OBJECTIVES

To disseminate to RCA engineers technical information of professional value.

•

To publish in an appropriate manner important technical developments at RCA, and the role of the engineer.

•

To serve as a medium of interchange of technical information between various engineering groups at RCA.

•

To create a community of engineering interest within the company by stressing the interrelated nature of all technical contributions.

•

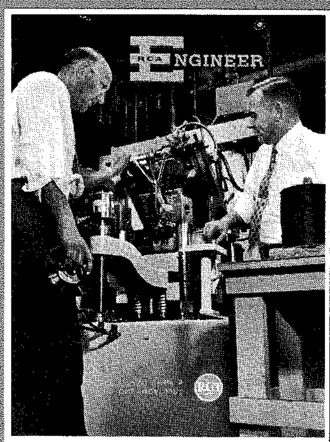
To help publicize engineering achievements in a manner that will promote the interests and reputation of RCA in the engineering field.

•

To provide a convenient means by which the RCA engineer may review his professional work before associates and engineering management.

•

To announce outstanding and unusual achievements of RCA engineers in a manner most likely to enhance their prestige and professional status.



OUR COVER

The two engineers pictured here examining the "45" automatic record press are the ones largely responsible for its success. L. C. Harlow, Manager of Equipment Development, proposed it and his group was responsible for development and design. S. D. Ransburg, engineer, lived with it during initial factory operation and brought it up to present day operating efficiency. Incidentally, not all of the presses are so gayly decorated. Colors were picked to emphasize the various parts of the press.

RECORDS AND ENGINEERING

The many millions of phonograph records produced by the RCA Victor Record Division in 1956 made it the banner year since the Victor Talking Machine Company was founded in 1901. Production rates at Indianapolis ranged as high as 300,000 records in a 24-hour period. Record sales have continued to swing upward with substantial gains each year.

What has brought about this increase in acceptance and sale of records? Of course, much credit for increasing Record Sales is due to an imaginative merchandising program. The answer to acceptance, I think, lies largely with Engineering . . . backed by Management's desire to have the finest and a determination of Manufacturing to make it so.

Let's see how engineering fits into the picture! In the late 30's and 40's engineers were assigned the challenging project of improving the phonograph. Engineering studies revealed that, if substantial improvements were to be made, the "78" record would have to be greatly revised.

It was proposed instead that the record, pickup, and record changer be designed together as a system so that each would be compatible with all other components. The engineering studies showed that the necessary improvement in quality could be obtained by utilizing fine grooves, a slower turntable speed, and a pickup of low mass with a small stylus. A finer groove and a slower speed would also result in a smaller record for the same playing time. Thus, the RCA "45" was created and introduced to the public in 1949!

About a year later RCA Victor went into production of long play records. These records were compatible with the "45" as to groove and stylus dimensions but required a slower operating speed—33⅓ rpm instead of 45. It is interesting to note that RCA Victor had first introduced a 33⅓ rpm phonograph and records in 1931, but the market was not then ready and production was later discontinued. Now, in 1950, quantities of new fine groove records were available for public evaluation, and won instant acclaim.

What was in back of this unusual performance record, as far as the engineer is concerned? The introduction of narrow-groove records required entirely new techniques and a tightening of controls throughout the entire process from recording to pressing. Recording techniques and equipment had to be improved. New electroforming means had to be developed. Methods of electrocleaning had to be evolved to avoid scrubbing practices. Finer compound had to be developed to minimize surface noise. New tools had to be developed, and molding techniques revised in order to assure smooth, quiet grooves—all of which are Record Engineering problems.

In the instrument field, turntables had to be made smoother and quieter. A vast amount of development work was required on pickups, and still is today, in order to fully realize the quality of recording available on the present day disc. These too are engineering problems.

The desire to give the customer something better, the utilization of engineering to its fullest extent, and a firm resolve to produce a quality item are factors that have resulted in a product that is appreciated and enjoyed by the public.

H. E. Roys

H. E. Roys, Manager
Engineering
RCA Victor Record Division
Indianapolis, Ind.

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RCA ENGINEER

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CREATIVE ENGINEERING

by

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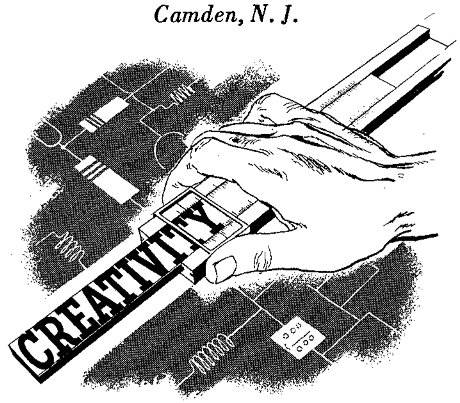


"LEARN A NEW WORD and you will hear it or read it within twenty-four hours." Have you ever noticed how often this saying holds true? Certainly it is so with "Creativity" or "Creative Engineering." Once brought to our attention, these words seem to crop up daily. If you haven't noticed it yet, take a look at the key words used lately in advertisements for engineers.

CREATIVITY IS NOT NEW

Creative engineering is not a new classification to be set up alongside professional classes such as electronics, mechanical, and civil engineering, nor is it a new functional class to be set up alongside research, development, and design engineering. Creativity is simply another tool, like mathematics and skills in human relations, which the engineer and engineering manager can add to his tool kit.

Although at least one university, Massachusetts Institute of Technology, has made creative engineering a specific part of the curricula, the purpose is not to anticipate a job occupation of Creative Engineers sometime in the future, but rather to recognize and enlarge the creative talent which is latent in every human being.

WHAT IT IS

The creative process has been defined as a mental process in which past experience is combined and recombined, frequently with some distortion, in such a fashion that one comes up with new patterns, new configurations, new arrangements, that better solve some need of mankind. Note that the association, or synthesizing, or inductive type of thinking is emphasized here. This is distinct from analytical, or deductive, thinking as well as from the mental process of judging or evaluating. This distinction is necessary for the premise that all of us are born with a certain amount of creative potential which is largely independent of the intellectual potential we receive at birth. "Intellectual" refers to deductive and analytical powers in this case.

The ability to think inductively, to combine old concepts into an entirely new concept, in other words to be creative, can be strengthened in each of us by understanding the process and by exercising it. Furthermore, creativity is not at all limited to engineering—if a Campbell's Soup executive asks himself why his company shouldn't can watermelon juice, or a housewife decides to broil cantaloupe, it is quite likely that the one is a creative business man and the other is a creative housewife. The mere fact that each is willing to consider something out of the ordinary, associating separate concepts to get something new and novel, argues strongly that the same people will have other attributes of drive, self-confidence, etc. that predominate the make-up of a creative person. Among these attributes is "Flexibility of Thinking."*

INSPIRED APPROACH

Methods, or techniques, of creativity are *inspired*, or *organized*. The foundation for the "inspired approach" lies in a period of searching. This is a time of hard work. The problem is carefully stated and isolated from confusing and conflicting material. This could be an unconscious or informal organization. Facts that bear on the problem are collected and assimilated. The problem is considered from every angle and with many variations. This period of preparation sometimes occupies many years as in Kepler's discovery of the law of planetary motion. After hard work on the problem comes a time of relaxation. This is a time when the "unconscious" or "subconscious mind" is active. Although the presence of an "unconscious" is apparent to most of us only by such evidence as slips of the tongue, dreams, and hypnotism, there is medical agreement that it has a powerful influence on our lives. The idea that comes from "nowhere" while one is shaving or watching a movie is generated in the "unconscious." It is an example of the "AHA" or "EUREKA" experience that caused Archimedes to jump from the bathtub and run through the streets of Syracuse. It is also the logical consequence of the periods of preparation and relaxation. The fourth and last step in the "inspired" solution to the problem is the consolidation of the idea. Generally the idea is in embryo form. It must be expanded, and developed, made practical, and "sold" to the rest of the world. This is another period of hard work. Lack of effort at this time often results in loss of the idea. This is the time when self-confidence and drive make the difference between a great invention and a silly idea.

BRAINSTORMING

Although most truly great inventions originated at least partly by the intuitive approach, there are organized methods by which creative output can be increased. Among these methods are brainstorming, about which much has been written (See "RCA Engineer," Vol. 1, No. 6, 1956, page 2) and simple check lists with words that might start one's thoughts along new lines. Examples of such words are "substitute," "modify," "expand," "minimize," "reverse," "combine," "adapt," etc. Both techniques are the grandchildren of one of the pioneers

* Consider this problem, which illustrates rigidity of thinking as opposed to flexibility. A big Indian and a little Indian were crossing a bridge. The little Indian was the big Indian's son but the big Indian was not the little Indian's father. Why? You may be surprised how long it takes to figure out that the big Indian is the little Indian's mother. Nothing in the problem makes the solution difficult, except that by rigid mental association all of us are used to thinking of an Indian as a *male* Indian.

in the field of creativity, Mr. Alex Osborn, whose book, "Applied Imagination," is a textbook on creativity.

CONSIDER ALL VARIABLES

Another interesting device usable for producing a tremendous number of possible ideas was first suggested by Dr. Fritz Zwicky, of Aerojet Corporation. After a problem is stated as broadly as possible (e.g., How may we transport something from A to B), all the independent variables are then listed (Type of carriage, Motive power, and Medium to move through).

Now, under each heading, of which there are three in our example, list as many possibilities as you can think of. (Under "Type of carriage" might be platform, sling, closed solid body, solid body with doors, etc. Under "Motive power" might be steam, compressed air, momentum, combustion engine, etc. Under "Medium to move through" might be solids such as the earth's surface, or a vacuum.)

Now consider all possible combinations of all possibilities under the three main headings. With only ten possibilities in each of the three categories there will be one thousand ideas to be evaluated! Many of these combinations will be foolish, such as a wagon powered by steam moving through oil. These may be rapidly rejected. A few ideas may be novel and practical—it is these you are looking for. Note that with this method, if properly used, every means of transportation known today can be listed in something less than one full day's work.

Another useful working tool is the organized procedure given below for tackling any engineering problem.

1. Define problem in as general and broad terms as possible.
2. Give important past history of idea and show why solution of the problem is desirable.
3. Include important data or indicate where such data might be obtained.
4. Describe system that is to be replaced, pointing out undesirable features.
5. List features desired in new system.
6. List limitations on new design.
7. Suggest possible approaches and solutions by definite statements, suggestive questions, or the inclusion of check-lists.
8. Use special folders for proposals and directives.
9. Include a tentative schedule of design and development costs.
10. Set definite date for idea-review and evaluation meeting.

In this brief article other techniques will not be described, but the literature is readily available to anyone interested in learning more about organized approaches to creativity.

ENEMIES OF CREATIVITY

Even though a person possesses creative ability, he may not be able to exercise it fully. The factors that inhibit and prevent creative activity are called blocks. Professor Arnold of MIT groups these blocks under the headings of Perceptual Blocks, Cultural Blocks, and Emotional Blocks. The perceptual blocks prevent us from getting true information about the outside world. Examples are difficulty in isolating the problem, neglecting to consider environment, failure to distinguish between cause and effect.

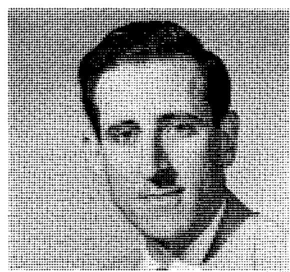
Our culture—the influence of our family, friends, schooling, church, political association etc.—may either help or hinder creative work. Some cultural blocks to creative work are the desire to conform to an accepted pattern, over-emphasis on a quick "practical" solution, and too much faith in reason and logic.

Emotional blocks probably constitute the largest group and are by far the most devastating. The influence of our unconscious mind and our emotions on creative work is tremendous. Some of the emotional blocks are fear of making a fool of oneself, over-motivation, pathological desire for security, and inability to relax and let "incubation" take place.

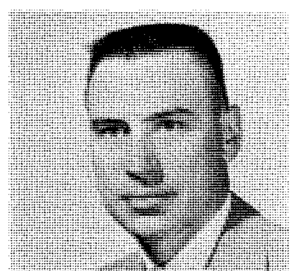
It is comforting to know that all three types of blocks, once recognized by the individual, can be largely eliminated by his own efforts.

CONCLUSION

In concluding, we note that the direction and management of creative people has become a large and important field. Several important factors in the management of creative people are: *Stimulation*, such as contact with outstanding colleagues, opportunity to do creative work, and an understanding of its importance; *Encouragement* in the work and a tolerance for the inevitable troubles; *Assistance* in technical problems, and the provision of the proper environment and tools to do the work; *Recognition* and *Reward* of accomplishment through publication of work, proper titles and position in the organization hierarchy, salary and other remuneration, and the acknowledgement of a valuable contribution.



JAY J. NEWMAN received a BS degree in electrical engineering from Purdue University in 1946, and a Bachelor of Laws degree cum laude from Harvard Law School in 1951. From 1946 to 1948 he was an electronics engineer at Bell Aircraft. Mr. Newman joined RCA in 1951 as a Product Analyst in the New Products Division. In 1956, he was appointed to his present position, Manager, New Product and Market Development, Components Division. Mr. Newman is a member of the Bars of the U. S. District Court and the Court of Appeals for District of Columbia; a member of the Harvard Law School Assn. and Harvard Law School Assn. of N. J. As a member of IRE, he served as Program Chairman of the 1956 Creative Engineering Symposium sponsored by the IRE and AIEE Philadelphia Chapters.



H. J. WOLL received his BS in EE from North Dakota State College in 1940. After a year of graduate work at Illinois Institute of Technology, he joined RCA at Indianapolis, and transferred to Camden in 1946. He continued graduate work at U. of P. as the first recipient of an RCA Fellowship, and received his PhD in 1953. Dr. Woll has been engaged in circuit development and systems engineering for the past 16 years. At present, he is Manager of Optical, Mechanical and Circuit Development, Special Systems and Development, Defense Electronic Products.

Dr. Woll is a member of IRE, AIEE, and Phi Kappa Phi.

He is a contributing author of HANDBOOK OF SEMICONDUCTOR ELECTRONICS.

C. M. SINNETT. For a biography of Mr. Sinnett, see his article (Ideas),[n] which appeared in RCA ENGINEER, VOL. I, NO. 6.

STORY OF RECORD MANUFACTURING

By **C. O'D. KNUE, Mgr.**
Factory Engineering
RCA Victor Record Division
Indianapolis, Ind.

PROBABLY, THERE ARE very few engineers, or other employees for that matter, aside from those employed in the Record Division, who know of the many steps that must be taken in producing phonograph records. It is not because the processes are secret, for the basic system is much the same in each of the many record companies operating at this time.

Amazing as it may seem, some have the conception that each record produced is individually cut. Were this so, production costs would be prohibitive and mass production, if not impossible, would be wholly impractical.

In order that the engineering and production processes employed in the Record Division may be more easily understood, a series of descriptive articles are devoted to this subject! The front cover of the magazine, the inside message by Mr. H. E. Roys, and a series of six articles following this brief introduction will picture and describe the various phases of RCA Record Division activity. The flow chart and the picture spread on the following two pages entitled "HOW RCA VICTOR RECORDS ARE MADE" have been prepared so that the reader can visualize the main flow, starting with the recording of the master through the shipping of the finished record.

PROCESS INVOLVES MANY SKILLS

A likely impression when the flow chart is first examined is that the disc record manufacturing process is complex. This is true, because many arts, sciences, or skills enter into the production of a record.

Actually, to make a record, not only is it necessary to make the recording, but also to make the labels, the matrix for molding, the disc composition (compound), and the album or sleeve into which the finished record is packaged. And although the process is unchanged for each record produced, it is still a situation in which each selection is like a new model because the labels, matrix, and packaging are for the one selection and are not interchangeable.

TWO MAIN PHASES

In order to simplify the description of the record manufacturing operation, the process may be broken down into two main phases . . . recording and mass production.

Both the flow chart and the articles that follow have been built around this visualization. On the flow chart the central stem starts with the recording phase, and is followed by the manufacturing phase. Contributing activities and functions of manufacturing feed in from the left and right of the main stem—such as production of the labels and of the compound. Most of the process is described in separate articles, and except for label production, finishing, inspection and packaging, detailed papers have been prepared for the entire flow chart.

BRIEF REVIEW OF PROCESSES

The thumbnail review below may help the reader in studying the flow chart and in picturing the areas of activity which are covered by the two main phases, for which companion articles have been prepared.

RECORDING, the first phase, is accomplished using master tapes, but in order that the recording be in the form of record grooves a transcription is necessary to a lacquer disc. It is this step in which a record is "cut", and basically only this one cutting is required per selection.

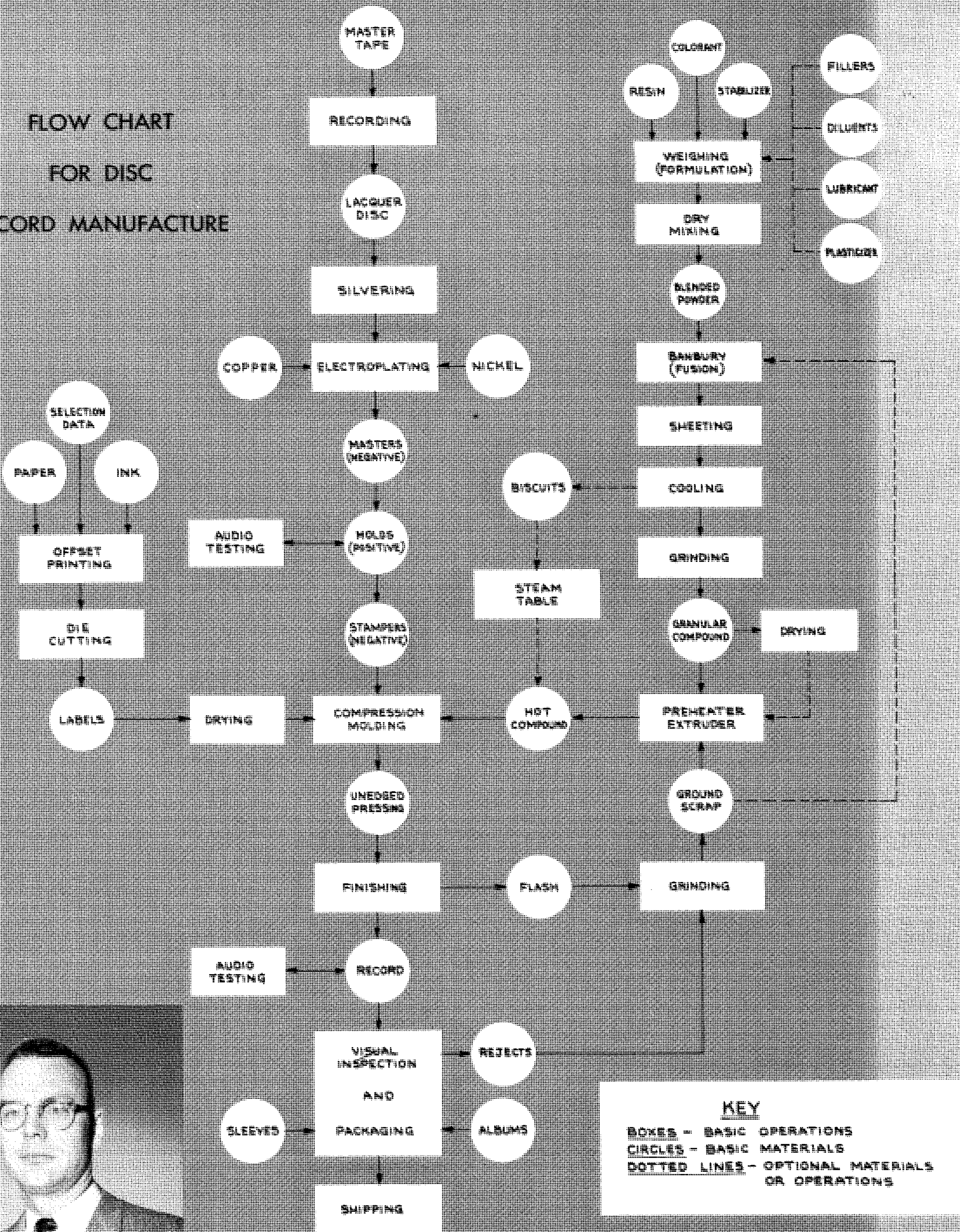
MASS PRODUCTION, the second phase, is accomplished first by producing a master by metallizing the lacquer disc with silver so that the original cutting may be duplicated, in negative, by electroplating; and second by reproducing additional negatives (stampers) in quantity by electroforming them from metal positives (molds) which previously have been duplicated from the master. Having the means for mass production . . . the stamper negatives made by electroplating . . . producing disc records is now a matter of forming a plastic composition (compound) into discs and at the same time to form the recorded grooves in the disc. The actual practice is also to mold on the disc the paper labels which have been preprinted for the record.

SEE DESCRIPTIVE ARTICLES THAT FOLLOW

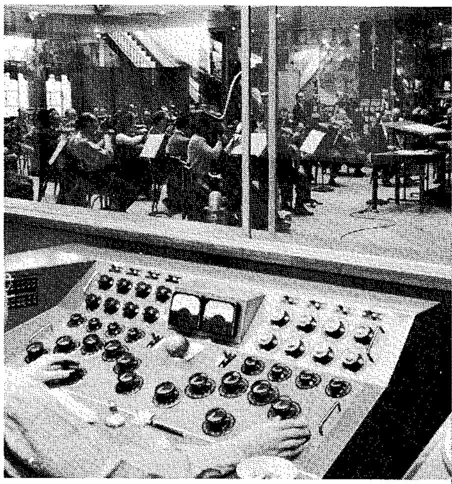
Descriptions in this article have been kept brief since the major steps illustrated in the flow chart and on the next two pages are elaborated upon in other articles in this issue. These papers are seven in total, six written by authors from the Record Division, and one by R. S. Fine of the Radio & Victrola Division, dealing with recording and reproduction. W. Miltenberg and R. C. Moyer, of the Record Division, have written articles pertaining to recording; and in addition articles on producing records and matrix have been prepared by Dr. A. M. Max and S. D. Ransburg respectively. Other important articles in this issue, from a Record Division standpoint are; one by G. P. Humfeld covering the preparation of compound, and another by L. C. Harlow covering the design and development of machinery and equipment for the record factories.

CHARLES O'D. KNUE, B.S.CH.E., received his engineering degree in 1943 from Purdue University. After serving during World War II as a Field Artillery Motor Officer, he joined RCA in 1945 in Indianapolis. His first assignment was the final development of the transparent red vinyl plastic composition for the 78rpm "Deluxe" record, having started as a Development Engineer in the Record Design and Development Engineering Laboratories. In 1946 he transferred to the Factory Engineering Section of the Indianapolis Record Plant and coordinated the use of the newly developed synthetic record plastics for production to replace shellac compositions which had been used for years in the industry. In 1949 he was advanced to Group Leader in the section, and in 1950 was promoted to his present position of Manager, Factory Engineering, Indianapolis Record Factory.

FLOW CHART FOR DISC RECORD MANUFACTURE

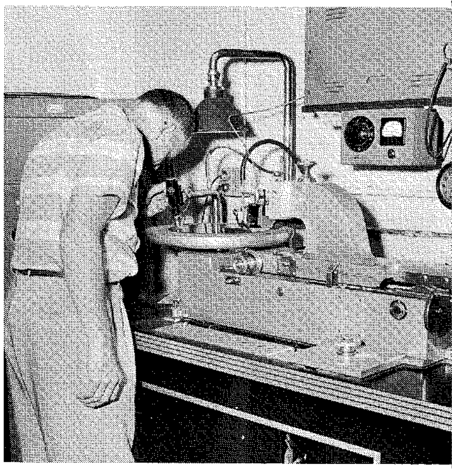


HOW RCA VICTOR RECORDS ARE MADE



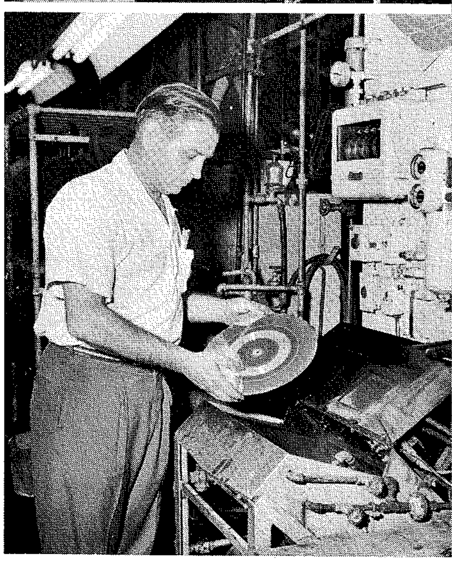
1

As the orchestra plays in the recording studio, a tape recorder picks up the sounds. An engineer adjusts the controls of the recorder for loudness and musical quality.



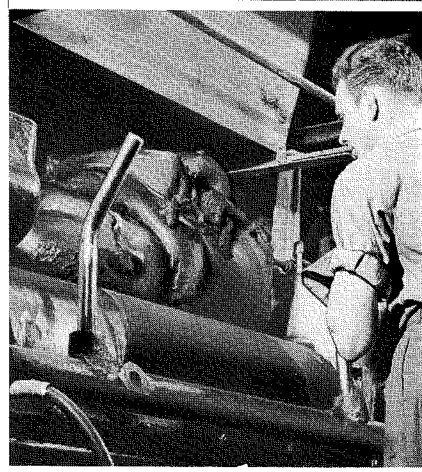
2

From the tape the music is recorded onto a lacquer disc. Here the sound grooves are being cut into the disc's surface.



3

The lacquer disc surface is metallized with silver so that it can be reproduced in negative by electroplating. Separate layers of nickel and copper are deposited on the silver, and then the metal portion is separated from the lacquer disc giving us a "Master."



The art of making today's high fidelity phonograph records is a fascinating one indeed. It is a combination of many skills and highly complex machinery. Here are some of the scenes involved in record production at the RCA Victor Record plants in Rockaway, N. J., Hollywood, Cal., and Indianapolis, Ind.

4 A metal "Mold" disc is then made from the surface of the "Master," by electroplating layers of nickel and copper on its face and again separating the new metal portion from the old. Finally, the surface of the "Mold" disc is used for making the final disc of hard nickel, called the "Stamper." It is this disc that actually presses the record.

7 Highly trained women working in sound-proof booths listen for faults in records taken from each lot. If the record is not correctly made it is discarded, and the rest of the lot and the stamper discs are examined as well. Testing insures high quality.

5 Records are made from Vinyl plastics that are a compound of various ingredients blended and fused in a giant mixing machine. The hot pliable compound is flattened into sheets on huge rollers shown here. The sheets of compound subsequently are cooled and granulated ready for use in the extruders at the record presses.

8 The finished product, another RCA New Orthophonic High Fidelity record, is visually inspected and placed in its colorful package as it leaves the RCA Victor plant. For added protection, LP records are also placed in an inner sleeve of glassine.

6 Two "Stamper" discs are put into a press—one for each side of the record. Here the operator is placing a record label on the top stamper disc. She then puts the heated compound into the machine and closes the press. Hydraulically the grooves and labels are molded into the record. The record then goes into a machine next to the press that automatically trims off the excess material around the rim. In the case of 45's the center hole is punched at the same time.

RCA RECORDING PRACTICES

by **W. H. MILTENBURG**
RCA Recording Studios
New York, N. Y.

WITHOUT QUESTION, the general function of the Recording Department has changed only slightly since the time of Eldridge Johnson. Briefly, that function is to capture sound and impress it on a form which ultimately can be used by the consumer. Although the general function remains the same, the methods employed have varied through the years. Significant changes during the last decade and a half have resulted in the introduction of the lacquer discs, magnetic tape, and fine groove recordings. In the near future, developments covering multi-track tape records may be expected to provide greater fidelity — consequently more enjoyment to home music enthusiasts.

In order to provide a clear and logical presentation, this paper will deal exclusively with the technical phases of the Recording Department.

The accompanying flow chart (Fig. 1) shows the sequence of operations required to produce a master part. The duplications of this master provide recorded music for worldwide consumption.

During a recording session, sounds are collected in a studio, mixed in the proper musical proportions, and recorded onto magnetic tape. At the end of the studio session, the various tapes are delivered to an editing room where a superior performance is spliced together from the best portions of several takes. This edited product is then sent to the re-recording room where level and response improvements may be made. The master tape provides the programming that is cut into lacquer discs which are then tested in the quality booths.

The re-recording room also supplies master tapes for shipment to foreign affiliates who produce lacquer masters locally.

LIVE STUDIO RECORDING

During the last decade, we have seen the "dead"—"live"—"dead" studio transition. Of course, each studio type has its individual faults. However, the "dead" studio is the one most widely accepted today. The trend to flat walls and the elimination of polycylindrical panels is also widespread at present.

The dead studio technique allows the recording engineer to "mike" each orchestra section intimately. He is thus able to control the individual microphones which then may be fed to various echo chambers. Selective echo may be added to these individual sections.

Low-frequency reverberation is the most difficult characteristic to control in the recording studio. Absorbtive panels sometimes enclose the rhythm section, preventing low-frequency reverberation from "washing" into other sections of the orchestra. An isolation booth is sometimes employed in order to obtain the proper perspective between a vocalist and the accompanying orchestra.

There are many types of microphones used to achieve sound heard on current recordings. The unidirectional mike is popular today because it allows a greater degree of isolation between orchestral sections. This characteristic enables the control engineer, at a central control console, to add equalization and reverberation to a particular microphone without affecting the overall orchestral sound.

Our 16-position control console can be combined into several groups or combinations of groups. It has a four-channel mixer with microphone equalization and reverberation control on each mixer position. There are four echo mixers available with VU meters bridged across the transmission lines to measure levels. This is necessary to prevent acoustic overload in the chambers. Gain reduction in the form of compression or limiting is possible for each mixer group. The limiter compressor amplifiers serve a dual purpose: (a) as gain reduction devices, and (b) as voltage amplifiers. Visual indication of the percentage of gain reduction is available to the control engineer.

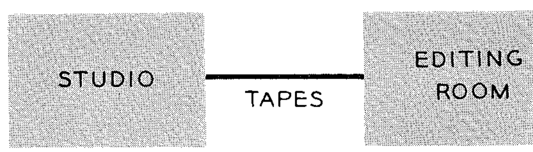
TAPE MASTERS

Because of better flexibility plus ease of handling, tape has been used almost exclusively since 1947 for instantaneous master recording. High density oxide, uniform coating, even slitting and the development of a mylar base are significant changes which have improved magnetic tape as a master recording medium.

TAPE EDITING

The so-called perfect recording is seldom obtained at a recording session in one "take".

The engineer may find the artistic performance superior in one take, while the musical balance on another take more closely represents the desired sound. In the old days of recording live performances on discs, a com-



WILLIAM H. MILTENBURG graduated from the California Institute of Technology, Pasadena, California. Mr. Miltenburg was employed by Major Motion Picture Studios, Warner Brothers, Columbia, and Universal International. He was first employed by RCA in 1947 in the Engineering Products Department in Hollywood, California. Here, he dealt with sound recording equipment for major and individual motion picture producers.

In 1951, Mr. Miltenburg transferred to the Record Division in Hollywood, and later assumed his duties in the RCA Recording Studios in New York City. He is a member of the Audio Engineering Society and the Society of Motion Picture and Television Engineers.

promise in selecting the master take was generally the only course open, since it was almost impossible to do any exact combining of takes. The added generations in disc dubbing made the signal-to-noise ratio objectionable. Quality, too, was impaired by additional generations. Because of its extreme versatility and flexibility, tape readily lends itself to the intricate and precise editing and re-recording functions. Musical notes or phrases from separate takes must be joined without any semblance of musical interruption or "jump".

Other editing functions include "tick" and "pause" editing. When old discs are dubbed to tape, it is imperative that the noises inherent in the old metal masters be removed for a cleaner and more pleasing sound. Each "tick" represents an eighth of an inch of tape (or less) and must be removed without any musical loss or beat. Long play and extended play tape masters are edited with definite time pauses.

To perform these splicing functions, editing consoles are provided. Equipped with a reproduce head (with associated preamplifier and monitoring arrangement), easy accessibility for marking the tape at the desired cutting point is possible. Specially machined splicers are utilized which can splice tape uniformly either straight across or, at a forty-five degree angle.

TAPE RE-RECORDING

A focal point of the overall recording process is present in the re-recording operation. The re-recording phase categorically includes three basic operations. These are reduction of multiple-track recordings into monaural or dual-track stereophonic tapes, enhancement and embellishment of an original tape source, and one-to-one copying. When an original recording is re-recorded, (whether a single or multi-track tape) its characteristics may be changed by the addition of equalization or reverberation to obtain a desired effect. These processes, coupled with a knowledge of artistic attributes make possible the production of a superior product.

With the introduction of triple-track recording, a valuable new recording method has been made available to the Recording Studio. Splitting the orchestra into three sections using a three-track recorder can now be accomplished during live recording sessions. It is then possible to rebalance and equalize individual orchestra sections without affecting the overall sound. From this original three-track recording, we can produce superior two-track stereo recordings and improved monaural records.

Utilizing the method of separating components of an overall sound source onto separate tracks has become extremely popular both on symphonic and popular type recording. It is a simple procedure, via the re-recording process, to revise balance. This method readily adapts itself to changing electrical characteristics of a singular group.

Re-release of old tape and disc sources constitutes a major re-recording program. An artistic approach is necessary, since it is now possible to enhance richly overall quality utilizing available facilities.

Finally, the re-recording operation envelopes the one-to-one copying of the final master tape for shipment.

LACQUER TRANSFER

The lacquer transfer room consists of a number of identical channels, each of which is capable of electrically transferring program material from tape to simultaneous master lacquers. Tape machines in these lacquer mastering channels are capable of reproducing all tape speeds and record characteristics now in use. Also available on the machine is an auxiliary reproducing head which is used to feed a pitch control device (to be described later). Compensators as well as amplifiers are incorporated into each channel in order to handle properly taped programs that require further sound revision. RCA Victor master tapes require only the addition of the orthophonic disc recording characteristic* during the cutting operation, but often master tapes received from outside sources require more extensive sound correction.

Each of the channels is set up with two Scully lathes, thus providing for simultaneous cutting (as previously mentioned) of two master lacquers. These lathes are equipped to produce masters at any standard speed and size. The lathes have a planetary gear arrangement governing the feed screw rotation, so the mechanical pitch of the cut can be varied between wide limits while the recording is being

* See R. C. Moyer, "Standard Disc Recording Characteristic," p. 11 in this issue.

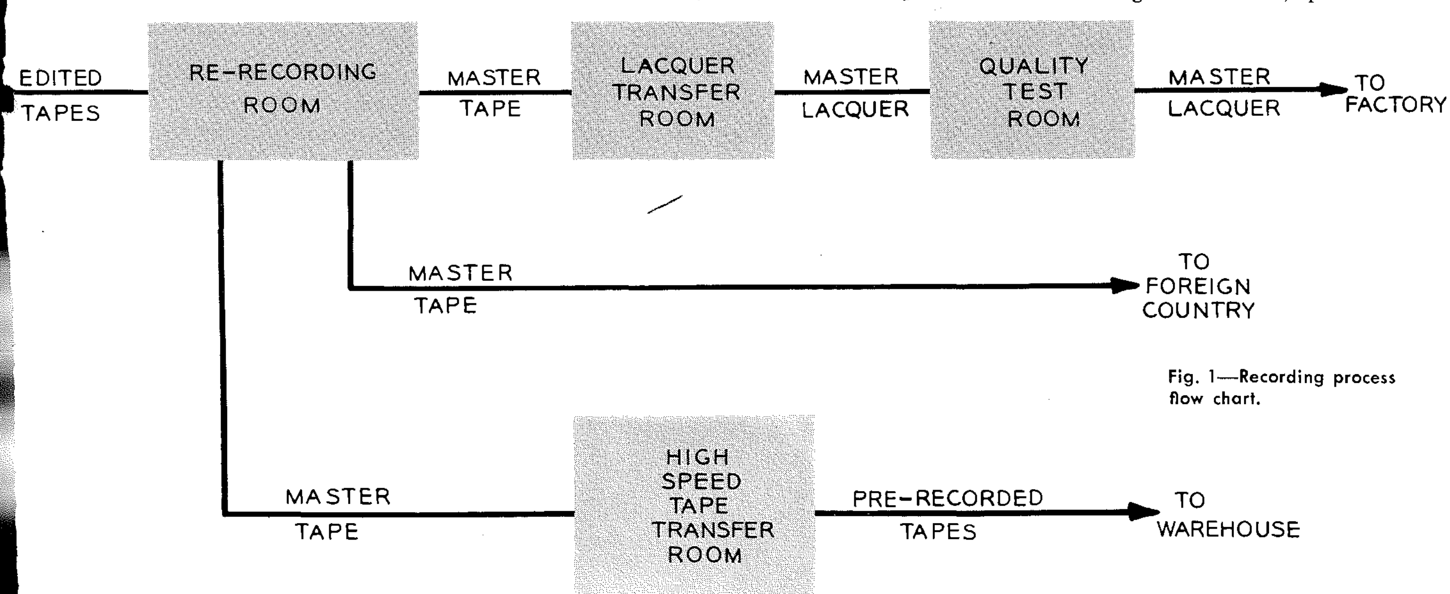


Fig. 1—Recording process flow chart.

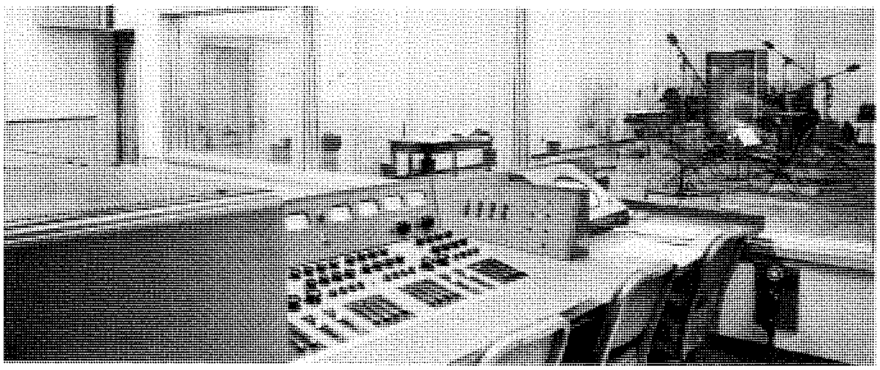


Fig. 2—Live recording studio with control console in foreground.

made. When a servomechanism controlled by the auxiliary head on the tape machine is applied to the variable pitch control unit of the lathe, the action becomes automatic and dependent only on the instantaneous amplitude and frequency content of the tape program. Thus, a greater wall thickness can be provided for high-amplitude grooves. This automatic allocation of the allowable, workable area on a disc thus provides for a better balance between the length of time of the program and the volume level at which it can be recorded on the lacquer, without over-cutting between grooves.

Each lathe is equipped with feedback cutters and complimentary amplifiers whose response extends from 20 to 20,000 cps. and can be precisely controlled by the feedback arrangement. During the cutting process, automatic diameter equalization is applied to compensate for losses in the high-frequency response inherent in the reproduction of the smaller diameters of a recording. Monitoring facilities may be switched across either the output of the recording buss or across the output of the feedback coil on the cutting mechanism.

RECORDING QUALITY CONTROL

Recording quality control has the responsibility of establishing the release level and mechanical perfection of the master lacquer. To perform these functions, a visual check employing a high-powered microscope to measure groove width is primary. An aural test is then necessary for each master lacquer, to establish program level and electrical faults possibly inherent in the recording. The serial number appearing on each record indicates to the quality control tester the speed, width of groove, size of record, year of recording and type of record; i.e., International, Popular, Red Seal, and Custom.

The function of the quality tester and inspector is to satisfy the Artist and Repertoire representative or the Custom client while staying within the mechanical, electrical, and engineering specifications.

HIGH-SPEED TAPE DUPLICATING

The high-speed tape transfer room is equipped with several production lines each consisting of a tape reproducing master unit, associated amplifying equipment and a number of tape recording "slave machines". As many as ten slaves can be used with each master unit. These units are operated from a remote position and utilize automatic start and stop facilities. The master playback and recording amplifiers are capable of handling frequencies up to 500,000 cycles with a minimum of distortion. This feature is necessary due to the extremely high speeds used when transferring the original master. Master tapes have a frequency range from 20 to 20,000 cycles. When these are reproduced at from 4 to 8 times their original speed, frequencies in the range of 150,000 to 200,000 cycles are encountered. Experiments are now being conducted to duplicate at 16 times the released speed; therefore, the additional frequency response was designed into these "record and playback" amplifiers.

Pre-recorded tapes are boxed and shipped to record distribution warehouses for allocation.

PRODUCTION CONTROL AND VAULT

In the master storage vault, approximately 185,000 master tapes are stored at this time. To insure maximum protection of these parts, the storage vault is as nearly fireproof as possible. It is air conditioned and fifty-percent humidity is maintained. A program is now in progress to duplicate all original masters. They are to be stored in a similar vault at the Indianapolis plant so that in case of possible disaster the availability of masters will nevertheless be insured to future generations.

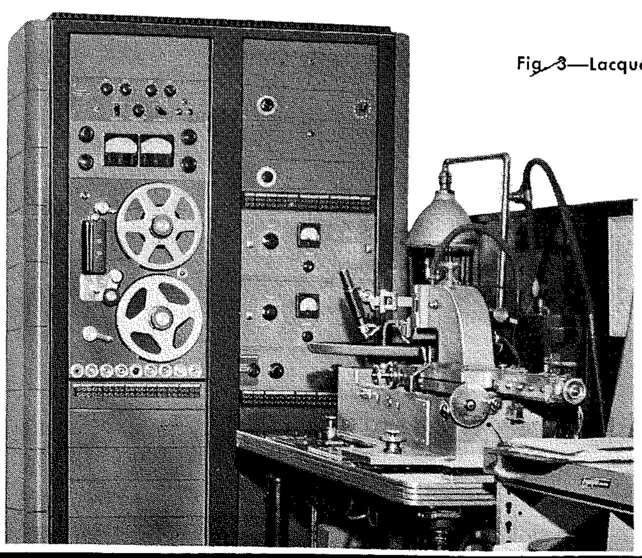


Fig. 3—Lacquer transfer equipment.

Fig. 4—High-speed tape transfer room.

STANDARD DISC RECORDING CHARACTERISTIC

by

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In August of 1952 the RCA Victor Record Division introduced a new disc recording characteristic for all of its commercial disc recordings. The records were called "New Orthophonic" to describe both the new recording curve and the new style of high-fidelity recording then being introduced. Now, five years later, it is interesting to note the almost universal acceptance of this curve and the great degree of stability and standardization that has come to the record industry.

RECORDING CHARACTERISTIC DEFINED

In the process of disc recording, the modulation amplitude is not held constant with frequency due to the limitations imposed by tracing the recorded groove with a stylus tip of finite size. It is customary to record low frequencies up to 500 cycles with a constant amplitude, and frequencies above that at a gradually decreasing amplitude. The exact manner in which these recorded amplitudes vary with frequency (with constant input signal voltage applied to the recording bus) is called the "recording characteristic." A recording characteristic may be defined by a curve showing recorded amplitude vs. frequency. It is more common, however, to plot the curve in terms of recorded velocity vs. frequency. By recorded velocity we mean the actual lateral or vertical velocity which a record would impart to the stylus of an ideal pickup. This assumes perfect tracing of groove modulation with no deformation of record material.

ELECTRICAL NETWORKS

Modern feedback recorders when properly adjusted will cut almost constant velocity throughout the audio range. This means that electrical networks have to be used in order to obtain the desired recording characteristic. A typical network

Fig. 1

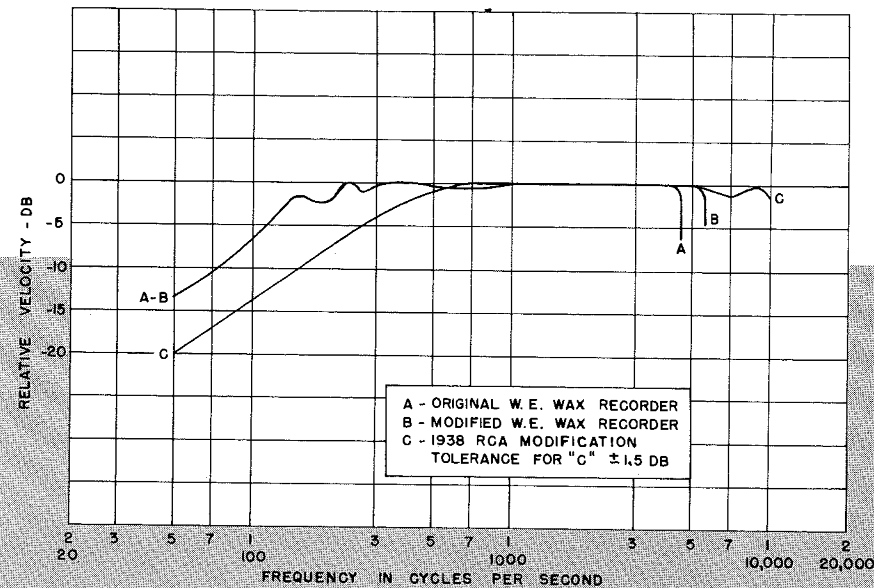
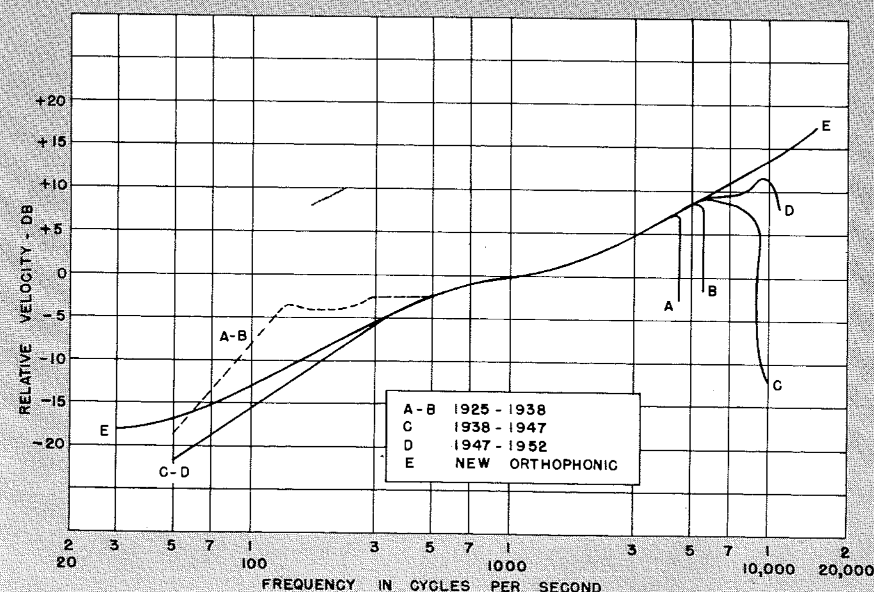


Fig. 2



can be considered in two or three parts depending on the desired end result. First, the transition or cross-over frequency is selected and a network is designed to attenuate voltage at the rate of 6-db per octave below this frequency. The amount of high-frequency preemphasis desired is then introduced by a network which will give a rising characteristic above a certain point, usually around one- to three-thousand cycles. Finally, low-frequency preemphasis may also be added, usually starting below 200 cycles.

Definitions of a characteristic by two or three separate parts has proved extremely helpful in the design of both recording and reproducing equalizers since it is difficult to glean the necessary design data from a single composite curve. Fortunately, the various parts of a practical characteristic may be defined by impedance or admittance curves of a simple two-element network consisting of a resistor and capacitor, or a resistor and inductor. In practice, the complete curve can be very closely approximated by relatively simple RC networks.

EARLY RECORDING CHARACTERISTICS

During the "78" era (prior to the introduction of "45's" and "L.P." records) the average record enthusiast was scarcely aware of such things as recording characteristics. To be sure, they existed with many variations in cross-over frequency and amount of preemphasis but they were far less important due to equipment characteristics and record surface noise. Furthermore, it was almost impossible for the technically-minded listener with professional type equipment to obtain reliable information about the characteristics that were being used. This was partially because the record companies were not in complete agreement regarding recording characteristic. Furthermore, most companies were inclined to treat that as confidential information.

Following the introduction of the "45" and "L.P." record, the picture changed materially. Both the record consumer and the equipment manufacturer entered into what might be called the "era of confusion." Record manufacturers began publishing reliable information about the characteristics they were using, equipment manufacturers taking advantage of this information began making amplifiers and preamplifiers with adjustable equalization and tone controls. The public sat back and twisted knobs and dials as they had never done before. As an indication of the magnitude of the problem, Audio Magazine in 1953 stated editorially that over one-quarter of the correspondence they were receiving dealt with recording characteristics matters. Another example of the interest and confusion on the part of the record purchaser is the fact that we, in the engineering section, answered an average of over 100 inquiries a month for the two-year period after the New Orthophonic characteristic was introduced.

That such interest should exist is not difficult to understand when one considers that there were at least eight different recognized characteristics being used or to be considered during the early 1950's. These involved cross-over frequencies from 250 to 800 cycles, high-frequency preemphasis anywhere from about 8 to 16 db at 10,000 cycles as well as varying amounts of low-frequency preemphasis, or none at all.

"NEW ORTHOPHONIC" CURVE ADOPTED

The introduction of the "New Orthophonic" curve was not designed to add still another characteristic to the then existing long list. It was, on the other hand, an attempt to combine the desirable features of the more generally used curves in order to form one overall characteristic which could be well defined theoretically and at the same time, it was hoped, form a reasonable compromise which all record companies could adopt without drastically changing the curves they were using.

Early in 1953, a National Association of Radio & Television Broadcasters disc recording committee met to consider revision of the old National Association of Broadcasters curve which apparently was not being followed by many recording companies making transcriptions. Each record company was asked to furnish the committee with its own characteristic. The variation in curves received was considerable, however, by taking the average of all curves, a new curve was formed which was within one and a half db of the RCA New Orthophonic curve at all frequencies from 50 to 10,000 cycles. For this reason and because the RCA curve fulfilled the objectives of slightly less high-frequency preemphasis and a smoother low-frequency preemphasis, it was decided to propose the RCA New Orthophonic curve for the new National Association of Radio & Television Broadcasters standard characteristic. It was officially adopted in June of 1953.

Following this came adoption by the Radio-Electronics Television Manufacturers Association, Record Industry Association of America, Inc., and the British Standards Institute. The Audio Engineering Society also adopted the inverse as a Standard Disc Reproducing Characteristic. As a result of this general acceptance, there has been a gradual decrease in the number of inquiries received about recording characteristics. At the present time it is unusual to receive more than one or two a week. Another factor that has helped this situation greatly is the fact that most record companies now advertise the characteristic they are using in one way or another.

In Fig. 1 are shown the response frequency characteristics of the Western Electric wax recorder used by RCA Victor in its original form, as modified by Western Electric and later by RCA Victor. The actual recording characteristics used on Victor records since the start of electrical recording are shown in Fig. 2. The dashed portion of curves A and B reflect the recorder characteristic but not what was actually recorded on the record since it was common practice to use a rather elaborate "bass filter" in the recording channel. This was done to reduce the low-frequency response to a practical value as far as recorded amplitude, record wear and general sound quality are concerned. The effective cross-over frequency was considered to be approximately 500 cycles which is the same as that obtained with the improved version of the recorder. It can be seen from the curves of Fig. 2 that the 500 cycle cross-over has been maintained for many years and is still in effect in the New Orthophonic curve. It is also apparent that the high-frequency preemphasis has remained essentially the same except for the gradual extension of the range above 4000 cycles as recorders were improved. One notable variation occurred during the period of 1938 to 1947 when an 8500-cycle low-pass filter was used. This effect is shown in curve C of Fig. 2.

The most significant change in going to the New Orthophonic curve was in the low-frequency range. Here, the former measured curve had a slope slightly greater than 6 db per octave due to amplifier and recorder characteristics, while the new curve eliminated the low-frequency loss and added 3-db preemphasis at 50 cycles. Simple RC equalization was used in the recording channel since it produces a smooth curve which is easy to match in reproducer equipment. This was not true of the old National Association of Broadcasters characteristic which required rather expensive tuned circuits. Needless to say, special attention was given to the ranges between 30 and 50 cycles and between 10,000 and 15,000 cycles which had not been seriously considered in the past.

By definition the New Orthophonic Characteristic is represented by the algebraic sum of the ordinates of the following three curves expressed in db:

1. CROSSOVER — a curve which conforms to the admittance of a series resistor and capacitor network with a time constant of 318 microseconds‡.
2. HIGH-FREQUENCY PREEMPHASIS—a curve which conforms to the admittance of a parallel resistor and capacitor network with a time constant of 75 microseconds.
3. LOW-FREQUENCY PREEMPHASIS—a curve which conforms to the admittance of a parallel resistor and inductor network with a time constant of 3180 microseconds.

"STANDARD" DISCS

In order to facilitate adjustment of reproducing equipment, the Record Division made available to the public through its distributors and dealers ten-inch 33-1/3 "L.P." and seven-inch 45 rpm test records containing frequencies from 30 to 15,000 cycles per second recorded to the New Orthophonic characteristic. The outer band of these records contains frequencies from 15,000 to 10,000 cycles at a recording level 20 db below standard recording level. The next band contains frequencies from 10,000 to 30 cycles 14 db below standard level. The level reduction was necessary to insure proper tracking with a .001″ tip radius stylus.

When using these records to check equalizer designs and system performance up to the power amplifier output, it is considered desirable to adjust fixed compensation to give essentially constant amplifier output. Tone controls are kept in their mid positions, and the volume control set for a normal listening level. By so doing, it is possible to raise or lower bass or treble to suit individual preferences and listening conditions.

It should be borne in mind that turntable rumble or hum may make it difficult if not impossible to obtain reliable readings on some equipment. This is especially true of the frequencies between 10 and 15 kc, where the recorded level is 20 db below normal and the pickup response is poor. When this condition exists, some indication of high-frequency performance can usually be obtained by setting the bass tone control for minimum response, thereby reducing the hum and rumble to a minimum. After checking high-frequency performance in this manner, the tone controls normally should be reset to give approximately flat response up to the highest frequencies which give reliable readings.

‡To be precise, as the British Standard points out, the time constants should be 3183 and 318.3 microseconds for 50 and 500 cycle transition frequencies respectively.

RECORDING VS. REPRODUCING CHARACTERISTICS

The question as to whether the recording or reproducing characteristic should be standardized is complex and has been handled in various ways by different organizations. During the days of mechanical and early electrical reproducers, there can be no doubt that the reproducing characteristic was standardized and records were tailored to give the best sound. After the introduction of more flexible recording and reproducing equipment with variable equalizers, tone controls, etc., there was no real standard. The difficulty was that record companies tried to make discs sound right on what they considered to be the best phonographs of the day while the phonograph manufacturers were bringing out new models which they believed to sound best with all makes of records.

Even today, with modern high-fidelity recording and reproducing equipment, this tendency still exists to a considerable extent*. Fortunately, however, the situation now is greatly clarified for all concerned because of the standard recording characteristic, which automatically defines a standard reproducing characteristic if the output signal voltage of a reproducer is to match the input signal voltage to the recording bus. Now the listener can know approximately how the tone control should be set to get the balance intended by the recording musical director. He also has the opportunity to vary the response to compensate for speaker characteristics, room acoustics and personal preference. At the same time, the recording engineer has the facilities in the form of equalizers, etc. to adjust the frequency characteristic of the signal until he gets the desired sound when monitoring at the recording bus or when reproducing a record on a "standard reproducer."

*See article this issue by R. S. Fine, "Factors in Phonograph Record Reproduction."

AN AREA OF AGREEMENT NOW EXISTS

After considering all variables, it may seem that perhaps no standardization has been achieved, after all. One has only to realize however, that now a common meeting ground has been established for the record company, the instrument manufacturer, and the listener, whereas in the past, no such area of agreement existed. Now, for the first time any or all parts of the overall process of recording and reproducing records may be varied intelligently for special reasons without in any way, defeating the standard.

In conclusion, it can be stated that (although in the final analysis sound quality and balance are usually judged on an "average" or "standard" reproducer) no specific reproducer characteristic was generally accepted by the industry until a standard recording characteristic was adopted by the majority of record manufacturers. By implication, or in fact then, the inverse of this characteristic became the standard reproducing characteristic which now can be used by recording companies to judge records and by reproducer manufacturers as a guide to the characteristic desired by record manufacturers.

Complete freedom of expression still remains with the recording engineer†, musical director or artist and repertoire men of each record company and in fact, their positions are considerably enhanced since they now have a better chance to convey their intentions to the consumer.

†See article this issue, "RCA Disc Recording Practices," by W. H. Miltenburg.

ROBERT C. MOYER was born in Boston, Massachusetts. He attended Bowdoin College, where he was graduated with an A.B. degree in 1932. Prior to 1942, he worked in the Commercial Sound Section of the Eastern Company, RCA Distributor, in Cambridge, Mass. From 1942 to 1945, he was employed as a Special Research Associate at the Radio Research Laboratory located at Harvard. In November, 1945, he joined RCA, where he is now Manager of the Recording Development group.

He has served on disc and magnetic recording committees with the National Association of Radio and Television Broadcasters, the Institute of Radio Engineers, and the Audio Engineering Society. Currently, he is serving as Chairman of the Magnetic Recording and Reproducing Subcommittee and vice chairman of the main recording committee of IRE. He was Central Vice President of the Audio Engineering Society in 1954.

Mr. Moyer is a Senior Member of the Institute of Radio Engineers and a Fellow in the Audio Engineering Society.

RECORD STAMPER MANUFACTURE

By **DR. A. M. MAX, Mgr.,**
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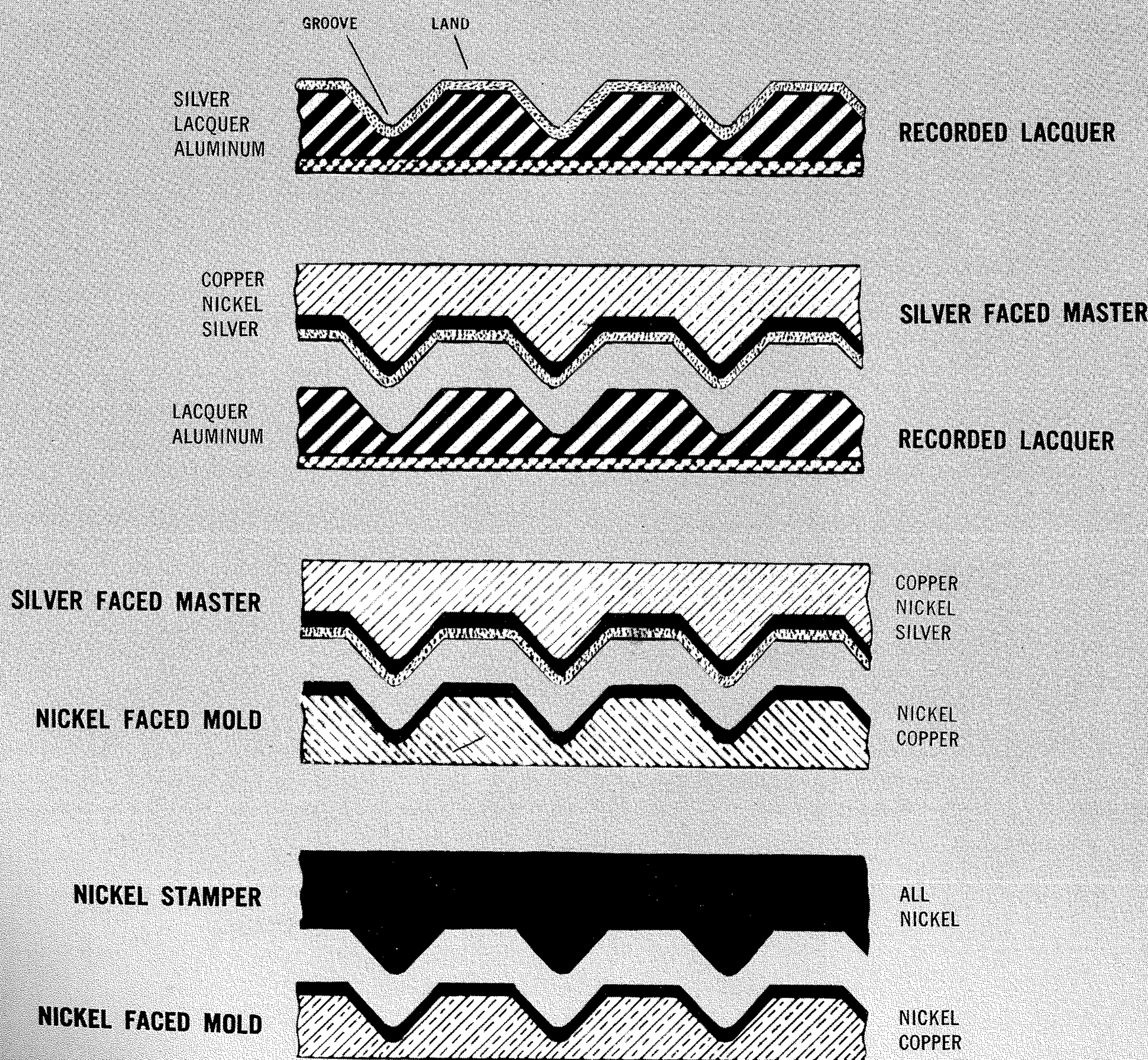
SINCE DISC RECORDS are molded from plastics under high pressures, a metal die is necessary. This die must be a negative replica of the recorded surface which reproduces the recorded surface down to extreme detail, 3 to 4 micro-inch amplitudes. Representative surface noise measurements on the metal music surface run between –54 to –58 db with respect to normal recording level corresponding to less than 1.0 micro-inch rms amplitudes.

To obtain a surface with such detail, electroforming is used. No other method has achieved so accurate a surface reproduction. The process in brief consists of metallizing the surface of the recorded disc to obtain an electrically conductive surface. The metallized recording is then made cathodic in an electrolyte containing the metal desired, the current passed until the desired thickness of metal is obtained, .020 to .025 inch. The electroformed metal disc is then separated from the recording. The surface of this disc is a negative of the recorded surface. It is referred to as the master. This master can be used in a press to mold records and when relatively few records are desired it is the practice to do so. For most commercial work, however, the master is used to generate more masters by a succession of

Fig. 1—Matrix processes.



ABRAHAM M. MAX attended the University of Wisconsin. He received his B.S. and M.S. in Chemical Engineering in 1934 and 1935, respectively. His Ph.D. was granted in 1937 for work in corrosion and inhibitors of corrosion under the late Prof. O. P. Watts.

From 1937 to 1941, Dr. Max was a chemist with Ternstedt Division of General Motors Corporation in Detroit, working primarily on decorative plating development on automotive hardware. From 1941 to 1944, Dr. Max was Assistant Professor of Chemical Engineering at the University of North Dakota. From 1944, Dr. Max has been with Engineering and Development of the RCA Victor Record Division in Indianapolis. To 1950, he was supervisor of the Metallizing and Plating Group, in 1948 was awarded the RCA Award of Merit for the development of matrix processing methods which contributed to materially improved record quality. Since 1950, Dr. Max has been Manager of the Chemical and Physical Laboratory.

He is a member of the American Chemical Society, the Electrochemical Society, and the American Electroplaters Society, Phi Lambda Upsilon, Tau Beta Pi and Sigma Xi, honorary societies.

duplications.

The duplication process starts with the cleaning of the master followed by a treatment to prevent the subsequent metal deposit from adhering. Following this treatment metal is deposited on the master surface by electrolysis until the desired thickness is reached. The prior surface treatment makes possible the separation of the newly formed disc, called a mold, from the master. Its surface, being a negative of the negative master, is a positive. The mold is used by a repetition of the duplication process to make pressing masters, which after finishing to fit the press, are called stampers. By this procedure a number of stampers can be made from one recording. Fig. 1 illustrates this sequence of parts.

With this brief survey, let us go into further details into the operations.

SILVER PLATING THE RECORDED DISC

The recording comes to the factory cut into a nitrocellulose lacquer disc. The disc is larger than the finished record. For example, a 12-inch long play record comes on a 16-inch lacquer disc. This disc after inspection, is cleaned by soaking in a mild detergent solution for five minutes. It is then rinsed with water following which it is put into the silvering machine, Fig. 2. Here, the lacquer rotates on a spindle as it is sprayed with a sequence of solutions. First a water rinse, then for about one minute a fine atomized solution of stannous chloride sensitizer. This is followed by a tap water and a deionized water spray. The disc is then sprayed with an ammoniacal silver solution from one atomizer gun and a formaldehyde dextrose reducer solution from another gun. Both sprays converge within a few inches of the guns and about eight inches from the lacquer surface. In forty seconds the lacquer is covered with a bright silver coating. The surface is then rinsed with deionized water. This sequence of events is controlled by a sequence timer through air operated valves. The silvering is one of the most critical operations. Any uncovered or thin spots will result in a defective surface since no plating will occur where there is no silver.

ELECTRODEPOSITING THE SILVERED MASTER

The initial coverage of the surface with an electrodeposited metal is also very critical. Here we prefer to use a nickel deposit. We find it easier to obtain fine grained nickel deposit. A coarse crystal structure can raise the noise level of the groove surfaces by as much as 5 db. The nickel is deposited from a Watts solution containing nickel sulfate and chloride and boric acid. This solution has a tendency to deposit plates which are stressed. We therefore use a small amount of an addition agent to keep the deposit stress low.

The silvered lacquer is mounted on a rack which is hung on the cathode rods of the nickel plating tank, Fig. 3. The current must be kept low or the points of contact will burn out. On the other hand rapid coverage of the silver is desirable to give a uniform surface. A current density between 15 and 20 amperes per square foot gives best results. Plating is continued for forty minutes during which approximately .0005 inch of nickel is deposited. The rack is removed from the nickel tank, rinsed and hung on the cathode rod of an acid copper plating tank for five minutes. The part is then rinsed and removed from the rack.

The lacquer with its nickel and a thin copper coating then has its back and edges protected with a rubber masking ring. This ring avoids unnecessary plating of metal at the edge and back and facilitates the separation of the metal master from the lacquer. The assembly is mounted on the cathode head of copper plating equipment

Fig. 2—Silvering Machine—The precleaned lacquer disc is placed on the turntable in this chamber. By a sequence of sprays, the lacquer surface is covered with a mirror silver film.

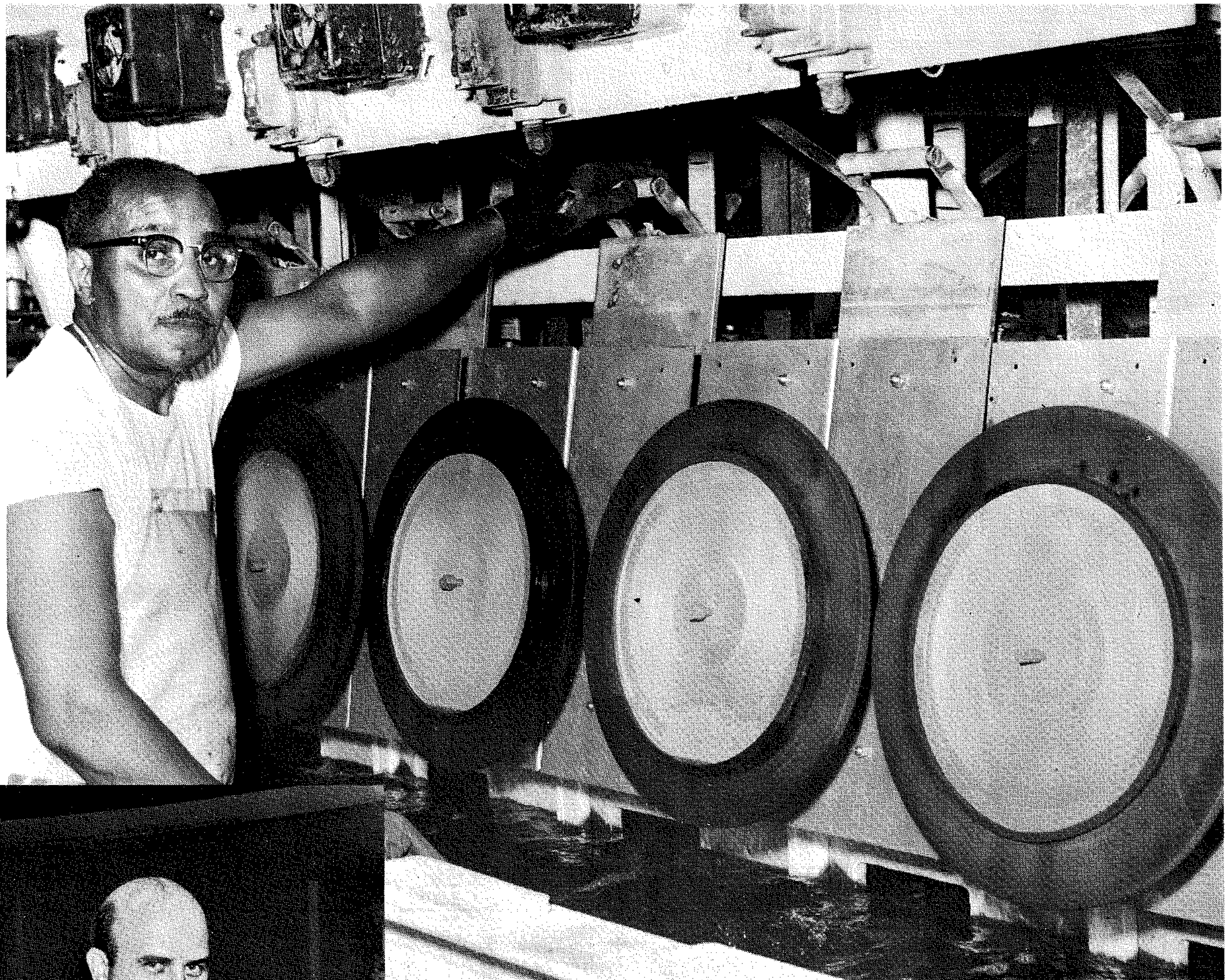


Fig. 4—High Speed Copper Electroforming Equipment—This machine plates copper at .010 inches per hour. The ampere-hour meters on the panel board are set to the proper value and automatically shut off the current when this value is reached.

Fig. 3—Nickel Preplate Tank—The silvered lacquer is plated with a layer of nickel .0005 inches thick in this preplating tank.

shown in Fig. 4. This equipment, especially built to our specifications, deposits copper at the rate of approximately .010 inch per hour. Thus a master can be completed in about two hours compared to eight to sixteen hours for conventional equipment. In this equipment the part is rotated at 180 rpm while filtered solution is pumped against its face. The high rate of agitation permits the use of high current densities.

MASTER IS SEPARATED FROM LACQUER

After the build up, the disc sandwich is removed from the electroforming machine and rinsed. The parts are moved to a bench where the master is separated from the lacquer disc. This involves carefully working the thin plate on the back around the edge and pulling the two discs apart. Care must be exercised since it is desirable to be able to make more masters from the lacquer disc and the lacquer, being soft, is easily damaged. The metal disc is trimmed on circle shears giving us a flat round disc whose surface of silver is backed by about .0005″ nickel and .020 to .025″ copper. The surface of this master is a negative replica of the lacquer surface.

ADDITIONAL PLATING NEEDED

The master is placed on a plating rack and made cathode in a boiling alkaline cleaner for one minute after which it is rinsed in cold water, dipped in dilute sulfuric acid and rinsed again. It is then immersed in a dilute solution of potassium dichromate for 15 seconds followed by a rinse of the same duration. The rack is then hung on the cathode rod of a nickel plating tank and plated at 20 amperes per square foot for forty minutes. This is followed by rinsing, a few minutes of copper plating and a water rinse. At this point the part is removed from the rack and the rubber edge mask is placed on it. It then goes to the copper electroforming machine to be built up to a thickness of .020 to .025 inch. After removing from the solution and rinsed, we separate the parts by cutting about $\frac{1}{32}$″ from the edge on a circle shear. The two parts can then be separated, Fig. 5.

The newly formed mold goes to an inspection booth and is played, Fig. 6. A water soluble lubricant is used on the mold face to protect both the mold and pickup stylus. If satisfactory, the mold is used to produce stampers.

MOLD PRODUCES STAMPERS

To produce stampers the mold is put on a plating rack and made cathodic in the boiling alkaline cleaner for fifty seconds and the current is then reversed for ten seconds. The anodic treatment forms an oxide film on the surface. The part is then rinsed and goes into the nickel plating solution for twenty minutes to get a thin coating of nickel. The disc is then removed only long enough to put on the rubber edge mask and mount the disc on a baffled plating rack and replaced in the nickel solution. Using over 75 amperes per square foot, the part is plated to a total thickness between .008 and .010 inch which takes a little over two hours. After rinsing and drying, a small amount of metal is removed from the outer edge on the circle shears and the stamper can then be separated from the mold. Six or more stampers can be made from a mold with no discernible deterioration. It is not a gradual deterioration which spoils a mold but a scratch or other physical damage.

The thin nickel disc is now ready for finishing. The back is ground on a rotating wheel using medium grit emery cloth. The disc is then put on a turntable, centered accurately with respect to the music grooves under a microscope and a one-inch pilot hole is punched in the center. The part is then put on a punch press and the O.D. and I.D. punched out. Another punch press operation gives the coined edge profile to the stamper. The stamper now is ready for delivery to the press floor.

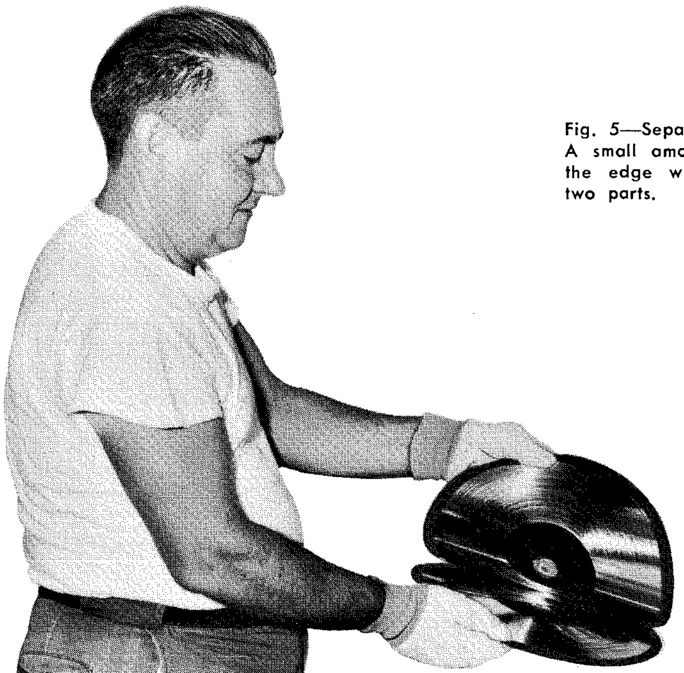


Fig. 5—Separating a Master from a Mold—A small amount of metal is removed from the edge which permits separation of the two parts.

RIGID CONTROL NECESSARY

The foregoing summarizes the operation that one can see and follow. In addition, these operations are backed up by a control laboratory. The solutions are analyzed at periodic intervals. Additions are made to the solutions on almost a continuous basis. At least, frequent small additions of the required chemicals are used. Special test parts are made frequently in the nickel solution and the deposit tested for ductility and strength.

One of the important factors in the nickel solution is the control of the stress of the deposit. Note that in all cases of the initial nickel plating we have no adhesion to the starting surface. The deposit from the nickel solution we use is inherently stressed and would pull away from the starting surface and sometimes rupture during plating. We control the stress by the use of a chemical addition agent in concentrations of the order of ten parts per million. The stress of the deposit is determined by plating a helix on a spiral contractometer under standardized plating conditions. The deposit stress expands or contracts the helix which results in a twist of the one floating helix end. The twist displacement is geared to a needle indicator on a dial. The needle displacement is calibrated for the determination of stress as a function of the thickness of the nickel deposit.

The nickel stress and ductility are affected not only by the addition agent but also impurities. Consequently, continuous purification is used on all nickel solutions as well as continuous filtration through activated carbon. The nickel solution is thus closely controlled in many ways.

The laboratory control of the solutions and operations enables an operational stability close to the practical limit of present ultimate quality. This control, with the possibility of corrective action before harmful results are evident, is the major difference between today's matrix operation and that of the past.

Fig. 6—Play Testing the Mold—The Mold is checked for audio quality.

THE STORY OF PLASTICS IN PHONOGRAPH RECORDS

By **G. P. HUMFELD, Mgr.**
Record Compound Engineering
RCA Victor Record Division
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THE STORY of phonograph records covers a span of years dating from the early 1870's to the present day. In this period the public has seen records develop from cylinders to flat 78 rpm discs and more recently to the fine groove 45's and LP's. The transition has brought about a broad and varied application of record materials beginning with tin foil, wax and hard rubber. Later, shellac was used and it has played such a significant role that even today 78 rpm records are referred to as shellac records, although shellac has been replaced by synthetic materials. After World War II, when the new fine groove 45's and LP's were introduced, a completely new type of record material was needed. A material was required that was reasonable in cost, easy to process, and uniform in properties, and one that would result in a quiet, high quality record. The vinyl resins were chosen and these have continued to be used as the major record material.

SHELLAC

To tell the story about record materials one must start with shellac. It is not a man-made material, but occurs naturally in certain sections of the Far East as a secreted waste product of the lac insect. In record compound formulations it was mixed with ground limestone and slate and acted as a binder for these fillers. Records produced from it gave very satisfactory service under the conditions existing in those early days. Unfortunately, the little lac insect was unable to control production conditions and as a result the quality of its product varied greatly from wet to dry seasons. This led to many production problems and as a result it was not uncommon during the shellac days to reject one record out of every three manufactured.

World War II spelled the doom of shellac. During actual hostilities all shellac supplies were cut off. Old records were collected and reworked with the small amount of shellac doled out by the government in order to meet production requirements. At the close of hostilities a new picture confronted the record industry. Synthetic resins that were laboratory curiosities suddenly became plentiful so the record industry had a number of man-made synthetic materials available. Ethyl cellulose was the first major man-made resin to find wide spread use in records. It came into use in 1947 and has continued up to the present day as an important ingredient in 78 rpm records. Its function is the same as that of shellac which it replaced; specifically, to act as a cement to bind together the ground limestone and slate which make up about 70% of the weight of a 78 rpm record.

VINYL RESINS

When "45's" and "LP's" were under development, the primary objective was to produce a composition which would give the best possible sound reproduction. Experience with transcription records indicated the vinyl resins might be adaptable. A survey

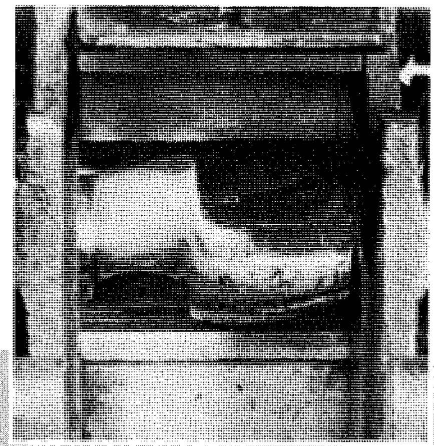

Fig. 2—Laboratory Banbury mixer with side open showing the mixing chamber. Walls are connected to pressure regulated steam line to control Banbury temperature.

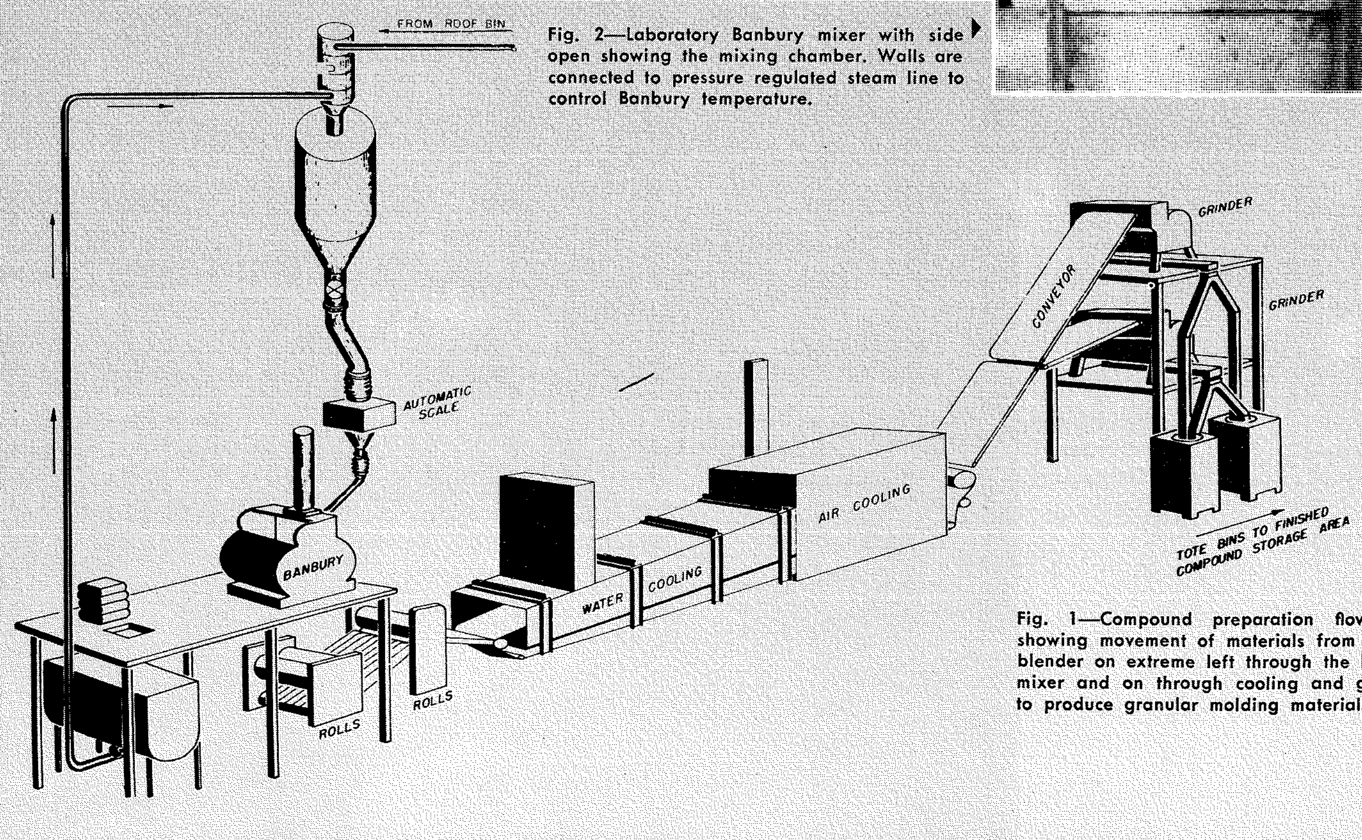

Fig. 1—Compound preparation flow chart showing movement of materials from powder blender on extreme left through the Banbury mixer and on through cooling and grinding to produce granular molding material.

showed these materials were readily available and they could be processed in equipment generally in use in the record industry. When the word vinyl is mentioned, most people think of shower curtains, table cloths, draperies, auto seat covers, and other forms of highly plasticized vinyl resins. A plasticized vinyl resin usually contains anywhere from 20% to 40% of a liquid plasticizer, such as dioctyl phthalate and as such is not satisfactory for record usage. Rigid vinyls are used for records. Generally speaking they are copolymers where the primary polymeric material is vinyl chloride. The second material copolymerized with the vinyl chloride can be such materials as vinylidene chloride, vinyl acetate, acrylonitrile or dimethyl maleate to mention some of the more commonly used commercial chemicals. Actually, the list is not limited to these few modifiers. Practically, every month the patent literature discloses additional new materials suitable as vinyl chloride copolymer agents. Specifically for records, a vinyl chloride-vinyl acetate copolymer in the ratio of approximately 85 parts vinyl chloride to 15 parts vinyl acetate finds most wide spread use for "45's" and "LP's." It is compatible with a wide range of extender materials. These can be used to replace up to about 10% of the vinyl resin to give a cost reduction without changing the physical properties to any great extent. Table I gives a typical formulation for fine groove records.

OTHER RESINS

The vinyl resins are thermoplastic materials. This means they can be softened by the application of heat without undergoing appreciable chemical change, provided the heating is not carried beyond the decomposition point. While hot, they can be formed into any desired shape and then cooled to a solid state. Usually this cycle of heating, forming, and cooling can be repeated as often as desired.

There are many types of resins besides the vinyls which fall into this category. The list includes such materials as methylmethacrylate (Plexiglas or Lucite), polyethylene, the polyamides (nylon), polystyrene and the cellulosics such as ethyl cellulose or cellulose acetate. From this group, polystyrene and ethyl cellulose are the only ones useful in records. Ethyl cellulose was discussed earlier as a shellac replacement. Polystyrene has come into the picture more recently. Its main advantages lie in the fact that it is slightly cheaper than the vinyls and is quite stable at high molding temperatures. The latter fact makes it applicable in injection molding machines for the automatic injection molding of records, which so far, has been used mainly in the automatic injection molding of "45's" and 7" 78 rpm children's records.

Polystyrene has two disadvantages which have restricted its use. First, it is not as strong and break-resistant as the vinyls. Second, it does not always wear as well as the vinyls.

THERMOSETTING RESINS

Brief mention should be made of the possible application of thermosetting resins in records. They are characterized by the property of undergoing a permanent physical and chemical change during the molding operation.

In this group are the phenol formaldehyde resins, ureaformaldehyde resins and the alkyd resins. All of these except some of the fast curing alkyd resins require a relatively long molding cycle (3 minutes or more at 300° F). They all go through a change in volume as curing progresses so must be mixed with large quantities of inert fillers to get satisfactorily molded records. This makes the records quite poor in quality.

Another serious problem arises with the use of these materials. The record industry is built upon the policy of regrinding and reusing reject records, records returned from dealers and distributors, etc. This can result in regeneration of as much as 20% to 30% of material returned to the process based on the total formulation weight. The reuse of thermosetting materials in this way is not practical; therefore, thermosetting materials have not been successfully developed for use by the industry.

COMPOUND PREPARATION

Compound preparation is illustrated in the flow diagram shown in Fig. 1. The ingredients in powder form are loaded into a blending machine at the extreme left of the picture and carefully mixed. A bulk flow system transfers the blended powders to a storage hopper above the banbury mixer. Three hundred pound lots of the blend are fed into the steam-heated banbury, heated to fusing temperature and mixed for about 1½ minutes at a temperature of 300° F to a bread dough consistency. Fig. 2 is a picture of a laboratory size banbury which mixes 5 lbs. of compound. Because it is small it is easier to see the mixing chamber and the rotors which carry out the mixing of the heated plastic material.

When banbury mixing is complete, the batch is transferred to a set of mill rolls where it is rolled into a thin sheet onto a conveyor belt. It then moves through a cooling tunnel to cool it before grinding in a hammer mill to produce the granular molding material used on the press floor. Molding compound is produced in this equipment at the rate of approximately 40,000 pounds per 8 hour shift. The granular molding compound is stored in large aluminum Tote Bins containing about 3000 pounds of compound and transferred in them to the press floor to feed the preform heaters at the presses.

TABLE I
Typical Vinyl Record Formulation

	% By Weight
Vinyl Resin	82–96
Diluent Resin	3–10
Heat Stabilizer	.5– 3
Colorant	.5– 5

GEORGE P. HUMFELD received the B.S. Degree in Chemical Engineering from Purdue University in 1937. He worked as a chemist in a non-ferrous foundry for 5 years after graduation and then joined U. S. Rubber Company as a rubber compounder during the war years. He joined RCA in 1946 as an engineer in the Record Compound group and in 1947 he was appointed to group leader. In 1956 he was made Manager of this group. He is a member of the American Chemical Society and a member of the board of directors of the Central Indiana section of the Society of Plastics Engineers.

MECHANIZATION OF RECORD PRESSING

By **L. C. HARLOW Mgr.,**
Equipment Development
RCA Victor Record Division
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THE DISC RECORD as we know it today, was first demonstrated by Emile Berliner back in the 1880's. It is interesting to note that although earlier processes are not those used today, record press drawings in our active file date back to 1912. Some of the basic castings are still used in presses which are turning out thousands of records per week.

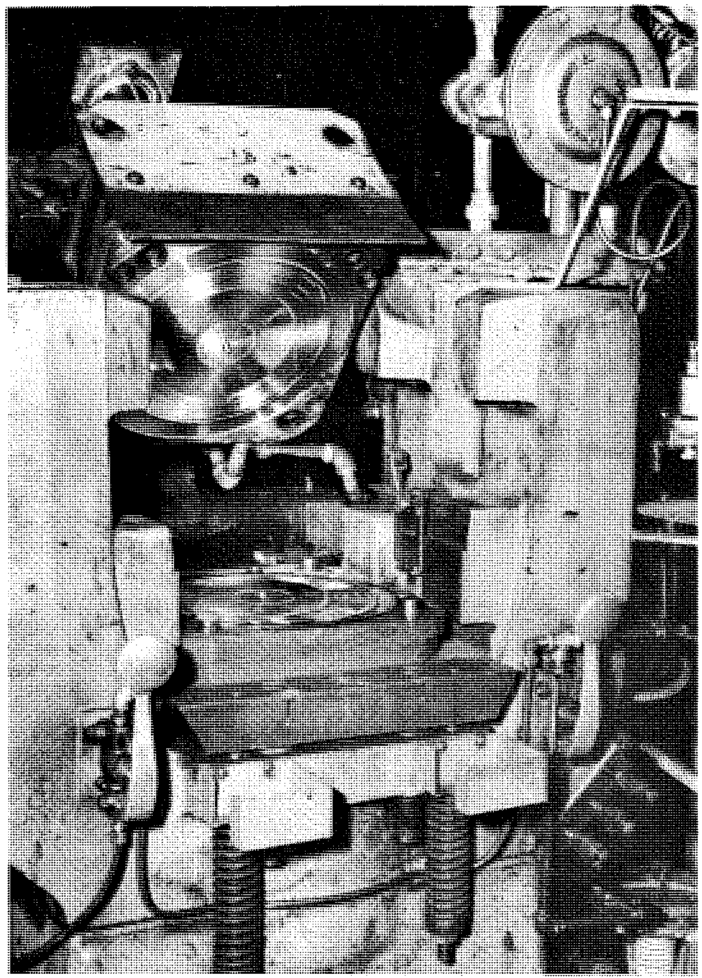


Fig. 1—"Swing leaf" type record press showing "swing leaf" in open position ready for loading.

THE PRESS

The press, Fig. 1, we use is a "swing leaf" type in which the upper platen (leaf) is pivoted to open like a waffle iron. This provides ready access for loading the compound and unloading the pressing. As late as the 1930's the presses were completely hand operated and controlled. The operator loaded the labels and hot plastic, closed the press manually and by means of hand valves and a clock, controlled the cycle of hydraulic power, steam, and water to produce the molded record. Artistic ability plus a strong back were needed.

In 1939, the adoption of air cylinders to open and close the heavy swing leaf of the press resulted in the elimination of a large portion of the manual labor. Faster molding cycles thus became possible increasing the output and permitting the use of women operators, who are better suited for repetitive tasks of this nature.

TIMER

One of the first steps towards mechanization was the development of a timing system to accurately control the application of steam, cooling water, and hydraulic power. The first system introduced in 1938, consisted of a line shaft which drove control cam drums on twelve different presses. The cams operated air valves in the proper sequence to control the steam, water, and hydraulic pressure. The time of the overall cycle could be varied, but the percentage of steam, water, and hydraulic pressure remained constant and all twelve presses were affected alike. With the development of new record compositions, this system became inadequate, and in 1944 a completely flexible timer, Fig. 2, was developed to control each press independently. This timer is still in use today, and in a matter of seconds an entire press cycle can be changed to provide any variation necessary to produce a quality product.

LABEL LOADING

The older record presses were equipped with a fixed center pin on the lower platen ("A" side) and an open hole to receive it on the upper platen ("B" side). The "A" label was loaded into the press by placing it directly on the fixed center pin. In the case of the upper ("B") label, it was necessary to place it on a long wooden "label stick" which was then inserted into the hole in the upper platen. While the record was being molded, the "label stick" which protruded from the top of the upper platen was removed and made ready with another label. An automatically retracting upper center pin was developed in 1939, and the "B" label was then loaded in the same manner as the "A" label on the fixed lower pin. This development saved several seconds of the operators time.

PRESS TOOLING

"Press tooling"[1] refers to the means used to hold the stampers on the heating and cooling die. The earlier press tooling required the soldering of the stampers, which were 20-30 mil electroplated copper, to a steel plate approximately ⅛″ thick. The combined steel plate and stamper was then secured to the heating and cooling die by means of a clamping plate in the center at the label area and a ring around the outside. This outer ring ("hold down ring") also served to form the beveled edge on the outside

1. S. D. Ransburg, "Molding Phonograph Records," Fig. 3 this issue.

of the molded record. As late as 1944 the press tooling was nearly the same except that a high temperature cement (glyptol) was substituted for solder. There were three major objections to this tooling. First, the heat transfer was poor and quite variable through these many contact surfaces between the heating and cooling fluids and the record plastic. Second, this method of mounting stampers was time-consuming and expensive. Third, it was very difficult to prevent plastic from leaking between the "hold down ring" and stamper. The press operator used a tool known as a "pick" to pry the rigid (78 rpm) records loose, and consequently record breakage in the press was quite common. "Ring leakage" became even more troublesome when records were molded from non-breakable plastics. Efforts to overcome these objectionable features of the press tooling resulted in a series of changes, which by 1947 had led to the use of tooling known as "coined edge." This tooling consisted of all-nickel stampers (approx. .010″ thick) mounted directly on the heating and cooling dies. The outside diameter of the stamper was formed to take the place of the "hold down ring," and thus leakage as well as the expensive "hold down ring" was completely eliminated.

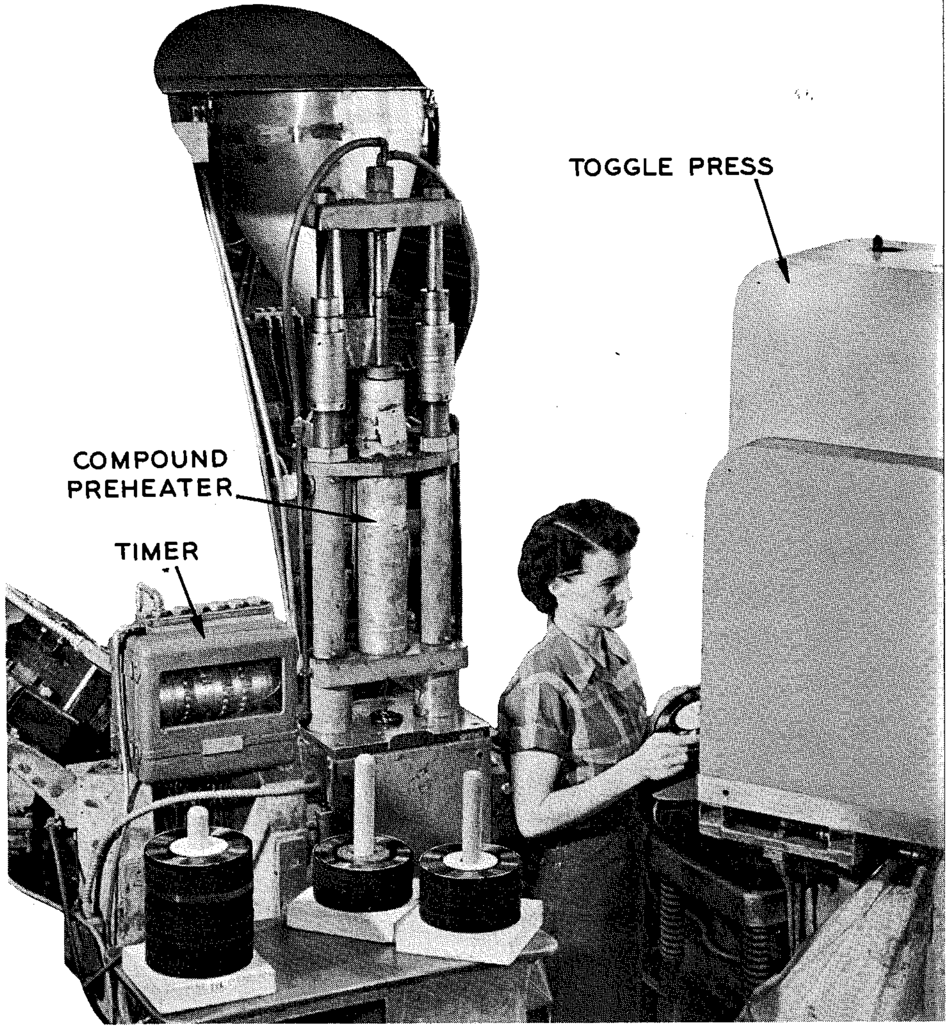


Fig. 2—The duplex operation arrangement for "45's" showing the press timer, the compound preheater and the air operated toggle press for punching the center hole and O.D.

DUPLEX OPERATION AND PREHEATERS

By 1945, reductions in the press operator's work cycle had exceeded reductions in the record molding cycle to the extent that the operator was waiting for the press. Since the operator had idle time, the duplex press operation was developed so that the operator ran two presses. Although this resulted in an increase in operator output of approximately 30%, it became obvious that again it would be advantageous to further reduce the operator's work cycle. The largest element remaining in the work cycle was the handling of the "compound biscuit" (record plastic), which was placed on a steam heated platen and, after being heated, was folded into a wad and placed in the press. To minimize this operation a compound preheater (shown in Fig. 2) was developed. The preheater, at the proper time in the press cycle, automatically delivered a measured quantity of preheated compound so that the operator had only to place it in the press. This permitted an additional 30% increase in operator output.

"45's"

The use of non-breakable vinyl plastic in the "45" record gave rise to the need for a different type of mechanization on the press floor. It was necessary that the large center hole of the "45" be punched, and the outside diameter was also punched because of the close dimensional requirements. This punching operation was originally performed as a separate operation on a multiple station punch press.

In 1949, a compound punch and die in a small air operated toggle press, Fig. 2, was mounted on the record press so that the operator could complete the entire finishing operation (called "dinking") in less time than was previously required to trim the flash. The addition of a compound preheater for vinyl compounds in 1951, together with the toggle press, permitted the operator to press and finish non-breakable "45's" as rapidly as she had been producing "78" records.

HOT KNIFE EDGER FOR LP's

Edge finishing of "78" rigid records is done as a separate operation and the record material is brittle so that the operator merely brushes the flash from the molded record by hand. However, when non-breakable records, such as our present 10″ and 12″ Long Play, were removed from the press, it was necessary to trim the flash with a knife. This operation was not only time consuming but also subjected the record to great risk of being scratched. A Hot-Knife Edger, Fig. 3, was mounted on each pair of presses in 1951 to perform the flash trimming operation and, at the same time, produce a finished edge on the record.

AUTOMATICS

By 1950, Engineering had made definite plans to develop a fully automatic "45" record press. The first element developed was the "45" compound preheater which as mentioned previously was first placed in production with hand operated presses. The remaining elements needed for a fully automatic unit were automatic mechanisms for label loading, compound loading and record removal. These mechanisms and an appropriate control system were developed and by 1953 four fully automatic units were in production. Eight more units were added in 1956 so that there are now twelve units attended by four men.

The operation of the fully automatic press may best be understood by reference to Fig. 4. In this sketch, portions of the machine have been cut away to show the mechanism more clearly. The following sequence of events is automatically controlled.

1. A measured quantity of ground molding compound is dropped from the hopper into the cylinder of the preheater.
2. After a heating period, the hydraulically operated piston on the preheater forces the charge of hot compound into a receiving cup on the compound loading arm.
3. The loading arm swings around and deposits its charge of hot compound on the "A" (lower) stamper of the pressing station. (The station has previously been loaded with labels.)
4. As the compound loading arm swings out of the way, the press swingleaf closes, and the record is molded.
5. At the end of the molding period, the press opens and a pair of steel fingers (the record remover) grasps the record by the flash (the extra compound which has molded out beyond the edge of the record).
6. These fingers carry the record to the first finishing station where the 1½ in. center hole is punched.
7. The fingers then carry the record on to the second finishing station where the outer diameter of the record is punched and the finished record falls through the die onto the spindle located immediately below it.
8. During the record finishing operation, the press has been preparing itself for the next molding cycle. The "A" label loader has picked up a label by means of a vacuum cup and deposited it on the "A" center pin. The "B" label loader has picked up its label and deposited it on the upper or "B" center pin.

The entire series of operations is now ready for repetition.

Thus we see that a series of developments since the introduction of the "45" record in 1948 has resulted in a completely automatic press and an operator output increase of 400%.

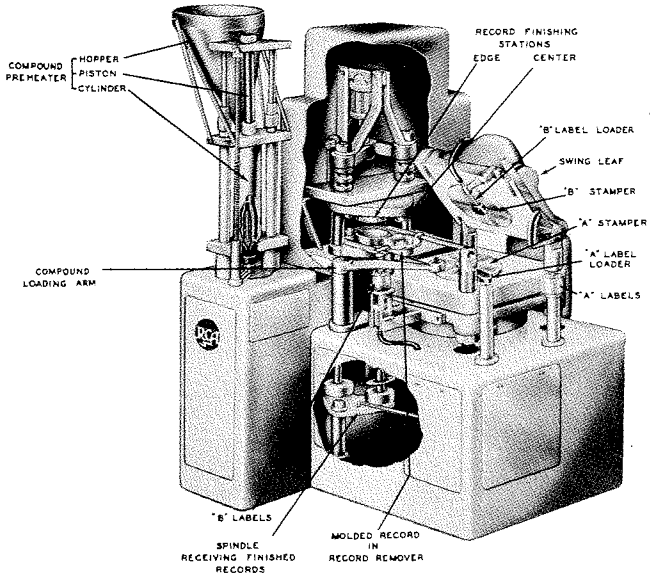


Fig. 4—Pictorial Description of the Automatic Press.

Fig. 3—The operator is placing a freshly molded record in the Hot Knife Edger, which will trim off the excess plastic and produce a smooth finished edge.

L. CHARLES HARLOW graduated from the University of Nebraska in 1943 with a B.S. degree in mechanical engineering. He was an instructor at the University and then joined RCA Victor Record Engineering in 1944. After a short period of military service he rejoined Record Engineering in 1946. He has been concerned with mechanical development and design of record manufacturing equipment since he joined RCA Victor. He was responsible for the development and design of the automatic press for 45's. Mr. Harlow is manager of Equipment Development.

MOLDING PHONOGRAPH RECORDS

by **S. D. RANSBURG**
Record Engineering
RCA Victor Record Division
Indianapolis, Ind.

CANNING FRESH FOOD is done to preserve it for future enjoyment as desired. "Canning" music or sound is done for exactly the same reason. For music, however, the "preserving jar" is a plastic disc called a phonograph record.

All RCA Victor records are made from synthetic thermoplastic materials. The word plastic means, "Capable of being shaped or molded." A thermoplastic material can be compared to sealing wax. It is a dense hard material at room temperatures. When it is heated, it becomes soft and pliable and may be molded or shaped. On cooling this molded wax back to room temperature, it becomes dense and hard again and retains the newly formed shape.

This is similar to how records are molded. The relatively rigid plastic compound is pre-heated until it becomes a soft viscous mass. Then it is formed or pressed, using many tons of pressure, between two hot molds containing the music stampers. These molds are then cooled and the forming pressure released. The plastic is again rigid but now has a new shape. It is in the form of a thin flat disc having impressed on its surfaces the music grooves that were on the stampers. Briefly stated then, the molding of a phonograph record consists of the transfer of heat from one point to another during controlled deformation of the plastic material.

MOLDING EQUIPMENT AND TOOLING

All RCA Victor records are molded on either semi-automatic or fully automatic compression presses. These presses are of a tilting head type and resemble a rather oversized waffle iron in their action.

The "brain" of the press is a synchronous motor-driven drum called a timer. It contains several bands of adjustable segments which activate air operated valves or cylinders controlling the various services and mechanical actions during the press cycle. The drum is started when the press closes, and makes only one revolution in determining the length of the molding cycle.

A flash type mold allows the material to escape as the mold is closing. Thus an excess of material is needed to provide the necessary back pressure to properly fill the lands between the music grooves. This type of mold is best suited for non-bulky type compounds and facilitates maintaining close tolerances on the thickness of the record.

The molds are made of steel and consist of two halves. The lower half is called the "A" mold while the upper half is referred to as the "B" mold.

Record molds are of the flash type and are cored for steam and water passage. These channels can be seen in Fig. 1. They consist of a series of concentric grooves with the inlet at the center. This type of design allows the mold surface to heat and cool very rapidly. Steam and water pressures of 120-130 pounds per square inch gauge are used, being alternately circulated through the mold. Special care must be taken in engineering the installation of the piping to and from the molds. A steam trap valve is provided for obtaining better heating efficiency.

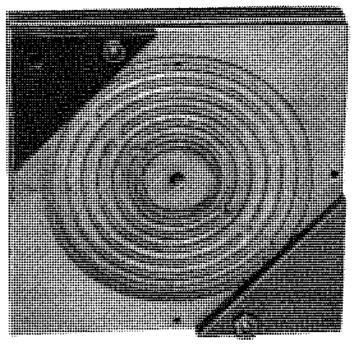
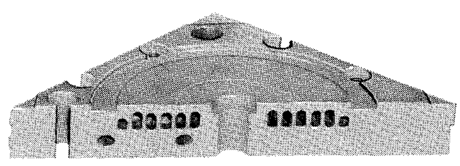


Fig. 1—View of mold showing heating and cooling channels. Below is a cross-section of channels in mold half for circulation of steam and water.



Thin nickel stampers containing the music grooves are held on each mold half by means of center plates and hold down rings which clamp the inner and outer diameters of the stampers. See Figs. 2 and 3. The coined rings act as an orifice, restricting outward flow of the hot plastic. This orifice is called the "cut-off" and controls the final thickness of the pressing.

Molding pressures of 1800 to 3600 p.s.i.g. are obtained from a central water hydraulic system.

The hot plastic for loading the mold is supplied from a pre-heater extruder which has been nicknamed a "Boomer". It consists of a hydraulically operated plunger or piston that forces the cold granular material into a heated cylinder. As the material begins to soften, it is forced around a torpedo-like spreader inside the cylinder. This spreader is also steam heated and aids in giving a rapid even flow of heat into the plastic material by greatly increasing the surface area. This type construction also permits rapid cooling by water circulation. Such requirements are necessary when using the vinyl type plastics since overheating or too long a heating period will cause the material to degrade, giving off corrosive acid fumes. Fig. 4 shows a cross section of a "Boomer". The hot material is forced out through a nozzle and formed into a wad ready for molding. The correct amount of material is controlled volumetrically by properly setting the length of the plunger stroke. This wad of hot material is called a "shot."

PRESSING, FINISHING, AND TESTING

Basically, molding a record consists of:

1. Pre-heating the plastic material to make it soft and pliable. (320-330°F)
2. Pre-heating the music stampers to aid in flowing the plastic around the music grooves. (290-310°F)
3. Deforming the plastic by use of high pressures causing it to flow. (1800-3600 p.s.i.g.)

Fig. 2—Tooling used in manufacturing 7-inch 45 rpm type records. Stamper mounted on mold half is shown at right of picture.

4. Cooling the formed plastic by removal of heat. (90-100°F)

Completing these four steps in a minimum of time but still maintaining a high-quality pressing is the constant aim of the molding engineer. Selecting the optimum molding cycle for accomplishing this properly depends on many factors, such as the record size (diameter and thickness), the viscoelastic properties of the plastic material at elevated temperatures, the groove geometry of the music stampers, the heat transfer characteristics of the molds, and the equipment set-up.

Today the greatest majority of records being made are the 12-inch LP Gruve-Gard and the 7-inch 45's. Both are considered fine groove recordings. The 12-inch size records are now being molded at the rate of one record every 40 seconds. Less than a year ago the cycle time was 50 seconds and three years ago it took 60 seconds to make one record. Correspondingly, the 7-inch cycle has been reduced in steps from 45 seconds to 38 seconds to 30 seconds to 24 seconds, and a 15-second cycle is now in the pilot plant stage.

Just how are records pressed? The following sequence of operations occurs during molding as graphically illustrated in Fig. 5.

1. The pressing from the previous cycle is removed from the mold by the operator.
2. The steam has been automatically turned on and allowed to purge the cooling water from the molds before being trapped. This pre-heats the mold and stampers for the next cycle.
3. During this pre-heat period the operator places the "A and B" labels on their respective mold halves. They are held in position by being forced over center pins that form the hole in the record.
4. The operator then centers the wad of hot compound on the top of the "A" label and mold.
5. The operator next activates two pneumatic hand valves which close the swing leaf of the press and starts the timer.
6. The timer takes over the molding cycle by activating the hydraulic, steam, and trap valves. (Some cycles do not require additional steam other than that used for pre-heating)
7. The molds close, flashing the excess material as the record is pressed.
8. The steam valve shuts off, the trap opens, and the water is turned on.
9. After sufficient cooling, the water is shut off and the hydraulic pressure released.
10. As the swing leaf opens, the operator removes the pressing containing the flash.
11. The molds begin pre-heating for the next cycle and the operations are repeated.

During the closed part of the cycle, the operator finishes the pressing made on the previous cycle and stores it on a spindle. In the case of a 12-inch LP pressing, the finishing operation consists of removing the flash by use of a hot knife edger. In the case of a 7-inch 45 rpm type pressing, the flash is removed when the O.D. and I.D. are "dinked" to size on a small air actuated toggle press.

In the case of the 12-inch LP (40 second cycle) and the 7-inch 45's being molded on a 30-second cycle, the above operations are only half the story as far as the operator is concerned. Since one operator runs two presses, they go through the same sequence of operations on the second press but approximately 180 degrees out of phase with the first press. Besides all this, the operators find time to count their production and fill in production control cards. They are also required to keep their labels hot, as moisture absorbed by the paper would generate steam during molding cycle, causing blistering of the labels.

An impressive overall efficiency of

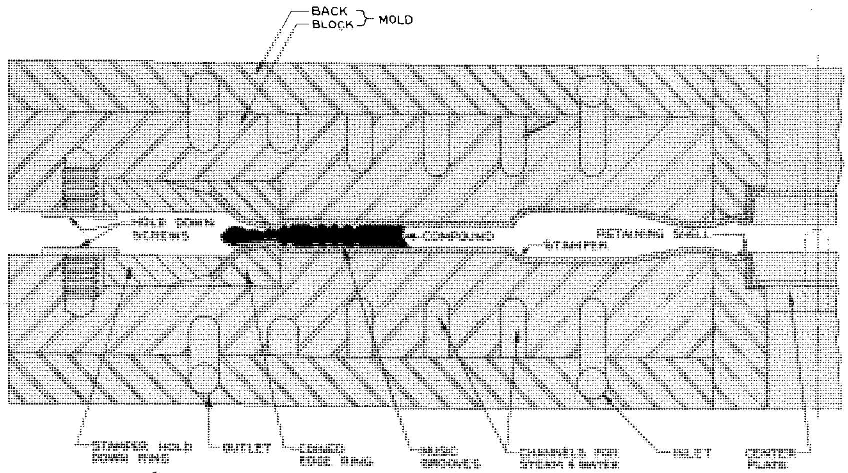


Fig. 3—Pictorial drawing of cross section of record being molded, shawing tool assembly.

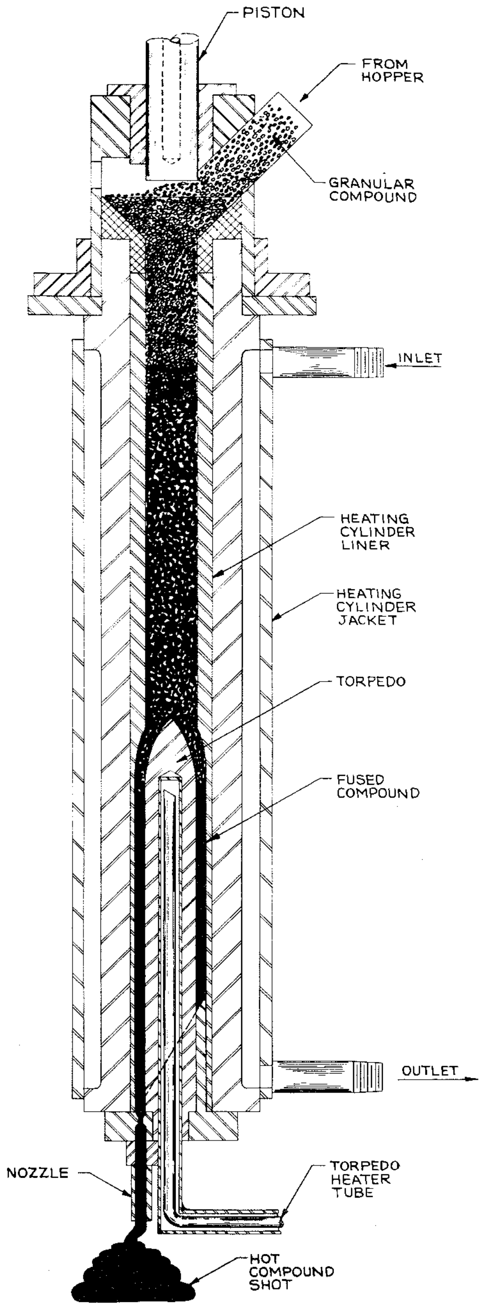


Fig. 4—Pictorial drawing of cross section of compound extruder showing flow of material.

S. D. RANSBURG graduated from Tri-State College, Angola, Indiana in 1943 with a B.S. degree in Ch.E. After graduation he joined RCA at Indianapolis Record Engineering Development Laboratory as a development engineer on record formulations and molding problems. In 1944 he entered USNR and completed courses in Pre-Radio, E.E., R.M., and Advanced Radio Training at Oklahoma A.&M. and Naval Air Technical Training Center, Corpus Christie, Texas. He rejoined RCA in 1946 as a Development Engineer on phonograph records. Mr. Ransburg helped pioneer the 45 rpm records in both formulation and molding procedures and did development work on molding techniques for "Gruv-Gard" records. He also worked on the development of the fully automatic record press and is presently engaged in molding the 45 rpm records on a 15 second cycle.

He is a charter member of the Central Indiana Chapter of the Society of Plastics Engineers.

70 to 75 percent of theoretical maximum production is maintained for this type of operation. This takes into account all kinds of shutdowns and lost production including rejects.

During the pressing run, regular samples are taken for audio testing. A trained audio tester listens to the record and determines if any objectionable noise defects have appeared during molding. After the records have been pressed, each record is inspected for visual faults.

These reject records can be reprocessed for their material content after having the label area removed. This is necessary, otherwise the paper fibers would cause a high surface noise level. The excess flash is also reused. Approximately 22 percent of the record "shot" weight is flash.

Part of the 7-inch 45 rpm production is now being done using fully automatic presses. The molding operation is similar to the semi-automatic method except that the operator has been replaced by a record remover, compound arm, and vacuum label cups. Fig. 6 graphically illustrates the sequence of these operations. These presses produce one record every 24 seconds. An operating crew of 3 attendants per 12 presses is required.

Following the visual inpection operation, the records are placed in their respective package and sent to a central warehouse for shipment to distributors across the country.

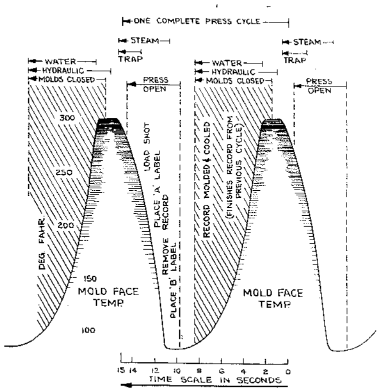


Fig. 5—Sequence of operations in relation to mold surface temperature for pressing 7-inch 45 rpm type records on a 15 second cycle using high speed molds. (Semi-automatic molding)

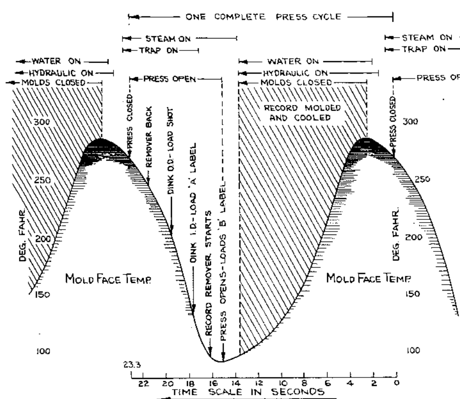


Fig. 6—Molding cycle and operations for making 7-inch 45 rpm records on fully automatic compression type record press.

FACTORS IN PHONOGRAPH RECORD REPRODUCTION

by **ROY S. FINE**
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As is pointed out elsewhere in this issue, a tremendous amount of thought, care, work, and technical knowledge are required to produce each phonograph recording. Since this effort results in a generally excellent product, it is important that the reproducing system be designed to effect optimum performance from the playback of each record. Of course, the problems of reproduction in general are the subject of a large volume of papers on high fidelity. This article will attempt to clarify the engineering aspects of the playback systems with respect to disc record reproduction.

STANDARD PLAYBACK CHARACTERISTIC

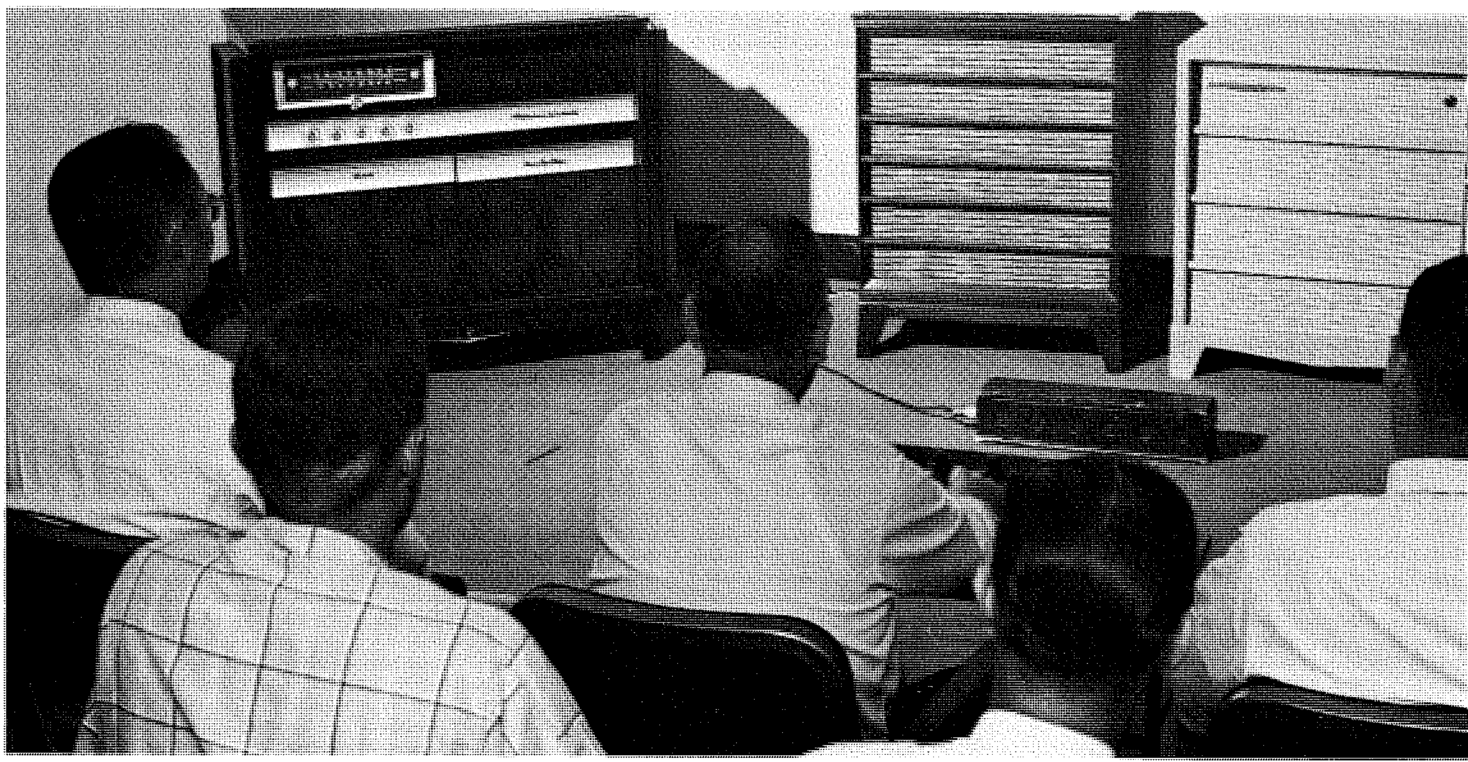
The philosophy of the Record Division is that a "standard" playback system be used for reproduction of all records, and the characteristic sound of each record must be optimized on this system before release. This process is actually effected by the Record Division in manufacturing all production discs, and a *specific* pickup, preamplifier, power amplifier and loudspeaker system is used. There is, of course, a certain amount of "art" as well as "science" used in this process. The art results in the particular sound of a specific record when played on the "standard" system; the science results in a specific published recording characteristic of the actual velocity on records in general, so that a reproducer playback curve can be evolved. This published curve, the "New Orthophonic Recording Characteristic" is used as a guide in adjusting the playback characteristic of all New Orthophonic High Fidelity instruments. However, some modifications must necessarily be made, since a variety of production designs are engineered in a wide price range and do not necessarily give the same reproduction as the "standard" system.

SOME MODIFICATION NEEDED

The Record Division supplies a "New Orthophonic" test record and indicates that the reproducer should be adjusted for constant output when playing the record. Since constant output cannot be achieved acoustically, the measurement is reverted to constant voltage across the speaker voice coil. If all sets were built with constant voltage across the voice coil, the reproducing characteristic would be that of the loudspeakers alone and detectable frequency response differences from one set to another would be represented primarily by the differences in the acoustic response of the speakers themselves.

Assume that a speaker and cabinet have been adjusted for optimum acoustic performance and that a modification of this performance is required. A change can be made in the voice coil voltage response, such as adjustment in the low- or high-frequency output, to accomplish this. This results in a voice coil voltage curve which does not have equal amplitude at all frequencies, but in sound the system is comparable to that heard on the "standard" system.

There are other considerations which can further modify the specified curve. It is recognized, for example, that not all high quality pickups are essentially flat in frequency response through the audio range. It is not within the scope of this paper to dis-



A listening panel judging sound qualities of RCA instruments in a specially constructed listening room.

cuss the relative merit of pickups, but some deviations from flatness are thought to enhance reproduction. This opinion notwithstanding, the fact remains that the effect of pickup irregularities can also cause deviation from flatness in the voice coil voltage curve.

LISTENING PERFORMANCE

Other ways of setting the performance of a record playback system have been successful in yielding good results. The most common is one based on final listening performance. This method requires versatility in the control of experimental response so that a variety of adjustments can be made until the reproduced sound is optimized for a listening panel. Then it can then be said that the corresponding voltage across the voice coil is the proper one for playing back New Orthophonic records on that particular instrument. Fig. 1 represents examples of proper performance curves. Curve A deviates from a constant voltage across the voice coil, and curve B is essentially flat; yet the overall performance of the two instruments, including the speaker and cabinet acoustics, is quite close.

OTHER ASPECTS CONSIDERED

The foregoing has been concerned with the frequenecy response of a high fidelity playback system. There are, however, other aspects which as far as reproduction is concerned can best be lumped together under the general category of distortion. The usual problems of proper geometry of the pickup and tone arm must be considered for minimizing tracking error, tracing distortion and needle talk, and needless to say, the tracking ability of the pickup is an important factor in determining performance.

Although virtual standardization has been achieved by the recording industry in general, and a reproducing instrument can be adjusted for optimum reproduction on most records, some problems still arise because all manufacturers do not stick strictly together on standards. For example, most record companies specify either their recording characteristic or the proper playback response, but this is viewed as a frequency response specification only. It has been found that records still vary one from another, the greatest difference being one of recording level. Wide variations have been observed with some records being made at higher than average level. This is noted primarily on popular 45's. It is therefore necessary to design amplifier circuits that can accept this higher level without distortion. It has been found that distortion inherent in the record universally accompanies such levels.

For a more complete treatise on the subject of the entire reproducer of disc records, please refer to the article, "Some Practical Aspects of High Fidelity Design" in the August-September, 1956 issue of the 'RCA Engineer.'

CONCLUSION

In conclusion, an attempt has been made here to emphasize the fact that the engineering of high fidelity performance is *not cut and dried; it is not dictated by a firm set of rules.* It is certainly guided by such standards as are available, but experience emphasizing the realization of the many faceted problems in this field is invaluable if not mandatory. It is primarily because RCA as a company has such a background that it has become a leader in the recording and reproduction of sound.

ROY S. FINE graduated from Brown University with a degree of Bachelor of Science in Engineering in 1944. He spent three years in the Signal Corps, with the majority of this time at the Signal Corps Engineering Laboratories, Ft. Monmouth, working on radar and microwave communications. Mr. Fine joined RCA as a student engineer in 1946 and worked in the Advanced Development Section of RCA Victor Home Instruments Division until 1951. He then transferred to the Radio and "Victrola" section and is now working on product design of high fidelity instruments and tape recorders.

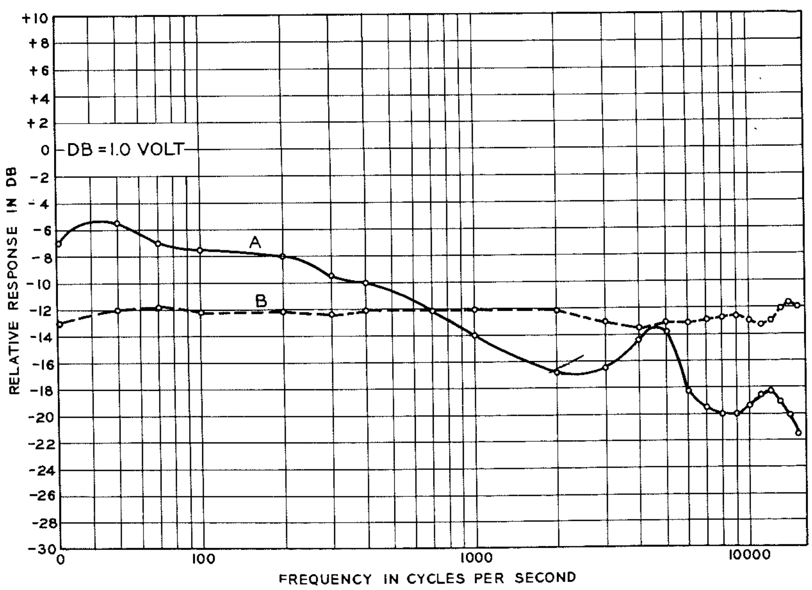


Fig. 1—Voice coil voltages of two different high fidelity instruments using New Orthophonic Test Record 12-5-49. Curve A illustrates the deviation from constant voltage required to optimize the performance of a particular instrument. The rise from 1000 cycles down is necessary for adequate bass response. The peak at 5 Kc is the pickup element resonance and the peak at 13 Kc is the pickup stylus resonance. Curve B illustrates on instrument having a pickup with much greater flatness of response and an acoustic system with more bass response. This curve, of course, is quite flat, almost ideal from a theoretical standard. However, the performance of the two instruments although not identical, is quite close; enough to be included in the same family line of high fidelity phonographs.

RCA COMMUNITY ANTENAPLEX SYSTEMS

by **R. C. ABBETT**
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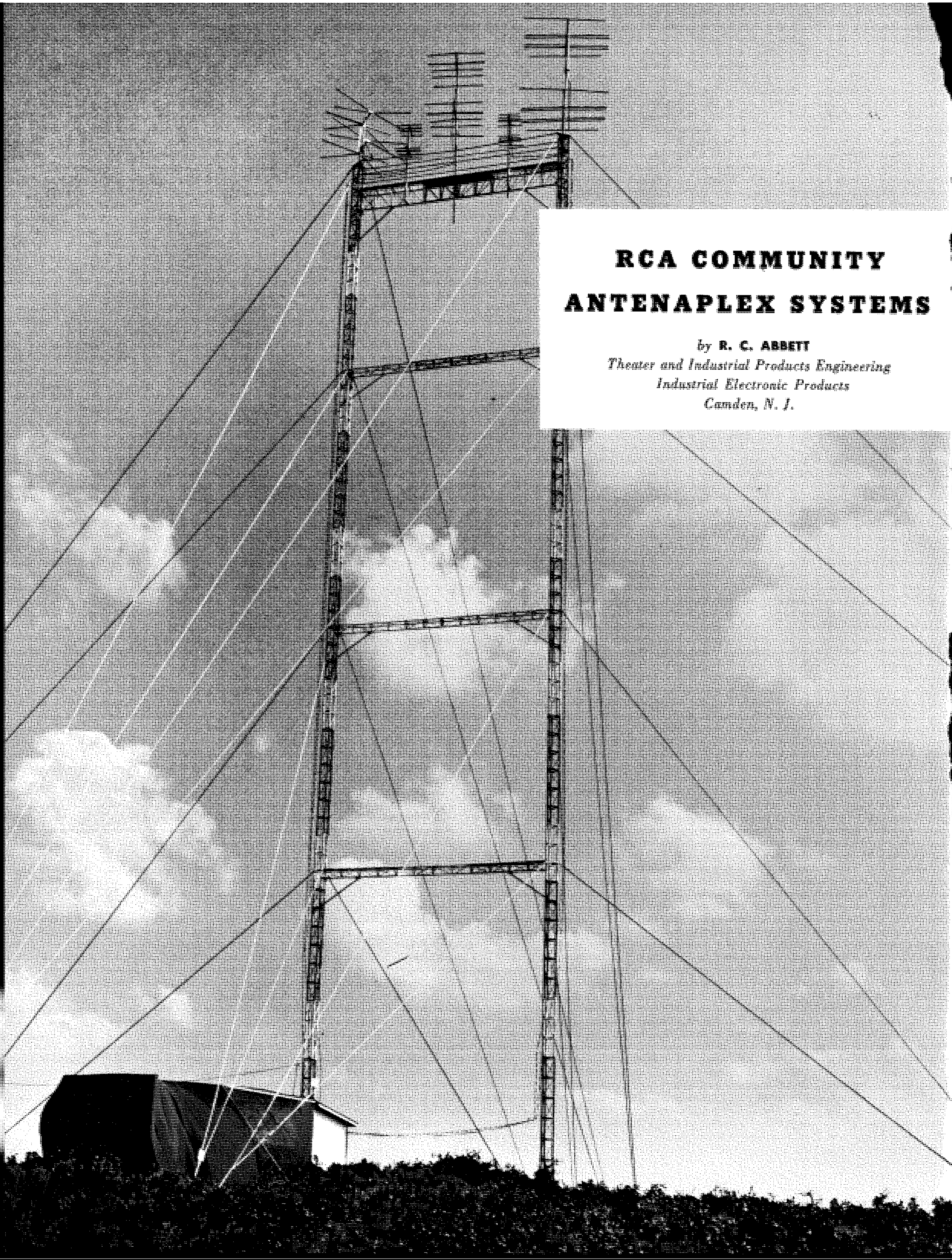


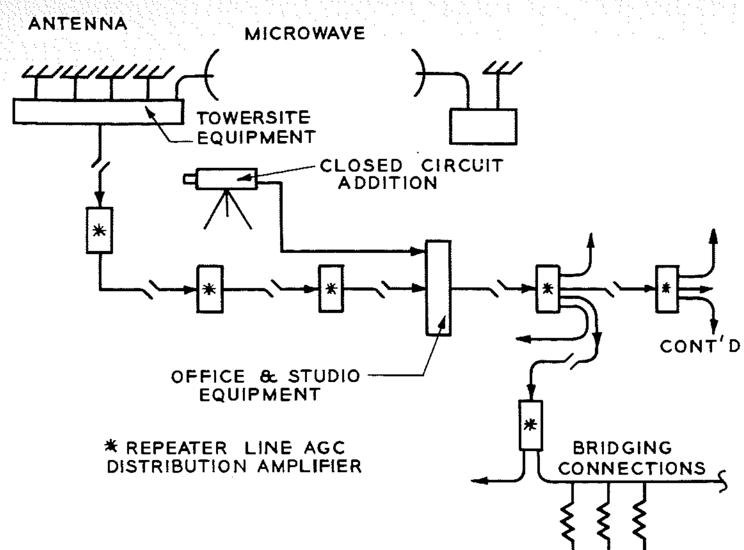


Fig. 1—Community antenna system diagram

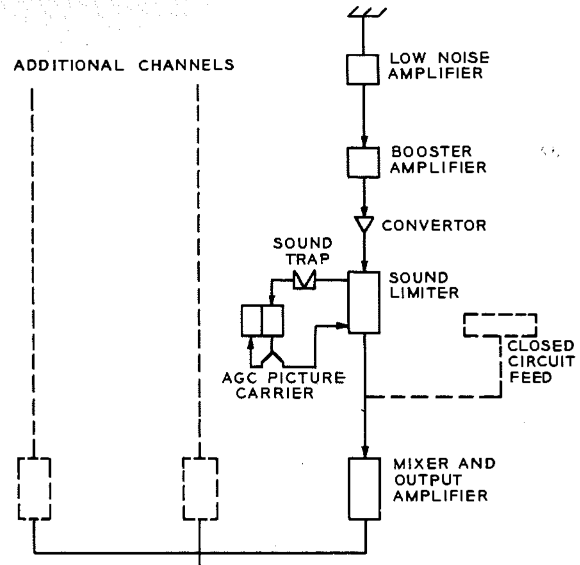


Fig. 2—Tower site diagram

DURING ITS EARLY YEARS the television industry was confronted with numerous problems. One was that of providing signals to a multiplicity of receivers within large buildings such as hotels and apartment houses. This was solved through the development of a system comprised of a centralized amplifier, a single antenna for each channel to be received and a coaxial cable distribution network, together with the necessary fittings and outlet accessories.

The Community Antenaplex system provides service in a similar manner to cities or small communities that are deprived of a good television signal by the shielding effects of mountainous terrain as well as the distance separating them from the nearest broadcasting stations.

RCA was among the first pioneers supplying Community Antenaplex Systems. The first installations were planned and completed during 1950 and 1951. Since that time approximately 570 systems have been installed throughout the United States and Canada. The estimated subscriber listing is 400,000. Usually a locally operated corporation is formed to handle the details of installation, operation and maintenance. The costs are borne by the subscribers who pay a connection fee and a monthly service charge similar to that for telephone service.

SYSTEM DESCRIBED

Fig. 1 is a simplified line diagram of a community antenna system showing the routing of the electronic signal from antenna to subscriber.

The antennas, one for each channel, are mechanically rugged to meet industrial requirements. The services of RCA Service Company antenna specialists are generally used in various phases of antenna work. Tower procurement, erection, etc. is the responsibility of the local operation with RCA participating only to the extent of location, heights, specifications, etc. Tower heights vary from ground level (mountain top locations) to 500 feet or more for reception from a distant point.

The tower site equipment on early installations was simple and included pre-amplifiers, converters and output mixing amplifiers—one for each channel. Weaker and more variable signals have demanded the development of numerous additional equipment and in many cases the use of microwave apparatus. Fig. 2 shows the use of low-noise pre-amplifiers, booster amplifier, converter, automatic gain control, sound limiters and mixing amplifier. Fig. 3 is a photographic illustration of the tower site apparatus for Paducah, Kentucky, during final adjustment. Shown with the equipment is J. K. Malinoski, Antenaplex Engineer, and R. C. Abbett, author.

REPEATER AMPLIFIERS

Repeater amplifiers of various descriptions are used depending upon the service requirements. Early models were channelized and their use was restricted to channels 2 through 6 due to lower loss of the cable used for distribution purposes. Recent developments in broadband equipment offer opportunities for their use in repeater service especially in view of radiation restrictions on higher level operation. In some cases it is desirable to operate adjacent channels to allow distribution up to 5 channels within the low band (channels 2-6), and in these instances broadband repeater equipment offers the only solution. In order to operate adjacent channels, it is customary to adjust the level of the sound carrier downward approximately 10 db and fixing its level with respect to the picture carrier using the sound limiters or other suitable means. This reduces interference with the picture carrier of adjacent channels.

The number of repeater amplifiers varies with distance from the tower to nearest distribution point, size of the community, density of population, number of potential subscribers, channels utilized and cable loss. Large communities may have upwards of 200 amplifiers, and some systems have subscriber listings of approximately 6,000. Others in the planning stage have a potential of 20,000.

Some repeater amplifiers contain automatic gain control and are required for correcting changes in cable loss due to temperature change from day to night and shifts in level resulting from tube aging or other causes. For coaxial cable in current use the amount of change is approximately 4% of the line loss for a 40° F. change in temperature. This percentage can be considerable on a long line where the total losses run as high as 500 db.

Fig. 4 shows a repeater amplifier as it is being checked during installation by Charles Collins, Paducah, Kentucky, and Mr. Frank Hensley, supervisor from the RCA Service Company.

When a closed circuit channel is to be added it is usually inserted ahead of the first distribution point. Equipment for this purpose includes camera chain equipment and studio gear. The signals are then mixed with other channels in the same manner as at the tower site.

For distribution purposes it is normal for low-loss cable to be used to transmit the signal from one repeater to another and an additional cable to be used for providing distribution of signals to individual subscribers. The distribution cable is tapped at locations near the home by devices which puncture the cable and make a bridging connection to the cable's center conductor, and a ground connection to the outer shield braid. A service cable is then run to the house in the manner common to telephone practice. This cable is terminated into an outlet box containing a 75/300 ohm impedance matching transformer and isolating capacitors. The TV receiver is then connected to this outlet to complete the circuit from antenna to receiver.

SYSTEM CONSIDERATIONS

Numerous technical considerations are required prior to installation of equipment to determine the number of amplifiers, their most strategic location and length of each distribution cable, etc. This is done based upon the knowledge of equipment specification of amplifiers, dividing networks, tapping devices and other losses of the system including cable, together with a complete map of the town, including pole locations, residential locations, dealer locations and other pertinent information (such as railroad crossings) which require special consideration. After equipment and labor costs are determined for the individual situation, then the probable economic factors can be determined.

During the growth of this new sidelight to the television industry, two important happenings took place.

ASSOCIATION FORMED

The Federal Communication Commission recently proposed rules to regulate the amount of spurious radiation permissible from the systems. Prior to this time, there were no applicable rules due to the fact that neither Congress nor law-enforcing agencies had visualized such systems as a possibility. As a result of a rather stringent proposal, an industry committee of RETMA was formed which prepared comments on the FCC proposal and a final rule was issued which compromised the issue on Dec. 23, 1955.

The National Community Television Association (NCTA) was formed as the number of Community Antenna Operators grew. This was a result of the growth of common tax, legal, technical and business problems. The Association now maintains a staff and holds annual trade conventions to further the purpose of its members. The Association has demonstrated through legal advice, technical forums, technical papers and accounting procedures that they are a necessary organization by providing various services for their members and the public. This has a stabilizing influence on the industry and is proving to be of benefit to the public in general.

FUTURE OUTLOOK

A continued demand for community television systems exists although the number of new systems per year has decreased. The systems of today have been designed to provide a greater number of channels, usually 5 as compared to one, two, or three for the initial systems.

The connection fee and monthly charge has not changed appreciably due to the added expense of tall antenna towers, microwave equipment where used, more complicated tower site equipment, more industrialized type of repeater amplifiers and accessory equipment and increased labor costs. The demand for systems and cost to subscribers is expected to remain at current levels unless there is a significant change in the broadcasting of television signals.

ROY C. ABBETT received the degree of BSEE from the University of Kansas in 1943, and joined RCA upon graduation in Application and Development Engineering on Intercommunication Equipment for shipboard use at Indianapolis. He transferred to Camden Broadcast Studio Engineering in 1946, and became associated with TV Antenaplex in 1949. He was made leader of that activity in 1953, and currently continues in this capacity with projects associated with Broadcast Studio equipment, Chemical Gas Alarm, and Airborne Television Equipment.

Fig. 4 — Repeater amplifier under installation test by Charles Collins while Frank Hensley, supervisor from RCA Service Company observes.

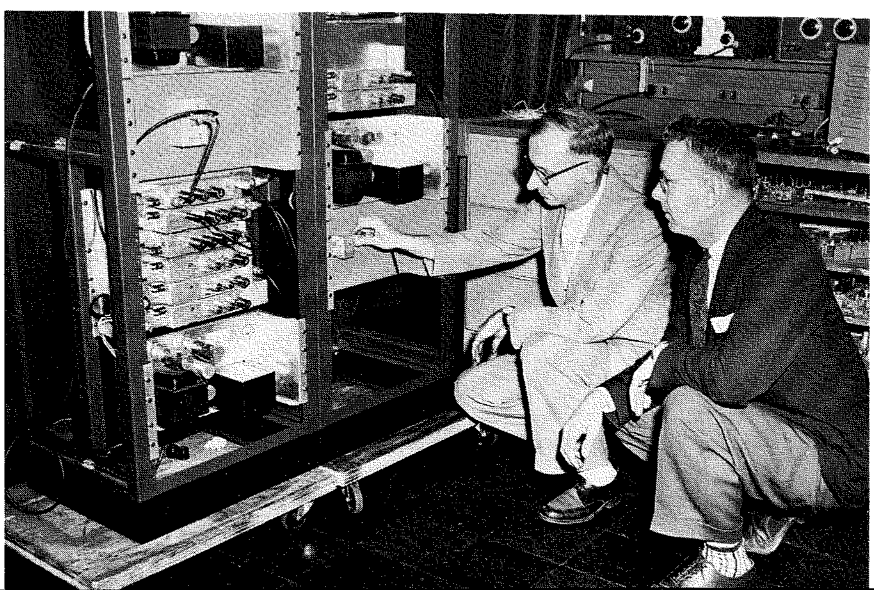


Fig. 3—Tower site equipment built for Paducah, Ky., under final test. J. K. Malinoski, Antenaplex engineer and R. C. Abbett (right).

THE RCA TELECOMMUNICATIONS GUIDANCE COMMITTEE*

THE RADIO CORPORATION OF AMERICA came into existence in 1919 as a communication company. It has always maintained a prominent position in communications even though its interests grew into many other fields with the phenomenal expansion of electronics. The rapid increase in the uses for radio communication, the differentiation of technical specialization that evolved, and the growth of RCA that led to decentralization, brought about a situation where our work in communications goes on at several different locations. This of course raises problems of communication between all our people engaged in communications, from research to marketing, field engineering and operations in public correspondence. Almost all RCA units are concerned with 2-way radio communication in some form.

To improve the coordination of these diverse activities throughout RCA, and to encourage and facilitate concerted efforts, General Order F-29-E was issued on October 20, 1955, creating the "RCA Telecommunications Guidance Committee." This General Order reads as follows:

> "The RCA Telecommunications Guidance Committee is hereby established as follows:
>
> "E. W. Engstrom, *Chairman*
> M. Brunet
> D. H. Ewing
> O. B. Hanson
> A. L. Malcarney
> J. L. McMurray
> T. H. Mitchell
> C. M. Odorizzi
> D. F. Schmit
> D. Y. Smith
> T. A. Smith
> W. W. Watts
> E. A. Laport, *Secretary*
>
> "The Committee shall be responsible for a coordinated RCA program to accomplish maximum effectiveness of research, development, design, manufacturing, marketing, and overall operations for domestic and international telecommunications matters.
>
> "The Committee shall coordinate the work of existing task groups in its sphere of activity including the Single-Sideband, Scatter Propagation, Terminal Equipment and Microwave System groups and shall reorganize existing task groups or establish additional ones as it may determine.
>
> "Meetings of the Committee shall be held upon call of the Chairman, at least one such meeting to be held every six months."

The task groups named in the General Order were informal committees dating from 1947 and 1948. They grew spontaneously out of the need to coordinate inter-Divisional efforts, to build personal acquaintances among RCA people having common interests, to exchange technical experience and information and to suggest the direction of future efforts. These task groups include research, engineering and marketing people.

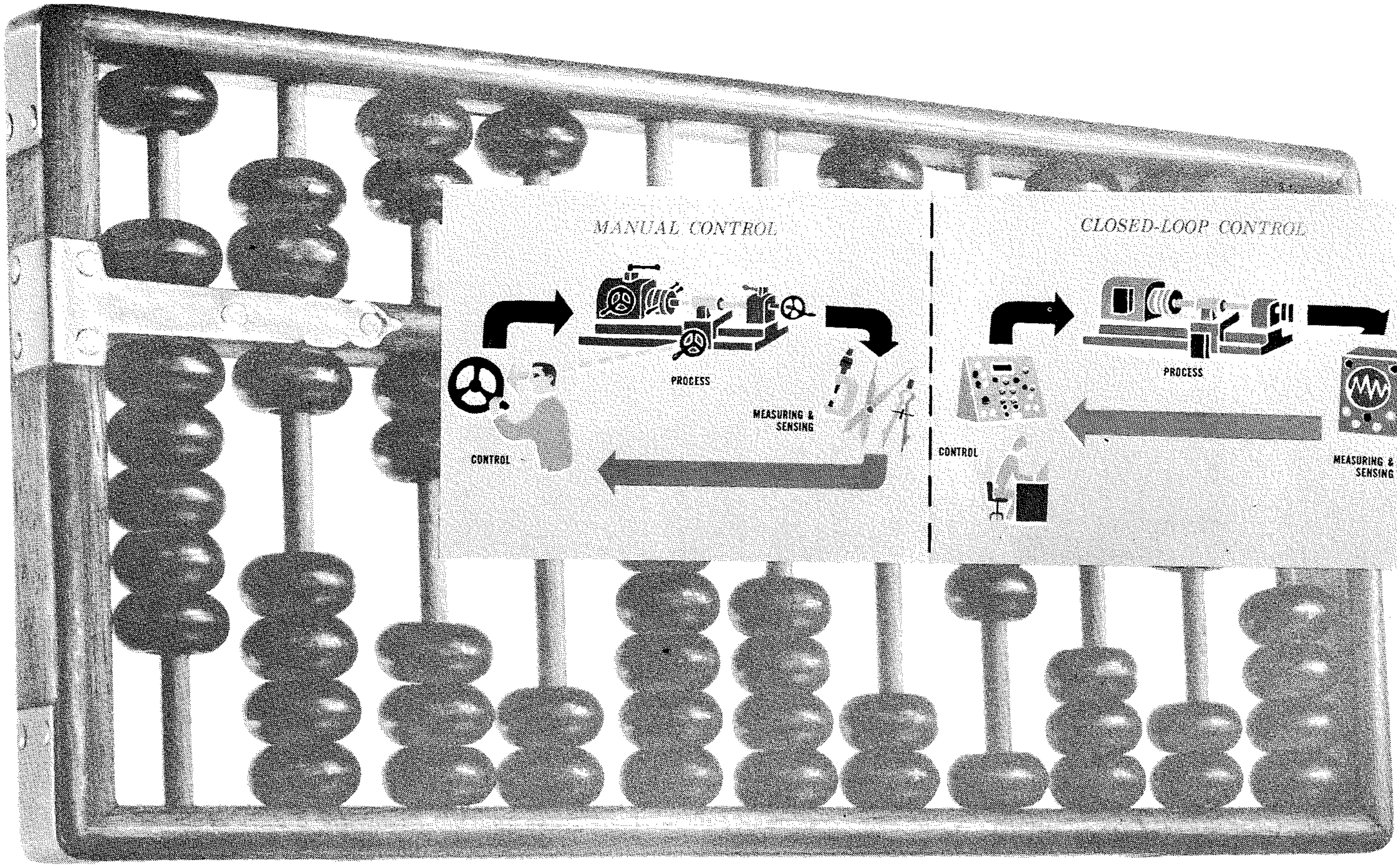
More recently the Microminiature Committee has become a task group under the Telecommunications Guidance Committee.

The activities and recommendations of the task groups are reported to all members of TGC and are reviewed at each meeting. Plans and decisions of inter-Divisional nature are made by TGC, whose sponsorship is essential before the initiation of certain long-range projects.

The Telecommunications Guidance Committee has sponsored the RCA Type MT-21 (formerly called MM-X) high capacity 2000-mc radio relay system which is now well along in development, and the Multiplex-ARQ telegraph terminal equipment with automatic error correction. The first production of this equipment is now in service on long-haul radioteleprinter circuits by RCA Communications, Inc. and others. It encouraged the manufacture and marketing of mechanical filters, and supported the high-frequency single-sideband system comprising a 20-kw transmitter SSB-T3 and diversity receiver SSB-R3. It also sponsored accelerated work on microminiature communication equipment development.

These events are all contributory to an ever stronger and broader RCA position in telecommunications.

* This brief article on the RCA Telecommunications Guidance Committee was prepared by E. A. Laport, secretary of the Committee, to inform each member of RCA's technical staff about the Committee and its activities. Radio communication takes on increasing importance each year. RCA's participation in this service and market is being strengthened continually. The RCA Telecommunications Guidance Committee has an important place in RCA's program of growth.



DIGITAL CONTROL SYSTEMS

By **ABRAHAM KATZ**
BIZMAC Engineering
Industrial Electronic Products
Camden, N. J.

An area of human activity in which the digital computer appears destined to play an increasingly important role is that of *control.* The essence of *control* is action which adjusts operations to predetermined standards, and its basis is *information* at the disposal of the controlling agents. The control of a process, economic or physical, may be facilitated by inserting into the control loop a device for preparing information for use by the controlling agents, be they human or servo actuators. One such device is the digital computer which, in executing a set of internally-stored instructions, accepts raw data from its environment, applies prescribed processes to this data, and supplies the finished data to its environment for further action. Since the computer can only process data which are in the form of a code of voltage pulses or levels having two discrete values, transcribing devices are required at its input and output. Furthermore, the set of instructions, or program, to be executed is of equal importance with the "hardware" characteristics of the computer in determining system adequacy. To a great extent it is the program which determines the transfer function by which the computer may be characterized.

It is the purpose of this paper to present certain aspects of digital control. A digital control system, as herein discussed, is one in which the control function is accomplished by means of a man-machine complex, one or more units of which are digital data processing devices. Subsumed under such control systems is the "Sampled-data" system[1,2,3] as a complex for the control of physical variables (e.g., pressure, temperature, and flow in an oil-cracking process). Two large-scale systems will be examined to determine the influence of the application on the computer design, and to demonstrate the basic unity underlying all control activity.

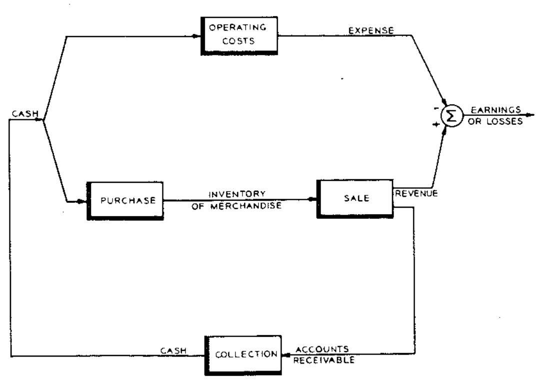


Fig. 1—Flow of assets for a Merchandising Concern.

INVENTORY CONTROL

Since the dynamics of economic processes may be less familiar to the reader than are those of physical processes, it is desirable to examine the problems inherent in inventory control from a more fundamental point of view. The basic purpose of inventories is to decouple the successive operations involved in the manufacture of a product and its subsequent distribution to consumers. Since several stages exist in both manufacture and distribution, inventories (raw materials and semi-finished or finished goods) may exist at several points in the total economic process of meeting the needs of the consumer. Inventories make it possible to manufacture goods at a distance from either sources of materials or consumers. They enable production to proceed with lessened dependence on consumption. Alternatively, they free consumption from the rigidities inherent in volume production. By decoupling one stage in the process from the next, inventories enable each to operate more economically.

Management, whether of a distributing or manufacturing enterprise, has long been concerned with the control and valuation of inventories. The reasons for this become apparent on consideration of the costs involved. For most distributing concerns, the outlays involved in obtaining merchandise are by far the largest single element of the costs of doing business. For most manufacturers, the costs of acquiring materials are likewise a major factor; in many cases the value added by labor, plant, and administration is less than the outlay required to obtain the basic raw or semi-processed goods. Whereas the costs of labor and purchased services are relatively stable (increasing gradually in recent years), those represented by inventories may change value markedly between purchase and sale. For example, the labor costs involved in the manufacture of women's clothing may remain static throughout an annual labor contract period. The inventories of clothing accumulated, however, may be rendered virtually valueless by seasonal or climatic variations several times during the same contract period.

Referring to Fig. 1, we see, in block diagram form, the flow of assets for an enterprise engaged in the distribution of merchandise. For simplicity, it is assumed that all sales are made on account. For accounting purposes, earnings (if any) occur at the time of sale. Note that business activity is cyclic in nature and consists of capital conversions: cash to inventory; and capital expansions or contractions: accounts payable to cash. With each episode of business activity, or transaction, some record is associated. These records—requisitions, invoices, and memos—are among the data to be processed.

TWO ASPECTS

The decisions associated with inventory control are twofold in aspect:

a) the strategic aspect of determining the optimum size of inventory required at each of the various stages in the production-distribution process, and

b) the tactical aspect of implementing the maintenance of the inventories so determined.

In making the strategic decisions, management seeks that particular control configuration which is best related to the overall objectives and operational restrictions of the company. The making of the tactical decisions,

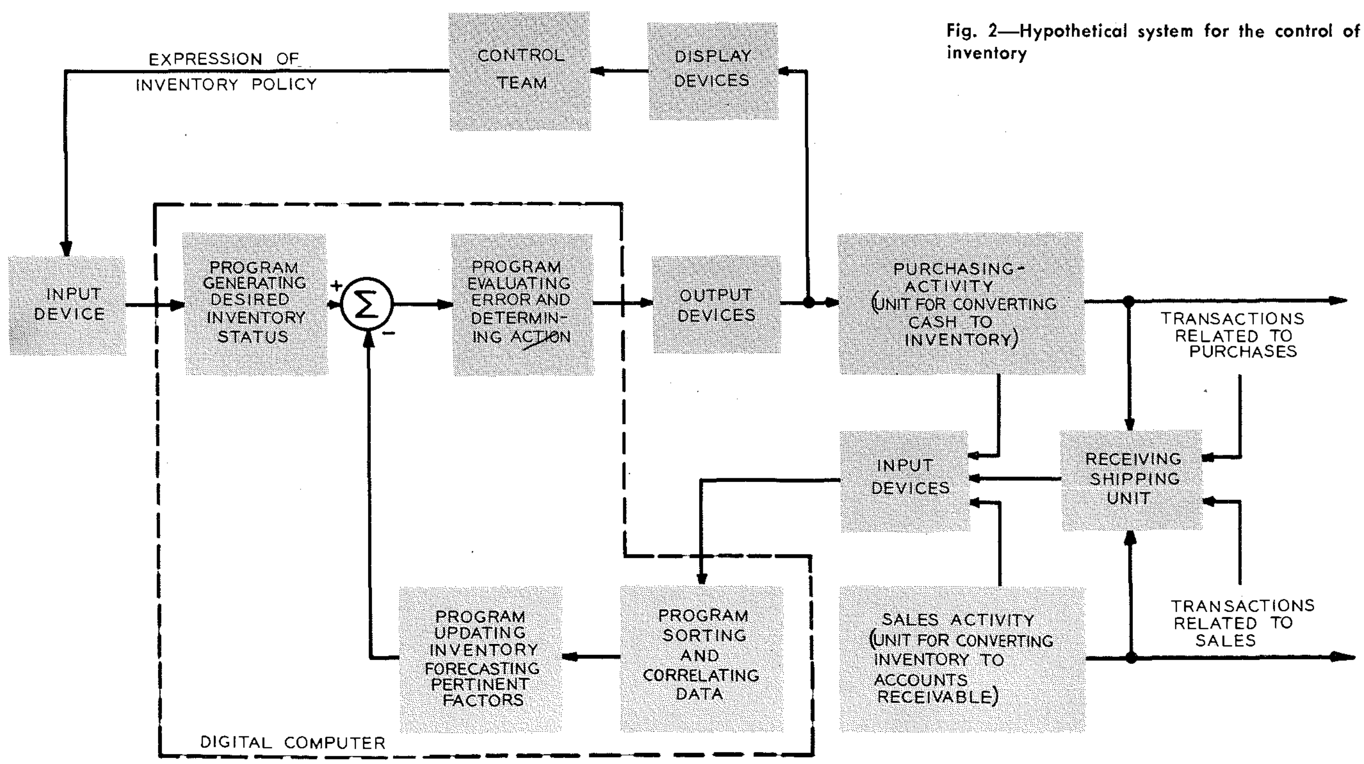


Fig. 2—Hypothetical system for the control of inventory

on the other hand, requires local choices to be made on each inventory item individually so as to achieve an effective control over the operation as a whole. It is with the latter aspect that we shall here concern ourselves, although it is clear that the two aspects are intimately related.

A hypothetical system for the digital control of inventory is shown in Fig. 2. The strategic aspects of inventory control enter into the expression of inventory policy. The basic elements of such an expression[6] include such factors as order quantity, order point, average usage rate, unit cost, lead time; average inventory investment, cost per dollar invested; number of orders processed, and cost per order processed.

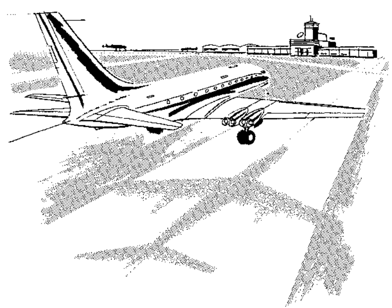
From an engineering point of view, the control of inventory is analogous to that of maintaining levels in a set of reservoirs, one for each item of inventory. Inflow of goods results from the efforts of the Purchasing Activity; and outflow (hopefully), from the efforts of the Sales Activity. The control complex might operate as follows:

a) Information as to inflow and outflow of goods enters the system by means of peripheral devices capable of reading punched tags, cards, or paper tape, or of reading documents. These data are transcribed on magnetic tape to speed the processing operation.
b) The inventory items affected by the transactions are sorted into stock number sequence.
c) The sorted transaction tape and the master inventory tapes are then processed so as to up-date the latter and to forecast the factors of interest to the various segments of management (buyers, controllers, etc.).
d) On the basis of the expression of inventory policy discussed earlier, a program generates the desired status of inventory and of the control factors.
e) The desired and the actual results are compared and evaluated, and appropriate action is initiated.
f) By means of output devices such as printers and typewriters, this action is communicated to the complex external to the computer.

A SYSTEM CURRENTLY IN OPERATION

To assess the nature of this control problem, let us consider a typical large-scale system. One such is the BIZMAC System installed by RCA for the Army Ordnance Tank-Automotive Command (OTAC) in Detroit. This system includes over 200 transcribing, sorting, and computing units. It maintains control over more than 155,000 types of automotive and equipment parts at twelve depots. The central computer is a general purpose alphanumeric machine which handles information serially, character-by-character, under the control of the stored programs.

Economy of data organization and storage is achieved through the use of variable item length. Its internal storage facilities include a high-speed core memory supplemented by a large medium-speed memory. Access to the external bulk storage of 180 magnetic tape stations is obtained through a central switching system. Through the use of electronic sorting devices, the burden of processing by the computer is greatly reduced. The RCA system includes a variety of output devices for providing information in a form intelligible to the human units of the control complex.



AIR TRAFFIC CONTROL

Consider a system for the control of air traffic at a large airport where many aircraft may be approaching a set of airstrips. For each aircraft the relevant data must be evaluated rapidly and the approach to an airstrip must be prescribed in a manner consistent with the safety of the remaining aircraft. Although such systems are now being operated by control teams, the ever-increasing traffic load will soon saturate human capabilities. The control problem is real, even though the system to be analyzed is hypothetical and greatly oversimplified. Operational data for the system would include aircraft positions and velocities, identification, flight plans, weather conditions, requests for instructions, information as to fuel, and emergency conditions in the air or on the ground. Referring to the block diagram in Fig. 3, we see that the system might operate as follows:

a) The radar detection system surveys the surrounding region and supplies information as to the velocity and position of each aircraft with respect to the airstrip.
b) These signals are fed back to the encoder which samples and quantizes them, thus providing numerical data for the computer. It is this data conversion process which distinguishes the "sampled-data" system from the more conventional servo system.
c) A computer program sorts this data and correlates it with that stored internally pertaining to previously computed tracks.
d) A second program smooths and extrapolates this data for each aircraft so as to obtain the best possible values for its path variables at the next sampling instant.
e) A third program, having weather, radio, and teletype information as its inputs, generates the desired future flight path.
f) The actual and the desired values are compared to yield an error quantity, which is then evaluated by a fourth program. After deciding what action must be taken to correct the error, the program transmits this information to the aircraft via the decoder.
g) This information, modified by the servo actuator and the aircraft dynamics, then determines the path of the aircraft as it makes its landing.

Examination of the block diagram shows that the components of the control system tend to fall into three categories—digital, analog, and conversion devices—depending on the nature of the signals which they are to process. In the first category, the signals are in the form of discrete time series of numerical data; in the second, in the form of a continuous time series of voltage or position. Time series may be defined as sequences of quantita-

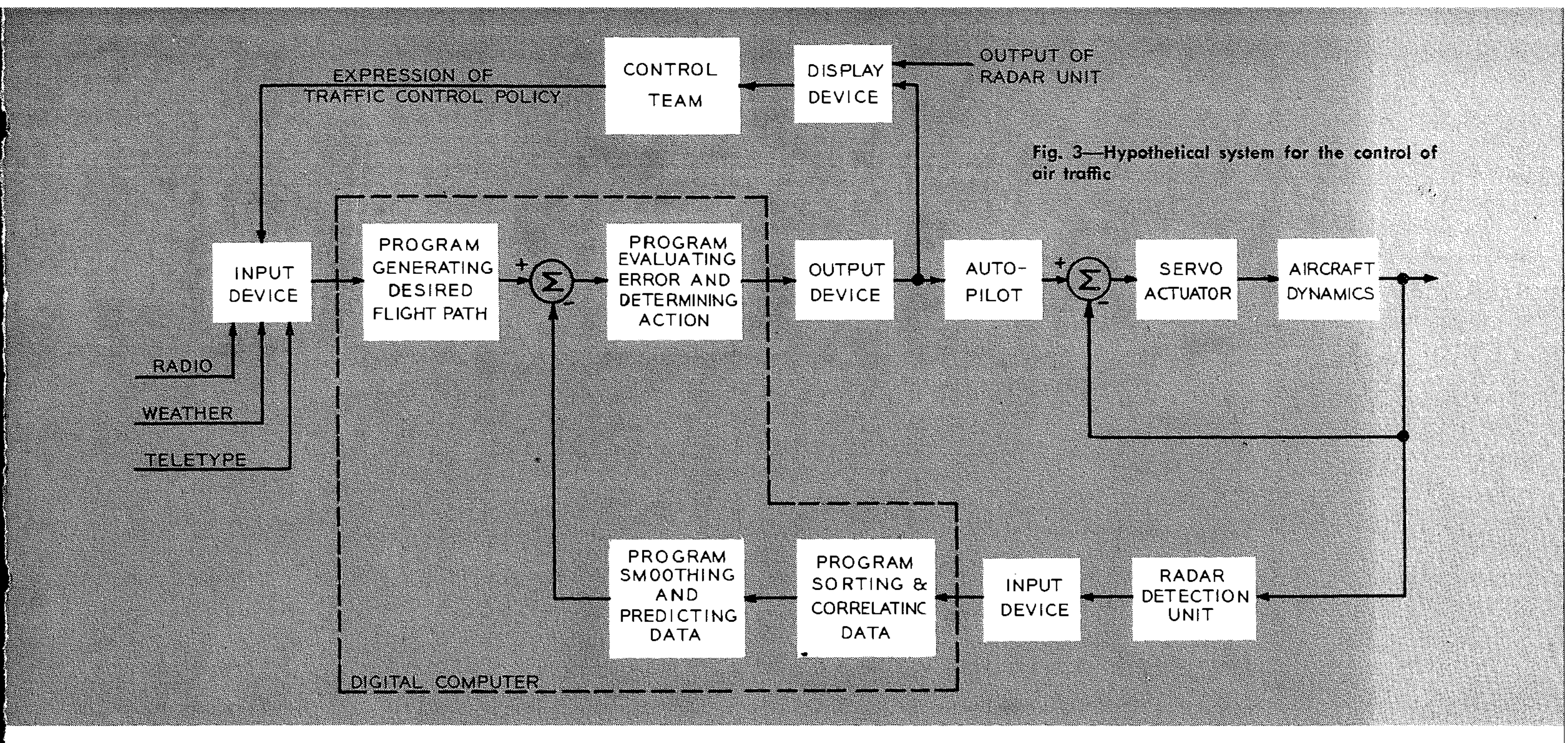


Fig. 3—Hypothetical system for the control of air traffic

tive data assigned to specific moments of time. The purpose of conversion devices in a mixed digital-analog system is evident.

CONCEPTS OF SAMPLED-DATA CONTROL

With this hypothetical system as background, let us first indicate certain concepts important in sampled-data control systems:

a) The design of mixed digital-analog systems is facilitated by the fact that their behavior may be interpreted by a common discipline, that of conventional filter theory. Thus, the computer programs handling the discrete signals will be considered "discrete filters," while the servo compensating networks will be considered "continuous filters."

b) The signals, be they discrete or continuous, are essentially statistical in nature. The design of a filter should logically be preceded by a study of the statistical characteristics of the signals which it is to process.

c) The input signals to the discrete filters are always contaminated by noise, an important component of which is that introduced by the encoding process.

A continuous filter is a transmission device characterized by elements of resistance, capacitance, and inductance, and by inputs and outputs which are continuous functions of time. A discrete filter is a transmission device which, when supplied with discrete data from an external source at regular intervals, furnishes at essentially the same moments output data which may depend on input data, past output data, and on time. Not only are the input and output signals discrete time sequences, but the filter itself is characterized by a sequence (or sequences) of numerical weights. Linear systems, be they discrete or continuous, are those in which the relation between input and output is governed by the superposition principle. From the analogies shown in Fig. 4, it is evident that the powerful techniques of filter and servo theory are readily extensible to the design of sampled-data systems.

$f_i\ (t)$	$h\ (\tau)$	$f_o\ (t)$
$F_i\ (s)$	$H\ (s)$	$F_o\ (s)$

Linear Constant-Coefficient Filter for Continuous Signals

Time domain description

a) differential equation
b) superposition integral
c) impulse response or weighting function given by $h(\tau)$.

Frequency domain description

a) transfer function is rational in s.

$$H(s) = \frac{F_o(s)}{F_i(s)} = \frac{a_0 + a_1 s + a_2 s^2 + \ldots\ldots\ldots + a_m s^m}{1 + b_1 s + b_2 s^2 + \ldots\ldots\ldots + b_n s^n}$$

$i\ (t_k)$	w_n	$o\ (t_k)$
$I(e^{-sT})$	$W(e^{-sT})$	$O\ (e^{-sT})$

Linear Constant-Coefficient Filter for Discrete Signals

Time domain description

a) difference equation
b) superposition summation
c) impulse response or weighting sequence given by w_n.

Frequency domain description

a) transfer function is rational in e^{-sT}.

$$W(e^{-sT}) = \frac{O(e^{-sT})}{I(e^{-sT})} = \frac{c_0 + c_1 e^{-sT} + \ldots\ldots + c_p e^{-psT}}{1 + d_1 e^{-sT} + \ldots\ldots + d_q e^{-qsT}}$$

Fig. 4—Analogies between "continuous signal" and "discrete signal" filters

Consider now the nature of the signals propogating around the servo loop. To begin with, many performance inaccuracies are essentially random functions of time, and cannot be prescribed in advance except in a statistical sense. For example, because of fading and similar effects, the position of an aircraft indicated by the radar unit contains components of noise which vary with time in an unpredictable way. Secondly, the sensitivities and other fixed parameters of the systems are subject to slight fluctuations with time. Thirdly, a control system is usually designed to perform a task selected at random from a repertoire of possible tasks, rather than a single pre-specified task. For example, the traffic control system must be capable of handling aircraft traveling with a wide range of velocities. Finally, the very process of encoding further corrupts a signal which is already rich in noise components. It is then evident that the computer program, in addition to exercising its normal data-processing function, will frequently be required to act as a smoothing filter if its output sequence is not to be divergent or oscillating.

Having indicated the nature of the control application and certain techniques available for system design, let us now consider the implications for the computer itself. In participating in the control function, the computer must cope with a dynamically changing process, since the finished data immediately and directly affect the evolution of the process. Depending on the time constants of the system under control, the specification of the computer may include a high operating speed as well as extensive storage facilities. If the system is to handle the heavy traffic at a large airport, this would indeed be the case. An appreciation of these specifications may be obtained from a consideration of the characteristics of a computer designed for a related large-scale control application.[4] These included the following:

a) Internal high-speed storage provided by a magnetic core memory with a capacity of 270,000 bits with an access cycle of 6 microseconds. The high speed core memory was supplemented by a medium speed drum memory with a capacity of 3,250,000 bits.

b) A dual arithmetic element for handling data expressed in Cartesian coordinates Execution times for the arithmetic instructions is measured in the tens of microseconds.

c) A buffer drum memory and an input-output control system which permit the computer to

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continue its work while waiting for transfer of raw and of processed data.

For the smaller airport handling fewer aircraft, a simpler, less expensive system is clearly in order. Such systems have been under consideration since 1947, and at least two of them have undergone test[5] by the Civil Aeronautics Authority at Indianapolis.

SUMMARY

As indicated earlier, the essence of *control* is action which adjusts operations to predetermined standards, and its basis is *information* at the disposal of the controlling agents. The limitations of the human mind are such that, although overwhelmed by masses of details, it can nevertheless make complicated decisions rapidly. The digital computer, by virtue of its ability to apply repetitive processes to large volumes of data at very high speeds, can pre-digest the information for subsequent use by human beings.

The nature of the control application has a great influence on the characteristics of the central data processor. In the examples given, the function of the complexes was that of controlling a number of closely interrelated, dynamically varying elements, of which the time constants were such that it was possible to time-multiplex the use of the processor. Since the time constants of economic processes are measured in days or even months, while those of physical processes are much shorter, the number of elements controlled in the case of the former is much greater than for the latter. Time multiplexing creates the need for high rates of input and output, for large internal and external storage facilities, and for means to sort and correlate data with their associated element. The organization of data and the repertoire of instructions which the computer can execute must be tailored to the particular application. Control of air traffic requires that data be organized in a purely binary-coded form, and that special arithmetic instructions be provided. Control of inventory, however, requires an alphanumeric binary code and special logical instructions for manipulating and modifying data. Peripheral devices are even more profoundly influenced by the application since they must effect the transfer of data into and out of the central processor.

A man-machine complex, in which one or more digital data processors are included, implements the control function by allocating to each unit of the complex that subfunction which it is best able to execute. It appears likely that digital control systems will find increasing utility in an expanding industrial society.

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INERTIAL NAVIGATION

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Inertial guidance has been emerging in recent years as the most logical direction for advancement in airborne systems navigation. The subject is fascinating, and Mr. Daigle's series should do much to enlighten our readers on its principles.

The first article will review basic principles of inertial navigation. The second will discuss instrumentations of inertial systems, and the third and concluding article will deal with stabilization.

With the advent of high speed jet aircraft, intercontinental ballistics missiles, longer bombing ranges, and continuing tight accuracy requirements in our airborne weapon systems, the need for more accurate and stable directional reference and position indicating systems has grown. No relaxation in the system requirements can be expected. In fact, the future requirements will in all probability be even more stringent.

The navigational requirements of all-weather weapon systems to date have been met by radar, the only operationally available technique. At the end of World War II, however, inertial methods of navigation appeared promising to the extent that a substantial mass effort has since been made in this country to develop operational inertial systems. Originally spearheaded by Dr. C. S. Draper of MIT and the North American Aviation, Inc., this effort is now spread over a broad front. Consequently, inertial navigation is coming into its own and is now recognized by our military as a major candidate for fulfilling the needs of our future weapon systems, both manned and unmanned.

In view of this all-important role to be played by inertial navigation, a few unclassified articles on inertial guidance and navigation are appearing in our technical and industrial journals in an attempt to describe the techniques and implications of inertial navigation. The writer is also attempting this task; however, because of the scope of the subject, only broad generalizations can be considered in this article. More detailed discussions are planned in articles to appear in future issues.

Needless to say, the unclassified nature of these articles will leave much to be desired, since the details of inertial instrumentation are necessarily classified for security purposes. The writer, however, will welcome any proper queries on the identification of sources of inertial information.

PRINCIPLES OF INERTIAL NAVIGATION

Inertial navigation may be defined as the means of indicating and/or controlling a vehicle's position in space based on measurement of the acceleration of the vehicle. This definition implies that for the case where navigation is on the earth's surface, distance travelled is defined as that distance represented by the angle between a reference vertical and the local position vertical in an earth-fixed coordinate system. Distance measuring therefore can be labeled as a basic inertial navigational system function.

Distance measuring in a particular direction can be performed simply by doubly integrating one's acceleration with respect to time in that direction. Consider a vehicle constrained to a horizontal track along a meridian. An accelerometer in the vehicle with its input axis aligned in the forward direction of the vehicle would indicate the horizontal north acceleration of the vehicle. Fig. 1 shows the geometry of this hypothetical distance-indicating system and outlines the steps required to obtain the tangential distance S (or latitudinal increment λ) travelled from point P_1 to point P_2 on the meridian. Since the accelerometer would forever be horizontal, gravity would not enter the picture and only the vehicle's horizontal north acceleration a_H would be sensed.

Such a hypothetical vehicle as above, although useful in helping to illustrate distance measuring, has a low probability of being a physically operational system. Vehicles navigating over the earth's surface are normally not constrained to horizontal tracks nor to earth-fixed directions. The problem therefore arises in (a) how to maintain the accelerometer sensing axis horizontal while the vehicle maneuvers, and (b) how to maintain the accelerometer sensing axis parallel to an earth-fixed azimuth heading. Solving this dual problem thus becomes the very purpose of inertial navigation.

VERTICAL INDICATING

Gravity Isolation. To maintain the accelerometer sensing axis horizontal and thus render the accelerometer insensitive to gravity requires that the accelerometer be continuously rotated in space while traveling from point P_1 to point P_2 through the corresponding angular travel λ. Were the accelerometer supported by and continuously driven with respect to a stable space platform whose attitude were maintained non-rotating in space and independent of the direction of gravity g, a simple double integration of a_H divided by the earth's radius R_e would represent the required angular rotation between the accelerometer and the space stable platform.

Consider Fig. 2 which shows such a space platform on which it is desired to maintain an accelerometer horizontal.

It is the purpose of the leveling function to continuously drive the accelerometer casing with respect to the stable platform so that the accelerometer input axis is maintained continuously horizontal. However, since the accelerometer reacts to accelerations and the force of gravity in identical fashion, any misalignment of the accelerometer input axis from horizontal will result in gravity coupling into the accelerometer with the attendant falsely indicated acceleration.

For a small deviation angle θ_s from the horizontal, the accelerometer indicated acceleration can thus be represented by

$$a_i = a_H \cos \theta_s - g \sin \theta_s \quad (1)$$

The angle θ_s is normally quite small such that equation 1 can be rewritten approximately as

$$a_i \approx a_H - g\,\theta_s \quad (2)$$

Doubly integrating the indicated acceleration and dividing through by the earth's radius R_e nets the indicated angular travel from the departure point P_D.

$$\theta_i = \frac{1}{R_e p^2}\, a_i \approx \frac{1}{R_e p^2}\, a_H - \frac{g}{R_e}\,\frac{1}{p^2}\,\theta_s \quad (3)$$

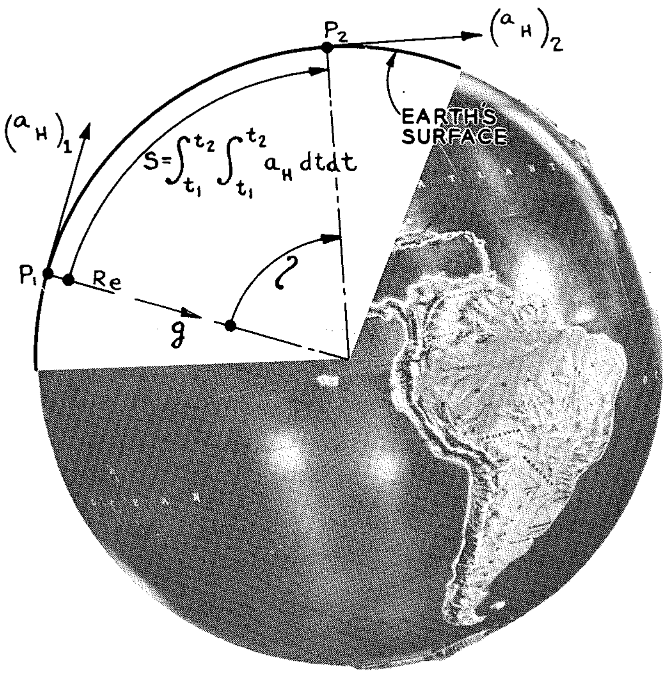


Fig. 1—Distance indicating on the Earth's surface.

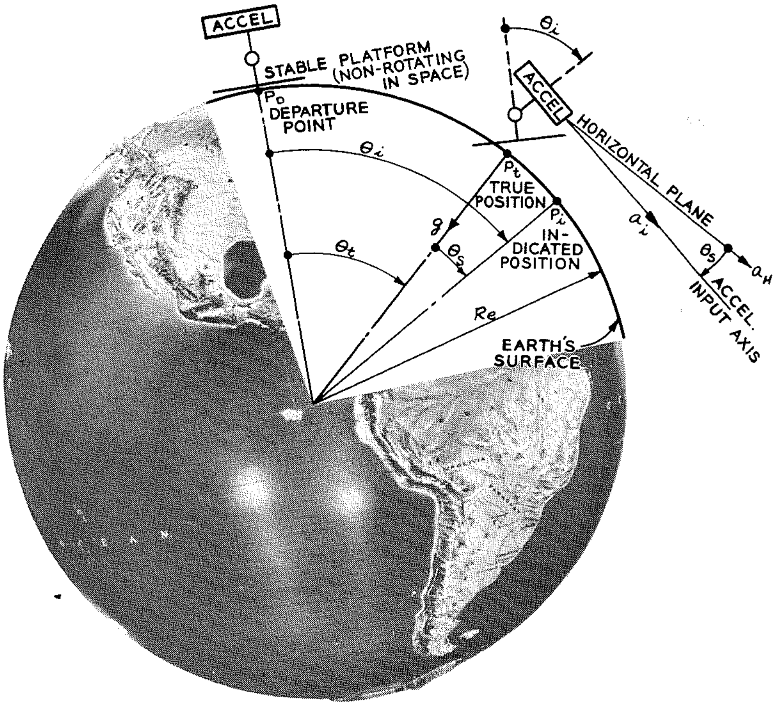


Fig. 2—Components of acceleration sensed by an accelerometer.

The true distance θ_t travelled from departure point P_D to the present position P_t is represented by the first term on the right of equation 3. θ_t can also be represented after inspection of Fig. 2 by

$$\theta_t = \theta_i - \theta_s \qquad (4)$$

Thus,

$$\frac{1}{R_e p^2} a_H = \frac{1}{R_e p^2} a_H - \frac{g}{R_e}\frac{1}{p^2}\theta_s - \theta_s \qquad (5)$$

or,

$$\left(\frac{g}{R_e} + p^2\right)\theta_s = 0 \qquad (6)$$

Equation 6 should be recognized as the basic characteristic form of simple harmonic equation for which the argument θ_s can be expressed as

$$\theta_s = \Theta_s \sin \omega_s t, \qquad (7)$$

where Θ_s is the amplitude of the oscillatory θ_s and

$$\omega_s = \sqrt{\frac{g}{R_e}} \qquad (8)$$

Equation 8 represents the so-called "Schuler" oscillation named after its discoverer, which has a period of 84.4 minutes at mean sea level and where g has a value of 32.2 feet/sec^2 and R_e of 3,440 nautical miles. This is the period of rotation of an Earth satellite in a circular orbit at sea level. Tuning a pendulum to this period endows it with a valuable immunity to irregularity of motion of the vehicle carrying it, thus making it a very good vertical indicator. A true undamped Schuler pendulum cannot be excited solely by accelerations over a uniform spherical earth.

The foregoing development of the basic distance and vertical indicating scheme used in inertial navigation can be mechanized by the instrumentation shown in Fig. 3. The accelerometer continuously oscillates about local vertical while it is driven from the reference vertical. Were the instrumentation ideal and the accelerometer aligned and maintained perfectly horizontal while at rest at the departure vertical, the amplitude of the Schuler oscillation while in motion would be zero. However, with physical equipment, such a condition can only be approached at best and the accelerometer does oscillate about local vertical at a small amplitude with the attendant Schuler period of 84.4 minutes.

Other Undesirable Accelerations. The above gravity-isolation technique allows for the vertical-indicating package to discriminate against the acceleration of gravity. In the process of doing so, of course, it indicates the direction of gravity, or local vertical.

There are other accelerations, however, to which the horizontal accelerometer is sensitive but against which discrimination is not so easy. These occur in the horizontal plane with the tangential accelerations to be measured and can be computed and compensated. Such accelerations are commonly referred to as Coriolis accelerations and are due to cross-coupling effects between one's linear velocity over the earth's surface and the earth's angular rotation in space. (Coriolis accelerations are one of the prime factors in the cause of hurricanes, tornados, and other rotary surface wind phenomena. Coriolis accelerations are also of some concern in computing bomb trajectories.)

The direction of Coriolis acceleration is always perpendicular to the plane containing the velocity vector and the earth's rotational vector, and can be expressed by the vector cross product,

$$\text{Coriolis Acc.} = 2V \times \omega_e \qquad (9)$$

where V is the total velocity vector on the earth's surface and ω_e is the earth's angular velocity in space. Were one travelling easterly at the equator, he would experience an upward acceleration as given by equation 9. At a northerly latitude, the same easterly velocity would produce both an upward acceleration equal to $2(V \times \omega_e)$ cos Latitude and a southerly acceleration equal to $2(V \times \omega_e)$ sin Latitude. North and vertical velocities would also produce similar computable results.

Since the horizontal accelerometer in a vertical-indicating package cannot be isolated from Coriolis accelerations, it is instead compensated for

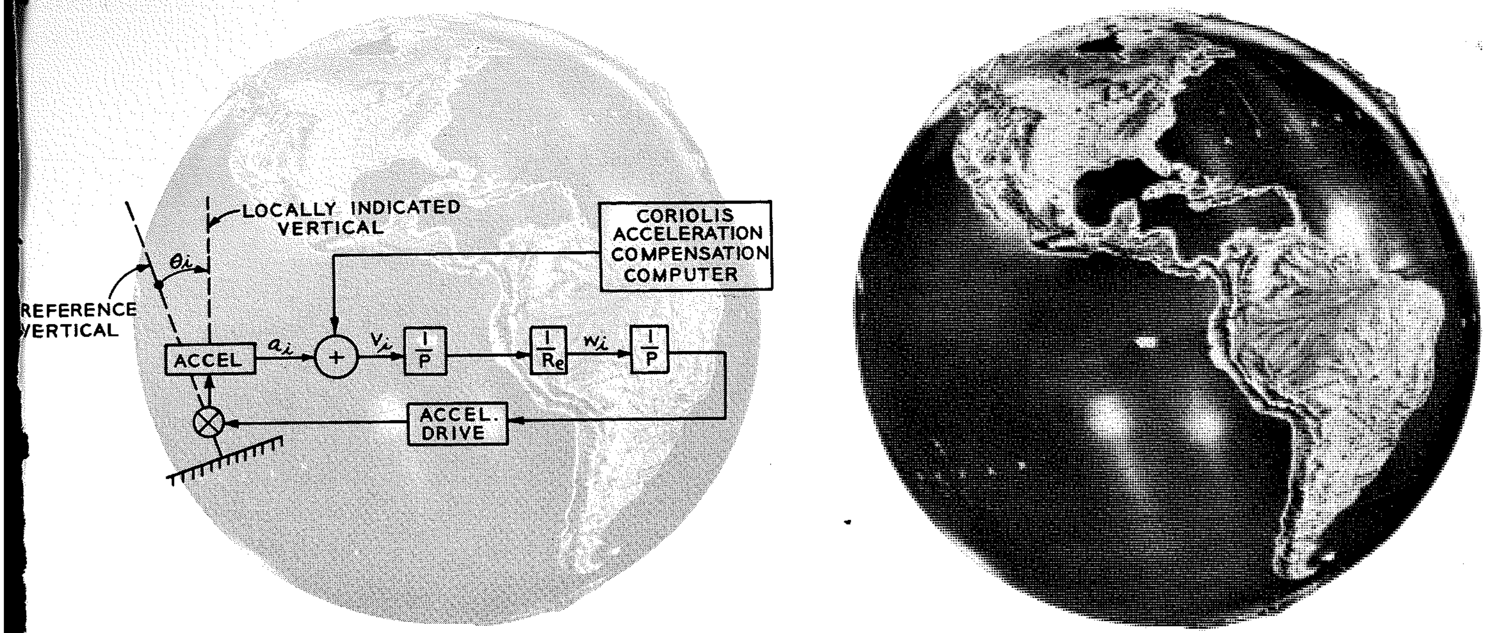


Fig. 3—Space-to-local vertical indicating instrumentation.

these computed accelerations. The compensation can be simply the subtraction, or addition, of a voltage proportional to the computed Coriolis acceleration, from the electrical output of the accelerometer. Or, should the accelerometer be of the pendulous-integrating type, the gyro is torqued by an amount proportional to the computed Coriolis acceleration. (Components for inertial navigation will be discussed in a future article.)

Other undesirable accelerations appear in the form of gravity anomalies and represent the discontinuities which exist in the earth's radial gravity field. Anomalies arise where a large protruding land mass (the Himalayas or Rocky Mountains), or concentration of dense material exists in an otherwise homogeneous structure. The net result is an indication of gravity away from the "radial" direction.

In most cases, the anomalies are small and of short duration (small fraction of time of flight) and prove to be negligible. In other systems, however, the gravity anomalies must be considered and constitute an error in position indicating.

SPACE STABLE REFERENCE

The space stable platform referred to in the previous section can be represented by a set of gyroscopes, which by virtue of their high angular momentum have a high tendency to remain non-rotating in space. How to most effectively use gyros to represent a space reference, however, is a subject for heated discussion among inertial designers in the field today. Some prefer to simulate space coordinates with a set of undisturbed gyros independent of the vertical-indicating package, while others favor carrying the gyros on the vertical-indicating package and relying on a computer to integrate position. A third approach is one which carries the accelerometer package on the stable and undisturbed gyro space package, computing the effects of gravity.

The undisturbed and uncoupled gyro approach constitutes what is commonly referred to as the "geometric" or "angular-position" philosophy, in which one's position on the earth's surface is indicated directly by the angle, or set of angles, which exists between the vertical-indicating package and the space gyros. The slaved-gyro approach is referred to as the "analytical" or "angular-velocity" philosophy and relies on an external integrating computer to obtain distance from the indicated velocity. The third variety might be referred to as a "free-gyro analytical" system since it, too, would rely on an external integrating computer to obtain position on the earth's surface. This third variety could also be truly called a space navigator, since velocity and position would be most readily computed as space quantities and not as earth quantities.

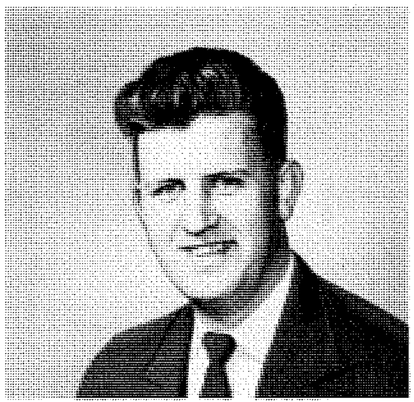
Geometric (Angular Distance) approach. To configure a geometric inertial navigator requires that sufficient degrees of freedom and control be provided in the system to isolate the space simulating gyros from the earth's rotation as well as from vehicle maneuvers. The gyros are aligned with 3 non-rotating space axes, one of which is conveniently made parallel to the earth's polar axis. This allows for a gimbal which represents the earth to support the gyro configuration about a mutual earth-space axis. To account for earth rotation, a time drive is introduced about this mutual axis such that the gyros are left undisturbed while the earth rotates. The time drive can be envisioned as a highly precise space clock in which the supporting earth gimbal rotates $(365 + 1)$ complete rotations in space per year. This space clock rotates at what is commonly referred to as "sidereal rate" and accounts for the additional revolution performed by the earth in space in completing its yearly orbit about the sun.

Having isolated the space gyros from the earth by virtue of a time drive, one can mount two vertical-indicating packages on the earth gimbal to dynamically indicate the direction of local vertical in both relative longitude and latitude. Thus, the present longitude would be indicated directly as the angle between the earth gimbal and the longitude vertical package and present latitude would be indicated by the angle between the equatorial plane (perpendicular to the earth gimbal) and the latitude vertical package.

To isolate and stabilize the earth gimbal and Lat.-Long. indicating systems from vehicle maneuvers and perturbations, three more gimbals are required. These can take on any convenient order but must isolate the position indicating system from the vehicle in roll, pitch and yaw. (Isolation from vehicular maneuvers is discussed in *Maneuver Isolation.*)

Such a geometric system requires four gimbals for stabilization and isolation in addition to the undisturbed three-gyro package and the two vertical-indicating packages. Needless to say, this creates a gimbal system of large size and weight.

Analytical (Angular Velocity) Approach. The need for more compact, less complex, but equally precise inertial navigation systems has swayed the majority of inertial designers to adopt the analytical philosophy for inertial navigation. Unlike the practice in geometric systems, the gyros of an analytical system are not left undisturbed, but rather are slaved to (torqued or precessed by) the vertical-indicating package. Since this slaving function does not permit a space-reference platform to be maintained within the system, the space-to-local loop as shown in Fig. 3 must be amended to a form as outlined in Fig. 4, which shows one vertical-indicating axis, namely latitude.



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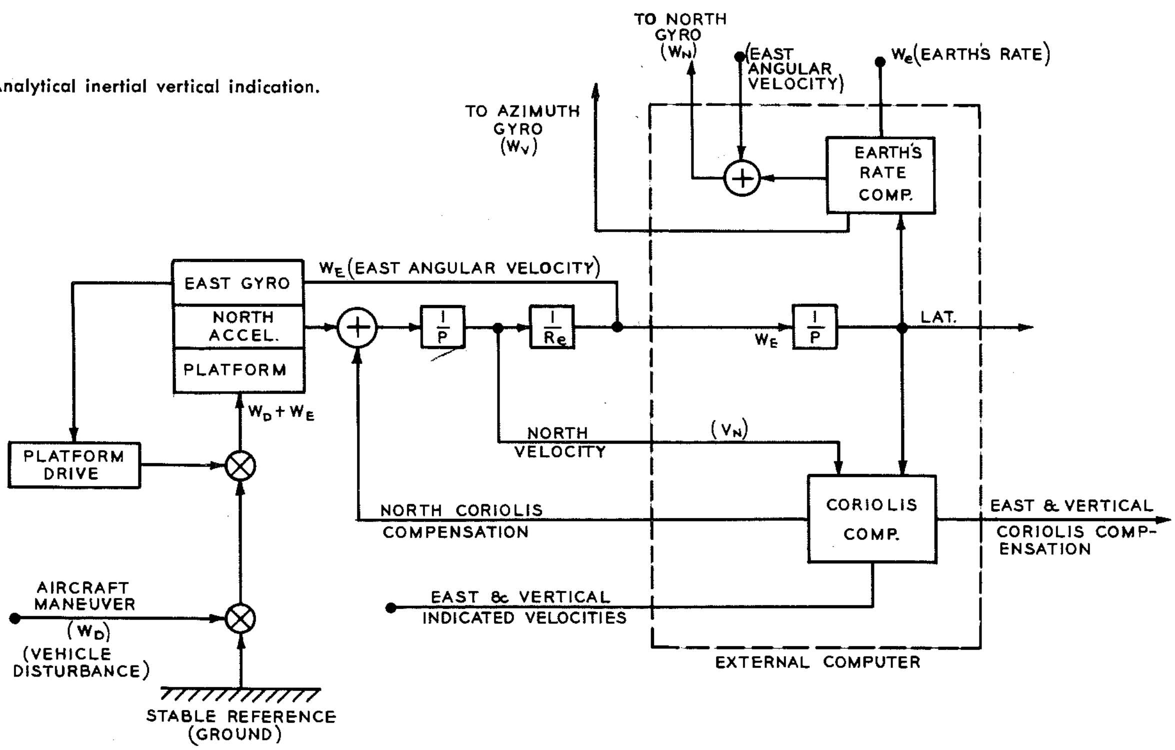
As in Fig. 3 for geometric vertical-indicating, the output of the north accelerometer is doubly integrated and divided by earth's radius to give local latitude. The basic difference, however, is that the second integration required to obtain latitude is not in the Schuler vertical-indcating loop but is open-ended (except for coriolis and earth's rate feedback).

The second integration required in the latitude vertical-indicating loop is provided by the east gyro which has its sensitive axis aligned east. As the vehicle travels north, the north accelerometer senses the north acceleration which when singly integrated and divided by earth's rate represents the vehicle's angular rate in the north direction (latitude rate). The east gyro is then torqued by this latitude rate so that it produces a signal which is approximately proportional to the time integral of the angular rate. When the gyro signal output is applied to the latitude drive (after suitable voltage and power amplification), the north accelerometer, as well as the east gyro, are rotated at a space rate just sufficient to produce a torque within the gyro which will oppose and nullify the torque developed by the gyro input signal. The east gyro is thereby slaved to the north accelerometer and

Fig. 4—Analytical inertial vertical indication.



is forced to precess through space at the proper rate. (Components of inertial navigation will be discussed in a future article.)

Since the analytical gyros are required to keep track of local vertical, their space-inertia tendencies must be offset as discussed above for motion over the earth's surface in addition to the earth's angular space rate. The components of earth's rate which apply to each gyro are computed as a function of the computer-indicated latitude. For the case shown in Fig. 4, the east gyro is not subject to earth's rate and therefore need not be compensated as the north and azimuth gyros must be.

The analytical accelerometers are also subject to coriolis accelerations, as were the geometric accelerometers. Components and compensations for these accelerations are readily computed in the external computer where present vehicle latitude and crosscoupling velocities are known for the longitude (east accelerometer, north gyro) and vertical channels.

Fig. 5 is a line schematic of an analytical inertial system gimbal configuration. Three gyros are required, whereas only the north and east accelerometers are required for navigation. (Coriolis computations considering vertical velocity can use vertical velocity as indicated by other transducers such as barometric altimeters, etc.) The vertical accelerometer is included to show where an accelerometer would be mounted should it be desired to compute and indicate vertical velocity.

Analytical (Free Gyro) Approach. This type of inertial system has not been favored by the majority of inertial designers in the field today largely because of the extensive and highly precise techniques required to compute position on the earth's surface from space rates. This paper will therefore not discuss it further except to point out that this type of inertial system is not Schuler-tuned in the normal sense since no direct observation of gravity is made. The analytical free-gyro system does however more readily apply itself to space navigation which may someday be of import. No problem of Coriolis compensation exists as such for this approach.

MANEUVER ISOLATION

The leveling of a vertical-indicating platform as discussed above assumes that vehicle maneuvers in roll, pitch and yaw are not coupled into the accelerometers. Therefore some means must be provided to decouple the vertical-indicating package from such aircraft disturbances as would be encountered during maneuvering, air buffeting, and other vehicle perturbations.

Were the outer support gimbal bearings frictionless, the inertia of the inner gyro and accelerometer packages, which have a tendency to remain nonaccelerating in space, would be its own best isolation force. However, to offset the coupling which does exist through the gimbal bearings in a physical system, a device which is sensitive to angular space rates must be provided from which signals corresponding to the disturbing vehicle maneuvering angular rates can be derived. Such a device of course is the gyro itself, which is highly sensitive to the components of vehicle angular rates which lie about its input axis.

In the case of the undisturbed geometric gyros, for instance, a vehicle maneuvering rate is coupled through bearing friction, etc. into the gyros whereupon the gyros are precessed and output signals result. These signals are next power amplified and applied to gimbal drive motors (after suitable gimbal coordinate transformations as will be discussed in detail in a future article) which rotate the gimbals just sufficiently to nullify the rates incident on the gyros. This closed-loop stabilization and isolation is necessarily of wide bandwidth, since the geometric gyros must be maintained undisturbed as much as possible in order to represent a stable directional reference in the navigation system.

The analytical gyros, on the other hand, act as both passive and active elements. This can best be appreciated by considering the gyro as playing two functional roles in the analytical navigator: (1) The gyro represents a terminal impedance for the electrical signal which is proportional to the angular space rate of the local vertical as the vehicle travels over the earth's surface, and, (2) The gyro produces an electrical drive signal proportional to the integral of the input disturbing rate. The correct terminal impedance is attained when the gyro precesses in phase with the vehicle's angular space velocity. Simultaneously, the gyro produces signals which represent commands for isolating the accelerometer platform from perturbation.

(A future article will discuss gyros and their uses in greater detail.)

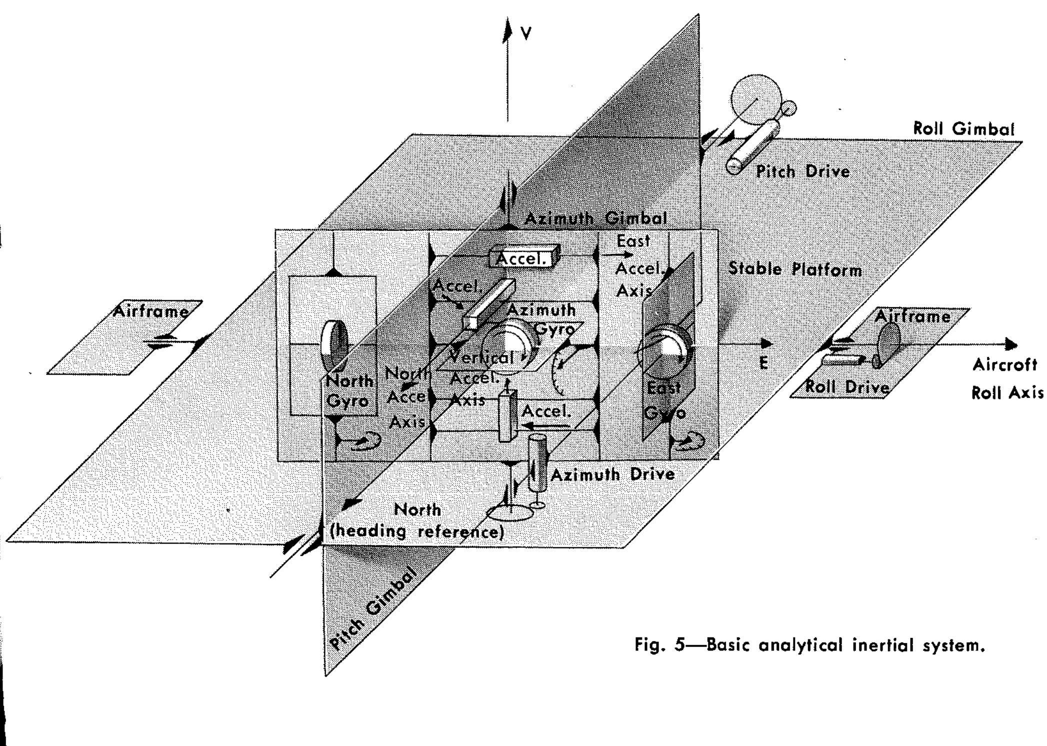


Fig. 5—Basic analytical inertial system.

MEASUREMENT OF ELECTRON-TUBE CHARACTERISTICS WITH WT-100A MICROMHOMETER

by

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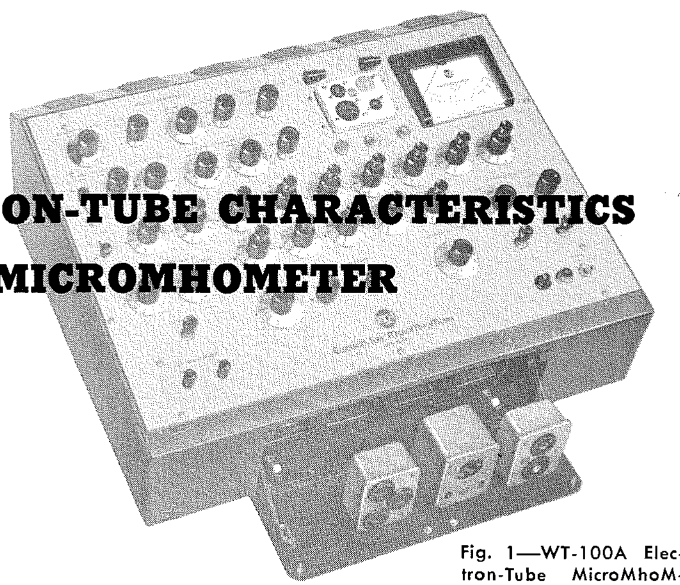

Fig. 1—WT-100A Electron-Tube MicroMhoMeter.

THE INCREASING DEMAND for stable, trouble-free electronic equipment has reemphasized the need for effective utilization of electron-tube characteristics. Consequently, tube testing and tube-testing equipment now play extremely important roles in final circuit design.

Conventional amplifier tubes can be used in so many applications, however, that tube testers which evaluate only a single characteristic cannot be considered adequate indicators of tube quality. Entertainment-type receiving tubes, for example, cannot be properly evaluated for use as class AB or class B amplifiers and as TV deflection-oscillators except by tests which accurately reflect conditions in the intended applications.

Tube characteristics which should be measured include not only "true" grid-plate transconductance, but also the peak-emission capabilities of the cathode, the grid voltage required for cutoff, and, in many cases, the grid-current characteristics. In the case of a multigrid tube, it is often necessary to determine the transconductance between grid No. 3 (suppressor grid) and plate as well as between grid No. 1 (control grid) and plate. Similarly, the quality of a rectifier tube cannot be determined by a tester which shows the emission current at some arbitrary anode voltage, but only by measurement of its internal voltage drop at an anode current proportional to the anticipated peak current through the tube.

Equipment capable of making such tests on the great number of tube types now in general use has, until recently, been available only on a custom-built basis, and has been economically beyond the reach of all but larger research organizations and equipment manufacturers. The recently announced RCA WT-100A MicroMhoMeter shown in Fig. 1, however, provides facilities not only for the tests described above, but also for many others, in a single compact equipment which is economically within the reach of smaller laboratories, equipment manufacturers, and service organizations, and is suitable for use by semi-skilled personnel. A block diagram of this instrument is shown in Fig. 2.

TRANSCONDUCTANCE TESTS

Perhaps the most important single test for a large percentage of tube types is a transconductance measurement. For the measurement of "true" transconductance, a small a-c signal is applied to the control electrode of the tube and appropriate d-c voltages to other electrodes. The resulting a-c current in the plate circuit is then measured. This method, known as the "amplifier" method, is generally preferable to the "balancing" or "null" method because it is simpler and faster. All d-c supply voltages should be very well regulated so that no readjustment is required to compensate for the effects of tube loading. Metering facilities should also be provided to permit the test circuit to be set up at precisely the desired operating point.

For maximum accuracy, the load resistance of the test instrument used for transconductance measurements should be very small compared with the plate resistance of the tube under test because some present tube types have plate resistances as low as 125 ohms. All power supplies in the WT-100A have extremely low internal impedance to minimize the effects of regulation on the accuracy of a-c plate-current measurement.

Transconductance measurements are made in the WT-100A at a relatively high signal frequency (45 kilocycles) to eliminate errors due to power-supply ripple and hum. A block diagram of the transconductance-measuring circuit is shown in Fig. 3. The output of the 45-kilocycle oscillator is applied to the voltage divider R_1R_2 and to the grid of the tube under test. R_1, R_2, and R_L are precision resistors. For each measurement range, R_L and R_2 are equal, and R_1 is chosen so that the equivalent conductance, $1/(R_1 + R_2)$, is equal to the corresponding full-scale transconductance indicated by the meter. The meter is preceded by a low-noise, high-gain preamplifier designed to produce full-scale deflection with an input of 0.025 volt. The circuit of the transconductance preamplifier is shown in Fig. 4.

When the oscillator output is adjusted to produce full-scale deflection of the meter with switch S in the CALIBRATE position, the measurement circuit is calibrated in terms of an accurately known current-voltage ratio I_{R2}/E_{R2}. During the measurement operation, the transconductance preamplifier is connected across R_L and the oscillator signal voltage is applied to the grid of the tube under test. If the a-c signal current produces a voltage of 0.025 volt across R_L, then the tube under test has a transconductance equal to the full-scale value of the meter. If a value less than 0.025 volt appears across R_L, then the measured value of transconductance will be proportionately less than the full-scale value. Because the meter is calibrated to produce full-scale deflection with the oscillator output used for the measurement operation, the accuracy of measurement is independent of the oscillator, the preamplifier, and the tube under test. Even resistance changes due to aging of the resistors used in the voltage divider do not reduce the accuracy of measurement because the percentage of change generally is the same for both resistors.

The tube-operating conditions employed in the oscillator and the transconductance preamplifier allow for large variations in the characteristics of the tubes used in the WT-100A. The transconductance preamplifier has substantially flat response from 15 kilocycles to well beyond 100 kilocycles, and provides attenuation greater than 50 db for frequencies below 10 kilocycles. Consequently, the oscillator output frequency is not critical. The important considerations in the design of the oscillator were substantially pure sine-wave output and low output impedance. These requirements are achieved by the use of a high-Q tank circuit.

In the case of tube types having more than one signal grid, it is often necessary to measure the transconductance between each signal grid and the plate. The WT-100A has facilities for supplying appropriate d-c voltage to each grid and switching the a-c signal from one signal grid to the other for the different measurements. This feature also permits rapid measurements on multiunit tubes.

ELECTRODE CURRENTS

Another test which is an important consideration in the evaluation of tube performance is current measurement. Facilities are provided in the WT-100A to measure plate, grid-No. 2 (screen-grid), grid-No. 3 (suppressor-grid), and grid-No. 1 (control-grid) currents over a range from 3 microamperes full scale to 300 milliamperes full scale. This range of current-measurement facilities permits the measurement of minute tube currents such as gas current, interelectrode leakage, and reverse grid current, as well as the high peak currents of rectifiers and tubes used in deflection amplifiers.

The ability of a multigrid power tube to carry high peak plate current at low plate voltage is an important factor in determining its usefulness

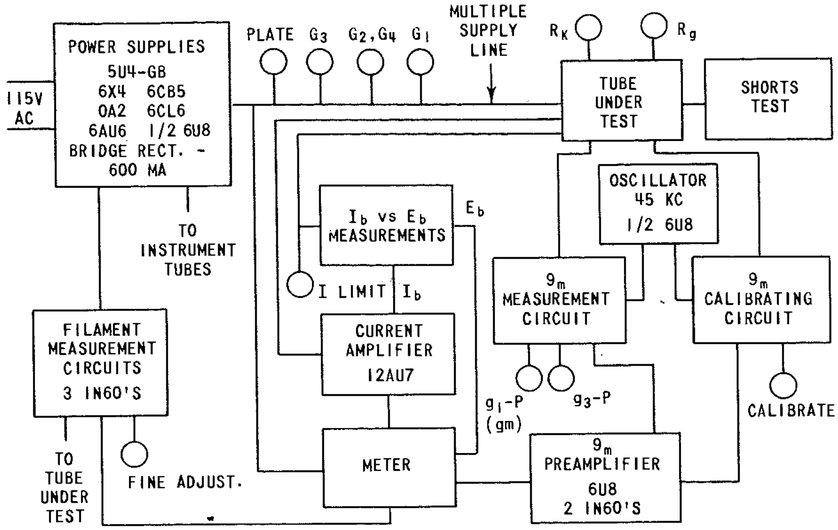

Fig. 2—Block diagram of the RCA WT-100A Electron-Tube MicroMhoMeter.

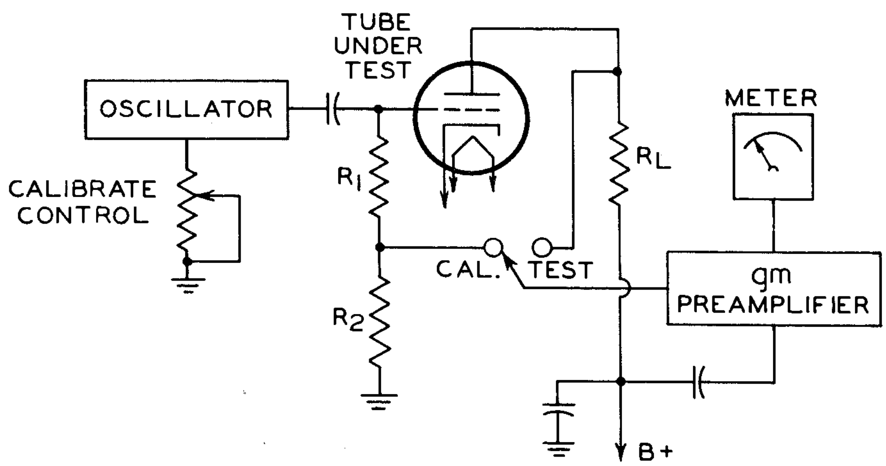

Fig. 3—Block diagram of transconductance calibrating and measuring circuit.

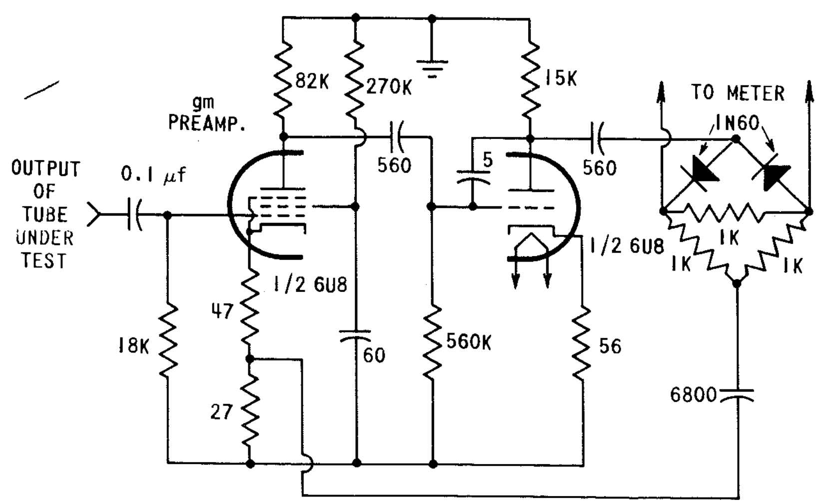

Fig. 4—Simplified circuit of low-noise, high-gain amplifier used for transconductance measurements.

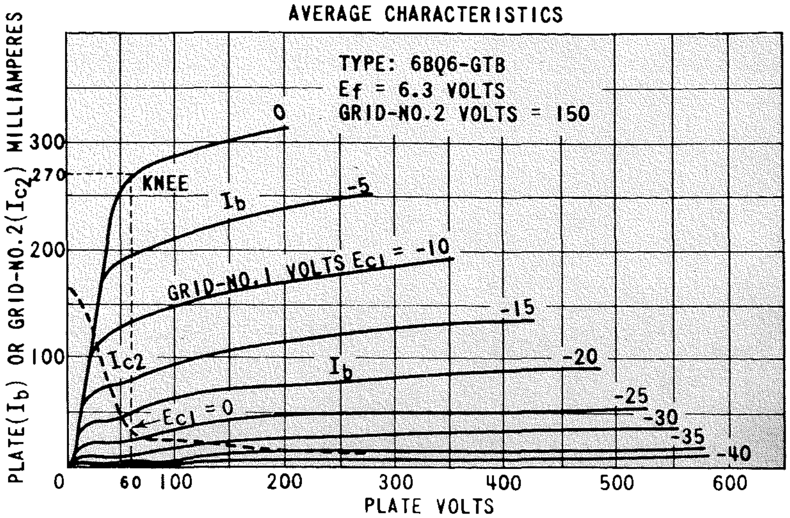

Fig. 5—Average plate characteristics curves for type 6BQ6-GTB showing the sharply defined "knee" in the low-plate-voltage region.

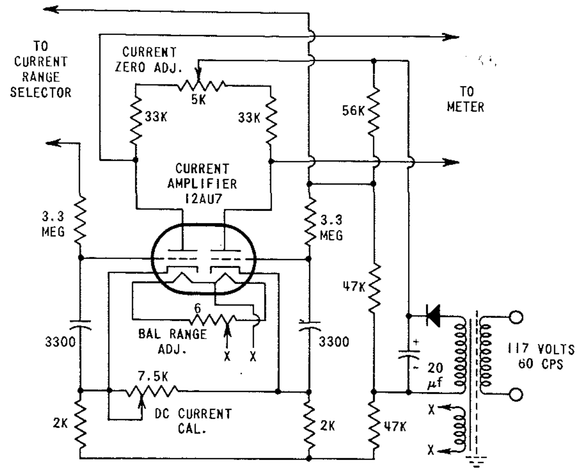

Fig. 6—Simplified circuit of balanced amplifier used for direct-current measurements.

for deflection-amplifier service. The optimum operating point for this measurement is usually the point at which the chosen grid-No. 1-voltage curve for a given grid-No. 2 voltage terminates its rise from the zero-plate-current point and levels off. This point is called the "knee," and is rather sharply defined for each combination of grid-No. 1 and grid-No. 2 voltages, as shown in Fig. 5. Because measurements at the "knee" usually involve very high currents, they should be made on a short-duty-cycle basis to avoid tube damage.

The circuit used for d-c electrode-current measurements is shown in Fig. 6. For these measurements, the meter is driven by a push-pull cathode-coupled differential amplifier which produces full-scale deflection with an input of 0.5 volt. The 3-megohm series resistor in the grid circuit serves a double purpose: it protects the amplifier tube from damage in the event that excessive voltage is accidentally applied to the input circuit, and it prevents the tube from being driven into the positive-grid region, thus limiting the maximum plate current to a value well within the capacity of the meter. A large amount of negative feedback is employed in the amplifier to assure good linearity. The balanced bridge circuit helps to minimize the effects of line-voltage fluctuations on the accuracy of current measurements.

VOLTAGE DROP

Vacuum power rectifiers are evaluated by measurement of the voltage drop across the tube at chosen values of plate current. Because in such measurements the tube is switched abruptly from cutoff to full conduction, sufficient resistance must be used in series with the plate to assure that the resulting current surge will not damage the tube or the test circuit. The value of this current-limiting resistance should be based on the maximum current that would flow if the device under test were suddenly short-circuited. For maximum utility, the range of resistances available in the WT-100A is adequate to handle currents ranging from a few milliamperes to several hundred milliamperes. Voltage-drop curves are usually furnished in the technical data for vacuum-tube rectifiers.

SHORTS OR LEAKAGE TESTS

Adequate interelectrode shorts and leakage tests are among the most important considerations in tube evaluation and, consequently, in the design or selection of the testing equipment. Under JAN-1A and MIL-E-IB Specifications, leakage currents as low as 1 microampere or less are considered significant. Another requirement is a means for checking continuity of all internally connected tube pins and jumpers. Interelectrode shorts, filament or heater continuity, and the continuity of internal jumpers are determined in the WT-100A by means of neon-lamp tests. In addition, the actual leakage currents can be measured between any two elements or combination of elements. These tests can also be used to indicate leakage resistances up to several megohms. Sufficient series resistance is provided in the neon-lamp leakage-test circuits to protect delicate grid structures from damage by the surge currents which flow when the neon lamp fires.

GAS TUBES

The performance of glow-discharge (cold-cathode) tubes used in voltage-regulator service may be predicted with considerable accuracy from measurements made with the WT-100A. These measurements include breakdown or ionization voltage, voltage drop at the regulating point, and the effect of variations in the regulating current over the permissible range of operation. In the evaluation of tubes from such measurements, however, consideration should be given to the operating conditions at which the tube was used prior to test, the ambient temperature, and the test conditions, all of which have a direct bearing on the final regulation point. For best results, the proposed circuit conditions should be simulated as closely as possible, and the tube-operating current under circuit conditions used to determine the regulation point.

Thyratrons can be tested by the same methods used for voltage-regulator tubes. The critical grid-No. 1 voltage of a thyratron at a given anode voltage may be determined by operating the tube first with a high negative grid voltage, and then reducing this voltage until the tube fires. Because a thyratron normally draws a small amount of grid current, the firing point is dependent on the grid-circuit resistance as well as the grid voltage. Both anode voltage and grid-circuit resistance of the proposed circuit should, therefore, be considered in these tests. Anode breakdown voltage

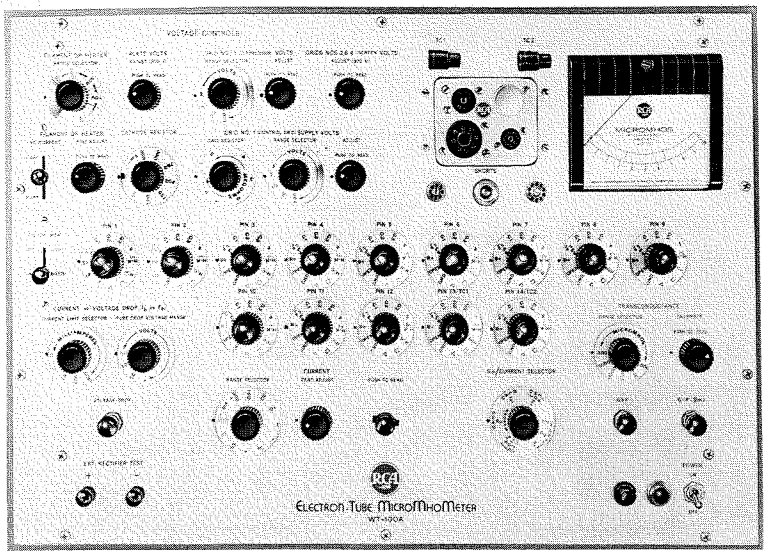

Fig. 7—Photograph of the RCA WT-100A Electron-Tube MicroMho-Meter showing panel arrangement, and plug-in, socket-adapter boxes.

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At the present time Mr. Lowery is a development engineer on test and research equipment with the Components Division of the Radio Corporation of America. Mr. Lowery joined RCA in September, 1953.

is another significant factor in evaluation of thyratrons, and should be measured with the control grid tied to the cathode.

TEST METER

A single high-quality meter having only two linear scales (0 to 3 and 0 to 10) and only three unit markings—micromhos, volts, and amperes—is used for all of the 72 different measurements which can be made with the WT-100A MicroMhoMeter. The 100-microampere movement of the meter has a fundamental accuracy of 1 per cent and a tracking error of not more than 1 per cent. The meter is completey disconnected from all circuits until the button for the desired function is depressed.

POWER SUPPLIES

All a-c and d-c power supplies in the WT-100A are continuously adjustable over their full operating ranges. The d-c plate, grid-No. 2 (screen-grid), grid-No. 3 (suppressor-grid), and grid-No. 1 (control-grid) supplies are adequately regulated to minimize the effects of changes in line voltage and load conditions. The maximum current limits of 300 milliamperes for the plate supply and 30 milliamperes for the grid-No. 2 supply were selected to satisfy conventional test requirements.

CONNECTIONS AND SWITCHES

The tube-connection and switching facilities of the WT-100A, shown in Fig. 7, are simple, flexible, and rugged. Multiple-socket adapter units are provided which can accommodate up to 14 base-pin connections. Any type of basing may be easily connected to the circuits of the instrument. Each of these adapter units includes a 16-contact gold-plated connector which plugs into a receptacle inside a silver-plated well on the instrument panel. The units are easily disassembled so that sockets may be replaced or changed without disturbance of the instrument wiring.

The pin-switching system is also designed to accommodate up to 14 base-pin connections, and therefore is flexible enough to meet a wide variety of test conditions. For instance, each tube element may be connected to any of the available voltage sources, open-circuited, grounded, or paralleled with any other element. In addition, any two separate elements may be brought out to external connections. Any element may be checked for shorts, or polarized negatively or positively and checked for leakage to any other element or to ground.

All switches have solid coin-silver contacts. This feature, together with good mechanical design, insures reliable switch operation over long periods. All measurement circuits are mechanically or electrically interlocked through the switching system so that meter burnout is virtually impossible.

CONTROLS

Specially designed dual controls consisting of concentrically mounted switches and potentiometers permit simultaneous adjustment and measurement of all electrode voltages. Each control button is clearly labeled and positioned for ease of operation. The arrangement of the controls was carefully planned on the basis of operator tests and "human-engineering" principles. Rotation of a control while it is pressed down adjusts the corresponding electrode voltage to the value indicated on the meter. This design substantially reduces the number of control knobs on the instrument panel, and permits a clear indication of the particular voltage or current on the meter. However, no voltage except filament or heater voltage is actually applied to the tube under test unless the GM, GM-CALIBRATE, CURRENT, or VOLTAGE-DROP buttons are pressed.

A single, clearly labeled function-selector switch automatically sets up the proper internal circuits for transconductance and d-c electrode-current measurements. This switch has separate positions for plate, grid-No. 2, grid-No. 3, and grid-No. 1 currents, and automatically removes the transconductance test signal from the tube in these current positions. Separate range-selector switches are provided for transconductance and current measurements. These switches are so designed that all multiplier or shunt resistors not actually in use are removed from the circuit.

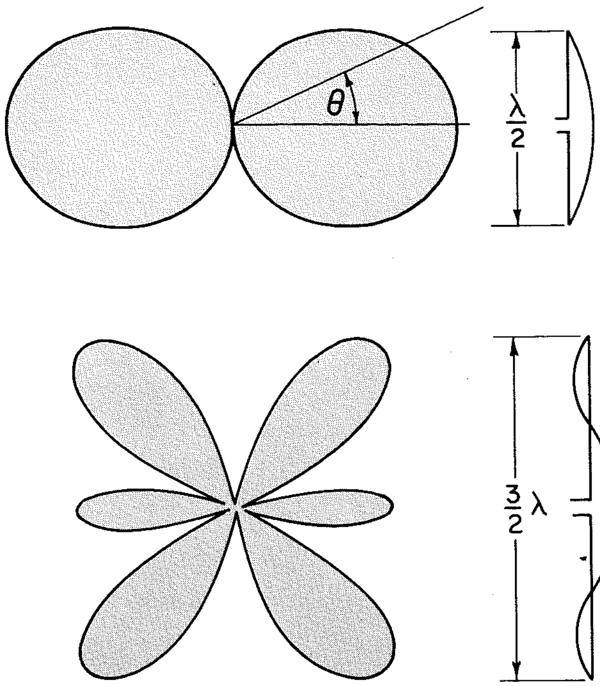

Fig. 1—At top is the current distribution along a half-wave dipole and polar pattern at resonance. At bottom is the same relationship for a dipole 1.5 wavelengths long.

TELEVISION RECEIVING ANTENNAS

By

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THE SERVICE AREA of a television transmitter can be enlarged by two alternatives: either by increased transmitter power, or improved receiver sensitivity. A good receiving antenna contributes substantially to the effective sensitivity of any receiver.

A fringe-area antenna must have both high gain, or directivity, and sufficient bandwidth to cover all the desired channels. Maximum gain and bandwidth are not realized simultaneously, and a compromise must therefore be made. Fortunately, the three-to-one frequency difference between the centers of channels 2-to-6 and 7-to-13 reduces the bandwidth problem somewhat, as far as impedance matching is concerned. However, an antenna operating at its third harmonic has a multi-lobed directivity pattern and some means must be devised to suppress the undesired lobes.

Maximum power cannot be transferred to the receiver unless a reasonably good match to the transmission line is obtained. As elements are added to an array, its impedance is reduced, and it is necessary to raise the impedance back to the required level.

The need for high gain is not peculiar to fringe area reception. Very often, a high-gain antenna, which is highly-directive, is needed in metropolitan areas in order to eliminate unwanted signals. The gain of an array can be increased by properly connecting several identical antennas. To eliminate unwanted stations, it is often possible to shape the directivity pattern by correctly phasing the antennnas in an array. Although each antenna installation is a problem in itself, the customer will usually accept a picture which is less than perfect. Therefore, with knowledge of how to cope with specific problems, such as multipath transmission, the service man can usually provide an acceptable picture with available antennas.

In order to select the correct antenna for a given installation, an understanding of propagation phenomina is needed.

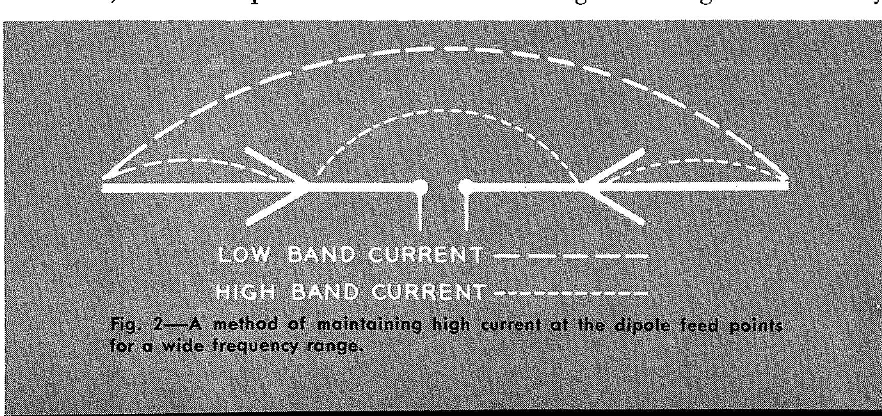


Fig. 2—A method of maintaining high current at the dipole feed points for a wide frequency range.

PROPAGATION

It is common to consider three types of propagation known as the earth wave, sky wave, and direct wave. The earth wave travels along the surface of the ground and is rapidly attenuated at high frequencies so it is of little value for VHF or higher frequency propagation.

The sky wave is made up of that portion of the energy radiated into the upper atmosphere. However, since atmospheric ionic density is normally too low to cause appreciable bending of high-frequency waves, long-distance television reception due to Heaviside diffraction is rare. Consequently, transmitting antennas are designed to minimize radiation directed toward the upper atmosphere.

The direct wave is of most importance in television reception. It would travel a line-of-sight path between the transmitting and receiving antennas, if the atmosphere of the earth were of constant density. However, dielectric constant of the atmosphere varies with pressure and temperature.

Temperature of the lower atmosphere normally decreases at a constant rate with increasing altitude. When this rate is reduced a temperature inversion exists. Greater than normal wave bending takes place, and startling improvements in long-distance reception sometimes occur. However, conditions accounting for this reception are unstable. The signal usually fades rapidly and the phenomena are usually of short duration.

The energy fed to a transmitting antenna results in time-varying charges

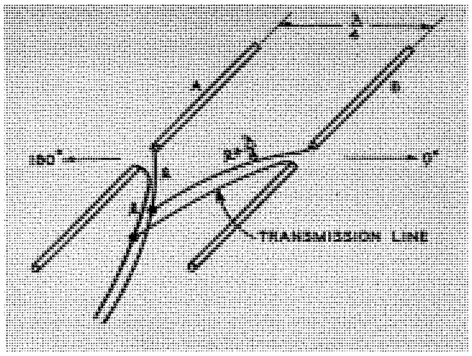


Fig. 3—A technique of providing high-gain, directional reception by phasing two driven elements.

being built up on the surface of antenna elements. Motion of these charges activates further charge motion in the space near the antenna, resulting in an electro-magnetic charge motion or field at more and more remote points. As more energy is supplied to the antenna, the fields move out into space in the form of waves. At the receiving antenna these oscillating fields cause charge motion in the elements, and currents flow in the antenna circuit and receiver input.

The basic theoretical antenna is the elementary electric dipole, a very short wire having a constant current throughout its length. The equations for the field of this antenna have terms which vary as $1/r$, $1/r^2$ and $1^1/r^3$ where r is the distance from the element to a point in space. Near the source, all the components must be considered. However most antenna calculations are made at a great distance from the antenna so that only the $1/r$ terms, or the radiation field, need be considered — higher order terms being negligible.

Antenna calculations are based on fields set up by the elementary electric dipole. Any antenna can be considered as a number of dipole elements of varying magnitude and phase. Therefore, if the antenna current distribution is known, it is possible to compute the field on the basis of the individual fields of the dipoles, using the principle of superposition.

FIELD PATTERNS

When a thin wire antenna having a sinusoidal current distribution is considered as a series of elementary dipoles, the antenna fields can be computed directly from expressions for the elementary dipoles. The total field is obtained by integrating fields from all the infinitesimal dipoles making up the antenna. Calculated results for thin wire dipoles are shown in Fig. 1.

As dipole length increases, current distribution along its length changes; and antenna lobes become narrower. When the antenna becomes more than one-wavelength long, part of the antenna current reverses; and the polar pattern develops multiple lobes. For an antenna 1.5 wavelengths long, the response curve develops secondary lobes of magnitudes greater than that of the forward lobe. This occurs because a partial cancellation of the field in the forward direction results from a reversal of current in one section of the antenna. As the wire gets longer, more secondary lobes appear. From these curves, it is evident that a thin wire antenna cut to provide good 60-mc performance for the low-frequency channels, would have undesirable multiple lobes on channels 7 to 13.

The current distribution on the antenna must be altered[2] in order to prevent the polar patterns from breaking up at the higher frequencies. One method of changing the current distribution is shown in Fig. 2. Coaxial sleeves are degenerated into a "Vee" configuration, providing the desired bidirectional polar pattern.[3]

ARRAYS OF DIPOLES

To provide higher gains in a given direction, more than one element can be used to shape the polar pattern. For example, let two antennas be separated one-quarter wavelength in space as shown by Fig. 3. Let the transmission line from antenna B to the junction point be one-quarter wavelength longer than that from antenna A to the junction at the array design frequency. This is the same as saying that the current in antenna B lags that in antenna A by 90 degrees.

Consider an approaching wavefront from the zero-degree direction. The voltage induced in antenna A lags that induced in antenna B by 90 degrees. However, the signal from B is delayed 90 degrees behind that from A since there is one-quarter wavelength more transmission line from B than from A measured to the junction point. Thus signals from the two antennas arrive at the junction point in phase. Waves arriving from the 180 degree direction are delayed 90 degrees, going in space from A to B, and another 90 degrees in the transmission line from antenna B to the junction point. The total phase difference between signals from the two antennas at the junction point is 180° and there is zero net signal.

Not all the elements of an array need to be driven in order to secure the desired directivity. When a conducting rod is placed in an electro-magnetic field, currents flow in the rod. If this conductor is brought near another element, energy is coupled from one rod to the other. The voltage developed in one rod by virtue of the field surrounding it differs in phase from that induced by the other rod. Phase relationship is established by the position of the two rods and their impedances. Impedance of a rod is a function of its length.

An element not connected to the transmission line is said to be parasitic. When a parasitic rod is located between the driven element and a signal source to reinforce the received signal, it is called a director. If the driven element is located between the parasite and the transmitter, the undriven rod is called a reflector.

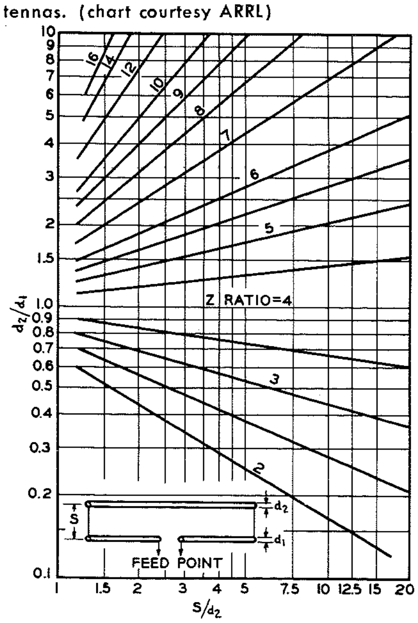
A Yagi is a high-gain, narrow-band antenna having both directors and reflectors.

FOLDED DIPOLES

Since parasitic elements tend to reduce antenna "self-impedance" the driven element of a Yagi usually consists of a folded dipole. The impedance of a folded dipole, having rods of equal diameter, is four times that of an ordinary dipole of the same length.

Folded dipoles having a wide variety of impedance ratios can be de-

Fig. 4—Design chart for folded dipole antennas. (chart courtesy ARRL)



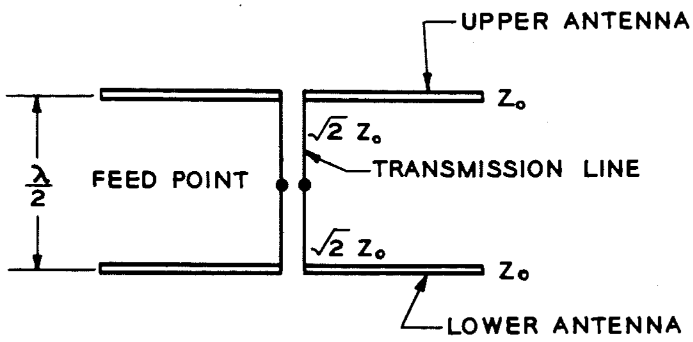


Fig. 5—Method of vertically stacking antennas.

signed by using Fig. 4. This curve shows the impedance ratios obtained by using rods of different diameters. A good description of folded dipoles is given in reference 4.

VERTICAL STACKING

In fringe areas a single antenna seldom produces sufficient energy to operate the receiver. In these cases, "stacking" of two or more antennas on the same mast provides additional gain and directivity. Antennas may be stacked either horizontally or vertically. The vertical method is more convenient since horizontal stacking requires outriggers, complicating the suporting structure. A maximum of 3 db additional power gain is realized by doubling the number of identical antennas. This assumes that impedance does not change when connecting more than one antenna to a common transmission line through appropriate phasing sections.

Vertical stacking is accomplished by vertically spacing antennas one-half wavelength apart and connecting one of the antennas of Fig. 5 to each quarter wave section of line (section impedance is $\sqrt{2}$ times the impedance of Fig. 5 antenna). Since the impedance seen at the end of this quarter-wave section is twice the impedance of the antenna, the sections of line extending from the two antennas may be connected together. The impedance resulting at the junction is then equal to that of one of the antennas. Currents from the two antennas, having travelled equal distances down the line, will arrive at the junction in phase and will add to produce twice the power available from a single antenna.

One method of phasing four antennas is by connecting two pairs as described above and then treating each pair as a single antenna.

HORIZONTAL STACKING

Vertical stacking improves directivity by narrowing the main lobe of the vertical polar pattern. Similarly, antennas, can be stacked horizontally to improve the horizontal polar pattern; or to produce a null in the direction of an interfering station. Horizontal stacking is particularly useful in reducing co-channel or adjacent channel interference.

ANTENNA MEASUREMENTS

Most antennas are sold in areas where only local reception is of interest. Consequently, emphasis may be placed on a few basic types proven through experience to do an adequate job in most cases. There are, however, certain measurable factors which give a good idea of how an array may be expected to perform in a given location.

Power Gain—One of the most important constants which can be measured is power gain. Receiving antenna gain can be defined as the maximum radiation intensity in a given direction, divided by the maximum radiation intensity from a standard source, the same power being supplied to both antennas. The gain is then plotted in decibels relative to the standard source.

One type of "reference" radiator is an isotropic source which radiates equally well in all directions. Since an isotropic source is physically unrealizable, the standard of measurement usually consists of a half-wave dipole cut for each test frequency. Because television receiving antennas normally operate with a 280-ohm transmission line, a folded dipole designed to properly match such a line is used as a reference.

Directivity—Directivity is defined as the ratio between the maximum radiation intensity from the source under consideration and the radiation intensity from an isotropic source radiating the same power. Directivity is thus the same as the absolute gain in a lossless system.

A highly directive antenna discriminates against ghost images. Directivity is also very important in areas where adjacent channel or co-channel interference is a problem. In this case, the depth of nulls in the directivity response is of primary importance, as they permit the antenna to be oriented until unwanted signals are rejected.

Directivity patterns can be plotted in several ways. The most common is to plot relative response in all directions on polar-coordinate paper.

Antenna response (as a function of direction) can be plotted as relative voltage or power, or it can be plotted in decibels. Fig. 6 shows a comparison of the three methods of plotting the polar pattern of the same antenna. Note in Fig. 6 that there are minor lobes in evidence on the voltage plot which do not show up on the relative power plot. These lobes could cause difficulty when it is desired to reject a signal from a direction such as 130

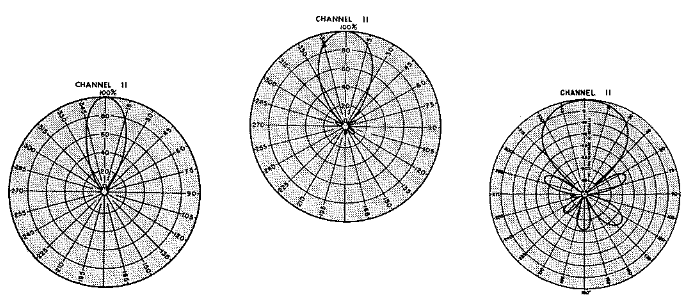


Fig. 6—Comparison of three methods of plotting the polar pattern of the same antenna. (a) relative power, (b) relative voltage, and (c) decibels.

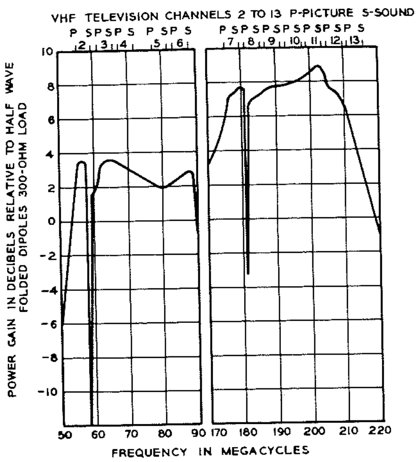


Fig. 7—Gain curve of an antenna not suitable for color reception.

degrees. If only the relative power plot were available, there would be no indication of the presence of these minor lobes. The minimum value on the polar power chart of Fig. 6c is —40 db. For many applications, polar patterns plotted in this way are the most valuable. A television set located in an area of high-signal strength will act as predicted by the logarithmic plot. This method of plotting shows all significant minor lobes whereas on both power and voltage plots some of the lobes are too low in amplitude to be detected.

Impedance Measurements—For best performance, an antenna should match the transmission line over the frequency range for which the antenna is designed. In order to determine how well an antenna will match the line, it is necessary to have reliable equipment for making impedance measurements.

The most accurate method of making impedance measurements is to use slotted-line techniques. The line should be fed from a matched generator for maximum accuracy. The detector must be calibrated for accurate measurement of standing-wave ratios on the line. With a standing-wave ratio and the location of a null on the line known, the impedance of the load can be computed by use of transmission-line equations, or a Smith Chart calculator.[5]

SPECIAL CONSIDERATIONS FOR COLOR TELEVISION RECEPTION

Problems associated with color television reception are the same as those of good black-and-white television reception. However, a black and white picture having certain faults may be acceptable to the customer while a color transmission having the same transmission faults may be entirely unacceptable. For example, a multipath signal with a phase difference between the direct and reflected signal of 180 degrees at the color subcarrier frequency, can cause cancellation of the color subcarrier. The same condition might have no visible effect on a black-and-white picture.

Although some difficulties in poor color reception can be traced to the antenna, more arise in bringing the signal from the antenna to the receiver. Where more than one receiver is driven from a single source, extremely high standing-wave ratios may result (on the line feeding one set) from a poor termination at the other receiver. An inexpensive solution is to isolate one set from the other by resistive pads. Then, when sufficient isolation is obtained, there is often insufficient signal to drive either receiver satisfactorily. This requires booster amplifiers in the line to provide an acceptable signal.

Antennas causing partial loss of color subcarrier are those having sharp dips or "suck-outs" in the power gain curve.

The gain curve of such an antenna is shown in Fig. 7. Deep suck-outs of this type are caused by a director turning into a reflector at a specific frequency. This results in an abrupt 180° change in the direction of maximum radiation. See Fig. 8 where the direction of maximum radiation is 0° at 55.25 mc, 180° at 57.7 mc, and back to 0° at 61.25 mc. Removal of the offending elements in this case corrects the problem at the sacrifice of gain at other frequencies.

CONCLUSIONS

Fortunately, antennas which exhibit suck-outs of the type are rare. Most difficulties encountered in color reception can be traced to a fault in the installation. It is not good policy to drive more than one receiver from a given antenna unless adequate signal is available to allow proper isolation to be used between the receivers. Where multi-path reception causes the complete or partial cancellation of the color subcarrier, the problem can often be corrected by relocating or reorientating the antenna.

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ROBERT F. KOLAR received the B.S. degree in Electrical Engineering in 1949 at Purdue University and the degree of M.S.E.E. at the University of Pennsylvania in 1956. He joined the Advanced Development Section of the RCA Victor Television Division in 1949 and since that time has done a large amount of work on television receiving antenna development and other radiation problems. Mr. Kolar is a member of Eta Kappa Nu, Tau Beta Pi, and the Institute of Radio Engineers.

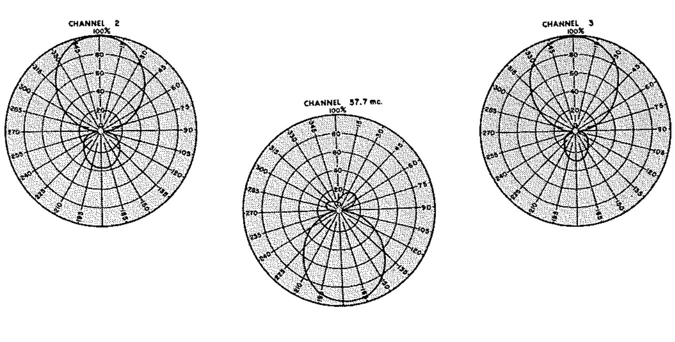

Fig. 8—Polar patterns of the antenna in Fig. 7, showing the reversal of radiation occurring at the suck-out in channel 2.

SINGLE-SIDEBAND RECEIVERS

by
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Surface Communications Engineering
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OVER THE PAST twenty-five years, the growth of radio communication by use of single-sideband techniques has been "slow but sure." As early as 1922, Hartley[1] discussed the "Relations of Carrier and Sidebands in Radio Transmission." But, the separation of the sidebands from the carrier wave and from each other . . . and their separate use for radio communication was not seriously undertaken until a decade later. In 1933, Reeves[2] reported on "The Single-Sideband System applied to Short Wave Telephone Links." Two years later in the Proceedings of the Institute of Radio Engineers, Polkinghorn and Schlaack[3] described "A single-Sideband Short Wave System for Transatlantic Telephony." The study of single-sideband techniques became quite widespread in the ensuing years.

RETARDING FACTORS REMOVED

Widespread adoption of single-sideband communication systems was retarded for some years by the size and complexity of the equipment and the requirement of extreme frequency stability. Techniques are presently available, however, for securing adequate frequency stability. At the same time electromechanical filters, new phasing systems, transistors, and modular assemblies are reducing the size and complexity of the circuits and equipment. Currently, then, the retarding factors have been largely removed.

One purpose of this paper is to describe a modern system of frequency generation, stabilization, and control of such accuracy that it is unnecessary to transmit any carrier at all for demodulation or synchronization purposes. Another purpose is to describe a receiver design which has been successfully used over a wide range of high frequencies for long-distance reception of single-sideband transmissions.*

REASONS FOR CONSIDERING SSB

Single-sideband communication systems were first adopted to relieve an over-crowded radio spectrum resulting from the rapid growth of radio communications for commercial, military, and amateur uses. It was recognized that the bandwidth of radio frequencies required for communication by a single-sideband system was only half as great as that needed for the conventional double-sideband transmissions. At the same time, studies of the fading of amplitude modulated radio signals over long distances revealed that the fading was frequency selective. The carrier was found to fade intermittently, compared with one or the other of the two sidebands. Further, the sidebands would fade with respect to one another.

On radio waves, modulated to 100% by audio-frequency signals, the selective fading of the carrier with respect to the sidebands produced over-modulation. This resulted in the existence of distortion in the audio signals recovered from the transmitted wave by demodulation at the receiver.

Distortion of the phase relationships of carrier and sidebands due to multipath transmission is fully as serious as direct relative amplitude changes. Both of these troubles are avoided by use of single-sideband communication except for a possible slight amount of selective fading within the one sideband itself.

ADVANTAGES OF SSB

Of course, the inherent advantages of narrower bandwidth and relative freedom from selective fading still exist in single-sideband communication today. Now, others are also recognized.

A third advantage is that an interfering signal near the desired frequency is less troublesome than that of conventional AM transmissions. With a suppressed carrier SSB transmission, no carrier is present at the receiver to heterodyne with the interfering signal. A fourth advantage (compared with AM) is the marked decrease in power needed from primary sources at the transmitter for a given radiated power. This power gain has been indicated by various writers to be in the order of 12 to 15 db, depending upon the transmission conditions.

The single-sideband system decribed here incorporates all of these design features.

SSB FREQUENCY STANDARD

A special feature of this SSB system is that it uses separate master frequency standards at both transmitting and receiving stations of such accuracy that frequencies equal to those

* Also see RCA ENGINEER, Vol. 1, No. 6; Design of Single-Sideband Radio Communication Equipment by N. L. Barlow.

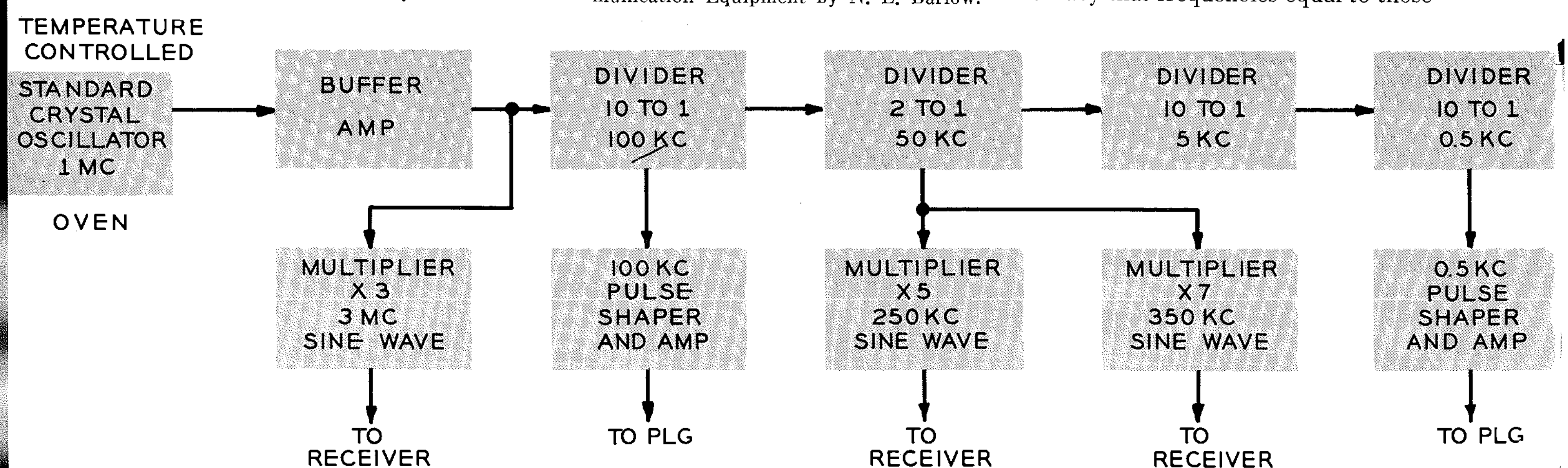


Fig. 1—Block diagram of the RCA-developed Frequency Standard for the Single Sideband system.

Fig. 2—Block diagram of the Pulse Locked Generator (PLG) which supplies accurate phase-locked frequencies.

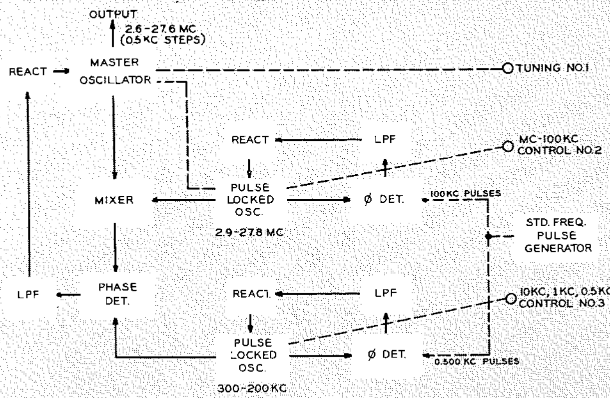


Fig. 3—Panel view of the Pulse Locked Generator.

at the transmitter can be generated locally at the receiver, without necessity of synchronizing signals from the transmitter. The frequency standard at both stations is a 1-megacycle, highly-stabilized crystal oscillator, "oven-controlled." Each standard is accompanied by the necessary number of frequency dividers, multipliers, and pulse shapers to produce the required standard radio frequencies as well as pulsed output signals. Signals are precisely spaced pulses, of 100-kc and 0.5-kc repetition rates, used to "lock" the frequencies of the Pulse Locked Generator. The "standard" frequencies are the 3-mc and 350-kc standard injection frequencies and the 250-kc local carrier fed to the SSB demodulators.

A block diagram of the Frequency Standard developed by RCA is shown in Fig. 1.

The basic unit of this frequency standard is a 1-mc crystal controlled Colpitts oscillator. The quartz crystal is supported on a shock and vibration-free, octal-base mounting enclosed in an evacuated glass envelope. Firmly clamped in its socket and mounted in an oven of accurately controlled temperature, this crystal controls the oscillating circuit, the pulse-locked generator, and the whole receiving system . . . *within one part in ten million*, under all conditions of shock and vibration.

The 1-mc output voltage of the frequency standard is passed through a buffer amplifier to a multiplying circuit and then a dividing circuit. The multiplier gives a standard reference 3-mc voltage which is fed to one of the mixers in the receiver. In the "divider" circuit, the standard frequency is accurately divided by 10, resulting in a 100-kc standard reference frequency. This is then fed to a 100-kc pulse shaper and amplifier. Sharp pulses from the latter are fed to the pulse-locked generator used with the receiver.

The output of the 10-to-1 "divider" circuit is further divided and multiplied so that 350-kc and 250-kc sinusoidal voltages are produced. These are fed to the receiver for conversion and demodulation. In a separate circuit, the 2-to-1 "divider" output is further divided, resulting in a 500 cycle signal, still accurately referenced to the 1-mc frequency standard. This passes through a pulse shaping circuit and thence to the pulse-locked frequency generator. It is now a train of pulses with a repetition rate of exactly 500 pulses-per-second.

PULSE-LOCKED GENERATOR

The pulse-locked generator supplies phase-locked frequencies held accurately to their required values. The pulses, with 100-kc and 500-cycle repetition rates, are the ones used for phase-and frequency locking of the pulse-locked generator (PLG) of Fig. 2.

The term "generator" means the production of signals of more than one frequency. The RCA pulse-locked generator contains three oscillators, as follows. Two are "locked" (or phase and frequency stabilized) by phase comparison of their output signals with the 100-kc and 500-cycle pulses obtained directly from the master Frequency Standard. Each is a conventional L-C oscillator, one with a 2.9-to-27.8 mc frequency range, and the other a 300-to-200 kc range. The output of each oscillator, the 100-kc pulses, and the 500-cycle standard-frequency pulses are fed to their appropriate phase detectors.

Now, if the phase of either oscillator output is different at arrival than it was when an earlier pulse arrived, the associated phase detector develops an output-error voltage. This voltage is of such polarity that, when applied to an oscillator-reactance tube or voltage-sensitive capacitive diode, transient changes are initiated in frequency and phase of the oscillator voltage, restoring the oscillator outputs to their proper values.

The third oscillator of the pulse-locked generator produces an output voltage that is mixed with incoming signals. A 2400-kc i-f mixer output signal results for all frequencies in the upper three bands of the receiver . . . and for the two lower bands an intermediate frequency of 600 kc is produced.

In each frequency-control loop of the pulse-locked generator, the d-c error voltage is passed through a low-pass filter to eliminate any spurious signal or hum voltage. This frequency-

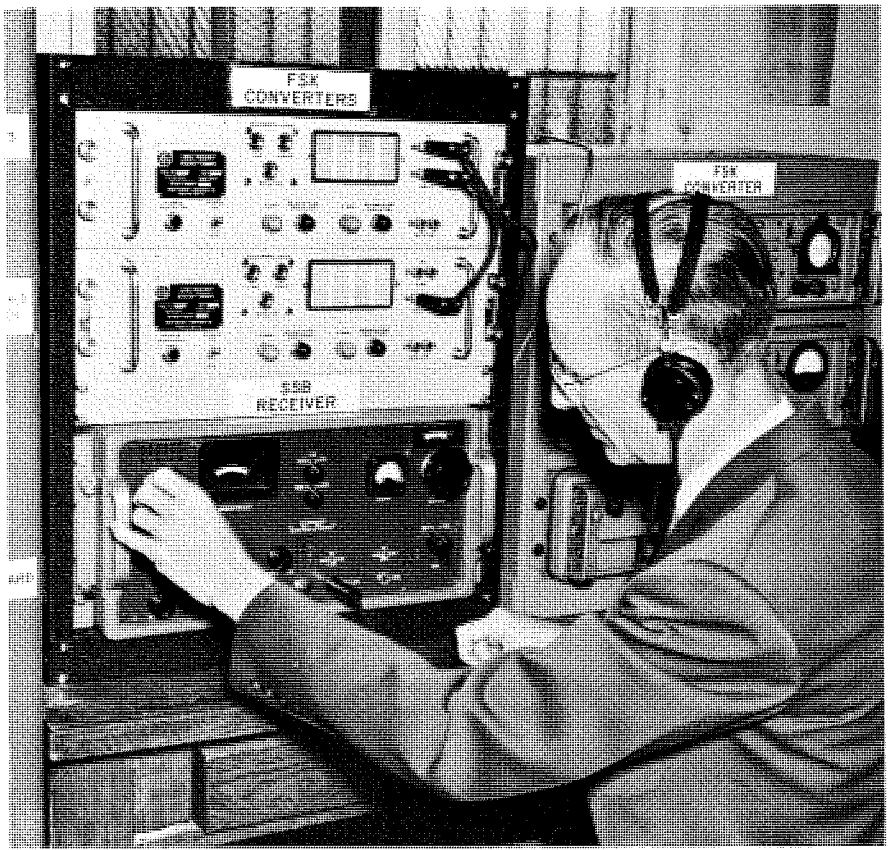


Fig. 4— The author tuning the SSB receiver.

control system has been tested under all standard prescribed conditions of shock and vibration. In no case have deviations of the system exceeded the prescribed goal of one part in ten million—or 3 cycles at 30 megacycles.

Fig. 3 is a photo of the Pulse-Locked Generator showing cabinet and front panel controls.

THE SINGLE-SIDEBAND RECEIVER

Several factors were involved in reaching a decision on the type of receiver to design and the types of communication service to be provided. With the limited time set aside for the project, it was decided not to attempt to design and build a packaged receiver as a final, fully developed model. However, a goal was adopted that the receiver must be capable of straightforward progression into a fully developed model, capable of meeting all military requirements such as vibration, shock, and extremes of temperature and relative humidity.

It was believed that for use by the Armed Services the receiver should be capable of single-sideband or twin-sideband operation with either partially- or fully-suppressed carrier, as well as possible use with conventional amplitude-modulated signals, i. e., double-sideband operation with full carrier, or continuous wave operation. The receiver should have low distortion in multiple-tone operation, good sensitivity, and freedom from cross-talk when operating in the vicinity of powerful transmitters. For some tactical uses, a SSB receiver for military communications would need only to operate on one sideband with completely suppressed carrier, and would be used primarily for speech communication. However, it was considered advisable to design the receiver to cover the greater variety of services mentioned above.

The final receiver (see Fig. 5) is capable of receiving single-sideband transmissions with or without carrier suppression, twin-channel single-sideband transmissions, conventional amplitude modulated signals, frequency-shift-keyed signals, tone-modulated continuous wave, or interrupted continuous wave signals.

The r-f amplifier has two tuned circuits ahead of the first tube, followed by two tuned stages using pentode tubes. As shown in the block diagram, the amplified r-f signal proceeds from the amplifier to the first mixer stage. Here, the correct frequency is injected from the pulse-locked generator when it is tuned to the precise frequency which, when mixed with the chosen incoming r-f signal, produces the correct i-f signal. The dials of the pulse-locked generator are calibrated to read the exact frequency of the desired incoming signal instead of the difference between it and the intermediate frequency to be produced in the mixer. In the r-f section of the receiver, any one of five sets of r-f coils may be chosen by the bandswitch on the front panel. The h-f range of 2-to-30 megacycles is thus divided into five bands: these are 2-to-4, 4-to-8, 8-to-14, 14-to-22, and 22-to-30 mc.

Single- or double-sideband reception may be selected from the front-panel function switch. In the case of double-sideband operation, this switch disconnects the upper sideband amplifier and passes the double-sideband signal through the same audio amplifier used for the lower sideband in SSB operation.

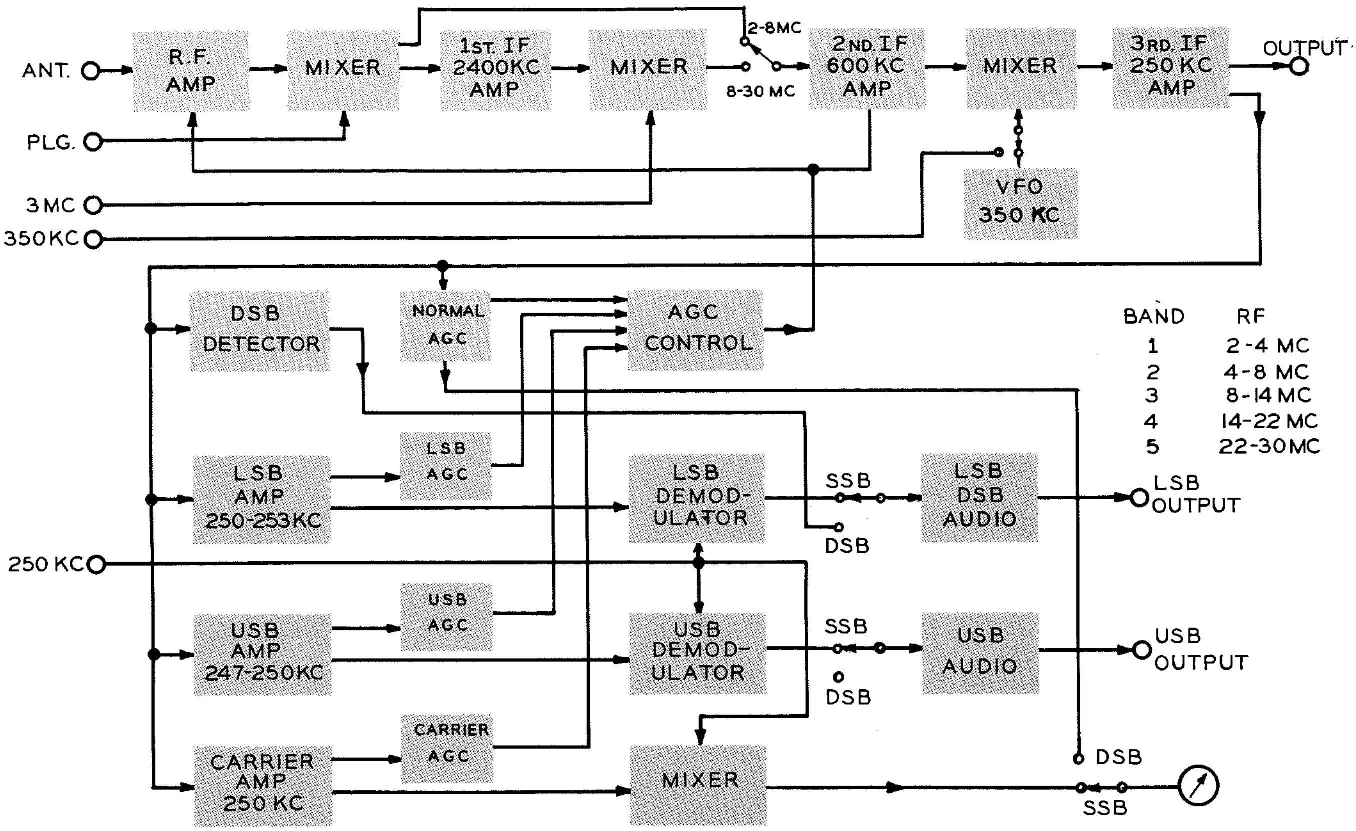
With the function switch in the SSB position, either sideband can be used for voice. Or, voice can be used in the upper sideband channel while multiple tone operation (with as many as sixteen frequency-shift-keyed (FSK) channels) is occurring in the lower sideband channel. Continuous wave (CW) signals can also be processed in the lower sideband branch.

A narrow band carrier amplifier is used primarily to supply a noise and modulation free carrier source of voltage for automatic gain control (AGC) when a partially suppressed carrier is transmitted.

CONVENIENT FRONT-PANEL CONTROLS

The completed communications receiver (see Fig. 4) was designed for companion control and operation with the Frequency Standard and Pulse-Locked Generator. The front-panel is arranged to provide maximum convenience for this type of operation. The function switches, allowing a choice in the class of reception, are in the center of the front panel. The wave bandswitch is seen at the center

Fig. 5—Block diagram of the SSB receiver.



left and the r-f tuning control and frequency dial on the upper left portion of the panel. Various degrees of carrier suppression can be compensated for by use of the front-panel carrier level control.

Selection of reception of upper-sideband transmissions, lower-sideband, or conventional AM are provided by jacks on the front panel. The tuning meter at the left of the VFO tuning knob indicates when a given radio transmission, not an exact multiple of 0.5 kc, is correctly tuned by the VFO.

GENERAL OBSERVATIONS

The following conclusions concerning the new receiver seem to be in order:

1. The mechanical design of the equipment uses the subassembly type of construction with modular construction for the tubes and associated components. The layout can very easily be adapted to printed wiring which would appear to be desirable in the final model design.

2. In the model built, miniature tubes were used in nearly all stages of the receiver. In a final model it would be possible and desirable to use transistors in much of the circuitry. Germanium diodes are used in the present model in the ring demodulators in order to obtain low distortion output in multiple tone operation.

3. Distortion in the audio amplifiers is minimized by the use of negative feed-back obtained by omitting bypass condensers for the cathode resistors.

4. Temperature control and voltage regulation of the plate and screen supply voltages are both used to obtain the desired stability in the operation of the variable frequency oscillator (VFO) when used.

ACKNOWLEDGMENT

The author wishes to acknowledge the contribution of I. I. Grasheim of RCA who was responsible for the design of the frequency control portion of the receiver, and the contribution of Dr. Paul K. Taylor of RCA for his assistance in the preparation of this paper.

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2. The Single-Sideband System applied to Short Wave Telephone Links, A. H. Reeves, Journal IEE, Sept. 1933.
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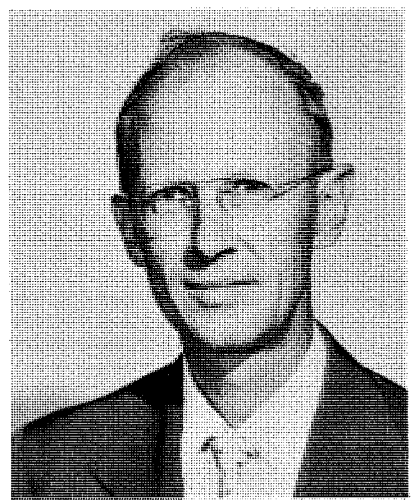
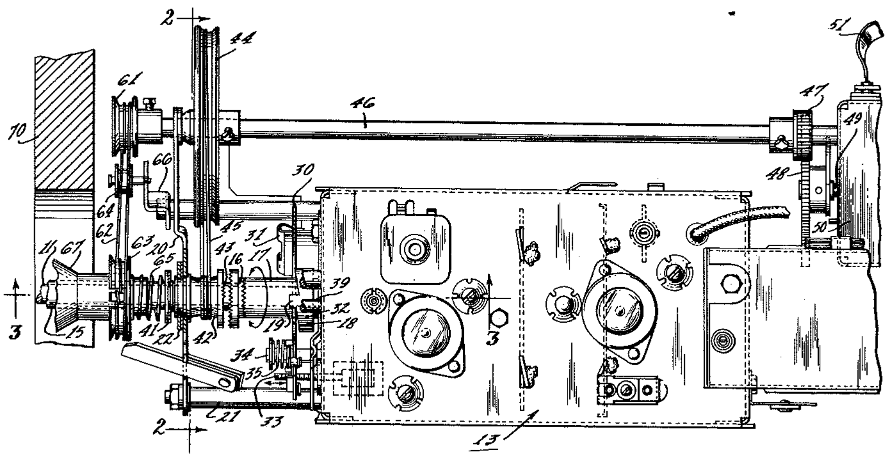


HAROLD F. COMFORT is Leader, Receiving Equipment Development Group, Defense Electronic Products Surface Communications. He graduated from Drexel Institute in 1933 with a B.S. degree in E.E. and has been active in the military radio receiver field since graduation starting with several years of production engineering and production supervision.

Mr. Comfort joined RCA in 1940 and has been active in the Receiver Development Group since 1945, where he participated in the design and development of various communication equipments for the Armed Services. He was responsible for the design of the AN/SRR-16, a single sideband receiver for the U. S. Navy, and was recently promoted to his present position of Engineering Leader.

Patents Granted
TO RCA ENGINEERS

Based on Summaries Received over a period of about two months



Pat. No. 2,788,668

WEB FEEDING MEANS (Patent No. 2,782,-355)—granted February 19, 1957 to Roy C. Wilcox, Defense Electronic Products, Camden, N. J. Three servo loops providing different control functions at different tape speeds during acceleration of the tape to proper speed are integrated into a system providing accurate speed control. Comparison of triangular and pulse signals in a phase detector makes the system sensitive to the direction of speed variation.

ELECTRON TUBE AMPLIFIER CIRCUIT (Patent No. 2,735,957)—granted February 21, 1956 to Robert G. Neuhauser, Electron Tube Division, Lancaster, Pa. In industrial TV systems, for example, the camera deflection yoke is often driven by a cathode follower stage. In accordance with the present invention, the cathode follower load impedance is made part of a DC bridge circuit along with a potentiometer to provide beam centering adjustment. In order to reduce size of bypass capacitor needed across potentiometer, a feedback path from yoke to grid of cathode follower is provided. This also improves linearity.

ELECTRICAL SIGNAL STORAGE (Patent No. 2,781,473)—granted February 12, 1957 to F. D. Covely, Industrial Electronic Products, Camden, N. J. and R. E. Baker (formerly with RCA). The signals erased by the reading beam are delayed and fed back to the writing beam, the delay interval being such that the delayed signals are rewritten on the storage screen at the same places from which they were erased.

HIGH FREQUENCY DIELECTRIC HEATING SYSTEM (Patent No. 2,785,264)—granted March 12, 1957 to Henderson C. Gillespie and Joseph E. Joy, Industrial Electronic Products, Camden, N. J. Pulse circuitry is provided for applying a negative blocking bias to cut off the high frequency oscillator in response to a breakdown between the dielectric heat applying electrodes.

MONITORING SYSTEM FOR STEREOPHONIC SOUND CHANNELS (Patent No. 2,791,629)—granted May 7, 1957 to John F. Byrd, Industrial Electronic Products, Camden, N. J. To check each channel separately or all channels simultaneously of a multiple channel sound system, high impedance "T" pads are bridged across the respective channels with a loading resistor in the input to a high gain amplifier. This provides high isolation to prevent crosstalk and gives approximately the same level in the monitor speaker regardless of the number of channels being monitored.

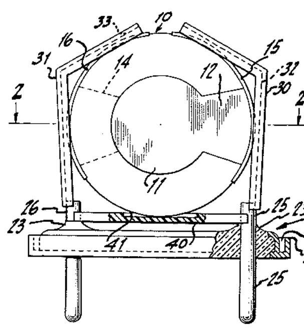
CRYSTAL MOUNTING (Patent No. 2,784,-326)—granted March 5, 1957 to Edward J. Purdue, Industrial Electronic Products, Camden, N. J. A piezoelectric crystal 10 is firmly held at its edges by the V-shaped channels 32, 33 which run longitudinally along the facing surfaces of the bent posts 30, 31, and by an indented strip of insulating material 40. The posts 30, 31 hold the crystal 10 firmly and securely by exerting pressure inward toward each other, and downward toward the insulating material 40. The posts 30, 31 permit the crystal 10 to be easily inserted and withdrawn.

SORTING APPARATUS (Patent No. 2,788,-124)—granted April 9, 1957 to Charles T. Miller, Electron Tube Division, Harrison, N. J. A sorting device is provided including an endless belt having an upper course adapted to receive bent and straight wire work pieces. The upper course is inclined upwardly in its direction of travel and is connected to a means for vibrating the course in transverse movements. A deposit of bent and straight work pieces on the aforementioned course will result in a flow of straight work pieces to the lower end of the course, and bent ones to the upper end, a receptacle for work pieces being provided at both of said ends.

INDIRECTLY HEATED CATHODE STRUCTURE & METHOD OF ASSEMBLY (Patent No. 2,753,480)—granted July 3, 1956 to William K. Batzle, Electron Tube Division, Harrison, N. J. and William C. Dale, Semiconductor Division, Somerville, N. J. For increasing the insulation between a cathode sleeve and an insulated heater therein, and for shielding the cathode from the heater, an insulatingly coated wire coil is disposed between the heater and cathode sleeve.

TUNING CONTROL MECHANISM FOR MULTIPLE RANGE RECEIVERS AND THE LIKE (Patent No. 2,788,668)—granted April 16, 1957 to Edward J. Sperber, RCA Victor Television Division, Cherry Hill, N. J. The tuning mechanism is provided with a pair of manually controllable shafts (11 and 15) arranged in concentric relation to each other. The first shaft 11 has twelve VHF positions and one UHF position. When the first shaft is in any of the VHF positions, the mechanism couples the second shaft 15 to the VHF fine tuning control means. When the first shaft is in the UHF position the actuating cam automatically shifts the second shaft to drive the UHF tuning control element. The first shaft is continuously rotatable in either direction for ease in channel and range selection.

TAPING MACHINE (Patent No. 2,781,932)—granted February 19, 1957 to Herbert W. Hittle and William H. Dearborn, Jr., RCA Victor Record Division, Indianapolis, Indiana. The machine comprises a platform upon which cartons are stacked and which is mounted on an air cylinder by means of which the platform is raised and lowered. A tape dispenser automatically dispenses and projects a strip of gummed tape over the top of the stack. The stack is then forced upwardly through a taping head which aligns



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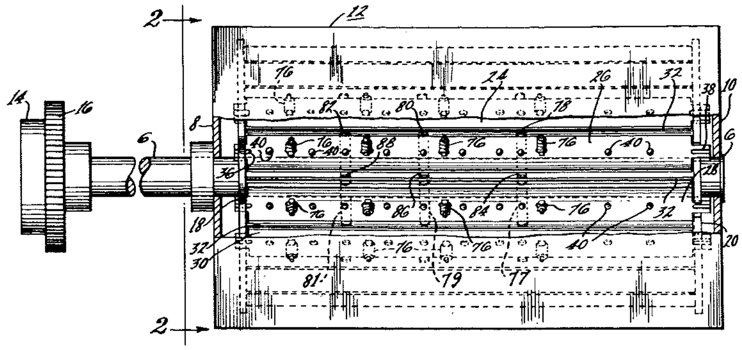


Pat. No. 2,789,227

the cartons and presses the tape against the cartons. When the platform is lowered the taped cartons are held in the taping head. The taped cartons are ejected from the top of the head when a succeeding stack of cartons is forced into the head. A suitable control system is provided for the operation of the machine.

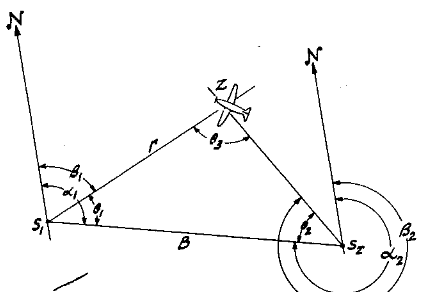
TUNING MEANS FOR MULTIPLE-BAND SIGNAL RECEIVING SYSTEMS (Patent No. 2,789,227)—granted April 16, 1957 to Tomomi Murakami and John C. Achenbach, RCA Victor Television Division, Cherry Hill, N. J. To establish a substantially constant bandwidth over the UHF band, the UHF tuning strips 24 of a 16 position turret type tuner are provided with spaced conductive bars (77, 79, 81) between the tuned circuits. The bars contact the sides of the shielded compartments of the turret and form inductive loops therewith, thereby modifying the coupling between the tuned circuits and establishing a constant bandwidth.

ELECTRON PHOTOGRAPHY PLATE CONSTRUCTION (Patent No. 2,748,288)—granted May 29, 1956 to Theodore A. Saulnier, Jr., Electron Tube Division, Lancaster, Pa. A base plate of glass has a metal layer and then a film of resin or shellac which is insolubilized by electron bombardment. On top of the resin film is a relatively thin electron transparent film of metal. The exposed metal film makes the plate opaque to visible light as from the cathode of an electron tube. The bottom metallic film prevents the accumulation of charges.

VOLTAGE SUPPLY SYSTEM (Patent No. 2,786,150)—granted March 19, 1957 to Arch C. Luther, Industrial Electronic Products, Camden, N. J. and Irving Bosinoff (formerly with RCA). Pulse-type supply providing regulated positive (for dynodes) and negative (for photocathode) output voltages. Positive pulses developed in H.V. pulse transformer primary are rectified to provide positive output voltage; inverted pulses in transformer secondary are rectified to provide negative output voltage. Negative output is compared with B+; variations in resultant are amplified and applied to control tube in shunt with input of pulse generator driving the transformer. Additional regulator tube, controlled by comparing positive output voltage with regulated negative output, appears as part of the load on the negative supply, introduces an additional variation in the negative supply circuit which when corrected for by the negative regulator results in regulation of positive output also.

REELING SYSTEM (Patent No. 2,781,982)—granted February 19, 1957 to Warren R. Isom, Defense Electronic Products, Camden, N. J. A system for reeling a separate sound film in synchronism with a motion picture film using a single driving sprocket for both films which are reeled along paths in the same plane.

BEAM CONTROLLING APPARATUS (Patent No. 2,729,759)—granted January 3, 1956 to William H. Barkow, Components Division, Camden, N. J. and Jerrold K. Kratz, Components Division, Findlay, Ohio. A cylindrical shield is adapted to be slipped over the neck of a triple-gun color kinescope and fixedly mounted thereon to shield the beams in their low-velocity regions from the effects of external fields. Color purity coil is rotatably mounted within the shield, which serves as a return magnetic circuit for the purity coil flux. Beam alignment magnets, in the form of magnetized screws, are adjustably mounted in the shield in radial positions with respect to the tube axis. Either pole of each magnet may be inserted to determine the direction of deflection imparted to the associated beam, and the amount of deflection may be determined by screw adjustment of the proximity of the selected pole to the particular beam. Attainment of proper magnet settings is simplified and shield tends to localize fields minimizing interaction between the alignment magnet field.



Pat. No. 2,792,989

MEANS FOR LOCATING THE POSITION OF A MOBILE CRAFT (Patent No. 2,792,989)—granted May 21, 1957 to David G. C. Luck, Defense Electronic Products, Camden, N. J. Directional navigation signals radiated by a pair of spaced omni stations are received aboard an aircraft. The azimuth bearings β_1 and β_2 of the craft with respect to the omni stations are translated into corresponding mechanical shaft rotations. The β_1 and β_2 shaft rotations, and other data known in advance, are combined and applied to an impedance bridge including a pair of parallel connected rheostat-potentiometer combinations. The values of these components are chosen so that the position of the arm of one of the potentiometers is caused to assume a position proportional to the range of the craft from one of the omni stations.

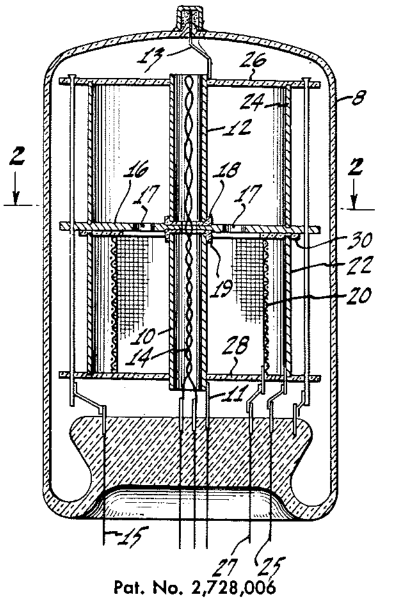
PHOTOSENSITIVE ELECTRODE AND METHOD FOR PRODUCING SAME (Patent No. 2,779,888)—granted January 29, 1957 to Richard G. Stoudenheimer, Electron Tube Division, Lancaster, Pa. The invention comprises evaporating a pellet of an alloy of antimony and manganese onto a face plate and then treating in order with oxygen and cesium.

PUNCHED TAG READER (Patent No. 2,781,973)—granted February 18, 1957 to John S. Baer and Robert A. Oberdorf, Industrial Electronic Products, Camden, N. J. A tag reader advances a special coded tag by a sprocket drive. A geneva provides intermittent advance. By suitable camming, the perforation positions are sensed during portions of the cycle when the tape is at rest. Designed to accommodate tags other than presently used Kimball or Dennison.

MONOSTABLE MULTIVIBRATOR CIRCUIT (Patent No. 2,784,309)—granted March 5, 1957 to Jerome D. Sable, Defense Electronic Products, Moorestown, N. J. Circuit comprises a monostable multivibrator using cathode-follower coupling to provide a very short recovery time. The first tube plate is directly coupled to the second tube grid. The second tube plate is coupled through a cathode-follower amplifier and RC timing network to the first tube grid. Triggering pulses are fed to the circuit thru a buffer stage. The output gate voltage from the multivibrator swings both positive and negative with respect to ground and may be directly connected to utilization circuits. The multivibrator may be operated at a high duty cycle and with a frequency-modulated trigger.

CALIBRATION METHOD AND DEVICE THEREFOR (Patent No. 2,791,696)—granted May 7, 1957 to Roger E. Schell, Industrial Electronic Products, Camden, N. J. The method of calibrating ampule inspection machines is based on the idea that once a criticalness of inspection (particle size) is determined, any ampule inspection machine can be calibrated. The light that would pass through the ampule is decreased and modulated 100 per cent. Signals derived from such modulated light at a phototube are then attenuated a predetermined amount. The output of the attenuator is then amplified until a signal large enough to trigger a rejecting mechanism is obtained.

STABILIZED TWO-STAGE OSCILLATORS (Patent No. 2,792,498)—granted May 14, 1957 to Bion D. Pewitt, Defense Electronic Products, Camden, N. J. The circuit comprises a conventional Butler two-stage oscillator wherein a gain-limiting negative self bias is developed at the grid of one of the tubes, a portion of which is also applied to the grid of the other tube. In this type of oscillator, the output of the first tube is fed to the input of the second, and energy is fed from the second back to the first in the proper phase to maintain oscillations. Initial absence of grid bias on the tubes provides high static loop gain and easy starting under adverse conditions of environment and supply voltage. Negative self-bias is subse-



Pat. No. 2,728,006

quently developed during operation and a portion of that developed on the first tube fed back to the second, providing a low dynamic loop gain with attendant harmonic reduction and stability.

REELING SYSTEM (Patent No. 2,782,029)—granted February 19, 1957 to JOSEPH M. URITIS, DEFENSE ELECTRONIC PRODUCTS, Camden, N. J. The guide is a structure which is pivotally mounted, having a tape carrying arm depending from the pivot mounting.

GAS DISCHARGE DEVICE (Patent No. 2,728,-006)—granted December 20, 1955 to WILLIAM M. WEBSTER, JR., SEMICONDUCTOR DIVISION, Somerville, N. J. An auxiliary cathode 12 is coaxial with a main cathode 10. Intermediate the cathode is an apertured element 16 that focuses the auxiliary discharge so that it will enter the main current path symmetrically around the main cathode 10 at a high velocity. Due to the symmetry, the high velocity of the electrons and the fact that the auxiliary discharge is perpendicular to the main current path the plasma in the main region will be of a high uniform density.

PROTECTION APPARATUS (Patent No. 2,-787,725)—granted April 2, 1957 to ALTON J. TORRE, RCA VICTOR TELEVISION DIVISION, Cherry Hill, N. J. The suppressor grid of the horizontal output tube is externally connected to the cathode via a resistor, which, during the existence of momentary internal suppressor-screen or suppressor-anode shorts, limits the current drawn from the power supply through the protective fuse to a level which precludes fuse vaporization thereby. Avoidance of unnecessary fuse vaporization, and thus avoidance of unnecessary receiver disabling, is achieved without the power waste and reduction of B+potential that would inhere in arrangements to effect the current limiting in anode and screen grid circuits.

VOLTAGE DROPPING SYSTEM FOR PHONOGRAPHS WITH AMPLIFIERS (Patent No. 2,-789,235)—granted April 16, 1957 to JAMES R. SHOAF, II, RCA VICTOR RADIO & "VICTROLA" DIVISION, Cherry Hill, N. J. The phonograph is provided with a motor having a pair of field windings which are connected in parallel for operation from 110 volts a.c. and in series for operation at 220 volts a.c. The audio amplifier which may be self-contained in the phonograph, and designed to operate from a fixed voltage (110 volts) is connected across one of the field windings. The motor windings are used as an autotransformer to supply the same operating voltage to the audio frequency amplifier for 220-volt operation. This construction eliminates the high wattage resistors which were formerly used in connection with the amplifier to drop the 220 volts to 110 volts thereby reducing power waste and heat dissipation in compact instruments.

RASTER CENTERING CONTROL (Patent No. 2,784,344)—granted March 5, 1957 to BERNARD V. VONDERSCHMITT, COMPONENTS DIVISION, Camden, N. J. Direct current controlled by a potentiometer is passed through the deflection yoke via an inductance in series with each yoke lead. The yoke is capacitively coupled to the output transformer via a capacitor in series with each yoke lead, thus blocking the DC from entering the transformer winding. The inductances block the deflection energy from entering the DC power source. Width control may be achieved by making the inductances variable.

MAGNETIC TAPE (Patent No. 2,782,043)—granted February 19, 1957 to DALLAS R. ANDREWS, RCA VICTOR RADIO & "VICTROLA" DIVISION, Cherry Hill, N. J. Reflecting indicia in the form of marks running other than perpendicularly to the edges of the tape are spaced from each other along the length of the tape. Signals for synchronizing the speed of the tape with some standard can be photoelectrically derived from the indicia. Sync indicia running perpendicularly across the tape were found to produce unwanted modulation effects.

REGULATED HIGH VOLTAGE SUPPLIES (Patent No. 2,785,336)—granted March 12, 1957 to JOHN A. KONKEL and JOHN STARK, JR., RCA VICTOR TELEVISION DIVISION, Cherry Hill, N. J. Control voltage for controlling HV regulator in ultor supply is derived from a B-boost bleeder rather than from an HV bleeder shunting the output of the ultor supply.

CONSTRUCTION OF GAS-FILLED TUBES PARTICULARLY SHIELDING (Patent No. 2,770,751)—granted November 13, 1956 to HANS J. PRAGER, ELECTRON TUBE DIVISION, Harrison, N. J. and WILLIAM C. DALE, SEMICONDUCTOR DIVISION, Somerville, N. J. In a gas tube (sub miniature thyratron) a shield is provided between the anode lead in and the cathode lead in. The shield extends from the press to the bottom mica and across the envelope to closely adjacent the envelope walls. A second shield is provided to shield the anode and cathode ears extending beyond the other mica. The second shield is U-shaped, with the U opening toward the cathode, and supports a third mica that supports a getter. The blocking grid is connected to the U-shaped shield.

HIGH FREQUENCY ELECTRON TUBE (Patent No. 2,768,326)—granted October 23, 1956 to BARREMORE B. BROWN and LESLIE KOVACH, ELECTRON TUBE DIVISION, Harrison, N. J. and JOHN W. SEACHRIST (formerly with RCA). A cavity resonator anode and a coupled tuning cavity resonator are mounted in a glass envelope and supported substantially entirely by a stem structure at one end thereof comprising a heat-dissipating tubular member and an exhaust tubulation sealed through a glass disk closing the envelope.

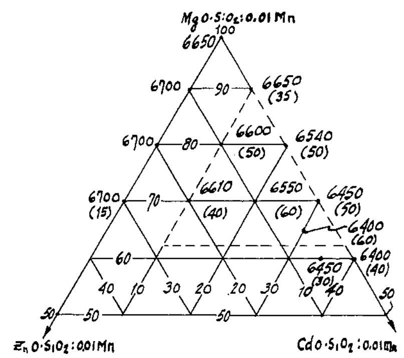
CONTROLLED FEED DEVICE (Patent No. 2,-791,422)—granted May 7, 1957 to JOHN S. BAER, INDUSTRIAL ELECTRONIC PRODUCTS, Camden, N. J. Two inputs of a differential are driven, respectively, by a pair of motors. Clutches, coupling the motors to the differential inputs, are responsive to control signals for transmitting motion from a motor to an input, whereby desired incremental motion is transmitted to the differential output. The device is used for producing multiple collating copies.

16 MM SOUND PROJECTOR FILM PROPELLER APPARATUS (Patent No. 2,783,995)—granted March 5, 1957 to WARREN R. ISOM, DEFENSE ELECTRONIC PRODUCTS, Camden, N. J. Guide roller has relatively small diameter at the end over which the sprocket hole area of film (along one edge thereof) passes, and a somewhat larger diameter at portion over which the film area at the opposite edge (the sound track area) passes. When disposed between the sound translating station and the feed sprocket for the film, such a guide roller provides a component of film propelling force which keeps the film moving toward the sprocket for proper engagement of the sprocket teeth with the sprocket holes in the film.

CAVITY RESONATOR CIRCUIT (Patent No. 2,790, 855)—granted April 30, 1957 to RAYMOND L. MEISENHEIMER, INDUSTRIAL ELECTRONIC PRODUCTS, Camden, N. J. Coaxial line cavity resonator construction, with outer cylindrical wall of input cavity common to inner wall of output cavity and connected to screen grid terminal of tube. This wall is slotted adjacent screen grid terminal to provide mutual inductance element, and inductance of slots adjustable by varying the position and number of metallic bridging links across slots.

OUTPUT OR INPUT CIRCUITS FOR VACUUM TUBES (Patent No. 2,790,857)—granted April 30, 1957 to THOMAS M. GLUYAS, JR., DEFENSE ELECTRONIC PRODUCTS, and LESLIE L. KOROS, RAYMOND N. CLARK, INDUSTRIAL ELECTRONIC PRODUCTS, Camden, N. J. Output circuit with coaxial inner and outer conductors, inner conductor being coupled to tube anode ring and outer conductor to cathode ring. Annular coupling capacitor of "sandwich" construction mounted between inner and outer conductors to form resonant cavity on tube side of capacitor and transmission line on other side, this capacitor being axially movable.

TRANSIENT CORRECTING NETWORK (Patent No. 2,790,954)—granted April 30, 1957 to MURLAN S. CORRINGTON, RCA VICTOR TELEVISION DIVISION, Cherry Hill, N. J. A series resonant trap is coupled in shunt to


Pat. No. 2,790,921

a low-pass filter to remove transient signals applied to the filter. The trap is tuned to the frequency of the first half cycle of the transient signals.

RED-EMITTING CATHODOLUMINESCENT DEVICES (Patent No. 2,790,921)—granted April 30, 1957 to Arthur L. J. Smith, Electron Tube Division, Lancaster, Pa. Luminescent screens comprising red-emitting magnesium-cadmium-zinc-silicate with manganese activator. The red-emitting phosphor component exhibits cathodoluminescence emission in the range between 6400A and 6650A and has the molar composition $aMgO \cdot bCdO \cdot cZnO \cdot dSiO_2 : eMn$, wherein $a = .25$ to $.80$, $b = .20$ to $.75$, $c = .00$ to $.55$, $d = 0.9$ to 1.1, $e = 0.001$ to 0.1 and $a+b+c = 1$. Invention includes luminescent screens, kinescopes and methods of preparing the red-emitting phosphor.

DIODE FREQUENCY CONVERTER WITH COMBINED LOCAL OSCILLATOR-INTERMEDIATE FREQUENCY AMPLIFIER HAVING COMMON TRIODE (Patent No. 2,789,215)—granted April 16, 1957 to Wen Y. Pan, RCA Victor Television Division, Cherry Hill, N. J. The conversion system includes a dual function stage that operates simultaneously as an i.f. amplifier and as a UHF oscillator. This stage is coupled to a mixer through a single circuit which serves to couple oscillation signals to the mixer and the resultant i.f. signals from the mixer to the i.f. amplifier.

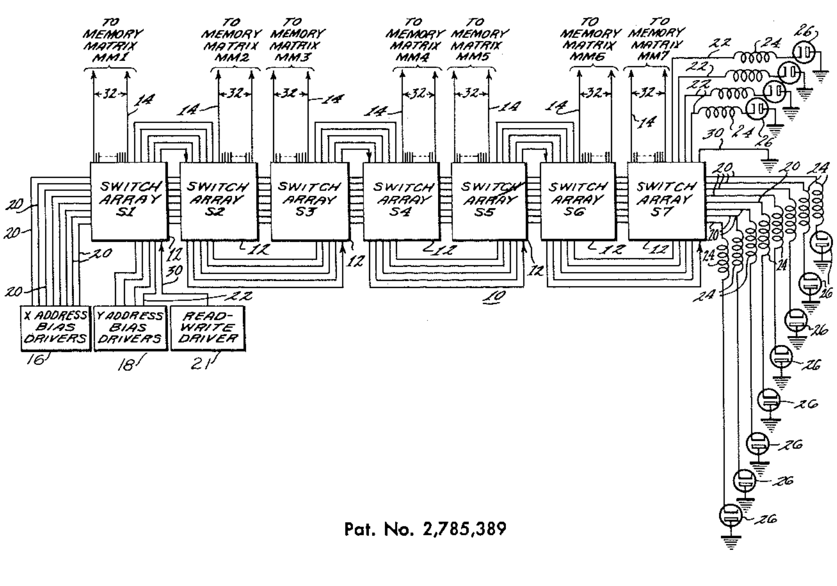
RADIO RELAY SYSTEM (Patent No. 2,791,-683)—granted May 7, 1957 to James S. Williams, Defense Electronic Products, Camden, N. J. Radio relaying system has single transmitter and single receiver, and two directional antennas; system can relay signals in either of 2 directions alternatively or can transmit locally originated signals simultaneously in both directions. The two antennas are normally connected to the receiver; when a signal is received by one of the antennas, the transmitter is connected to the other antenna.

MAGNETIC RECORDING AND REPRODUCING APPARATUS (Patent No. 2,782,263)—granted Feb. 19, 1957 to John J. Hoehn, Industrial Electronic Products, Camden, N. J. and Fielding B. Hills, RCA Service Company, Cocoa, Florida. A single locking bar cooperates with especially placed protuberances on push buttons which control the operational functions of the recorder so that tape throw-out is prevented between fast reeling and scanning operations.

FREQUENCY CONTROL SYSTEM (Patent No. 2,790,848)—granted April 30, 1957 to Winfield R. Koch, RCA Victor Television Division, Cherry Hill, N. J. A color television receiver includes a local oscillator and mixer to convert a received color television signal into IF picture carrier and color subcarrier components, which are separated by a fixed frequency. The picture and color subcarrier frequencies are at discrete intermediate frequencies which bear a direct relationship to the oscillator frequency and the color subcarrier component is to be maintained at a fixed position on the selectivity curve of the IF amplifier. This is accomplished by heterodyning a harmonic of the receiver color oscillator with the picture IF to produce a control beat signal that varies in frequency with local oscillator frequency variations. A frequency discriminating circuit produces from the control beat signal an AFC signal which controls the frequency of the local oscillator.

BISTABLE CIRCUIT (Patent No. 2,788,473)—granted April 9, 1957 to Jack Breckman, Defense Electronic Products, Moorestown, N. J. A flip-flop circuit incorporates a relay having a transfer contact and a hold contact. By successive actuations of an actuating contact, or switch, a condenser discharges to activate the relay, which remains actuated due to the "hold" contact. A successive actuation causes the relay to release by directing the "hold" current to ground through the discharged capacitor.

AMPLIFIER CIRCUITS FOR TELEVISION PICTURE SIGNAL CHANNELS (Patent No. 2,707,-730)—granted May 3, 1955 to A. J. Torre, RCA Victor Television Division, Cherry Hill, N. J. A simplified interstage coupling circuit is provided comprising a M-derived T-section filter having double rejector legs. Each of rejector legs is tuned to series resonance at one of the pair of frequencies closely adjacent to either side of the desired passband.



Pat. No. 2,785,389

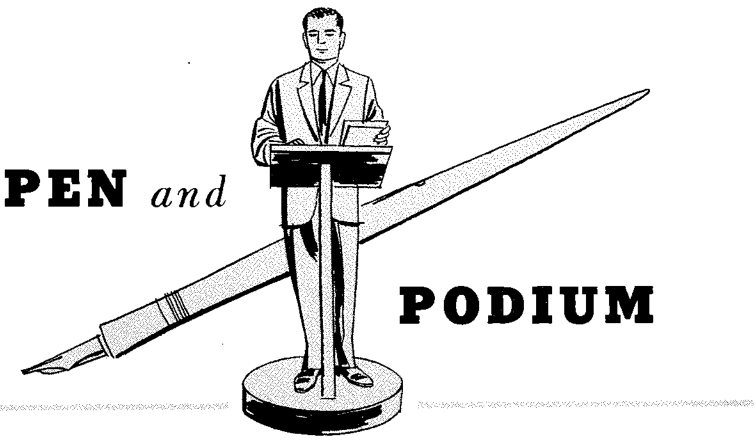
REGULATED BIAS VOLTAGE SUPPLY (Patent No. 2,782,340)—granted February 19, 1957 to Manuel Siskel, Defense Electronic Products, Moorestown, N. J. A portion of the voltage divider of a power supply is connected in shunt with a plurality of VR tubes. The shunted portion of the voltage divider is connected in parallel with a triode tube and a cathode resistor. The anode of the triode tube is connected to the cathode of a CRT. The cathode of the triode tube is connected to the grid of the CRT through a high impedance. This high impedance is shunted by a diode for d-c restoration purposes. The grid of the triode tube is supplied with a fixed bias. The circuit operates to maintain the voltage at the cathode of the triode tube substantially constant.

ART OF MAKING COLOR-PHOSPHOR SCREENS (Patent No. 2,785,331)—granted March 12, 1957 to Daniel J. Donahue, Electron Tube Division, Lancaster, Pa. Method of making a color-phosphor screen which comprises: Assigning different phosphor-particle sizes to the different color-phosphors of which said screen is to be formed, and then separately laying down said color-phosphors on the target-surface of a screen plate in a sequence corresponding to the increasing order of said phosphor particle sizes. This minimizes color-impurities by preventing the smaller phosphor particles from being caught between particles of larger sizes.

METHOD AND MEANS OF MARINE MARKING (Patent No. 2,783,209)—granted February 26, 1957 to Leopold Pessel, Components Division, Camden, N. J. Compositions which on dissolution in water form a milky suspension of high luminosity comprise about 50% by weight of a water soluble salt of bismuth, antimony, tin, titanium, 25% by weight of a dispersing agent, 25% by weight of a matrix material, such as polyalkylene glycol. Cakes of this composition may be used in sonobuoys and similar marine devices.

MAGNETIC SWITCHING SYSTEM (Patent No. 2,785,389)—granted March 12, 1957 to Charles S. Warren, Defense Electronic Products, Camden, N. J. Circulating currents are prevented from flowing in the row lines 20 and the column lines 22 of the switch 10 by means of the inductive elements 24 and the unilateral conducting devices, such as the diodes 26. A different inductive element 24 and a different diode 26 are connected in each row and column line. During selection, the diodes 26 in the selected row and column lines 20 and 22 are maintained cut-off due to the inductive "kick" provided by the inductive elements 24 of the selected lines.

ELECTRONIC CIRCUIT (Patent No. 2,783,453)—granted February 26, 1957 to Harry E. Rose, Defense Electronic Products, Camden, N. J. Invention consists of equality detector applicable to analogue computers for determining whether three or more signals are all equal. The maximum of three or more input signals is detected, and the minimum one of the inputs is detected. These maximum and minimum signals are compared for equality. A signal indicating equality of the maximum and minimum signals indicates equality of all the inputs.



PEN *and* PODIUM

Based On Reports Received Over a Period of About Two Months

A PRECISION RANGING SYSTEM . . . By A. G. Chressanthis and A. J. Lisicky, Defense Electronic Products, Moorestown, N. J. Presented by Mr. Lisicky at the IRE National Conference on Military Electronics, Washington, D. C., June 19, 1957. This presentation was divided into three sections. In the first section, a block diagram of electromechanical unit was displayed and a brief description of the components was included. Section two explained the generation and selection of the precision range pip and indicated the sources of error. The final section was concerned with the search, detection and acquisition scheme employed to acquire assigned targets.

THE APN-70 . . . By J. P. Eugley, Defense Electronic Products, Waltham, Mass. Presented at the 2nd RETMA Symposium on Applied Reliability, Syracuse, N. Y. on June 10-11, 1957. The paper stressed those design features which contribute to the high reliability experienced in current field use of the APN-70, airborne long range navigation receiver. One of these features is the built-in marginal testing facilities. Through the use of these self-explanatory testing facilities it is possible to keep a high field reliability by detecting impending faults.

RELIABLE SYSTEM DESIGN . . . By M. M. Tall and S. M. Sherman, Defense Electronic Products, Moorestown, N. J. Presented on June 11, 1957 at the 2nd RETMA Symposium on Applied Reliability, Syracuse, N. Y. An aspect of system design and a procedure for evolving the best system plan in terms of reliability, system capacity and initial costs are discussed. The objectives of the system plan procedure are twofold: 1) minimum equipment investment in terms of system capacity and 2) maximum system capacity in terms of achievable reliability.

INTRODUCTION TO TRANSISTOR THEORY AND APPLICATIONS . . . By E. J. Mozzi, Defense Electronic Products, Camden, N. J. Presented at the AIEE/IRE Student Section Meeting, Drexel Institute of Technology on May 22, 1957. A discussion of the basic fundamentals of transistor operation is presented together with the physical concepts involved in semiconductor theory. The paper is intended for engineers possessing little or no knowledge of transistor electronics and as such is aimed at providing overall general concepts with no attempt at formal analysis.

ROLE OF POWDER DENSITY IN DRY PRESSED CERAMIC PARTS . . . By W. C. Allen, T. F. Berry and W. A. Hassett, Electron Tube Division, Harrison N. J. Presented at American Ceramic Society Meeting, Dallas, Texas, May 6-9, 1957. The bulk density of a granular ceramic powder for dry pressing is its single most important physical property, because it influences pore distribution, die fill, pressing load, compressive ratio, pressed density, pressing defects, fired density, fired porosity, and fired shrinkage. Lubricants, plasticizers and binders are of secondary importance in their influence on the above effects. Bulk density is dependent upon the particle shape, particle-size distribution, amount of tempering medium added during the mixing operation, and the rate and temperature at which the granulated material is dried.

CHARACTERISTICS OF SINTERED CdS and CdSe PHOTOCONDUCTIVE CELLS . . . By R. W. Christensen, Edward Fischer, C. P. Hadley and H. W. Kuzminski, Electron Tube Division, Lancaster, Pa. Presented at Physical Electronics Conference, M.I.T., Cambridge, Mass., March 21, 1957. Electrical, mechanical, and optical characteristics of sintered CdS and CdSe photoconductive cells are presented. The structures of the cells are described and photoconductivity data given for various applied voltages and light levels. The analysis shows that sintered CdS and CdSe photoconductive cells are sensitive, dependable under rigorous environmental conditions, and stable throughout extended periods of operation.

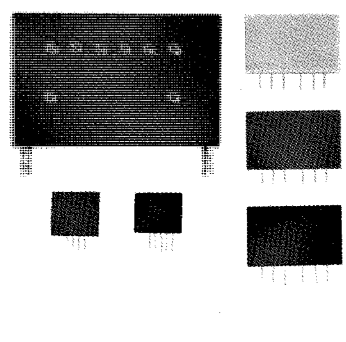
PHASE RELATIONSHIPS IN THE QUATERNARY SYSTEM — LIME — TITANIA — ZIRCONIA—SILICA . . . By Paul G. Herold, Electron Tube Division, Lancaster, Pa. and Robert M. Gruver, Linden Laboratories, State College, Pa. Presented at the American Ceramic Society Meeting, Dallas, Texas, May 6-9, 1957. The phase compatibility relationships for the quaternary system—lime—titania—zirconia—silica have been determined by solid phase reaction technique. An extended area of solid solution was found to exist along the join between calcium titanate and calcium zirconate. A low melting region was shown to extend through the quaternary system parellel to the join from titania to calcium metasilicate near ten per cent zirconia. Equations have been derived for determining the phase composition of samples in this system.

CALCULATION OF THE ANODE CURRENT FROM A HOLLOW CATHODE . . . By T. N. Chin, Electron Tube Division, Lancaster, Pa. Published in the June, 1957 issue of JOURNAL OF APPLIED PHYSICS. A simplified model of an apertured hollow cathode is developed for the case in which the anode is at a positive potential with respect to the cathode. The electric field at the emitting surface in the absence of space charge is calculated and is used to determine the regions of temperature-limited current flow and of space-charge-limited current flow. The space-charge-limited anode current is then calculated by a) an approximate method, employing the Child-Langmuir 3/2-power law; b) Langmuir's exact method, considering initial electron velocities and employing point-by-point analysis in the region of space-charge-limited current flow. Results are compared with those obtained with a spherical hollow cathode.

IMPROVED SIGNAL-TO-DRIFT IN D-C AMPLIFIERS FROM THE NOISE ANALOGUE . . . By J. E. Lindsay, Defense Electronic Products, Camden, N. J. Presented on June 10, 1957 at Princeton University, Princeton, N. J. An outstanding source of difficulty in d-c amplifier design is drift. With drift, as with noise, the use of degenerative feedback does not improve the ratio of the signal to the undesired disturbance. By analogy to an approach used with the noise problem the procedure is to seek a relationship between the driving source and the amplifier which will yield optimum performance with respect to signal-to-drift ratio.

OUTPUT CHARACTERISTICS OF MULTIPLIER PHOTOTUBES DETERMINED BY VOLTAGE-DIVIDER PARAMETERS . . . By R. W. Engstrom and E. Fischer, Electron Tube Division, Lancaster, Pa. Published in the REVIEW OF SCIENTIFIC INSTRUMENTS, June 1957. This paper describes a method of controlling output characteristics of multiplier phototubes by means of a voltage-divider network. Design considerations for the voltage-divider network are discussed, and typical circuit shown.

ENVIRONMENTAL PROTECTION OF PRINTED CIRCUITS . . . By J. A. Clanton and E. Fuzer, Defense Electronic Products, Camden, N. J. Presented on June 5 at the 1957 Electronic Materials Symposium, University of Pennsylvania, Phila., Pa. This paper describes various means of increasing the reliability and performance of printed circuits through potting and coating. Means of meeting moisture, vibration, fungus, and thermal shock requirements are described. The advantages and disadvantages of solvent-type and thermosetting coatings are considered.



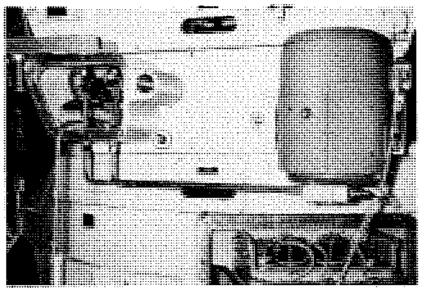
A NOISE SHIELD FOR MICROPHONES USED IN NOISY LOCATIONS . . . By M. E. HAWLEY, DEFENSE ELECTRONIC PRODUCTS, Moorestown, N. J. Presented on May 23 at the Meeting of the Acoustical Society of America, New York, N. Y. Intelligibility tests are used for speech audiometry, architectural evaluation, communications system evaluation, and research in psychoacoustics. A sub-committee of the American Standards Association has written a standard which should result in good agreement among a group of systems when each group is tested by several different laboratories.

CONTROL OF DEPOSITION OF BORON AS A DIFFUSION SOURCE FOR SILICON . . . By L. D. ARMSTRONG and D. DES JARDINS, Semiconductor Division, Somerville, N. J. Presented on July 15, 1957 at the IRE/AIEE Semiconductor Device Conference, Boulder, Colorado. Two methods of obtaining controlled deposition and diffusion of boron into silicon are described. The first method uses boron trichloride as a source; parameters controlling the nature and amount of deposition are discussed. The second method involves a smoke of boron oxide formed by air combustion of methyl borate. Preparation and use as a deposition source are given in detail. Methods of evaluation of the two processes are included.

PENCIL-TUBE, S-BAND, PULSED OSCILLATOR UNITS FOR MILITARY BEACON USE . . . By D. W. POWER, D. K. WILDE and H. G. PARISH, ELECTRON TUBE DIVISION, Harrison, N. J. Presented at the IRE National Convention on Military Electronics, Washington, D. C., June 18, 1957. This paper describes two pencil-tube, S-band, pulsed oscillator units for Signal Corps beacon use. Units are small, lightweight, and inexpensive, and maintain a high degree of frequency stability under severe conditions. One is a low-power, grid-modulated unit, and the other a higher-power, plate-modulated unit. A new pencil tube for both types is described, together with a cavity-type circuit arrangement differing from the reentrant type commonly used at S-band frequencies.

THE TRAVELING WAVE VHF TELEVISION TRANSMITTING ANTENNA . . . By M. SIUKOLA, INDUSTRIAL ELECTRONIC PRODUCTS, Camden, N. J. Presented on April 27, 1957 at the 11th Annual Technical Conference on TV, Cincinnati, Ohio. A new simple and rugged television antenna has been developed for VHF high channels. The antenna utilizes pairs of slot radiators cut longitudinally in a vertical pipe. In each pair the slots are fed in opposite phase, and the pairs are displaced one quarter wavelength from each other along the pole. Every other pair is in one vertical plane and the remaining pairs in another perpendicular to this. The slots are fed with a traveling wave within the pole.

ELECTRO-MECHANICAL FILTERS . . . By D. L. LUNDGREN, INDUSTRIAL ELECTRONIC PRODUCTS, Camden, N. J. Presented to the South Jersey Radio Club, Haddonfield, N. J. on April 25, 1957. A descriptive analysis of the various types of electro-mechanical filters was given with the aid of twenty slides that included characteristic curves and the construction of plate, disc, slug-coupled longitudinal and neck-coupled torsional filters. Principles of operation of these various filter configurations were discussed.



A HYDRAULIC DRIVE APPLIED TO A TRACKING RADAR . . . By H. PERKEL, DEFENSE ELECTRONIC PRODUCTS, Princeton, N. J. and G. STEVENS, DEFENSE ELECTRONIC PRODUCTS, Moorestown, N. J. Presented on June 19, 1957 at the IRE National Convention on Military Electronics, Washington, D. C. A method is shown by which a hydraulic motor controlled by a servo valve operating from a constant pressure source is applied to a tracking radar. The analytical methods used are compared to test results derived from an experimental system employing the elevation axis of an RCA developed tracking radar with good correlation. The smooth motion obtained for position commands imposed on the closed loop system demonstrated its general adaptability to tracking.

TRAVELING-WAVE-TUBE COLLECTOR-EFFICIENCY STUDIES . . . By FRED STERZER, ELECTRON TUBE DIVISION, Princeton, N. J. Presented at Electron Tube Research Conference, Berkeley, California, on June 26, 1957. Collector-potential depression is a long known (but little used) means for improving efficiency of beam-type tubes. Three factors limit efficiency obtained by collector depression: secondary electrons, space charge, and the velocity spread of the electrons. Experiments conducted with 100-watt, S-band, helix-type traveling-wave tubes give beam efficiencies in excess of 45 per cent with one-section collectors, and over 55 per cent with two-section collectors. Indications are that effects of secondary electrons and space charge are minor. Improvements by use of more sections are calculated.

THEORETICAL CONSIDERATIONS IN SELECTING SHIELDING MATERIALS FOR PROTECTING ELECTRONIC COMPONENTS FROM NUCLEAR RADIATION . . . By J. R. HENDRICKSON, DEFENSE ELECTRONIC PRODUCTS, Camden, N. J. Presented on June 5 at the 1957 Electronic Materials Symposium, University of Pennsylvania, Philadelphia, Pa. Comparisons of various nuclear shielding materials with respect to their effectiveness in attenuating gamma ray and neutron radiations are presented. A proposed design of a nuclear shield for reducing the nuclear radiation intensity by a factor of ten is outlined.

SINGLE SIDEBAND RECEIVERS . . . By H. F. COMFORT, DEFENSE ELECTRONIC PRODUCTS, Camden, N. J. Presented on May 21, 1957 at the Armed Forces Communications and Electronics Association, Washington, D. C. A SSB receiver equipment with pulse locked generator frequency control system was described. This equipment was developed with frequency control that will meet performance requirements for multiple-tone operation, voice and twin side-band. The advantages and disadvantages of SSB versus DSB were discussed.

APPLICATION OF VACUUM METALLURGY TO ELECTRONIC MATERIALS . . . By C. W. HORSTING, ELECTRON TUBE DIVISION, Harrison, N. J. Presented as part of one-week course in Vacuum Metallurgy at N.Y.U. on June 14, 1957. This paper describes the application of vacuum metallurgical processes to electronic materials, including production and processing. Electronic materials are classified as those used in construction of electronic devices and, in particular, electron tubes. Applications cover the following categories: (1) processing metals at high temperatures in vacuum; (2) vacuum-annealing processes; (3) joining metals-to-metals and metals-to-ceramics by vacuum-brazing; (4) vacuum evaporation of metals; and (5) preparation of alloys by melting in a vacuum.

HEATER SURGE CHART . . . By M. P. FEYERHERM, DEFENSE ELECTRONIC PRODUCTS, Camden, N. J. Published in ELECTRONICS, June, 1957. Effect of heater current surges when voltage is applied to cold tube and efficiency of surge-restricting arrangements can be evaluated with chart. Hot and cold characteristic curves are typical for most tubes.

EFFECTS OF AUTOMATION ON MILITARY EQUIPMENT DESIGN ACTIVITIES . . . By R. H. BAKER, DEFENSE ELECTRONIC PRODUCTS, Camden, N. J. Presented on June 6, 1957 at the Meeting of the Ground and Shipborne Committee, American Ordnance Association, Phila., Pa. The purpose of this paper is to outline the nature of the results that automation has on the design of military equipment. The introduction of Automation produces at least 3 basic causal conditions that require new techniques and new approaches in the design process. These are: the use of printed circuit boards, the use of modules and submodules in place of individual parts, and the mechanized processing and handling of information and material.

THE VALUE OF RANGE AND OVERLAPPING COVERAGE IN AIR DEFENSE MISSILE SYSTEMS . . . By S. N. MILLS, D. A. COLE, A. D. DAVIES and M. E. HAWLEY, DEFENSE ELECTRONIC PRODUCTS, Moorestown, N. J. Presented by Mr. Mills on June 18, 1957, at the IRE National Convention on Military Electronics, Washington, D. C. Considerations involved in distributing a limited number of missiles among a small number of launching sites were discussed. Allocation to the individual launching sites is based upon arbitrarily defined values of the defended regions. Cost factors for different missile systems were discussed qualitatively.

DEPOT TEST EQUIPMENT CONCEPTS . . . By D. B. DOBSON, DEFENSE ELECTRONIC PRODUCTS, Camden, N. J. Presented at the National Conference on Aeronautical Electronics, May 13-15, 1957. In complex fighter aircraft fire control various aspects of maintenance must be examined and special test and repair equipment designed and built. RCA has studied the three levels of maintenance; Organizational, Field, and Depot with respect to the Fire Control Radar utilized in the Lockheed F104 Star fighter, and has designed or recommended an integrated series of test equipments for all three levels.

OPPORTUNITIES IN CERAMICS . . . By P. G. Herold, Components Division, Camden, N. J. Presented at Metropolitan N. Y. Section of American Ceramic Society, New York City, March 1, 1957. This presentation describes the field of ceramics and the training required of an engineer in this field. New fields opening up in Electrical Ceramics, Refractories, and Glass were discussed and the required training was described.

LIGHT-WEIGHT HOUSINGS FOR ELECTRONIC APPARATUS BY USE OF SILVER-COATED MAGNESIUM . . . By R. P. Dunphy and E. F. Bailey, Defense Electronic Products, Camden, N. J. Presented at the 1957 Electronic Materials Symposium, University of Pennsylvania, Phila., Pa. on June 4-5. The difficulties in protecting magnesium from corrosion when coated with cathodic metal, such as silver, can be resolved by painting the magnesium surfaces with a corrosion-protecting paint film followed by a coating of conducting silver paint. Low impedance joints in electronic equipment cases can be obtained.

DERIVATION OF ELECTRONIC PART-FAILURE STATISTICS FROM MATERIAL PROPERTIES . . . By D. I. Troxel, Defense Electronic Products, Camden, N. J. and J. A. Conner. Presented on May 14, 1957 at the Insulation Symposium of the 111th Meeting of the Electrochemical Society, Washington, D. C. There is a mounting need for suitable "mortality" statistics for component parts to be used in military electronic equipments. Materials-investigation studies are potential "gold mines" of correlation data. The selection, analysis and interpretation of these data must be based upon certain compromise factors dictated by the ultimate statistical utility of the end result.

COORDINATED WEAPON ASSIGNMENT IN MISSILE SYSTEMS WITH OVERLAPPING COVERAGE . . . By J. K. Carlyle, Defense Electronic Products, Moorestown, N. J. Presented on June 18, 1957 at the IRE National Convention on Military Electronics, Washington, D. C. This paper describes a method of determining a coordinated weapon assignment sequence for two surface-to-air missile batteries with partially overlapping coverage. The order of target engagament is determined in five computational steps, resulting in assignments based on the characteristics and previous engagement history of the target, and on the availability and limitations of the weapons. Application to a more complex defensive environment is discussed.

MECHANICAL DESIGN FEATURES OF A RADAR FOR THE MILITARY SERVICES . . . By L. Jacobs, Defense Electronic Products, Moorestown, N. J. Presented on June 10, 1957 at the 2nd RETMA Annual Symposium of Applied Reliability, Syracuse, N. Y. The suitability of a radar for military applications depends greatly upon its ability to withstand the severe environmental conditions of shock, vibration, corrosive atmosphere, and wide temperature range. High degree of accessibility to simplify maintenance is also an important factor. Specific mechanical design features of a radar that satisfies these requirements were presented. In addition, some considerations of the mechanical design from the standpoint of manufacturability were also presented.

APPLICATIONS OF MICROWAVE RADIO RELAY . . . By D. G. Hymas, Industrial Electronic Products, Camden, N. J. Presented on April 25, 1957 at the American Public Works Association, Engineers Club, Philadelphia, Pa. A survey was made of the various commercial and military applications of microwave radio relay systems. Some of the factors affecting system performance and reliability were discussed and a semi-technical description of the operation of typical systems was given. Slides of actual system installations were used.

BORESIGHT SHIFT IN GROUND RADOMES . . . By M. H. Paiss, Defense Electronic Products, Moorestown, N. J. Presented on June 5, 1957 at the Ohio State University—Wright Air Development Center Radome Symposium. The requirements for ground radomes are discussed along with the several advantages of air-supported vs. rigid radomes. The electrical characteristics of thin radome walls are described and a combination of theory and experiment used to predict the boresight shift caused by strucural discontinuities for a proposed radome.

FLATTENING RESPONSE OF CRYSTAL PICKUPS . . . By A. L. Cleland, Semiconductor Division, Somerville, N. J. Published in the May, 1957 issue of ELECTRONICS. This paper analyzes characteristics of crystal pickups in terms of equivalent circuits, and describes a simple method for designing matching networks for use with amplifiers. It discusses considerations in matching crystal pickups to transistor preamplifiers. Similar design considerations apply to systems using vacuum-tube preamplifiers.

WEAPON SYSTEMS RELIABILITY . . . By M. M. Tall, Defense Electronic Products, Moorestown, N. J. Presented on June 19, 1957, at the IRE National Convention on Military Electronics, Washington, D. C. This paper illustrates how the techniques of reliability assurance and improvement are being applied in a large weapon system. The concept of system effectiveness as a measure of reliability achievement is discussed and its use as a means of setting detailed reliability goals is explained.

AIRBORNE GUIDANCE EMPLOYING TELEVISION DISPLAYS . . . By L. Brotman, J. Minker and S. W. Spaulding, Defense Electronic Products, Camden, N. J. Presented by Mr. Brotman on June 19, 1957, at the IRE National Convention on Military Electronics, Washington, D. C. Feasibility of navigating an airborne vehicle to a target utilizing a ground based television display and a radio command link was made. Investigations showed that within the limitations, it is feasible to successfully guide the vehicle, and for this particular application the human operator can accurately be simulated by a linear transfer function.

NEW DESIGN IN TV BROADCAST ANTENNAS . . . By M. S. Siukola and G. A. Kumpf, Industrial Electronic Products, Camden, N. J. Published in ELECTRONIC INDUSTRIES & TELE-TECH, May, 1957. This paper describes a new design in VHF-TV broadcast antennas. It is called "Traveling Wave Antenna" and features simplicity in its mechanical construction and feed system, improved pattern characteristics and high power handling capacity.

A WORKING PROCEDURE FOR PREDICTING THE THERMAL EFFECTS ON AIRBORNE EQUIPMENT RELIABILITY . . . By T. C. Reeves, Defense Electronic Products, Camden, N. J. Presented on June 17, 1957 at the IRE National Convention on Military Electronics, Washington, D. C. Evaluation of equipment survival probability in airborne environments is usually required before the equipment thermal environment can be determined accurately by flight test. Even complete simulation testing of equipment is sometimes impractical within the time and cost limitations of a reliability analysis. A procedure is described for obtaining a first order engineering approximation of thermal effects.

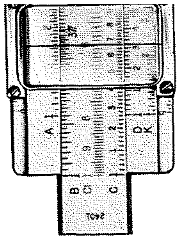
CREATIVE MIND . . . By Dr. L. Pessel, Components Division, Camden, N. J. Dr. Pessel took part in a Creative Thinking Symposium at La Salle College, Philadelphia, Pa. on June 18, 1957. His remarks were based on his paper "An Interrogatory Evaluation of the Creative Mind" published in the January 1957 RCA ENGINEER.

A SUPER-POWER RADAR TRANSMITTER . . . By R. M. Fisher, Defense Electronic Products, Moorestown, N. J. Presented on May 2, 1957, at the Symposium on Guided Missile Detection Radars, M. I. T. Described is a radar transmitter operating in the UHF region employing gridded vacuum tubes in the R.F. chain and a line-type pulser. Transmitter power is the highest ever achieved in equipment of this type. The equipment described is the result of the combined efforts of Surface Communications Engineering, Broadcast Transmitter Engineering, and Missile and Surface Radar Engineering.

FAILURE RATE MEASUREMENTS BY MEANS OF ACCELERATED TESTS . . . By I. K. Munson, Defense Electronic Products, Camden, N. J. Presented on May 13, 14, 15, 1957, at the IRE National Conference on Aeronautical Electronic Components, Dayton, Ohio. Increased reliability of component parts points to the need for development of accelerated test techniques so that failure-rate measurements can be made with a reduced sample-hour factor. This paper discusses several technical problems and solutions.

AN EXPERIMENTAL INVESTIGATION OF THE EFFECTS OF NUCLEAR RADIATION ON TRANSISTORS . . . By A. J. Schwartz, Defense Electronic Products, Camden, N. J. Presented on May 1 at the 1957 Electronic Components Symposium, Chicago, Ill. This paper discusses the results of a comprehensive experimental investigation of nuclear radiation effects on transistors. Tests were run on approximately 150 transistors of sixteen different types under various levels and kinds of radiation. The effects on various transistors are included.

A STUDY OF THE MOLDED NICKEL CATHODE . . . By C. P. Hadley and W. G. Rudy, Electron Tube Division, Lancaster, Pa. and A. J. Stoeckert, Electron Tube Division, Harrison, N. J. Presented at Electrochemical Society Meeting, Washington, D. C., May 13-16, 1957. Research work on the molded nickel cathode is described. Results are given regarding the effects on emission and life of variations in nickel powder, alkaline-earth carbonates, reducing agents, sintering, and activation. Data on pulsed emission are presented.

Engineering  NEWS *and* HIGHLIGHTS

TV IMAGINEERING CONTEST WINNERS ANNOUNCED

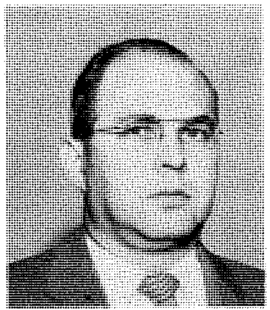
1ST PRIZE

W. H. Tsien

2ND PRIZE

A. J. Wohlgemuth

3RD PRIZE



P. W. Kaseman

After careful deliberation, the judges have announced their decision on the winner of RCA Victor Television Division's TV Imagineering Contest. Sponsored as a means of uncovering supplementary approaches to television receiver remote control design, the contest offered lucrative prizes for the best suggestions.

The first prize winner is **Wei-Hwa Tsien,** of IEP Television Terminal Equipment Engineering in Camden. Mr. Tsien suggested a multi-function control system which offers simplicity plus wide flexibility in application.

Second prize is awarded to **Adolph J. Wohlgemuth** of the Electron Tube Division's Equipment Design and Development activity at Harrison. Mr. Wohlgemuth suggested an extremely practical method of wireless energy transfer from the remote unit to the receiver.

The third prize winner is **Paul W. Kaseman,** a design engineer with Camera, Oscillograph and Storage Tube Development, Electron Tube Division, Lancaster. Mr. Kaseman suggested a unique method of remote control with attractive merchandising possibilities.

The contest was open to all design and development engineers in RCA product divisions. The contest objective was to obtain new ideas for a low cost, reliable remote control tuning system and to develop new approaches to tuning a television receiver.

Prizes are in the form of RCA Victor and RCA Whirlpool merchandise, with $3500 worth as first prize, $2000 and $1000 worth as second and third prizes respectively.

Wei-Hwa Tsien was born near Shanghai, China, and received the degree of BSME from Chiao-tung University, Shanghai, in 1935. He taught in college for one year after graduation, and worked as a mechanical engineer at a shipyard before coming to this country in 1937. After receiving the Masters degree in Mechanical Engineering at MIT in 1939, he was employed in engineering for the Chinese Ordnance Department in New York until 1953, when he came to work for RCA. Mr. Tsien worked on the mechanical design of studio monitors for the TV Terminal Equipment Engineering, and for the past two years has been applying automation techniques to TV broadcast studio equipment.

Adolph J. Wohlgemuth received the BS degree in EE at Cooper Union in 1931, and continued his studies in mechanical engineering at that school. He worked toward a Master's degree in EE at Brooklyn Polytechnic Institute. Mr. Wohlgemuth was employed by Telautograph Corporation until 1938. He then became Assistant Chief Electrical Inspector for the City of New York, a position he held until 1944.

Following two years with the armed services, he returned to his previous position with the City of New York until 1951. He was then employed by Weston Electrical Instrument Corporation as an electrical engineer until 1952. He held a position as Project Engineer with Thermo Electric Company from 1954 to 1955, following two years of self employment.

Mr. Wohlgemuth joined RCA Tube Division as an electrical engineer in Equipment Design and Development at Harrison in 1955. He is a Licensed Professional Engineer in New York and New Jersey, a member of the AIEE, IRE, the Instrument Society of America, and the N. J. Society of Professional Engineers.

Paul W. Kaseman attended Lycoming College at Williamsport, Pa., and received the BS degree in EE at Pennsylvania State University in 1950. After graduation he was employed by RCA as a Manufacturing Engineer in the Pick-up Tube activity and in 1954 joined the Camera, Oscillograph and Storage Tube Development activity, where he has served as a design engineer to the present.

Mr. Kaseman is a member of the Sigma Tau honorary society, an Associate Member of the AIEE, and an Associate Member of the IRE. He is currently serving as Vice Chairman of the IRE Lancaster Subsection.

DAVID SARNOFF FELLOWSHIPS AWARDED TO TEN RCA EMPLOYEES

Ten employees of RCA will receive David Sarnoff Fellowships for the 1957-58 academic year, according to a recent announcement by Dr. C. B. Jolliffe, Vice-President and Technical Director of RCA.

The fellowships are valued at approximately $3,500 each. The grant includes full tuiton fees, $2,100 for living expenses and $7.50 as an unrestricted gift to the university. Although appointments are for one academic year, each fellow is eligible for reappointment.

The David Sarnoff Fellows were selected on the basis of academic aptitude, promise of professional achievement and character. They will pursue graduate studies in physics, electrical engineering, applied mathematics, business administration and dramatic arts.

RCA product engineers who will be on a leave of absence durng the next college year are:

Edward Kornstein will work toward his Doctorate in Physics at Boston University. Mr. Kornstein received his Bachelor's degree from New York University in 1951 and a Master of Science degree from Drexel Institute of Technology in 1954. He is a member of the Optical Society of America, Society of Motion Picture and Television Engineers and American Institute of Physics. Mr. Kornstein joined the Corporation in 1951 and is employed by RCA Defense Electronic Products at Camden, N. J.

Walter F. Denham will pursue studies leading to a Doctorate in Applied Mathematics at Harvard University. Mr. Denham received his Bachelor of Science degree in Physics from Rensselaer Polytechnic Institute in 1956. He is employed by RCA Defense Electronic Products at the Airborne Systems Laboratory in Waltham, Mass.

Herbert R. Meisel will work toward his Master's degree in Physics at Stevens Institute of Technology. Mr. Meisel received his Bachelor's degree in Mechanical Engineering from Rensselaer Polytechnic Institute in 1950. He is currently studying at Newark College of Engineering toward a Master's degree in Management Engineering. Joining RCA in 1953, Mr. Meisel is employed in the Transistor Section of the RCA Semiconductor Division at Somerville, N. J.

John W. Caffry will continue work toward a Master's degree in Business Administration at Harvard University. In 1952, Mr. Caffry received his Bachelor of Science degree in Electrical Engineering from Cornell University. He joined RCA in 1952 and is employed in the Color Kinescope Operations Department of the RCA Electron Tube Division at Lancaster, Pa. Mr. Caffry also was awarded an RCA Fellowship for the 1956-57 college year.

Others receiving Fellowships are:

Robert J. Pressley, John A. Inslee, and Herbert W. Lorber, RCA Laboratories, Princeton, N. J.
Charles A. Passavant, RCA International Division, Clark, N. J.
James M. McCook, RCA Victor Company, Ltd., Montreal, Canada.
Morgan A. Barber, Jr., National Broadcasting Company, New York City.

FORMER ENGINEERS IN NEW EXECUTIVE POSTS

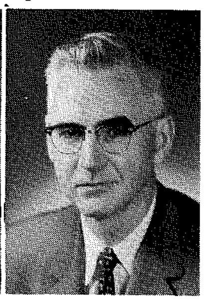
Establishment of the first executive posts in the newly formed Industrial Electronic Products organization was announced recently by T. A. Smith, Executive Vice President, RCA Industrial Electronic Products.

Thompson H. Mitchell, President, RCA Communications, Inc., has been appointed General Manager of a new Telecommunications Division which will bring together communications and broadcasting activities of the former RCA Commercial Electronic Products organization with RCA Communications, Inc. Mr. Mitchell also will continue as President of RCA Communications, Inc.

A. R. Hopkins, formerly Manager, Commercial Electronic Marketing Department, has been advanced to Manager, Industrial Electronic Marketing Department. He assumes administrative and functional responsibilities for the planning and marketing of all RCA industrial electronic products.

T. H. Mitchell

A. R. Hopkins



J. P. Taylor

Mr. Mitchell joined RCA as an engineer in 1927. In 1930, he transferred to RCA Communications, Inc., and during the next twelve years was successfully District Manager for RCA Communications, Inc., in Honolulu and Los Angeles. From 1942 to 1944, he served with the United States Army, as communications engineer and officer in charge of the Traffic Operational Engineering Section of the Army Communications Service, Washington, D. C.

Mr. Hopkins has been associated with RCA sales, merchandising, and engineering activities for more than twenty-eight years, and is well known throughout the broadcast and communications industry. He joined RCA as an engineer in 1929. In 1949, he received the RCA Victor Award of Merit. He was graduated in 1926 from Ohio State University with a degree in electrical engineering.

J. P. Taylor Named to New Post

Appointment of John P. Taylor to the new post of Manager, Marketing Plans and Services, RCA Industrial Electronic Products, has been announced by A. R. Hopkins.

Mr. Taylor will be responsible primarily for the formulation of broad marketing and services plans to meet the electronic equipment needs of business and industry.

He joined RCA as an engineer in the Camden, N. J., plant in 1930, the year following his graduation from Harvard University with a degree in electrical communications. Prior to joining RCA, he participated in the development and testing of some of the earliest broadcast transmitters and was a member of the staff of W2XAF, one of the first high-powered transmitters for shortwave communications.

In 1952 he received the RCA Victor Award of Merit.

LOWELL GOOD IN NEW ENGINEERING UTILIZATION POST

Appointment of Lowell H. Good to the newly created post of Director, Engineering Utilization, Radio Corporation of America, was announced recently by D. F. Schmit, Vice President, Product Engineering, RCA Staff.

For the past eighteen months an engineering executive in RCA's Defense Electronic Products organization, Mr. Good now assumes responsibility for developing and executing a comprehensive program for effective, economical coordination and utilization of Engineering manpower and resources in all areas of RCA operations.

Mr. Good has been associated with RCA product and developmental engineering activities since 1941, when he joined the engineering staff of RCA's Indianapolis, Indiana, manufacturing plant. Prior to his appointment to his previous post, in January, 1956, as Manager, Optical, Mechanical and Circuit Development, RCA Defense Engineering Department, he held various executive engineering positions in the former RCA Engineering Products Division, Camden, N. J.

An Arts and Sciences graduate of Indiana Central College, Mr. Good received his Master's Degree in physics from Indiana University.

DR. CARL W. STEEG JOINS RCA WALTHAM STAFF

Dr. Carl W. Steeg, MIT staff member since 1947, has recently assumed the position of Manager of Analysis and Simulation at RCA's Airborne Systems Laboratory in Waltham, Mass. He received his AB degree in mathematics from DePauw University of Indiana and his Ph.D. from MIT in 1952. Professionally active in his field, Dr. Steeg is a member of the American Math Society, the American Association for Advancement of Science and Sigma Xi. His latest book, "Control Systems Engineering", will be released this fall by the McGraw Hill Publishing Company.

In his new capacity at RCA, Dr. Steeg will guide the efforts of engineers, mathematicians and psychologists, all working together in the simulation of weapon systems, interceptor aircraft, target flight control systems, cockpit displays and problem geometry. —*R. W. Jevon*

R. S. BURNAP HONORED ON 40th ANNIVERSARY WITH RCA

Robert S. Burnap, Manager of Commercial Engineering, was honored at a special luncheon in Harrison on July 30th for his 40 years service with RCA. D. Y. Smith, Vice President and General Manager of the Electron Tube Division, praised Mr. Burnap's many contributions in the fields of standardization and technical literature. Mr. Smith remarked that Mr. Burnap's activities in these fields have benefited not only RCA but the entire electronics industry. Dr. G. R. Shaw, Chief Engineer, after reminiscing on electron-tube progress during Mr. Burnap's 40 years of service, presented him with a handsome dispatch case.

Mr. Burnap received the S.B. degree from MIT in 1916. He started as an engineer with the Edison Lamp Works of the General Electric Company in Harrison, New Jersey in 1917 and, after an interruption for military service during World War I, advanced to the position of Manager of their Commercial Engineering Section in 1925. He has been Manager of Commercial Engineering, RCA Electron Tube Division, since 1930. Mr. Burnap was elected Fellow of the SMPTE in 1934, of the IRE in 1947, and the AIEE in 1951. —*R. L. Klem*

Pictured at luncheon for R. S. Burnap are (back row, from left) H. V. Knauf, J. T. Cimorelli, Dr. G. R. Shaw, W. M. James, W. E. Bahls, R. B. Ayer, J. F. Hirlinger and H. F. Bersche. (Front row, from left) S. F. Phillips, G. W. Crowford, Miss A. A. DeMott, Mr. Burnap, D. Y. Smith, Miss Helen McMahon and C. D. Mitchell.

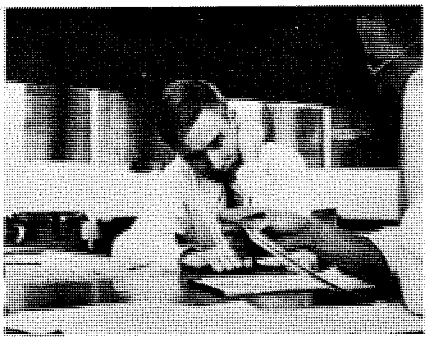
ACS HONORS DR. VINAL

The American Ceramic Society, New England section, recently honored Dr. F. E. Vinal, Manager of the Components Division's Needham (Mass.) Laboratory. Dr. Vinal received an award "for outstanding service." He is a charter member of the Section, and was its chairman in 1954-55. (See RCA ENGINEER Vol. 2, No. 6 for biographical information on Dr. Vinal.)

According to Dr. Vinal, the award plaque presented to him is fabricated by an unusual process. It is ceramic in character, being made of a photosensitive glass. The process, invented by the Corning Glass Company, is quite different from normal photographic techniques in that the image is developed in the glass by heat treatment.

—T. A. Richard

IVAN H. SUBLETTE RECEIVES DOCTORATE



Ivan H. Sublette, DEP Special Systems and Development, was recently awarded the PhD degree in electrical engineering by the University of Pennsylvania. Dr. Sublette, who did his undergraduate work at Purdue, joined RCA in 1949. He received an MS in EE from Moore School, University of Pennsylvania, in 1954.

—L. M. Seeberger

NEW EDITORIAL REPRESENTATIVES APPOINTED

Herman L. Wuerffel, DEP Standards Engineering, has been appointed to replace Warren M. Kitter of that activity in Camden and Irmel N. Brown of the DEP Missile and Surface Radar Engineering at Moorestown has replaced J. A. Bauer in representing Moorestown Engineering.

Mr. Wuerffel received a BSEE degree from Illinois Institute of Technology in 1943. He completed work for a MS degree at the University of Maryland in 1949. From 1943 to 1955 he was employed by the Naval Research Laboratory, working in search-radar systems and computers.

Mr. Wuerffel joined RCA in 1955 as a Systems Engineer in DEP Components Application Review. He is currently Manager, Reliability Analysis and Measurements Engineering, DEP Standards Engineering. He is a member of the AIEE, IRE, Eta Kappa Nu and Tau Beta Pi.

Irmel N. Brown received the BS degree from the University of Kentucky in 1933. He joined RCA in 1944 as an engineer in Infrared and Sound Products, and advanced to Manager of Infrared and Associated Equipment. He later became Manager of Systems Studies, Shoran and Specialty Engineering before assuming his present post as Manager of Systems Engineering of DEP Missile and Surface Radar at Moorestown. Mr. Brown is a Senior Member, IRE, a member of the IRE Professional Group on Engineering Management, and the Tau Beta Pi.

MEETINGS, COURSES, AND SEMINARS

SOLID-STATE PHYSICS . . . Engineers from several groups at RCA Lancaster have cooperated in setting up a continuing Seminar on Solid State Physics. The seminar was initiated by Charles W. Rector of Camera Tube Development and includes R. L. Van Asselt, T. N. Chin, P. P. Damon, J. Kolostyak, R. P. Stone, and B. H. Vine of Camera Tube Development; R. W. Christensen, H. W. Kuzminski, and J. L. Weaver of Phototube Development; and P. G. Herold, G. P. Kirkpatrick, and R. N. Summergrad of the Chemical and Physical Laboratory.

—D. G. Garvin

TV MICROWAVE . . . A special television microwave seminar was given to a group of approximately thirty-five New York Telephone Company operating engineers in Albany on June 4 and 5. The seminar and demonstration were conducted by J. B. Bullock and C. I. McDowell of IEP Broadcast Studio Engineering. *—J. H. Roe*

ASA MEETING . . . A meeting of the Acoustical Society of America was held in New York on May 23 thru May 25. The following personnel from DEP Surface Communications Engineering attended technical sessions: J. C. Bry, W. F. Meeker, M. L. Touger, and L. Weinreb. An RCA paper was read by Mones E. Hawley of DEP Missile and Surface Radar at Moorestown. The subject was a microphone noise shield developed by Mr. Hawley

The International Conference on Audiology, held at St. Louis, Missouri on May 15 and 16, was also attended by W. F. Meeker, who has made a comprehensive report on the papers which he attended.

—T. T. N. Bucher

COMMITTEE APPOINTMENTS

J. H. Pratt, DEP West Coast Engineering at Los Angeles has been appointed to the Radio Technical Commission for Aeronautics Special Committee S8-D, Minimum Performance Standards for Airborne Equipment Employing Pulse Techniques.

L. S. Bensky, DEP Special Systems and Development, has been elected Chairman of the Philadelphia Chapter of the IRE Professional Group on Electronic Computers.

—L. M. Seeberger

E. Cornet, Advanced Development group, Radio and "Victrola" Division, has been appointed to serve with the subcommittee of IRE 17, which has been organized to revise the 1948 Standards on Radio Receivers.

—W. S. Skidmore

T. H. Story (DEP Surface Communications Engineering) has been appointed Chairman of the Papers and Meetings Committee of the Philadelphia Section, AIEE for the 1957-1958 term. *—T. T. N. Bucher*

J. H. McCusker, of Components Division's Needham Laboratory has been appointed to the Commonwealth of Massachusetts Advisory Committee in the field of Electronics as a member of the Massachusetts Apprenticeship Council and the Division of Apprentice Training. The first meeting of this committee was held on June 15, 1957. The Massachusetts Apprenticeship Council is made up of three appointed members representing management, and three appointed members representing labor, and two *ex-officio* members and the director of the Division.

—T. A. Richard

REGISTERED PROFESSIONAL ENGINEERS

The following names have been added to the RCA ENGINEER list of registered professional engineers:

Name	State	Licensed As	License No.
DEP Airborne Fire Control, Camden			
Dr. Morton I. Radis	Pa.	Prof. Eng.	2172-E
DEP Airborne Communications and Navigation Engineering, Camden			
Albert R. Alter	Pa.	Prof. Eng.	3440-E

NEW PUBLICATIONS OF INTEREST TO RCA ENGINEERS

NEW BOOKLET ON TRANSISTORS AND SEMICONDUCTOR DIODES

A new 24-page booklet, titled "RCA Transistors and Semiconductor Diodes" has been published by the RCA Semiconductor Division.

The booklet contains a general explanation of transistor theory and operation, with a specific section devoted to the RCA-developed 'drift' type transistor. Complete characteristic data on the 18 RCA types of transistors and four semiconductor diodes are supplemented by equivalent circuits and dimensional outlines.

The booklet contains an Interchangeability Directory, and concludes with eight pages of circuit diagrams which illustrate 20 applications of RCA transistors and diodes.

NEW BOOK ON ATOMIC RADIATION AND ITS EFFECTS

Publication of a new 120-page book on atomic radiation and its effects was announced recently by the Government Service Department, RCA Service Company, Inc.

The book, "Atomic Radiation," discusses, in simplified terms, nuclear physics, observed biological effects of radiation, shielding methods, monitoring instruments, permissible radiation doses and medical evaluation of injuries and treatments.

APPLICATION NOTES

AN-170

REDUCTION OF SNIVETS INTERFERENCE IN TELEVISION RECEIVERS . . . This Note discusses the problem of "snivets" interference in television receivers, points out probable sources of such interference, and describes several methods by which the interference may be reduced through careful circuit design, chassis layout, and lead dress.

AN-171

ANODIZED ALUMINUM OR MICA WASHERS FOR INSULATED MOUNTING OF RCA-2N301 and 2N301-A TRANSISTORS . . . This Note describes a method for mounting RCA-2N301 and RCA-2N301-A power transistors which provides electrical insulation of the collector electrode from the chassis without appreciable reduction in heat-transfer efficiency.

NEWLY AWARDED DEGREES

DEFENSE ELECTRONIC PRODUCTS

S. Aron, Missile and Surface Radar Engineering; M.S. degree in Electrical Engineering, Drexel Institute of Technology.

F. E. Beaumont, Missile and Surface Radar Engineering; B.S. degree, Drexel Institute of Technology.

O. N. Bowen, Missile and Surface Radar Engineering; M.S. degree, Drexel Institute of Technology.

F. D. Covely, Surface Communications Engineering; M.B.A. degree, Drexel Institute of Technology.

F. DiFelice, Missile and Surface Radar Engineering; B.S. in Mechanical Engineering, Drexel Institute of Technology.

R. B. Dyson, Special Systems and Development, M.S. degree in Mechanical Engineering, University of Pennsylvania.

M. Feryska, Surface Communications Engineering; M.S. degree in Electrical Engineering, University of Pennsylvania.

B. Goldstone, Airborne Systems Engineering; M.S. degree in Electrical Engineering, Moore School of Electrical Engineering, University of Pennsylvania.

A. A. Gorski, Missile and Surface Radar Engineering; M.S. degree in Electrical Engineering, Drexel Institute of Technology.

W. B. Harris, Surface Communications Engineering; M.B.A. degree, Drexel Institute of Technology.

John Jarem, Missile and Surface Radar Engineering; M.S. degree in Systems Engineering and Operations Research, University of Pennsylvania.

N. I. Klavens, Surface Communications Engineering; M.S. degree in Electrical Engineering, Drexel Institute of Technology.

Paul Levi, Missile and Surface Radar Engineering; M.S. in Mechanical Engineering, University of Pennsylvania.

N. Lesso, Missile and Surface Radar Engineering; M.S. in Electrical Engineering, Drexel Institute of Technology.

Frank Low, Missile and Surface Radar Engineering; M.S. degree in Electrical Engineering, University of Pennsylvania.

R. A. Merkh, Missile and Surface Radar Engineering; B.S. degree in Mechanical Engineering, Drexel Evening College.

E. S. Miller, Airborne Systems Engineering; M.S. degree in Aeronautical Engineering, Drexel Institute of Technology.

A. J. Montimuro, Special Systems and Development, M.S. degree in Physics, Drexel Institute of Technology.

R. Orth, M.S. in Electrical Engineering, Drexel Institute of Technology.

C. Pappas, Missile and Surface Radar Engineering; M.S. in Electrical Engineering, University of Pennsylvania.

R. W. Plummer, Missile and Surface Radar Engineering; B.S. in Electrical Engineering, Drexel Institute of Technology.

Augustus Prince, Airborne Systems Engineering; M.A. degree in Physics, Drexel Institute of Technology.

D. L. Pruitt, Missile and Surface Radar Engineering; M.S. in Electrical Engineering, University of Pennsylvania.

G. Rauscher, Surface Communications Engineering, recently received his diploma with honors from Drexel Institute of Technology. He has won the George W. Childs scholarship which will assist him in continuing his work toward his degree.

W. C. Reise, Surface Communications Engineering; M.S. degree in Mechanical Engineering, Drexel Institute of Technology.

A. L. Rizzo, Missile and Surface Radar Engineering; B.S. degree in Mechanical Engineering, Drexel Evening College.

O. E. Rosner, Airborne Systems Engineering; M.S. in Electrical Engineering, Drexel Institute of Technology.

Leonard Siegal, Missile and Surface Radar Engineering; M.S. degree in Electrical Engineering, University of Pennsylvania.

A. Sinclair, Missile and Surface Radar Engineering; B.S. degree in Electrical Engineering, Drexel Institute of Technology.

J. H. Smith, Missile and Surface Radar Engineering; M.S. degree in Electrical Engineering, Drexel Institute of Technology.

K. T. Strickland, Airborne Systems Engineering; M.S. degree in Electrical Engineering, Drexel Institute of Technology.

D. E. Townsend, Jr., Special Systems and Development, Masters degree in Physics, Drexel Institute of Technology.

INDUSTRIAL ELECTRONIC PRODUCTS

H. W. Clay, BIZMAC Engineering; B.S. degree in Mechanical Engineering, Drexel Evening College.

F. J. Hermann, Manager of Scientific Instruments, Industrial Electronic Products; M.E.E. degree, Drexel Institute of Technology.

Leon Levy, BIZMAC Engineering; M.S. degree in Electrical Engineering, Harvard University.

R. R. Wolf, BIZMAC Engineering; B.S. degree in Electrical Engineering, Drexel Evening College.

SEMICONDUCTOR DIVISION

Four engineers at the Somerville Plant received Master of Science degrees in June of this year. They are:

John D. Amitrani — Applied Statistics and Quality Control, Rutgers University.

Herbert R. Meisel — Management Engineering. Newark College of Engineering.

James W. Ritcey — Industrial Engineering. Stevens Institute of Technology.

Stephen C. Simons — Electrical Engineering. Newark College of Engineering.

RADIO AND "VICTROLA" DIVISION

A. J. Mannino, Components Engineer in Radio and Phonograph Engineering, was granted a degree of Master of Science in Applied Statistics and Statistical Quality Control by the Graduate School of Villanova University in June.

ELECTRON TUBE DIVISION

Norman Goldstein, Tube Development Shop of Lancaster's Color Kinescope Engineering, Master's degree in Physics from Franklin and Marshall College.

ENGINEERING MEETINGS AND CONVENTIONS

October-November, 1957

OCTOBER 7-9:
National Electronics Conference, IRE, AIEE, RETMA, SMPTE, Hotel Sherman, Chicago.

OCTOBER 7-11:
American Institute of Electrical Engineers, Fall General Meeting, Chicago, Ill.

OCTOBER 9-11:
Fourth Annual Symposium on High Vacuum Technology, Committee on Vacuum Techniques, Hotel Somerset, Boston, Mass.

OCTOBER 9-12:
New York High Fidelity Show, Presented by the Institute of High Fidelity Manufacturers, N. Y. Trade Show Bldg., New York City.

OCTOBER 16-18:
IRE Canadian Convention, Automotive IRE Canadian Convention, Automative Building, Exibition Park, Toronto,

OCTOBER 21-26:
Institution of Radio Engineers Australia, Annual Convention, IRE, Hotel Australia, Sydney, Australia.

OCTOBER 24-25:
Annual Aircraft Electrical Society, Pan Pacific Auditorium, Los Angeles.

OCTOBER 24-26:
Fifty-fourth Meeting, Acoustical Society of America, Ann Arbor, Michigan.

OCTOBER 28-31:
Second Winter Meeting, American Nuclear Society, Henry Hudson Hotel, New York City.

OCTOBER 31-NOVEMBER 1:
Professional Group on Nuclear Science, Fourth Annual Meeting, Henry Hudson Hotel, New York, New York.

OCTOBER 31-NOVEMBER 1:
1957 Electron Devices Meeting, PGED, Shoreham Hotel, Washington, D. C.

NOVEMBER 2-8:
Second World Metallurgical Congress and 39th National Metals Exposition, International Amphitheatre, Chicago.

NOVEMBER 2-10:
1957 *International Congress of Measuring Instrumentation and Automation, Interkama, Dusseldorf, Germany.*

NOVEMBER 4-6:
Third Annual Symposium on Aeronautical Communications, PGCS, Hotel Utica, Utica, New York.

NOVEMBER 11-13:
Third Instrument Conference, IRE, PGI, Biltmore Hotel, Atlanta, Ga.

NOVEMBER 11-13:
Radio Fall Meeting, PGBTS, PGBTR, PGED, PGRQC, RETMA, King Edward Hotel, Toronto, Canada.

NOVEMBER 13-14:
Mid-America Electronics Convention (Ninth Annual Technical Conference) sponsored by Kansas City Section of IRE, Municipal Auditorium Arena, Kansas City.

NOVEMBER 18-20:
Conference on Magnetism and Magnetic Materials, AIEE, APS, IRE, ONR, Sheraton-Park Hotel, Washington, D. C.