possible to select any one, any combination,

or all tracks of such a machine simultaneously for any recording. But if we wish to add to the collection of recordings on a multi-channel tape, on a channel which previously was unrecorded, and to insure that the added channel is in perfect synchronization with the previously recorded channels, the "Sel-Sync" feature is needed, in addition to the separate-erase feature, as we have seen.

With the separate erase feature, it is possible to erase one channel only of a previously recorded tape. When crosstalk-rejection is very high, and good acoustical separation has been obtained in the original recording between the channels, this erasure of a single channel only will obliterate entirely from the over all multi-channel recording the information which was contained on the erased channel. If we are to replace that channel, now, with a corrected version or perhaps a better version of the same information, we can do so in perfect synchronization with the other previously-recorded channels only if the "Sel-Sync" feature has been added to the separate-erase feature.

Soloist Separated

In a recording studio this would make possible the recording of the orchestra on one or more channels of a multi-channel recorder, while the vocalist or instrumental soloist is simultaneously and separately recorded on his own separate channel on the tape. This could be from a separate studio to insure adequate acoustical crosstalk-rejection.

Once satisfied with the pace of the orchestral portion of the recording, it would be possible for the soloist to practice his solo over and over, long after the expensive recording session, itself, were disbanded, while listening through the headphones only to the orchestral portion of the multi-channel recording. Once sure that his rehearsals have resulted in exactly the interpretation he wishes, he can now erase the version of the solo which was made during the studio session, and simultaneously replace it with his now thoroughly rehearsed version of the solo. With the "Sel-Sync" feature, he could be assured of having his revised solo in perfect synchronism with the original.

Separate Sessions

Of course, a separate-erase "Sel-Sync" multi-channel recorder would make it entirely possible to record orchestral accompaniment at one time, and solo part at another. Such recordings can, however, be made by dubbing from machine to machine, adding solo to the second or copying machine during the dubbing. While the procedure has been carried out many times in the past, recording directors generally seem to feel that such a performance is mechanical and lacking in spirit.

The multi-channel separate-erase "Sel-Sync" recorder makes it possible for the soloist to be present with his accompaniment, to achieve with the musical director exactly the pace and spirit wanted, and yet to be assured that the minor "fluffs" can be easily corrected at a later time, without the necessity of holding the entire recording company together for yet another "take."

A Versatile Recorder

Since this multi-purpose machine makes it possible to remove any one channel of a multi-channel recording at any time after the recording has been made, and to replace it with a perfectly synchronized later version, the machine is by no means confined to "sound on sound" or corrective procedures. It also opens the way for the creation of effects never before possible, through the synchronized addition of any desired material in synchronism with previously recorded material.

Psychological Data

Any type of information which is conveyed by sound may be treated in this manner. In the psychological laboratory, for example, it would be possible to record on one channel the unchanging sound stimuli which are to be presented to a number of different subjects and then to record in perfect synchronism with the stimulus information the reactions of each of several different subjects, or groups of subjects on separate channels. These could be collected at various times, after the original stimulus recording was made.

IV.

SELECTION OF MULTI-CHANNEL TAPE RECORDERS

At the outset, the value of owning a standard, catalogued machine of reputable make should be considered. If the purpose is the preparation of two-channel stereo tapes for broadcast or duplicate sale, one or more standard two-channel stereo recorders will certainly

be needed, even when masters are to be prepared on machines of three or more channels. Beyond the standard two-channel recorder, everything is more or less custom-built, and prices necessarily reflect the cost of low quantity and special engineering.

Highly specialized equipment may have low resale value, and eventual need for special parts will have to be anticipated well in advance, since they will often have to be made to order. But specialized applications frequently justify the cost, delay, and special parts entailed in custom-built equipment. Contemporary engineering can produce almost anything, given enough time and enough money. It's interesting to see what factors the engineers must take into consideration when they design a multi-channel recorder, whether standard or special, to see how some special features are readily and inexpensively built, and why others are more costly.

A. CROSSTALK REJECTION

During the past year or two means have been found to build two-channel recording and playback heads, their gaps in line, with crosstalk rejection sufficient to permit the simultaneous recording of entirely different signals. Playback heads of this new construction can even handle, without audible crosstalk interference, half track tapes which have been recorded (single channel) in one direction on the upper half, and in the other direction on the lower half.

High crosstalk rejection (HCR) previously could be obtained for two channels on one-quarter inch tape with normal (0.09 to 0.1 inch) width tracks only by "staggering" half-track heads along the tape path. Cutting and editing such staggered tapes was unsatisfactory, and maintenance of accurate simultaneity on playback depended on precise gap-to-gap spacing.

A Difficult Achievement

Achievement of HCR on in-line heads looked, at the beginning, very difficult. 90-mil stacked heads, separated by only 70 mils or so, form a small transformer. The units, after all, consist of windings precisely aligned to one another on magnetic cores. Means were sought to break the magnetic path which bound one coil to the other, to make the unit as poor a transformer as possible. Interwinding shields proved satisfactory when their dimensions, material and position were delicately interrelated. One cause of crosstalk, however, could not be reduced.

This is due to the sheer geometry of the head structure, and is the direct pick-up by one head of flux passing the other head. When the wavelength of the magnetic pattern on the tape is not large compared to the inter-track space, this is no problem. But at long wavelengths — which is to say, low frequencies — the effect becomes measurable. The same occurs, of course, with separate heads used for half-track operation, and from experience we know these are entirely satisfactory for audio purposes.

Sensitivity Changes With Frequency

Fortunately, the sensitivity of human hearing becomes less and less as frequency becomes lower and lower. So a certain absolute level of crosstalk, which would be audible and intolerable in the critical mid-range, is entirely inaudible at very low frequencies. To know how effective is crosstalk rejection, then, we look at a "weighted" curve. If the curve of crosstalk rejection either matches the curve of normal hearing response, or falls outside it, we can measure the effectiveness of the rejection by measuring its value at a frequency in the band of greatest sensitivity in the curve of normal hearing. Thus crosstalk rejection is usually given as a number of decibels *effective*. At very low and very high frequencies, rejection is usually much less than this adjusted figure, yet remains no more audible than the figure would lead us to expect.

Values of 30 db were once common in multi-channel in-line audio recorders, but current design has moved this to 40, 50, 55 and, on some designs, even more. 55 db is quoted for Ampex standard two-track one-quarter-inch recorders. Older machines can be brought up to this degree of performance by replacing the head assembly with one of the newer type.

On special machines of three or more chan nels, this high degree of crosstalk rejection may be expected if track and tape widths permit inter-track spacing of 70 mils or more. Typical is the three-track one-half-inch tape machine now in use by at least five major record companies. Tracks are 100-mils wide, each, symmetrical about the center of the tape, with 100-mils of separation.

B. SIGNAL-TO-NOISE RATIO AND DISTORTION

Much confusion exists concerning the real, usable S/N ratio of magnetic recorders. Because sound itself, at least the sound of music and speech, is a series of complex transients, the subject is necessarily complex. For the sake of simplicity, measurements are made with steady tones of continuous and measurable level. To define S/N ratio, we must establish the maximum and minimum levels which the ratio defines. We begin with a signal of given frequency and given level, or, to be more precise, of a given magnetic flux level. And we determine a standard way of measuring noise.

Magnetic tape, in contrast with disc and photographic recording, has a very gentle overload characteristic. When we drive the recording head with more and more undistorted audio current, we record the tape closer and closer to its saturation limit. Distortion begins to increase, due solely to the decreasing linearity of the relation between recording current and the resulting flux density on the tape.

Distortion and Saturation

At a certain flux level, total r.m.s. distortion due to the approach of tape saturation will equal 1%. If we increase recording level 6 db further, distortion will equal 3%. We can now increase the flux level on the tape to the point where we derive 10 db higher output still, but no matter how much further we increase recording current, playback level will rise no more, for the tape is now recorded to saturation. Distortion will be very high.

Typical disc and photographic systems will show differences as little as one db between level at which distortion is 3% and that at which saturation occurs. Such systems, obviously, must be worked well below maximum because of their very steep overload curve. Tape can be worked higher, since an occasional excursion 2 or 3 db above 1% or 3% will not produce ear-shattering distortion.

Ampex has standardized its method of measuring S/N ratio, so that specifications on any of its machines may readily be compared.

S/N Ratio Defined

Signal-to-noise ratio is defined as the ratio, in decibels, of the level of output of a 400-cycle tone from a tape recorded to that level at which total r.m.s. distortion reaches 3% due to the approach of tape saturation, in relation to the r.m.s. noise level at the output, under the same gain conditions, when playing a tape which has been passed over erase and record heads with erase and bias currents on, the noise being measured across a band of 30 to 15,000 cycles.

C. SIGNAL-TO-NOISE RATIO AND TRACK WIDTH

In well designed magnetic tape recorders, noise is determined by the tape, not by the recorder. In such recorders, we increase the output of the magnetic play-back head by 6 db when we double the track width; noise from the tape also increases, because twice as wide a track on the tape is traced, but the increase in noise is only 3 db. Doubling track width, then, increases S/N ratio by 3 db, in recorders whose noise is solely determined by tape.

How Much S/N Ratio is Needed?

The annoyance value of noise behind the recorded signal is a "non-linear function." That is to say, so long as noise is inaudible, it is of little consequence whether it is one decibel or twenty decibels below audibility, in comparison with the signal. However, the moment the noise becomes audible, it becomes annoying in proportion to its audibility.

There can be no fixed, firm rules for the degree of signal-to-noise ratio which may be required for the given application. In monaural transmissions, noise of a certain level may be audible and annoying, when, in a stereophonic transmission, with the same music and the same signal-to-noise ratio, the noise may be only detectable. This, again, is due to the facility which stereophonic transmission gives us to exercise our normal power of selection among the sounds we hear, in contrast to monaural transmission, in which no selection according to position of source is possible.

Some of the sounds we wish to record may have a narrow dynamic range, which is to say that their quieter portions are only a little quieter than their louder portions. Where narrow dynamic range is involved, it is comparatively easy to maintain signal well above noticeable noise. But where the sounds of interest occupy a wide dynamic range, with some very quiet passages and some much louder passages, a much higher signal-to-noise ratio will be required if the noise is to remain unnoticeable, or even tolerably low.

Symphonic Range 45 db

It has been shown that symphonic music can, for the most part, be contained within a dynamic range of 45 decibels. But there is a small proportion of symphonic music which can barely be contained inside a dynamic range of 70 decibels. It is impractical to attempt to reproduce, in ordinary home or studio settings, music or other sounds with so great a dynamic range. Quite aside from the severe technical problems involved in obtaining S/N ratio of more than 70 decibels, neither studios nor quiet living-rooms are quiet enough to prevent the quietest passages in a transmission of 70 decibels dynamic range from being buried in local acoustic noise, unless the maximum level were allowed to be ear-shattering.

We can look at it this way: if a musical selection, of that unusual kind which has 70 decibels of dynamic range, were to be played into a living-room at such a level that its quietest passages slightly over-ride local noise, these quietest passages would measure between 45 and 50 decibels above the bare threshold of normal human hearing, since average room noise in a quiet residence measures about 40 decibels above the threshold.

Maximum Tolerable Sound

The loudest passages, then, would be from 110 to 120 decibels above threshold, which is in the region of maximum tolerable sound, and much above the region of pleasant listening. Yet, if such a selection were played in an average room at such a level that maximum level were held to 100 db or less (above the threshold of hearing), then the quietest passages would fall 10 decibels below the noise level in our average quiet residence.

Thus it is that recordings which are designed to be finally played in residences, motion picture theatres, auditoriums, and most other locations must, necessarily, be limited in dynamic range. This may be accomplished by the musicians or other performers at the time of original recording, or it may be accomplished artificially before recording. Automatic devices are often employed for "peak limiting" with or without human monitoring of the recording. These reduce the level of sudden, unexpected peak intensities, which the human monitor, "riding gain," could not be expected to check effectively.

Compressors, which act more slowly, are sometimes used to do the monitoring job. These act, according to the time-constants designed into them, to maintain average levels at or near a predetermined value. Artistic monitoring, which preserves the effect of dynamic variations in the recorded material, without actually permitting recorded excursions of level to reach their natural values, requires skilled human monitoring.

Background Music Restricted

Generally, background music must be very tightly restricted in dynamic range; its dynamic excursions are usually held within ±5 decibels, approximately, of the desired average. Light, popular music usually is contained within a dynamic range of 20 decibels. Dramatic popular music, "serious" jazz, and light operatic music usually falls within a range of 30 decibels. Recorded symphonic music commonly is released, even on discs, with a range up to 45 decibels. These figures are only averages, since for artistic effect, within the limitations of the recording equipment, any dynamic range may be called for.

Considering the wide variations in dynamic range which are typical of professional recording, it appears that a master tape needs to have at least 50 decibels of signal-to-noise ratio. In professional magnetic tape recorders, the background noise is, characteristically, hiss. The dynamic range which any professional recordist may employ from time to time seems to call for at least this value of signal-to-noise ratio, if objections to hiss are to be avoided. It must be remembered, of course, that this degree of signal-to-noise ratio must exist in the final dubbing, and that successive dubbings may be necessary following the original, if the director is to achieve his desired effects. Since a certain amount of degradation, even though small, necessarily accompanies each dubbing, it is well to employ original recording apparatus, with more than 50 db of signal-to-noise ratio.

55 db With 80-100 Mil Tracks

Upwards of 55 db of S/N ratio may be obtained with highly refined professional magnetic tape recorders, when recorded tracks are 80 to 100 mils in width. Slightly over 50 db are characteristic, even in fine equipment, when tracks of 40 to 50 mils width are employed.

Thus, for most mastering purposes, a two-channel recorder, using quarter-inch tape with tracks 90 to 100 mils wide, appears to be satisfactory.

Three channels on quarter-inch tape requires tracks of 50 mils width, or less. This gives us about 50 db S/N ratio, which may not be considered adequate for mastering purposes. Since inter-track spacing on the quarter-inch tape three-channel recorder cannot be more than 50 mils, crosstalk-rejection is about 30 decibels. Yet the machine has great usefulness where it is to be used mainly to playback original tapes, where frequent new recordings are to be made, and where tape economy is of considerable importance.

100-Mil Tracks With One-Half Inch Tape

With half-inch tape, three tracks, each 100-mils in width, with inter-track spacing of 100-mils, become possible. In such a recorder, signal-to-noise ratio on each channel may exceed 55 decibels, and crosstalk rejection can be at a similar figure. Other than the two-channel, one-quarter-inch tape recorder, the half-inch, three-channel machine is most widely used for mastering purposes.

Using tape one-half inch wide, four channels are the maximum which can be accommodated, with high signal-to-noise ratio and high crosstalk rejection. In this case, track width of 80 mils is used, with inter-track spacing of 60 mils. Signal-to-noise ratio, in this case, is about 55 decibels, crosstalk rejection around 50 decibels.

It follows that, with one-inch tape, six 100-mil tracks with 80-mil inter-track separation would be accomodated, giving both signal-to-noise ratio and crosstalk rejection in excess of 55 decibels. It is also possible, with 80-mil tracks and slightly over 50 mils inter-track spacing, to achieve signal-to-noise ratio of approximately 55 decibels, with crosstalk rejection around 40 decibels. The effectiveness of inter-track shielding, in practical construction, is somewhat higher, for the same separation, with the larger recording and playback heads than with heads for quarter-inch tape.

"Staggered" Technique

Under rare circumstances, it may be desirable to place as many separate tracks as possible on a tape of given width. The "staggered head" technique may be used to accomplish this. Recorders have been built, for example, to employ one-inch tape, and to record fourteen channels. In this case, two stacks of seven in-line recording heads, each, are installed, and two corresponding stacks of playback heads, each. The first recording stack will record tracks one, three, five, seven, nine, eleven, and thirteen, reading from the top, while the second stack will record the even-numbered tracks.

Gap-to-gap spacing between the two record stacks is held, within very narrow limits, to the same value as that maintained between gaps on the playback stacks measuring longitudinally along the tape. In this way a high degree of accuracy is maintained in the simultaneity of signals during recording versus signals in playback. But, of course, with such an arrangement, editing of the tapes becomes complicated by the overlap on the tape of simultaneous bits of information, and signal-to-noise ratio can only be that of the 50-mil tracks employed.

High Crosstalk Rejection

Crosstalk rejection, however, can be well over 55 decibels, since adjacent heads are separated by 100-mils or more on each stack. The space occupied by the four heads precludes the possibility of including, in addition, an erase head, making it necessary that tape be bulk-erased before recording. Apparatus of this kind has application, for the most part, where the maximum possible number of information tracks is needed, where editing may be approximate, where signal-to-noise ratio requirements are moderate, and where dubbing and copying are not contemplated. This deviates widely from the usual audio requirement, and so it is that very few such recorders are in use for audio purposes.

A Conclusion About S/N Ratio

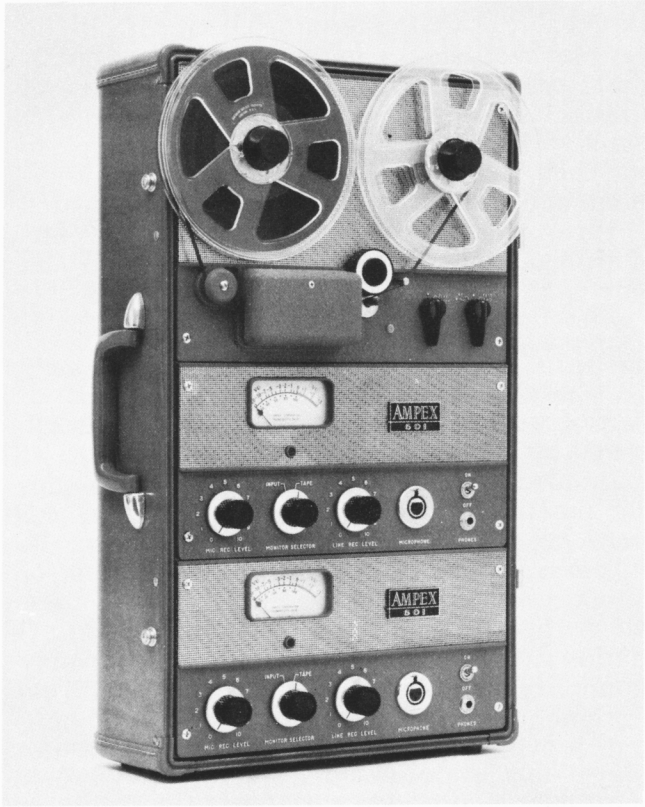
It is proper to conclude that only the finest available professional recorders give us nearly enough S/N ratio, and that we could benefit from even more S/N ratio than we can presently achieve. At the present state of the art it would be unprofitable, generally, to sacrifice S/N ratio in favor of wider range or lower distortion, since more than anything else we need still more S/N ratio. Needless to say, it is good sense to regard the extra cost of the machine with highest S/N ratio as money well invested in professional tools for professional results.

V.

SOME AIDS IN SELECTING CUSTOM-BUILT VERSIONS OF AMPEX MULTI-CHANNEL RECORDERS

The applications for multi-channel magnetic audio recorders are so numerous, and the pos-

sible variations which Ampex can supply are so extensive that only a part of the many possibilities can be described here. Ampex Professional Products representatives are ready to discuss many more.



Model 601-2
Portable two-channel recorder/reproducer.

A. MODEL 601-2 OFFERS PROFESSIONAL STEREO RECORDING QUALITY WITH MAXIMUM PORTABILITY

Model 601-2 was designed to give the professional recordist a stereophonic recording facility of professional quality in the smallest and lightest possible package. It offers 15-kilocycle bandwidth, more than 50 db of S/N ratio, and low flutter in a portable package weighing only 42 pounds.

Not only will the machine record and play back stereophonic tapes, but it will also play back half-track or full-track tapes, thanks to its high crosstalk rejection heads.

The 601-2 should be selected for every stereophonic recording application where its combination of high quality and portability is needed. It should not be selected where, in addition, the recorder must also record single-channel half-track tapes. In 601-2 the bias and erase currents all originate in one of the two electronics chassis. The erase head is fed from this chassis. Through an interconnecting cable this supply is tapped, and simply fed through the other chassis as bias for the second record head.

Thus the upper channel cannot be switched off, to permit recording half-track with the lower channel only, for this would remove bias; and if the lower channel were disconnected, the load on the bias and erase oscillator would change substantially, altering bias and erase on the remaining connected heads, and impairing quality.

In addition, of course, 601-2 has the usual full-track erase head. Even if we could satisfactorily record a half-track in one direction, we would erase it in passing the tape through a second time, in an attempt to record the other half-track. And if we disconnect the erase head the second time through, we disturb bias level still more, and even further impair quality.

Completely separate control over upper and lower tracks of a two-channel recorder can be achieved through the use of a Master Bias Oscillator and two "Slave" electronics chassis. This facility is available on Series 300 and Series 351 recorders, where the additional weight and size components permit it.

With its high S/N ratio, response to 15 kilocycles, high crosstalk rejection, and ability to record up to 48 minutes without interruption, 601-2 fully complies with most professional stereo recording needs. But where higher tape speed is needed, heavier equipment is usually necessary in order to provide the larger reels which are then needed for adequate recording time. While consideration has been given to designing a 15 ips version of 601, all surveys have indicated relatively few potential users, and, at this time, it still appears that the rather large engineering program which this design would need, should go instead into satisfying other and more pressing industry needs.

B. SOME USES OF THE SEPARATE ERASE 351-2 AND 300-2

351-2 or 300-2 recorders, with separate erase

are excellent stereo recorders and also can be used for recording of half-tracks, single-channel. They will produce tapes identical to those produced by a half-track single-channel recorder of the same series. In this service the upper channel only is actuated and the signal to be recorded is fed to it. One word of caution: if the signal were fed into the *lower* channel, the resulting half-track tape would play forwards only on a machine with two-channel high crosstalk rejection heads, and not on ordinary half-track playback equipment. The standard method of recording half-track single-channel tapes is forward (i.e., left to right) on the upper track. Thus, when the tape is turned over, the tracks opposite one another run in opposite directions.

Copies Both Tracks

Two-track separate-erase equipment will copy stereo tapes, and may also be used to copy simultaneously both halves of a half-track single-channel tape. The tape to be copied would be threaded on a machine which is equipped with high crosstalk rejection two-channel heads, and the outputs of the reproducing equipment fed separately into the channels of the two-channel separate-erase high crosstalk rejection recorder. The fact that one channel is being recorded backwards is of no consequence whatsoever. The resulting copied tape will play satisfactorily on ordinary half-track reproducing equipment.

C. INTERCHANGEABILITY OF RECORDED MULTI-TRACK TAPES AMONG DIFFERENT MACHINES

If a multi-track tape recorded on one machine is to be played back on another similar machine, a very high standard of accuracy in head construction is required.

Ampex two-track stereophonic recorders built since early 1957 are all equipped with new high crosstalk rejection two-track in-line record and playback heads of cast construction. "Casting" allows precision alignment of the stack of corresponding pairs of heads. Interchange of tapes among such machines is altogether possible, inside the frequency response specifications published for this equipment.

Three Channels with HCR

During 1957, Ampex began to market half-inch three-channel recorders, also using high crosstalk rejection, cast-construction head assemblies. The same very high degree of precision in alignment of in-line tracks was achieved in these machines, and tapes may be interchanged among them, maintaining the published frequency response specifications upon interchange.

However, where "sandwich" construction heads have been employed in multi-track recorders, interchangeability is not always achievable while maintaining the frequency response characteristics which apply to the original recorder when playing back its own tapes.

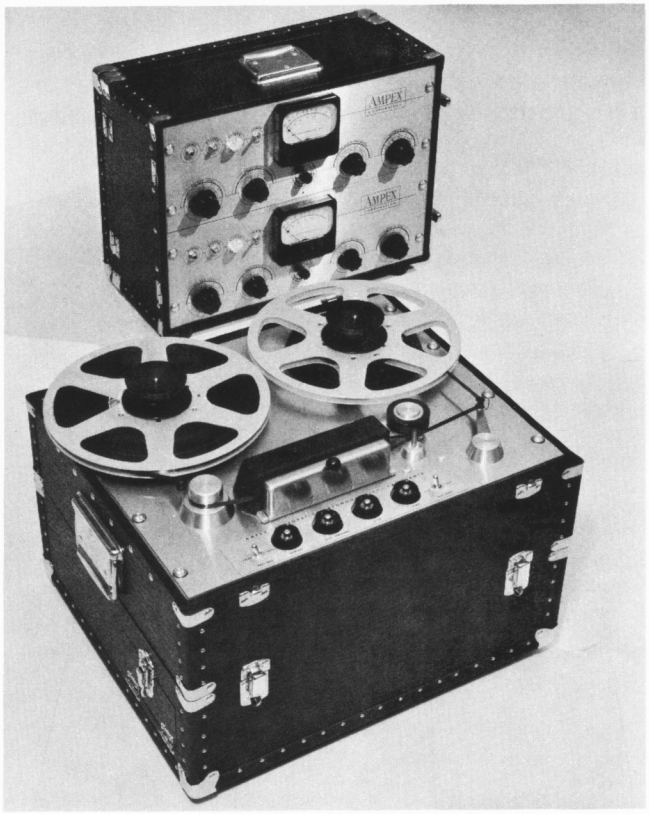
"Sandwich" Meets Specifications

Many of our multi-track recorders are equipped with "sandwich" construction heads, which may be built with sufficient accuracy that typical Ampex specifications are maintained when these recorders play back their own tapes, but not sufficient that tapes may be interchanged among two or more such recorders. "Sandwich" construction involves the piling up of numerous in-line heads, from individual stacks. If the gaps are held, within micro-inches, to exactly in line, and playback heads for the machine are similarly held tightly in line, the tapes will reproduce, on the recorder on which they were made, well within Ampex specifications.

If however, the upper record head of a multi-track stack is very slightly tilted with respect to the other head gaps in its stack, it will be necessary that the corresponding playback head be similarly slightly tilted, if full-range frequency-response is to be obtained when this recorder plays back its own tapes. Such compromises are made in constructing heads for special multi-track recorders when no substantial number of such machines are expected to be built. The customer, therefore, before purchasing such a recorder, should understand that, while the machine will play back its own tapes within the specifications offered, it may not produce tapes which are interchangeable with other recorders built in the future, which may carry the same specifications, each to itself.

Heads Built With Cast Technique

At present, only two-channel quarter-inch heads and three-channel half-inch heads are built with the cast technique. Three-channel quarter-inch machines, having narrow (50-mil) heads, interchange with one another very satisfactorily, although their heads are of "sandwich" construction, since the degree of accuracy obtainable in sandwich construction is entirely adequate to standardize reproduction of narrow-track recordings. Other cast heads will be added, of course, as future needs develop for special assemblies.



Model 351-2P
Portable two-channel recorder/reproducer.

D. MODEL 351 EQUIPMENT FOR GREAT FLEXIBILITY AT LOW COST

Equipment of the 351 series has been designed to meet the highest commercial standards, and is intended especially for broadcasting purposes, where the utmost in ruggedness and reliability is required, where the need is for making originals or copies, but seldom for extensive further processing after recording. 351 equipment is fully remote-controllable in all its versions.

Quarter-Inch Tape Models for One or Two Channels

Quarter-inch Model 351 recorders are available at operating speeds of 7½ & 15 ips or 3¾ & 7½ ips, operating on 60 cycles, or, on order, 50 cycles. Single-channel custom models may be had with special head configurations, and with European-standard C.C.I.R. equalization. All one-channel machines are available in console, as well as in portable or unmounted form.

Quarter-inch multi-channel versions include the standard 351-2, with two-channels and separate erase. This may be ordered in 3¾ & 7½ ips or 7½ & 15 ips speeds, and 60 or 50 cycle models.

Multi-channel Model 351 machines are built in portable or unmounted form only.

Model 351 Equipment Handles Reels Up to 10½ Inches Diameter

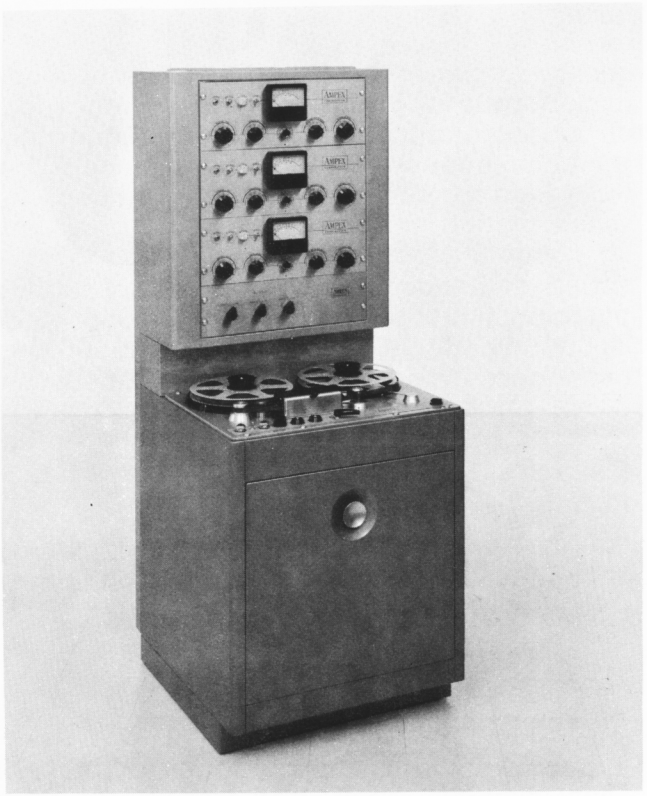
The 351 transport mechanism has been designed for minimum size and weight for high-quality performance with reels up to 10½ inches in diameter. Like other Ampex recorders, it is distinguished by extremely rigid frame construction, whose value is high in assuring freedom from frequent readjustments, low flutter and wow, and great ruggedness. Extension arms for 14-inch reels have been tried, and found to introduce objectionable limitations on performance, thus emphasizing the importance of rigid support for all elements of the tape-moving system.

E. MODEL 300 FOR MAXIMUM PERFORMANCE IN MASTERING

Series 300 equipment was designed to exceed the highest commercial performance standards. These machines are for applications where original tapes must be several times better than released copies. Series 300 equipment is intended especially for mastering.

Fourteen-Inch Reels for Model 300

Model 300 is available with turntables spaced to accommodate 14-inch reels of tape, supporting the entire tape-moving system with adequate rigidity.



Model 300-3C-SS
Three-channel console type recorder/reproducer with sel-sync control panel.

Model 300 For Operation With Half-Inch or One-Inch Tape

Model 300 equipment may be had with half-inch tape in three- and four-channel versions, with separate erase heads. One-inch tape on Model 300 permits six- or eight-channel models.

Wide Range of Tape Speeds Available On Custom Model 300 Equipment

While the most popular operating speeds are 7½ & 15 ips, special versions of Model 300 may be had with operating speeds of 3¾ & 7½, 15 & 30, and even at 1⅞ & 3¾ ips. Three-speed models may also be built, providing any three adjacent standard speeds from 1⅞ to 30 ips.

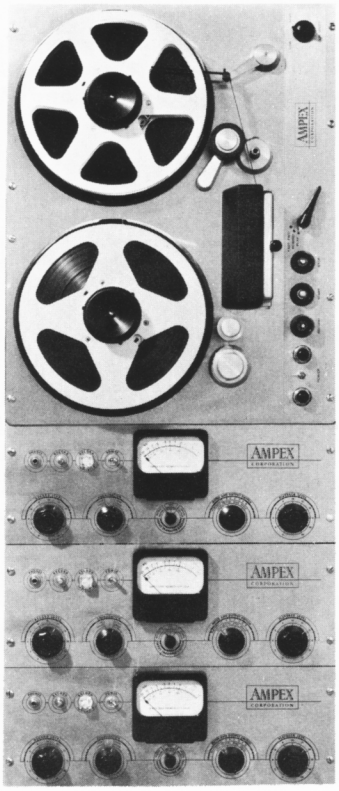
Selective Equalization on Model 300 Recorders

As standard equipment on all new 300 series recorders, a selector switch is provided for NAB and Ampex Master Equalization (AME). CCIR equalization is available on special order.

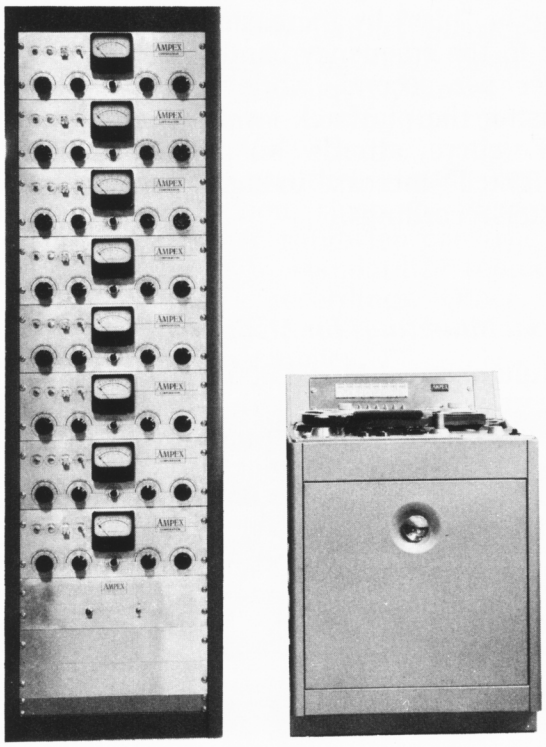
The AME curve was adopted to reduce tape noise or "hiss" by increasing the signal to the tape in the frequency band from 2000 to 6000 cycles per second, while simultaneously decreasing the playback level in that band. The AME curve affords an approximate 7 db (weighted) increase in signal-to-noise ratio on master recordings.

Special Mountings for Model 300 Recorders

Multi-channel Model 300 recorders are available, in all versions, with transport mechanism in console mounting, electronics in adjacent deluxe-finished cabinets. Up to three channels, Model 300 multi-channel machines are also available in portable cases or consoles. All versions may be ordered unmounted, for mounting in standard racks or in locally built cabinets.



Model 300-3U
Three-channel Rack Mount recorder/reproducer.



Eight-channel Model 300 with "Sel-Sync", using one-inch tape. A custom-built machine for recording artists Les Paul and Mary Ford.

F. INSTRUMENTATION RECORDERS FOR OTHER THAN AUDIO APPLICATIONS

An immense variety of magnetic recording equipment is available from the Ampex Instrumentation Division for scientific data-handling purposes. It is quite possible to design magnetic tape recorders with frequency response far beyond 15,000 cycles, as the Videotape Recorder, and the Instrumentation recorders have so adequately shown.

Instrumentation Recorders For Direct Recording Beyond 15,000 Cycles

We have seen that there is a trio of characteristics which depend on one another: frequency-response, signal-to-noise ratio, and distortion. To exceed 15,000 cycles in upper frequency response, some sacrifice must be made in S/N ratio or in distortion. The Ampex line of audio recorders has struck a remarkably good compromise among these characteristics, for sound-recording applications. Ampex Instrumentation recorders have achieved a similar compromise for equipment which gives a variety of frequency ranges, for data-handling purposes. Machines with upper response of 30,000, or 50,000, cycles, or several other ranges, are available. These should be selected where the special recording purpose requires response beyond the normal audio limit of 15 kilocycles. For such special purposes a limitation of S/N ratio, to a value less than that needed for sound recording, is usually acceptable.

Constant-Current Recorders for Instrumentation Uses

Recording with "constant current" provides equal dynamic range at all frequencies inside the specified bandpass of a given magnetic recorder. Providing equal recordable range in this manner involves the sacrifice of overall signal-to-noise ratio, of course. Such recorders are very useful for many purposes. They typically give overall S/N ratio of 35 to 40 db. Whenever such a recorder is needed, selection should be made among the machines offered by the Ampex Instrumentation Division, since these are especially designed and carefully constructed for such applications.

For audio purposes, however, an Ampex Professional Audio recorder is the more desirable choice. The equalization characteristics of these recorders exploit the fact that nearly all sound has its energy concentrated in the mid-range, and not at the frequency extremes. Equalization methods raise the level of high-frequency recording currents so that recorded level is well above noise, and provide the high S/N ratio which is so important in audio recording.

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