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.

•

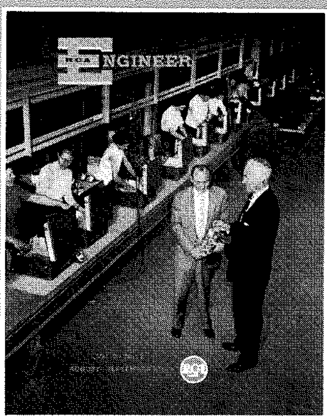
To help publicize engineering achievements in a manner that will promote the interests and reputation of RCA in the engineering field.

•

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

P. A. Collier, Manager, Manufacturing Engineering and C. E. Miller, Manager, Cambridge Resident Engineering, are observing the amplifier used in the stereo-orthophonic "Victrolas" being assembled on a conveyor line. This is one of sixteen assembly conveyors used to produce the "Victrola" line of stereo-orthophonic instruments, tape recorders, table and clock radios, and transistor portable radios. The Plants Parts Manufacturing produces most of the metal parts used in the assembly of these units. Stereo-magnetic record-play and erase heads and stereo disc pick-ups are also produced at Cambridge.

FOREIGN COMPETITION

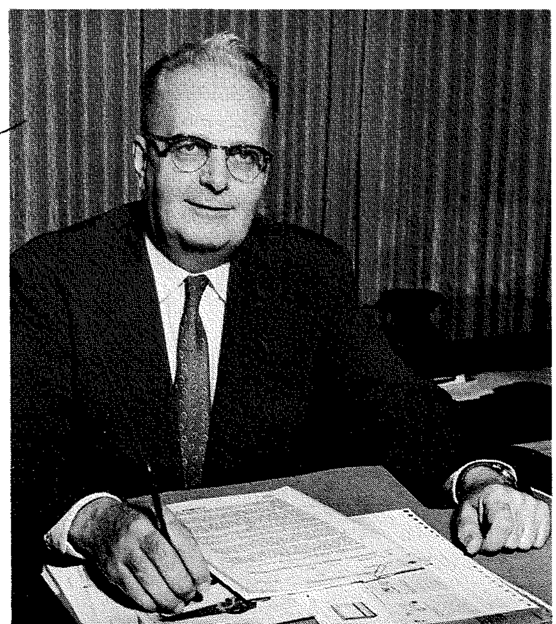
It's not news to any of us that the United States position in world trade is changing. Our exports are dropping and our imports are increasing. In RCA we are feeling the effects of foreign competition in various areas. In Home Instruments the impact of imports from both Europe and Japan is substantial, particularly in the small transistor-radio field. In the future we can expect to feel increased competition in other areas.

It would appear that we Americans are trying to be as helpful as possible to our foreign competitors. Each year we inflate the dollar a little more and each time we do it the foreign competition finds it easier to capture our markets, both foreign and domestic, and we find it harder to sell our products. In addition we act like we "had it made" — like no one could possibly compete with us and all we have to do is to divvy up the spoils.

These foreign competitors, who are now starting to hurt us, earn about 1/10 to 1/3 as much as Americans. But they have always earned much less than we. Why then haven't they hurt us before? Low wages result in low costs only when they are combined with modern production techniques. They are now in the process of mastering these techniques.

We engineers owe a double responsibility to our country, to our children and to ourselves. One responsibility is to use the logic and the reasoning powers of which we are so proud to analyze what is going on around us and then to guide our fellow men along economic lines which are best for our long term interests.

Our second responsibility is to develop our technology fast enough to keep ahead of the foreign competition. We haven't been doing nearly well enough and they have been catching up to us. Because we engineers are largely responsible for the growth of technology, the alternatives are obvious. Either we live up to our responsibility and develop rapidly enough and efficiently enough to keep ahead of the competition or we concede defeat.



E. I. Anderson,
Chief Engineer,
RCA Victor Home Instruments
Radio Corporation of America

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Send all inquiries to Bldg. 2-8, Camden, N.J.

OUTLOOK: RADIO "VICTROLA" PRODUCTS

By

RAYMOND W. SAXON,

Vice President

RCA Radio "Victrola" Products

RCA Victor Home Instruments

Cherry Hill, N. J.

Today—more than ever before—the public insists on quality and dependability in home entertainment. Moreover, the consumer is continually changing his living habits and requires a constant flow of new products. This demand for increased utility and innovation in a product, that will induce the incentive to buy, presents a challenge to all of us in management, engineering, production, and marketing.

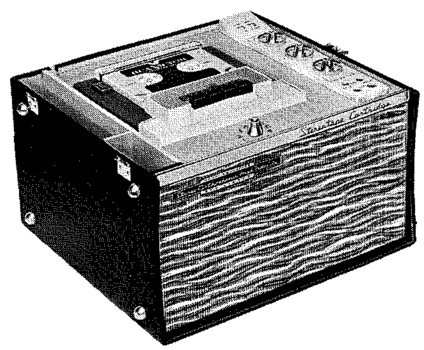
ACHIEVEMENT AND JOINT EFFORT

Shortly after the turn of the century, the Victor Talking Machine Company made the "Victrola" a fixture in every living room. Since then, RCA has continued to play a major part in a succession of electronic developments for the American home including AM-and-FM radio, black-and-white and color television. Four years ago, we introduced packaged high fidelity to the mass market and more recently became the first major company to popularize Stereophonic Sound—initially with Stereotape players, and soon thereafter with a complete line of Stereophonic "Victrolas."

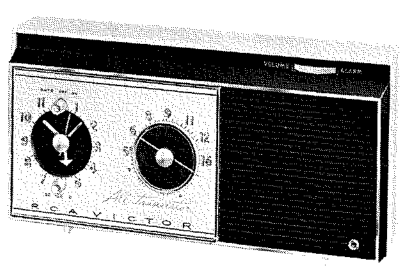
The old standbys are continually being reborn in radically improved forms as the state of the art expands. Witness, for example, the tremendous impact of the "transistor" on portable radio design, and the improved table radio reception provided by the "Filteramic Antenna." Our latest development is the stereo tape-cartridge player-recorder. This system has revolutionized the industry by making tape as simple to play as a record.

Each of these achievements results from management, engineering, marketing, and production working together as a team. This joint cooperation is a necessity due to the competitive nature of our business. The time

The TPR-8 Stereo-Orthophonic High-Fidelity Combination AM/FM Phonograph Console with Swing-Out Detachable Speakers. Among unusual features are separate AM and FM tuners and speaker balance.



The SCP-2 Stereo-Orthophonic High-Fidelity Tape Cartridge Player Recorder, an innovation in tape reproduction—an RCA "first."



The TC-1 All-Transistor Clock Radio, the first of its kind with a self-charging clock battery.

lapse between the birth of an idea and its introduction as a product to the consumer is very critical. Once a product is decided upon, the major burden of speeding the design to completion must be assumed by engineering. The important part research and engineering played in developing RCA's position of leadership in the home entertainment field is well known. Presently, as in the past, we look to the scientist and engineer for the new ideas necessary for our continued growth.

CURRENT INTEREST IN STEREO

The great public interest in stereophonic sound gives us a fine marketing opportunity. Due to RCA's pioneering efforts in stereo, we have attained a position of leadership in this new business. The trend of record sales is a good indicator for this market. Although the first stereo record players were introduced only a little over a year ago, the RCA Victor Record Division reports that 40 per cent of all Red Seal records being sold are stereo, and that 14 per cent of all record owners are now equipped to play stereo records. These figures are increasing day by day as a result of the increasing sale of stereo players and the many stereo record promotions on the market.

BUSINESS OUTLOOK

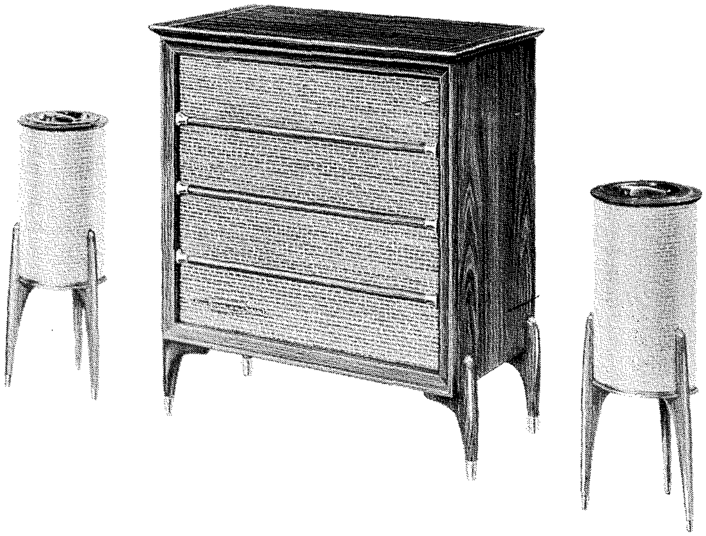
All signs point to a good year in the entertainment business, and the long range economic forecast predicts constantly increasing prosperity for those who are in the forefront of the business. Most major manufacturers look for an increase of approximately 30 per cent to 50 per cent in the sale of stereo equipment. According to all available sources, an industry sale of more than one-half billion dollars will be attained in phonographs, phonograph combinations, and tape recorders alone.

NEW STEREO EQUIPMENT

Stereo is not limited to tape and records alone. The newest development is its application in the field of broadcasting and promises to open new horizons for the radio and television industry. Even now there is limited programing of stereo, both experimentally and commercially, and RCA plus some other manufacturers have incorporated in their equipment provisions for receiving these broadcasts. The simultaneous reception of separate FM and AM channels is rapidly being supplemented by other more desirable methods. Techniques that permit the broadcasting and receiving of complete stereo information over a single FM or AM channel, look very promising. Our research and engineering departments are fast at work determining the most suitable means for broadcasting stereo—consistent with the best interests of the public and industry.

CONTINUING CHALLENGE

General Sarnoff very aptly stated that "there is no security in standing still; those who rest on the rock of stabilization sooner or later find that rock becomes their tombstone." This philosophy is particularly applicable to the consumer products' part of RCA's business. The many developments forthcoming from our scientific and engineering laboratories will help us meet the challenge of the future, with new and exciting products, guaranteeing our position of leadership for home entertainment in the years ahead.



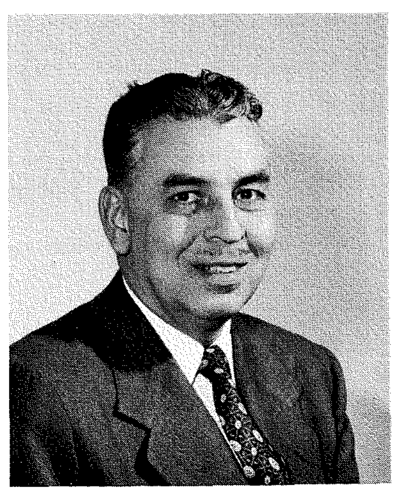
The PS-16 three-piece Stereo-Orthophonic High-Fidelity Phonograph features cylindrical-designed satellite Speakers for mid-range and high frequency.

RAYMOND W. SAXON is presently Vice President RCA Victor Radio "Victrola" Products. He rejoined the Consumer Products organization in February, 1958.

Mr. Saxon formerly was Director, Regional Operations, with supervision of RCA's eight regional offices, a post he had held since September, 1956.

Joining RCA in 1940, Mr. Saxon has served as Manager of RCA's Northeastern Region and General Sales Manager of the RCA Victor Television Division among other duties.

A member of the RCA Victor Award of Merit Society, Mr. Saxon received this highest honor the company can bestow on a salaried employee in 1949.



SOME HISTORICAL NOTES ON TERMS

Orthophonic High Fidelity Stereophonic

By
S. V. PERRY
Advanced Development Engineering
RCA Victor Home Instruments
Cherry Hill, N.J.

Editor's Note: Some of the terms used in this issue of the RCA Engineer have interesting backgrounds — "stereophonic," "orthophonic," and "high-fidelity" are woven deeply into the historical structure of RCA. They come to us not as newly coined words, but as part of our rich heritage in RCA engineering eminence from the formative years of the electronics industry to the present time.

We have asked Sydney Perry, who has been continuously engaged on acoustic development work since 1923, to describe these terms in light of their meaning to us today. For Mr. Perry's Biographical Sketch, see Vol. 2, No. 6, p. 52.

ORTHOPHONIC

THIS TERM dates back to the middle '20's, when the Victor Company made its first major step toward improving home phonograph reproduction. Previous phonographs had used a short horn driven at its small end by a mica diaphragm actuated by a lever system directly from the record groove, through a steel needle. Victor contracted with Western Electric Company to "modernize" its recording and reproducing set-ups. This development resulted in electric recordings using condenser microphones, amplifiers, and electrically driven cutters. The reproducing phonograph was redesigned, using a long exponentially curved horn, ingeniously folded into a cabinet of moderate dimensions. It was still mechanically driven from the record groove by a steel needle and a lever system, but the "sound box" was redesigned for smoother performance, and employed a corrugated aluminum diaphragm. The overall result was a striking improvement over previous phonographs. The treble response was much smoother and somewhat extended upwards in range, and the bass response was vastly improved. There was also a worthwhile improvement in loudness due to the extension of both bass and treble ranges, and due to the improved efficiency of both the horn and the "sound box". This instrument was known as the "Orthophonic Victrola" and very rapidly established itself as the leader in tone quality.

The name "Orthophonic" (from the Greek *orthos* and *phone*) signified "straight," "right," "true," or "correct" sound. Despite its improved performance the "Orthophonic Victrola" did not last very long commercially because it was soon replaced with the Electric Victrola, using an electromagnetic pickup, electric amplifier and loudspeakers. This was the advent of "all electric" reproduction, first used about 1928. The electric phonograph was very versatile, from the designer's viewpoint, and could be made to yield almost any desired degree of performance, depending only on the cost and the state of development of the art at the particular time. The work of improving phonograph reproduction, both in the record and in the reproducer, has continued unabated since about 1928, taking full advantage of development of vacuum tubes and amplifiers.

HIGH FIDELITY

This term signifies a high degree of faithfulness of reproduction. It has no exact technical definition. It came into use in the early '30's when, despite the depression, a serious effort was made to improve the quality of phonograph reproduction. The use of dynamic speakers and adequate amplifiers had improved the response in the bass region to the point where the deficiency in reproduction was obviously at the treble end of the scale. A great deal of work was done to improve the treble (or high-frequency) response in both the recording and the reproducing processes, and the resulting improved instruments were known as "High-Fidelity" instruments. This work was interrupted by World War II but was picked up again in the early post-war period. Perhaps the most important of all the improvements in this period were the introduction of magnetic tape into the recording process and the adoption of vinylite as the record material. These changes reduced the surface noise on the records almost to zero, thereby removing the one overwhelming disadvantage of extended high frequency reproduction. This made the reproduction of the entire audio spectrum (to or beyond 20,000 cycles) feasible and desirable. It also spurred increased engineering development both in the recording and reproducing fields, and ushered in the era of "High-Fidelity" for both records and home reproducing systems.

It was soon found that full reproduction of the audio frequency range does not necessarily give lifelike reproduction of the original sound. A great deal of work was done worldwide by all recording companies to improve the "quality" of recorded sound. Besides purely technical problems of recording and duplicating, it was found that studio technique, microphone type and placement, room reverberation, and such factors, all have a distinct bearing on the "naturalness" of the sound. During this development, the terms "New Orthophonic" and "High-Fidelity" were applied to records made by RCA. Reproducers have been designated "New Orthophonic High Fidelity."

STEREOPHONIC

All of the developments cited above gave improved performance of recorded music in the home, but still some factors were lacking for perfection. One of these was the spatial separation of various sound sources in a multisource program. Without going into all the details, two-channel stereophonic sound, properly reproduced in the home, produces a remarkable degree of spatial separation of instruments and other sound sources, adding to the realism of reproduced sound. This is stereophonic reproduction.

The combination of "High Fidelity" with "Stereophonic" reproduction has produced the present high degree of realism in reproduction. Reproducers incorporating these principles have been designated as "Stereo-Orthophonic High Fidelity" instruments.

Even with this high degree of development in the state of the art, however, perfection remains a goal, and there is still room for future developments resulting in even better fidelity and realism. Certainly, such development will result in our enjoyment of new devices, and the addition of new terms to our vocabulary.

CAMBRIDGE - THE "HIGH-FIDELITY" CAPITAL OF THE WORLD

by

T. F. WHITTEN, Plant Mgr.
TV & Radio "Victrola" Production
RCA-Victor Home Instruments
Cambridge, Ohio

THE RADIO CORPORATION of America acquired the Cambridge Plant facilities from the Continental Can Company in March, 1953, and assumed possession on April 15 of that year. Originally our production requirements were to produce from 500,000 to 1,000,000 parts annually for Television, Radio, and "Victrola" products. Parts fabricating equipment, as well as small-parts assembly area, were immediately installed and the first parts, detent plates and assemblies for TV tuners, were manufactured in May. June saw the first "Victrola" line placed into production marking RCA's re-entry into the highly competitive record changer manufacturing business from which it had been absent since 1952.

The original 135,000 sq. ft. plant was soon outgrown due to the increasing tempo of sales in the RCA Victor Radio and "Victrola" Division and during 1955 ground was broken for an additional 220,000 sq. ft. of much-needed manufacturing and warehousing space. The 3-Speed and "45" "Victrola" record changer production had increased by 67% during 1956 as compared to 1954, the first full year of operation. By the end of 1958 over two million "45" changers, our largest item, had been produced. A new product for the Cambridge Plant and the Radio and "Victrola" Division—the tape recorder and player—was introduced in 1956; and, was our first venture into the manufacture of low-cost domestic magnetic tape equipment. Our production and experience up to this point had been devoted entirely to parts fabrication and record changer production.

The new plant facilities were completed in 1957 and dedicated as "The High-Fidelity Capital of the World." The plant now has sixteen assembly lines which can be converted to various models as production schedules require. Three assembly lines to produce the RCA "Security Sealed" circuit board are included for the production of certain radio models. With the additional manufacturing facilities, capacity of the plant increased to a capability of producing 8700 units in a single eight-hour shift, or 18 units a minute.

NEW EXPANSION—NEW EQUIPMENT

In keeping with the growing demand of increased "Victrola," and tape equipment production, our Parts Manufacturing facility expanded with the addition of new equipment. Of all the metal parts used for the production of instruments at our plant, 80% are fabricated by this facility, and some of the most recently developed manufacturing techniques are employed to produce these parts.

The revolutionary new concept of the Stereo-Magnetic Tape Cartridge instruments required new equipment for production of magnetic record-play and erase heads. We also developed techniques for producing the 45°-45° system stereo disc pickups. We were again confronted with a business new to us and considerable development was necessary to meet the requirements of high quality mass production techniques with a minimum of time.

A full line of radio production was introduced at Cambridge in January of this year with Transistor Portable, AM Table, AM Clock, and AM-FM Table radio lines. Only a few short production runs were manufactured at Cambridge prior to this year.

The Cambridge Plant has shown a growth from 600 to over 2700 employees and the production facilities have nearly tripled in size since we came to Cambridge six years ago. Production for this year will more than double the 1958 figure. We have grown from a small Parts Manufacturing facility to a plant with the flexibility of producing a wide variety of units for the Consumer Products Division.

THOMAS F. WHITTEN graduated from Pennsylvania State University in 1938 with a B.S. Degree in Industrial Engineering.

His employment with RCA started in November, 1940 as a Timestudy Engineer with the Home Instrument Department in Camden, New Jersey. In 1942 he transferred to the Indianapolis Plant as Supervisor of Timestudy; and, in 1946 was made Manager, Manufacturing Engineering. He was appointed Manager, Manufacturing at the Indianapolis Plant in 1951, and served in this capacity until being promoted to Plant Manager of the Cambridge Plant in March, 1953.

A view of the entrance to the Cambridge Plant Offices. The plant was originally intended for a Parts Fabricating facility and has grown since its opening in 1953 to become the "High Fidelity Capital of the World."

Fig. 1—Aerial view of RCA Victor's Radio and "Victrola" plant at Cambridge, Ohio —world's largest and most modern factory producing packaged high-fidelity and stereo units. It employs nearly 2700 persons and has sixteen assembly lines with a capacity for turning out 8700 high-precision instruments during an eight-hour shift.

MANUFACTURING ENGINEERING AT CAMBRIDGE

by

P. A. COLLIER, Mgr.

Manufacturing Engineering
TV-Radio & "Victrola" Production
RCA-Victor Home Instruments
Cambridge, Ohio

MANUFACTURING ENGINEERING at the Cambridge Plant is responsible for establishing manufacturing facilities and techniques required to produce various items from small metal parts to the largest combination Stereophonic "Victrola" AM-FM Radio Console marketed by RCA. It is one of few such activities that services both Parts and Assembly Manufacturing operations. Our organization consists of Parts and Assembly Manufacturing Process (including time study and parts tool design), Test Engineering, and Methods Development groups. In addition to meeting present day requirements they are constantly seeking new and better ways of doing the job so as to maintain Cambridge as the most modern and up-to-date plant (Fig. 1) of its type.

PARTS PROCESS, TIME STUDY AND TOOL DESIGN

This group is responsible for the facilitation and tooling of a wide range of Manufacturing equipment used to fabricate parts for the manufacture of record changers, and tape transports, and metal components for radio and television assemblies. Equipment for finishing operations (painting and plating), power presses, screw machines, drill presses, milling machines, and parts-assembly machines (for staking, welding, and riveting) make up the shop's facilities.

In the past few years several significant development projects have been placed in operation at the Cambridge Plant. Among these are mechanized welding lines and specially designed mechanized paint equipment. The welding operation is accomplished by using a projection welding technique, allowing many different size studs and brackets to be welded with the same time and heat settings. With four welding machines we are assembling approximately twenty parts to the underside of a record changer motorboard (see Fig. 2). The mechanized paint equipment was placed into full operation during 1958. This unit degreases, applies paint, and bakes the finish on our stereo record changer motorboards and turntables at a rate of 600 units per hour. The paint is applied in an enclosed room kept under pressure by

Fig. 2—A view of a conveyorized high-production resistance-welding line where each of four machine operators weld four to seven items to a 4-speed stereo record changer motorboard.

Fig. 4—A Boesch BW-2 Universal Coil Winder has been tooled to produce coil assemblies for the stereo tape head. Tooling is designed for automatic pyramidal winding of five layers of #39 wire on an insulated laminated core.

Fig. 5 — A high-vacuum evaporator is being used by Don Temple, Mgr., Methods Development, during the manufacture of stereo tape heads. Pressures of 1x10-4 mm of Hg are required for the evaporation process. Material being evaporated is silicon monoxide to develop the 90 micro-inch gap in the new tape head.

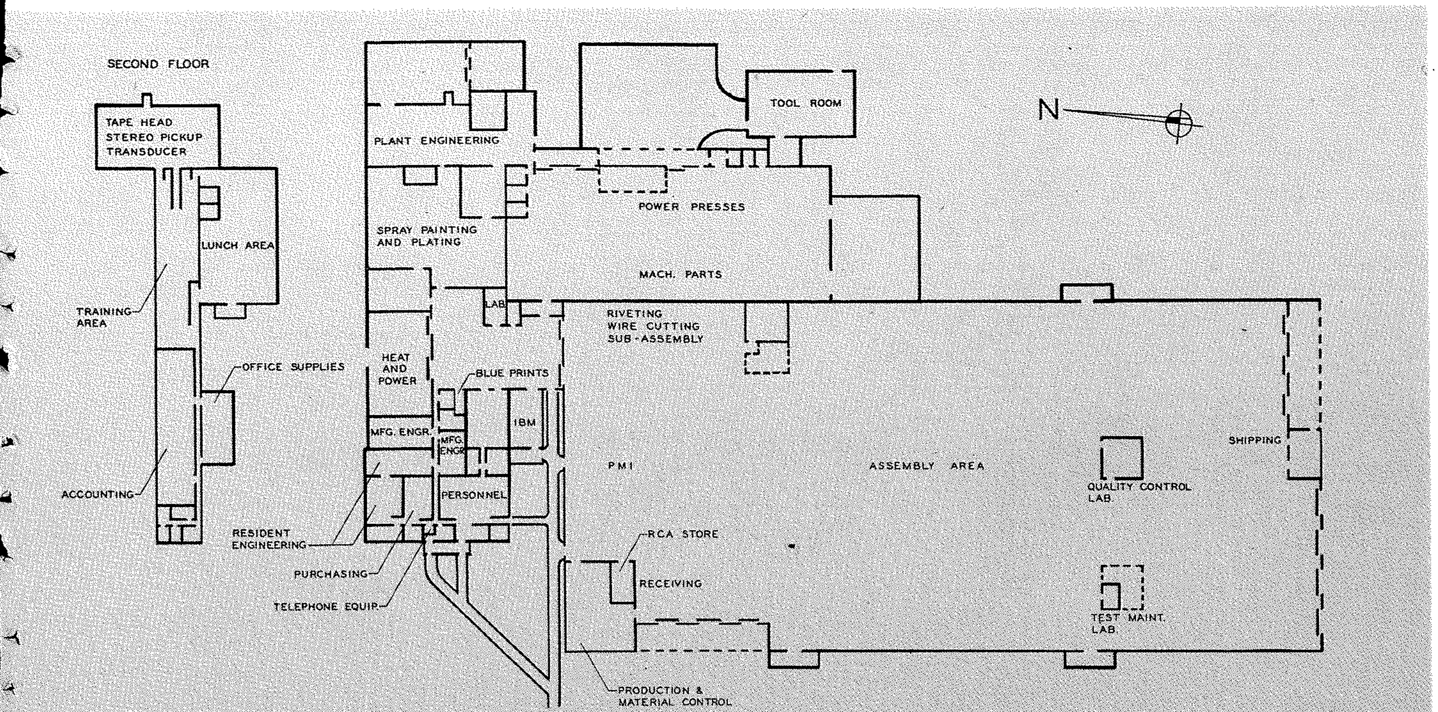


Fig. 3—Floor plan showing the arrangement of engineering, manufacturing, assembly, and service areas. A total floor area of 355,000 square feet accommodates production facilities that have nearly tripled in a six-year period.

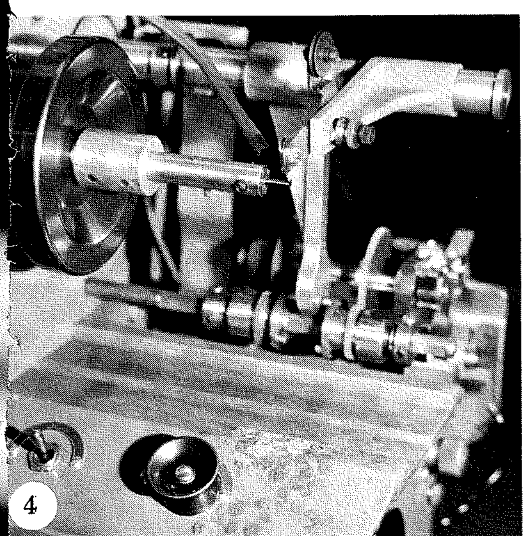
forced, filtered air and is programmed by means of "memory drums" to control preset spray guns.

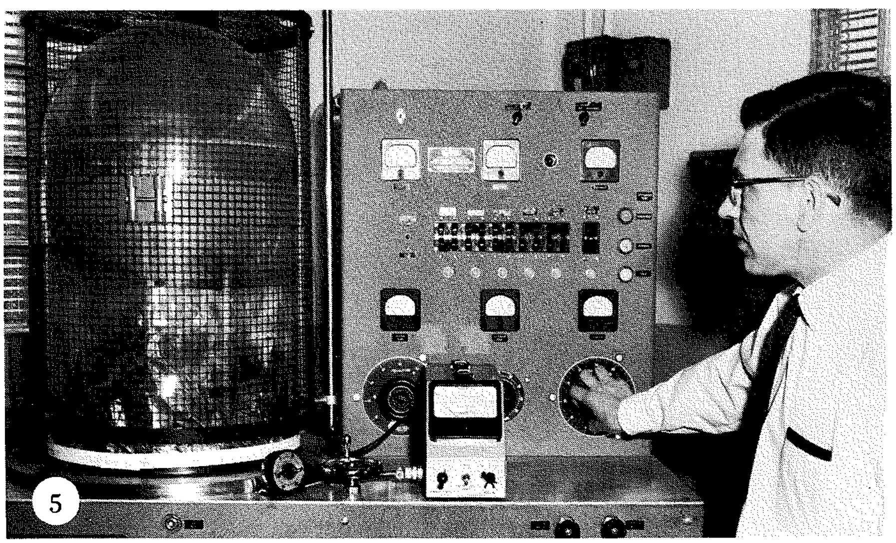
ASSEMBLY PROCESS AND TIME STUDY

In our Assembly Manufacturing activity, an additional 220,000 square feet of assembly manufacturing space was facilitated during 1957. The Assembly Process group provides all layouts of the production lines and facilities, the design of tools and fixtures, and the development of processes and time-studies used to control assembly operations in the manufacturing area (see Fig. 3).

Many innovations were developed by this group during the expansion period to make the Cambridge Plant one of the most versatile assembly plants in our type of industry. Some of these include adjustable-height instrument assembly conveyors, horseshoe conveyors, universal facilities racks which supply lights, power, air and regulated voltage for the assembly lines, special chain conveyors for amplifier production, and, special belt conveyors for radio, tape recorders, and record player production. There is also one "slat-type" conveyor installed for the assembly of the console type combination unit manufactured at the Cambridge Plant.

In addition to instrument assembly planning, as indicated before, the group handles such items as the 45°-45° stereo disc pickup. Pickup assemblies were new to the Cambridge plant and the stereo type further compounded the assembly difficulties that needed to be resolved. Individual elements were fragile in comparison with those of record changers and tape transports. Critical mechanical specifications and tight tolerances were necessary to achieve and maintain high performance standards. With the





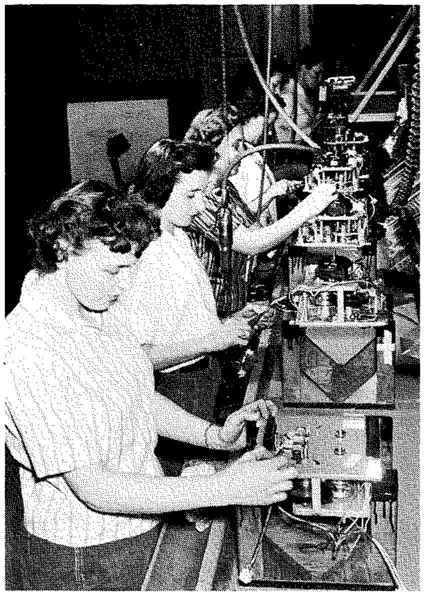


Fig. 6—A typical assembly line operation of the transport for the SCP-2 stereo tape-cartridge recorder. This type of assembly line is also used to assemble record changers, amplifiers, conventional radios and tape recorders.

help of Radio and "Victrola" Design Engineering and the Parts Manufacturing Tool Design Group, numerous technical difficulties were overcome. Techniques were developed that have resulted in high-quality production parts.

TEST ENGINEERING

Test Engineering is responsible for the design, construction, and maintenance of all electrical and mechanical test equipment in the plant. This group supplies information to the production floor by interpreting engineering data in terms of test processes.

A test signal generating room was designed by this group and was constructed in the vicinity of the manufacturing floor to transmit signals of various audio and radio frequencies to the many test positions. Two-channel input and output equipment was also included for use in the manufacture of stereo amplifiers.

Special equipment is always necessary when new or different products are introduced for manufacture. Specific examples are the 45°- 45° stereo disc pickup and the four-track stereo tape play-record head. In both instances it was necessary to provide a means of comparing production parts with a known standard of performance. The test equipment must not only be easy to operate, but must also be of the highest quality to make certain that performance of the production part is being accurately observed.

METHODS DEVELOPMENT

During the latter part of 1958, the Cambridge Plant began initial production of dual-track stereo tape heads. Since the Methods Development Group is responsible for the advance design, development, procurement and installation of improved production equipment and investigation of new manufacturing techniques, they were assigned the project of facilitating a production area for the manufacture of this component.

Fig. 7—A finishing and polishing operation is being performed on a SHC-6 "Victrola" console prior to packing the instrument for shipment. All large consoles are assembled by use of the slat-line conveyor shown here.

Fig. 8—These spinning machines are forming stereo record-changer parts. The machine rollers are activated by a foot lever to form round heads on the rivets of fastened parts.

Fig. 9—Coiled steel is fed automatically into straightening rollers before entering an 88-ton punch press in the Parts Manufacturing activity. This press is forming stereo record changer parts by use of a progressive die.

A number of specialized semi-automatic machines were developed and tooled for the fabrication of the tape head and related components. The coil winding equipment and head grinding machines were tooled by the Camden Equipment Development Group. Tooling developed for the winder includes an automatic layer indexing device designed to wind a lesser number of turns on succeeding layers. The head is ground on abrasive belt grinders using a 600-grit silicon-carbide belt, and infeed is automatically controlled by cams and microswitches.

A vacuum evaporator is used to develop the gap on the playback-record head. A deposit of quartz, forty-five micro-inches in thickness, is evaporated on each half of the head which gives an effective gap of ninety-micro-inches when the head is assembled. The thickness of the deposit is accurately controlled by an optical system. This compares the amount of deposit with the specific wavelength of the light source. Pressures of .03 microns are attainable with the evaporator, and the evaporation cycle is completed in the .03 to .1 micron range.

Prior to assembly, the case halves are lapped flat within six micro-inches.

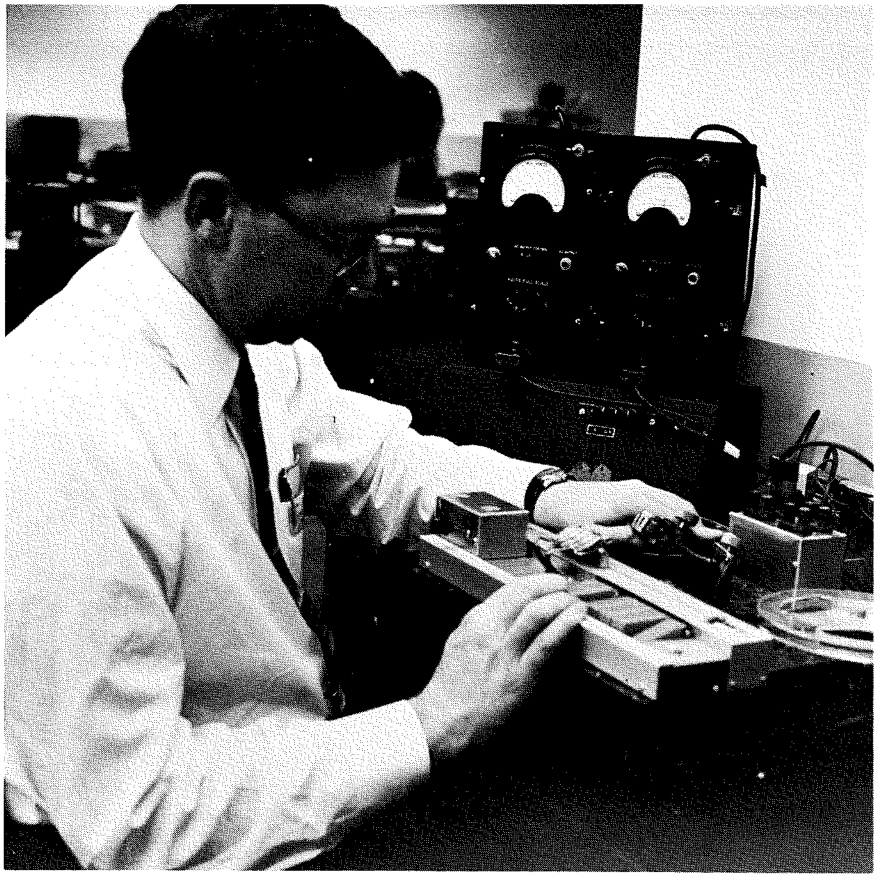


Fig. 10—Final head-test equipment. W. D. McComb, Mgr., Test Design and Process is shown making a final operational record and playback test on tape recorder heads.

P. A. COLLIER graduated from Purdue University in 1946 with a B. S. degree in Mechanical Engineering. He joined RCA in September, 1946, at the Bloomington, Indiana, Home Instrument Plant as a Process Engineer. In July, 1950, he was transferred to the Canonsburg, Pennsylvania, Plant as a Supervisor in the Manufacturing Engineering Activity. In March, 1952, he was appointed Manager, Manufacturing Engineering at the Canonsburg Plant before assuming his duties as Administrator, Manufacturing Facilities at Cambridge. In January, 1957, he was made Manager, Manufacturing Engineering.

A 12″ lapping machine has been adapted for this operation. Flatness is checked optically with a monochromatic light source and optical flats.

SUMMARY

These four groups, which comprise the Manufacturing Engineering activity, are constantly working closely together to tool, facilitate and establish direct labor requirements for the plant operations. From the time a new product design arrives from our Design Engineers, until production has been completed, a continuous program is maintained to utilize the most efficient manufacturing techniques available.

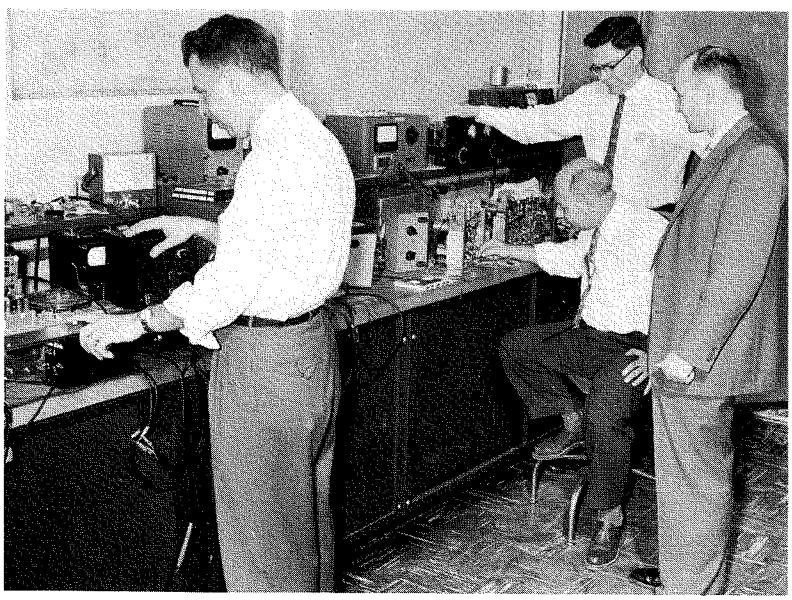


Fig. 11—Engineering Laboratory where test equipment is designed. On the left is the tape-head test equipment and on the right laboratory measurements are being made on the tape recorder amplifier. Shown are (l to r) R. C. Martin, R. C. Works (Design Engineers), W. D. McComb and P. A. Collier, the author.

Fig. 12 — A. J. Curry, Quality Control Inspector is shown operating a laboratory test setup for making Quality Control checks on the completed tape recorder instrument.

RESIDENT ENGINEERING AT CAMBRIDGE

By

C. E. MILLER, Mgr.

Resident Engineering
Radio "Victrola" Product Engineering
RCA Victor Home Instruments
Cambridge, Ohio

THE RESIDENT ENGINEERING Section at Cambridge serves as Engineering liaison between design and production groups to facilitate manufacture of Radios, "Victrolas," Tape Recorders, Components such as Tape Heads, Stereo Pickups and transducers, and the Parts Fabrication of various metal components. The activities of the department cover a broad scope in solving engineering and manufacturing problems for over 85 different instrument models, exclusive of color variations, scheduled for production during 1959. From the reproduction of VanDykes that arrive from the Radio & "Victrola" Design Engineering office at Cherry Hill until the instruments are shipped to the dealers, Resident Engineering is responsible for assisting in the maintenance of production in order to assure the most efficient operation.

DESIGN REVIEW

The production of each new model or component is preceded by a thorough review of the product design with the Cherry Hill engineers. Employing the design drawings and prototype instruments provided by Cherry Hill, this review eliminates foreseeable production problems before they occur. Consideration is given to available manufacturing facilities, experience gained from solutions of previous production problems—and the most economical tooling, fabricating and assembly methods consistent with good design and quality. Thus, a relatively smooth transition is made from the design stage to mass production of the finished product.

Prototype instruments received from Cherry Hill Design Engineering are checked for performance. These data are then correlated with Cherry Hill measurements made on the same home instruments. Based on these engineering tests, preliminary factory test specifications are issued, and the prototype instruments are retained as "standards" of performance. In the case of complex amplifiers and radio chassis, additional prototypes are provided by Cherry Hill to be used by manufacturing groups in establishing production processes.

Future pilot run and initial production dates are established prior to or concurrent with the design reviews. During the interim period, Resident Engineering directs its attention to component parts arriving at the plant in sample quantities for approval.

Fig. 1 — Quality is built-in approximately 120 model variations of "Victrolas", radios, and tape recorders scheduled for production during 1959 at the Cambridge Plant. Cambridge employees are made aware of the value of producing quality products through the use of quality displays such as the one shown here.

COMPONENTS APPROVAL

Sample lots from outside suppliers are checked by the Purchased Materials Inspection group which submits a report of its findings to Resident Engineering. Components manufactured by the Cambridge Parts Fabrication section are also evaluated and reported separately by that group.

In determining part acceptability, the reviewing engineers consider many factors such as the effect on production schedules, the quality of the finished product, the adaptability of the component to machine or assembly fixtures, and the possible need or extent of tooling changes. Occasionally, a compromise involving a minor tooling change of an associated part results in an overall major saving of time and expense.

Components and parts that are essentially "appearance" items are also approved by the styling and Merchandising groups at Cherry Hill. Resident Engineering issues M–forms in order to relay decisions on components to all interested sections. Purchasing can then arrange for the delivery of production quantities.

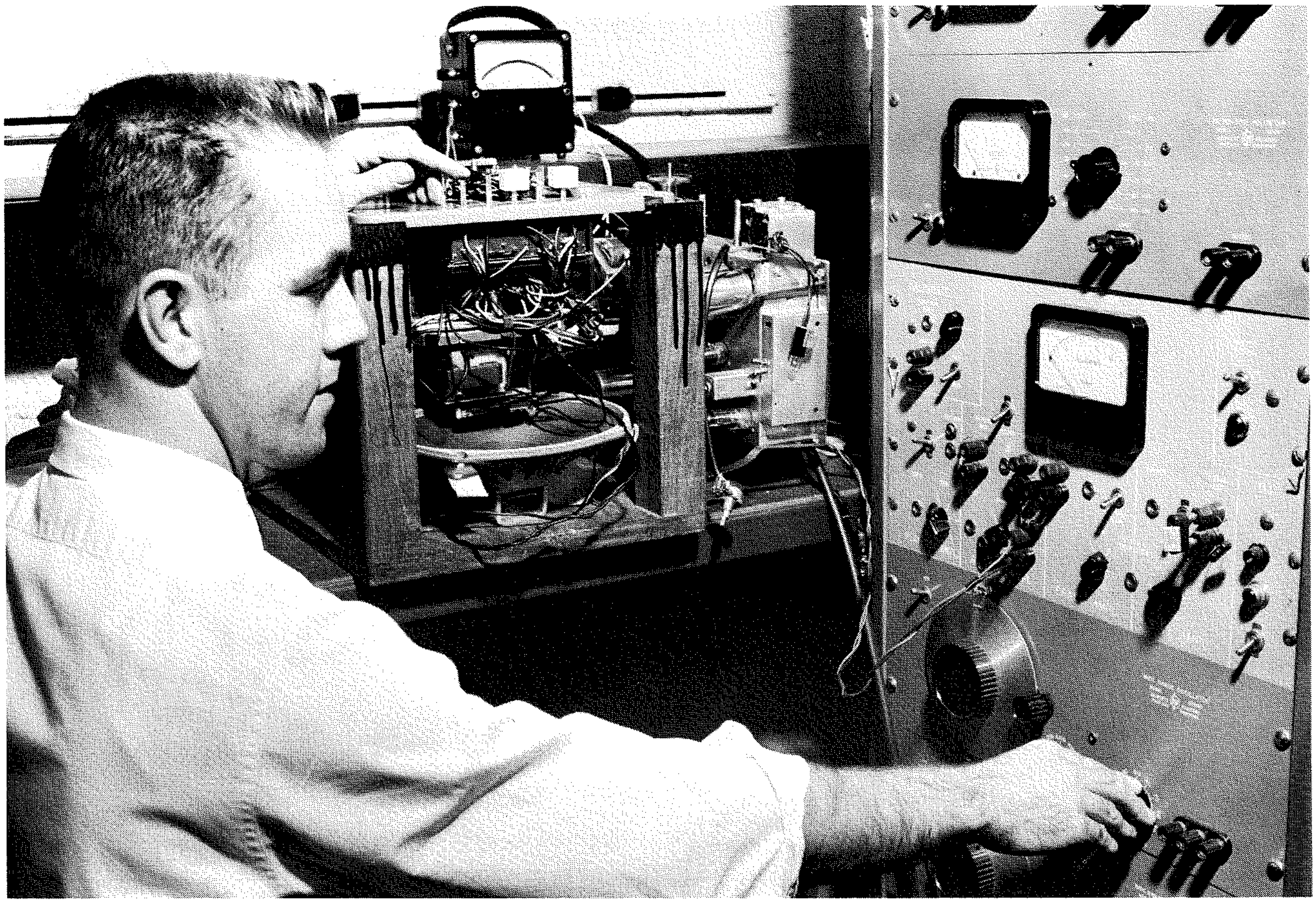


Fig. 2—Test equipment designed at the Cambridge Plant to determine tape-head response is being used by Jim Legault, Resident Engineer to inspect an automatic (TCT-1) Tape Transport. Many of the electrical circuits used in the Semi-automatic and Automatic Transports were developed by the Resident Engineering Group.

THE PILOT RUN

Pilot runs, of a limited quantity of instruments, are assembled by manufacturing personnel to prove in processes and obtain engineering approval of the model. Parts from the sample lots submitted are used for the pilot runs prior to initial production. Resident Engineering actively participates in this program, assisting in the solution of problems encountered with the first assembly of parts from mass production tooling.

A pilot run instrument, upon completion of tests by Manufacturing and Quality, is submitted to Resident Engineering. The instrument is checked for conformance with design specifications, discrepancies are noted, and the instrument and a report are sent to the design engineer at Cherry Hill for approval.

PRODUCTION FOLLOWUP

Final factory test specifications are then issued, based upon satisfactory evaluation of a representative quantity of "pilot-run" or early production instruments. From this stage on through the production run of the model, Resident Engineering is frequently called upon to solve problems encountered in production. Such problems invariably require "on-the-spot" solutions in the interest of preventing costly production curtailment. Frequently, such solutions are, of necessity, temporary in nature and must be followed with permanent changes which may involve tooling revisions or procurement of new parts to arrive at the most economical methods, consistent with quality.

Occasionally, however, the efforts of the Resident Engineer are extended to include unusual assignments. One such program, which should be of particular interest to readers of this "Orthophonic" issue of the RCA ENGINEER, is the product design of "Tape Cartridge Transports."

SPECIAL TAPE-TRANSPORT PRODUCT DESIGN PROGRAM

Because of the urgency of the new tape cartridge program and due to many favorable conditions, including proximity to tool design, tool shop and production facilities and personnel, the Cambridge Resident Engineering Section was assigned in January 1958, the added responsibility of completing the product design of two tape transports which had been developed by the Record Changer Engineering Section in Cherry Hill. Both of these transports, an automatic and a semi-automatic model, use the new tape cartridge.

The new concept of using a tape cartridge in place of the two tape reels created revolutionary design requirements in the transport mechanisms. The new cartridge system utilizes a maximum of four record-play tracks on standard $\frac{1}{4}''$ wide tape, at a tape speed of 3.75 inches per second.

C. E. MILLER joined RCA in July, 1935, as a Draftsman. In 1940 he was transferred to the Auto Radio Engineering Department as a Mechanical Engineer. In 1941 he was transferred to the Bloomington, Indiana Plant where he was responsible for the design of special mobile communications equipment manufactured for the Armed Forces. He returned to Camden in 1944 to resume his activities in the design of auto radios, and followed this program for three years as Manager of Mechanical Engineering for Auto Radios.

Prior to assuming his present position in April, 1953, he was Manager, Mechanical Engineering for the Radio and Phonograph Engineering Section of the Home Instrument Department.

Mr. Miller holds patents related to radio timing mechanisms and various types of tuning mechanisms applied to auto radios.

In utilizing four tracks on the same 1/4″ width tape formerly used to record only two tracks, the tape for the fully automatic transport traverses across the tape heads from one hub to the other. It is automatically reversed in direction and placed in the next track position. This transport plays all four tracks separately, or in pairs for stereo, and shuts off automatically upon completion. On the semi-automatic transport, the cartridge is turned over manually to play each succeeding track, or pair of tracks. This transport shuts off automatically after completion of each track. Both transports have fast forward and fast rewind functions.

TRANSPORT DESIGN REQUIREMENTS

The design requirements for the new transport were much more severe than those of the familiar two-reel type instruments. The enclosing of tape hubs and the tape itself within a cartridge, and the tape passing over three heads in place of the one or two previously used result in additional friction in the system. This condition, plus the fact that the uncoated side of the tape is driven by the capstan shaft, required additional driving force, more constant takeup torque, and generally closer tolerances to avoid speed variation and slippage.

The additional frictional loading along with the reduced play-record speed resulted in critical balance requirements of torque for takeup and fast forward and rewind drives. Considerable research was undertaken to design the clutches for this tape movement and to obtain the appropriate clutch facing material to overcome clutch chatter and excessive idler wear. Many new materials and lubricants for clutches, and rubber compounds for idlers were tested to obtain a suitable combination.

The limits for "wow" and "flutter," compared with previous models, were automatically reduced by 50% due to the requirement of obtaining at least equal performance at one-half the operating speed. Tolerances on many machined component parts were reduced to meet these conditions.

The design of the two transports was completed early in 1959. Both transports have been incorporated into instrument designs by the Radio Victrola Engineering Section at Cherry Hill. After rigid plant and field life tests of many pilot-run samples, the production of the semi-automatic model has proceeded smoothly since its start in May. Production of the automatic model is scheduled for August 1959.

MANY AREAS OF RESPONSIBILITY

An appreciation of the range of the responsibilities of the Cambridge Resident Engineering Section may be gained by considering the varied nature of the many products manufactured at Cambridge.

For example, during the time that the tape-transport program was progressing to completion, our basic Resident Engineering responsibilities were also increased when the first series of stereophonic "Victrola" instruments was produced. A newly designed stereo pickup was facilitated and produced; so also, were new tape heads for the cartridge transports, and a transducer for television remote controls. A great many radio instruments, including AM-FM receivers, clock radios, portables, "Security sealed circuit" and transistor models were transferred to Cambridge for production.

This continuous requirement for assistance from Resident Engineering throughout the production of such a diversified line of products presents a perpetual challenge to all the members of this department.

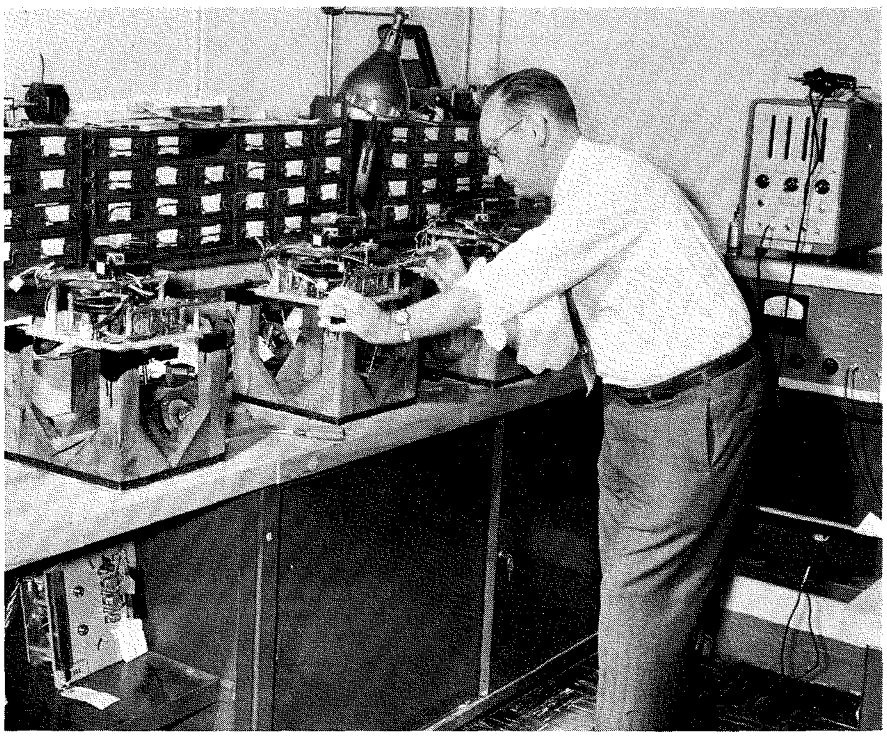


Fig. 3—Shown making adjustments to the Semi-automatic TCT-2) Tape Transport is Phil O'Connell, Mechanical Engineer, Resident Engineering Section.

A REVIEW OF STEREOPHONIC SOUND RESEARCH

by

DR. HARRY F. OLSON

RCA Laboratories

Princeton, N. J.

To achieve realism in a sound reproducing system four fundamental conditions must be satisfied, as follows: (1) The frequency range must be such as to include all the audible components of the various sounds to be reproduced. (2) The volume range must be such as to permit noiseless and distortionless reproduction of the entire range of intensity associated with the sounds. (3) The reverberation characteristics of the original sound must be approximated in the reproduced sound. (4) The spatial sound pattern of the original sound should be preserved in the reproduced sound.

Satisfying the first three conditions constitutes high fidelity, as the term is used today. The improvement in the performance of sound reproduction brought about by the advent of high fidelity has resulted in a greater interest in sound reproduction in all its aspects and ramifications than has existed at any time in its history. The next significant step in the consumer field is stereophonic sound which will satisfy condition four by providing auditory perspective of the reproduced sound. If the stereophonic sound reproducing system is a high-fidelity system, then all four conditions of realism are satisfied. However, the advantages of stereophonic sound are universal in that they can be demonstrated as distinct improvements in systems of all qualities of performance and frequency ranges.

The commercialization of stereophonic sound in the consumer field is developing at a rapid rate. For example, there are prerecorded stereophonic magnetic tape and stereophonic disk records with instruments for reproducing the recorded material.

Steps are now being taken with the object of developing practical stereophonic sound systems for frequency modulation radio, amplitude modulation radio and television sound which can be ultimately commercialized. The application of stereophonic sound in all the media could bring about a revolution in sound reproduction which might result in a large new business.

It is the purpose of this paper to present a general description of some of the aspects of stereophonic reproduction of sound as follows: a comparison with monophonic sound reproduction, auditory perspective, the applications in the home and the automobile, and the systems.

MONOPHONIC AND STEREOPHONIC SOUND REPRODUCING SYSTEMS

A monophonic sound reproducing system is a field-type sound reproducing system in which one or more microphones, used to pick up the original sound, are coupled to a single transducing channel which in turn is coupled to one or more loudspeakers in reproduction. A schematic diagram of a monophonic sound reproducing system is shown in Fig. 1. It is the most widely employed of all sound reproducing systems, and is used in disc phonographs, radio, sound motion pictures, television, magnetic tape reproducers and general sound systems. The sound at the microphone is reproduced at the loudspeaker. The transducer may be an amplifier, radio transmitter and receiver, a phonograph recorder and reproducer, a sound motion picture recorder and reproducer, a television transmitter and receiver, or a magnetic tape recorder and reproducer. The monophonic sound reproducer may be constructed to satisfy conditions 1, 2 and 3 on realism of sound reproduction. It cannot under any conditions satisfy condition 4.

The sterophonic sound reproducing system of greatest interest is a field type sound reproducing system in which two or more separately located microphones, used to pick up the original sound, are separately coupled to a corresponding number of independent transducing channels which in turn are separately coupled to a corresponding number of loudspeakers arranged in substantial geometrical correspondence to that of the microphones. A schematic diagram of a stereophonic sound reproducing system is shown in Fig. 2. The transducer may be an amplifier, radio transmitter and receiver, a phonograph recorder and reproducer, a sound motion picture recorder and reproducer, a television transmitter and receiver, or a magnetic tape recorder and reproducer. Two channels are used in the disc phonograph and radio. The stereophonic sound reproducer may be constructed to satisfy conditions 1, 2 and 3 on realism of sound reproduction. It can be constructed to provide auditory perspective of the reproduced sound and in this sense the stereophonic sound reproducer satisfies condition 4 on realism of sound reproduction.

Referring to Fig. 2 it will be seen that the subjective location of the reproduced sound sources corresponds to the physical location of the sound sources in the studio. A description of the subjective effects which lead to lateral and depth perception in stereophonic sound will be given in the section which follows.

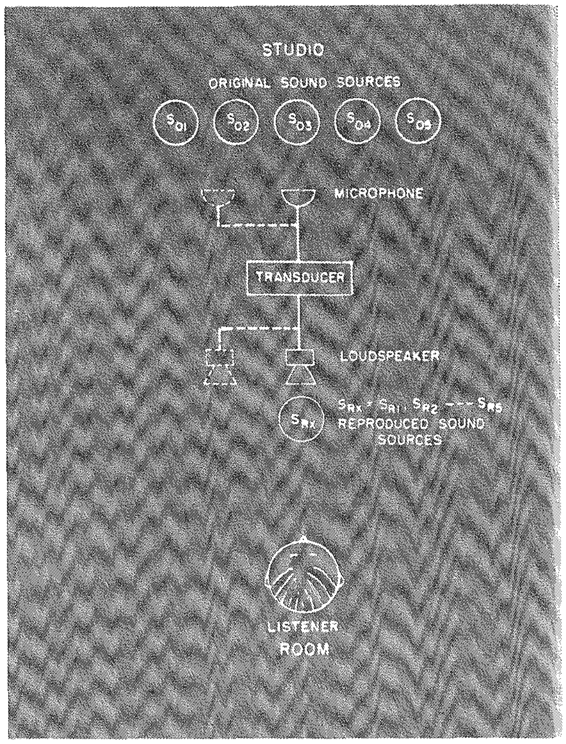
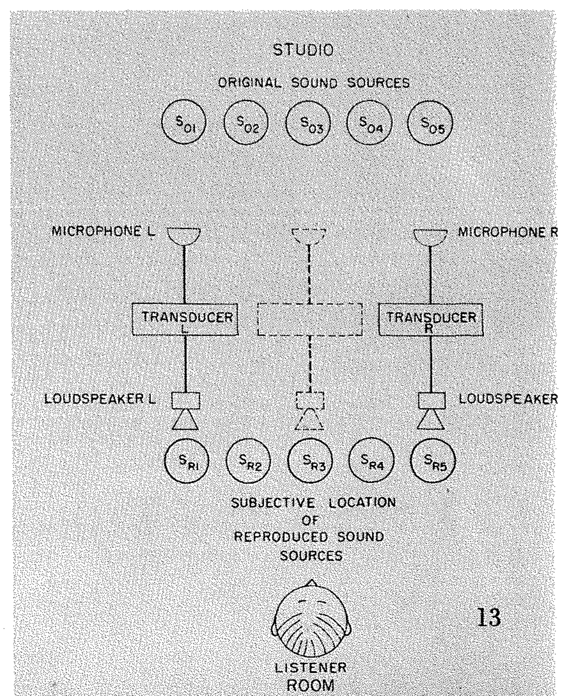


Fig. 1—A schematic diagram of a monophonic sound reproducing system.

Fig. 2—A schematic diagram of a stereophonic sound reproducing system.



AUDITORY PERSPECTIVE

Reproduction of sound in auditory perspective provides a subjective illusion of the distribution of the reproduced sound sources in lateral directions as well as depth in a geometrical correspondence which approximates the disposition of the original sound sources. A stereophonic sound reproducing system provides a means for the reproduction of sound in auditory perspective. It is the purpose of this section to describe the subjective aspects of the auditory perspective of the sound reproduced by a stereophonic sound reproducing system.

Lateral Localization. There are two factors that determine angular or lateral localization of a source of sound, namely, phase and intensity. The experiment which demonstrates angular or lateral localization with regard to phase and intensity is shown in Fig. 3. The same speech signal is reproduced from loudspeakers 1 and 2. The speech signal[2] from loudspeaker 1 can be delayed by means of the delay system. For each value of delay, the ratio of the voltage input to the two loudspeakers is varied until it is impossible to distinguish which loudspeaker appears to be the source. The results of this test are shown by the graph of Fig. 3. This experiment shows that there can be considerable unbalance in amplitude before the sound ceases to appear to come from the undelayed source. The above experiment shows that both phase and intensity plays a part in angular localization.

In performing the lateral localization experiments, some precautions must be taken to avoid errors in observation. For example, if the observer can see the loudspeaker he tends to point to either one or the other as a source of sound. This is a natural state of affairs because there are two visible sources of sound. Obviously, the sound must come from one or the other. In order to avoid this subjective bias, the loudspeakers were located behind a light-opaque-sound translucent screen. The arrangement[3] is shown in Fig. 4.

When the intensity and the phase of the sound emanating from the two loudspeakers is the same, the sound appears to originate from a point midway between the two loudspeakers, designated as S'_1. If the intensity of the sound emanating from both loudspeakers is the same but the phase of loudspeaker A′ of Fig. 4 is delayed two milliseconds with respect to loudspeaker B′, the sound appears to come from the point S'_4 of Fig. 4. If the delay is increased to five milliseconds, the sound appears to come from point S'_3 of Fig. 4. If the intensity of loudspeaker A′ is made 5 db higher than loudspeaker B′ and loudspeaker A′ is delayed 5 milliseconds with respect to loudspeaker B′, the sound appears to come from point S'_4. If the intensity of loudspeaker B′ is made 5 db higher than loudspeaker A′ but the phase of the sound emanating from the two loudspeakers is the same, the sound appears to come from point S'_3. If the intensity of loudspeaker B′ is made 2 db higher than loudspeakers A, but the phase emanating from the two loudspeakers is the same, the sound appears to come from point S'_4. If the intensity of the sound emanating from loudspeaker B′ is 5 db higher than loudspeaker A′ and the sound from loudspeaker A′ is delayed about 5 milliseconds, the sound appears to come from point S'_2. This experiment shows that the apparent position of the reproduced sound can be shifted over wide limits by varying the relative phases and/or relative intensities of the sound sources.

DR. HARRY F. OLSON, internationally known pioneer in acoustics and Director of the Acoustical and Electromechanical Research Laboratory, RCA Laboratories, was elected recently to membership in the National Academy of Sciences, the nation's leading professional scientific organization. For a complete biography of Dr. Olson, see RCA ENGINEER Vol. 4 No. 2 (Aug.-Sept. 1958) p. 36.

As an extension of the above experiments, the stereophonic arrangement of Fig. 5 was employed. The configuration of the microphones and loudspeakers are shown in Fig. 5. A person speaking was located at the different positions S_1, S_2, S_3, S_4, and S_5 in the free-field room. The corresponding apparent locations of the reproduced sound in the listening room are shown as S'_1, S'_2, S'_3, S'_4, and S'_5 in the free field room. The relative estimated sound levels in decibels are also shown with position S'_1 designated as the reference level and was arbitrarily designated as 0 db. This experiment shows that the apparent position of the reproduced sound follows the actual position of the sound in the studio with small deviations. The deviations are as follows: The reproduced sound sources tend to be spread out in middle positions. The over-all spread of the reproduced sound sources is less than the distance between the loudspeakers. The reproduced sound level appears to be lower in the middle positions.

In the next experiment an attempt was made to reduce the spreading out and reduction of level of the reproduced sources in the middle positions. The configuration of the positions of the sound source in the studio, which were evolved so that practically equal spacing of the apparent sound sources in reproduction was obtained for the different positions of the sources in the studio, is shown in Fig. 6. The experiment of Fig. 6 shows that it is possible to obtain an equal spread of the sounds in reproduction. Furthermore, there is only a slight reduction in level for the middle positions.

In all the preceding experiments the listener has been located on a line perpendicular at the mid-point of the line joining the two loudspeakers. With the studio sound source positions the same as in Fig. 6, the listener was located 2¼ feet from the center line as shown in Fig. 7. The location of the apparent sources appeared as shown in Fig. 7. The apparent sources are concentrated towards the loudspeaker nearest to the observer. As would be expected the apparent intensity falls off with the distance from the loudspeaker nearest to the observer. In spite of the fact that the apparent sources are not equally spaced or of constant intensity, from a practical standpoint, the stereophonic aspects are preserved.

Depth Localization. In any true stereophonic sound reproducing system, there should be a sense of relative depth as well as a sense of lateral distribution. However, in this connec-

[1] The auditory perspective experiments reported in this paper were performed over a period extending from 1947 to 1955.

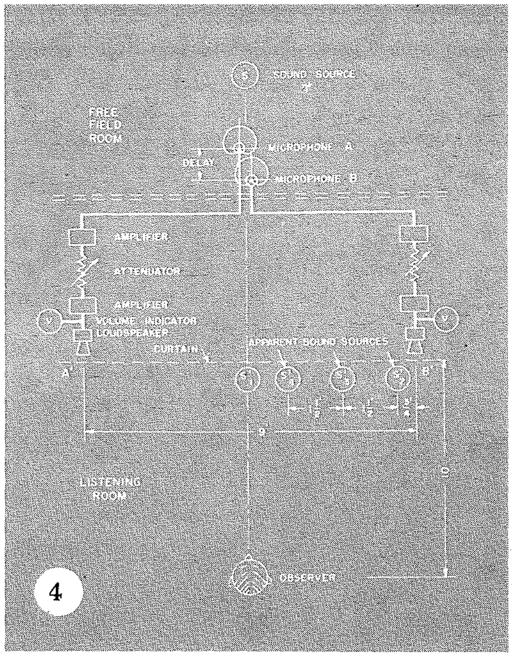
[2] Speech was used as the source of sound in all the auditory perspective experiments reported in this paper.

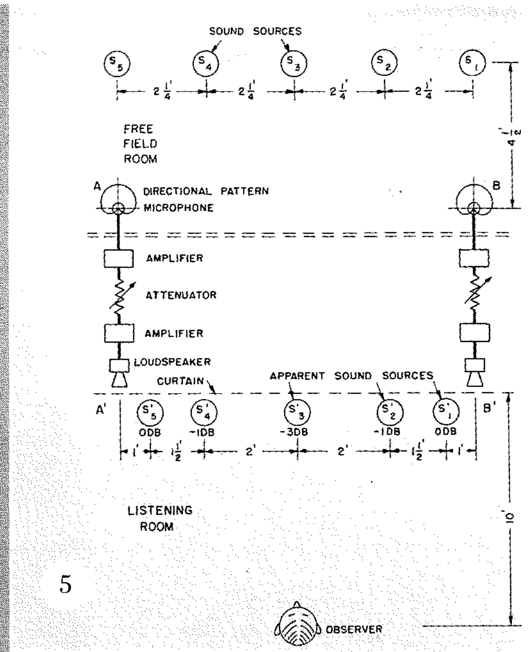
[3] In the experiments depicted in Figs. 4, 5, 6, and 7, the listener was asked to locate the apparent lateral location of the reproduced source of sound at the surface of the curtain. In other words, the apparent location of the source of sound with respect to depth was not determined. In the section on depth localization, experiments relating to the apparent location of the source of sound with respect to depth will be described.

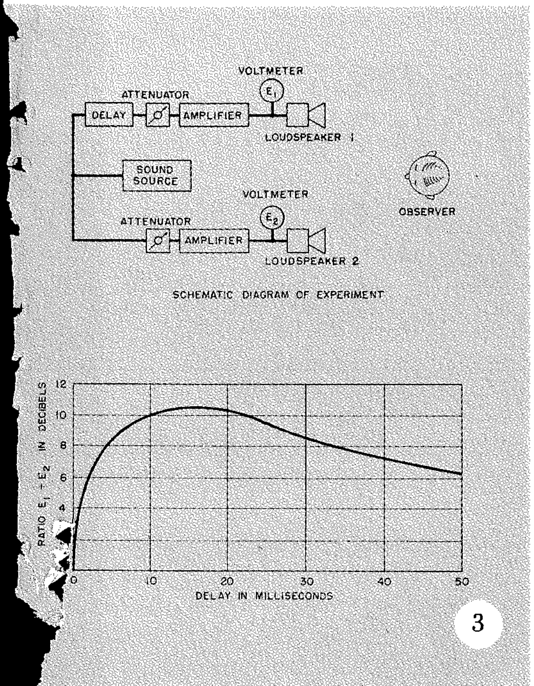
tion, it is generally recognized that a subjective effect of lateral distribution is more important than a subjective effect of relative depth. There are many factors which contribute to the sense of depth in stereophonic reproduction of sound. Some of the subjective effects of depth include a difference in the response frequency characteristics of the sources and a difference in the reproduced reverberation of the sources.

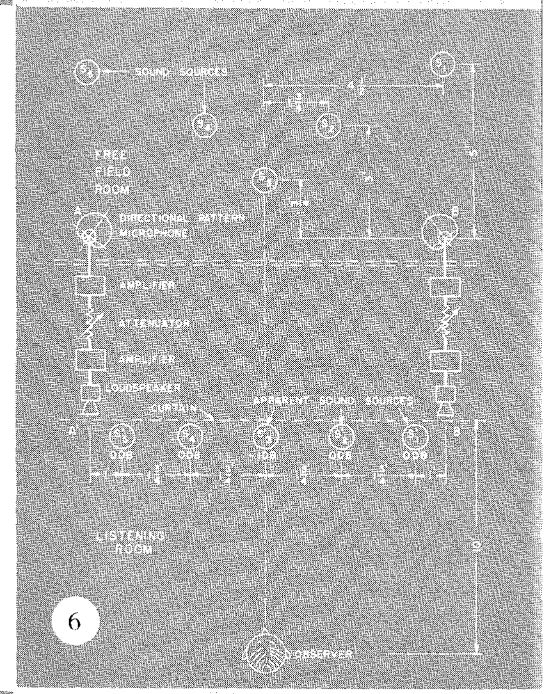
To determine the subjective effect of depth, an experiment was carried out as shown in Fig. 8. A person speaking was located at the positions S_1, S_2, S_3, S_4, S_5, and S_6 in the free-field room. The corresponding apparent estimated locations of the reproduced sound in the listening room are shown as S'_1, S'_2, S'_3, S'_4, S'_5, and S'_6. The relative estimated sound levels in decibels are also shown with position S'_1 designated as the reference level and was arbitrarily designated as 0 db. It appears that in this experiment the apparent locations in depth are determined by intensity.

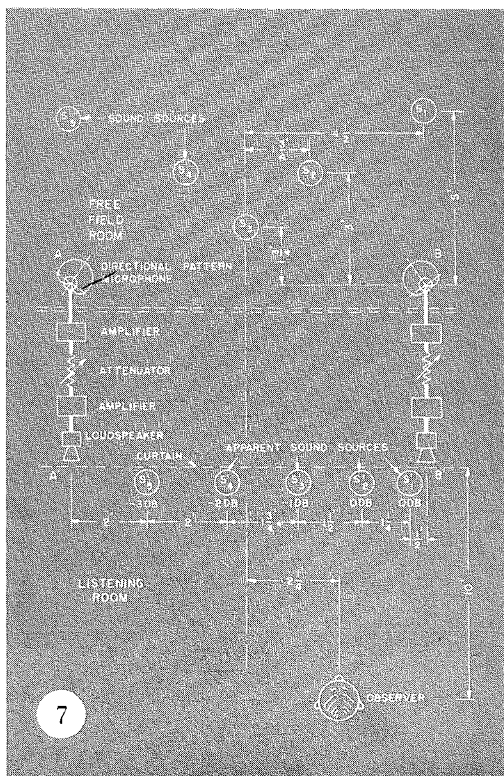
In another experiment, the person speaking was located in the free field room at position S_1, of Fig. 8. The apparent location of the reproduced sound could be moved from the apparent location S'_1 in the listening room with a uniform over-all response characteristic to a position toward the listener when the response was accentuated in the frequency range from 1000 to 4000 cycles, or to a position away from the listener when the response was reduced in the same frequency range. The frequency range from 1000 to 4000 cycles plays an important role in determining











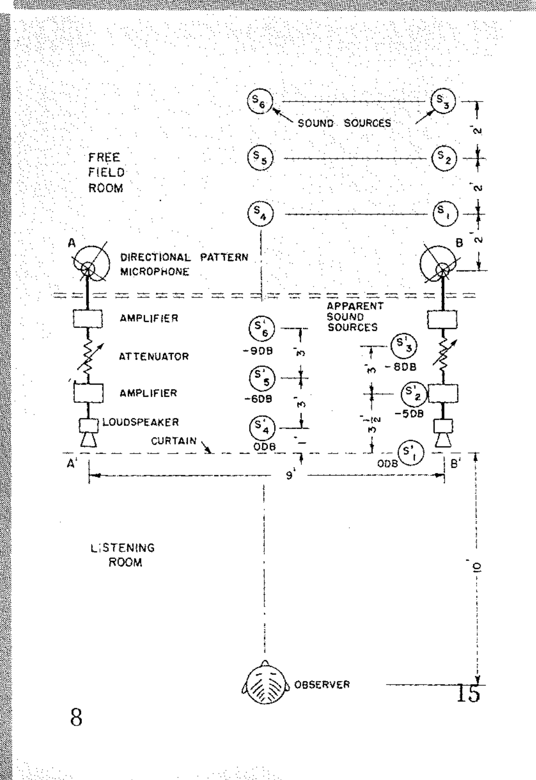


Fig. 3—Schematic arrangement which illustrates the effect of phase delay and amplitude upon the localization of a sound source.

Fig. 4—Schematic arrangement which illustrates the effect of the relative delay and amplitude of two spaced sound sources in determining the apparent lateral location of the reproduced sound source.

Fig. 5—Schematic arrangement of stereophonic system showing the locations of the sound sources in the free-field room and the apparent sound sources in the listening room.

Fig. 6—Schematic arrangement of a stereophonic system showing the arrangement of the sound sources in the free-field room which will give a uniform spacing of the sound sources in the listening room.

Fig. 7—Schematic arrangement of a stereophonic system using the arrangement of the sound sources in the free-field room of Fig. 6 and showing the location of the apparent sound sources at the curtain in the listening room with the observer located 2¼ feet from the center line.

Fig. 8—Schematic arrangement of a stereophonic system showing the arrangement of the sound sources in the free-field room and the apparent location and relative sound level of the sound sources in the listening room.

the presence[4] of the reproduced sound. The presence is increased when the response in the region from 1000 to 4000 is increased. When the presence is increased, the effect is to move the source closer to the listener.

In another experiment, the person speaking was located in a room of 5500 cubic feet and reverberation[5] time of 0.7 second at positions S_1, S_2, S_3, S_4, S_5, and S_6 of Fig. 9. In this experiment the level of the reproduced sound was adjusted so that the output was the same for all locations of the reproduced sound. The corresponding relative locations of the reproduced sound in the listening room was S'_1, S'_2, S'_3, S'_4, S'_5, and S'_6. As the distance between the source of sound and the microphone is increased, the effective reverberation of the source of sound is increased. As the effective reverberation of the reproduced sound is increased, the presence is decreased. Therefore, the apparent location of the source of reproduced sound will move away from the listener as the effective reverberation of the reproduced sound is increased.

The systems and experiments depicted in Figs. 4, 5, 6, 7, 8 and 9 demonstrate that practical stereophonic reproduction

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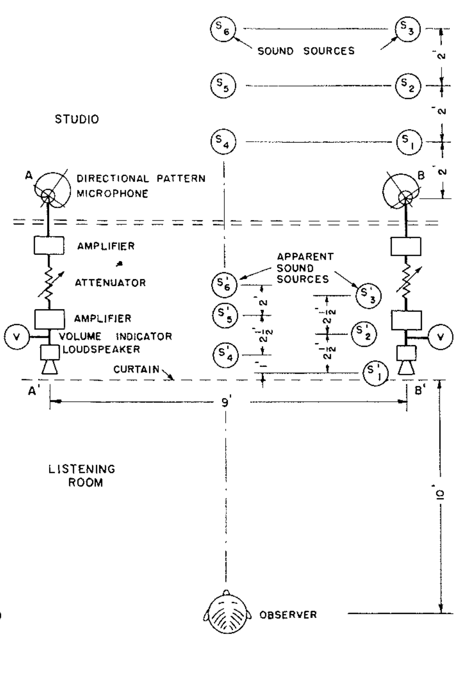
4 Olson, *Musical Engineering*, McGraw Hill Book Company, New York, N. Y., 1952.

5 The reverberation time of the studio as a function of the frequency corresponds to that recommended in Olson, *Acoustical Engineering*, D. Van Nostrand Company, Princeton, N. J., 1957.

Fig. 9—Schematic arrangement of the apparatus of a two channel stereophonic sound system showing the arrangement of the sound sources in the studio and the apparent location of the sound sources in the listening room. The reproduced level of the sound was adjusted so that the output was the same for all locations of the reproduced sound.



of sound with the subjective effects of both lateral and depth distribution of the reproduced sound sources can be achieved by the use of a two-channel system.

REPRODUCTION OF STEREOPHONIC SOUND IN THE HOME AND IN AN AUTOMOBILE

The two major applications of stereophonic sound reproduction in the mass market or consumer field are in the home and in the automobile. It is the purpose of this section to describe the reproduction of sound in auditory perspective in a room and in an automobile.

Reproduction of Stereophonic Sound in a Room. The results of the subjective experiments in the preceding section can be translated to the reproduction of stereophonic sound in the home. A plan view of a typical living room for the reproduction of stereophonic sound in the home is shown in Fig. 10. The arrangement of the loudspeakers, the preferred listening area, and relative dimensions apply to practically any room in the average home. If the dimensional ratios and preferred listening area, depicted in Fig. 10, are maintained, the important subjective effects, namely, the angular and depth distribution of the sound sources will be maintained.

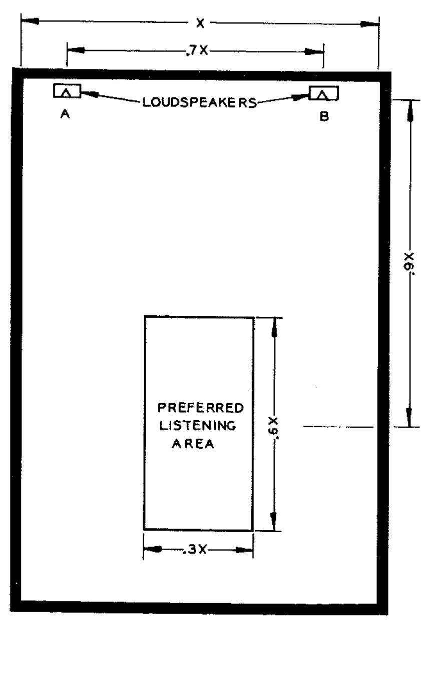
Reproduction of the Stereophonic Sound in an Automobile. The experiments on the stereophonic sound reproduction in an automobile were conducted with two different types of reproducers, namely, a two-channel magnetic tape reproducer and a two-channel disc phonograph. A schematic diagram of the apparatus used in the experiments is shown in Fig. 11. In order to evaluate the performance of stereophonic sound reproduction means were provided for comparison with a monophonic system. The change from stereophonic to monophonic sound reproduction was made by means of a switch. The loudspeaker system consists of a combination of a first-order gradient unidirectional loudspeaker employing a three-inch sound mechanism and a zero-order nondirectional loudspeaker employing a four by six inch elliptical mechanism. The directivity pattern of the unidirectional loudspeaker is a cardioid. The unidirectional loudspeaker covers the frequency range from 300 to 8000 cycles. The nondirectional loudspeaker covers the frequency range from 80 to 300 cycles. An electrical network allocates the power delivered to the two loudspeakers to the frequency ranges covered by the loudspeakers.

A plan view of the automobile and the location of the loudspeakers is shown in Fig. 12. The stereophonic loudspeakers are located on the top of the dash in the extreme corners. The monophonic loudspeaker is centrally located.

It has been established that excellent stereophonic sound reproduction can be achieved in a certain preferred area in a living room. The geometry of the loudspeakers and the listeners in the automobile shown in Fig. 12 are shown in Fig. 13. In a typical living room the two loudspeakers for stereophonic sound reproduction are usually separted by a distance of 8 feet. The location of the listeners in a living room for the same phase as that obtained in an automobile are shown in Fig. 13. There is also very close correspondence in the relative intensities of the direct sound at the listeners in the automobile and living room for the geometry of Fig. 13. The listeners in the living room are located within the area what has been the preferred listening area of Fig. 10. Recalling the results of the experiments of Figs. 3, 4, 5, 6, 7, 8, and 9, and comparing the phase and intensity relations at the listener in the automobile with those in the living room there is every reason to expect excellent stereophonic sound reproduction in an automobile. This conclusion has been confirmed under actual listening test of stereophonic sound reproduction of speech and music in an automobile.

The results of extended listening tests comparing the monophonic sound reproduction with stereophonic sound reproduction in an automobile has led

Fig. 10—The arrangement of a two channel stereophonic tape reproducing system in a room showing the optimum relative dimensions and the preferred listening area.



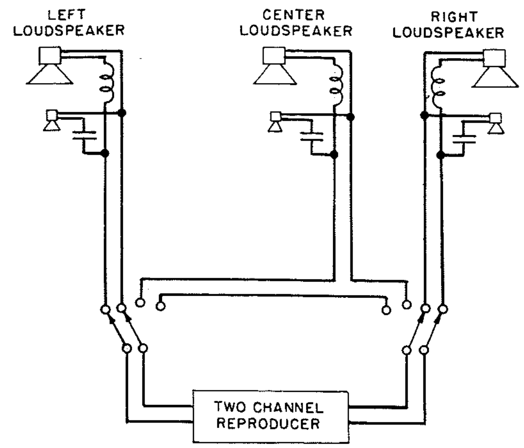


Fig. 11—Schematic circuit diagram of apparatus used in the reproduction of monophonic and stereophonic sound in an automobile.

to the following observations and conclusions.

Excellent auditory perspective is obtained from stereophonic sound reproduction in an automobile.

The recording studio characteristics, such as reverberation, etc., are more apparent in an automobile as compared to a living room due to a larger ratio of direct to generally reflected sound in the automobile. This appears to lead to more pleasing sound reproduction in the automobile.

There is more apparent low-frequency response in stereophonic sound reproduction as compared to the monophonic sound reproduction even though the measured response frequency characteristics are the same.

There is more apparent discrimination against ambient noise in stereophonic sound reproduction in an automobile as constrasted to monophonic sound reproduction with the sound from both reproduced at the same level. The improvement in discrimination against ambient noise is very important in a motor car because the ambient noise level is very high.

STEREOPHONIC SOUND SYSTEMS

The following transducers are ones most commonly used in the mass market or consumer field for the reproduction of sound, namely, the magnetic tape sound reproducer, the disc phonograph, the radio, and television.

Prerecorded stereophonic sound magnetic tape and stereophonic magnetic tape reproducers were commercialized in 1955. Stereophonic disc phonographs and stereophonic disc phonograph records were commercialized in 1958. Experimental broadcasting of stereophonic sound reproduction by means of frequency modulation multiplex was started in 1958. Frequency modulation radio receivers capable of receiving and reproducing the sound in auditory perspective were available in 1958. An experimental stereophonic sound amplitude modulation radio system was demonstrated in 1958 and was demonstrated in a broadcast in 1959. An experimental stereophonic-sound frequency-modulation multiplex element of a television system was demonstrated in 1959.

Stereophonic sound provides a large and significant step in achieving realism in sound reproduction. For this reason it is expected that stereophonic sound will ultimately be developed and commercialized in all of the media in the consumer sound reproduction complex.

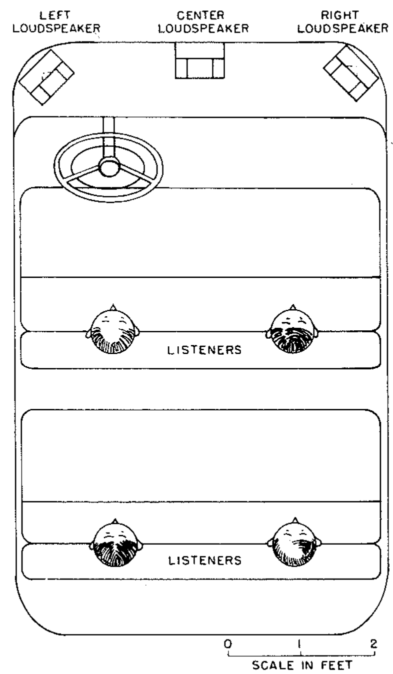


Fig. 12—A plan view of the loudspeaker system and the listeners for the subjective evaluation of monophonic and stereophonic sound reproduction in an automobile. The left and right loudspeakers were used for stereophonic sound reproduction and the center loudspeaker was used for monophonic sound reproduction.

The application of stereophonic sound in all the media could bring about a revolution in sound reproduction which might result in a large new business. The new business will be prerecorded stereophonic-sound magnetic tape and stereophonic-sound magnetic tape reproducers, stereophonic-sound disc records and stereophonic-sound phonographs, stereophonic-sound, amplitude-modulation radio transmitters and receivers, stereophonic frequency-modulation radio transmitters and receivers, and stereophonic-sound television transmitters and receivers. All these instruments and systems may ultimately displace existing instruments and systems.

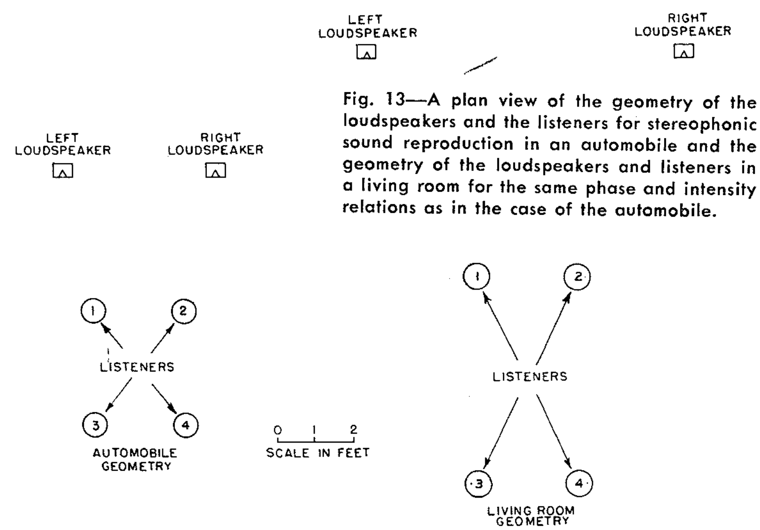


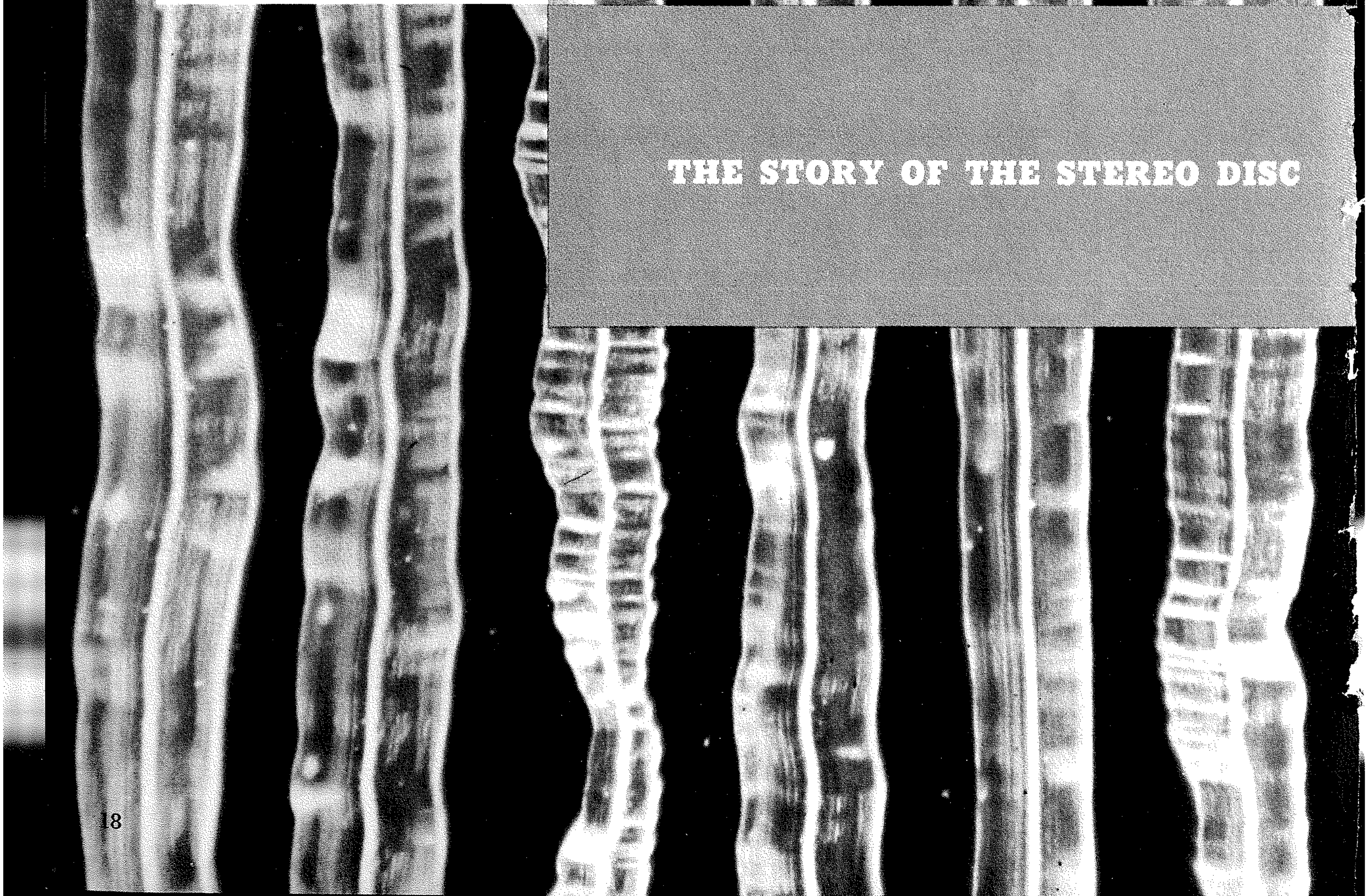
Fig. 13—A plan view of the geometry of the loudspeakers and the listeners for stereophonic sound reproduction in an automobile and the geometry of the loudspeakers and listeners in a living room for the same phase and intensity relations as in the case of the automobile.

H. E. ROYS received his BSEE from the University of Colorado, and joined RCA in 1930 in the phonograph section. In 1937 he became a member of the Advanced Development group of the Photophone section, and from 1941 to 1946 was located with this group in Indianapolis, working mainly on disc recording and reproducing problems. He returned to Camden in 1946 to General Engineering Development, as Manager of Optical and Recording Systems Development. He is now Manager, Engineering, RCA Victor Record Division at Indianapolis.

Mr. Roys is an authority in the fields of audio, acoustics and recording and his work in these areas has brought him several awards. Among these are an award by the National Association of Broadcasters for "Meritorious Service" for his work in the development of NAB recording and reproducing standards, and the Emile Berliner award from the Audio Engineering Society for his contributions to the audio art.

Mr. Roys is a member of Tau Beta Pi and Eta Kappa Nu. He is a Fellow of the Audio Engineering Society, the Acoustical Society of America, and the IRE.

THE STORY OF THE STEREO DISC



H. E. ROYS, Mgr.
Engineering
RCA Victor Record Division
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STEREOPHONIC PHONOGRAPH RECORDS with two separate channels of information recorded in a single groove became a commercial reality in 1958, less than a year after the adopted system had been publicly demonstrated. A stereophonic system utilizes two or more independent channels, with separate microphones in recording and separate loud-speakers in reproduction, so arranged as to produce a sense of realism of recording-hall acoustics and location of the instruments in the orchestra with respect to lateral position and depth. The effectiveness of stereophonic reproduction was demonstrated by the Bell Telephone Laboratories in 1933 when an orchestra playing in Philadelphia was reproduced over loud-speakers located in Washington. The material was not recorded but was transmitted directly over telephone lines. Walt Disney used several sound tracks to obtain spread sound in *Fantasia*. Wide screen motion picture presentations in many cases employ multi-channel recordings to obtain stereophonic effects. Two track stereophonic tape for the home became common in the '50's and Emory Cook produced some commercial stereophonic records, laterally recorded, in which the two channels of information were recorded as separate inside and outside bands on the record.

EARLY HISTORY

The 45°-45° system adopted by industry and the one that has become a national and international standard almost overnight was disclosed in patents some twenty years ago. A. D. Blumlein, of Electric and Musical Industries, England, obtained two patents, British 394,325 in 1933 and U.S. 2,093,540 in 1937, and A. C. Keller and I. S. Rafuse obtained U.S. patent 2,114,471 in 1938 (assigned to the Bell Telephone Laboratories) which describe the 45°-45° system.

The Bell Telephone Laboratories cut stereophonic records during their experimental work but used the vertical-lateral (V-L) system (one channel vertically, the other laterally) instead of the 45°-45° system. There was little commercial interest in stereophonic records at that time so the experimental work was dropped.

THREE SYSTEMS

In September 1957 the Westrex Corporation, a subsidiary of the Western Electric Company, demonstrated stereophonic records cut in accordance with the 45°-45° system. These were private demonstrations, mainly to persons in the record industry. Shortly afterwards, in October 1957, they described and demonstrated the 45°-45° system at the Audio Engineering Society Convention in New York. This was probably the first public demonstration of the 45°-45° system. The system was again described[1] at the IRE National Convention in March 1958.

About the same time, in the fall of 1957, the Decca Company of London also demonstrated stereophonic records but these were cut in accordance with the vertical-lateral system. Somewhat later Jerry Minter demonstrated stereophonic records in which all of the information was recorded laterally, using an FM system with a carrier of about 30 kc to accommodate the additional information needed for stereophonic recording.

Thus in the latter part of 1957 the phonograph industry was presented with a problem of deciding which of the three systems should be selected as an industry standard. There was a strong desire, both in this country and abroad, that one and only one system be chosen and made available to the public.

INDUSTRY APPROACH

The approach taken by industry was indeed a very logical one. Engineering committee meetings of industry associations, Electronic Industries Association (EIA) and the Record Industry Association of America (RIAA) were held, information was presented concerning the different systems, and the problems were discussed openly and frankly. RCA Victor Record and Radio and "Victrola" Divisions commissioned M. S. Corrington, who had done an outstanding job on Tracing Distortion studies for the 45 rpm record, to make similar studies for the V-L and 45°-45° systems[2] and to make the information available to the engineering committees.

During the latter part of 1957 the Engineering Committee of the Record Industry Association of America decided in favor of the 45°-45° system and in early 1958 the Phonograph Committee of the Electronics Industry Association agreed with their decision. The agreement was welcomed by phonograph engineers for it cleared up many uncertainties and allowed them to concentrate their efforts on the 45°-45° system.

In March 1958 the Board of Directors of RIAA formally approved the

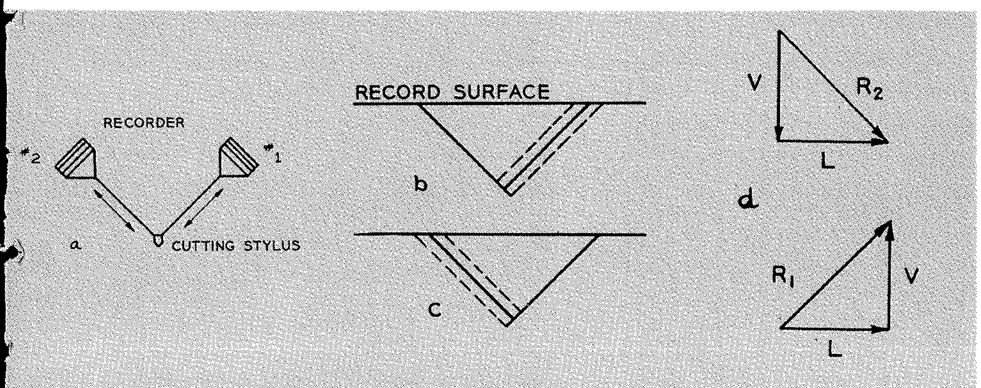

Fig. 1—(a) The recorder has two driving coils, 45 degrees with respect to the record surface and 90 degrees with respect to each other. The connecting member between each drive coil and the stylus is stiff under compression or tension but has lateral flexibility to permit bending.
(b) Groove variation with signal applied to coil #2.
(c) Groove variation with signal applied to coil #1.
(d) Vector diagrams showing that both vertical and lateral components exist with 45 degree modulation. Combining the vectors with the phasing illustrated will result in maximum lateral and minimum vertical modulation.

Fig. 2—Photograph of stereo grooves. Note how the groove width varies and modulation on one side does not always appear on the opposite side of the groove.

Engineering Committee's recommendation and proclaimed the 45°-45° system as an industry standard. The decision was welcomed in Europe for the European recording engineers at a meeting in November 1957 had already concluded that the 45°-45° system offered the greatest advantages and they were pleased that RIAA and EIA engineers had reached the same conclusion. Thus, less than six months after the first public demonstration, basic industry standards were agreed upon both nationally and internationally. This I believe is an unheard of precedent—industry reaching a world-wide agreement before production starts.

THE SYSTEM

The 45°-45° system uses a single stylus to cut the groove and, as the name implies, modulation takes place at an angle of 45 degrees with respect to the surface of the record (Fig. 1, a). Since the groove is "V" shaped with an included angle of 90 degrees, the groove walls are normally 45 degrees with respect to the record surface. Consequently for the 45°-45° system a signal from one channel varies the position of one groove wall about a mean (no signal condition) without changing the position of the other, Fig. 1, b and c.

For reproduction, the pickup also uses a single stylus and the configuration with the voltage generating device may be similar to that of the recorder illustrated in Fig. 1, a; the main consideration being the pickup be designed to produce two practically independent signals in accordance with the motion components along the two axes that are displaced 90 degrees with respect to each other and 45 degrees with respect to the record surface.

ADVANTAGES

Operation at 45 degrees provides a symmetrical arrangement that offers advantages in the design of both recorders and reproducers. The 45°-45° system may be considered as two independent vertical recording channels displaced 45 degrees with the surface of the record. Since these are alike, frequency response, distortion, and other characteristics are the same for each channel. For a vertical-lateral system they are different; tracing distortion showing one of the greatest differences. The frequency response is different because most designs of vertical-lateral combination pickups show the lateral mode of operation to have a greater high frequency response. This is because inertia is involved in the lateral mode of operation due to the arcuate motion of the stylus and moving system, whereas direct mass is involved in the vertical mode because of linear motion, and the effective inertia is less than the mass.

Another consideration, and by no means a small one, in favor of the 45°-45° system concerned a compatibility feature. By proper phasing of the two stereophonic signals to the recorder, a lateral modulation would be effected adding together the signals from both channels. Reproduction of this groove with a *suitable* lateral pickup would result in a combined output much the same as though the signals from the two channels were first combined electronically and then recorded with a standard lateral recorder. The vector diagrams of Fig. 1, d show that each 45 degree modulation displacement may be resolved into two components, one lateral and the other vertical. For a sound source located centrally with respect to the microphones of the two channels, sound waves will arrive at the two microphones essentially in phase. Assuming that the same phase relationship is maintained throughout the electronic amplifiers, the resulting groove modulation then depends upon the phasing of the two driving coils. These may be connected so that the resulting lateral modulation is the sum of the two lateral components. In this case the vertical components are opposing and the vertical modulation is low. The phasing of the vectors of Fig. 1, d illustrates these two conditions. Obviously it is desirable to phase the driving coils for additive or "in phase" operation so that good reproduction can be obtained with a suitable lateral pickup. The RIAA Engineering Committee so specified the phasing in their specification for the stereophonic record. The qualifying term "suitable" for the pickup is necessary in order to exclude those pickups with high vertical stiffness since they would be unable to properly track a groove that contains vertical as well as lateral modulation. The vector diagrams of Fig. 1, d show that both forms of modulation exist in a stereophonic groove.

COMPATIBILITY

P. C. Goldmark[3] seeking to make the stereophonic record usable on existing monophonic machines without changing the pickup, proposed that the vertical modulation be controlled dynamically and be so limited as not to exceed tracking capabilities of existing monophonic pickups, thus making it necessary to produce only one type of record—a modified stereophonic record.

Record manufacturers, however, not wishing to risk possible degradation of quality, decided to follow the recommendation of RIAA and produce monophonic and stereophonic records separately.

Monophonic records can be reproduced on stereophonic systems and in fact should sound better since, for one thing, the output is from two speakers. In addition, due to the small tip radius (0.7 mil) used for stereophonic reproduction tracing distortion will be less and the high frequency response somewhat greater than that obtained with the one mil tip normally employed for L.P. reproduction. There is no problem therefore with instruments designed for stereophonic reproduction. For existing monophonic equipment it may be necessary to replace the pickup with one having greater vertical compliance. This may be a stereophonic pickup, for stereophonic pickups are usually designed so that the two channels may be connected at the pickup and hence not require a change in wiring of either tone arm or instrument. If the pickup is replaced, less vertical force should be used because of the smaller tip so as to minimize record and stylus wear; otherwise, no other changes should be necessary.

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RECORDING AND REPRODUCTION OF STEREOPHONIC DISC RECORDS

by
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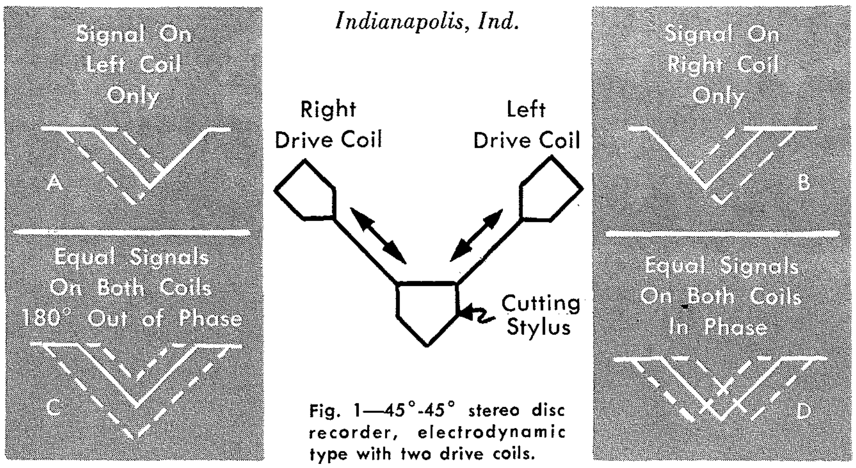


Fig. 1—45°-45° stereo disc recorder, electrodynamic type with two drive coils.

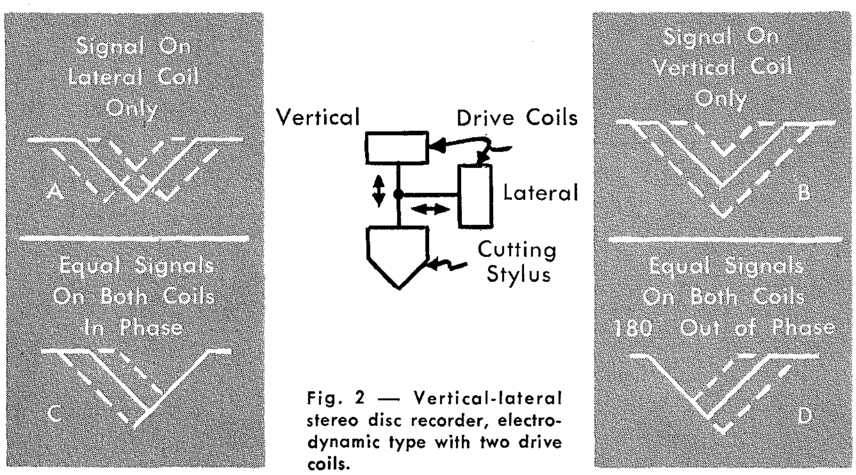


Fig. 2 — Vertical-lateral stereo disc recorder, electrodynamic type with two drive coils.

THE 45°-45° system described in the article by H. E. Roys was accepted by the record industry as the system which could produce the best over-all stereophonic performance on phonograph records. Provided with the characteristics of this basic system, the recording of stereo discs requires the consideration of many factors important to the consumer of phonograph records. Some of these factors, common to monophonic recording, are: recording level, available "playing time," the recording frequency characteristic,[1] and constant reproduced frequency response from the outside to inside of disc.

Still other factors must be considered in stereophonic recording. Most important of these are recording level balance between channels and inter-channel phasing. In order to re-create the original stereo "sound picture" in proper perspective, channel balance and inter-channel phasing must be accurately preserved throughout the entire recording-reproducing process.

Geometric symmetry of the 45°-45° system has made solutions to the problem of balance and phasing much simpler than they would have been otherwise. Thus, along with the acceptance of the 45°-45° system, the record industry adopted the convention that "equal and in-phase signals fed to the stereo recording system shall produce lateral modulation on the disc." This is useful in recording and provides a convenient check on channel balance and phasing.

RECORDER CONSTRUCTION

The effect of two-channel signals combining to produce different modes of modulation is most readily shown by an example of recorder construction. Fig. 1 indicates four possible modulation modes obtained with individual and combined signals. The recorder shown is the 45°-45° type whose modulation axes are inclined 45° to the disc surface. Equal and in-phase mechanical motions of the drive coils are seen to cause the cutting stylus to move vertically. However, in order to comply with the phasing convention adopted, the polarity of one of the coils must be electrically reversed so that equal and in-phase signals will produce lateral modulation.[2]

Fig. 2 shows the basic construction of a vertical-lateral type of recorder. This type can be used, in conjunction with a sum and difference matrix, to record 45°-45° discs. The output of the sum matrix is fed to the lateral drive coil while the output of the difference matrix is fed to the vertical drive coil. Thus, equal and in-phase electrical signals will add in the sum matrix and energize the lateral coil. Also, equal signals 180° out-of-phase will add in the difference matrix and energize the vertical coil.

Both recorder types are commercially available and produce good results.

OPERATIONAL METHODS

For highest quality stereo recording, the two recording channels should be exact duplicates throughout their operational range. Frequency and phase response should match closely. To establish proper phasing, the channels are connected in parallel to a single oscillator. An oscilloscope, connected to the outputs of the two channels, should then display an in-phase Lissajous pattern throughout the entire frequency range. Conversely, a 180° signal input phase reversal should result in a 180° out-of-phase scope pattern. Providing the above is correct, the stereo disc system will then produce a lateral modulation, when fed in-phase, and a vertical modulation when fed out-of-phase. The same phasing care must be exercised in production of master tape source material.

Standard reference level for a lat-

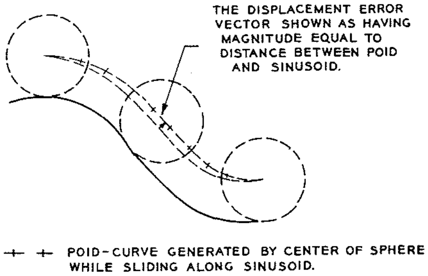


Fig. 3—Displacement error vector as a result of tracing distortion.

erally recorded signal is 5.5 cm/sec velocity at 1,000 cps. In the 45°-45° system, standard lateral level will produce velocities 3 db down in each channel, or 3.9 cm/sec. Initial cuts can be optically measured to give an approximate balance of the two channels. After this is done, in-phase 1-kc signals are fed to the channels to produce a lateral cut. This cut is then compared to a calibrated lateral 1-kc disc signal to determine necessary level adjustments to be made in each channel. A pickup and arm combination of reasonably good quality, when referenced to a lateral disc, can be depended upon to display channel balance to an accuracy of 0.2 db.

After establishing the level and balance at 1-kc, the over-all response can then be checked by the light pattern method. An in-phase (lateral) response cut can be compared with a 180° out-of-phase (vertical) response cut. If these two cuts compare favorably, it can be assumed that the individual channels will have a similar response. Phase shifts can be seen as a peak or dip in the front pattern and a corresponding dip or peak in the back pattern. Lacquer cutting problems in stereo are basically the same as in monophonic recording with some exceptions. Film build-up on stylus face and burnishing facets must be avoided. In lateral recording there is a build-up of substance from the lacquer which becomes heavy at a point just above the groove depth point, on the cutting stylus. In stereo this same condition can exist during sustained low-level portions, therefore, causing a severe marking or lining of groove walls during high level (deep groove) portions. It becomes apparent that greater care is necessary to maintain cleanliness of the stylus and avoid excessive heating.

PROCESSING CONSIDERATIONS

Recorded stereo lacquers are processed in the same manner as conventional monaural ones. However, greater care must be exercised in handling stereo stampers (negatives), after being separated from their molds (positives). Since the stampers are negatives, there will be high points of modulation projecting above average groove height. These points can be easily damaged if they are carelessly slid or scuffed. Back grinding of stampers should be done lightly enough to avoid pressure lines on the face. Surface condition of press molds is important also. Any fatigue lines or grinding chatter on these molds will usually appear on the finished record. Slight refinements of mold contour at the beaded edge portion of the disc led to some further noise reduction.

Most of these items collectively, have a bearing on the low-frequency noise spectrum. They generate noise in the 200 to 400 cycle region which is not to be confused with turntable rumble, usually 120 cycles or lower. When proper care is taken with each of these problems, the total 200 to 400 cycle noise (often termed "roar") can be lowered to a point of insignificance.

High-quality record compound is necessary because of the increased sensitivity of the stereo system to noises in the vertical plane.

PROBLEMS OF REPRODUCTION

The problems of disc reproduction fall into two categories: one, the problems of tracing geometry and, two, the problems of tracing mechanics. Basically, tracing geometry is concerned with the physical wave-lengths of modulation and the size of the reproducing stylus; that is, the ability of the stylus to resolve the modulation on the record. Tracing mechanics is concerned with the ability of the reproducing stylus to follow the motion imparted by the modulation on the record. The advent of stereo records has placed stringent requirements on both aspects of reproduction.

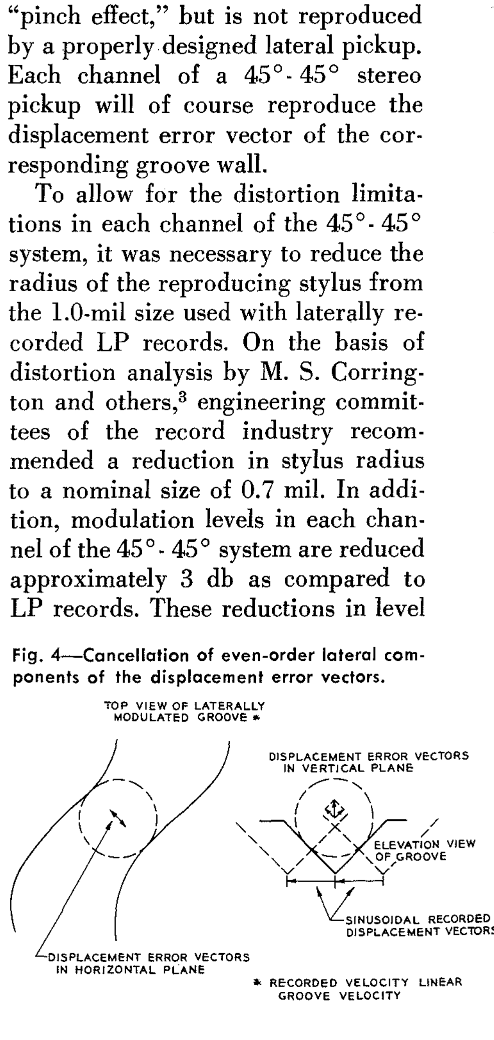
Tracing Geometry and Stylus Size

Tracing distortion, although generally small in a well-designed disc system, is inherent in disc reproduction and is a direct result of the geometry of the system. Fig. 3 shows a sphere sliding along a sinusoid. The sphere represents the tip of a reproducing stylus and the sinusoid corresponds to a modulated groove wall. The curve traced by the center of the sphere is called a poid. Representing the distance between the poid and a true sinusoid is the displacement error vector. It is evident from Fig. 3 that the center of a reproducing stylus of finite size will never trace a curve that exactly matches the modulation of the groove. However, the resulting tracing distortion can be kept low by a design compromise between modulation amplitude, linear groove velocity and reproducing stylus size.

As stated in the preceding article by H. E. Roys, tracing distortion in each channel of the 45°-45° stereo disc system is equivalent to that found in vertical disc recording.[3] Total distortion in the reproduction of a vertical recording is greater than that found in lateral recordings. This is because the lateral disc system, using a pickup electrically insensitive to vertical motion, is essentially a symmetrical or "push-pull" system, and even-order distortion components are cancelled. Fig. 4 shows the cancellation of even-order lateral components of the displacement error vectors. The vertical component of the displacement error vectors is referred to as "pinch effect," but is not reproduced by a properly designed lateral pickup. Each channel of a 45°-45° stereo pickup will of course reproduce the displacement error vector of the corresponding groove wall.

To allow for the distortion limitations in each channel of the 45°-45° system, it was necessary to reduce the radius of the reproducing stylus from the 1.0-mil size used with laterally recorded LP records. On the basis of distortion analysis by M. S. Corrington and others,[3] engineering committees of the record industry recommended a reduction in stylus radius to a nominal size of 0.7 mil. In addition, modulation levels in each channel of the 45°-45° system are reduced approximately 3 db as compared to LP records. These reductions in level

Fig. 4—Cancellation of even-order lateral components of the displacement error vectors.



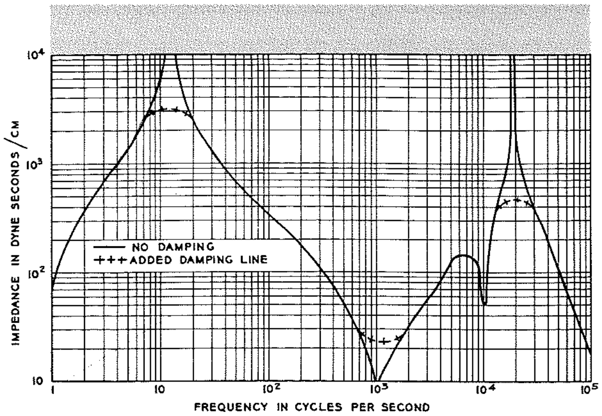


Fig. 5—A plot of mechanical impedance vs. frequency for a high quality lateral pickup-arm combination for LP records.

and stylus radius have resulted in less odd-order distortion components—more harsh to the human ear than are found in monophonic record reproduction. Even-order distortion components are greater in the 45°-45° system than in lateral recordings, but are not excessive.

Tracing Mechanics and Mechanical Impedance of the Pickup

The aspect of tracing mechanics involved in disc reproduction is generally as important for low distortion as the aspect of tracing geometry. Familiar to many who have played lateral disc records in their homes is the need for a pickup that will follow or "track" grooves without skipping or causing excessive wear.[4,5] With stereo pickups, the need for low-mechanical impedance is even greater because of the requirement of following any motion in the plane of modulation, that is, the plane formed by the modulation axes of the recorder. Problems of tracing mechanics are further complicated by the reduction in reproducing stylus radius. Record groove walls, being plastic, are subject to permanent damage if pressures on walls become excessive. Expressed mathematically, the pressure exerted by a spherical stylus on elastic walls is given by A. M. Max,[6] F. V. Hunt,[7] and others[8] as

$$P_m = K\sqrt[3]{\frac{W}{R^2}}$$

where K is a lumped constant, W is the "playing weight" or vertical tracking force, and R is the stylus radius. Although pressures normally encountered in disc reproduction do exceed the elastic limit of record materials, the above expression is useful in analyzing the degree of plastic deformation or relative wear rates of different disc systems. Thus, with the reduction of stylus radius from 1.0 to 0.7 mil for stereo records, the tracking force on the pickup should be halved to obtain ideally the same degree of wall deformation. The necessity of reducing the vertical tracking force on stereo pickups requires that the lateral mechanical impedance should be reduced accordingly. In the ideal case, the impedance should be approximately half that required in lateral pickups for LP records using a 1.0 mil stylus.

Reducing the mechanical impedance while driving two sensing elements in a stereo pickup is a considerable challenge to designers. Fig. 5 shows a plot of mechanical impedance vs. frequency for a high-quality lateral pickup-arm combination for LP records. The dominant poles of the mechanical system occur at a low frequency, referred to as "swinging resonance," and at a high frequency, called stylus-groove resonance. Swinging resonance is a resonance between the mass of the arm and compliance of the pickup armature. Stylus-groove resonance is a resonance between mass of the stylus and compliance of the groove walls. A reduction in mechanical impedance of pickups usually requires an increase in pickup compliance and a reduction of effective stylus mass, thereby moving troublesome resonances outside the audio spectrum.

CONCLUSIONS

Far from painting a gloomy picture of the prospects of stereo records, a realistic appraisal of the problems involved is necessary to insure progress of the art. In the short time since the introduction of the 45°-45° stereo disc system, several new recorders have appeared on the market. Stereo pickups that track well with playing weights as low as two to three grams have also appeared commercially. The general quality of stereo record reproduction is felt by many to be more than adequate. Most important, wide public acceptance of the new stereophonic medium is highly satisfactory.

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H. D. WARD attended Purdue University and entered the Air Force in 1943. He graduated from Sioux Falls AAF Radio School and Truax Field (Madison, Wisc.) specializing in JLS Aircraft, Blind Landing Systems. Mr. Ward joined RCA's Recording Engineering Section in 1946. He was instrumental in fine-groove recording development, including stylus design. As a development engineer in Indianapolis, Mr. Ward is responsible for all Test and Technical Series and disc recording and production.

A HIGH-QUALITY STEREOPHONIC PICKUP FOR MASS PRODUCTION

By

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THE PRINCIPLE involved in recording and reproducing two signals in a single record groove is surprisingly old. "The Story of The Stereo Disc," by H. E. Roys, this issue, tells of historical developments which preceded the standardization of the 45°-45° system as it exists today. Mr. Roys also describes three recording systems that were under consideration by the phonograph industry in the latter part of 1957. Two of these were the 45°-45° and the vertical-lateral systems. It was noted that a satisfactory stereo transducer for one system could also reproduce the other, providing a suitable network was used. Therefore the development of a suitable pickup could and, in fact, did proceed before the record industry had adopted its standards.

DESIGN REQUIREMENTS

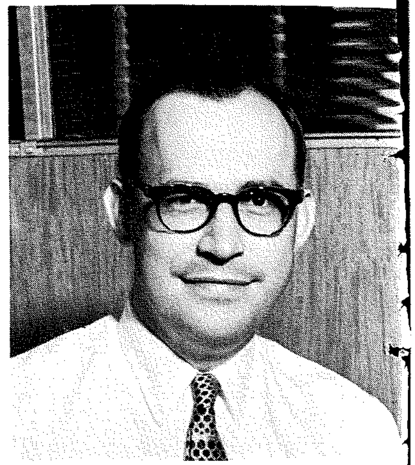
The first step in designing the pickup was to select the most desirable mechanical driving method for translating the record modulations to the transducing elements. Several possibilities existed and our "straight-line" approach was selected since it offered the best control of known variables which would exist during mass production of the pickup. The performance of a suitable design should be at least equal to present day monophonic cartridges in frequency response, and "record tracking" capability. It is also desirable to have low mechanical "needle talk", which is a problem that is compounded by the presence of the two modes of stereo record modulation. In order to keep overall instrument costs within reasonable limits, it was a "must" requirement that maximum audio performance be obtained without the necessity of elaborate preamplifiers, equalization networks, and hum shielding.

DESIGN PROBLEMS

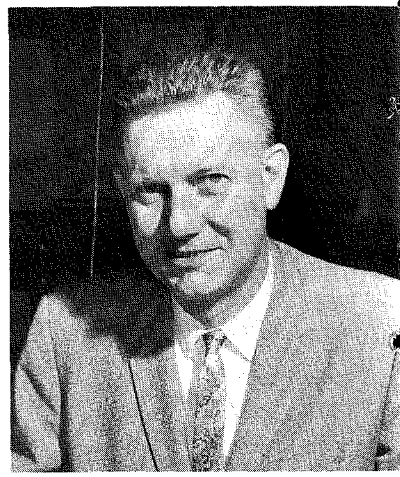
The tracing distortion had to be comparable to that encountered in good monophonic systems. This introduced some complications since mathematical studies indicated that the standard 1-mil tip radius used with LP's was too large to trace the high-frequency modulation on stereo discs. Also to keep record life comparable to that of monophonic LP's, the stress on the groove wall must not exceed that imposed by a 1-mil stylus with 10 grams tracking force. This stress is approximately proportional to the inverse square of the tip radius. Subjective listening tests were made with identical pickups using 1/3-mil, 1/2-mil, and 7/10-mil styli and no difference in distortion could be detected. The 7/10-mil stylus was adopted and required reducing the tracking force to 5 grams. To "track" satisfactorily at this force, a corresponding reduction in the mechanical impedance must be accomplished. With this reduction of the mechanical impedance and stylus force, the mass of the cartridge and tone arm, and the bearing friction must be correspondingly reduced so that proper control of low-frequency response, and good mechanical performance on a record changer will result.

To satisfy the need for high-voltage output and low hum, piezo-electric type pickup elements were required. A suitable ceramic-element material, lead zirconium titanate, was selected. This material has a much flatter temperature characteristic than Rochelle salts, and its output voltage and compliance exceeds other ceramics. These elements were arranged and driven as shown in Fig. 1.

A major problem was encountered in devising the novel driving-translating member that couples the piezo-electric elements to the stylus. To obtain widest range frequency response, the "leg" portion must be very rigid axially to translate faithfully all stylus



DAVID E. LAUX received the Bachelor of Science degree in Electrical Engineering from the University of Nebraska in 1952, and joined RCA the same year as a Student Trainee. After fulfilling this program he was assigned to Components Engineering in the Tube Division as a Design and Development Engineer working on loudspeakers. In 1957 he transferred to Radio and "Victrola" Division in Transducer Development, and is presently working on stereo pickup design.



J. A. TOURTELLOT studied at Columbia University and graduated in 1937 with an A.B. degree in Physics. From 1937 to 1939 he was engaged in his own private business and joined RCA in 1940. From 1940 to 1945, he was engaged in UHF, electromechanical modulators and "butterfly" circuits work for military applications. From 1945 to 1953 he was with the Philco Corporation, and upon his return to RCA in 1954 joined the Radio & "Victrola" Record Changer Design group. His work since then has been concentrated on phonograph pickups, motors, and record changers, and tape recorders.

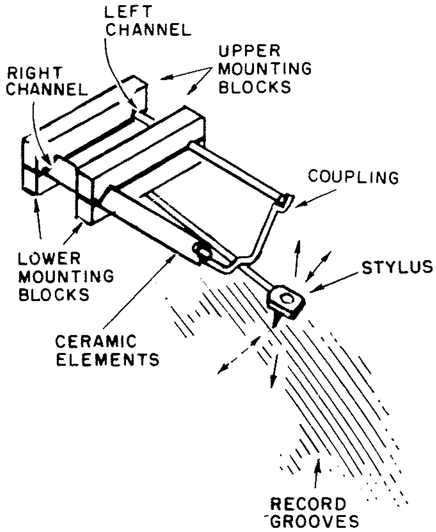


Fig. 1—Stylus movement vs. element output.

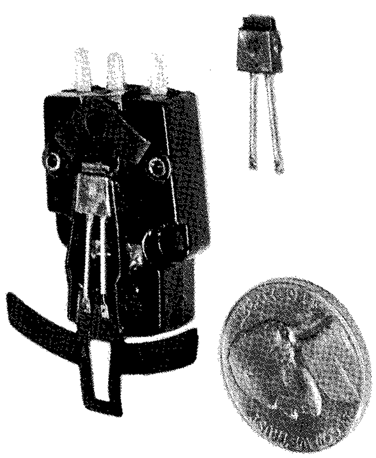
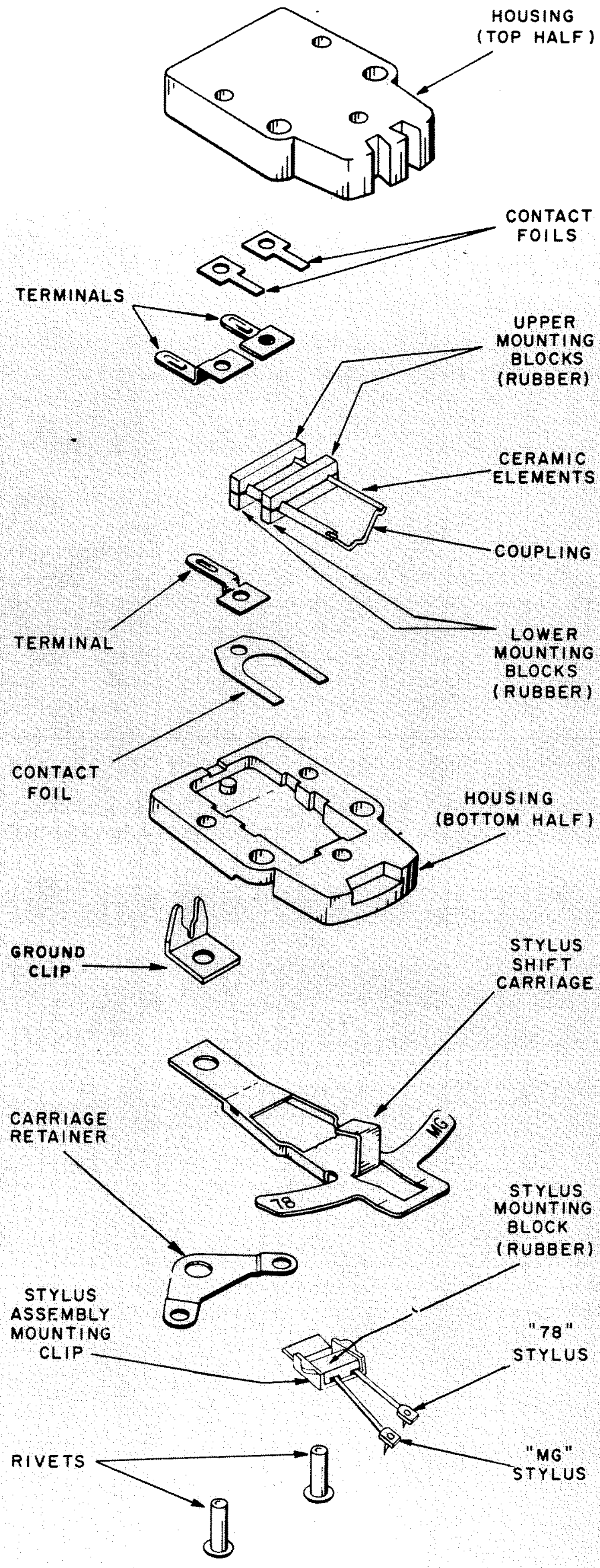


Fig. 3—The "Swing-Aside Stylus" and its replacement styli.

Fig. 2—Dynamic assembly of the stereo pickup.



motion into element bending. For maximum channel separation, the "legs" must be flexible enough to isolate each element from the other. Symmetry of response between the two channels requires that the dimension of the member be precisely controlled. The choice of steel wire results in greater strength, reliability and freedom from temperature effects.

The damping properties of both the element mounting blocks and the styli mounting blocks required much attention. Several materials were tried before a "low Q" rubber was selected. It was supplemented by the presence of a temperature-stable silicone damping compound that surrounds the elements. The requirement of low "needle-talk" was met by the use of a tubular beam, with a low-mass stylus tip.

The dynamic assembly is shown with respect to other components in Fig. 2. The choice of 5/8" mounting center for the pickup makes it far easier to control performance and uniformity by allowing our "straight drive" system to be of sufficient size. This choice also results in minimum overall thickness since this dimension adds to the height of record player mechanisms, and, if large, makes the required cabinet larger and more expensive. It was preferable that the unit employ a 78 rpm (3-mil) and a microgroove stylus in order to play all types of records. A mechanical arrangement permits this selection and also eliminates any compromise in performance for either stylus. This arrangement was given the trade name the "Swing-Aside Stylus." The complete unit and its replacement styli are shown in Fig. 3.

TEST RECORD MADE

Testing our early models presented a problem in that suitable test records were not available in early 1957. A modified magnetic record cutter, which can be oriented to simulate vertical, lateral and stereo record modulation, enabled measurement of frequency response in all modes.

A continuous sweep-frequency record was made by RCA Record Engineering, using a lateral cutter for one side of the record and a vertical cutter for the other. This record has the unquestionable advantage of having a very small amount of crosstalk. The channel separation in a 45° pick-up can accurately be evaluated by phasing the pickup for lateral playback while playing the vertical record, and vice-versa.

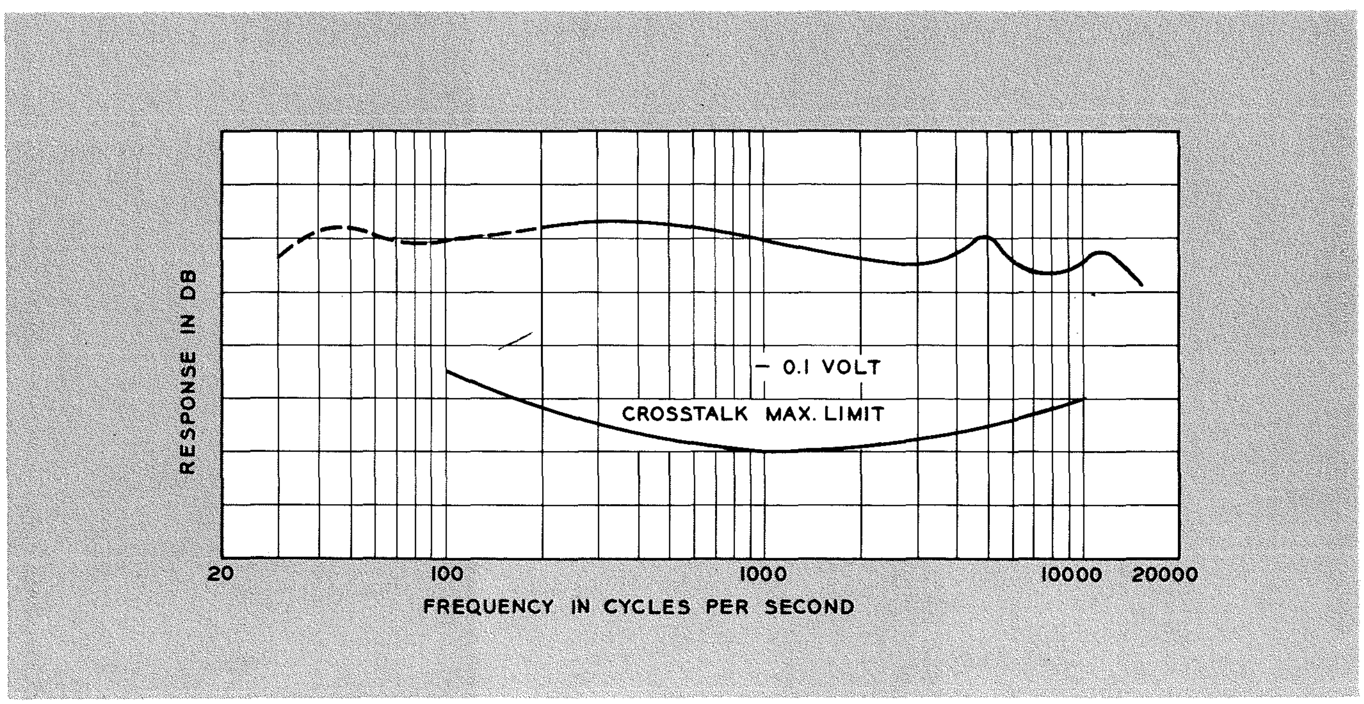
An oscilloscope was connected to the pickup, each channel feeding one set of deflection plates, and the cathode ray tube was oriented so that the lateral components of the record signal are presented as horizontal motion of the spot. This gave a very useful means of checking performance, since unbalance in amplitude or phase response can be easily detected.

PERFORMANCE RESULTS

Channel-to-channel isolation is greater than 20 db at 1 kc and greater than 12 db at 100 cps and 10 kc. Subjective listening tests indicated the stereo effect was impaired when channel separation was less than 12 db, and was not improved when the separation was greater than 20 db. The 1-kc output of each channel is .4 volt at 5.5 cm/sec. The response from a RIAA frequency record does not require equalization when the pickup works into a 3-megohm load as shown in Fig. 4. For record changer use, 4 to 6 grams of tracking force is recommended. The electrical impedance is capacitive, 600 mmf per channel. Measured compliance is 2 x 10^{-6} cm/dyne in both vertical and lateral modes. Production performance checks indicate a high degree of uniformity among units.

Record wear tests show the life of stereo records will probably be on the order of 180 plays or more before appreciable wear can be detected. This compares well with LP record life with good monophonic pickups.

Fig. 4—Stereo pickup response from a RIAA frequency record.



A NEW MAGNETIC RECORDING SYSTEM

by

D. R. ANDREWS

Record Changer and Tape Systems
Radio "Victrola" Product Engineering
RCA Victor Home Instruments
Cherry Hill, N. J.

THE AVERAGE MODERN American is becoming spoiled. He has become accustomed to having things done with a minimum of effort. Magnetic tape is no exception. Under our present day standards, the inconvenience associated with the operation of tape machines is out-dated. One cannot expect the average person to thread tape over heads and pulleys, then fasten it onto a reel.

Magnetic tape fulfills the quality requirements of the most discriminating person. The frequency response and signal-to-noise are excellent. The ease with which good home recordings can be made is astounding, but the inconvenience and cost of the medium are detrimental. More than five years ago, we determined to correct this condition and modernize tape recording equipment.

THREE PROGRAMS INITIATED

Three programs were initiated to overcome these defects. One program was aimed primarily toward the improvement of frequency response so that the speed of the medium could be reduced. A second program was an investigation to find how narrow the tracks could be made without unduly sacrificing signal-to-noise. The third program was a thorough investigation of all possible methods of handling the tape without the present inconvenience of threading, and rewinding. This program included both the design of a new tape cartridge and the development of machines to operate it.

SLOWER TAPE SPEED

The first program revealed the fact that if a good head were constructed and if slightly less bias were used during recording, the present $7\frac{1}{2}''$ per second tape speed could be reduced by a factor of two and still maintain good frequency response. In order to do this, special heads were developed. These heads are constructed with a gap in the magnetic circuit of only 90 micro-inches.

Fig. 1 shows an uncompensated tape curve made with such a head. This curve was made by recording with constant current and reproducing with an uncompensated amplifier having high input impedance.

Fig. 2 shows a curve of the proposed E.I.A. (Electronics Industries Association) standard compensation for the reproducing amplifier.

Fig. 3 is a curve of the overall system operating at $3\frac{3}{4}''$ per second tape speed.

NARROW TRACKS

An investigation of narrower tracks was made in order to verify the available theoretical information with experimental data. The output level of recorded signals varies directly with the track width, but the output level of random noise varies with the square root of the track width. Therefore, the signal-to-noise ratio is decreased somewhat, but not directly with the track width. The azimuth angle error produces a decrease in the output of short wavelength signals. This reduction in output for any given angle error is increased very rapidly when the wavelength is shortened, but is decreased very rapidly when the track width is decreased.

loss in *db*

$$= 20 \log_{10} \left[\frac{\sin\left(\frac{\pi\, w \tan \infty}{\lambda}\right)}{\left(\frac{\pi\, w \tan \infty}{\lambda}\right)} \right]$$

w = width of sound track
∞ = angle of tilt
λ = wavelength of recorded signal

This formula reveals that if the track width were reduced in the same proportion as the physical wavelength for any given frequency, the losses from azimuth angle errors would remain the same.

The calculation of crosstalk between discretely separated tracks on the tape becomes rather involved. However, it is a function of recorded wavelength, track separation and track width.

TO THOSE WHO CONTRIBUTED

By
A. D. Burt, Manager
Record Changer and Tape Systems
Radio "Victrola" Product Engineering
RCA Victor Home Instruments
Cherry Hill, N. J.

The articles in this issue of the RCA ENGINEER, with respect to magnetic tape, touch upon a subject involving many facets of RCA Engineering. The authors and the editor acknowledge the contributions made by the various people in the RCA organization.

Currently, we are marketing a Tape Cartridge Instrument known as the SCP2 with others to follow. How did this come about, who solved the many problems, how long did it take, how much did it cost, and will it be successful are a few of the questions one could ask?

First of all, it came about as a result of a suggested program covered by a letter — "Establishment of Tape Cartridge Development Program" — dated April 5, 1954, which formalized the objective approach. Prior to this date, much technical background had been developed. In the creative minds of those involved, success seemed possible. Nor, can we neglect commercial pressure as a real force — since experience in threading tape "reel-to-reel" pointed the need for a better way.

The many problems were solved by many people. Those in Consumer Products, DEP, IEP, and the Laboratories who worked in the various activities involving magnetic tape contributed the narrow track and made possible the high resolution of information by means of a very small magnetic gap in the magnetic head. Those who worked in the amplifier field contributed to the accomplishment of high signal-to-noise ratio. There were many contributions from Staff personnel. Those in the New Products group arranged and actively pushed specific project programs.

Those who worked in the mechanical field resolved the Cartridge problem and the mechanism to operate the Cartridge. Those in Product Design concluded the final Cartridge, mechanism, heads, amplifier, the complete instrument, and Manufacturing successfully produced the product.

As a "consultant," Dr. Alfred N. Goldsmith, to mention one name, contributed to the resolution of the cartridge problem. Top Management and Operating Management were sympathetic to the many problems and offered encouragement when needed. This is truly an example of an all-RCA effort to make a major contribution, resulting in increased enjoyment of "tape" in the home.

It took a long time — five years, and it cost a great amount of money to say nothing of the wear and tear on dispositions of those involved.

Finally, will it be successful? This can only be answered in the market place. This accomplishment has a sound technical and commercial foundation. It has one other force — the dynamic power of a great corporation — The Radio Corporation of America — people like you.

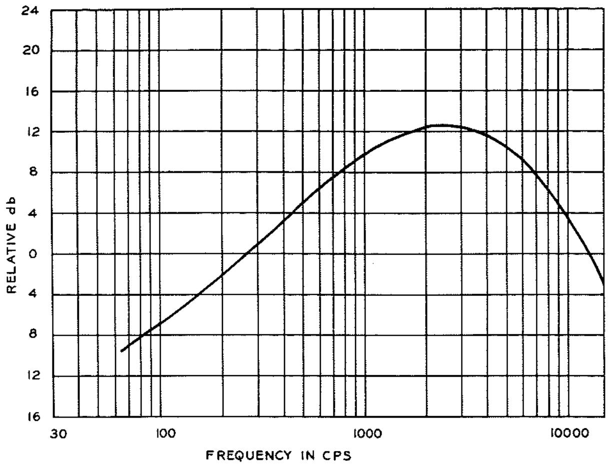


Fig. 1—Uncompensated tape curve made with a head having a 90 micro-inch gap in the magnetic circuit.

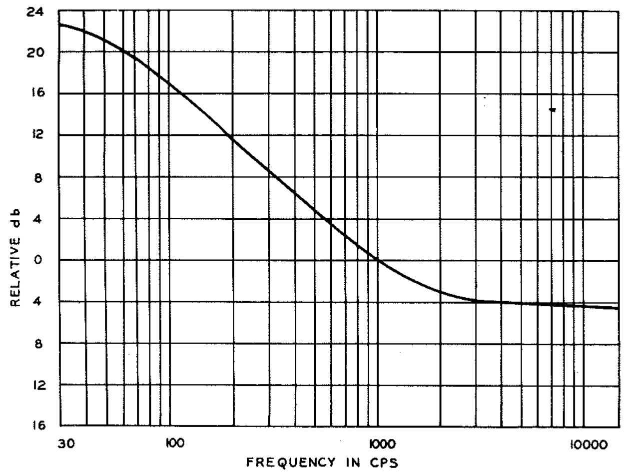


Fig. 2—Curve of the E.I.A. proposed standard compensation for reproducing amplifier.

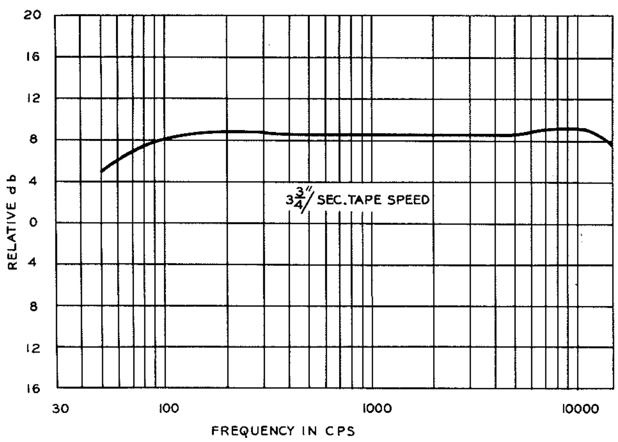


Fig. 3—Curve of overall frequency response for the system operating at a speed of 3¾ inches per second.

The tape speed was decreased to 3¾″/sec. which decreased the physical wavelength of any given frequency by a factor of 2. Therefore, the track width could be reduced by a factor of 2 without increasing the loss in output due to azimuth angle error or substantially increasing crosstalk between the tracks.

By selecting track widths of .043″ and separation between tracks of .025″, four tracks could be recorded on standard ¼″ tape. Fig. 4 shows the track placement. The tracks are recorded with the tape traveling in the direction shown by the arrows.

MAGAZINE LOADING CARTRIDGE

In order to find the most convenient method of handling magnetic tape, every conceivable means was investigated. Work which we had done several years previously was reviewed. This work included a self-threading tape machine, a coaxial spring loaded wire recorder cartridge, and coplanar film magazines for original sound-on-film recording. All available continuous-loop tape cartridges were tested. Additional work was also done to improve the performance of continuous-loop cartridges.

In all this work, the viewpoint of the consumer was kept in mind. Commercial advantages as well as technical details were considered in making decisions.

Self-threading tape machines are usually designed with a leader left in the machine permanently. Some sort of hook or latch is provided to snare the free end of the tape and pull it into operating position. Such a machine might be built which is practical, but most attempts have either been complicated or unreliable.

Spring loaded coaxial cartridges are usually made by using a clock spring between the two reels to maintain the tape tautly as it is unwound from a reel of one diameter onto a reel of another diameter. Such a cartridge is very difficult to repair and is inherently expensive.

Coplanar film magazines have been very successful over a period of years. Two hubs are used without flanges. In this manner, as one reel increases in diameter, the other decreases. In this way, the distance between hubs can be reduced substantially.

The continuous loop cartridge is operated by pulling the tape from the center of a spool and winding it on the outside of the same spool. This causes slippage between each two adjacent layers of tape. Special lubricants are sometimes used to reduce the friction caused by slippage. However, because of the inherent non-reversibility, the continuous-loop cartridge does not lend itself to home recording. It is also very difficult, if not impossible, to wind the tape initially so the free loop will not change length. The proper tension is usually approximated, then the length of the free loop is adjusted after a "run-in" period of time, all of which is quite costly for pre-recorded tape.

By the process of elimination, the coplanar tape cartridge was selected as the most logical, and was developed into a commercial product.

THE COPLANAR TAPE CARTRIDGE

Fig. 5 is a photo of a cartridge and its shipping box. The cartridge is approximately 7¼″ x 5″ x ½″. It is essentially rectangular in shape and will store in any average book shelf. Fig. 6 is a photo of the cartridge with the cover removed. Fig. 7 is a sketch of the various parts of the cartridge.

The polystyrene case is made in two parts. The tape is wound on two polystyrene hubs. A metal slide is moved by a spring to provide a brake on the hubs during shipping and storage. When the cartridge is placed on the machine, the brake is released. Two sheets of polyester film (Mylar) separate the tape from the walls of the case. These Mylar sheets perform several functions: the coefficient of friction between acetate tape and Mylar is very low; the melting point of Mylar is comparatively high, which reduces scoring; the sheets close the windows used for indicators and separate the brake and tape; and a film of air is trapped between the sheets and walls of the cartridge case, which reduces mechanical noises.

Pre-recorded tapes will be furnished in cartridges with holes in the back edge. An interlock switch may be provided on the machine which will interlock the recording amplifier if these holes are present. Blank tapes are furnished with knock-outs over these holes which may be removed for preserving tapes after recording, if desired.

Fig. 8 shows how the tape is fastened to the hub by a simple loop, spliced in the end of the tape, and hooked over a pin in the hub. The end of the tape is fastened to the hub to provide automatic stopping when the tension is increased. The tape passes over a trip pin on the mechanism as shown in Fig. 9 Before the end of the tape is reached, the tape and trip are in the position as shown by the dotted lines. A semicircular wall encloses the trip pin when in the tripped position. This prevents the tape from falling on the wrong side of the trip when the cartridge is placed on the machine.

SEMI-AUTOMATIC MECHANISM

Two different transport mechanisms were designed to operate the cart-

TRACK PLACEMENT

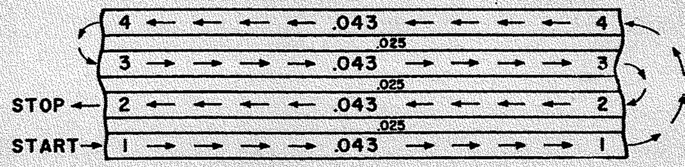
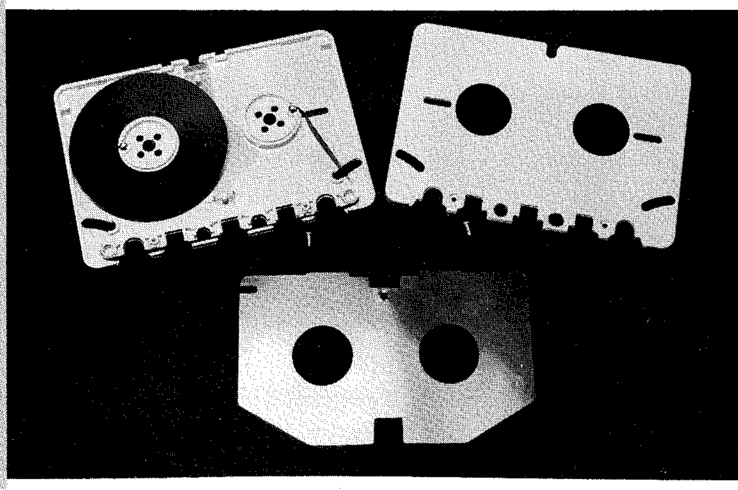


Fig. 4—Sketch of the arrangement for placing four tracks on standard ¼-inch tape.

Fig. 5—Photo of the cartridge in its shipping box.

Fig. 6—Photo of tape cartridge with cover removed.



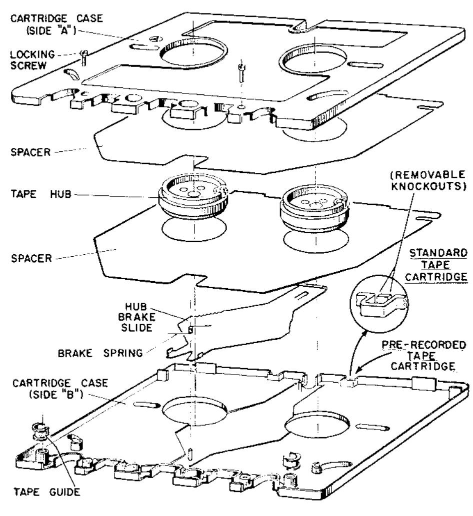


Fig. 7—Sketch showing how various parts of the cartridge fit together.

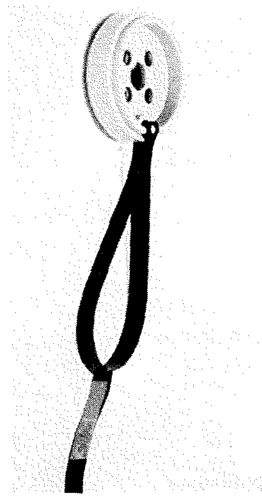


Fig. 8—Photo showing how tape is fastened to the hub.

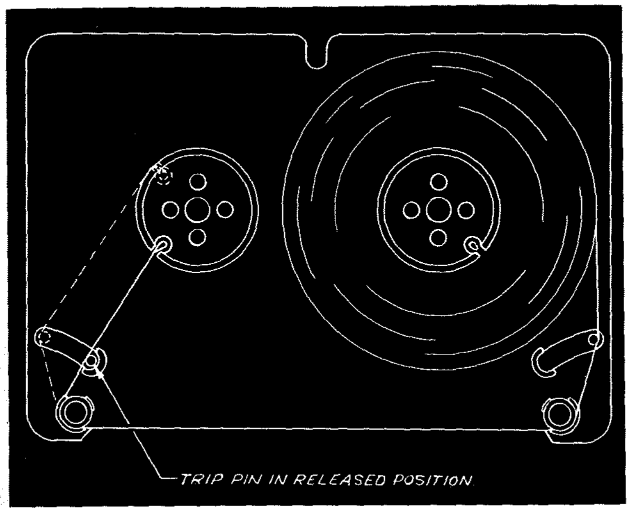


Fig. 9—Sketch showing how tape passes over a trip pin located on the mechanical assembly.

ridge. Both mechanisms may be used in either monaural or stereo instruments and both machines may be used as recorders as well as reproducers. One machine has been designed for the budget-minded customer and the other is a deluxe item.

Fig. 10 is a photo of the semi-automatic machine. The edge of the cartridge is placed in the guide bar at the back, and the front of the cartridge is merely pressed downward. The push-button on the left is depressed and the machine will operate up to one-half hour then automatically shut off. The cartridge is then turned over and restarted to play a different track on the tape. Four manual push-buttons are provided, having the following functions: Play/Record, Rewind, Fast Forward, and Stop.

When the tape reaches the end in either normal or fast speed, the increased tape tension is used to stop the machine. On first thought, it might seem impossible to stop a reel of tape during fast rewind without breaking. However, simple calculations as shown on Fig. 11 indicated that the stored energy in 600 feet of tape rotating at 500 RPM would produce a force at a tangent to the outer diameter of only slightly over 12 ounces. This nominal force, nonetheless, immediately challenges the ingenuity of the machine designer. When the problem is carefully considered, certain requirements become evident: the trip mechanism must operate in a minimum of time; all excessive inertia such as that developed by the motor and other mechanism parts, must be disconnected from the tape; and the take-up torque must be limited. A detent type of trip mechanism was chosen which would fulfill the first requirement. Clutches were chosen to fulfill the other two requirements.

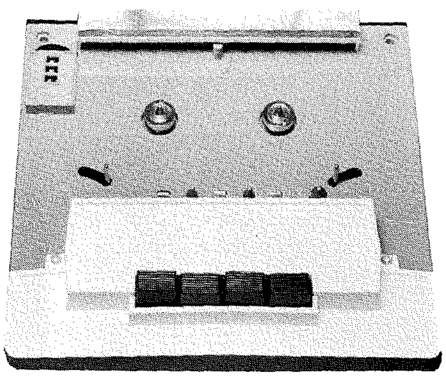


Fig. 10—View of the semi-automatic tape machine.

$$\text{ANGULAR VELOCITY, } V = 500 \text{ rpm} = 8\tfrac{1}{3} \text{ rps}$$

$$\text{RADIUS OF GYRATION, } r_g = \sqrt{\frac{{r_1}^2 - {r_2}^2}{2}} = \sqrt{\frac{2^2 - .75^2}{2}} = 1.31 \text{ in.}$$

$$\text{LINEAR VELOCITY, } v = V 2\pi r_g = 8\tfrac{1}{3}\, 2\pi\, 1.31 = 68.5 \text{ in./sec.}$$

$$E = \frac{W r^2}{2g} = \frac{4(68.5)^2}{2(32.17)12} = 24.35 \text{ in. oz.}$$

$$F \text{ @ } r_1 = \frac{24.35}{2} = 12.175 \text{ oz.}$$

Fig. 11—Calculations showing that it is possible to stop a reel of tape during fast "rewind" without breaking.

FULLY-AUTOMATIC MECHANISM

The second mechanism, shown in Fig. 12, was designed to be fully automatic. After starting, it records or reproduces all four tracks on the tape, then shuts off at the point of beginning. To accomplish this, two capstans are rotated in opposite directions. The tape is propelled in one direction or the other by pinching the tape with a rubber pressure roller against one of the capstans. The control system is a combination electromechanical system. A programming motor is used to select the direction of tape travel, to connect the proper heads to the amplifiers and to stop the machine automatically.

The consumer is now offered a new system with all the former desirable features, plus new conveniences and economies.

DALLAS R. ANDREWS majored in Mathematics and Physics at Ball State Teachers College at Muncie, Ind. He later studied Radio Engineering at Purdue University Extension at Indianapolis. He has been engaged in development engineering at RCA in various phases of magnetic and disc recording for the past fifteen years. He is presently in the Record Changer Engineering Group of the Radio & "Victrola" section of the Home Instruments Department. He is a member of Audio Engineering Society, Institute of Radio Engineers, The Franklin Institute, and American Society of Inventors.

Fig. 12—View of the fully automatic tape mechanism.

TAPE RECORD DEVELOPMENT

By

A. J. VIERE and A. G. EVANS

Record Engineering
RCA Victor Record Division
Indianapolis, Ind.

MAGNETIC TAPE AS a medium for recorded music in the home has been available for the past decade. Although there continues to be growing interest in this recording medium, it has not become sufficiently popular to "take over" the recorded music field because of two distinct disadvantages as compared to disc records. These are handling and cost. With this realization, RCA Victor set up a program to develop a new product which would provide for tape to be played as easily as a disc record and also be available to the public at somewhat comparable prices.

High-speed duplication and larger production tend to reduce the manufacturing cost of tape records. However, material costs of the tape and reels still far exceed the material costs of a phonograph record. It is apparent, then, that the cost of recorded tape could be decreased by reducing the amount of tape required to record a given amount of music. Two basic methods to achieve this are reducing the tape speed and reducing the width of the recorded track.

TAPE SPEED

At one time, professional recordings were made at a tape speed of 30 ips and home equipment used a speed of 7½ ips. Since then, commercial tape and professional recorders have been improved so that satisfactory results are obtained at 15 and even 7½ ips. Today home recorders, which originally were limited to frequencies up to about 8 kc, give satisfactory frequency response to 15 kc at 7½ ips and, in general, this performance is required for reproduction of recorded music.

The tape speed of 3¾ ips which was chosen for the new system would result in a very poor frequency response using recording techniques existing at the time. This is due to shorter recorded wavelengths and is indicated by present day recorders, operating at 3¾ ips, having a limited recording and reproducing audio frequency range of from approximately 50 cps to 8,000 cps. However, one of the specifications and goals was to have full frequency range from 50 cps to 15,000 cps and with a performance which equals the quality of the 7½ ips recorded music tapes. To satisfy these requirements, heads with shorter gap widths than the conventional were necessary. This problem was undertaken as a design objective by Advanced Development of Defense Electronic Products. A playback head with 90 micro inch gap width was designed in order to permit faithful scanning of the high-frequency (shorter) wavelengths thereby maintaining full frequency range. A gap width of 120 microinches was chosen for the record head.

TRACK WIDTH

Two 0.090-inch wide tracks on a quarter-inch tape has been standard for home-type tape recorders in the past. Numerous measurements and investigations were necessary to determine how much the sound tracks could be reduced in width without causing deterioration of the quality of the system. With a reduction of track width, problems of guidance, tape-to-head contact, signal level and signal-to-noise ratio are inherently developed.

Output voltage from a magnetic head is directly proportional to the number of lines of flux cutting the coil in the head. This means that if the track width is reduced by one-half, the output voltage from the head will be reduced by one-half. This in itself determines the additional amplifier gain required to obtain desired output signal level and with modern circuits it is not difficult to obtain gain to make up for the loss due to the reduced track width.

More important than the voltage output of the playback head is the resultant signal-to-noise ratio as a function of track width. In the analysis of background noise of tape, several sources determine the final signal-to-noise ratio. These are: "Tape Noise"—noise produced by irregularities in the random dispersion of the magnetic particles in the oxide coating. This noise tends to increase with any non-symmetry in the recording bias waveform; "Recorded Noise"—that noise recorded on the tape which originates from an original master and the electronics of the duplicating equipment; and "Amplifier Noise" — that inherent noise of the reproducing system including hum, thermal, and mechanical noises.

"Tape Noise" is found to be directly proportional to the square root of the track width. Since the waveform of this noise is random across the width of the track, the total contribution of all segments of the track will be

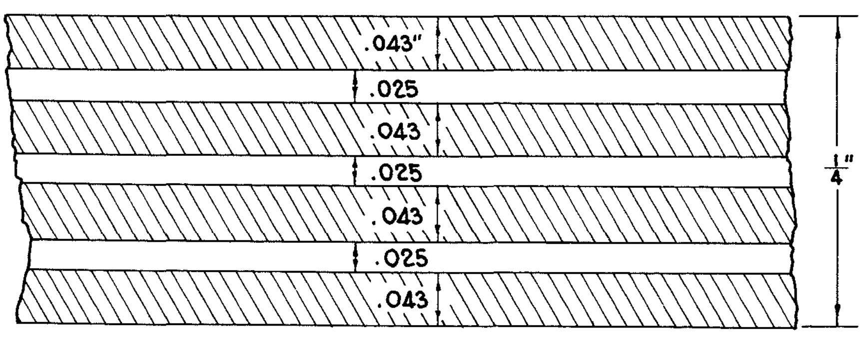
$$E_n = \sqrt{\sum_{i=1}^{n} e_{ni}^2} = \sqrt{n}\, e_n$$

where

$$e_{n1} = e_{n2} = \ldots\ldots e_{n_n} = e_n$$

and where E_n is the total noise voltage in the reproducer, e_{ni} is the RMS contribution from the i th segment of the track. It can be seen that tape noise

Fig. 1—Track arrangement for the 3¾ ips four track system.



level for varying track widths, as compared to the output from a standard track, would be

$$N_x = \sqrt{\frac{x}{s}}\, N_s$$

where x is the new width.

Therefore, the resulting ratio of signal-to-tape noise with bias in the record head can be expressed in db as

$$S/N = 20 \log_{10} \frac{E_s}{E_n} = 20 \log_{10} \sqrt{n}\ \frac{e_s}{e_n}$$

The relative change in this ratio with track width can now be derived. Let r be the ratio between the width of two tracks, with one track composed of n segments and one track composed of rn segments. For rn segments,

$$S/N = 20 \log_{10} \sqrt{rn}\ \frac{e_s}{e_n}$$

The relative change in the signal-to-tape noise ratio due to the difference in the track width is then

$$(S/N)_{rn} - (S/N)_n = 20 \log_{10} \sqrt{rn}\ \frac{e_s}{e_n} - 20 \log_{10} \sqrt{n}\ \frac{e_s}{e_n}$$

or relative $S/N = 20 \log_{10} \sqrt{r}$
where r is the ratio between the two track widths. Thus if the track width was reduced to one-half of the original width, the noise ratio will be decreased by $20 \log_{10} \sqrt{2} = 3\text{db}$

It should be noted, for this example, that the decibel reduction in "Tape Noise" ratio is only one-half the corresponding change in voltage output level. Also, it generally becomes the major noise source for slower tape speed systems. The analysis of "Recorded Noise" can be represented in a manner similar to "Tape Noise" and is found to vary directly with output level. The "Amplifier Noise" level for a given system is a constant and therefore is not a function of track width. However, the ratio of signal level to "Amplifier Noise" varies directly with track width. The use of "low noise" amplifiers tends to minimize this effect which is usually less than the "Tape Noise" for track widths greater than approximately .020 inches.

The final track width chosen was .043 inches, approximately one-half of the .090 inches which is the current standard for the two-track 7½ ips system. This was chosen on the basis of realizing a satisfactory signal-to-noise ratio, and providing an adequate width to minimize tape guidance and head contact difficulties for a proposed ¼ inch tape mechanism. The final design of the track placement on the recording medium is shown in Fig. 1.

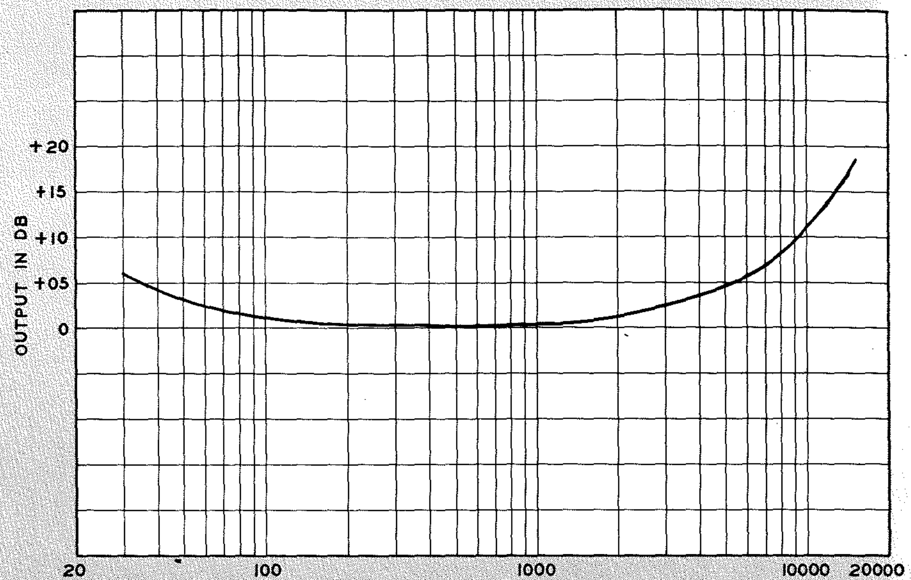


Fig. 2—Record characteristic for the 3¾ ips four-track system.

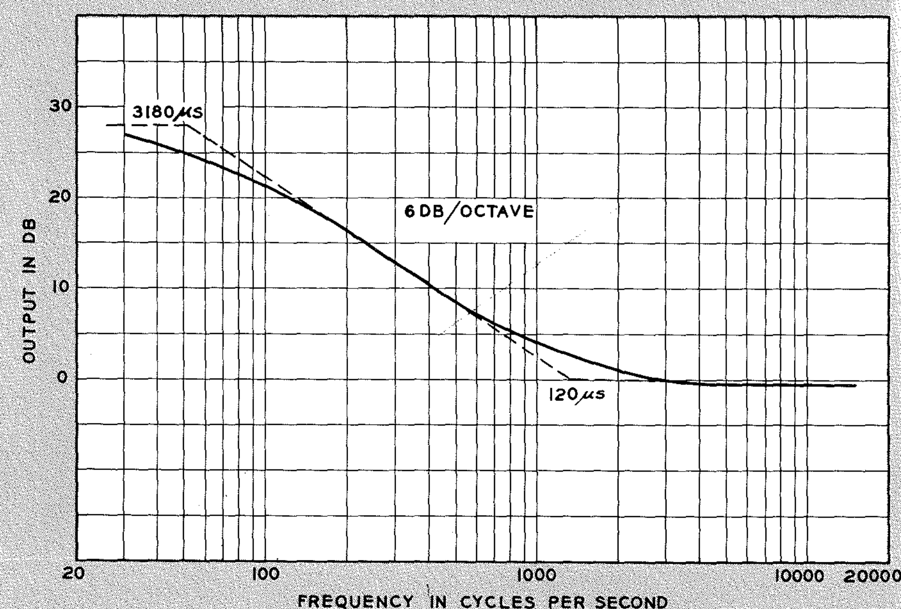


Fig. 3—Reproduce characteristic for the 3¾ ips four-track system.

CROSSTALK

For a four-track system with a recorded track width of .043 inches, the spacing between tracks becomes .025 inches. This is one-half of the .050 inch spacing used for the 7½ ips two-track system and results in increased crosstalk. In multitrack recording "crosstalk" is defined as the undesired signal picked up by the head from recorded signals on other tracks on the tape. In general, there are two types of crosstalk which may be bothersome. One is due to direct pickup by the head in use of the fringe flux lines from adjacent tracks. The separation that is necessary to prevent this type of crosstalk is a function of recorded signal wavelength. The longer the recorded wavelength, the greater the distance must be between the tracks in order to achieve a desired degree of freedom susceptibility. The two-to-one reduction in tape speed will reduce the wavelength by this same factor, and therefore crosstalk due to flux lines being reproduced from the adjacent tracks tends to be diminished to some extent. The other type is caused by direct coupling between two adjacent sections of a stacked head assembly. This crosstalk has been reduced to a sufficiently low level by the introduction of special shields between sections and by using interlaced tracks to provide increased section spacing. Investigation indicated that it was possible to reduce the distance between adjacent tracks to 0.025 inches with no increase in crosstalk.

OPERATING CONDITIONS

The general term "operating conditions" as used here actually covers a number of properties of the 3¾-ips four track system which are so interrelated that it is almost impossible to discuss them separately. This includes such things as the record and playback equalization, the high-frequency bias used in recording and the recording level. Each of these affects the quality of the over-all system and yet no one of them can be logically specified without specifying all the others.

The record and playback equalizations are the pre-emphasis and post-emphasis corrective circuits to compensate for losses in recording and reproducing and to make maximum use of the capabilities of the recording medium. If not enough pre-emphasis is used in the recording, the over-all system will suffer from poor signal-to-noise ratio; on the other hand, if too much pre-emphasis is used, certain frequencies will result in overload and cause distortion. Thus the choice of optimum record and playback equalization is very important; the determination of these characteristics is directly related to the energy spectrum of the signal to be recorded. Music as recorded today has no "typical" energy spectrum, and therefore can best be handled by experimental means. Different types of musical selections were recorded and checked by listening tests. Measurements were made of distortion and signal-to-noise ratio for a wide range of record and playback equalization curves until one gave the optimum results.

During the determination of the record and playback equalization, the high-frequency bias had to be considered. The undistorted output tends to vary directly with recording bias current changes. However, the relative frequency response tends to vary inversely with bias. Since these two properties are in direct opposition to each other, it is necessary that the bias current be accurately optimized for maximum undistorted output of low frequencies and minimum loss of high frequencies. Simultaneous determination of the various operating conditions provides optimum over-all quality. The record and reproduce equalization curves chosen to achieve the best results or performance are shown in Fig. 2 and Fig 3.

TAPE CARTRIDGE

The handling of reels of tape has always been a nuisance; the tape has to be threaded through the machine to the take-up reel prior to use and requires rewinding after it has been played. The net increase in playing time per unit length of tape as a result of the development of the slow-speed narrow-track system automatically suggested the packaging of this small roll of tape in such a way as to eliminate the direct tape handling.

The answer to the tape handling inconvenience was the design and development of a new product, the RCA Tape Cartridge and the Tape Cartridge Player. The cartridge is approximately 5 x 7 inches by ½ inch thick and permits a playing time of up to one hour of stereo or two hours of monophonic recording. It is only necessary to place the Tape Cartridge on the player and push the desired function switch to operate the player. It is unnecessary to handle the tape itself as is required with reel type machines.

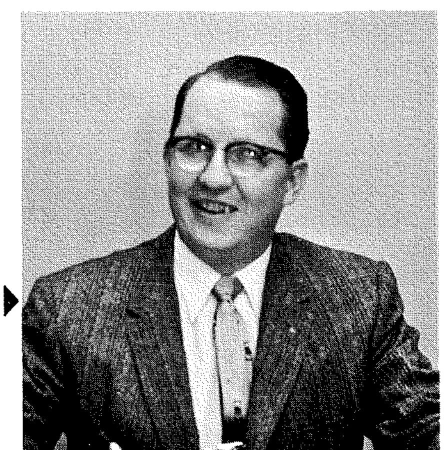
CONCLUSION

A system for tape recording has been developed which for all practical purposes equals the quality of standard 7½-ips tape and does this at a tape speed of 3¾ ips and with a recorded track width of only one-half that of the 7½-ips system. The development of the Tape Cartridge was a big step toward making magnetic tapes a desirable medium for recorded music in the home. A new design of the record and playback heads, a set of record and playback characteristic curves designed for minimum over-loading and maximum signal-to-noise ratio and determination of optimum operating conditions each contributed toward the improvement of the system. Any one of these changes in itself would not have represented a worthwhile improvement. However, with each component part being optimized for this particular application, a noteworthy advancement resulted in the field of magnetic recording.

ARNOLD J. VIERE received his BS degree in Electrical Engineering from the University of Illinois in 1951. After graduation he joined RCA at Indianapolis in the Record Engineering Laboratory as a Development Engineer. He has worked on phonograph record and magnetic tape recording development since he joined RCA Victor. Mr. Viere is a member of the Institute of Radio Engineers.

ARTHUR G. EVANS was graduated from the University of Illinois in 1947 with a BS degree in Electrical Engineering. After graduation he joined RCA at Indianapolis in the Record Engineering Laboratory as a Development Engineer. His work has been in the field of disc and magnetic tape recording, both in the development of new products and specialized electronic equipment.

He is a member of the Institute of Radio Engineers, and Audio Engineering Society and Eta Kappa Nu honorary society. He is currently Central Vice-President for the Audio Engineering Society.



A HIGH-RESOLUTION FOUR-TRACK STEREO HEAD

By

A. A. SARITI, Mgr.

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During 1955 several studies, within RCA, were made concerning the feasibility of narrow track, slow-speed tape recording. These studies proved conclusively that it was possible to record and play back frequencies as high as 15,000 cps at a tape speed of 3¾ ips. It was also found that the track width could be reduced one-half its nominal value and still satisfactorily maintain a signal-to-noise ratio for high-quality reproduction. Although the track spacing was reduced by one-half, measured crosstalk was minus 50 db or greater at one-thousand cycles.

When, in the summer of 1956, it was decided to engage actively in the development of a tape cartridge transport, a production design was started on a dual-track, in-line stereo head for this application. Up to this time, heads used for the above studies were handmade in RCA laboratories and, of course, were too costly a design for commercial application.

PRODUCTION DESIGN CRITERIA

Early investigations into all phases of the cartridge concept provided the necessary information from which design specifications could be developed. In most cases these were common or closely related to other components of the system. The performance considerations such as equalized frequency response and constant current record-playback characteristics were to be equivalent to high-quality heads operating at 7½ ips tape speed. Also the signal to noise ratio and crosstalk factor requirements were 50 db or better. These, you will note, are system requirements. The head, with "multiple-track" tape, and associated amplifiers are dependent on each other in producing the required results. Other specific criteria such as low head-impedance for driving a low-noise transistor pre-amplifier, controlled pickup of stray magnetic fields, and mechanical considerations of compatibility with the narrow tape tracks and cartridge were also dependent on individual components. Probably one of the most important goals was to achieve a design that would lend itself to large quantity production with a basic cost equivalent to the average unit presently available for high-quality recorders.

PRODUCTION DESIGN

The four-track stereo tape system dictates that the head must be an in-line stereo type. First consideration was given to the material to be used in the manufacture of the case half. Thermo plastic, thermosetting plastic and epoxy type case halves were reviewed. However, bearing in mind the degree of flatness needed on the case face and also the critical track spacing and tolerances required on a

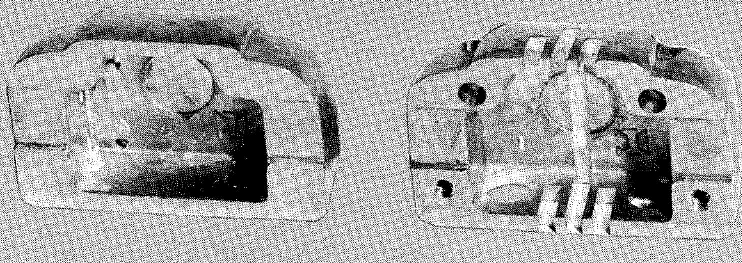


Fig. 1—Stereo case head before and after machining operations.

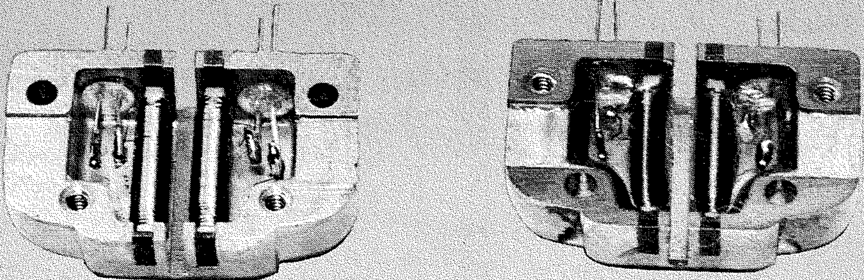


Fig. 2—Stereo case head before (left) and after epoxy resin filling and lapping.

Fig. 3—Finished stereo head in shielded case.

four track system, all of the above materials were found to be unsatisfactory. Dimensional stability with temperature and humidity variations was also a factor in rejecting these materials. Because of the above stated requirements, it was finally decided to use a cast aluminum case with precision milling and drilling operations. The case half before and after machining operations is shown in Fig. 1.

The thickness of the lamination material was next to be considered. Tests were made on both photo etched two-mil laminations and stamped six-mil laminations. After building a head from each type of lamination, an evaluation of the electromagnetic efficiency of each was made. A perfect head tested under these conditions would produce a 6-db per-octave curve. Both units showed excellent results. The greatest deviation from the 6 db per-octave curve was one decibel at 15 kc on the 6 mil lamination head. As this investigation showed very little difference between results obtained from either 2-mil or 6-mil laminations and also because of economic reasons, 6-mil punched laminations were used in production units. Balanced windings, which will cancel external fields, are used in order to reduce hum pickup from associated circuits.

After laminations and coil assemblies are placed in the case halves and the soldering operations on leads are completed, the unit is internally potted with epoxy resin. A precision lapping operation is then performed on the case half. This area has been undercut in order to achieve a high degree of flatness. Fig. 2 shows the case half ready for epoxy resin and also shows this same unit after pouring and lapping.

A 45-micro inch quartz spacer is then evaporated on each pole tip area, and the two mating halves are fastened together with four screws to form a working tape head. Fig. 3 shows the finished head in a shielded case and the front face polished.

The constant-current record-and-playback curve taken at 3¾ ips is shown in Fig. 4. The dotted curve is a typical one taken on a popular head designed for and operating at 7½ ips.

The head impedance is approximately 1000 ohms at 3000 cps. Its output is fed directly into an equalized transistor preamplifier. The signal-to-noise ratio measured at 1000 cycles from a one-percent third harmonic distortion signal is 54 db.

The equalized record and playback curve is shown in Fig. 5. This curve is flat within 1.5 db from 100 to 15,000 cps and rolls off 3 db from 100 to 50 cps. This response was taken 20 db below the one-percent third harmonic distortion point.

As wavelength is equal to tape speed divided by frequency, in order to reproduce a 15-kc signal at 3¾ ips, the head must resolve a wavelength of 250 micro inches. The effective gap width of the tape head to resolve this wavelength must be 125 micro inches or less. The capability of the RCA high resolution head to perform this task is shown in the overall frequency response in Fig. 5.

CONCLUSION

Current production has yielded a high-quality, uniform, low-cost tape head. Essentially flat response from 50 to 15,000 cps at a tape speed of 3¾ ips is achieved by this high-resolution head when proper record and playback equalization is employed.

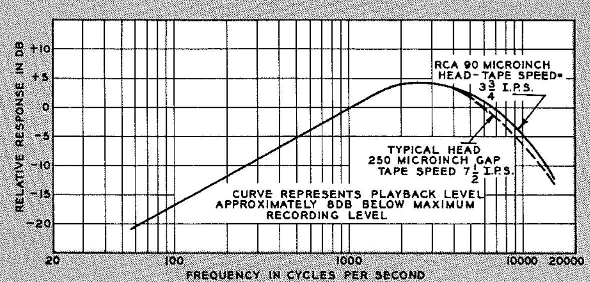


Fig. 4—Constant-current record and playback curve taken at 3¾ ips.

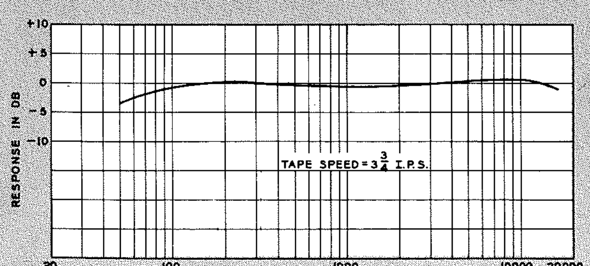


Fig. 5—Equalized record and playback curve.

ANTHONY A. SARITI joined RCA in 1941 as a troubleshooter in Special Apparatus. He attended Drexel Institute of Technology Evening School and graduated with a Diploma in Electrical Engineering in 1951. Mr. Sariti was then employed as an Acoustical Engineer in Component Parts until being transferred to the Radio and "Victrola" Division in 1957. He became Leader and then Manager of Transducer Engineering in 1959.

An active radio amateur, Mr. Sariti's call letters are W2RVV.

ENGINEERING DEVELOPMENT OF PRE-RECORDED TAPE IN A CARTRIDGE

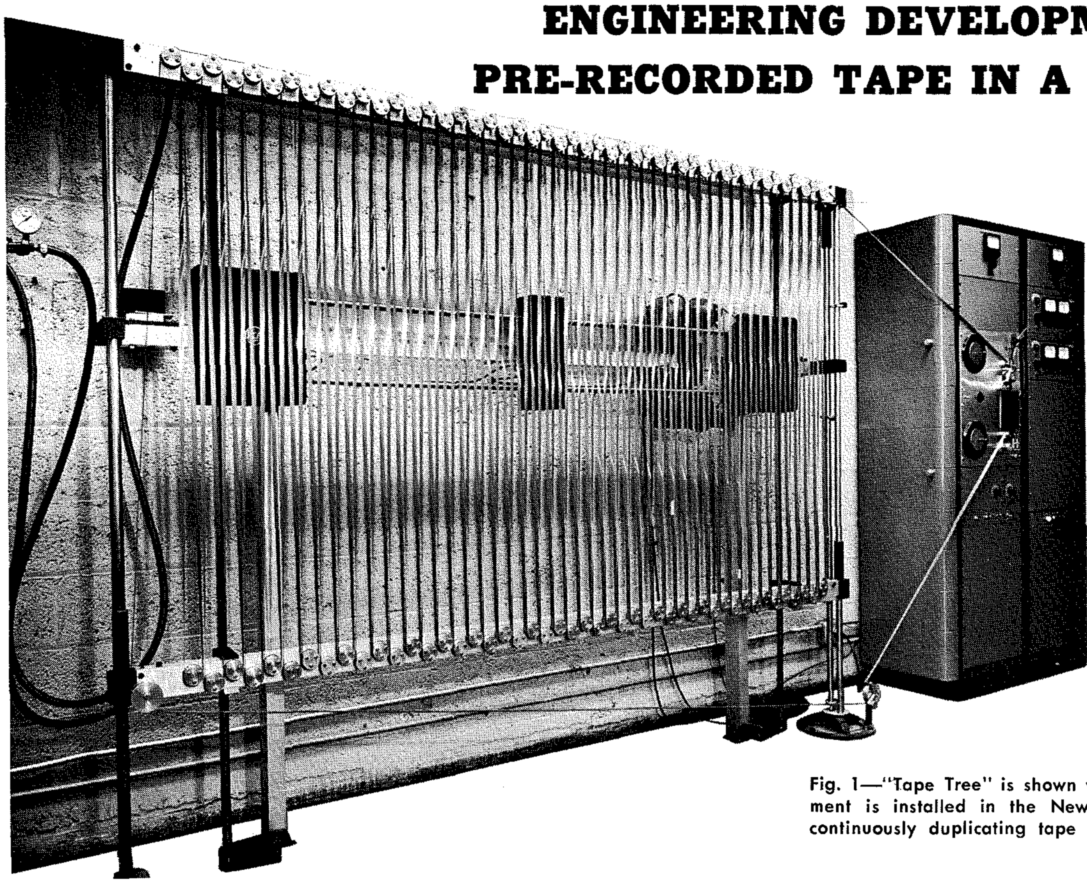


Fig. 1—"Tape Tree" is shown with its transport. This equipment is installed in the New York recording studios for continuously duplicating tape records from a master tape.

by
S. W. Liddle
Record Engineering
RCA Victor Record Division
Indianapolis, Ind.

THE INTRODUCTION of recorded magnetic tape in cartridge form is a major advancement in the home entertainment field. The cartridge makes a compact, self-contained package of music. Combined with the player, it eliminates threading of the tape, and in convenience and ease of handling, approaches the phonograph record. To play the tape, it is only necessary to place the cartridge onto the transport and push a button; it is no longer necessary to thread tape through magnetic heads and connect the free end to a reel. One hour of high-fidelity stereophonic music is available.

The original development work on the tape cartridge was carried out by the Radio and "Victrola" Division at Cherry Hill, in conjunction with their development of the transport mechanism. On completion of the initial design in the latter part of 1958, all future responsibility for the tape cartridge was assigned to the Record Division. This was a logical move since this division markets the cartridge with pre-recorded tape, and thus becomes the greatest user of cartridges.

It is the object of this paper to discuss the problems of recording and loading the tape into the cartridge. To accomplish this, new manufacturing techniques were developed to minimize both time and labor.

TAPE TREE

The tape used in the cartridge is one-mil base thickness by one-quarter inch wide. The music is recorded onto the tape on four separate tracks for reproduction at a tape speed of 3¾ inches-per-second. In the case of a stereophonic selection, two tracks are played in one direction and two tracks in the reverse direction. To compare this with two-track tape on a conventional reel operating at 7½ inches-per-second the cartridge will require one-fourth as much tape (for a given musical selection length). The reduction in the amount of tape needed (per musical selection) permitted new production techniques.

The shorter tape length, coupled with the requirement of minimum periods of silence during reversal of direction of tape travel, make it desirable to duplicate tapes from a continuously running master in order to reduce tape wastage. The continuously running master developed for this application is shown in Fig. 1 and is called a "tape tree." Basically the "tree" replaces the supply reel of the master transport unit, also shown in Fig. 1, in that it provides a "moving storage place" for the master tape. This enables the master tape to be played continuously with no rewinding.

The unique feature of this "tree" is that the tape is supported by an air film as it passes over the idlers (an idea conceived due to the work by DEP in air bearings). These air idlers make it possible to obtain the low tape tension needed using small idlers—a space saving feature permitting the "tree" to be erected in a small space.

To illustrate the operation of the "tree," let us assume a pre-recorded tape or tape record of approximately 400 feet in length is to be copied. A master tape, from which exact copies are to be made, has been carefully prepared. This tape with its four tracks recorded on one-half inch tape at 7½ inches-per-second is placed on the "tree" by weaving it up and down as can be seen in Fig. 1. The ends are spliced together at the transport with a 36-inch length of tape. This forms a continuous loop, and since the master was recorded at two times speed, the length of this master tape is 800 feet. The beams of the "tree" containing the air idlers are raised or lowered by motors to accommodate the exact length of master and maintain proper running tension.

The music on the master tape is now electrically transferred from the master transport to 4 slave units, each of which is supplied with a 7200-foot reel of blank tape. After 96 minutes of continuous operation, we have four 7200-foot recorded reels of tape, each containing 18 tape records. These are now ready to be separated or broken down into the individual tape record and placed in cartridges.

BREAK-DOWN MACHINE

Another piece of equipment used in the production of the recorded tape cartridge is shown in Fig. 2, which was designed and developed by DEP in accordance with recommendations by W. H. Miltenburg. This machine is called a break-down machine since its function is to separate or break-down the 7200-foot recorded reels of tape into the tape record length. As the tape record is wound from the recorded reel onto the plastic hub of the cartridge, an actuating signal stops the tape and starts a mechanical sequence which automatically cuts the tape at the exact separation point of the adjoining records, and forms two end loops. One end loop is the end of one record while the other is the beginning of the next record. Both loops provide the connecting link between the tape and the cartridge hub. The tape record, on its hubs, is now ready for insertion into the cartridge.

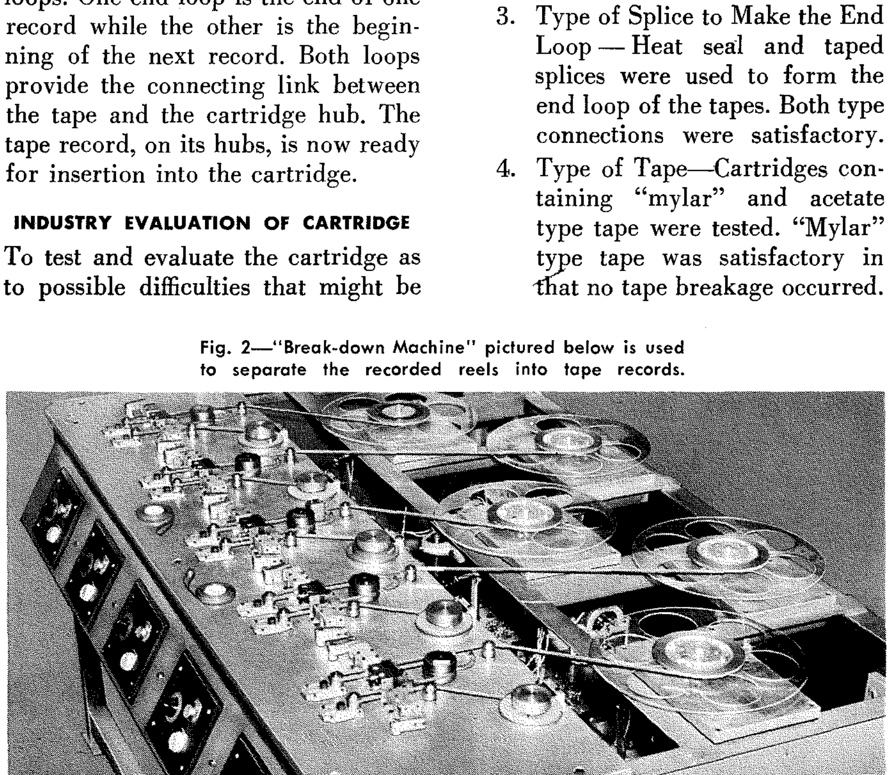
INDUSTRY EVALUATION OF CARTRIDGE

To test and evaluate the cartridge as to possible difficulties that might be encountered with transports of other manufacturers, an industry test was set up. Cartridges with known case designs, length of end loop, type of splice to make the end loop, and types of tape, were sent to ten transport manufacturers. The transports they used were in various stages of development, so actually the cartridges also defined for these manufacturers some definite requirements for their transports. Of the ten manufacturers to whom cartridges were sent, six were active and presented data by returning the cartridge unopened, after a failure had occurred, for our examination. In general, information of this nature, since the test sources were limited in number and since the transports were development models, merely indicated potential sources of trouble as opposed to hard, concrete facts that could only be obtained from customers.

Results of the variables represented by the test cartridges sent out indicated the following:

1. Case Design—Two case designs were included in the test. These cases were different in that internal ribbing was added to later designs to give the cartridge greater stiffness. Both designs gave satisfactory operation,
2. Length of End Loop—End loops of three different lengths were tested. Loops of one inch length were found unsatisfactory by one manufacturer. Longer loop lengths of $2\frac{3}{4}$ and $3\frac{1}{2}$ inches performed satisfactorily.
3. Type of Splice to Make the End Loop — Heat seal and taped splices were used to form the end loop of the tapes. Both type connections were satisfactory.
4. Type of Tape—Cartridges containing "mylar" and acetate type tape were tested. "Mylar" type tape was satisfactory in that no tape breakage occurred.

Fig. 2—"Break-down Machine" pictured below is used to separate the recorded reels into tape records.



S. W. LIDDLE received his B.S. degree in M.E. from Rose Polytechnic Institute in 1945. He joined RCA in 1946 as an engineer in Engineering Development of the RCA Victor Record Division, where he is currently employed. His activities have been chiefly concentrated on the design and development of tools and equipment for record manufacturing.

Mr. Liddle is a registered professional engineer in the state of Indiana and is currently doing graduate work at Purdue University.

Cartridges containing acetate tapes indicated that tape breakage might occur in two different regions. Five of the six transport manufacturers had breakage occur in fast wind where the end loop connects to the hub. It can be demonstrated that this breakage can be practically eliminated by proper radiusing of the hub slot. This in effect relieves the stressing point of the tape. Three of the six manufacturers had breakage occur along the "head-line" of the cartridge. This breakage is caused from either improper handling of the cartridge or damage occurring to the tape during insertion onto the transport. This damage usually does nothing more than tear or nick the tape edge ever so slightly, so that further strain breaks the tape. The breakage is very difficult to control or evaluate, as it is directly related to the handling of the cartridge.

The seriousness of the breakage is of course reflected by the number of plays and fast winds the tape is expected to survive. Based on experience with phonograph records, we use 100 plays or fast winds as the survival point. While applying the radius to the hub slot has increased the survival point of acetate tape to well over 100 plays, there is still the accidental breakage of the tape due to handling which at this time can not be evaluated. Based on results of the industry test and the breakage in the handling of acetate tape by inexperienced users, we selected "mylar" tape for our cartridges.

DESIGN OF STEREOPHONIC HIGH-FIDELITY INSTRUMENTS

By **P. B. SCOTT**
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Cherry Hill, N. J.

THE ORIGIN OF stereophonic sound reproduction goes back over twenty-five years. However, until recently there was little public interest in the use of two or more audio channels to increase special effects in electrically reproduced sound in the home. The widespread acceptance of high-fidelity techniques and sales of equipment for accurate sound reproduction gave impetus to the designer of high-fidelity instruments and equipment to develop new methods for enhancing reproduced sound. The introduction of multi-channel storage and reproducing systems for home high fidelity was a logical progressive step in the art.

Stereophonic recording and reproducing techniques make possible a very life-like replica of the original sound providing dimensions of width and sometimes even depth. The simple combination of two monophonic systems in one box is not sufficient in itself, however, to guarantee the maximum in desirable spatial effects and enhanced reproduction. Rather, careful design of both stereophonic recording and reproducing equipment together with the application of special techniques in the various phases of recording are necessary for good stereophonic high fidelity.

This article will be concerned with the problems encountered by the engineer designing home stereo high-fidelity instruments. The basic considerations affecting high-fidelity design in general have been well covered previously[1] and will be touched upon only as they concern the problems peculiar to stereophonic equipment design.

STEREOPHONIC vs MONOPHONIC

As with almost any departure from old and familiar methods the introduction of stereophonic techniques to home sound reproduction has met with some resistance from both industry and consumer critics. It has been argued that the spatial effect of stereo can be realized only if the listener is located in a restricted area to the front and between the loudspeaker systems. Actually, while this is partially true,

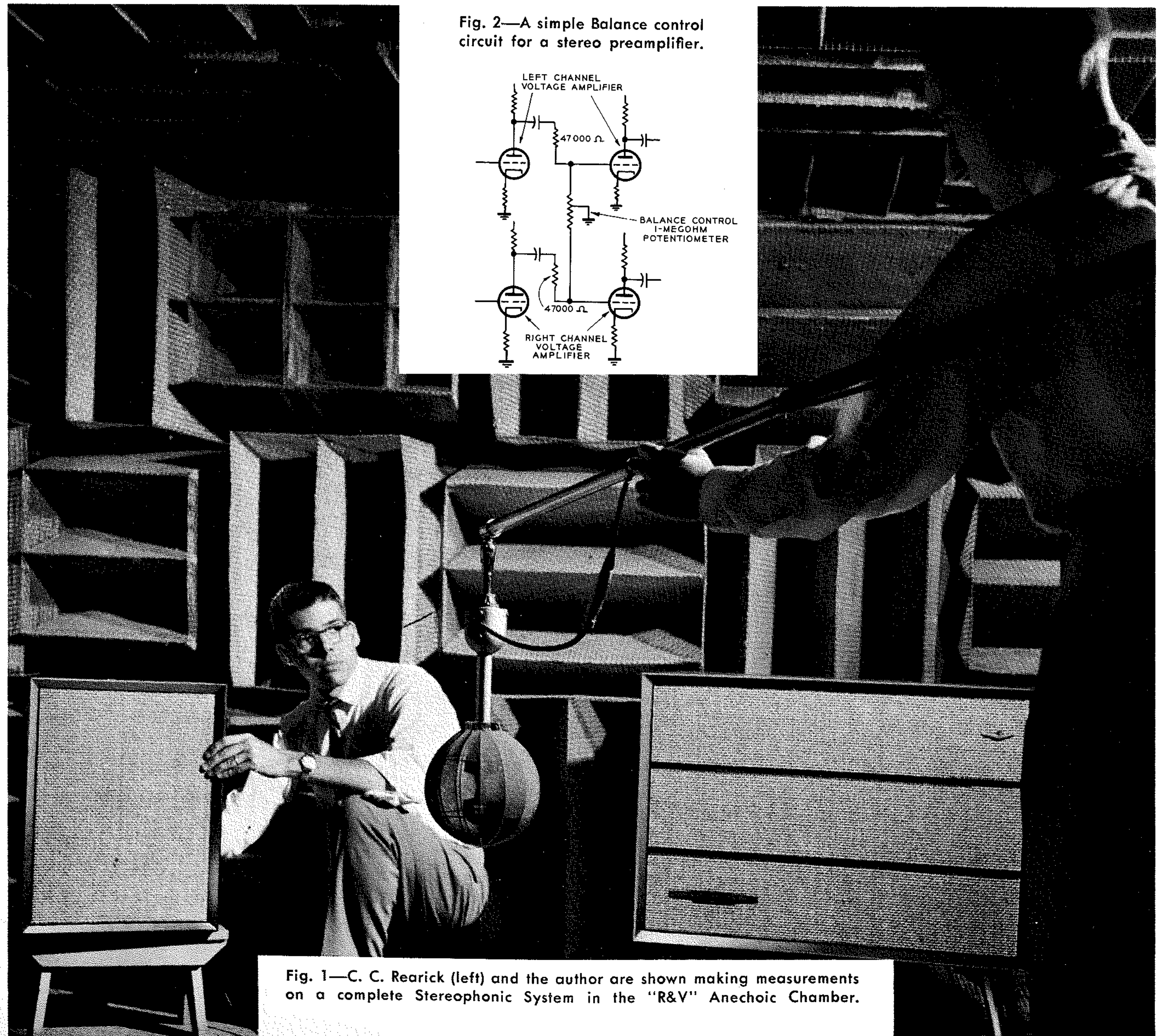

Fig. 2—A simple Balance control circuit for a stereo preamplifier.

Fig. 1—C. C. Rearick (left) and the author are shown making measurements on a complete Stereophonic System in the "R&V" Anechoic Chamber.

careful placement of speakers and furniture in a room will provide a reasonably large area in which stereo's added spatial effects can be enjoyed. In addition, much work has been done (see Fig. 1) to develop speaker systems which provide good stereo effects over most of the area to the front of the loudspeakers. Results are promising.

The use of two amplifier and loudspeaker systems certainly does not deteriorate monophonic reproduction but on the contrary tends to enhance a single-channel signal with regard to spatial effects. Also, a well designed stereophonic phonograph pickup will function as well when used on a monophonic record as will a good monophonic pickup. Therefore, the owner of a large library of monophonic records need not fear obsolescence when he purchases a stereo instrument.

Stereophonic disc records have been criticized as being inferior to their monophonic counterparts from the standpoint of general fidelity and to stereo tapes insofar as spatial effects are concerned. Most of the complaints were leveled at early stereo records and unfortunately some were partially justified. A similar situation occurred when long playing records were introduced. Now, as then, rapid improvements have occurred since the first records appeared so that stereo records of outstanding quality have become the rule rather than the exception. Happily, improvements in reproducing instruments have kept pace.

STEREOPHONIC SOUND ON TAPE

Stereophonic sound was first introduced three years ago into the home via the medium of pre-recorded tape pioneered by RCA and others. The first tapes were not competitive with monophonic disc records insofar as price was concerned but were the only means available at that time to provide stereo to the listener at home. In spite of the later introduction of stereo disc records some high-fidelity "hobbyists" continue to maintain that pre-recorded tape is the best means of achieving high-fidelity stereo reproduction. Actually the rapid improvements in disc quality have placed both storage media on roughly equal terms. Stereo discs still hold a price advantage, although recent price reductions in RCA reel-type tapes have narrowed this difference.

PERFORMANCE OF TAPE AND DISC

The recent introduction of 3¾ inch per second tape cartridges by RCA has brought the cost of pre-recorded tape even closer to that of stereo discs. It would be well, therefore, to discuss the technical advantages of tape and disc for stereophonic reproduction.

Tape provides greater channel separation than disc, in the range of 35 to 40 db in the case of the cartridge system. Listening tests have indicated that about 20 db or more separation is desirable for good stereo effects. A well designed stereo phonograph pickup will closely approach the latter figure at mid-frequencies but have not thus far exceeded 25 db. Increased distortion at the inner grooves is inherent to disc records whether monophonic or stereo due to the decrease in groove velocity.[2] If recorded correctly, tape has uniformly low distortion through its entire playing time. Commercial pre-recorded tapes have exhibited slightly inferior signal-to-noise ratios when compared with the best discs but the new cartridge system is capable of 55 db signal-to-noise despite its low speed and narrow tracks. This figure is quite adequate for high-fidelity reproduction. Perhaps the greatest advantage of tape is durability. Tape shows no appreciable wear after repeated playings, can be stored indefinitely under reasonable conditions of heat and humidity and is not as easily damaged as discs.

A tape record and playback instrument is necessarily complex and requires careful design.

Insofar as the complete stereo system is concerned, a tape recorder is generally treated as one of the several components necessary to achieve the desired result; the other components being disc reproducer, amplifier, tuner, and speakers. For maximum flexibility the system should include either a tape record-reproduce unit or at least provide connections for attachment of an external device of this type. In either case provision for recording from disc records or radio should be made for maximum use of the tape instrument.

STEREO DISC REPRODUCTION

As with monophonic records, either a record changer or a manual pickup arm and separate turntable can be used to play stereophonic records. The advantages of each for stereo are about the same as for monophonic records. The manual player arrangement is less complex mechanically than "automatics" and therefore more dependable; a larger and heavier turntable can be used, and better tone arm construction is possible. However, the "manual" setup usually requires expensive components approaching broadcast studio types and occupies considerable space. Changers on the other hand have the advantage of automatic handling of a number of records and give completely satisfactory performance in a home stereo instrument.

Historically, problems with acoustic feedback have occurred whenever disc players were housed in the same cabinet as loudspeakers. These problems have in some cases caused "howl" at maximum control settings, and in stereo instruments the added vertical sensitivity of a stereo pickup has compounded this problem greatly. As a preventative in RCA stereo instruments it has been advantageous to enclose completely the underside of the record changer. Performance is unaffected.

TUNERS AND STEREO BROADCASTING

Stereophonic radio broadcasting is in a state of flux at the present time because no one method or technique for transmission has been adopted as a standard in this country. Several schemes are now being used for experimental and in some cases commercial stereo broadcasts. Because of this somewhat confused situation, the manufacturer of stereo instruments is confronted with the problem of providing the consumer with a product which will receive at least one type of stereo broadcast, while guarding against product obsolescence.

The most widespread method of stereo transmission at present involves separate FM and AM transmitters and appropriate receivers in reproducing equipment. The system is as simple as it appears. One stereo channel is used to modulate the FM transmitter, in current practice usually the left, and the other modulates the AM transmitter. In the reproducing equipment obviously two separate tuners or tuner sections are necessary. An increasing number of AM and FM stations throughout the country are using this means of broadcasting and it has re-

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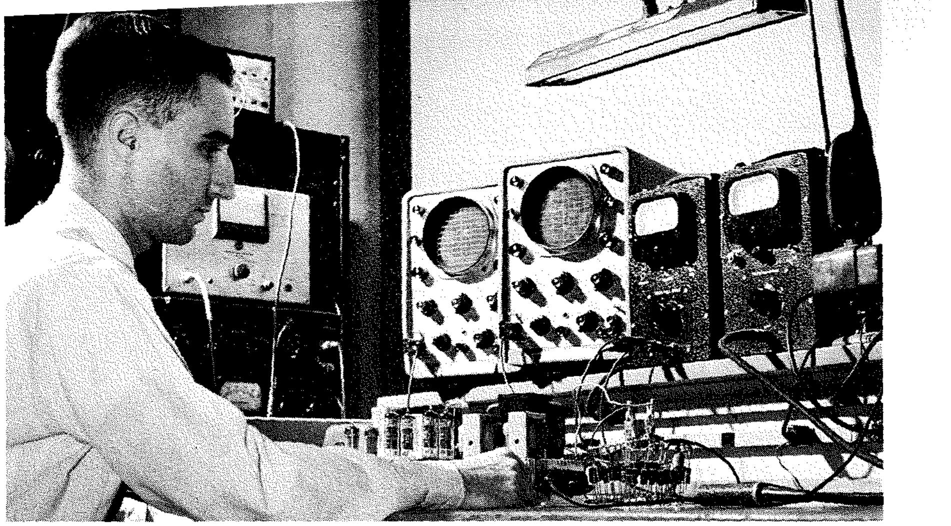


Fig. 3—In making engineering performance measurement on Stereophonic Amplifiers, a duplicate setup of precision equipment is needed. Here, the author is evaluating performance of a dual-channel, 50-watt amplifier.

ceived at least tacit approval by the FCC. Although this system has a number of limitations, such as the inferior fidelity of the AM channel, its widespread use makes possible the reception of AM-FM stereo in a complete stereo instrument.

A conventional high-quality AM-FM tuner design can usually be modified for AM-FM stereo reception without great difficulty or a large increase in manufacturing cost because the use of separate r-f, converter, and second detector stages is a common practice in the design of monophonic tuners. The major changes necessary for stereo operation include separation of tuning and dial drives and provision for separate i-f amplifiers usually necessitating an additional i-f stage.

In an effort to overcome some of the disadvantages inherent in AM-FM stereo broadcasting much work is being done in a number of quarters to perfect a method for two-channel transmission using a single FM channel and one transmitter.

One basic method for achieving this end involves frequency modulating the r-f carrier by the normal audio information plus a supersonic subcarrier. This system, known as multiplexing, is feasible, and is in use at present by a number of FM stations for transmitting subscription background music services on the subcarrier in addition to normal programming on the main channel.[3]

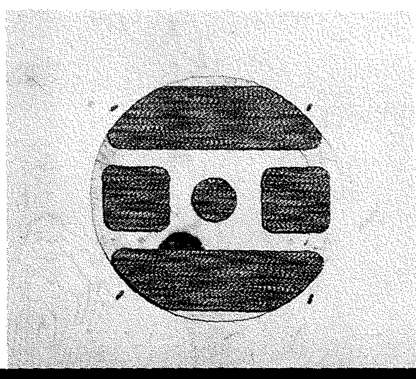
Several systems for FM multiplex stereo broadcasting are currently under development, with the goals of each approach being high-fidelity reproduction as well as compatibility with existing transmitting and receiving equipment. Thus far, no system for this type of broadcasting has been approved by the FCC for commercial use. However, since the possibility of future government approval of an FM multiplex system exists, provision for connection of an external multiplex adaptor unit to a stereophonic radio phonograph instrument is desirable.

Stereophonic instruments with tuner sections recently introduced by RCA Home Instruments feature not only connections for an external adaptor should FM multiplex stereo become a reality, but also provide simple switching so that the home listener could tune to a stereo broadcast as simply as to a monophonic program. The design of an adaptor for connection to these instruments would depend on the characteristics of the particular multiplex system adopted.

PREAMPLIFIERS AND POWER AMPLIFIERS

The design of preamplifiers and power amplifiers has probably been complicated least by the introduction of stereophonic sound. In fact, a few stereophonic instruments have been presented to the public with no consideration given to preamplifier or amplifier changes. Included in these particular instruments were duplicate monophonic preamplifiers and power amplifiers. While such a practice is sometimes necessary in the conversion of an existing monophonic instrument to stereo, it is a design compromise.

Fig. 4—This section of the speaker baffle of an extension speaker cabinet for a home instrument Stereophonic High-Fidelity System shows the Acoustic Filter. This is placed in front of the 12-inch speaker to balance response with the main instrument cabinet.



The use of ganged controls—control sections for a particular function in each channel physically linked together—is a virtual must. A few audio hobbyists may wish to manipulate a maze of controls but certainly the average music lover is not interested in complex adjustments for high-fidelity listening. When ganged potentiometers are used for loudness and tone control, each half should give approximately (within 20%) the same resistance change as the other for a given degree of rotation, lest loudness or tone balance between channels be affected when changing control settings.

In addition to the controls found in a monophonic preamp-control section such as function, loudness, bass, and treble, some additional controls are desirable for stereo instruments. Although loudness control sections should be linked together, some means should be provided for adjusting the gain of one channel with respect to the other. A circuit for such a balance control, as it is called, is shown in Fig. 2. This balance adjusting scheme is simple but the control is valuable to the listener because with it he can compensate for slight differences in amplifier gains or unusual acoustic unbalances in the listening area. Although not of great importance, controls can also be provided to reverse channel positions, and speaker phase.

Stereophonic power amplifiers can be produced most economically when a common power supply and chassis are used for both channels. The use of completely separate amplifiers generally means unnecessary cost due to duplications. For high-power applications push-pull amplifiers are more or less the accepted design for stereophonic as well as monophonic instruments. The Radio and "Victrola" Division has, however, had considerable success (Fig. 3) with a power amplifier,[4] commercially named "two-in-one," that provides one push-pull channel driving all speakers for monophonic operation. It utilizes the output tubes, 6V6GT or 6BQ5 types, as single-ended stages for stereo operation. Audio hobbyists may be horrified at the thought of single-ended operation of an output stage. Actually within reasonable power limits and with a large amount of negative feedback, low-distortion levels are possible without even-harmonic cancellation of push-pull operation.

While the amplifiers and control sections of well designed stereophonic instruments are little more complicated than their monophonic predecessors, they should be designed so that the complete instruments are simple in operation and are priced within range of monophonic versions having similar features.

LOUDSPEAKERS AND ENCLOSURES

A popular argument among audio hobbyists and writers for the popular magazines on the subject concern the degree to which loudspeaker systems may differ in performance in a given stereophonic reproducing system and still provide acceptable results. The "purist" insists on identical speakers in both channels, while some will settle for wide variations in performance. However, somewhere in the middle ground lies the best design for a home instrument to be marketed at a reasonable price.

While identical performance from both channels in a stereo system is a worthy goal it is somewhat uneconomical and not always practical. It has been claimed by a number of authorities in the field of acoustics that the human ear has great difficulty in determining the direction from which low-frequency sound is coming.[5] Tests of a great number of commercial stereophonic disc recordings using a calibrated oscilloscope connected across a stereophonic pickup in the labs at Cherry Hill have disclosed little stereophonic effect recorded below a few hundred cycles per second. Instead, both channels have approximately the same low-frequency content with regard to amplitude. One could conclude therefore that two-speaker systems with excellent low-frequency response would be somewhat unnecessary in the same stereo system. Listening tests at Cherry Hill have disclosed that it is quite possible to have restricted bass response in one channel or to mix low frequencies and still achieve good overall stereophonic reproduction. It is important to remember that up to 3 db of loudness will be lost at low frequencies if one channel lacks bass response. If overall frequency balance is to be achieved, this loss will have to be compensated for by increased bass response in the wide range channel.

A second approach to achieving good performance while keeping costs down in a stereo instrument concerns mixing low frequencies from both channels and impressing the combined signal across a single "woofer" while keeping mid and high frequencies separate and reproducing both channels at these frequencies through separate identical speakers. At least one component-type speaker system uses this scheme and mixes low frequencies by providing two voice coil windings in the low-frequency speakers.

The auxiliary or second channel speaker enclosures for use with most RCA "new Orthophonic" Stereo High Fidelity instruments are designed in a somewhat unusual manner in order to obtain good balance between both channels. To conserve space these auxiliary speaker enclosures contain one 12″ full range speaker and two 3½″ tweeters, while their companion instruments have two 12″ full-range speakers and two tweeters. The instrument cabinets have generally up to 3 db more response at frequencies below 300 cps, due to the acoustic configuration of the cabinet, than the auxiliary systems for the same input power. While such a difference is entirely satisfactory for good stereophonic reproduction, a simple acoustic filter in the auxiliary speaker cabinet (see Fig. 4) serves to attenuate frequencies above 300 cycles to balance the frequency response of this speaker system with respect to the instrument's internal speakers. The auxiliary is then about 3 db less sensitive at all frequencies, but this difference can be compensated for in its driving amplifier.

To summarize, two monophonic speaker systems can be utilized in a stereophonic reproducing system to give good results but at twice the cost of each speaker unit. On the other hand virtually equal performance can be obtained from two speaker systems especially designed for stereophonic at a cost somewhere between the cost of one and of two monophonic speaker units. This is possible because the greatest cost in a wide-range speaker system is expended in the attainment of good low-frequency performance. For stereophonic reproduction, compromises can be made in the response in one channel, or a common channel can be used for low frequencies.

SUMMARY

The state of the art of monophonic sound recording and reproduction has advanced in the last ten years to a level which can provide excellent reproduced sound within the limitations inherent in single channel systems, i.e., lack of a means to provide accurate spatial effects. The addition of a second channel and intelligent use thereof has gone a long way to add these elusive spatial effects which characterize live music in a concert hall.

The design of a two-channel home stereophonic high-fidelity system or instrument is based on the fundamentals determining good monophonic design plus the added "ground rules" imposed by the special requirements of two-channel operation. The engineer designing a stereo instrument should avoid the temptation to simply house two identical monophonic systems in the same cabinet. Instead, the design goal should be an integrated system with each component designed specifically for stereophonic reproduction.

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FIELD SUPPORT OF RCA VICTOR PRODUCTS

Editor's Note: The Reader will recall a previous article by E. C. Cahill, "The RCA Service Company—A Vital Link in Engineering" (RCA ENGINEER, VOL. 3, No. 5, April-May 1958) which described the wide range of the Service Company's activities and their relation to RCA engineering. One of the activities outlined in Mr. Cahill's article was the Commercial Service activity. This article will dwell more at length with this function in regard to RCA Consumer Products and the part it plays in closing the loop between engineering, manufacturing, and customer satisfaction.

by

P. C. McGAUGHEY

Commercial Service
RCA Service Company
Cherry Hill, N. J.

THE ACTIVITIES OF the RCA Service Company's Commercial Service activity are, for the most part, performed on behalf of the RCA Victor Television, and Radio and "Victrola" Products operations.

The primary intent of Commercial Service is product technical support from the factory to the customer's home, and in maintaining RCA's quality reputation during this vital transitionary period.

Twenty Field Service Representatives bear the brunt of this responsibility, traveling constantly among the eighty-five domestic distributors and their many dealers, rendering assistance with RCA products, and conducting distributor-sponsored service clinics and workshops for dealer and independent service techicians.

The Field Service Representatives in turn are supported by a home office organization which prepares Service Data manuals on each new RCA product, and prepares and writes service clinic lectures and periodic service information for field support.

The introduction of a new RCA Victor product, such as the recent stereophonic instrument line, always presents certain technical and commercial field problems.

FUNCTION OF FIELD MEN

Commercial Service is called upon to create product interest and acceptance by all service technicians at the time a new line or product is introduced, through service clinics and the introduction of technical data. In itself, this is quite a task, but the Field Service Representative must also show the distributor and dealer the best methods of product demonstration to the customer, as well as educate them on the proper installation in the customer's home after sale. He is also responsible for administering RCA's Warranty Policy. Since the Field Service Representative is in contact with the product at the distributor, dealer, customer, and service levels, he is in an excellent position to relay field quality information back to engineering and manufacturing.

By being organized to render such service as outlined above, the RCA Field Service Representatives activity places RCA Victor Radio-"Victrola" and Television Product Engineering and Merchandising Groups in the unique position of having "advance scouts" in every American market, so that little or no time is lost during the feedback cycle in maintaining RCA's product quality reputation and overall consumer satisfaction and acceptance.

An example of the Commercial Service activities in support of a new product is the recent national program to educate the trade channels upon the announcement of the 1959 line of RCA Victor stereophonic instruments. This field organization, of course, operates under the direction of a home office organization located in Cherry Hill, which instructs the field, as well as collects information from the field, and disseminates that information to interested groups company-wide.

Each product line is headed in the home office organization by a product administrator. The stereophonic training began in the home office group and centered around the administrator for Radio-"Victrola" products. Maintaining close contact with engineering, the administrator's duty is to learn all details of a forthcoming new line that would concern service technicians in

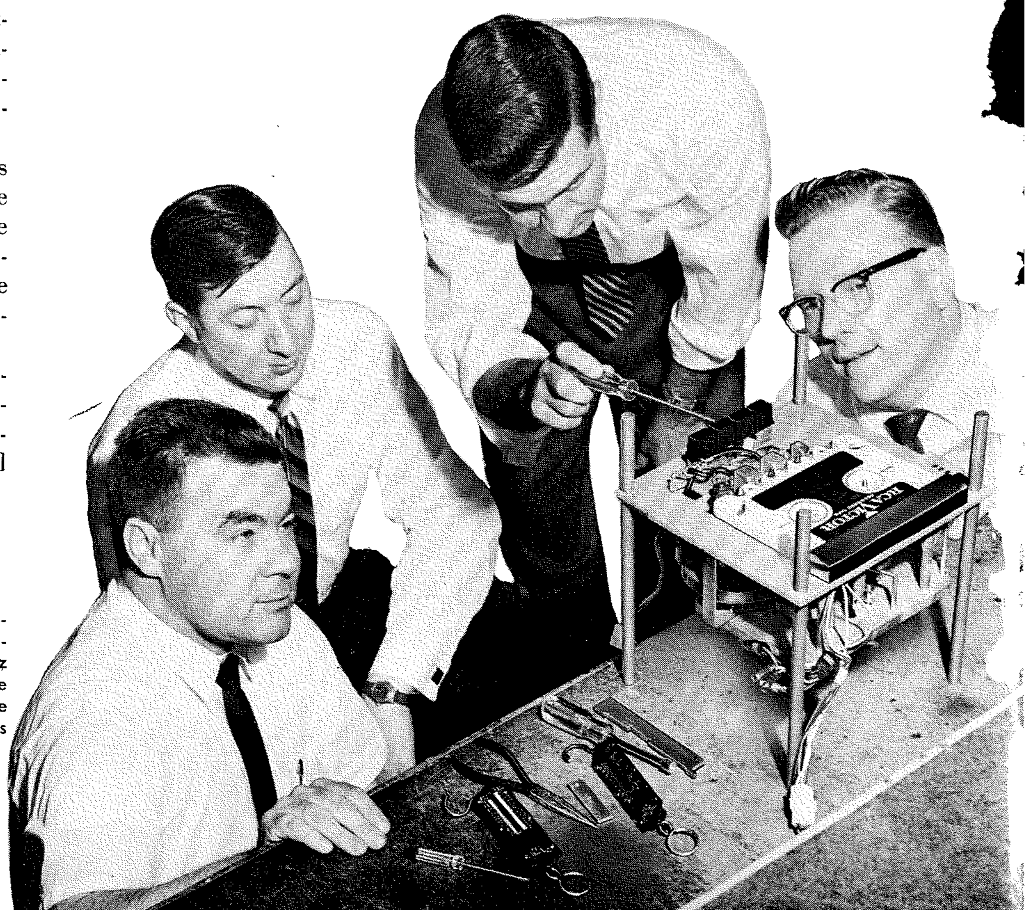


Fig. 1—Left to Right, Field Service Representatives R. L. Hamilton (Boston), R. P. Filips (Chicago), John Engel (Home Office), and J. A. Ratz (Detroit) discussing an adjustment procedure on the new RCA Victor Cartridge Stereo Tape Recorder during one of the Workshop Sessions held periodically at Cherry Hill.

Fig. 2—Field Service Representative J. T. Kavanagh (Florida) inspecting the packing of an RCA Victor instrument on delivery at a distributor's warehouse.

the field. At the same time, the Technical Publications activity of Commercial Service begins to collect technical data, and begins the draft of service data publications and lecture material.

The advanced planning and activity outlined above is all on a scheduled basis, so that the RCA Field Service Representatives can be trained in the necessary techniques to insure sufficient field information in advance of the new product announcement and shipment.

STEREOPHONIC INSTRUMENT PROGRAM

In the stereophonic instrument program, the Field Service Representatives were first assembled at the Cambridge Plant, where the stereo line was being manufactured, for several days' training on the various stereophonic instruments. This training covered the theoretical operation of the new stereo record itself, the stereo pickups, as well as giving each man actual workshop experience on the new instruments. As a result of factory experience during manufacture, many service problems were anticipated and discussed at this meeting.

At this same time the Field Service Representatives were trained at the factory, the Service Company's Regional training administrators were also instructed, so that they, in turn, could train the factory service branch technicians, who would also be prepared in advance for work on RCA Victor stereophonic equipment in Service Company branch areas.

The RCA Field Service Representatives then carried this educational program to the trade channels, starting with RCA Victor distributors, throughout the country. All distributor service managers and technicians in an area were assembled at one central location for a similar type program as the Representatives had received at the Cambridge Plant. These meetings were held in New York, Chicago, Cambridge (Ohio), Atlanta, Dallas and San Francisco, and were scheduled and held at the time the product was first reaching the distributors.

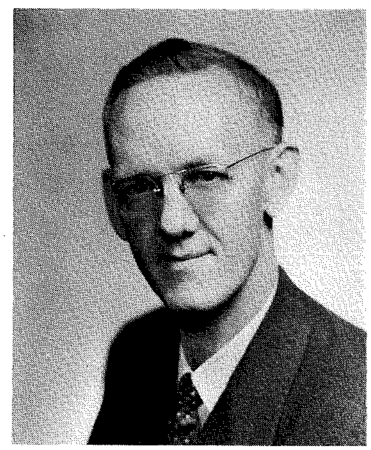
Immediately upon completion of this training program, the distributors in turn sponsored and scheduled meetings for training all of their dealer's service organizations and independent servicemen in his market area. These meetings were put on by the distributor service managers and technicians with some assistance by the RCA Representatives where needed.

After the new product is in the field, additional service information is circulated as problems arise, through the publication of "Tips" circulated to all distributors, dealers, and independent service technicians on our mailing lists.

In addition to training activities from the time the product actually begins arriving in the field, the Field Service Representative keeps a steady flow of information to Cherry Hill, based on his personal and factual experience with the new line in his market areas. This experience comes from his making rechecks on new shipments of instruments as they arrive from the factory, spot checking distributor warehouse stocks, accumulating reports and information factually obtained from service and installation problems, and from in-the-home consumer contacts. In addition, certain dealers have been set up as "quality" dealers by the Field Service Representative, and reports are sent to Cherry Hill covering all instruments that the dealer receives and/or installs in his market area. After this early information, continuous follow-up on service problems is obtained through distributor and dealer service facilities on all parts which have failed within the warranty period. Special quality reports are also regularly submitted by each of the Field Representatives covering specific quality and performance problems.

SUMMARY

A summary of the RCA Field Service Representatives' activity can be easily understood if it is realized that his main job is liaison between the market and RCA, and that this necessitates the complete cooperation of all company groups concerned, as well as the distributors and dealers. The RCA Field Service Representative provides Product Design and Engineering, Merchandising, Manufacturing, and Quality with the necessary feedback to cause him to reflect continuously on product designs from the user's standpoint. Then, too, he represents RCA and its engineering in the eyes of the dealer, the independent service technician, and the customer.



P. C. McGAUGHEY graduated from Colorado A. & M. with a BSEE and started work with RCA in 1929. He has had extensive experience in service and installation of RCA commercial, industrial and military products, including theater sound equipment, broadcast transmitters, consumer products, and aviation and naval electronics. After several years as Manager of RCA Service Company's Field Service Representatives, Commercial Service, Mr. McGaughey became Administrator, Radio-"Victrolas," Tape Recorders and Records (Technical) for the Commercial Service activity, RCA Service Company.

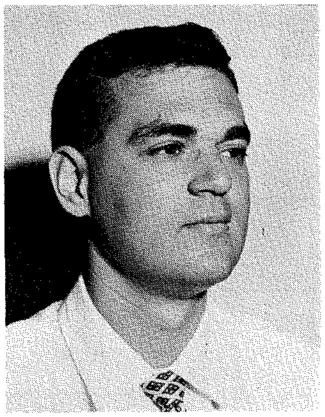
He is a Senior Member, IRE, and an active radio amateur, call K2CZ.

TUBES FOR HIGH-FIDELITY: PART I - INPUT TYPES

by **M. Y. EPSTEIN**
Electron Tube Division
Receiving Tube Design
Harrison, N. J.

Editor's Note: Part I in this issue covers tubes for use in input circuits; power-output types will be covered in Part II in a subsequent issue. Only input and power-output tubes will be discussed because intermediate voltage amplifiers and power-supply tubes present no unique problems in high-fidelity service.

In recent months, RCA has introduced into its line several new tube types intended specifically for high-fidelity audio service. Some of these types are already being used in equipment manufactured by RCA and other companies. This paper discusses these types from a tube designer's viewpoint and shows how their design, as well as the design of others still in development, is influenced by the special requirements of high-fidelity applications.



M. Y. EPSTEIN received the B.S. degree in Electrical Engineering from Pratt Institute in June, 1955. He is currently doing graduate work in Industrial Engineering at Stevens Institute of Technology. He joined RCA in 1955 as a specialized engineering trainee. After completion of the training program, he was assigned to the Receiving Tube Design activity at Harrison, N. J. Since 1956, Mr. Epstein has worked on many tube types for use in television and audio applications.

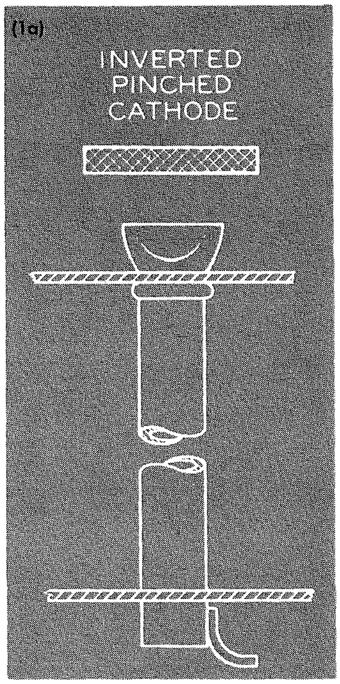
In high-quality audio systems, the input signal is often as low as 3 millivolts (or even 1 millivolt for the latest RCA 4-track stereo-tape pickup head). Because a signal-to-noise ratio of about 60 db is desired for high-fidelity applications, the input tube and its associated components must contribute total noise* of less than 3 microvolts.

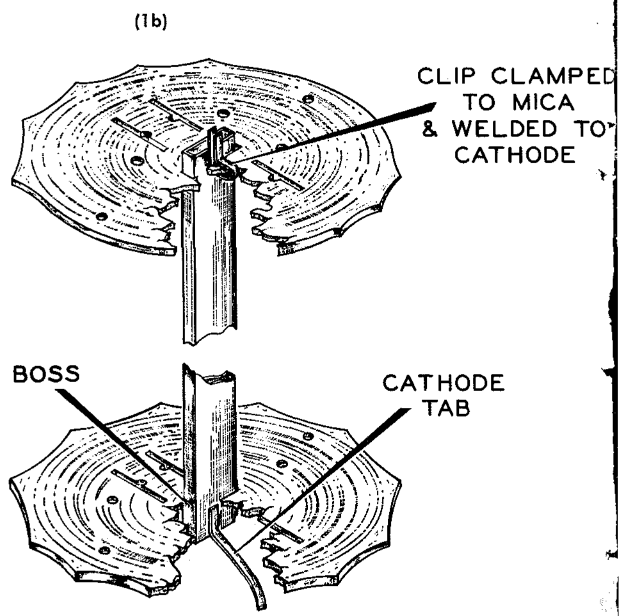
The most significant feature of an input tube, then, is low noise level. Electrically, the tube should have relatively high gain to raise the low input signal well out of the noise region of the following tubes. Because the 12AX7 high-mu twin triode has been very satisfactory in input-circuit designs, RCA recently brought out the 7025 having equivalent electrical characteristics but designed specially for low-level signals and carefully controlled for low noise.

The RCA-7199 medium-mu triode—sharp-cutoff pentode is also designed and controlled for low noise, but not to the same degree as the 7025. This tube can be used in practically all the stages (except the output) of a complete audio system. Except in very critical low-level applications, the 7199 performs satisfactorily as a preamplifier, a tone-control amplifier, and the phase splitter for the push-pull power-output stage.

NOISE

The sources of noise in a vacuum tube are varied. For convenience, different tube noises may be grouped together and discussed under three headings: microphonics, hum, and hiss (with hiss being a general term that includes thermal, shot, partition, and leakage noise).





NOTE: LOWER PART OF STRUCTURE ROTATED 180° WITH RESPECT TO UPPER PART.

MICROPHONICS

Microphonic noise is a result of fluctuations or modulations of the electron stream caused by varying electrode spacings. The tube elements are caused to vibrate by external mechanical forces applied to the tube directly through the air from the loudspeaker or through the chassis from switches, motors, and turntables.

The amplitudes and frequencies of these forces felt by the tube depend on such variables as the Q factor of the coupling elements between the tube and the mechanical-force sources, and the moduli and phase angles of the forces appearing simultaneously at the tube. Consequently, microphonic noise can be avoided to a great extent by proper design of the tube environment.

*Tube noise is measured in terms of equivalent volts at the grid input, i.e., the noise output, without signal, divided by the gain of the tube. This measurement permits direct noise comparison between tubes having different sensitivities.

For the tube designer, however, the problem is to reduce both the amount of electrode vibration and the sensitivity of response of the tube to external vibrating forces. Vibration of the tube elements consists of two forms—rattle and resonance. The former is due to the looseness of fit between the electrodes and their supporting and fixing members, and the latter is due to the natural resonant frequency or frequencies of the particular electrode or group of electrodes. Because the resonant frequency depends on the form and the tightness of fixing of a part, the two forms of vibration are related. The difference, however, is that it is theoretically possible to eliminate rattle completely, whereas resonant frequencies are impossible to avoid but may be shifted to reduce their microphonic noise effects.

Fig. 1 shows several well-known methods used to fix electrodes and eliminate rattle noise.[1] These methods include pinched cathodes, embosses on the cathode, mica eyelets, grid swages, and grid stitches. Because these methods add cost to the tube, however, the real question involved in the avoidance of rattle noise is to determine what devices are absolutely necessary to provide the proper margin of safety.

As mentioned above, resonant frequencies cannot be completely eliminated, but can be adjusted. In general, the resonant frequencies of the tube elements vary inversely with the square of their length and density, and directly with their diameter, the square root of their moduli of elasticity, and the tightness of fit. The amplitude of vibration varies inversely with the frequency.

Changes made to improve either rattle or resonance, therefore, benefit both. Tightness of fit to reduce rattle also raises the resonant frequency; higher frequencies reduce the amplitude of vibration resulting from a given mechanical shock, and also make the tube less liable to excitation from mechanical sources (which usually vibrate at low frequencies).

Both the 7025 and the 7199 are designed with short cages and rigid connectors to provide over-all mount structures which reduce both rattle and resonance. Cathodes have a tendency to warp or bow at high temperatures if they are fixed too tightly and cannot expand. Because this tendency limits the tightness of cathode fixing, the cathode is often the worst offender in the production of microphonic noise. A new tube is presently being developed which will be even shorter than the 7025 and also have a larger-diameter cathode. The increased structural strength of the shorter, larger-diameter cathode will allow the use of tighter fixing.

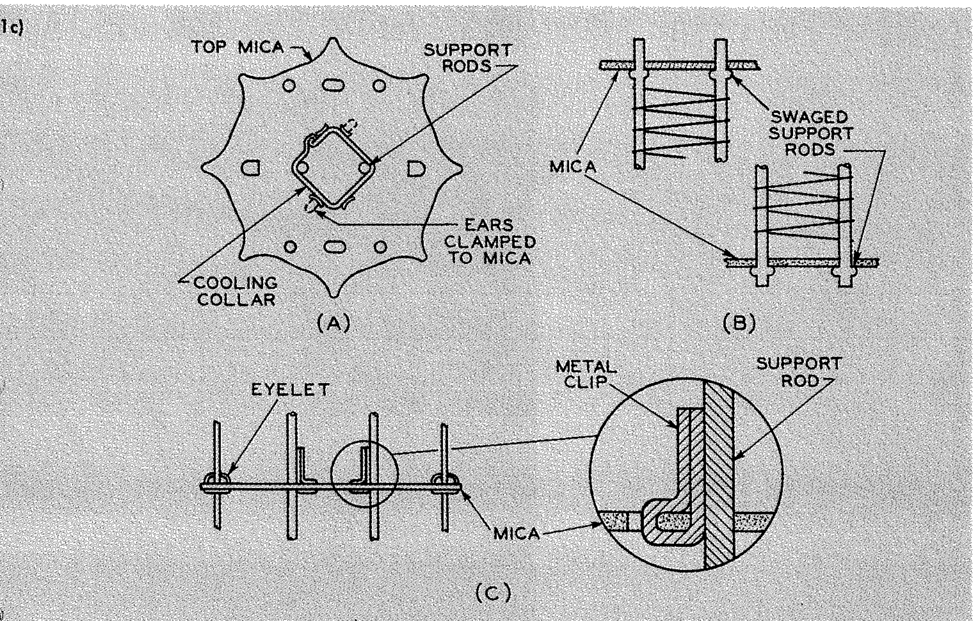


Fig. 1—Various methods used to fix electrodes tightly and eliminate rattle noise in electron tubes. Figs. 1a and 1b show cathode-"fixing" methods and Fig. 1c shows "grid-fixing" methods.

A desirable approach to the reduction of microphonic noise is to make the tube less sensitive to changes in its electrode spacings. Tube symmetry is important in this respect. Conventional tubes are built around a cathode, as shown in Fig. 2, and may be considered as two separate tubes connected in parallel. Movement of a given electrode structure increases the spacings on one side of the cathode while reducing them on the other. With good symmetry of spacings, the effects of such changes on tube characteristics tend to cancel. This simple-sounding requirement, however, is very difficult to achieve under mass-production conditions.

A very interesting technique for reducing microphonics that is presently being evaluated is based on the "inselbildung" phenomena and its effect on amplification factor.[2] At very small grid-cathode spacings, the control grid begins to lose its control over portions (islands) of the cathode, as shown in Fig. 3, because of excessive penetration of the plate equipotential lines through the control-grid lateral wires. Effect upon amplification factor is shown in Fig. 4. Microphonic noise is also affected because current (I) varies inversely with both amplification factor (μ) and grid-cathode spacing (D_{g1k}), as follows:

$$I = f\left[\frac{1}{(\mu)\,(D_{g1k})}\right]$$

Depending upon the region of operation in Fig. 4 (A or B), electrode displacements will produce changes in both D_{g1k} and μ that either add or tend to cancel the changes produced in I. In region A, the "inselbildung" region, the effects add to make microphonics worse.

Because of the need for high transconductance and cathode efficiency, modern-day tubes are invariably designed with small grid-cathode spacings and operate in region A. However, the electrical compromises necessary to move the tube design from region A to region B are not too critical in tubes for audio applications, and it is hoped that this technique will help to reduce microphonic noise in inexpensive, high-quality tubes of the future.

HUM

Hum noises are contributed by the

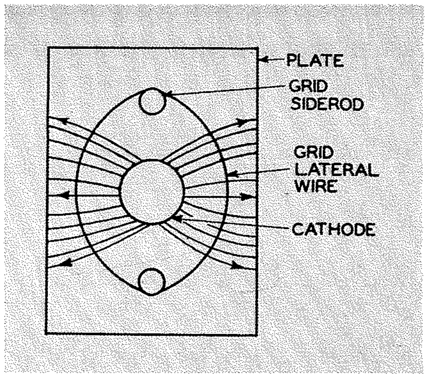
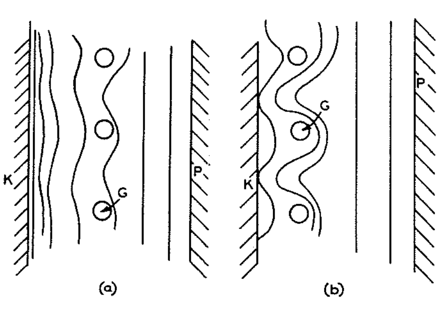


Fig. 2—Diagram illustrating formation of two separate sections in a tube as a result of effect of grid siderods.

effects of the a-c current flowing in the tube heaters.[3] This type of noise is conveyed from the heater to the tube output by essentially four different mechanisms: (1) electrostatic hum due to capacitive coupling between the heater and other tube elements, (2) inductive hum caused by mutual inductance between the heater and other elements, (3) magnetic hum caused by the influence of the magnetic field of the heater on the electron stream, and (4) insulation hum caused by the leakage currents from the heater to the cathode through the heater insulation. Use of d-c in the heater will eliminate all these noises.

The first two noise sources represent shielding problems. Because the cathode metal sleeve acts as a shield between the heater and other electrodes within the mount cage of the tube, most of the coupling occurs between the stem leads. Proper selection of basing arrangement is effective to reduce coupling effects, as is the use of shields to isolate the heater leads. Electrostatic hum between the heater and the control grid can be significantly reduced by the use of a potentiometer, as shown in Fig. 5. The electrode capacitances and conductances form a bridge network, with the external grid resistance as the cross-arm. Although inductive hum cannot be corrected in this manner, careful positioning and twisting of the socket heater leads is generally

Fig. 3—Effect of grid-cathode spacing on uniformity of electrostatic fields at the surface of the cathode.



sufficient to avoid this source of noise.

The magnetic field of the heater affects the space charge in front of the cathode, producing noise both by modulation of the cathode-current density and by deflection of the electrons from their normal paths and resulting variations in their rate of arrival at the plate. The 0.002-to-0.003-inch nickel cathode sleeve is no protection against this low-frequency magnetic field because the cathode is operated above the curie temperature of nickel. Pentodes are more susceptible to this form of noise than triodes because the presence of even a weak varying magnetic field usually increases the level of partition noise (see section on hiss below).

Fortunately, it is possible to design heater configurations that confine the magnetic field almost completely within the heater itself. Fig. 6 shows three forms of heaters. The folded heater produces a magnetic field which is directed into the cathode space charge and can be very troublesome. When the heater is folded so that the current in adjacent strands flows in opposite directions, the magnetic fields cancel. During insertion of the heaters into the cathode, however, the strands are aligned randomly. Consequently, the distribution of hum noise output with folded heaters is very wide.

The single-helix heater confines most of the magnetic field inside the heater, with only a weak field directed into the space charge. The double-helix heater is the best of all in this respect, with practically no fields outside the heater turns. The 7025 uses a single helix and the 7199 a double helix, both with very low hum noise. The shorter developmental tube previously referred to will also use the double-helix coil. At present, a double-helix heater cannot be made small enough to fit into the small-diameter 7025 cathode.

Varying leakage current between the heater and cathode through the heater insulation produces a noise voltage when it flows through the cathode-biasing resistor. Even when this resistor is completely bypassed, there is an internal cathode resistance of the order of 0.1 omh due to cathode interface, fusing of the cathode, and contact resistance between the tube leads and the socket. With excessive heater-cathode current, several microvolts of noise can be developed across even this small resistance.

Heater-cathode current depends strongly on temperature, as shown in Fig. 7. It is desirable, therefore, to operate the heater at as low a temperature as possible. If the cathode temperature becomes too low, however, excessive shot noise will develop, as described below.

Fig. 8 shows the current-voltage characteristics of the insulation coating between heater and cathode. Positive biasing reduces the effect of the a-c heater voltage on noise output because of the saturated current conditions. The slope of the curves in Figs. 7 and 8 suggests that, in addi-

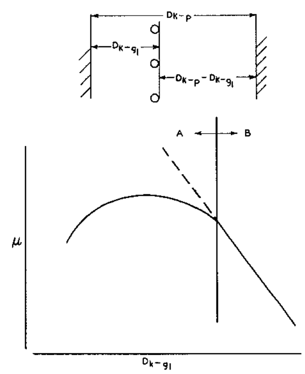


Fig. 4—Variation of amplification factor (μ) as a function of grid-cathode spacing (D_{g1k}).

tion to insulation leakage, there is also direct emission (with characteristics similar to the usual diode emission) from heater to cathode. Although positive bias supposedly reduces or causes saturation of the emission component of the total current, there are instances[3] where negative biasing achieves the same results.

The most satisfactory method to reduce heater-cathode hum in the 7025 and 7199 is to insure that materials used for the heater insulation are as pure and as effective as possible, that care is taken during tube assembly not to chip or scrape off the insulation, and that as much insulating material as possible (consistent with heater power and cathode size) be used on the heater.

HISS

The general term hiss includes those noises produced by the flow of the electron stream itself. Thermal noise,

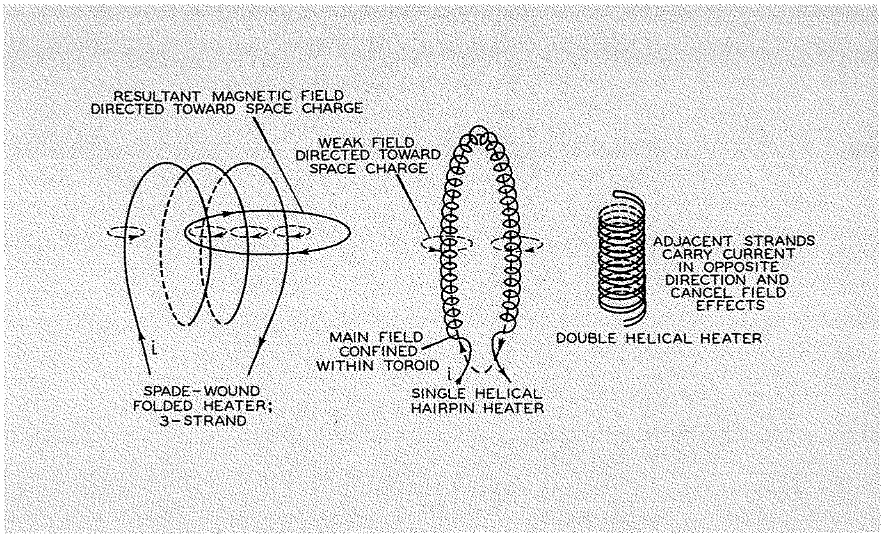


Fig. 6—Effect of heater configuration on heater magnetic fields.

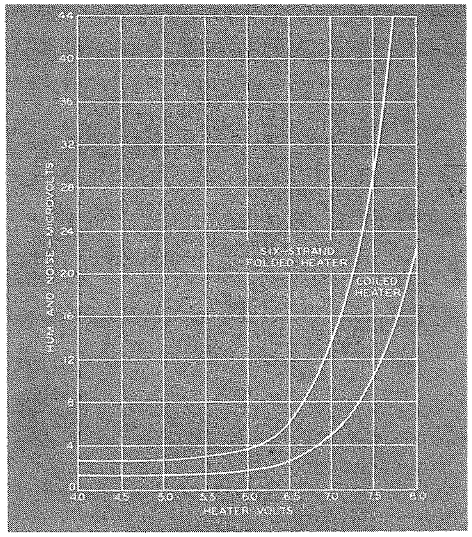


Fig. 7—Variation of heater-cathode leakage (hum noise) with temperature.(heater

although generally included, should not be directly associated with the input tube because it is caused by the thermally agitated random motion of electrons in conductors external to the tube.

Shot effect is the noise associated with random emission in a tube whose emission is temperature-limited. Although this noise is probably the loudest of the electron-tube noises,[4] it is greatly reduced when the cathode is hot enough to operate outside the temperature-limited region. Space-charge operation also tends to smooth out the effects of shot noise because emission of more than the average number of electrons in an instant results in an increase in space charge and, consequently, a compensating decrease in current in the next instant. With proper cathode temperature and tube operation, shot noise can be reduced below one microvolt.

For critical low-level applications, triodes have less hiss output than tetrodes and pentodes because of partition noise, i.e., noise due to random variations in the division of space current to the plate and screen grid. This noise is generally the dominant noise of a multi-positive-electrode tube. The noise output of a pentode is often three to five times higher than when the tube is operated as a triode (screen grid tied externally to plate).

Leakage noise is lumped together with other hiss noises because it is caused by current flow between electrodes, although not directly along the cathode electron stream. The leakage current flows along conductance paths on the mica spacers or through the glass separating the electrode-connecting leads. The greatest leakage occurs across conductance paths formed on the micas by metallic deposits driven from the hot electrodes and the getter (the barium deposit flashed onto the inside glass walls to adsorb gas during the life of the tube). Although the cathode is usually the largest contributor of these leakage-forming elements, inclusion of these materials in the cathode is essential for proper operation of the oxide-coated cathode. Consequently, a balance must be reached between low leakage and proper cathode performance.

Cathodes which have low levels of contaminants have been developed for low-noise tubes. The necessary environments for these cathodes are very critical, however, and great care must be taken to use clean parts and electrode materials that are compatible with the delicate cathode.

High-fidelity tubes are processed and operated at the lowest possible temperatures to avoid excessive evolution of particles from the electrodes. Processing of the 7025 and 7199 is delicately balanced between temperatures high enough to drive off gases from the electrodes during exhausting of the tube and to burn out contaminants in the heater insulation that might cause heater-cathode leakage, and temperatures low enough not to cause leakage paths due to the volatilization of materials from the electrodes.

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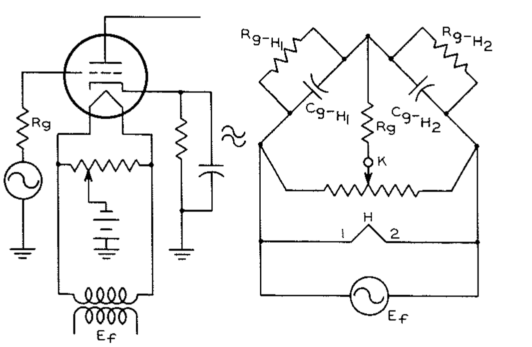
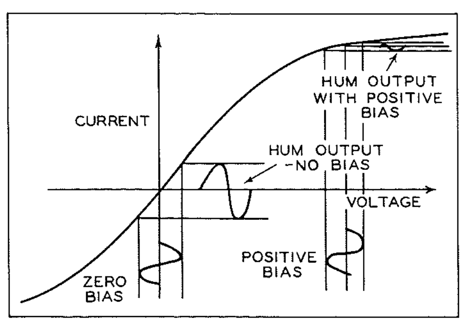


Fig. 5 — Bridge network using potentiometer (with external grid resistance as cross-arm) to reduce electrostatic hum.

Fig. 8 — Current-voltage relationship of heater-cathode insulation coating showing effect of positive bias on hum output.



SPEECH COMMUNICATIONS IN MILITARY ENVIRONMENTS

By

W. F. MEEKER and R. M. CARRELL

Surface Communications

Defense Electronic Products

Camden, N. J.

MILITARY SPEECH COMMUNICATION SYSTEMS differ from civilian systems in several important respects. First they must operate under more severe environmental conditions; military equipment is necessarily exposed to greater extremes of temperature, humidity, and rough handling. Second, their functions are much more likely to be connected with rapid decision-making and action, rather than information primarily, although the latter purpose is also served. Third, they must possess a higher degree of reliability than that of most civilian equipment.

ENVIRONMENTAL REQUIREMENTS

The more familiar military environmental requirements are those of temperature, humidity, salt spray, shock and vibration. A major environmental factor which is sometimes overlooked but which must be considered for speech communication systems is airborne noise. Noise varies over a tremendous range in military environments where personnel must communicate. For example, in a submarine maintaining quiet conditions to avoid detection, the noise level is very low. At the other extreme, the noise near a jet engine operating on the ground during an engine trim operation may be as high as 140 or 150 decibels. Noise levels within aircraft are generally between 90 and 120 decibels. Noise in armored vehicles generally lies between 90 and 130 decibels. Since speech can be completely masked by noise, the noise level and its spectrum must be taken into consideration in the design of any speech communication system. The noise levels encountered in military situations are illustrated in Fig. 1. (Nuclear explosions and missile launching are not included.) It is seen that many of the noise levels extend into the region of damage, risk, discomfort, and pain.

The noises encountered in military situations often offer a considerable challenge to the design of military speech communications systems. In some cases it is merely a matter of providing adequate power to overcome the noise. In other cases, the noise must be reduced by noise shields or ear protectors in order to protect the user as well as to permit communication. In very high noise even the mouth and the microphone must be enclosed in a noise shield, since the level of noise is greater than that of speech at the lips.

OPERATIONAL FUNCTIONS

In military operations, there are three important factors affecting the design of speech communication systems:

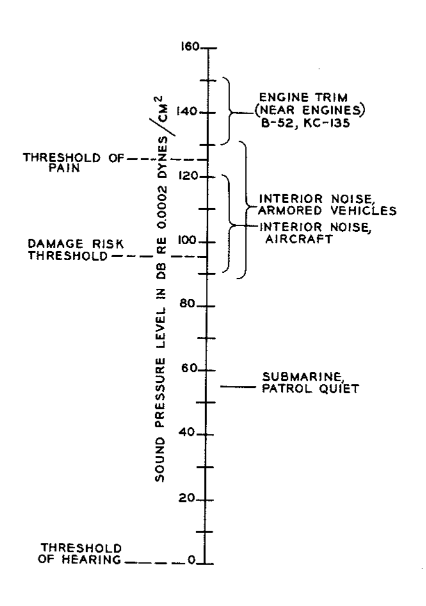


Fig. 1—Range of noise levels for military speech communication systems.

Fig. 2—Headset-Microphone H-157 (XA)/AIC. This is a light-weight, comfortable, high-performance unit for airplane interphone systems.

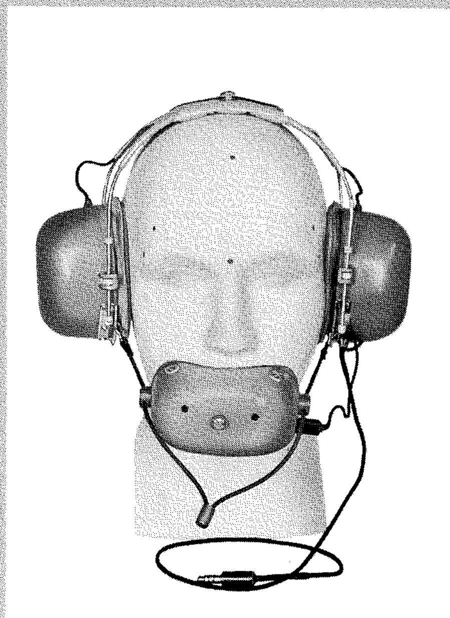


Fig. 3—Headset-Microphone H-166 (XA-1)/GIC, for ground crew use in noise levels up to about 140 db.

1. the urgency or timing of the operation involved,
2. the flow of information required,
3. the need for specialized transducers.

Although many phases of military operation are being made increasingly automatic, critical operations still require human decision and rapid flow of commands. For any given system, careful analysis must be made of the necessary flow of information, priorities (these often vary for different operations or for different phases of the same operation), and emergency requirements. Finally, careful attention must be given to human requirements in regard to microphones, headsets, handsets and loudspeakers. The need for such system planning has been recognized by the military and in many cases teams of engineers from RCA have made extensive analyses of the operations in military situations, which have then been used in the design of communications systems.

EXAMPLES OF MILITARY SPEECH COMMUNICATION SYSTEMS

Airplane Interphone—An early example in which these factors were taken into consideration is Aircraft Intercommunication Set AN/AIC-10 which RCA developed starting in 1947. This was a flexible, modularized system that could be adapted to any size or type of aircraft; it was also the first system to provide high intelligibility in 120 db of noise and at high altitudes. It was adopted by the Air Force and has been produced in large quantities since 1951. While this was a relatively simple system from the standpoint of information flow and priorities, it had severe environmental and human engineering problems.

A discussion of the problems involved in obtaining the performance desired is a story in itself.[1] One of the interesting details which illustrates the transducer problem involves the headset. While the original headsets performed well and were comfortable for moderate periods of wear, the required wearing period was continually increased so that improvements in the headset were needed. Consider the requirements for the headset.

1. It must meet the usual military requirements for resistance to shock, vibration, dropping, humidity, salt spray and fungus.
2. It must remain comfortable for many hours of continuous wear.
3. It must be light weight and remain stable on the head.
4. It must be unaffected by natural skin and hair oils (and hair tonics, as well!).
5. It must not deteriorate rapidly in the high temperatures encountered in aircraft parked on air fields in tropical or desert areas.
6. It must not stiffen or become uncomfortable in the arctic.
7. It must provide a high degree of noise exclusion to prevent hearing loss as well as to permit satisfactory speech reception.

To say that these requirements are difficult to meet would be regarded by

Fig. 4—Block diagram illustrating circuits and stations required for a submarine intercom system.

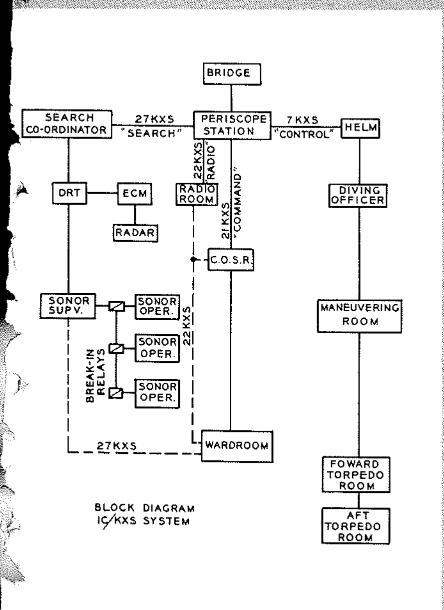
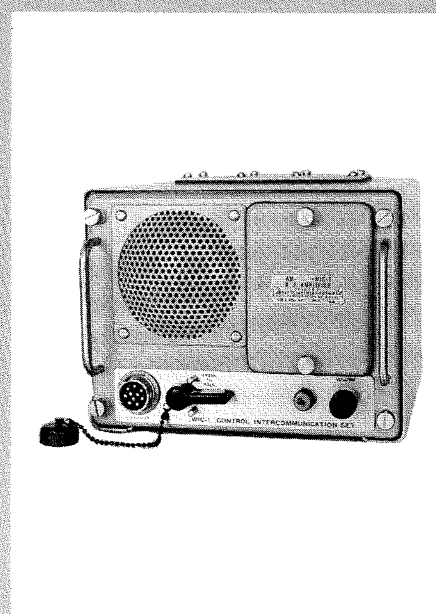


Fig. 5—Periscope station of submarine Intercommunication Set AN/WIC-1. The control unit of Fig. 6 is also associated with this unit.

Fig. 6—Control unit of submarine Intercommunication Set AN/WIC-1. This unit contains a one-watt amplifier and a loudspeaker which is also used as a microphone.



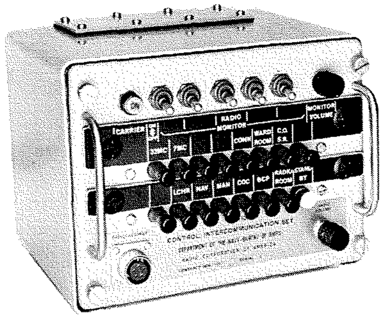


Fig. 7—Control unit for the submarine's missile control center. This is a part of the submarine Intercommunication Set AN/WIC-1.

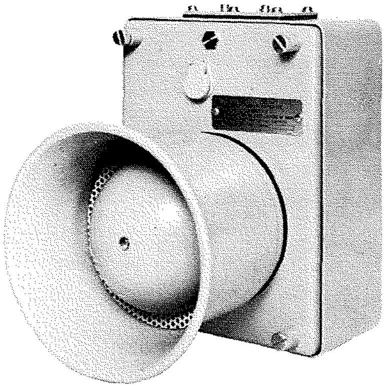


Fig. 8—Loudspeaker/amplifier unit for noisy areas. A 20-watt transistor amplifier is enclosed in the housing. This is a part of the submarine Intercommunication Set AN/WIC-1.

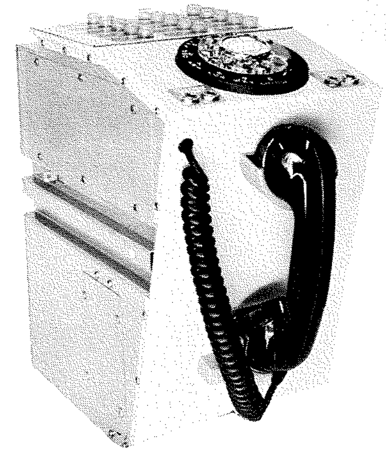


Fig. 9—Operational intercom for BMEWS. This unit integrates with an operator's console.

the headset designer as a gross understatement. Nevertheless, Headset-Microphone H-157/AIC, shown in Fig. 2, developed recently on a product improvement program does meet these requirements. It has now been adopted by the Air Force and will supersede previous models.

Another example of the specialized transducer problem is shown in Fig. 3. This is the H-166/GIC Headset-Microphone which is used by ground maintenance personnel when working around jet aircraft on the ground where noise levels are in the 130-140 db range. The large earphone shells are necessary to provide a large amount of noise exclusion. The noise shield over the mouth encloses the microphone.

Submarine Intercom—The interior communication system of a submarine provides another example of a military speech communication system with unique environmental and operational requirements. Such a system is more complex and has a greater variety of functions than an airplane interphone system. Considerably more attention must be given to the flow of information and the priorities in different phases of operation.

In 1952, RCA undertook, for the Navy, the study and design of an experimental submarine intercom system, the IC/KXS. Requirements for the system were first determined. This was done in three steps. First, noise levels and spectra at all important positions throughout the submarine were measured. Next, traffic on all existing circuits was observed and identified. Finally, operating personnel and BuShips personnel were interviewed to determine needed functions and priorities.

Fig. 4 shows a typical block diagram indicating the personnel who must communicate. Note that there are several essentially separate circuits, all tying in to the periscope station which is the normal command point of the submarine. There is, first of all, the "command" circuit which links the bridge, the periscope station, the commanding officer's stateroom and the wardroom. Then there is the "control" circuit which links the periscope station, the helm, the diving officer, the maneuvering room and the torpedo rooms. (Those unacquainted with submarines might question the presence of the torpedo rooms on the control circuit. This is necessary because torpedo firing causes a change in trim (balance) and buoyancy and must be closely coordinated with the control of the boat.) The radio room has a direct connection with the periscope station and its traffic is normally carried over this circuit. However, circuits to the commanding officer's stateroom and the wardroom are also provided. The search circuit includes the periscope station, the search coordinator, the dead-reckoning tracer operator (DRT), electronic countermeasures (ECM) and radar operator, the sonar supervisor and the sonar operators, with an auxiliary circuit to the wardroom.

After the locations of all stations were determined, a careful study of the noise level and spectrum at each location was made. System characteristics to provide adequate intelligibility were then determined, and from these the characteristics of component equipment was detailed. Finally, a detailed system design was formulated.

After reviewing the design plan with personnel of the Bureau of Ships, an experimental system was designed and constructed. This system, the IC/KXS, was delivered to the Navy and installed in the USS Croaker for evaluation. Originally intended for only a six-month evaluation, the system was so well liked that additional spares were procured and the system is still in use.

As a result of this experience, the Navy requested extension of the basic system to include the additional functions required in nuclear submarines, including those carrying Polaris missiles. This system, designated AN/WIC-1 is currently in production. Figs. 5-8 show typical units and give some idea of the complexity and appearance of the final equipment for the submarine environment.

Fig. 5 shows a part of the periscope station. Associated with this station is a control unit with loudspeaker and one-watt amplifier shown in Fig. 6. The periscope station is the most complex of the stations, since overall command of the boat normally originates here. Fig. 7 shows a control unit for one of the other stations. It, too, would have the control unit shown in Fig. 6 associated with it. Fig. 8 shows a loudspeaker unit used in noisy areas; it contains a 20-watt transistor amplifier. While size and weight are important factors for submarine equipment, requirements for dripproof and splashproof construction result in rather heavy housing for the equipment.

BMEWS—An area of growing importance is the use of operational intercommunication systems to link together operators and monitors of large and complex radar or missile systems. The equipment shown in Fig. 9 is a unit of the operational intercommunication system for the Ballistic Missile Early Warning System. While the system is electrically separate from the BMEWS equipment, the intercom unit is designed to integrate physically with an operator's console. (An unusual environmental hazard which had to be taken into consideration was the possibility of spilled coffee.) The intercommunication system thus becomes a functional part of the overall system. It is extremely useful in the initial adjustment and continuing operation of such equipment since it permits identification and correction of unanticipated emergency conditions associated either with errors or failure of equipment or with unusual situations.

In a large installation, such as BMEWS, which occupies many buildings, the paging system also constitutes an important speech communication system. Access to the paging system can be provided from many points but when this is done, priority of access must be considered. Many other useful features can also be provided such as dial access from the telephone system, area paging and entertainment.

FUTURE TRENDS

The growing emphasis on digital and machine-to-machine communications may appear to make speech communications obsolete. However, there are new trends of great interest which lead the authors to believe that speech communication will be in the picture for a long time to come.

First, of course, is the human need to hear a human voice. Even in the sophisticated world-wide communications networks such as the Air Force's 480L and the Signal Corps' Unicom, voice traffic will constitute about 30% of all traffic, and is the largest single class of traffic. The transmission of voice will probably be in digitalized form.

Digitalized speech has many advantages. It can be handled by pulse communications systems, which permit reliable regeneration of signals at repeaters. It is easily encrypted for secure communications. However, at present, digital speech requires considerable bandwidth. Pulse code modulation requires 30,000 bits/second or more for a 3-kc voice channel.

Because of this, there is an increasing pressure for practical systems for speech bandwidth reduction. It is now well known that speech, in an information sense, is highly redundant. There are many schemes which take advantage of this redundancy to reduce the bandwidth necessary for transmission.

The more sophisticated, and difficult, approaches make use of a knowledge of the production of speech to select at the transmitting end only those elements essential for the specification of the speech sound. These are slowly varying characteristics and can be transmitted over a channel of restricted bandwidth. At the receiving end, speech is synthesized using the transmitted signals as controls for the synthesizer. The problems involved are formidable and have been the focus of much research over the last 10 years. The art is believed to be approaching the product stage now and will be of great importance in the future.

An extension of this art is the machine which can recognize not only the sounds which are essential for intelligibility, but *what* is said as well. In other words, the machine is capable of recognizing the words spoken, and potentially, is capable of *synthesizing* spoken words on command (not repeating pre-recorded words). This permits two-way communication between men and machines; voice-operated typewriters; and voice communication over teletype networks. Fanciful as this may seem, the Air Force and Signal Corps have recently awarded contracts for the study and demonstration of such devices with vocabularies as high as 500 words. Olson and Belar of RCA Laboratories have already demonstrated a phonetic typewriter with a limited vocabulary[2].

Although these devices will undoubtedly be complex, they will lead to a greater understanding of how humans recognize speech. And with the rapid advance in micro-miniaturization or circuits, the speech-recognition and generation capability may become a practical component of many machines in the next few decades.

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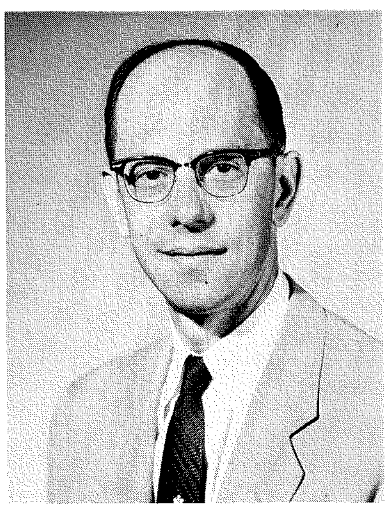

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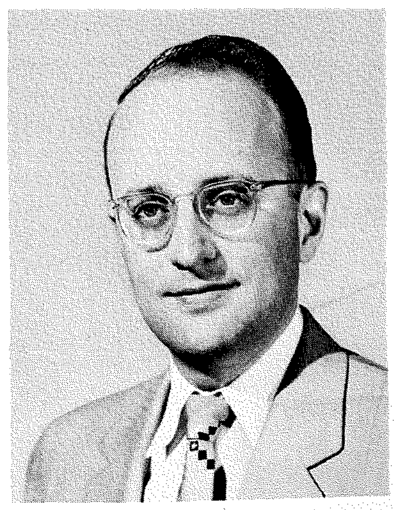

R. M. Carrell

TELEVISION SOUND REPRODUCTION

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The importance of high-quality sound reproduction is often overlooked in television. Wide-range, low-distortion, noise-free sound can give the program and music director an added tool not common in television today. High-quality sound, in turn, gives the viewer (listener) added pleasure by enhancing the illusion of reality presented by the home receiver. Better TV sound is possible if some of the following improvements are incorporated. Before describing these improvements, the techniques of TV sound transmission will be reviewed.

TRANSMISSION PROBLEMS & LIMITATIONS

Electrical Equipment—The aural transmitter in TV is high fidelity by Federal law. The frequency response is flat from 50 to 15,000 cps. The signal-to-noise ratio is usually about 60 db and the distortion is 1 to 2%. Likewise, the audio line connecting the studio to the transmitter is usually again a wide-range high-fidelity loop. However, in many cases, especially in large installations as New York and Hollywood, the high quality of the studio-to-transmitter audio line is somewhat cancelled by the studio-to-studio audio lines which may be slightly limited in frequency range. In keeping with the high-quality transmitter, the studio pick-up and amplifying equipment is also high fidelity. If the studio-audio equipment were purchased from a reputable manufacturer such as RCA (and most of them are) the pre-amplifiers, and power amplifiers, are all wide-range low-distortion components. Likewise, the microphones that are used in TV are, for the most part, very high quality, highly refined instruments.

Program Material—Some program material originating from the studio may be limited in its audio quality. The best example of this, of course, is movies. If the sound track on the motion pictures is optically recorded, it will probably have a maximum frequency response of 7500 cycles. However, when this is scratched due to wear, the noise level is increased so much that the sound channel from these movies is usually limited to 3500 or 5000 cycles. With the advent of video tape, there is a chance that program material other than live pickup can be high fidelity. The sound portion of video tape is designed to give wide-range low-distortion facilities. The greatest limitation to high-fidelity reproduction of live television sound at present is the physical problem of the studio. Television studios are usually noisy and, at least from a layman's point of view, when listening to a high-fidelity system, there is a high degree of rumble from changing scenes, changing backdrops, camera motion, and moving microphones. Of course, all these problems have solutions, but these solutions are costly and time-consuming. As yet, most TV stations have not found it economically feasible to get the ultimate in sound reproduction.

Network Lines—The final limitations on program transmission are the network land transmission facilities. Practically all network programs are transmitted on telephone lines that have a frequency response between 50 and 5000 cycles. Thus, if extreme care is taken at the studio to produce wide-range high fidelity sound, much of the effort is cancelled by narrow range network lines.

FM TRANSMISSION AND RECEPTION

The system of transmitting sound in TV is frequency modulation. It is quite similar to standard frequency modulation broadcasting except the deviation is reduced from ±75-kc deviation for standard FM broadcast to ±25-kc deviation for TV FM sound. Theoretically, the lower maximum deviation should give a poorer signal-to-noise ratio on TV sound than on FM. However, most TV aural transmitters are much higher powered than FM broadcast transmitters and the increased signal strength helps to compensate for the lower deviation of TV sound. It should be remembered that in an FM system, when there is enough limiting action to prevent any AM interference, and when the signal is strong enough to give good signal-to-noise ratio, then the resultant sound output will have a good signal-to-noise ratio. Both FM broadcast and TV aural transmitters use preemphasis of the audio signal above about 1000 cps. This, in turn, necessitates a complementary de-emphasis network in the receiver to produce a "flat" response.

Intercarrier Sound—Practically all TV reception today is done with an intercarrier sound system.[1] Intercarrier sound has two detecting processes that may affect the final sound quality. The first is the TV second detector. This detector performs at least two operations. One is to detect the video information from the video i-f (which incidentally is an amplitude-modulated signal) and the other function is to produce a 4.5 mc frequency-modulated signal which is amplified and goes into an FM sound detector. The TV second detector is usually a simple diode detector. This diode detector has several limitations but is a very simple and economical device.[2] One of the problems of a diode second detector is the characteristic which sometimes gives a buzz in the sound channel for high levels of video modulation. This is inherent in this type of detector and is discussed in two references cited. The sound FM detector can be a limiter-discriminator, a ratio detector, or more common today—a form of locked-oscillator detector. The limiter-discriminator is usually quite costly in components and is not common in TV. The ratio detector is a simple device and is quite efficient. It gives sufficient AM rejection so that it usually can be operated without other limiters. The signal-to-noise and distortion characteristics are quite good for a ratio detector if it is properly aligned. The audio output of a ratio detector is relatively low and therefore the audio signal must be amplified before it can drive a power output stage. A locked-oscillator quadrature-grid FM detector does not have the low output of a ratio detector. In fact, this type of detector may have an output of 10 to 20 times as high as a ratio detector. Our measurements have also shown that a locked-oscillator detector has low-noise and distortion characteristics.

TV Audio Amplifier—The audio amplifier, including the power amplifier, in a TV set is many times a cost compromise. Oftentimes most of the power in sound reproduction is used to reproduce low frequencies. When an acoustic system is incapable of low-frequency reproduction, a low-power amplifier is adequate. It has proved to be a good compromise to restrict the power and bandwidth on amplifiers feeding table model and consolette TV sets. In the design of a TV audio reproducing system, the parameters include (1) the size of the cabinet and thus the speaker size; (2) the current available to the amplifiers, and power output stage in the audio amplifier; (3) cost; and (4) the program material. A majority of program material on TV fortunately is speech, which requires a narrower bandwidth than music. In fact, if the TV set's overall-range is too wide, especially on the low end, the studio noise and rumble can be amplified on some programs to the point of giving a less pleasing rather than a more pleasing reproduction of the sound. Because we have found it desirable to limit the bandwidth somewhat, we have found in most cases a 1.5 watt power amplifier gives satisfactory sound reproduction for television.

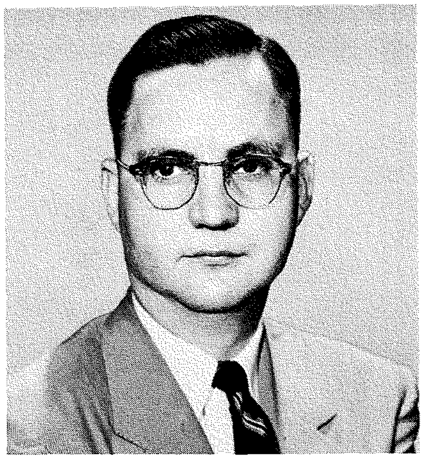
PRESENT ACOUSTIC SYSTEM

The acoustic systems of all TV sets, be they small portables or large consoles, are designed to give the most pleasing sound reproduction within the limits of the cabinet, the speaker size, and audio bandwidth available. The advertising slogan "Golden Throat" has meant to the engineer that in each type of instrument the range of the audio amplifier, the speaker, and the type of cabinet are all combined to give the most pleasing sound reproduction.

In general, receivers using a 4- or 5-inch speaker have a response from 150 to 4000 cycles. Receivers with a 6-inch speaker have a response from about 110 to 6000 cycles, and receivers with a 6 x 9 or 8-inch speaker have a response from 80 to about 9000 cycles. These responses are not necessarily flat, since many subjective listening tests have shown that in systems with a limited range, if we alter the response of the audio amplifier or of the speaker to give a deviation from flat response in specific regions, we may obtain a more pleasing sound reproduction characteristic for a given bandwidth. Usually, as the bandwidth becomes greater, a smoother, flatter response will give the most pleasing reproduction. Recently, we have deviated slightly from the aforementioned speaker responses by adding additional cones to make each speaker in the line a dual cone speaker. These added cones or "whizzers" considerably extend the high range on all speakers, making possible a much wider sound reproduction range.

IMPROVED TV SOUND REPRODUCTION

Acoustic Performance — The foregoing has been a general description of the characteristics of the transmitted and received TV audio signal as we know it today. To be sure, we have described limitations and compromises. The receiver acoustic engineer oftentimes will say, "With adequate signals coming from the networks, what could we do to improve the sound reproduction of our instruments?" Even though we wish to improve the sound reproduction capability of a receiver, these improvements must be in keeping with the styling, cabinet fabrication, and mass production techniques that are inherent in the TV receiver business. Thus, improving



For Mr. Libbey's Biographical Sketch, refer to Vol. 2, No. 2, p 6 (Aug-Sept 1956).

the low-end reproduction by incorporating a large corner horn can almost be discarded on grounds that it is not in keeping with today's "small cabinet" styling. The easiest type of cabinet from an acoustic design standpoint is a closed box. Closed boxes follow the basic laws of acoustics quite well and are thus quite predictable. The quality of sound from a properly designed closed box compares favorably with any other type enclosure. However, many times a closed box will prevent access, will not permit proper ventilation, or will not permit ready mass production.

Although not commonly stated in the literature, an open box can be analyzed somewhat like a closed box, especially if assumptions are made such as position in the room, and type of floor covering. Not only do open boxes lend themselves to theoretical analysis, but they sometimes present practical performance better than a similar closed box. Therefore, practically all of the RCA TV sets are built with open acoustic chambers.

There are several techniques that can be applied to both open and closed boxes to extend the range and lower the distortion of conventional loudspeakers. One of these techniques is called *energy loading*. Fig. 1 shows a simplified equivalent diagram of a loudspeaker around the low-frequency resonant point. The elements of speaker mass and compliance may be altered somewhat if the speaker is placed in a box. The compliance (stiffness) and mass of the material in the box (air or sound-absorbing material) will change the resonant frequency of the speaker. Usually this resonant frequency is raised. However, if the material is properly chosen and properly applied, it can lower the system resonance. Since it is desirable to

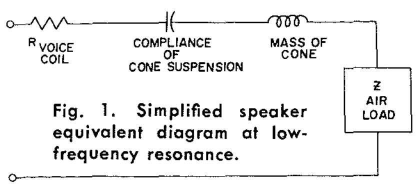


Fig. 1. Simplified speaker equivalent diagram at low-frequency resonance.

have a low-resonant system for good low-frequency reproduction, the proper material will load the speaker-cabinet system in a way that will improve the low-frequency reproduction. If the material is properly chosen, it can also add a resistive or dissipative component to the resonant circuit and thus lower the Q. Energy loading will reduce the resonance and lower the system Q to give better transient response. The disadvantage of energy loading is that the additional mass lowers the sensitivity of the system. By the fundamental equation $F = MA$, it can be seen that additional force is required when additional mass is added to give constant acceleration.

A second technique that improves the response, especially at the low end, and reduces the distortion of any given speaker, is *motion control*.[4] Basically, motion control is a feedback system that is designed to reduce the bad effects of low-frequency resonance and to reduce speaker distortion. This it does very effectively. The price is added amplifier gain and power handling capacity. (This technique is also known as a negative resistance amplifier, or ultimate damping.) Motion control can be added to practically any power amplifier to give better sound quality.

Besides motion control and energy loading, a great improvement in sound reproduction can be obtained in the middle range of the audio spectrum if the curve shape is very carefully chosen. Speakers that show extreme cone resonances and rim breakup produce distortion (including intermodulation) which can produce unpleasantness and fatigue for the listener.[5] Careful analysis of the transient response in the mid range has led to considerable improvement in the reproduction. The high-frequency range is usually quite difficult to design to produce smooth extended-range reproduction. The most economical method of high-frequency reproduction that we know of today is to use cone-type tweeters in an array to give the desired frequency and directive pattern. Usually wide-angle high-frequency reproduction is obtained by mounting these tweeters in angled housings, or cups.

STEREOPHONIC SOUND FOR TELEVISION

Any discussion of stereophonic sound for TV must be premised with the thought of "what does sound add to the entertainment quality of television." If stereophonic sound can add more to the enjoyment and realism, it should be incorporated. If not, it is a waste of bandwidth and facilities. We have carried on many experiments with stereo for

TV. These include live broadcasts and quite an extended series of experiments with the three-channel stereophonic sound, cinemascope movie, "How to Marry A Millionaire." This movie has the basic ingredients necessary to appraise the value of stereo for TV—a good, interesting program and well recorded stereophonic sound. Our conclusions are that stereophonic sound can be very advantageous to some types of program material. It adds very little, if anything, to a TV program without motion such as a news broadcast, single comedian, or soloist with piano accompaniment. Stereo does aid when it has been designed to be a part of the overall program. In the movie "How to Marry A Millionaire," one scene showed three girls seated in different parts of a room carrying on a conversation. The depth of stereophonic sound did add to the drama of this conversation, and as they moved about the room the sound moved with them; consequently, your attention was held more closely than with single-channel sound.

All experiments indicate stereo sound could be a powerful tool for drama on TV. Some techniques were developed to simplify the two- or three-microphone pick-up problem. For instance, if two microphones were used, they might be placed several feet apart to get the best stereo effect for TV. This might make it difficult to use a single microphone boom and dolly. A solution to this problem is shown in Fig. 2. If two microphones are used for channels A and B, one is fed straight through to channel A. The other microphone channel is fed to a tape delay. Note a potentiometer is connected between the direct channel B and the delayed channel B. When the arm of the pot is moved between the direct and delayed signal, the effect is that of moving the microphones apart or closer. The two microphones can be closely spaced as on a single boom but the effect of the spacing can be changed at will.

In the home, the aural display should be symmetrical with the TV screen. Stereo programs that have been transmitted using the TV audio for one channel and the AM radio for the other audio channel, have not proved to be satisfactory. This is especially true if the TV set has a side-mounted speaker. One satisfactory system is a receiver that has a front-mounted center speaker and two smaller satellite speakers on either side to give the directivity information. Such a system is now being used by Radio "Victrola" Engineering. One type is shown in Fig. 3. Experiments have shown that a stereo system having the lows from both channels (the low about 250 cps) in one center speaker plus right and left speakers, each to receive the highs from a channel, produces a fine speaker setup. The crossover network feeding the center low-frequency speaker must delay the lows about 2 μsec. The Hass effect says that, within certain limits, if one sound is delayed from the other, the sound will appear to come from the undelayed source; thus, although the delayed lows are present to add to the over-all balance, they do not contribute to the directivity. Another feature of the three-speaker system is the wide angle of stereo. It can be shown that one does not need to be "on axis" to get all the stereo effect. The satellite speakers in this system can be relatively small and still give a pleasing stereo effect.

In conclusion, the problem of high-fidelity sound for TV is quite complex and includes the studio transmission system and the receiver and acoustic system. There are several techniques available today that would make possible improvements in TV sound reproduction.

APPENDIX

Werner and Perry[4] give a thorough discussion of the motion control system to improve the performance of a loudspeaker. Werner even gives a circuit design for this type amplifier. It occurred to the author that a simple method for converting a conventional amplifier to this type of feedback might be valuable. This is shown in Fig. 4. It was decided that no internal connections (except possibly B+ and filaments) or modifications would be made on the existing amplifier. Most power amplifiers have one side of the output transformer grounded. Any change in this connection would upset the internal voltage feedback of the amplifier. Because of the necessity for the ground on the output transformer, the feedback signal must be derived by a unique tube circuit. Note in Fig. 4 that the output of the bridge feeds the grid and cathode of a triode. In this way the tube amplifies the unbalance signal. The capacitor C_2 is used to shunt out the signal at higher frequencies since the unbalance signal is most useful in the lower (piston) range of a speaker. The variable resistor is used to control the loop gain of the motional feedback system. R_1, C_1 are for bass compensation and R_2 is a volume control. It is important to keep the volume control and the bass compensation network outside the feedback loop. The connections to grid and cathode of the bridged tube can be reversed if the phase of the output transformer is incorrect.

REFERENCES

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4. Perry, S. V., "Motion Control of Loudspeakers," *RCA ENGINEER*, vol. 2, #6, April/May 1957, p. 48; and Werner, R. E., "Effect of a Negative Impedance Source on Loudspeaker Performance," *Jour. of the Acoustical Society of America*, Vol. 29, no. 3, March, 1957, p. 335.
5. Corrington, M. S. and Kidd, M. C., "Amplitude and Phase Measurements in Loudspeaker Cones," *Proc. IRE*, Vol. 39, pp. 1021-1026; Sept. 1951.

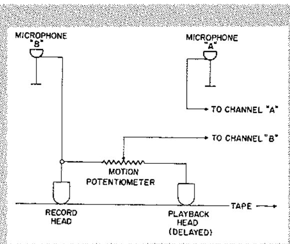


Fig. 2. Tape delay for two-microphone stereo pick-up.

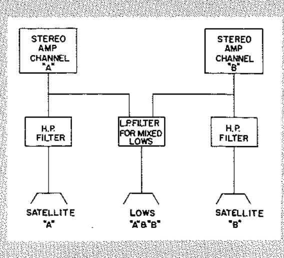


Fig. 3. Three-speaker stereo system.

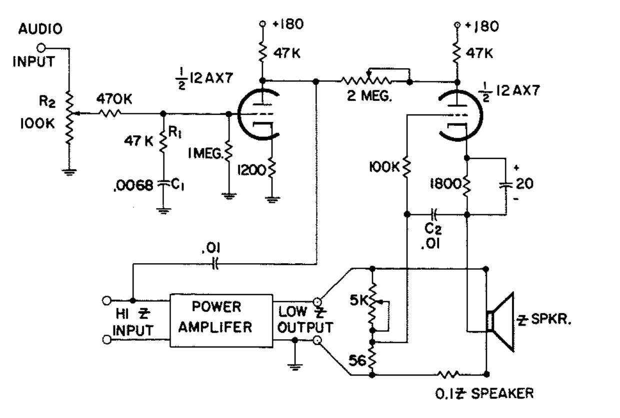


Fig. 4. Circuit for adding motion control to audio power amplifier.

Patents Granted
TO RCA ENGINEERS

BASED ON SUMMARIES RECEIVED OVER A PERIOD OF ABOUT TWO MONTHS

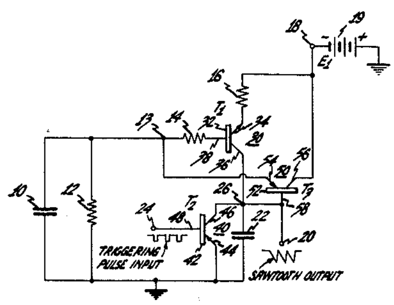
DEFENSE ELECTRONIC PRODUCTS

Camden, N. J.

Insulation of Printed Circuits
Pat. No. 2,885,601—granted May 5, 1959 to L. Pessel.

Sawtooth Wave Generator
Pat. No. 2,891,173—granted June 16, 1959 to W. A. Helbig.

Semi-Conductor Filter Circuits
Pat. No. 2,892,164—granted June 23, 1959 to H. J. Woll.



Pat. No. 2,891,173

Temperature Stabilized Two-Terminal Semi-Conductor Filter Circuit
Pat. No. 2,892,165—granted June 23, 1959 to J. E. Lindsay.

Limiter Circuit
Pat. No. 2,892,935—granted June 30, 1959 to R. D. Scheldorf.

Hollywood, Calif.

Direct Positive Sound Recording System
Pat. No. 2,885,490—granted May 5, 1959 to J. L. Pettus.

Constant Wavelength Control Tone System
Pat. No. 2,885,491—granted May 5, 1959 to A. C. Blaney.

ELECTRON TUBE DIVISION

Harrison, N. J.

Coating Method
Pat. No. 2,890,971—granted June 16, 1959 to W. L. Arnold and R. K. Pearce.

Electron Tube Insertion Apparatus
Pat. No. 2,891,305—granted June 23, 1959 to H. C. Waltke.

Apparatus for Removing Coatings
Pat. No. 2,891,433—granted June 23, 1959 to W. Ackermann.

Lancaster, Pa.

Audio Frequency Amplifier
Pat. No. 2,887,532—granted May 19, 1959 to R. E. Werner.

Electron Discharge Device
Pat. No. 2,887,594—granted May 19, 1959 to A. A. Rotow.

Marion, Ind.

Plural Gun Cathode Ray Tube
Pat. No. 2,887,598—granted May 19, 1959 to R. E. Benway.

RCA VICTOR TELEVISION DIVISION

Cherry Hill, N. J.

Amplitude Discriminatory System
Pat. No. 2,890,352—granted June 9, 1959 to H. C. Goodrich.

Color Television
Pat. No. 2,890,271—granted June 9, 1959 to R. K. Lockhart.

Signal Amplifying Systems
Pat. No. 2,890,330—granted June 9, 1959 to B. R. Clay.

Sawtooth Wave Generator
Pat. No. 2,891,192—granted June 16, 1959 to to H. C. Goodrich.

INDUSTRIAL ELECTRONIC PRODUCTS

Camden, N. J.

Magnetic Record Transducer
Pat. No. 2,872,530—granted Feb. 3, 1959 to S. T. Jolly.

Color Television Test Apparatus
Pat. No 2,877,291—granted Mar. 10, 1959 to J. W. Wentworth, A. C. Luther, Jr., and F. R. C. Bernard, not employed by RCA.

Frequency Control System
Pat. No. 2,888,562—granted May 26, 1959 to H. A. Robinson.

Airborne Store Ejector Bolt
Pat. No. 2,883,910—granted Apr. 28, 1959 to T. G. Nessler.

Television Control System
Pat. No. 2,890,276—granted June 9, 1959 to A. C. Luther, Jr., R. J. Marian, and I. Bosinoff, not employed by RCA.

Memory Systems
Pat. No. 2,891,238—granted June 16, 1959 to D. L. Nettleton.

Multivibrator with Cathode Stabilized by a Capacitor
Pat. No. 2,891,148—granted June 16, 1959 to A. C. Luther, Jr.

Image Signal Correction Apparatus
Pat. No. 2,892,025—granted June 23, 1959 to A. C. Luther, Jr., and I. Bosinoff, not employed by RCA.

Plural Channel Circuit Maintenance
Pat. No. 2,892,026—granted June 23, 1959 to W. L. Hurford.

SEMICONDUCTOR AND MATERIALS DIVISION

Somerville, N. J.

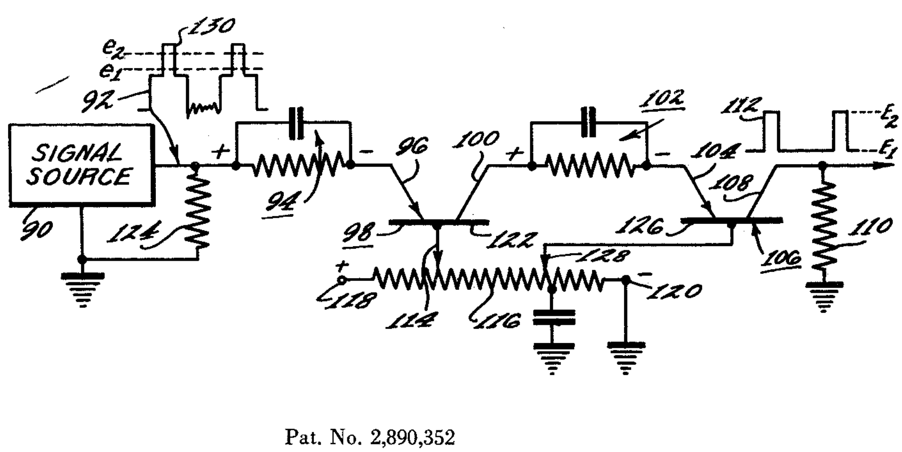
Magnetic Recording
Pat. No. 2,890,288—granted June 9, 1959 to J. J. Newman.

NATIONAL BROADCASTING CO.

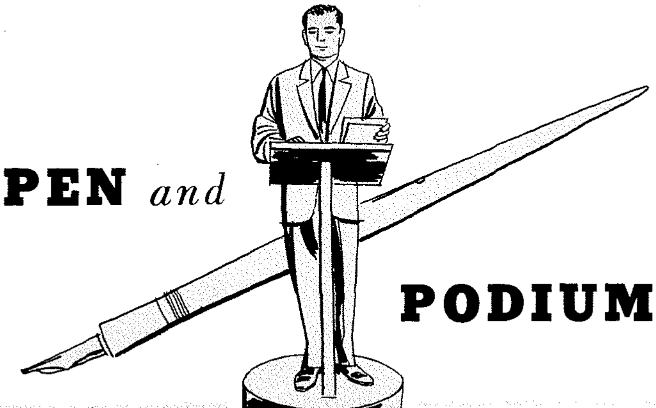
New York, N. Y.

Zero Output Impedance Amplifier
Pat. No. 2,886,659—granted May 12, 1959 to J. O. Schroeder.

Continuously Moving Film Scanner
Pat. No. 2,890,277—granted June 9, 1959 to V. J. Duke.



Pat. No. 2,890,352



PEN *and* PODIUM

Based On Reports Received Over a Period of About Two Months

DEFENSE ELECTRONIC PRODUCTS

Camden, N. J.

A Steady State Analysis of Chopper Networks

By E. D. Grim: Submitted as a Master's Thesis in the Moore School of Electrical Engineering, University of Pennsylvania. This thesis develops the values of the steady state currents and voltages in the respective dosed and open chopper intervals in a generalized circuit.

Automatic Communication System for Air Traffic Control

By R. E. Davis and D. T. Gross: Presented at the IRE 11th Annual National Aeronautical Electronics Conference, Dayton, Ohio, May 6, 1959. Automatic Ground/Air/Ground Communication/System parameters are discussed and detailed explanations of the airborne equipment are presented.

Automatic Testing—A Realistic Approach

By J. M. Laskey: Presented at the IRE 11th Annual National Aeronautical Electronics Conference, Dayton, Ohio, May 6, 1959. Automatic testing philosophy must be integrated with functional design requirements. Prerequisite considerations are discussed.

Transistorized Marker Beacon Receiver

By R. G. Erdmann: Published in the May 8, 1959 issue of *Electronics*. Junction transistors and diodes are used to replace tubes and relays in a marker beacon receiver. The receiver, which was developed by RCA and militarized for the Signal Corps, features printed circuits and light weight.

The Mathematical Bases for Reliability Tests

By C. M. Ryerson: Presented at UCLA, Los Angeles, Calif., May 5 and 6, 1959. This paper describes techniques and methods for interpreting test data. Longevity tests and short time reliability tests are described.

Moorestown, N. J.

Optimization of a Tracking Radar Servo for Low Speed Tracking

By D. J. Griep and G. M. Sparks: MS Thesis, June, 1959, University of Pennsylvania. Using a statistical design approach, a tracking radar servo system was designed to have an optimum rejection of load noise.

The Helisphere Antenna

By C. Clasen: A Master's Thesis in Physics to be presented to the Graduate School of the University of Pennsylvania by June 3, 1959. A three-dimensional, low-inertia scanning antenna system is described. It employs a spherically shaped, polarization-sensitive grating as a reflector.

Automatic Target Acquisition Circuit for Track Radars

By A. J. Lisicky: Thesis, Master of Science in Electrical Engineering, University of Pennsylvania. The thesis is concerned with the analysis of a target detection scheme which employs multiple search gates.

Accuracy of a Monopulse Radar

By D. Barton: Presented at the National Convention on Military Electronics, Washington, D. C., June 30, 1959. Significant components of noise and bias error in monopulse tracking radar are analyzed theoretically, and experimental results presented to verify the analysis. It is shown that overall error for a given radar track may be reliably predicted. Results for a modern radar tracking Sputnik II are presented.

INDUSTRIAL ELECTRONIC PRODUCTS

Camden, N. J.

Radio Station Automation

By G. A. Singer and P. W. Wildow: Presented at the IRE Professional Group on Broadcasting, WCAU Studios, Philadelphia, Pa., May 14, 1959. Automatic turntables for playing records and magnetic discs simplify programming of a radio station. Complete automation can be achieved through the punched paper tape actuated Automatic Programming System.

A Medium Haul Private Microwave System for TV

By J. B. Bullock: Presented at the AIEE Mid East District Meeting, Lord Baltimore Hotel, Baltimore, Maryland, May 21, 1959. This talk was a review of a three-channel microwave system between Pine Bluff, Wyoming and Rapid City, S. D. recently installed by the RCA Service Co. using the TVM-1A microwave relay equipment. The system relays programs of three Denver TV stations to Rapid City for distribution.

High Speed Tone Control Equipment

By A. W. Muoio: Presented as M.S. Thesis to the University of Pennsylvania for graduation on June 10, 1959. This paper describes transistorized equipment designed for high-speed protection of power systems.

Implementing Research

By W. C. Morrison: Presented at the Engineering Graphics Division of the American Society for Engineering Education, Pittsburgh, Pa., June 16, 1959. Human characteristics, together with business pressures, make it difficult to convert research ideas into marketable products. Two solutions to the problem are available: (1) A formal system to evaluate ideas and indoctrinate product engineers simultaneously; or (2) Placing individuals with perspective and ability in certain key positions.

ELECTRON TUBE DIVISION

Harrison, N. J.

A Ruggedized Coupled-Cavity Tunable Magnetron for Airborne Service

By T. J. Kelly and V. J. Stein: Presented at National Aeronautical Electronics Conference, Dayton, Ohio, May 4-6, 1959. This paper describes a ruggedized tunable magnetron designed specifically for the environmental requirements of airborne applications.

A New, Reliable, Low-Noise, Ceramic Pencil Tube for Use as a UHF Triode

By L. P. De Backer and J. J. Thompson: Presented at National Aeronautical Electronics Conference, Dayton, Ohio, May 4-6, 1959. Published in *Aeronautical Electronics 1959 National Conference Proceedings*. This paper describes a new ceramic-and-metal pencil tube designed for use as a small-signal amplifier at frequencies up to 1000 megacycles. Features of the tube include its low noise, high gain, and stability with heater-voltage variations.

Measurement and Effect of Cathode-Coating Impedance at Ultra-High Frequencies

By J. J. Thompson: Published in *Proceedings of 1958 Tube Techniques Conference*, May, 1959. This paper describes a method for determining the resistance and capacitance of the oxide coating of a cathode in a vacuum tube by means of a few uhf measurements.

A Novel Method of Fabricating Ceramic Stems

By A. J. Stoeckert: Presented at Electronic Components Conference, Philadelphia, Pa., May 6-8, 1959. This paper describes a proposed method for sealing metal leads in ceramic stems through the use of active metal alloys which braze directly to the ceramic, thus eliminating the need for premetallizing of ceramic.

Crushing Resistance of Glass Receiving-Tube Envelopes in a Gas Pressure Chamber

By J. Gallup: Presented at Annual Meeting of American Ceramic Society, Chicago, Illinois, May 20, 1959. This paper describes an investigation of the external gas pressures at which a number of different types and sizes of receiving-type electron tubes cracked or imploded.

Effect of Hydrogen Atmosphere on Thermal Shock Resistance of Various Ceramics

By W. A. Hassett and T. F. Berry: Presented at Annual Meeting of American Ceramic Society, Chicago, Illinois, May 19, 1959. This paper describes the results of temperature cycling tests in a hydrogen furnace on cylinders of alumina, beryllia, zircon, forsterite, and mullite, particularly with respect to microstructural changes in porosity, crystal growth, and glass formation.

Construction of Electron Guns for Traveling-Wave Tubes

By W. Johnson and A. J. Bianculli: Published in *Proceedings of 1958 Tube Techniques Conference*, May, 1959. This paper describes the design and construction of a "glass-beaded" electron gun which is strong, accurate, simple, and inexpensive.

Stoichiometry of Ceramic Dimensional Control

By W. C. Allen: Presented at Annual Meeting of American Ceramic Society, Chicago, Illinois, May 19, 1959. This paper reviews the fundamental mathematical relationships between compositional, pressing, and firing factors for ceramic materials.

A Traveling-Wave-Tube Amplifier Chain—An Aid to Reliable Communications in Aircraft Service

By H. J. Wolkstein: Presented at National Aeronautical Electronics Conference, Dayton, Ohio, May 4-6, 1959. Published in *Aeronautical Electronics 1959 National Conference Proceedings.* This paper describes an amplifier chain consisting of two small, light-weight, traveling-wave tubes which have been designed specifically to meet military environmental demands.

Design and Application Considerations for a Low-Crossmodulation, Low-Noise, Front-End Tube

By D. M. Burton: Presented at National Convention on Military Electronics, Washington, D. C., June 30, 1959. Published in 1959 *Military Electronics Convention Record.* This paper describes the design techniques involved in the development of a low-crossmodulation, low-noise, "front-end" tube.

Lancaster, Pa.

Determination of Residual Amounts of Organic Contaminants in Electron Tubes by Radiotracer Techniques

By H. A. Stern: Presented at Electrochemical Society Meeting, Philadelphia, Pa., May 3-7, 1959. This paper describes the use of radiotracer techniques in the study of organic contamination and its effects of cathode environment.

The Effect of Gases on Emission of Oxide Cathodes

By W. G. Rudy: Presented at Electrochemical Society Meeting, Philadelphia, Pa., May 3-7, 1959. This paper describes the effects of deleterious gases on the emission from oxide cathodes.

High-Power Beam Tetrode Amplifier for Pulsed Service

By S. G. McNees and L. G. Sutton: Presented at National Aeronautical Electronics Conference, Dayton, Ohio, May 4-6, 1959. This paper describes the design features of the RCA-6952, a liquid-cooled beam power tetrode rated to permit a peak r-f power output in excess of 750 kilowatts.

Recent Developments in Display Storage Tubes

By N. W. Patrick and P. P. Damon. Presented at National Aeronautical Electronics Conference, Dayton, Ohio, May 4-6, 1959. Published in *Aeronautical Electronics 1959 National Conference Proceedings.* This paper reviews developments at RCA in the field of display storage tubes since 1956, beginning with a review of the tube principles.

Evolution and Absorption of Gases in Electron Tubes

By J. C. Turnbull and R. H. Collins: Presented at Meeting of the Electrochemical Society, Philadelphia, Pa., May 6, 1959. This paper describes the determination of gas-evolution effects in vacuum tubes by use of the gas-collection method, in which evolved gases are collected with a mercury pump, stored, and measured.

Advances in the Techniques and Applications of Very-High-Power Grid-Controlled Tubes

By M. V. Hoover: Published in *Proceedings of Institution of Electrical Engineers,* Vol. 105, Part B Supplement 10, 1958. This paper describes four types of unitary electron-control systems—beam triode, shielded triode, uhf triode, and uhf tetrode—used in double-ended tubes and circuits to deliver very high power at uhf.

The Effect of Calcium in Thoriated-Tungsten Filaments on Emission

By P. D. Strubhar: Published in *Proceedings of 1958 Tube Techniques Conference,* May, 1959. This paper describes the investigation of the calcium content of tungsten filament wire to determine effects on cold resistance before carburizing and slumping emission during life-testing.

Evaluation of Coolants for High-Power Transmitting Tubes

By R. W. Etter, G. E. Hansell and I. E. Martin: Published in *Proceedings of 1958 Tube Techniques Conference,* May, 1959. This paper describes the investigation of fluid coolants for use with high-intensity-heat-dissipation beam power tubes, and describes the advantages of inert fluids.

Development of the Photographic-Exposure Unit for Color-Picture-Tube Screens

By N. R. Goldstein: Published in *Proceedings of 1958 Tube Techniques Conference,* May, 1959. This paper reviews the development of the optical system used to produce phosphor screens for color picture tubes, including work done on the three principal elements: light sources, light collimators, and light reflectors.

The Brazing of Tungsten and Molybdenum Above 1900 Degrees Centigrade

By L. C. Herman: Published in *Proceedings of 1959 Tube Techniques Conference,* May, 1959. This paper describes the successful use of seven metals or alloys for brazing tungsten to molybdenum at temperatures between 1900 and 2620 degrees centigrade.

Princeton, N. J.

RF Logic Circuits Using Subharmonic Oscillators

By F. Sterzer: Presented at IRE National Symposium on Microwave Theory and Techniques, Harvard University, Mass., June 3, 1959. This paper describes several logic circuits, in particular a "full adder" which uses subharmonic oscillators, which can operate at an effective repetition rate exceeding 100 megacycles.

Millimeter-Wave Oscillators

By D. J. Blattner and F. Sterzer: Published in *Electronics,* June 19, 1959. This paper describes the characteristics and performance of two RCA experimental backward-wave oscillator tubes designed to explore the possibilities of obtaining voltage-tunable oscillations over very wide frequency ranges in the millimeter-wavelength region.

SEMICONDUCTOR AND MATERIALS DIVISION

Somerville, N. J.

The Formation of SiC During the Growth of Silicon Crystals in Atmospheres Containing Hydrogen

By E. Sailer: Presented at Meeting of the Electrochemical Society, Philadelphia, Pa., May 5, 1959. This paper describes work leading to the observation of a second mode of carbon monoxide formation which causes the formation of SiC slag during the growth of silicon crystals.

A High-Frequency Silicon Transistor

By F. Katnack and W. Bosenberg: Presented at National Aeronautical Electronics Conference, Dayton, Ohio, May 4-6, 1959. This paper describes a developmental silicon transistor intended for high-frequency operation, and discusses the fabrication techniques used.

Transistors and Diodes for Micro-Module Applications

By E. L. Schork: Presented at Electronic Components Conference, Philadelphia, Pa., May 8, 1959. This paper outlines the objectives and accomplishments of various transistor and diodes groups and companies participating in the Army Micro-Module Program.

The Evolution of High-Frequency Transistor Design

By W. M. Webster and R. B. Janes: Presented at International Convention on Transistor Design, London, England, May 25-29, 1959. This paper discusses the use of a number of different device structures and different processing techniques through which the upper frequency limit of junction transistors has been steadily advanced.

A New Technique for Measuring Transistor Switching Times

By R. R. Johnson, R. D. Lohman, and R. R. Painter: Published in *Semiconductor Products,* May, 1959. This paper describes a new test method for improving and simplifying the measurement of transistor switching times, and presents circuits used in the test set.

Designing High-Quality AF Transistor Amplifiers

By R. Minton: Published in *Electronics,* June 12, 1959. This paper describes the use of transistors in a seven-stage, high-quality af power amplifier capable of delivering 25 watts of power when driven by a variable-reluctance magnetic pickup and operated from a —30-volts supply.

Needham, Mass.

New Inductor Ferrites

By H. Lessoff, W. Croft, and J. McCusker. Presented at Electronic Components, Conference, Philadelphia, Pa., May 6-8, 1959. Published in *Proceedings of Electronic Components Conference,* May 1959. This paper discusses the improvement of some of the electrical properties of nickel-zinc ferrites intended for use in i-f transformers, wide-band transformers, and miniature inductors, which require linear B-H characteristic, low induction level, and high stability.

Preparation and Properties of the Systems $LnFe_xCr_1—x°3$ and $LaFe_xCo_1—x°3$

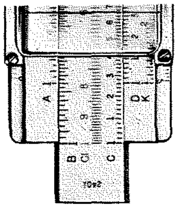
By A. Wold and W. Croft: Published in the *Journal of Physical Chemistry,* 63,447, 1959. This paper discusses the systems presented in order to determine whether an ordering takes place on the B sites of rare earth-iron-chromium, lanthanum-iron-cobalt oxides.

Crystallographic and Magnetic Properties of Several Spinels Containing Trivalent Manganese

By D. G. Wickham and W. J. Croft: Published in *The Physics and Chemistry of Solids,* Pergamon Press, 1958, Vol. 7. This paper discusses several new compounds from which we have gained an understanding of the mechanism of tetragonal distortions and compounds containing manganese.

Some Magnetic and Crystallographic Properties of the System $Li_xNo_{1-2x}\ Ni_x\ O$

By J. B. Goodenough, D. G. Wickham and W. J. Croft: Published in *The Physics and Chemistry of Solids,* Pergamon Press, 1958, Vol. 5. This paper discusses the electrical, magnetic, and crystallographic properties of the system of oxides represented by the formula $Li_x\ Ni_{1-2x}\ Ni_x\ O$.

Engineering  NEWS *and* HIGHLIGHTS

MAX BATSEL RETIRES

We on the Editorial Staff of the RCA ENGINEER would like to take the opportunity of Max Batsel's retirement to acknowledge the active part he has played on the RCA ENGINEER since its inception. His energetic support not only as an Advisory Board Member and frequent author, but with his administrative ability in stimulating professional papers for publication he contributed much to RCA and the magazine in his role as a capable engineer.

The best way we know of to pay tribute to the outstanding abilities and accomplishments of Max C. Batsel and his 39 year career in the limited amount of space available to us in these columns is to publish the citation below—a fine tribute paid to Mr. Batsel at his recent retirement dinner at Cherry Hill Inn. The tribute was written by Dr. C. B. Jolliffe, Vice President and Technical Director of RCA, and appeared in the excellently prepared souvenir banquet menu.

"To a young engineer looking for a model on which to pattern his aims and aspirations we would suggest taking a look at Max Batsel's long and fruitful career. The list of Max's personal contributions—developments, patents, general creativity—is indeed impressive. Yet it is in the field of engineering administration that his talents approach uniqueness. Modest and quiet-spoken, persistent and clear-headed at all times, he has the unusual ability to analyze a problem quickly, and then to move on swiftly and surely to its solution. In so doing he has on innumerable occasions prodded others into achievements which would not otherwise have occurred, and for which they, not he, got the principal credit. And that, incidentally, is the way Max always wanted it. No wonder the host of engineers with whom he has been associated revere him for fairmindedness, judgment, wisdom and insight; no wonder they salute him for a combination of talents few men are privileged to possess."

After his graduation with a BME degree from the University of Kentucky in 1915, Mr. Batsel worked with Western Electric Company and Westinghouse. He came to RCA's Photophone Division as Chief Engineer in 1929. In 1932, Mr. Batsel became Manager of Sound for RCA's Engineering Division. From 1941 until his appointment in 1945 as Chief Engineer of Engineering Products Division, he served as Chief Engineer on Special Equipment at RCA's Indianapolis plant. In 1956 he was appointed Chief Technical Administrator, DEP, a position he held at his retirement July 1, 1959.

Shown at retirement dinner (l to r) Mrs. M. C. Batsel, Dr. C. B. Jolliffe and Mr. Batsel.

Mr. Batsel is a member of Tau Beta Pi, a Fellow of IRE, a Fellow of SMPTE, a member of the American Society of Naval Engineers and of Radio Pioneers. He has received the Modern Pioneers Award of the National Association of Manufacturers.

His biography does little to reveal his accomplishments, both in engineering and in the leadership of engineers. From his early design work on the Aeriola Senior—the first production line home radio—to his recent valuable contributions to the field of military product assurance and reliability, M. C. Batsel has been an "Engineer's Engineer."

DR. ARTHUR ELECTED FELLOW, AAAS

Dr. George R. Arthur, Airborne Systems Department, DEP Camden, has been elected a Fellow of the American Association for the Advancement of Science. Dr. Arthur is also currently President of the American Astronautical Society.—*J. F. Biewener*

BILL SANDS DIES IN AUTO CRASH

William F. Sands, one of Radio & Television's pioneers with more than 20 years experience at RCA, was killed instantly in a headon crash of automobiles on Rt. 206 near Somerville, N. J. Mr. Sands, who recently transferred to the RCA Somerville N. J. Plant (Semiconductor and Materials Division), was returning to his home in Delaware Township near RCA's Cherry Hill Plant. The loss of Mr. Sands is keenly felt by his many friends and associates at RCA where he is considered one of the company's top physicists and electronics engineers.

Wm. Sands graduated from Penn State University with a Bachelor of Science and a Master of Science Degrees and also studied at Rensselaer Polytechnic Institute. He first worked at Atwater Kent Company until 1936 when he joined RCA's Radio and Television engineering activities.

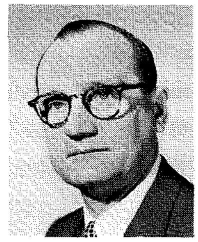
Mr. Sands worked for many years on the development and design of circuits used in Radio and Television products. He was a member of the Advanced Development Engineering group in the RCA Victor Television Division at Cherry Hill, N. J. until Feb. 16 of this year when he transferred to the Semiconductor and Materials Division at Somerville, N. J. Here, he worked on the development of Micro-modules for both government and commercial uses. During his 23 years of service at RCA, he has published many professional papers and has been granted more than 20 U. S. Patents in the electronics field. Mr. Sands was a member of Sigma Phi Sigma, honorary Physics Society and a Senior Member of the IRE. He also was a member of Alpha Mau Omega Fraternity.

ENGINEERS IN NEW POSTS

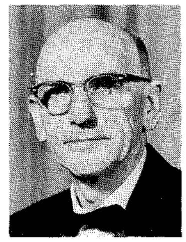
Dr. G. H. Brown, Vice President, Engineering, RCA has appointed **E. M. Leyton** as Staff Engineer.

In DEP, Airborne Systems Dep't. Mgr. **S. N. Lev** appoints **H. C. Lawrence** as Manager, Equipment Projects.

RCA Victor Home Instruments' Chief Engineer **E. I. Anderson** has announced his staff as follows: **K. A. Chittick,** Mgr. Engineering Administration; **D. D. Cole,** Mgr. Television Product Engineering; **D. H. Cunningham,** Mgr. Radio "Victrola" Product Engineering; **E. E. Moore,** Mgr. Engineering Services; **C. M. Sinnett,** Mgr. Advanced Development. **L. R. Kirkwood** reports to **D. D. Cole** as Mgr. TV Product Engineering Operations. In the Electron Tube Division, **W. B. Brown** becomes Plant Mgr. at Woodbridge and **F. J. Lautenschlaeger** becomes Harrison Plant Mgr. **R. L. Klem** is announced by **K. G. Bucklin** as Mgr. Engineering Administration and Special Project Control, Receiving Tube Operations.



J. A. Brustman



D. H. Cunningham

R. L. Kl

In IEP, **T. A. Smith** announces **R. W. Sonnenfeldt** as Mgr. of the newly formed Digital Control Systems Engineering Group in the Electronic Data Processing Division. . . . Chief Engineer **J. W. Leas** of that division announces his staff as follows: **C. M. Breder,** Mgr. Data Processing Engineering Administration; **J. A. Brustman,** Mgr. High Speed Computer Development and Design; **H. M. Elliott,** Mgr. Computer Product Line Engineering; **D. Flechtner,** Mgr. Input-Output Devices Eng.; **J. N. Marshall,** Mgr. Advanced Development and Digital Control Systems; **P. T. O'Neil,** Mgr. Special Projects and Autodata Eng.; and **R. E. Wallace,** Mgr. Custom Projects.

Dr. J. Hillier, V. P. RCA Laboratories, has appointed **William M. Webster** as Administrative Engineer.

J. W. Wentworth is named Staff Engineer for Educational Electronics, responsible for engineering studies to develop business opportunities in this field. In June he made a trip to Japan to study TV in that country.

DR. BEAUMARIAGE APPOINTED SLOAN FELLOW

Dr. D. C. Beaumariage, Manager of Electronic Systems Design for the Missile Electronics and Controls Department at Burlington, Mass., has been appointed as a Sloan Fellow in the Executive Development Program at Massachusetts Institute of Technology during the scholastic year 1959-60.

Dr. Beaumariage received the BEE degree from Cornell University in 1946, the MSEE from Carnegie Institute of Technology in 1948, and the Dr. Science in EE in 1950, also from Carnegie Institute. From 1950 to 1954 he was with Sperry Gyroscope Co. and joined RCA in 1954 as an engineer in the Missile & Surface Radar Department, Moorestown, working on systems engineering projects. In 1955 he was promoted to Leader, Development and Design Engineering, and in 1956 became Manager, Airborne Systems Project Development, Airborne Systems Dep't., Camden. In 1957 Dr. Beaumariage transferred to the function that has become Missile Electronics & Controls Dept. —*R. W. Jevon*

LANCASTER EMPLOYE AWARDED DAVID SARNOFF FELLOWSHIP

Upon completion of several competitive examinations, Charles W. Rector was named as one of the four recipients of the David Sarnoff Fellowship. He will begin studies toward a Doctorate in Physics at Johns Hopkins in October. Mr. Rector, an engineer in Dept. 981, received a Bachelor of Science degree in mathematics from the University of Chicago in 1949 and recently completed work under the RCA Tuition Loan and Refund Program toward a Master of Science Degree in Physics at Franklin and Marshall College. He joined RCA in July, 1954 as a specialized trainee assigned to Lancaster.

JENNINGS AND HALL IN NEW POSTS

Russell J. Hall, Assistant Editor, RCA ENGINEER and E. R. Jennings, Engineering Editor and Associate Engineer, Astro Electronics, recently moved to new posts.

In the moves, Mr. Jennings is promoted to Assistant Editor of the RCA ENGINEER. Mr. Hall, who formerly held this position, is advancing to Administrator, Defense Proposals, in Defense Electronic Products, Marketing, Camden, N. J.

The entire staff of the RCA ENGINEER extends best wishes to Mr. Hall in his new position and at the same time welcomes his successor, Mr. Jennings, as a member of the RCA ENGINEER staff and RCA's Product Engineering, RCA Corporate Staff.

Edgerton R. Jennings received the B.S. degree in Mechanical Engineering from the Illinois Institute of Technology in 1950 and since then has completed Advanced Journalism, Business, and Liberal Arts courses at the University of Chicago and University of New Mexico.

In 1950, Mr. Jennings held a staff-editor position with *Pit and Quarry* publications, and in 1952 joined the Chicago Bridge and Iron Co. as a structural design engineer. In 1954, he was on a Military assignment with the Ordnance Corps, U.S. Army White Sands Proving Ground where he wrote and edited technical reports and test procedures for training Ordnance Corps technicians. In 1956, Mr. Jennings was Assistant Chief, Reports Branch, Weapons Effects Test Group, Armed Forces Special Weapons Project, Albuquerque, N.M. Work here involved writing, editorial review, and supervision of production activities in the nuclear-test technical report program.

Mr. Jennings joined RCA's Astro Electronic Products Division in 1959, working on technical reports and proposals, prior to joining the RCA ENGINEER staff in August this year. He is a senior member of the Society of Technical Writers and Editors and the Technical Publishing Society.

R. J. Hall (left) and E. R. Jennings (right)

Russell J. Hall studied engineering at Rutgers University before going overseas with the U.S. Army Infantry in World War II. After the war, he taught radio communication and television at Spring Garden Institute and TV Training Institute.

Mr. Hall joined RCA Service Company in 1948 and in 1950 became Journeyman Television Technican. During the next five years, he taught radio, television, and air conditioning, becoming Leader of Technical Training. During this time he edited and produced technical manuals and home study courses for RCA technicians, including "Practical Color Television" of which 200,000 copies have been printed. Mr. Hall has written on such subjects as UHF propogation, color signal development and television installation and service.

In March 1955, Mr. Hall joined the RCA ENGINEER staff as Assistant Editor. In cooperation with Editorial Representatives and Engineers Mr. Hall helped plan the covers and contents of upwards of twenty-five issues published and distributed since inception of the magazine.

Mr. Hall is continuing his studies at Rutgers University College at Camden.

MEETINGS, COURSES AND SEMINARS

Communications Technical Liaison

Formation has been announced of a Technical Liaison Committee on Communications within RCA. Membership includes the following: J. S. Hepburn, RCA Communications, Inc. (Chairman); C. G. Arnold, DEP Surface Communications; J. Brandinger, RCA Laboratories; K. G. MacLean, Astro Electronic Products; K. Neumann, IEP Communication Products; and J. L. Owings, IEP Electronic Data Processing. The first meeting was held at 60 Broad Street, N. Y. on May 20. Meetings will be held bi-monthly.

Global Conference

Dr. Mark Lotkin of the Digital Communications Equipment Engineering Section, Surface Communications Department, presented a paper entitled "Characteristic Values of Arbitrary Matrices", at the International Conference on Information Processing. This global conference organized by the United Nations Educational, Scientific, and Cultural Organization (UNESCO), and sponsored by IRE, AIEE, and ACM on the part of the United States, was held in Paris, France, June 13-23, 1959. —*E. O. Selby*

Flight Safety Conference

GROUND SUPPORT EQUIPMENT—That was the theme of the 41st Air Force Aircraft Industry Conference on Flight Safety held in Los Angeles, Calif., June 16-18, and sponsored by the Air Force Directorate of Flight Safety Research, Norton Air Force Base, Calif. Nearly 400 representatives of the Army, Navy, Air Force, Federal Aviation Agency, and 110 American and Canadian corporations participated in the closed sessions at the Biltmore Hotel.

X-ray Diffraction Seminar

This seminar followed the pattern of the Electron Microscope Seminar. Approximately fifty people with varying interests in X-ray Diffraction and Spectroscopy attended this three-day session April 20-22, with one evening scheduled for first-hand examination of equipment in the demonstration laboratory by the participants. Guest Speakers were Dr. P. P. Ewald, Brooklyn Polytechnical Inst.; Dr. E. P. Bertin, RCA-Harrison; and Erich Mayer, Siemens & Halske. RCA Speakers were Dr. J. H. Reisner, Dr. V. E. Buhrke, F. J. Hermann, E. J. Guilfoy, R W. Preston, and L. Shapiro. —*C. W. Sall*

Electron Microscope Seminar

This seminar was held April 8-10 in Camden for the instruction of beginning workers in electron microscopy. About two-thirds of the participants were from the biological sciences and one-third from industry. Approximately sixty-five people attended. The series of lectures was augmented by closed circuit television to present close-up views of instruments and specimen preparation techniques.

Guest Speakers were Dr. C. E. Hall, MIT, and Dr. Hewson Swift, University of Chicago. RCA Speakers were Dr. J. H. Reisner, H. C. Gillespie, F. J. Hermann, E. J. Guilfoy, E. G. Dornfeld, W. R. Lasko, and L. Shapiro. —*C. W. Sall*

Shown here discussing GSE developments are, from left to right: William B. Ross, GSE Coordinator, North American Aviation, Inc., Los Angeles, Calif., Stanley Rosenberg, Manager, ASD Systems Support Projects, Radio Corporation of America, Camden; and Jack D. Entsminger, Supervisor, GSE and Test Equipment Group, North American Aviation, Inc.

DEGREES AWARDED

The following people in Broadcast Studio Engineering, IEP Camden, have received Scholastic recognition this past June: **D. M. Taylor** received the MSEE frmo the University of Pennsylvania, and **H. E. Hawlk** received the Diploma in EE from Drexel Institute of Technology. Formerly a Lab Technician, Mr. Hawlk has been reclassified as an engineer.—*J. H. Roe*

COMMITTEE APPOINTMENTS

Surface Communications—Camden

W. F. Meeker is a Member of the Technical Committee on Speech Communications and the Subcommittee on Methods of Calculating Speech Intelligibility, both of the Acoustical Society of America.

R. M. Carrell is President of the Phila. Chapter of the IRE PG on Audio.

H. R. Montague is Program Chairman of the IRE PG on Audio.

G. V. Jacoby is Vice-Chairman of the AIEE Science Electronics and Instrumentation Division, Phila. Chapter.

P. S. Alday is Vice-Chairman of the Science Committee for Junior Members of the Engineer's Group of America.—*E. O. Selby*

Color Kinescopes—Lancaster

Paul D. Strubhar, Chemical & Physical Lab., Electron Tube Div. Lancaster, was appointed Chairman of Sub-Committee G-1, "Methods of Test" of Committee B-5, "Copper and Copper Alloys" of the American Society for Testing Materials.—*D. G. Garvin*

Data Processing—Camden

T. T. Patterson is chairman, IRE Professional Group on Engineering Writing & Speech—and National Director of Dual National Symposium, Boston & Los Angeles Sept. 17-18.

RCA Communications, Inc., N.Y.

D. S. Rau has been appointed to the Nominations Committee and the Awards Committee of the IRE PG on Communications Systems. **Walter Lyons** is appointed Chairman, Papers Procurement Committee of the IRE PG on Communications Systems. Mr. Lyons has also been elected to full membership of the Polytechnic Chapter of the Society of Sigma Xi. **James M. Walsh** was elected recently to a second term as President of the Manhattan College Engineers Alumni Organization.

Broadcast Transmitters—Camden

J. C. Walter, Manager of High Power Radar Engineering, IEP, has been appointed Vice-Chairman of the AIEE National Committee on Periodicals and Transactions.

Industrial Tube Products—Lancaster

H. B. Walton of Manufacturing Engineering has been elected Vice President in charge of Programs for the Lancaster Chapter of the American Institute of Industrial Engineers. **J. J. Spencer,** also of Manufacturing Engineering, was elected Director of Research.

At a recent meeting of the Lancaster Subsection, Philadelphia Chapter of IRE, the following were among those elected officers for the 1959-60 season: Chairman, **Franz S. Veith,** Manager, Camera, Oscillograph & Storage Tubes Engineering; Vice Chairman, **William N. Parker,** Staff Engineer, Power Tube Engineering; and Secretary-Treasurer, **James S. Class** of Life Test and Data Engineering.

D. H. Gish of Standardizing Engineering was elected to a second term as Director for the Lancaster Chapter of the Society for Advancement of Management.

J. M. Forman of Life Test and Data Engineering has been made Public Relations Chairman in Lancaster County for the Pennsylvania Society of Professional Engineers.
—*H. S. Lovatt*

RCA Service Co.

E. Stanko, Manager of Engineering, Quality and Training, Technical Products Service, has been nominated as a representative on the RCA Institutes Board of Technical Advisors.

NEW EDITORIAL REPRESENTATIVES

E. W. Keller replaces Dr. A. H. Benner as Editorial Representative for the RCA ENGINEER in DEP Airborne Systems Engineering, Camden. Mearl W. Tilden replaces L. J. Reardon as Editorial Representative, Gov't. Service Dep't., RCA Service Co.

Mearl W. Tilden received the BSEE degree from the University of Iowa in 1929 and came to RCA as a Student Engineer in New York the same year.

He became a Photophone Field Engineer in 1938, working on Theater Sound Equipment for the RCA Service Dept. In 1942 he assumed the position of Contractor's Field Service Superintendent, preparing instruction manuals on radar for the Navy. After a year as an Electron Microscope Specialist, Mr. Tilden became Mgr. of Technical Publications for RCA Service Co., and in 1952 was made Mgr. of the Quality Test Lab at Brown's Mills, N. J. In 1958 he was Leader of Special Projects, BMEWS Service, Riverton, N. J., until assuming his present position of Mgr. Field Support Engineering in 1959.

E. W. Keller received a B. E. degree from the Johns Hopkins University in 1943 and the M. S. degree from M.I.T. in 1949. At M.I.T. he taught and conducted research in the field of electrical communications, advanced network theory, microwave theory and radar while from 1943 to 1955, advancing to Assistant Professor of E. E. in 1953. From 1955 to 1957 he was an Assistant Professor of E. E. at Columbia U.

During 1956-1957, he was a consultant to RCA's Airborne Systems Dept., working on advanced navigation problems. He came to RCA in 1957 as a Leader in Communications.

Mr. Keller has contributed to the second (1946) and third (1952) editions on "Principles of Radar" by the M.I.T. Radar School Staff. He is a member of the IRE, AIEE, the American Institute of Physics, the American Physical Society, the American Association for the Advancement of Science, Tau Beta Pi, and Sigma Xi. He is a member of the IRE Committee on Information Theory and Modulation.

"UNSUNG HERO" DEPARTMENT

To most people a magazine is something that is conjured up by some mysterious ritual of paper and ink conducted by the editors, who, waving their arms and mumbling incantations, produce from a nebulous mist the finished magazine copies.

Though they find it difficult to deny at least a residue of mysticism and luck, the editors are ready to relate to any willing ear the hard work it takes to produce a magazine. Our Editorial Representatives are witness to this.

This current issue is certainly testimony to the cooperative effort necessary to publish an issue of the RCA ENGINEER. Steve Ransburg at Indianapolis, Ed Dickey at Princeton, Bill Bohlke at Cherry Hill, and Charlie Meyer at Harrison helped immeasurably processing the papers and minutiae necessary to round out this issue. Particular kudos are in order for Bill Skidmore at Cherry Hill, who worked tirelessly with the editors in coordinating papers and approvals, chasing down biographies, collecting drawings and photos, and meeting deadlines like an "old pro." His editing effort was a source of amazement, using week-ends and evenings for these chores so as not to interfere with his assigned engineering work.

Our editorial hats are off to these men!

W. S. Skidmore M. W. Tilden E. W. K

DR. BUHRKE HEADS X-RAY LAB

Dr. Victor E. Buhrke has been appointed director of RCA's new X-Ray Diffraction and Spectroscopy Applications Laboratory which has been established for research and equipment demonstrations as well as for assisting customers in specific problems.

Dr. Buhrke majored in Physical and Analytical Chemistry at the University of Illinois where he received his Doctorate in 1954 while serving as teaching assistant in the chemistry department and operating the Testing Laboratory. In 1958 he was appointed supervisor of RCA's Application Laboratories for X-Ray Diffraction and Spectroscopy and Electron Microscopy.

REGISTERED PROFESSIONAL ENGINEERS

Addition to the RCA ENGINEER list of registered professional engineers:

Industrial Tube Products, Lancaster	*State*	*Licensed As*	*License No.*
H. B. Walton	Penna.	Prof. Eng.	5063

ENGINEERING MEETINGS AND CONVENTIONS

August 31-September 1 Elemental and Compound Semiconductors, Tech., Conf., AIME, Statler Hotel, Boston.

September 14-16 Quantum Electronics, Resonance Phenomenon, Office of Naval Research, Shawanga Lodge, Blooming-burg, N. Y.

September 15-17 Electronic Exposition, Twin Cities Electronic Wholesalers Assoc., Municipal Auditorium, Minneapolis.

September 17-18 Nuclear Radiation Effects in Semiconductors, Working Group on Semiconductor Devices, USASRDL, Western Union Auditorium, N. Y. C.

September 21-25 Instrument-Automation Conf. & Exhibit, ISA, International Amphitheater, Chicago.

September 23-25 Non-Linear Magnetics and Magnetic Amplifiers, AIEE, ISA, PGIE of IRE, Shoreham Hotel, Wash., D. C.

September 28-30 Telemetering, National Symposium, PGTRC of IRE, Civic Auditorium & Whitcomb Hotel, San Francisco.

September 30-October 1 Industrial Electronics Symposium, AIEE, PGIE of IRE, Mellon Inst., Pittsburgh, Pa.