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.

●

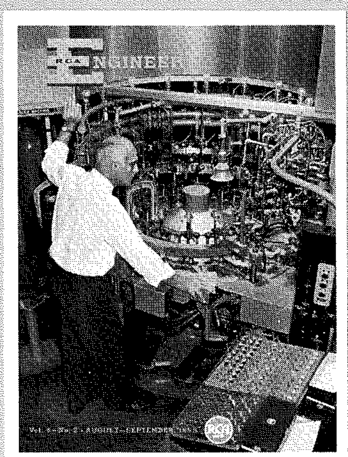
To help publicize engineering achievements in a manner that will promote the interests and reputation of RCA in the engineering field.

●

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

Our cover this issue features Receiving Tube Engineering at Harrison, N. J. Walter C. Fichter, Product Development Engineer in the Methods and Process Laboratory is shown observing the sealing and exhaust of developmental receiving tubes on a laboratory Sealex machine. For further information on this activity, see the article in this issue by K. G. Bucklin.

CHALLENGES

This issue of the RCA ENGINEER pays tribute to an important area of RCA's electron tube activities. This area is responsible for the development and production of receiving-type tubes used extensively in practically all electronic equipment for military, industrial, and entertainment applications. Receiving types of tubes are playing an important part in the dynamic fields of radio, radar, television, computers, guided missiles, and a wide variety of other industrial and military applications.

The electron tube industry has always been in the fortunate position of having challenges to face and competition to meet. The tube designer and the circuit designer are engaged in a running contest. The ingenuity and skill of the tube designers are being constantly challenged by the imagination and versatility of circuit designers who demand more and more from the electron tube in performance, power, and frequency. Conversely, the capabilities of available tubes have been a challenge to the circuit designers and have spurred them on into new and profitable areas of development.

In the course of its more than 50 years of development, the electron tube has become a sophisticated device virtually unhampered by power or frequency limitations. It is capable of many simultaneous functions in one envelope. It is rugged and dependable in performance, yet delicate in its response to control factors. It is a dynamic device having many inherent capabilities backed up by a resourceful technology. This technology permits the development of new types as fast as new applications create the need for them. The production of tubes is now at a rate that exceeds 400,000,000 units a year for the industry. Because of the continuing demands of new applications, the number of tube types increases continuously.

Today, the electron tube is facing several new challenges. Semiconductor devices, ferrite materials, magnetic amplifiers, and other developments, both foreign and domestic, are springing up and trying to find a niche in the electronics industry. In certain areas new devices may replace older ones. In some areas the new may temporarily supplant the old because of the "gadget" appeal of the new and different. When the novelty wears off, performance and economics will determine the choice of the consumer and, of course, the circuit designer. In most areas, however, the capabilities of new devices — whether they be tubes, transistors, or others—will stimulate new applications and open up new and profitable areas of development for all.

The technological resources of the electron tube industry, resulting from more than 50 years of design and production experience, have contributed much to the new developments. The semiconductor field in particular has already benefited substantially. It is also true that specialized studies in the semiconductor field have been of considerable benefit to the tube industry. Within RCA, the benefits of close cooperation have been many. But the competition is keen and the track fast.

We in the electron tube industry welcome the challenge. It will spur us on to greater efforts and greater accomplishments. Startling new tube developments are already warming up on the sidelines.

D. Y. Smith,
Vice Pres. and General Mgr.
Electron Tube Division
Radio Corporation of America

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RCA ENGINEER

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THE ENGINEER—FROM COLLEGE TO INDUSTRY

by

J. T. CIMORELLI, Mgr.

Receiving Tube Manufacturing
Electron Tube Division
Harrison, N. J.

THE IMPORTANCE TO THE young engineer of the transition period from college to industry has been recognized for many years. Those of us who have been through this period may have recollections of a happy, discouraging, or perhaps, merely confusing experience, depending on our own personal traits, our previous preparation, the attention of our supervisors, and the influence of our associates. A review of some of the factors influencing the success of this adjustment can be of help, not only to the engineer going through the transition, but, just as important, to the experienced engineer who can influence the new engineer by both example and counsel.

In a large organization such as ours, with thousands of engineers, and with a wide variety of products ranging from relatively simple devices to complex systems, the transition from engineering student to professional engineer means the integration of an individual into a new and complex array of organization, projects, and people. The graduate must add to his technical proficiency personal factors such as the ability to work with associates, with engineering groups, with other Divisions, and often with our customers.

PERSONAL FACTORS

In any discussion of personal factors a number of approaches can be taken. One approach might be based on "understanding". What is meant is more than just a knowledge of the Company and its operation. It must include an understanding first of certain personal characteristics of the individual, his associates, his supervisors, and broadly, an understanding of his company and its operation.

For example, consider the varied background of training and environment, not only of our engineers, but also of a large number of individuals in our Company. We draw our people from all parts of the nation and even the world. They come from both the large universities and the small colleges. They may come from either the large metropolitan areas or from the smaller towns. Family life, occupations, and interests can extend over a very wide range. Even speech expressions and personal mannerisms may vary widely. Yet, these individuals must work together as a team, understand each other, and must cooperate with each other if our business is to be successful.

In addition, there are certain personal factors which apply more directly to the engineer himself. Usually the engineer tends to be individualistic. Even before he began his formal training he was probably more curious than his associates about the "why" of things; he probably already showed signs of creative ability; he probably already showed an interest in using his hands in building things. These characteristics were encouraged and developed as he made progress through the college curriculum.

It is also important to remember that up to the time of his graduation, the individual has normally been a member of small groups such as his immediate family, his close friends, his classmates, and his teachers. The majority of his work assignments was closely directed and could be successfully completed as an individual.

TEAMWORK AND RESPONSIBILITY

Compare this background with the situation which normally exists in any large organization and into which the engineering graduate is suddenly projected. He now finds himself in a position in which it is difficult to accomplish any worthwhile objective without the voluntary cooperation of his associates. He has been conditioned to be individualistic, but now finds that he must work as part of a team. To a large degree he has probably visualized engineering as a matter of being given a problem and then being left alone until he has the answer. Instead, he finds that problems have to be clearly formulated, that he is faced with completion dates, budget limitations, competitive pressures, and with styling problems. He will find that there is seldom a single complete solution, and that in most cases a judicious balance of many factors is needed.

In a large company the engineer will also face another situation which, while important even in a small company, is often of paramount importance in the larger organization. This situation is the breadth of responsibility which the engineer must assume, and, in any large organization, he must realize the serious consequences which can result from errors. The strength of our competition, the urgent need for better performance, higher quality, and lower prices, and the technical nature of our products all tend to extend the engineer's responsibility from conception of an idea to an operating equipment in the hands of the customer. A faulty design may force the shutting down of a production line and throw hundreds of people out of work. Large sums of money may have to be spent in redesign. The loss in customer good will and company reputation and prestige can be great.

This breadth of responsibility in a large company also brings to mind what might be called a breadth of organization. In a large company it is necessary to divide the organization functionally into general areas of responsibility in order to take an idea through the various stages of engineering, manufacture, and sale. It must be remembered, however, that these terms are used in a very broad sense. For example, we sometimes say that a problem comes to engineering from "sales", but this is a generic word used to cover not only salesmen but field engineers, application engineers, product planning group, market research, and other activities. In the same sense, the words "manufacturing", "accounting", "purchasing", "personnel", and others, are generic terms encompassing a wide variety of individual or more specific functions and activities. The ability to intuitively understand specific responsibilities in a complex organization is the mark of an experienced and mature engineer.

AIDS TO INTEGRATION

Although adjustment to industry can be made to sound very formidable, the young engineer does not have to go it alone. He is assisted in many ways both prior to graduation and in his first years with a company. In recognition of a need, as early as 1930 some of our technical schools began to offer courses in human relations which were designed in part to help the engineering graduate to integrate himself more effectively into industry. In addition, schools and colleges offered many extra curricular opportunities such as sports, clubs, publications, student chapters of professional societies, student administration and similar activities in which cooperation and team work were the key to successful effort. It is primarily because of the valuable training which students receive in working with others that employment interviewers take great interest in their extra curricular activities.

Over the same period the Product Divisions have also presented a variety of induction and educational programs designed in part to help the engineering graduate make this transition within our Company most effectively. Periodically, these programs are carefully reviewed and revised for application throughout all the Product Divisions. Today this type of guidance is part of an over-all program which is provided to the new engineer.

Broadly speaking, this phase of our engineering training is directed toward a knowledge of our Company, and to a degree, toward some knowledge of the electronics industry. The programs cover company growth, products, policies, procedures, and facilities, as well as technical subjects.

Although the programs are excellent in content and administration, it must be recognized that there is an inherent danger that the new engineer may not receive the full benefit of our efforts if the program is simply an arrangement of more classes, more lectures, more reading, and more of the usual college routine. The material must be tailored to fill certain specific requirements and to suit the environment which we have been discussing and which is quite different from that of the college or university. Further, the program must be implemented in a spirit of understanding.

WHAT THE YOUNG ENGINEER CAN DO

Another area of paramount importance during the transition period is the proper orientation of the engineer as a professional man. This period is the most fruitful for continued study in either specialized subjects or in scheduled programs leading to advanced degrees. This is the proper time to encourage the young engineer to join his professional society, to attend the meetings of his professional society, and to participate in the operation of his local group through committee work. This type of activity often opens the way to new contacts and associates, to the stimulation of new ideas or concepts, to specialized information or data, and particularly to a broadening of approach in attacking new engineering problems. This association with other engineers in a professional society eventually leads the engineer to make his own contribution in the form of technical papers, and ultimately to recognition in his field.

It might be well to point out that the existence of a professional society, of an advanced level of technical knowledge, and the interchange of technical information, may be important requirements but they do not completely define a profession. Although these are some of the sources from which the young engineer can draw for his personal development as a professional man, it should be emphasized that a profession does not develop unless the members assume certain responsibilities. At the risk of oversimplification, these responsibilities would include at least active support of the professional society, high standards of performance, a sense of responsibility to society, and personal conduct of a high order.

One can certainly think of other factors of importance to the engineer making the transition from school to industry. These would only strengthen the need for "understanding" the complexity of the individual as a person, and the complexity of the environment he is entering as he begins to develop as a professional man in our industry. And this responsibility is shared to a very large degree by the established engineer because he, more than any other individual or group is in a position to strongly influence and guide the new engineer. It is a real tribute to our engineers, management, and every RCA activity that so many engineers have so successfully made the transition from college to industry.

JOSEPH T. CIMORELLI received the B.S. degree in 1932 and the M.S. degree in Electrical Engineering in 1933 from the Massachusetts Institute of Technology. He joined RCA in 1935 in Harrison, N. J. as a member of the Receiving-Tube Application Laboratory. From 1940 to 1944, he worked as a field engineer, and in 1944 was appointed Manager of the Receiving-Tube Application Laboratory in Harrison. He transferred to Camden in 1953 as Assistant to the Vice-President and Director of Engineering of the RCA Victor Division, and later became Administrative Engineer on the Staff of the Vice President, Product Engineering. In 1956 he returned to Harrison as Manager of Engineering for the Receiving Tube Operations Department of the Tube Division. Since the beginning of 1958 he has been Manager of Receiving Tube Manufacturing in Harrison, Woodbridge, Indianapolis and Cincinnati. He is Senior Member of the Institute of Radio Engineers and Fellow of the Radio Club of America.

RECEIVING TUBE ENGINEERING

K. G. BUCKLIN, Mgr.
Receiving Tube Engineering
Electron Tube Division
Harrison, N. J.

RECEIVING-TUBE ENGINEERING activities for Entertainment, Industrial, and Military applications are located at Harrison, New Jersey, the headquarters of the RCA Electron Tube Division. These activities develop and maintain RCA's extensive Receiving-Tube Product lines, which consist of over 600 active tube types. RCA's receiving tubes include the familiar glass, metal, and miniature types used in radio and TV sets, as well as thyratrons and regulator tubes, computer and premium types, pencil tubes, and unusual designs created for special applications and environments. They find their way into a host of diversified uses.

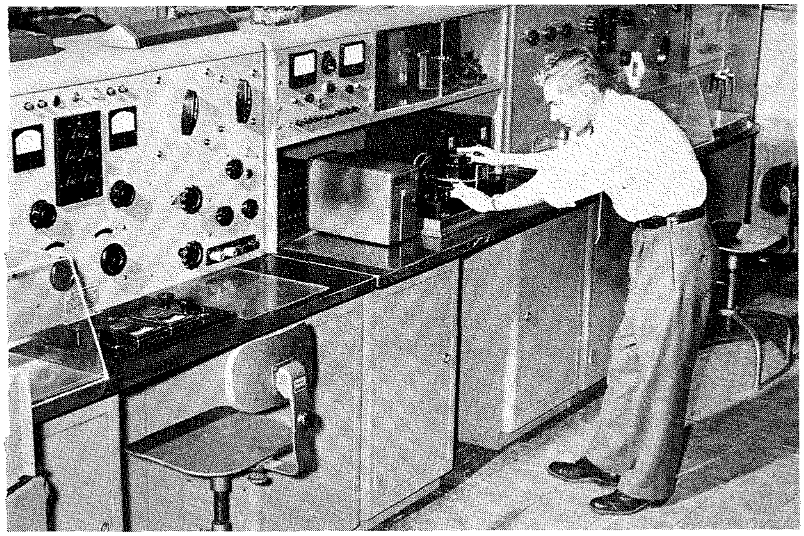
To give the reader some conception of the intricacies of receiving-tube engineering, I would describe our activities and our efforts as being of great variety, comprising practically all branches of engineering and science, and subject, because of the nature of our business, to rapid changes. As a consequence, we attempt to organize our efforts for maximum flexibility and to permit shifts in priority on as many as 200 basic engineering projects being carried on simultaneously by hundreds of engineers and technicians. These projects vary from those of an Applied Research or Advanced Development nature to those of assisting the manufacturing activities in keeping RCA tube quality foremost in the industry. Normal to our operations are projects in such broad areas as physics, chemistry, chemical engineering, optics, ceramics, radioactive materials and electronic systems, as well as specialized effort in the electronics, mechanics, and materials of electron tube design.

To improve emphasis in the area of markets, design, application, and test engineering of industrial receiving tubes are functions of the Industrial Tube Products Department. Other than this, Receiving-Tube Engineering in the Entertainment Tubes Products Department has, in addition to its own interests, the responsibility for servicing the industrial products operation in Advanced Development, Chemical and Physical Laboratory, Methods and Process Laboratory, Standardizing, Life Test and Rating Laboratory, and a well-equipped and staffed Library. Mention should be made of other separate activities having large staffs of engineers concerned with the development of tube-making machinery, the production engineers in each factory, and the Field Engineers in the Sales activity.

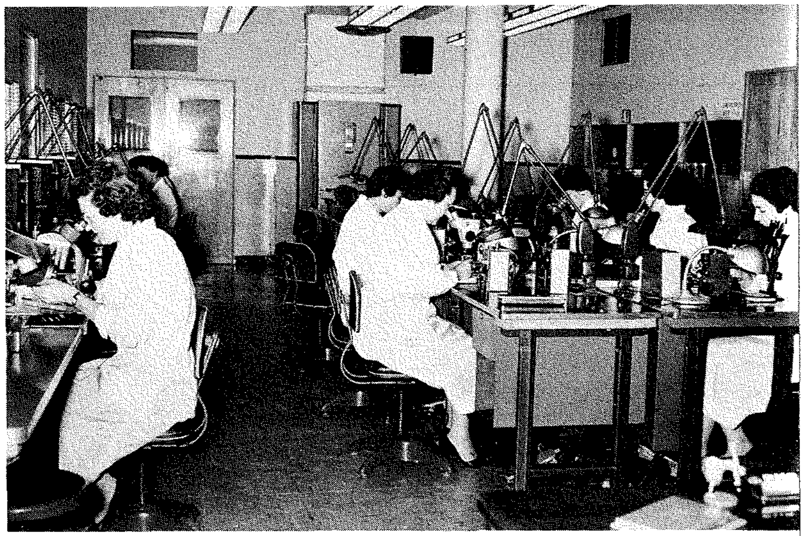
The various Receiving Tube Engineering groups are closely coordinated and work as a team, both in the development and in the introduction of new tube types and in the large effort that is devoted to factory assistance in cost and quality improvements. How the groups function can best be described by considering the procedures followed in the development of new tube types.

TUBE DESIGN

The Tube Design activity generally has, with some exceptions, the responsibility of project leadership on new tube developments. The design engineers establish an original, theoretical tube design and then have engineering models constructed in the Methods and Process Laboratory for evaluation. These models and subsequent adjustments and refinements will form the basic design for the particular application and will serve as the prototype for future production. The process of developing a tube having certain required characteristics and specifications at a competitive price may require anywhere from one month to several years, depending upon the complexity and final use of the tube. The new tube may be initiated as the result of a request from a customer or from Field Engineering, or it may be conceived as a basic idea initiated in Engineering or at the RCA Laboratories as a result of fundamental effort or an evaluation of industry needs. Because of the keen competition in the receiv-



Kenneth ReCorr, Engineer, making precision stability measurements on a power supply in the Rating Laboratory Standards Calibration Center.



Developmental electron receiving tubes are assembled in "super clean" areas where extreme control of temperature and humidity, and dust and lint is exercised. Shown is the Developmental Tube Assembly Area, Methods and Process Laboratory.

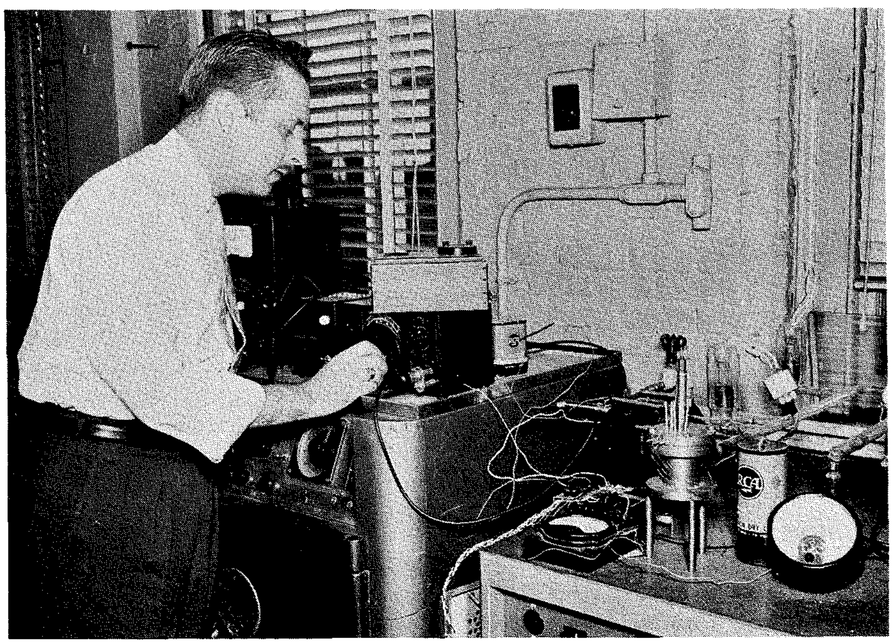
ing tube business and the significant importance of minor cost variations, it is often necessary to develop a number of versions of a type simultaneously, and it is of interest to note that as many as fifty per cent of the types designed and developed do not reach production.

APPLICATION ENGINEERING

Application Engineering works closely with the Field Engineers (see R. L. Kelly's article, page 12) and with the Market Planning group and as such is the group in Engineering closest to the customer. This activity has two basic responsibilities; the first is to establish objective specifications and broad outlines of developmental tubes and later to evaluate them from the circuit designer's viewpoint, and the second is to guide and assist the customer through the field engineers in the application of electron tubes. This group looks at new developments from the customer's standpoint and, therefore, the tube development is guided to a great extent by the work of this group.

METHODS AND PROCESS LABORATORY

The Methods and Process Laboratory, working from the original design, makes the developmental tubes and engineering models required by other groups of the Receiving-Tube activity, and is the source of developmental samples which are submitted to customers for their evaluation until such time as the factory has been equipped to produce production developmental samples. Since this responsibility requires that the laboratory must perform most of the functions found in the manufacturing activities, this laboratory can be considered to include a small-scale factory. The Methods and Process Laboratory has a staff of engineers who specialize in the fabrication and processing of developmental tubes. Parts making, tool and jig design, exhaust, aging, processing, and the development of general assembly techniques are some of the areas of effort undertaken by this activity to assist in the successful development of our products.

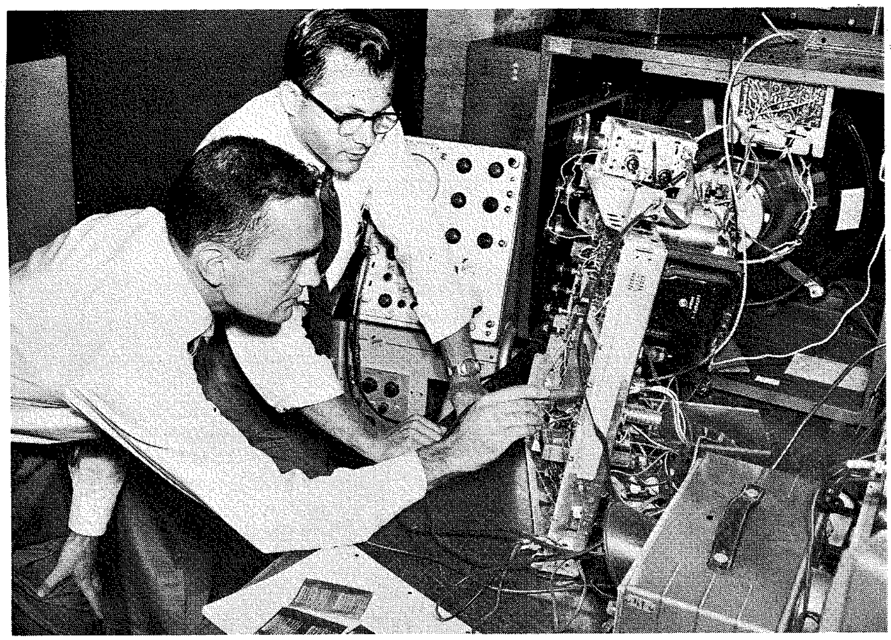


W. J. Helwig, Advanced Development Engineer, is shown here using a laboratory model of a cyclotron-resonance mass spectrometer to analyze gases in a developmental receiving tube.

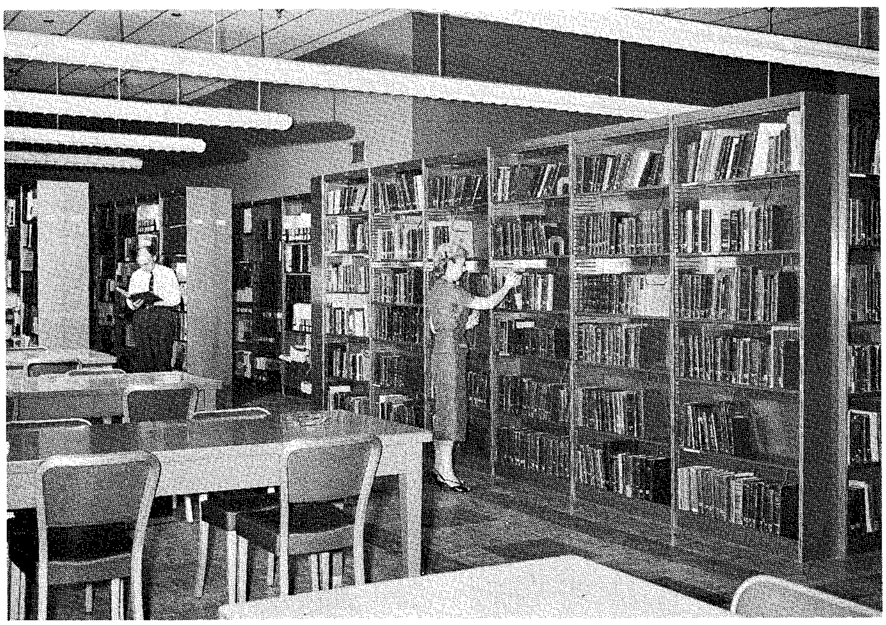
TEST ENGINEERING

The engineers in the Test Engineering activity establish testing specifications and prepare tube ratings and data for release to our customers. As part of the team developing a new tube type for addition to the RCA line, this group takes a prime part in the establishment of test specifications for use by the manufacturing activities. Their broad area of effort includes evaluation under special environmental conditions and mechanical shock as well as variations in electrical conditions which must be thoroughly analyzed to insure customer satisfaction. Through development of new methods of testing and test equipment, this group maintains a continual advancement of testing techniques, thus assuring satisfactory correlation with the applications of the tube.

During the development of a tube, the team of Design, Application, Methods and Process, and Test Engineers may be joined by physicists, ceramists, metallurgists, chemists, and



Herb Ruzinsky, Tube Design Engineer, and Don Matthews, Application Engineer, determining the improvement in circuit performance in a commercial color TV chassis using a developmental receiving tube.



A portion of the extensive library facilities at Harrison. Miss Elizabeth Molloy, Librarian, in the foreground.

others from our other engineering functions who will assist in the solution of specific problems. The wide variety of technical problems in electron-tube developmental calls for the close coordination of a team of scientists and engineers to complete most developments successfully. It is appropriate to point out that each engineer is usually a member of a number of teams simultaneously.

LIFE TEST AND RATING LABORATORY

An important service to Engineering, Manufacturing and other activities is performed by the Life Test and Rating Laboratory. Design tests and life tests are made on a regular basis by this activity on samples of product manufactured at the Harrison and Woodbridge Plants. These tests supplement the regular factory test and are part of the quality control procedure by which RCA maintains a high level of tube performance. Highly skilled technicians in this activity, working closely with the engineers, perform special engineering tests in connection with the design and development of tubes and in the search for better methods of part processing and tube fabrication. The tests include, in addition to a great variety of electrical tests, many unusual shock, vibration, and environmental tests that expose operating tubes to extremely high and low ambient temperature conditions. As an indication of the size of this operation and its facilities, some 25,000 tubes are tested each month for a large number of characteristics, and approximately 14,000 tubes are life tested continuously.

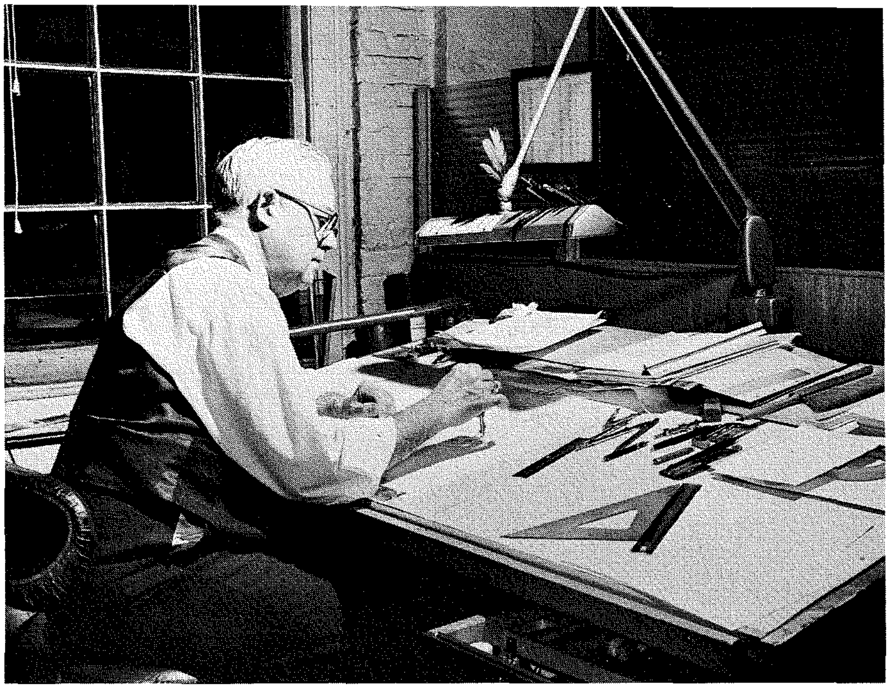
CHEMICAL AND PHYSICAL LABORATORY

The Chemical and Physical Laboratory is responsible for the investigations of materials and processes suitable for tubes being developed and for those already in our line. It is important to note that the application of new materials and techniques, and their cost, is often the controlling factor in the success or failure of a development. This activity is composed of a large group of engineers and scientists with specialties in many diverse branches of science. Their extensive laboratory facilities occupy approximately 20,000 square feet of floor area and accommodate basic work and current engineering in fields such as chemical analysis, thermionics, metallurgy, physics, ceramics, applied chemistry, glass technology and chemical engineering. While this activity initiates many projects of an advanced development nature that are aimed at broadening our knowledge in the electron tube field, they form part of the team on specific tube developments to apply their specialized knowledge to the solution of problems in materials and processes. The special skills and knowledge of the engineers permit their serving as consultants on special problems to many other groups of RCA.

ENGINEERING STANDARDS

The Engineering Standards activity has the responsibility for originating and maintaining the receiving tube standardizing notices. These notices describe, in complete detail, electron

Checking the voltage settings on receiving tube life testing equipment is Mike Chelak, Manager, Life Test Laboratory.



Roger Stickle, Draftsman in the Engineering Standards Activity, preparing a glass tube base drawing for inclusion in the Standardizing Notices.

tube specifications, constructional features, tolerances, parts and tube processing, inspection and sampling procedures, and much other pertinent information required to describe completely and to manufacture each of the tubes in our line. Manufacturing receiving tubes in large volume is a complex procedure and it is vital that minute details, such as the absolute control of the chemical processes used in making materials and parts for electron tubes, be specified. Engineers in this activity are continually alert to minimizing costs and improving quality by presenting additional guidance to the designers in the use of standard or available parts and processes.

ADVANCED DEVELOPMENT

The Advanced Development group has the responsibility for the early-stage development of new principles of tube operation, new tube constructional techniques, and in some cases, new types of applications. Its activities can also be called applied research, differing from those of the RCA Laboratories in that the primary aim is an eventual product rather than technical information. The work carried on varies widely in nature, having in the past ranged from theoretical tube design to an investigation of the problems and techniques of drilling diamond dies for drawing extremely fine wire. In general, it is directed toward tube design and closely related mechanical and circuit problems. Current work is being carried out on tubes for many fields of entertainment, military, and industrial applications, including the new processes and prototype equipment that may later be associated with a particular device. Although this activity is equipped with facilities to carry on experimental work of a diverse nature, the advanced development projects are actively supported by the other specialized groups within Product Engineering and by Equipment Development, a parallel activity.

In addition to the development work carried on by the engineering activities, a significant amount of effort is devoted to maintaining our current line of products and improving them from a quality, cost, and performance standpoint. A close working relationship with the manufacturing activities, and especially production engineering, is a necessity for maintaining high-quality products and a successful enterprise. This continuous and intimate working relationship with Manufacturing is maintained by special sections within Engineering such as the Resident Engineering activity that has the responsibility for the coordination

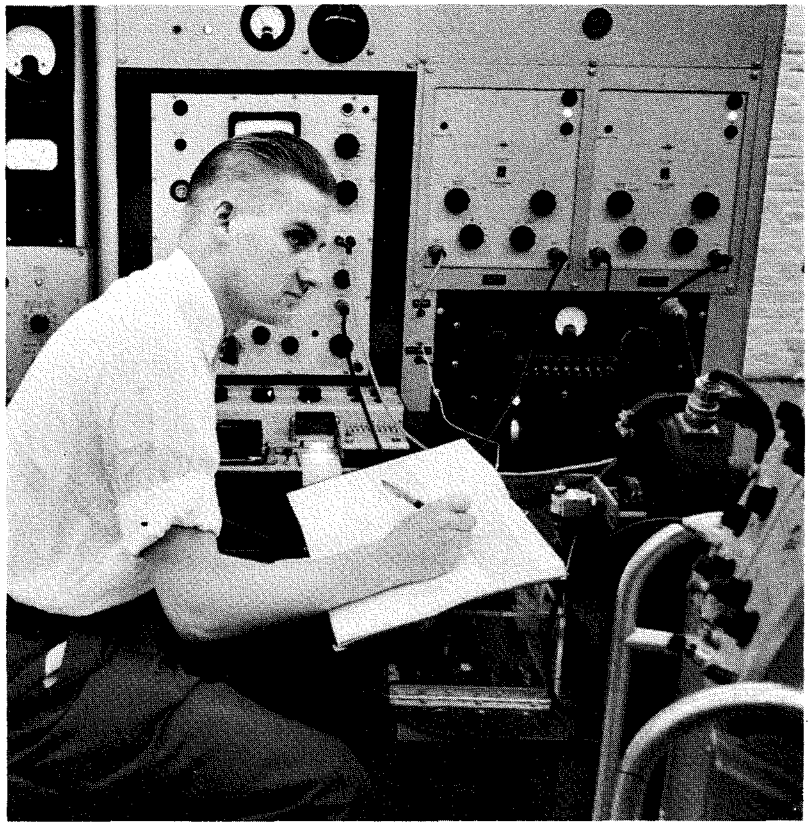
KENNETH G. BUCKLIN received the B.S. degree in EE from MIT in 1930. He joined the Engineering activity of the Tube Department of RCA in 1933 after several years with DeForest Radio Company. Mr. Bucklin held the position of Tube Design Engineer until 1939 when he became Manager of the Receiving Tube Design activity.

From 1942 to 1953, Mr. Bucklin served in several merchandising activities, becoming Manager, Tube Products Section of Product Administration. In 1953, he was promoted to Manager, Receiving Tube and Transistor Marketing. In 1954 when the Semiconductor Division was formed, he was assigned responsibility for Receiving Tube Marketing. In January 1958, Mr. Bucklin was appointed to his present position as Manager of Engineering, Entertainment Receiving Tube Operations.

In 1952, Mr. Bucklin received the RCA Award of Merit. He is a Senior Member of the IRE and is active in the Electronic Industries Association as RCA's representative to the Receiving Tube Section of EIA, as well as serving as Chairman of a Receiving Tube Statistical Committee. He is a member of Beta Theta Pi fraternity and is active in civic affairs.

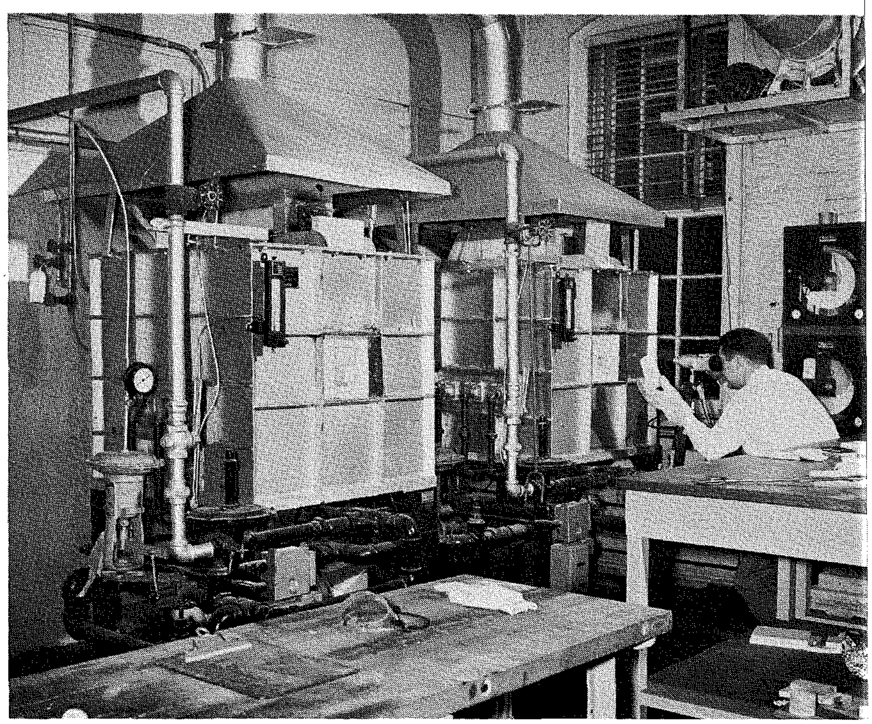
of effort between the various parts of Engineering and the manufacturing groups.

We of the tube Engineering activity find our work on electron tubes quite rewarding. While the glamour of the product does not measure up to that of a new rocket or a specific piece of home entertainment equipment, the knowledge that the electron tube is truly the "heart of electronics" and has made possible much of electronics as we know it has given us a tremendous sense of responsibility and pride in our accomplishments. Our objectives of providing our customers with tubes having the optimum balance between performance and cost and of keeping RCA the leader in electron tubes provide us with a challenging future. On our drawing boards and in our laboratories, we have new devices which hold promise of providing the circuit and equipment designer with new tools to broaden the use of electronics for the entertainment and industrial markets and to maintain the security of our country.



Otto Johnk, Test Engineer, recording sweep frequency response measurement on an RCA developmental subminiature tube type. The equipment sweeps over a frequency range of 5 to 10,000 cps and automatically records the vibrational output of the tube under test.

Gil Wolfe, an Engineering Leader, Product Development in the Methods and Process Laboratory, studying the effects of high-frequency heating of the internal parts of a developmental receiving tube while the tube is being evacuated. (Mr. Wolfe has recently been promoted to Manager, Engineering Standards).



Walter Lawrence, Engineering Leader, Product Development in the Chemical and Physical Laboratory, checking the temperature of developmental ceramic parts in a specially designed kiln.

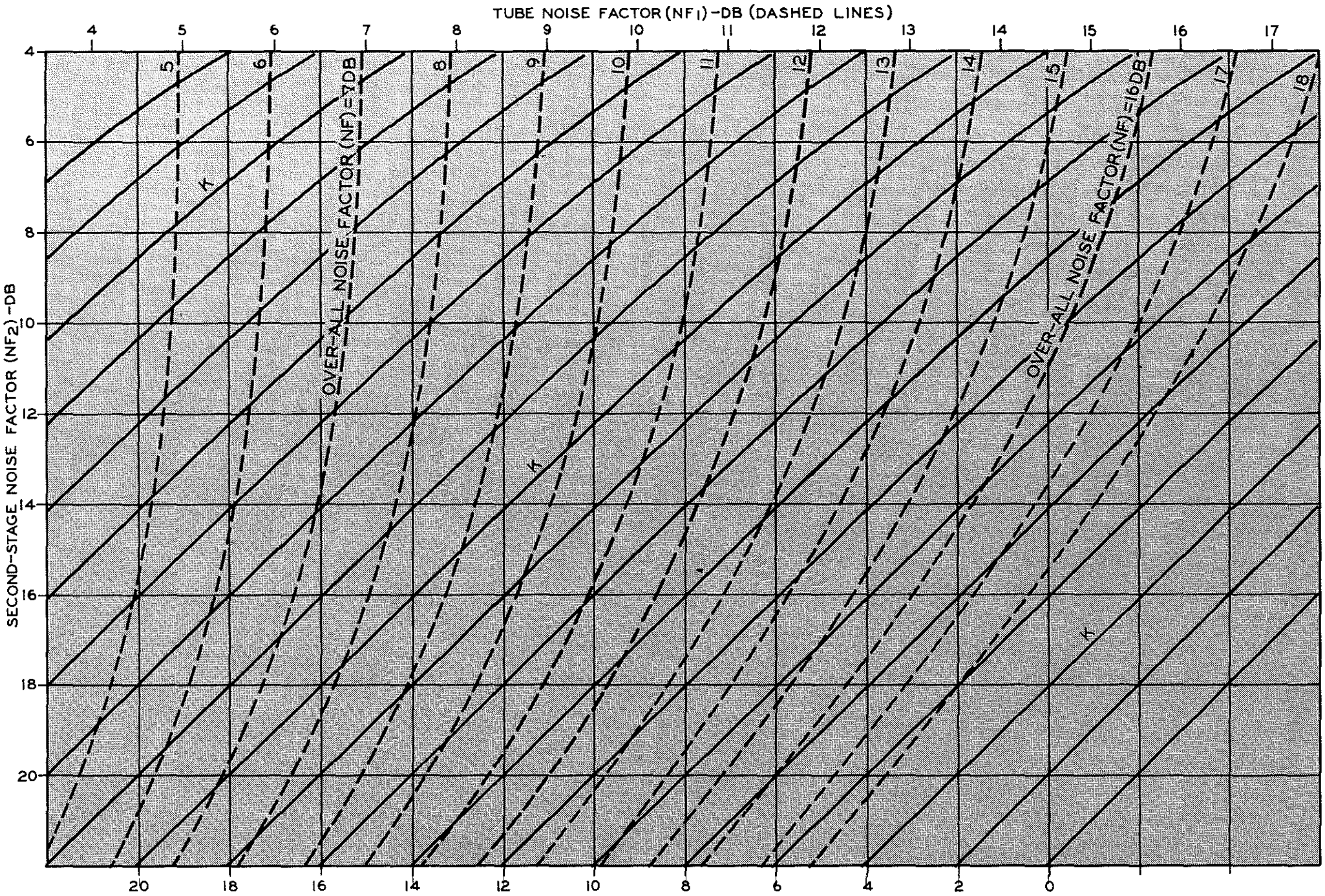


FIG. 1—Tube-Noise Factor Graph.

GRAPHICAL DETERMINATION OF TUBE NOISE FACTOR (NF_1)

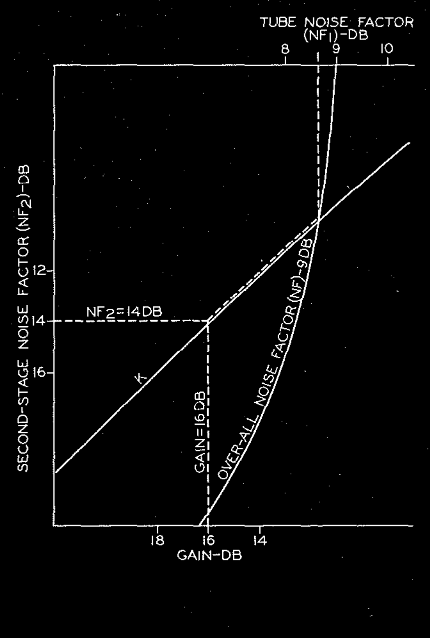
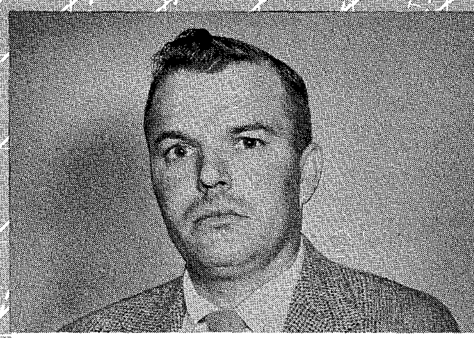


FIG. 2—Solution of Sample Problem.



LUCIEN P. DE BACKER was born in Antwerp, Belgium in 1931. He came to the United States in 1946, became a citizen in 1949, and served with the U.S. Navy from 1949 to 1952 as an instructor in aircraft electronics at U.S. Naval Technical Training Centers. He received the B.S. degree in Physics from the U. of Georgia in 1954, and the M.S. degree in Industrial Engineering from Stevens Institute of Technology in 1958. He joined RCA in 1954 as a Specialized Engineering Trainee, and was assigned to the Receiving Tube Design activity at Harrison, N. J. He is presently working on the development of ceramic "pencil" tubes. Mr. DeBacker is a member of Sigma Pi Sigma.

by

LUCIEN P. A. DE BACKER

Electron Tube Division

Radio Corporation of America

Harrison, N. J.

EXACT VALUES of tube noise factor are often required for the evaluation of radar receivers or other uhf equipment. Calculations of tube noise factor, which involve conversions to and from power ratios, are time consuming. This paper describes a graph that has been devised to eliminate these calculations.

The equation for calculating tube noise factor is

$$NF_1 = NF - \frac{NF_2 - 1}{G},$$

where NF_1 is the tube noise factor, NF_2 is the noise factor of the second stage (e.g., crystal noise factor), G is the gain of the tube (first stage), and NF is the over-all noise factor of the system corrected for cable losses and transit time.

Values of NF, NF_2, and G are usually measured in decibels, converted to power ratios, and substituted in the above formula to calculate NF_1. The value of NF_1 is then converted back into decibels.

The graph shown in Fig. 1 allows the above calculations to be performed in two steps, and eliminates the need for converting recorded decibel readings to power ratios.

How to Use the Chart:

To use the chart, locate NF_2 (in db) on the scale along the left-hand side of the graph, and G (in db) across the bottom scale. The intersection of perpendicular lines from these two points determines the location of a diagonal line along which the quantity $\frac{NF_2 - 1}{G}$ is a constant (K). Follow this line, and locate its intersection with the curve for NF (in db). The tube noise factor, NF_1, is given above this intersection on the scale across the top.

Fig. 2 illustrates the solution of a sample problem in which the following conditions are given:

Gain = 16 db; NF_2 = 14 db; and NF = 9 db.

The value for NF_1, read on the top scale, is 8.65 db.

How the Graph was derived:

In the equation

$$NF_1 = NF - \frac{NF_2 - 1}{G}$$

let

$$K = \frac{NF_2 - 1}{G}$$

Then, when the noise factor and gain are given in decibels,

$$K = \frac{10^{NF_2/10} - 1}{10^{G/10}}$$

$$= \frac{10^{NF_2/10}\,(1 - 10^{-NF_2/10})}{10^{G/10}}$$

and

$$\log K = NF_2/10 + \log(1 - 10^{-NF_2/10}) - G/10$$

or

$$10 \log K = NF_2 + 10 \log(1 - 10^{-NF_2/10}) - G$$

and

$$G = NF_2 - 10 \log(1 - 10^{-NF_2/10}) - 10 \log K$$

Successive values of K were determined by setting NF_2 at 20 db and varying the value for gain in 2-db steps between 0 and 30 db. For example, when NF_2 equals 20 db and gain equals 10 db, K equals 9.9. Some sample values for K are given in Table I.

Curves of gain as a function of NF_2 can now be constructed by determining values of NF_2 which correspond to several selected values of gain for these values of K, as shown in Table II.

Because these curves are equidistant along the horizontal axis of the graph, it is only necessary to compute values for one curve. For values of NF_2 greater than 10 db, the curves are nearly parallel straight lines. Thus, a chart is constructed of the second part of the equation

$$K = \frac{NF_2 - 1}{G}.$$

Next, a second set of curves is superimposed on this chart to express the equation $NF_1 = NF - K$, and scale of values of NF_1 is laid out across the top of the chart. Curves of constant NF are then constructed by determining the value of NF_1 corresponding to the chosen value of NF and each value of K. Sample values for NF_1 are given in Table III.

The value of NF_1 thus determined is located on the K curve directly below the NF_1 scale.

ACKNOWLEDGMENT

The author wishes to express his appreciation to Mr. W. A. Harris for his valuable recommendations and editing, and to Mr. S. W. Bogaenko for performing many of the calculations and for drafting the original chart.

TABLE I

Values Determined for K

$$K = \frac{NF_2 - 1}{G} \quad \frac{99}{G}$$

Gain (*db*)	Gain (*Power Ratio*)	K (*Constant*)
0	1	99.0
2	1.585	62.46
10	10.0	9.9
12	15.85	6.25
20	100.0	0.99
22	158.5	0.62

TABLE III

Values Determined for NF_1
(When NF = 15 db or 31.62 Power Ratio)

K (*From Table I*)	NF_1 (*Power Ratio*)	NF_1 (*db*)
0.62	31.0	14.91
0.99	30.63	14.86
6.25	25.37	14.04
9.9	21.72	13.37

TABLE II

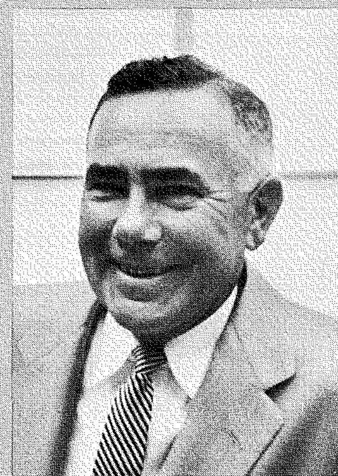
Values Determined for NF_2

$[NF_2 = G + 10 \log (K + 10^{-G/10})]$

Gain Values (db)	NF_2 for Values of K from Table I (db) K = 0.62	K = 0.99	K = 6.25	K = 9.9	K = 62.46	K = 99.0
0	0.25	2.99	8.60	10.37	18.02	20.0
2	2.99	8.60	10.37	18.02	20.0	21.98
10	8.60	10.37	18.02	20.0		
12	10.37	18.02	20.0	21.98		
20	18.02	20.0				
22	20.0	21.98				

ROBERT L. KELLY received the B.E. degree from Johns Hopkins U. in 1929. He joined the A. Atwater Kent Company in 1930, and spent the following six years designing radios for home, automobile, and farm. In 1936, he joined RCA as an application engineer in the Electron Tube Division at Harrison. He moved up to Manager of Application Engineering in 1946. He was appointed Administrator of General Quality Control of the Division in 1952, and in 1955 was appointed Manager of Customer Service Engineering. In 1957 he was promoted to his present position of Technical Coordinator for the Commercial Manager of the Electron Tube Division.

Mr. Kelly is a Senior Member of the Institute of Radio Engineers.



Editor's Note: Recommending appropriate circuitry for a particular tube—and offering the proper tube at the precise, opportune moment it is needed in customer's circuit . . . is a characteristic of Tube Division Field Engineering. And this is no mere "happenstance!" Rather, it is an ideal combination of know-how and years of practical experience. Having viewed this phase of engineering from the customer's vantage point, we can attest that it leaves a favorable and indelible impression, putting RCA always in the forefront.

ROLE OF TUBE DIVISION'S FIELD ENGINEERS

by

R. L. KELLY

Administrator, Technical Coordination
Electron Tube Division
Harrison, N. J.

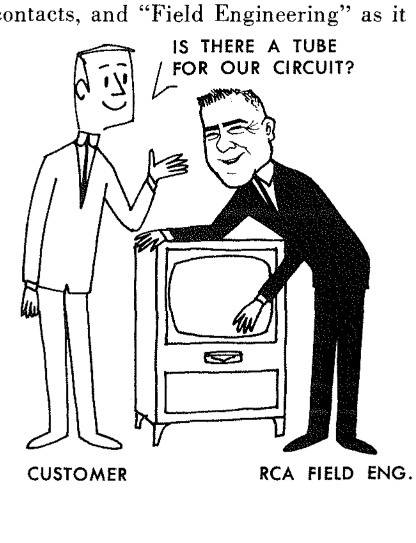
THIS PAPER DESCRIBES an important activity used in the Electron Tube Division for maintaining technical relations with customers. The need for such a function was recognized many years ago and has become increasingly important as the complexity of electronic equipment and the number of customers have increased.

EARLY LIAISON ACTIVITIES

During the early thirties, when the Electron Tube Division was known as the RCA Radiotron Company, an Application Laboratory was maintained as a part of Engineering. The function of this laboratory was to evaluate new tube developments in terms of circuit requirements for transmittal to equipment designers and, in addition, to translate complaints of tube malfunction in customers' circuits into terms of tube design or manufacturing control.

In those early days, when a new tube had been developed, engineers from the Application Laboratory often visited prospective tube customers to acquaint them with the tube's advantages and to give their design engineers guidance on the application of this new tube in radio equipment. In the case of a customer experiencing difficulty in the application of a tube, it was normal practice to invite him to bring his equipment into the Application Laboratory, where an analysis of the problem would be made and corrective measures recommended.

As tube designs and circuitry became more complex, it became evident that many problems could be avoided if the customers were visited regularly by an Application Engineer. In this way, improper application of tubes could be spotted during the early equipment design stage and corrective action suggested before a complaint of poor tube operation developed. Accordingly, a small group of Application Engineers was assigned to make regular customer contacts, and "Field Engineering" as it



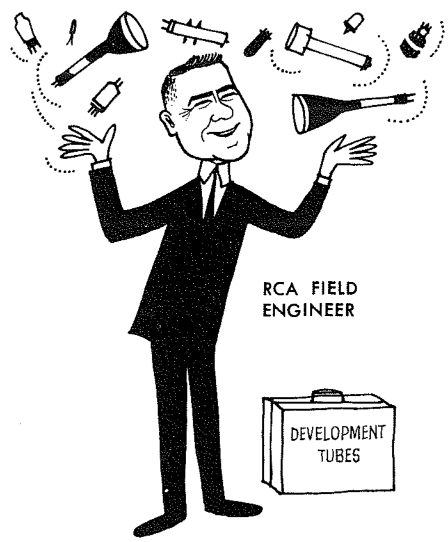
is known in the Electron Tube Division today came into being.

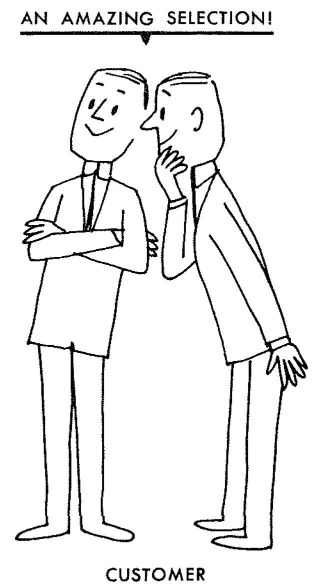
During this period, "Field Engineers" were part of Engineering, reporting to the Manager of the Application Laboratory. They supplied the technical liaison with the customer, while the salesmen handled the commercial phases of the business. The two activities combined to make up a real "sales team."

EXPANSION OF ACTIVITIES

World War II brought a rapid expansion of the Electron Tube Division's product lines to include cathode-ray, pickup, photo, gas, and power tubes. The "Field Engineer" thus became an even more important part of the sales team. Accordingly, responsibility for the field engineering activity was transferred from Engineering to Sales.

In the Electron Tube Division today, Field Engineers service the customers' technical needs in all areas, including distributor products, entertainment tube products, and industrial tube products. A total of 26 Field Engineers, located in the major market areas, maintain this important liaison with customers. These men are carefully selected and trained for their job, and are usually drawn from within the Electron Tube Division's engineering activities. Not only must these men have proven their professional competence as engineers, but they must also have proper personality and temperament characteristics. Engineering





experience and maturity are important prerequisites to the field engineer. The average age of Electron Tube Division Field Engineers is 37 years, and their average experience in the electronics industry is 15 years.

HOW NEW TUBES ORIGINATE

New tube developments originate in several ways. Basic research at the David Sarnoff Research Laboratories often leads to new tube developments, such as the radechon or the vidicon. Sometimes the idea for a new tube originates in the Electron Tube Division Advanced Development or Design groups, as in the case of the "pencil" tubes. However, in a great many instances, new tube developments result from recognized needs of the electronics industry, either as a result of specific customer requirements (such as tubes for automobile headlight dimmers) or as a result of general industry needs (such as tubes for television and for data-processing equipment).

One of the Field Engineer's most important responsibilities is to determine customer needs for new products, and to transmit this information to the Market Planning and Engineering groups. He not only learns from the customer the technical requirements, but the "future market potential" information as well. Because many of our important tube developments result from this kind of information, its gathering is an extremely valuable function.

An example of the Field Engineer's role in determining customer needs and in guiding tube development was shown recently in the case of the automobile radio. Recent changes by the automobile industry from 6-volt to 12-volt electrical systems, together with the development of power transistors, caused automobile-radio manufacturers to consider the elimination of the troublesome vibrator power supply. Adequate audio power output could be obtained from a transistor operating from the 12-volt car battery. The need, then, was for tubes for the amplifier stages of the receiver which would be capable of operating with 12 volts on the plates and the screen grids. Requests for such tubes were made through the Field Engineers to the Engineering and Market Planning groups. Suitable tubes have been developed, and a majority of today's automobile radio receivers utilize such a system.

NEW APPLICATIONS

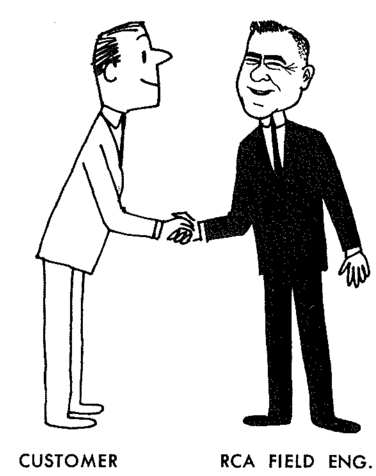
The Field Engineer also keeps the customer informed of new RCA tube developments, and aids him in the choice of tubes for particular applications. When new applications for existing or developmental tubes are found, this information is again fed back to the Market Planning groups. For example, some years ago the frequency for radiosonde operation was raised by the FCC from 400 to 1680 megacycles. Acorn tubes had been used successfully at the lower frequency, but no suitable small tubes were available for operation at the new frequency. At about that time, having recognized the general trend in the electronics industry toward equipments capable of operating at increasingly higher frequencies, the Advanced Development activity was working on a new tube design known as "pencil" tubes. Information about and samples of these tubes were shown to the customer (in this case, the U.S. Signal Corps) by the Field Engineer. Subsequently, the tubes proved capable of satisfying this new application requirement, and the modern radiosonde of today uses a "pencil" tube in its transmitter.

COMPLAINT HANDLING

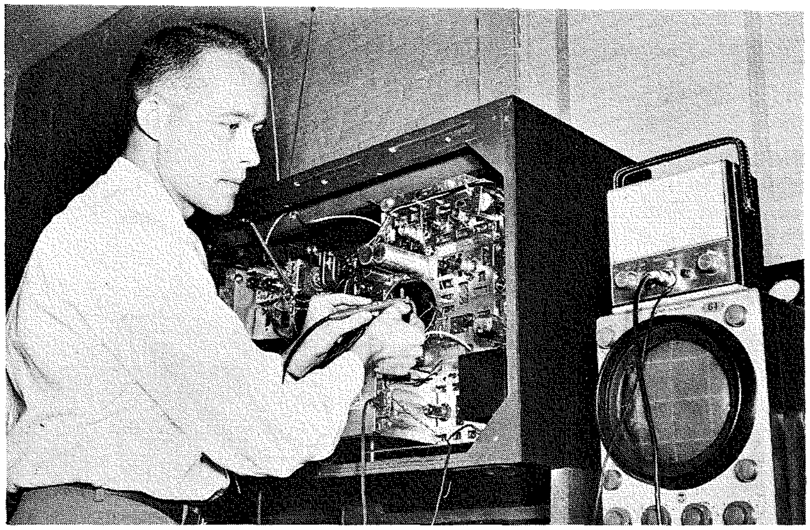
Another important function of the Field Engineer is to "keep the product sold." This job involves contacts with the customer's Quality Control and Production Engineering groups, where complaints usually originate. In some cases, investigation by the Field Engineer will disclose the trouble to be a result of the way the tube is being used or handled. In other cases, a new application or equipment may depend on tube characteristics which previously were not required to be tightly controlled. In any event, the Field Engineer is the necessary liaison between the customer and RCA's Engineering, Quality Control, and Manufacturing activities until the customer has been satisfied.

VARIETY OF TECHNICAL REQUIREMENTS

Although the examples given above illustrate the basic role of the Field Engineer in customer relations, they present a greatly over-simplified picture of his daily activity. Because RCA is involved in the development, production, and sale of a wide variety of highly technical electron-tube products, the Field Engineer is consulted on many technical aspects of tubes and their application. Tube reliability, for example, involves not only the design and processing of the tubes but the manner in which they are used. The effects of applied voltages, currents, circuit constants, and environment, as well as recognition of normal variation in characteristics from tube to tube and with life are factors that must be understood and recognized in the development of reliable electronic equipment. The Field Engineer plays a large part in improvement of equipment reliability in his role of technical consultant to customers.



KARL W. ANGEL received his BS degree in Electrical Engineering from the University of Arizona in 1955, and joined the RCA training program for new engineers in June of that year. After the completion of his training, he was assigned to the Receiving Tube Applications Laboratory of the Electron Tube Division at Harrison, New Jersey. Since that time, he has been working on rectifier and power-output tube types and has specialized in vertical and horizontal deflection applications. Mr. Angel is a member of the Institute of Radio Engineers.



Here the author checks power input to the vertical yoke winding in a typical TV receiver.

VACUUM-TUBE REQUIREMENTS IN VERTICAL DEFLECTION CIRCUITS

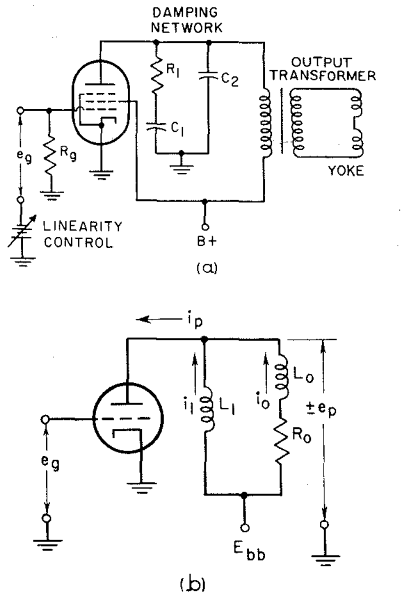


Fig. 1—Vertical-deflection-output circuit and its equivalent circuit during trace.

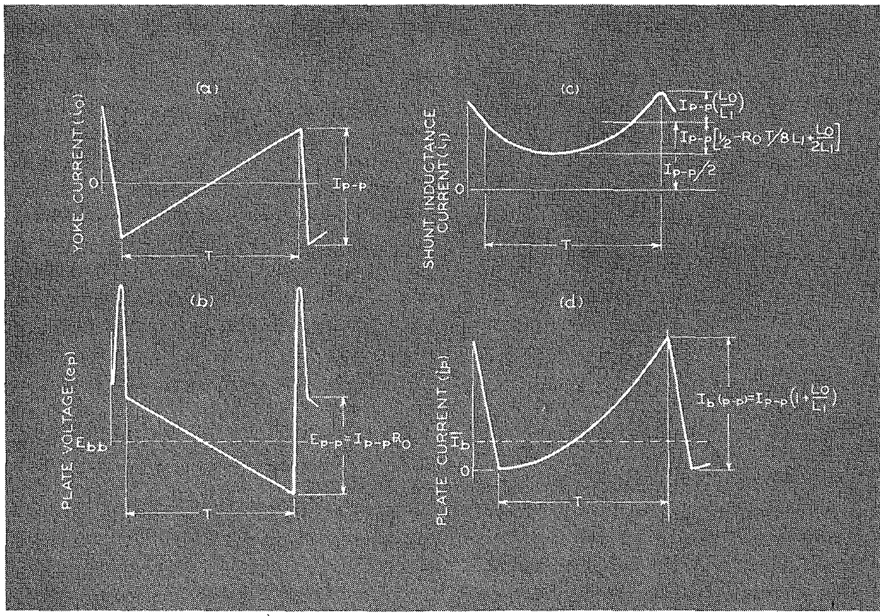


Fig. 2—Vertical-deflection current and voltage waveform during trace.

by

KARL W. ANGEL

Electron Tube Division

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THIS PAPER DISCUSSES linearity and efficiency problems which must be considered in the selection of an output tube for a vertical-deflection power amplifier. Because the purpose of the vertical-deflection power amplifier is to supply a given peak-to-peak current to the vertical yoke winding, the design problem is essentially one of matching the resistive component of the yoke to the tube characteristics in much the same manner as in audio-power amplifier design.

TRACE-PERIOD EQUIVALENT CIRCUIT

Fig. 1 shows a simple vertical-deflection circuit and its lumped-parameter equivalent circuit for the trace portion of the deflection cycle. In it, L_1 is the open-circuit transformer inductance L_o is the yoke inductance plus leakage inductance, and R_o is the yoke resistance plus transformer winding resistance. The yoke current, i_o, is assumed to have a constant rate of change, as shown in Fig. 2a, which will produce a linearly changing magnetic field in the deflecting yoke.[1] The waveforms for the plate voltage (e_p), current flowing in the equivalent shunt inductance (i_1), and plate current ($i_p = i_o + i_1$) in the equivalent circuit for trace are shown in Figs. 2b, 2c, and 2d.

For maximum efficiency, the average plate current, $\overline{I_b}$, should be a minimum,

$$\frac{R_o}{L_o + L_1} = 120, \text{ or } \left.\frac{di_p}{dt}\right|_{t = O} = O$$

If $L_o \ll L_1$, the average plate current for maximum plate efficiency is 1/3 the peak-to-peak plate current ($I_{p\text{-}p}$), and the maximum plate efficiency of an ideal pentode is 50 per cent.

In practice, the value of d-c plate cur-

[1] For wide-angle deflection of "flat-faced" picture tubes, the yoke current should be slightly "S"-shaped rather than linear.

rent can be made slightly less than 1/3 the peak-to-peak plate current because class AB operation is used to provide linearity control. Also, the practical efficiency of a pentode circuit is about 40 per cent due to the 25-per-cent increase in power input that is necessary because of tube drop. For triode circuits, the practical upper limit of efficiency is about 33 per cent. The transformer efficiency is simply the ratio of reflected yoke resistance to reflected yoke resistance plus winding resistance and is usually 85 to 90 per cent. The yoke efficiency is measured by the ratio of L to R and is not affected by the absolute value of yoke resistance.

REACTIVE POWER IN L_1

In addition to the real power input during trace, the portion of the energy stored in L_1 during trace and dissipated

Waveform photographs showing the effects of triode and pentode damping circuits are examined by author for comparison with effects based on theoretical considerations.

in the damping circuit during retrace must be supplied. In practice, the reactive power is only about 3.6 per cent of the output power and can be neglected. The peak-to-peak power capability of the amplifier must be increased by about 10 per cent over the theoretical minimum (for a typical L_o to L_1 ratio of 1 to 10) because of the additional energy stored in L_1.

PENTODE-CIRCUIT RETRACE

After the trace period, the plate current must be brought quickly to zero to prepare the circuit for another trace period. This reduction in current is effected by driving the tube rapidly into cutoff. The sudden stopping of plate current when the magnetic energy state is high results in a rapidly collapsing field which generates a large positive plate voltage pulse. The equivalent circuit for retrace is as shown in Fig. 3 if the relatively small current flowing in the equivalent shunt inductance (L_1) is neglected. The stored energy should be dissipated as quickly as possible to obtain rapid retrace. This action is by definition critical damping and is accomplished by the addition of the damping network, R_1, C_1. The capacitance C_2 is the total stray, wiring, and added capacitance, and its value is determined by the pulse rating of the tube plate and the desired flyback time. The capacitance C_1 is added for d-c blacking, and its effect is small for values of $C_1 \gg C_2$ if critical damping is assumed.

An approximate expression for the flyback voltage (e_f peak) for critical damping in a pentode circuit is

$$e_f \text{ peak} = \frac{I_{p\text{-}p}}{C_2\omega_r\varepsilon} = \frac{I_{p\text{-}p}\omega_r L_o}{\varepsilon},$$

where e_f peak is in volts, $I_{p\text{-}p}$ is in amperes, C_2 in farads, and ω_r the angular velocity equal to 2π times the resonant frequency of the series circuit L_o, C_2 (Fig. 3) in radians per second. The initial current at the start of retrace ($I_{p\text{-}p}$) is flowing through L_o. For simplification, the relatively small value of R_o and the initial voltage on C_2 (V_p) are assumed to be zero. The expression given above is the maximum value of e_f peak which occurs at $t = 1/\omega_r$. In practice, e_f peak will be somewhat less than this value depending on the cutoff rate of the tube. A typical example is a 50-microsecond cutoff time leading to a 20 per cent reduction in the plate pulse. The value of plate pulse voltage is above B+.

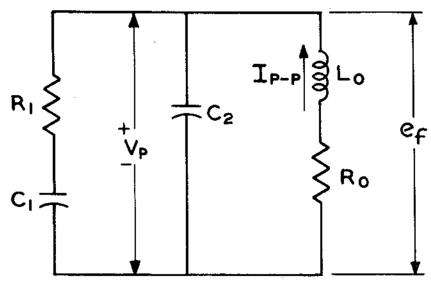

Fig. 3—Vertical-deflection equivalent circuit during retrace.

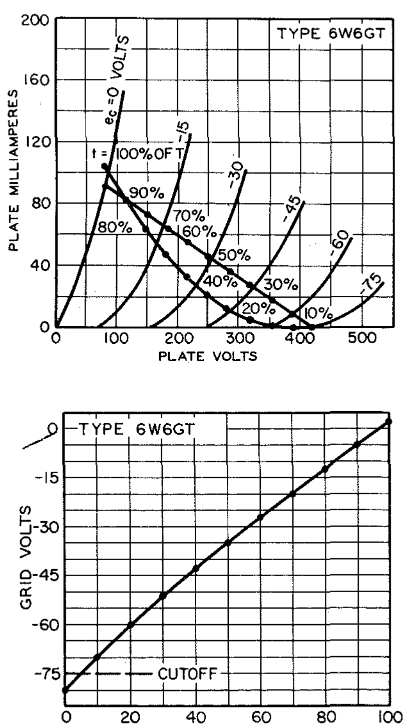

Fig. 4—Load line for linear deflection of a triode.

DESIGN OF DAMPING NETWORKS

The damping network may be calculated by the relationship $R_1 = \sqrt{L_o/4C_2}$ as defined by critical damping. For rapid retrace, capacitor C_2 should be chosen so that the time constant $1/\omega_r$ is as small as possible with e_f peak within the plate pulse rating of the tube and output transformer. The value of C_1 should be about twenty times larger than C_2 if its effect is to be kept negligible. If C_1 is made smaller than 20 times C_2 it will reduce the damping current in R_1, thereby delaying the plate pulse and making the circuit oscillatory unless the value of R_1 is adjusted for the given value of C_1. Retrace must be completed in 665 microseconds (4 per cent of field period); however, in feedback oscillator circuits in which the plate pulse is used to key the discharge tube, the retrace period should be 250 microseconds ±20 per cent for good interlace.

In triode output circuits the tubes acts as the damping resistance. The damping, then, is adjusted by varying a peaking resistor in series with the charge capacitor of the sawtooth generator. This value should be approximately 10,000 ohms with the exact value determined empirically to be just sufficient to allow completion of retrace at the instant peaking pulse is completed.

The expression for the flyback pulse for a triode output stage cannot be readily analyzed. However, if the flyback pulse is assumed to be a square pulse, then the flyback current will be sawtooth. The expression for the minimum theoretical flyback pulse is:

$$\hat{e}_{f(min)} = L_o I_{p\text{-}p}/T_r.$$

Where $\hat{e}_{f(min)}$ is the pulse voltage above B+ in peak volts, L_o is in henries, $I_{p\text{-}p}$ in amperes and T_r is the retrace period in seconds.

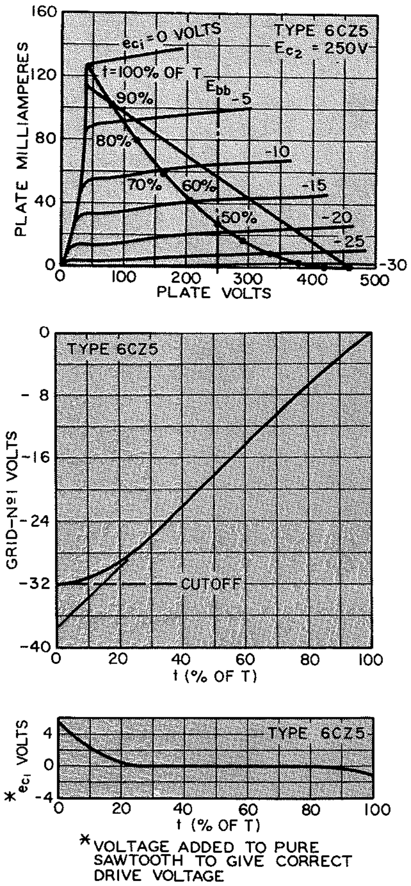

Fig. 5—Load line for linear deflection of a pentode.

This value can be closely approached in practice if the duration of the peaking pulse equals the desired retrace period. This period depends on the switching rate of the discharge tube, which in turn, depends on the grid-circuit time constants. The peak value of the triode plate pulse usually is 30 to 40 per cent less than the plate pulse of a pentode circuit for an equivalent deflection system.

TRIODE LOAD LINE

If, as shown in Fig. 4, the expression for plate current vs. plate voltage is plotted on the plate family characteristic curves of a typical triode, the required grid waveform can be derived. The resultant non-linear grid-drive waveform approximates the exponential form $1-\varepsilon^{-\alpha t}$. The high impedance sawtooth generator used in vertical deflection circuits delivers a voltage of this form, but in practice it is most economical to choose a large value for the time constant $1/\alpha$ so that the sawtooth voltage is nearly linear. Then the design can utilize smaller, less expensive, coupling capacitors and smaller grid resistors which lessen the effects of grid emission, gas, and leakage reverse-grid currents in the output stage. The operation of height and linearity controls is identical in principle for both triode and pentode circuits, and will be discussed when the pentode example is considered.

PENTODE LOAD LINE

The expression for plate current vs. plate voltage is plotted on the plate family characteristic curves of a typical pentode (6CZ5) in Fig. 5a. In the pentode case, the drive must be nearly linear for the last 80 per cent of the trace period, as shown in Fig. 5b. However, during the first 20 per cent of trace, a large amount of nonlinearity is required. The voltage shown in Fig. 5c must be added to a sawtooth voltage to drive this typical pentode correctly.

Obtaining the linear drive required by a pentode directly from the high-impedance sawtooth generator is not economical because large coupling capacitors are costly, and because large grid resistors increase the effects of grid emission, grid leakage, and gas reverse-grid currents. When smaller coupling capacitors and grid resistors are used, as in triode circuits, the resulting nonlinearity can be corrected by the addition of an easily obtained linearizing voltage. The linearizing feedback voltage will be discussed later.

STRETCH AT TOP OF PICTURE

The grid drive voltage shown in Fig. 5b is extrapolated from the linear portion to cutoff, and is found to cross the time axis after about 15 per cent of trace. If a sawtooth drive is used the tube should be cutoff for the first 15 per cent of trace or a severe stretch to compression will occur at the beginning of trace (top of picture).

Fig. 6 shows the load line[1] of a vertical-deflection output circuit having a ratio of R_o to $L_o + L_1$ equal to 120 (with no d-c flowing in the transformer primary), and an average ratio of R_o to $L_o + L_1$ of 141 during the trace period (with an average of 45.3 milliamperes of plate current flowing in the transformer primary). The grid drive is linear and the bias is −16.75 volts. The yoke current referred to the primary, i_o, is stretched by 23.3 per cent at the beginning of trace.

The initial 5 per cent of trace occurs when the drive voltage is below cutoff and, therefore, must be entirely supplied by energy stored in the inductance L_o. For good linearity during cutoff,

$$\left.\frac{di_o}{dt}\right|_{t=0} = 60\, I_{p\text{-}p}$$

[1] Load line was derived by the method of Finite Operators as described by A. Preisman in *Graphical Construction for Vacuum Tube Circuits.*

for a trace period of approximately 1/60 of a second. Therefore, the ratio of R_o to L_o plus L_1 must be equal to 120 during the time the tube is cutoff.

CRAMP AT TOP OF PICTURE

In the same circuit, if the bias is increased from −16.75 volts to −18.5 volts (for a constant deflection) as in Fig. 7, the yoke current changes from 23.3 per cent stretched at the top of the picture to a cramp of 15.4 per cent one fourth of the way down from the top of the picture, and a general compression occurs over the top half of the picture. This cramp is caused by the straightening out of the load line due to an increase in the inductive reactance of L_1, which results from an increase in the rate of change of grid drive; i.e., the drive varies from cutoff to zero bias in 85 per cent of the trace period rather than 95 per cent as in the first example. This difference reduces the peak-to-peak change in the current i_1 flowing in the shunt inductor. The bias control is called the linearity control because the stretch or compression of the top of the picture is caused by a small bias change. Good linearity can be obtained by adjusting the bias to some value that will allow the tube to

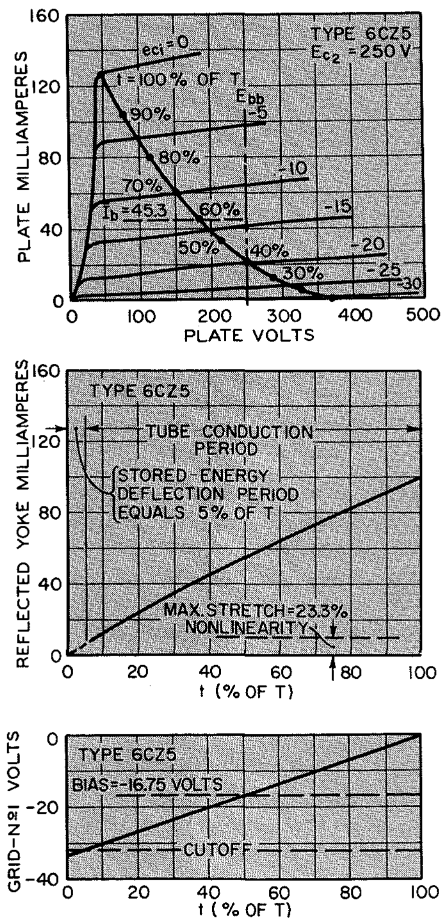

Fig. 6—Pentode load line for top picture stretch.

conduct during 85 to 95 per cent of the trace period.

It may be necessary to add a small peaking component to the drive voltage to smoothly blend the switching transition from cutoff to conduction in circuits using sharp cutoff pentodes. Too much peaking will result in an exaggerated variation of linearity with normal product cutoff range. The most convenient source of this peaking voltage is a parallel resistor-capacitor combination in series with the charge capacitor. In most practical cases, the capacitor should be 0.1 microfarads and the resistor should be about 5000 ohms with its exact value adjusted to provide good linearity over the top one fourth of the picture.

If the ratio of R_o to $L_1 + L_o$ is greater than 120 during cutoff, additional complex wave shaping is required to compensate for the tendency to stretch the top of the picture.

Additional stretching, cramping, and foldover can also result if the retrace damping is not nearly critical but is either oscillatory or overdamped. If the stored-energy deflection period (T_1) is 10 per cent of the trace period (T) then the cramping due to the exponential nature of i_o will result in about 2 per cent nonlinearity. If T_1 is made 15 per cent of T, the resulting 4 per cent nonlinearity approaches an objectionable value.

The linearity of the yoke current during tube conduction is controlled by the magnetization curve of the output transformer as well as the tube characteristics. To simplify the analysis, however, the magnetizing current is assumed to be constant at 1/3 of the peak-to-peak plate current. The resultant error is relatively small.

THE PRACTICAL RATIO OF $R_o/(L_o + L_1)$ FOR MAXIMUM EFFICIENCY

In practice the vertical-deflection circuit is operating Class AB rather than Class A_1 and, therefore, the statements made earlier about efficiency should be modified. The ratio of R_o to $L_1 + L_o$ was given[4] as 120 for maximum efficiency. However, if the tube is cut off during 15 per cent of the trace period, the conduction period is only 85 per cent of trace and then $R_o/(L_o + L_1)$ may be as high as 141 (i.e., 120/0.85). Greater values than 141 will yield greater efficiency, but will require complex linearizing grid voltages. For this relationship, L_1 should be measured with the average d-c operating current flowing in it. During the stored energy deflection period, however, the ratio of R_o to $L_o + L_1$ must be 120 for good linearity and the value of L_1 should be measured without d-c current flowing in the transformer.

Height control is effected by varying the peak-to-peak grid drive supplied by the sawtooth generator. The proper drive voltage is obtained by adjusting the resistor in series with the battery and charge capacitor and thereby altering the time constant and changing the final voltage developed by the charge capacitor.

LINEARIZING FEEDBACK

As was mentioned previously, it is not practical to obtain a linear drive directly from conventional sawtooth generators as shown in Fig. 8a. An approximate parabola must be added to the grid voltage, e_g, to obtain the required linear drive. Figs. 8b and 8c show simple methods of integrating a sawtooth to obtain an approximate parabola which can be added to e_g to give good linearity.

In Fig. 8b the bias voltage is derived from the grid of the discharge tube, and contains a large exponential waveform. This waveform is integrated by the action of the charge capacitor, C, which produces a parabolic waveform to correct for the voltage produced by the sawtooth generator. The degree of linearizing can be regulated by adjusting the size of the grid resistor R_g. In Fig. 8c the partially bypassed cathode resistor, R_k, generates the parabola which, when added to the sawtooth generator voltage, gives a linear grid drive. The drive linearity can be corrected by adjusting C_g, R_g, or C_k. Sharp cutoff pentodes may require the use of a parallel resistor-capacitor combination in series with the charge capacitor as explained under the discussion of a cramp at the top of the picture.

The statements that have been made about pentode circuits using linearizing feedback to compensate for the effects of small grid capacitors and resistors can apply equally well to triode circuits. In order to keep the effects of reverse-grid current as small as possible both triodes and pentodes should use small grid resistors (2.2 megohms or less) and linearizing feedback as required.

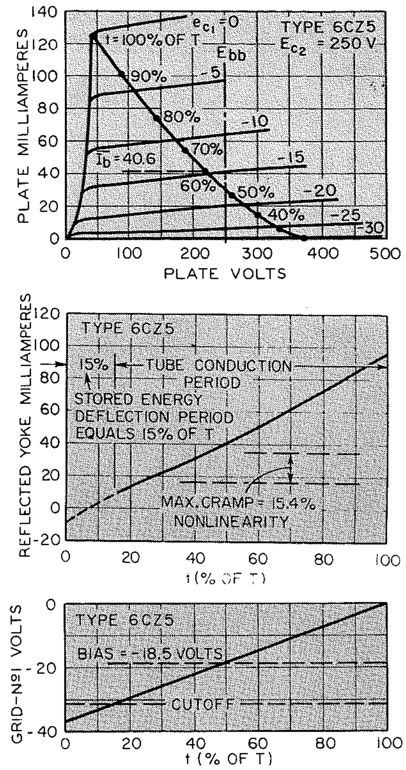

Fig. 7—Pentode load line for top picture compression.

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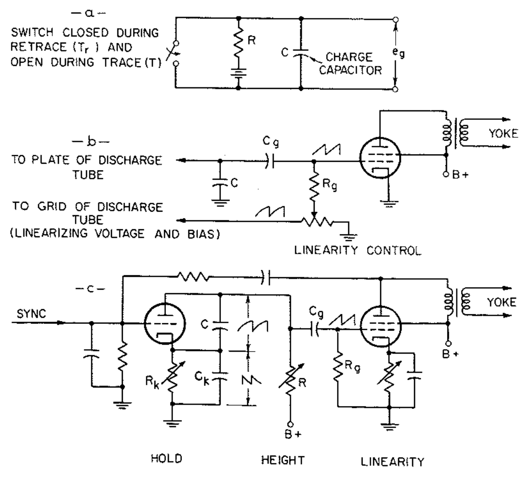
Fig. 8—Vertical-deflection sawtooth generator and linearizing feedback networks.



FACTORS AND TRENDS IN AUTOMOBILE RECEIVER DESIGN

by
CAMBELL GONZALEZ
Receiving Tube Development
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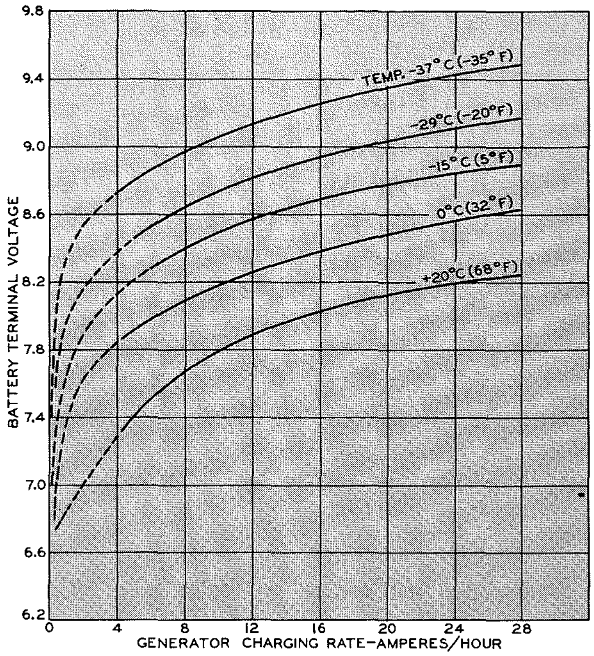
Fig. 1—Voltage of a Fully-Charged 90-Ampere-Hour 6-Volt Battery as a function of Temperature and Charging Rate.



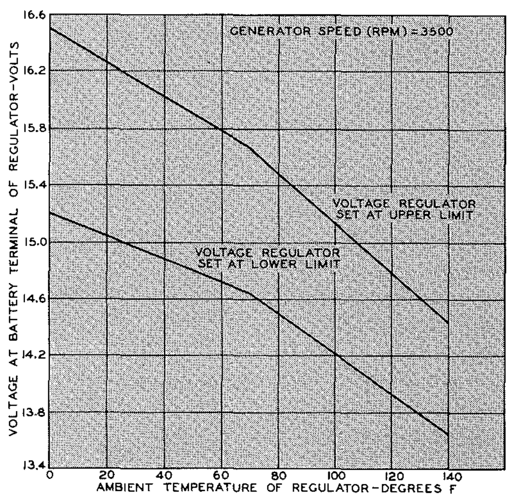


Fig. 2—Battery Voltage as a Function of Temperature In 12-Volt Battery System (Curves and Data Supplied by Delco-Remy Corp.).

RADIO RECEIVERS WERE introduced into the automobile experimentally in the early 1920's, but did not attract the attention of the industry until the beginning of 1930 when a group of radio manufacturers met and agreed to provide complete radio receivers for automobile use and to arrange for the merchandising of receiver kits. By May of 1930, three of the largest radio manufacturing organizations in the country were producing receivers, and sales for that year were in excess of 100,000 receivers. Since that time production has increased steadily. Production figures for late 1957 indicate that the number of automobile receivers manufactured will exceed two million sets, accounting for 25 per cent of the total sale of receivers.

These receivers are constantly undergoing changes in design which result from the availability of new products, advances in circuit development, and improvements in manufacturing techniques. This paper reviews some of the considerations inherent in automobile applications that have been important in the development of present-day receivers, and lists some of the problems that presently exist as an indication of future design trends.

SPECIAL CONSIDERATIONS IN AUTOMOBILE RECEIVER DESIGN

Rather early it became evident that the ordinary home radio receiver did not perform satisfactorily in an automobile. P. O. Farham in 1930[1] listed certain features of radio receivers which require special attention in mobile applications. These factors, if expanded to include the impact of later developments, have played major roles in deciding the trend in radio receivers as a whole. They include:
1) Physical structure and shielding,
2) The antenna or signal collector,
3) Electrical characteristics required,
4) Power supply.

PHYSICAL STRUCTURE AND SHIELDING

Radios for motor cars must be compact because of the limited space available. Components must be able to withstand the effects of wide changes in temperature and humidity, as well as repeated vibration and switching surges. Temperatures in the receiver may range from 0° to 160° F.

The automobile receiver also must be designed to operate in a field of considerable noise disturbances. Noise produced by the electrical system of the car itself is augmented by interference from power lines, electrical apparatus, spark or arc discharges, and other automobiles. The voltages produced by these disturbances radiate at frequencies up to 600 megacycles, and have peak fields greater than 20 millivolts per meter.[2] In order to obtain full operating efficiency from a sensitive receiver, therefore, it is necessary to keep these electrical fields from inducing interfering signals in the radio circuits by enclosing the receiver in a metal case.

ANTENNA

Many of the problems of the automobile receiver stem from the antenna and the antenna circuits. An efficient aerial has maximum signal "pick-up" with a minimum noise level. The antenna's efficiency is influenced by its effective height, resonant frequency, and directional characteristics.[3] Those employed in mobile use operate inefficiently[4] because of their low effective height and small capture area.

The collectors employed have varied from metal netting placed under the cloth tops used in the "thirties," through under-car arrangements of rods, wires, or plates, to vertical rods, overhead "towel racks," and telescopic whips.[5] Because of its directional characteristics, ease of location, and small size, the capacitance whip antenna is most widely used today.

ELECTRICAL CHARACTERISTICS

Electrically, the circuit of the automobile receiver is basically the same as that of the better type conventional home broadcast receiver. However, the low-efficiency antenna of the automobile receiver requires that its input circuits have high sensitivity and low noise generation. In the r-f and i-f circuits every effort is made to insure maximum sensitivity consistent with the required selectivity, the internal noises generated within the set, and the noise level likely to surround it. Lower-frequency i-f coils (262.5 kilocycles) and permeability-tuned circuits are normally used. The 455-kilocycle intermediate frequency of the home receiver is within the band of frequencies allotted to message traffic between ship and shore installations (375-500 kilocycles). Although mobile receivers have been built with 455-kilocycle i-f amplifiers, the danger of interference from ship-to-shore communications is increased. For better rejection of unwanted signals and for better sensitivity an r-f stage is always employed.

The detector and avc systems in automobile radios are similar in principle to those in use in the home receiver, but employ a different time constant to counteract rapid changes in signal strength. The signal strength of a transmitter will vary in intensity as the distance changes between transmitter and receiver. The presence of structures which absorb or reflect the signals result in further modifications; hence, the field strength may undergo variations of 100:1 within linear distances of two or three feet. The range of input voltages which must be handled may be higher than 120 db (from 1 microvolt to 2 volts). Protracted tests under a variety of conditions have shown that delayed avc is capable of giving the best performance under these conditions.

The amount of audio power output required in an automobile for a certain listening level is determined by the type of upholstery, the type of car (sedan, convertible, etc.) and the ambient noise level. In the simple home receiver, standard output is 50 milliwatts. One watt would exceed the capabilities and the needs of the majority of such receivers. For the automobile receiver, however, standard output is one watt, and many set makers require an undistorted output of 3 to 3.5 watts. Maximum or "squawk" ouput is of the order of 5 to 6 watts. In an automobile, the ambient noise level is generally high enough to require the increased power output.

POWER SUPPLY

In the early automobile receivers, "B" and "C" dry-cell batteries supplied the plate and grid voltages, and the storage battery was used for the filaments.[6] The introduction in 1931 of the 6-volt indirectly-heated cathode-type tubes permitted a reduction in the power consumption from the storage battery and spurred the use of motor-generators or dynamotors to replace the "B" and "C" batteries. Motor-generators and dynamotors were superseded to a large degree by vibrators. Most recently, the need for a vibrator has been eliminated by receivers using supply voltages obtained directly from the storage battery.

Today virtually all automobile radios make use of the storage battery with or without auxiliary devices as the source of power. One writer cites an investigation which showed that the average current consumption of the radio alone is 6.5 amperes at 6 volts.[5]

The necessity for limiting current drain on the battery power supply has an important influence upon the design of a receiver. Also, when a vibrator is used in a power-supply unit, additional problems of noise suppression and filtering are introduced which are absent from other supplies. A third consideration is the range of the battery voltage system due to ambient temperature and to the battery's charging rate.[7] Fig. 1 shows how the battery terminal voltage may vary with charging rate and temperature in a 6-volt battery system. A battery system employing a fully charged 12-volt battery supplies between 13.9 and 15 volts during 90 per cent of the operating time, an average of 14.4 volts, and peak voltages that can be higher or lower depending on the voltage regulator setting. Fig. 2 shows the variation with temperature of the voltage at the battery terminal of the voltage regulator for both the upper and lower limits of the regulator setting.

ADVANCES IN TECHNIQUES AND CIRCUIT DESIGN

As the automobile receiver progressed from tuned radio-frequency sets using "A" and "B" batteries to superheterodynes having synchronous vibrators, tube manufacturers kept pace. Filaments became heaters, and voltages changed from 2.5 volts to six, and then to twelve. The battery triodes of 1930 having transconductances of less than 500 micromhos and power tubes having transconductances of 1500 micromhos gave way to output tubes having

CHART I

Performance Data on All-Tube Receiver (1955 Model)

1. Sensitivity and Noise

Frequency (Kilocycles)	Sensitivity (Microvolts)	Noise (Milliwatts)
540	2.8	100
600	1.7	200
800	1.5	200
1000	1.8	110
1200	2.1	70
1400	3.4	29
1600	5.0	18

2. Selectivity

Frequency	Bandwidth (Kilocycles)	
	6DB Down	60DB Down
600	8.33	22.8
1000	6.42	23.5
1430	6.37	26.9

3. Image Rejection Ratio: >6

4. IF Rejection Ratio: >15

transconductances in the order of 6000 micromhos and amplifier tubes having transconductances in the order of 4000 micromhos.

By 1955, permanent-magnet speakers, variable inductance tuners having automatic or semi-automatic tuning, and many other advances had made the performance of the automobile receiver better than that of the average home broadcast receiver. Data on the performance of one such radio receiver are given in Chart I.

The greatest change in automobile receivers in the past few years came with the development of the power transistor. The use of a power transistor in the audio output stage of the receiver made it feasible to eliminate the power-supply unit in the automobile by operating tubes at low plate and screen-grid potentials. Besides saving space, this change reduced the battery power required for the receiver by more than twenty per cent. Moreover, the vibrator and associated components which were eliminated had long been a major cause of field failures and a source of noise in the receiver.

A radio receiver employing a transistor and tubes was first introduced commercially in 1955. The basic circuit was essentially the same as that of the conventional receiver through the first audio amplifier stage, but here an additional tube was introduced as a driver for the transistor power-output stage. An indication of all the approaches used would be exceedingly difficult; therefore, only those which appear to have gained the greatest acceptance will be discussed here.

DEVELOPMENT OF HYBRID RECEIVERS

When the first part-tube, part-transistor or "hybrid" receivers were introduced, little or no cost saving was realized because the additional driver tube, the driver transformer, and high transistor costs (including the transistor heat radiator) offset savings from the vibrator, the rectifier, and the other components which had been removed. Moreover, when requests for tubes for these applications were first received, little or nothing was known of the capabilities of tubes for operation at 12-volt B+ potentials. Existing tube specifications did not include controls for characteristics in this area and modifications in test equipment were required in order to obtain accurate measurements of tube characteristics at the low potentials. Difficulties with tube specifications were speedily overcome, however, and tests and controls for the new region of operation were determined. With the exception of the transistor driver, the tubes used in the first "hybrid" receivers were those employed at higher potentials.

The development of a commercially successful tube-and-transistor receiver was still largely dependent on the development of an effective driver for the transistor output stage. The transistor is essentially a current or power amplifier which operates on power from the driving stage, and few, if any, tubes were available which would give sufficient driving power with low distortion at the 12 or 14 volts available.[8] In the early receivers, a power tetrode of the space-charge-grid type, the 12K5, was used almost exclusively as the driver stage. The low output impedance of this type made coupling from the plate circuit of the tube to the input of the transistor less costly. Sufficient power output was present to drive the transistor adequately. In addition, distortion characteristics of this tube permitted a greater range of variations of the input impedance of the transistor without resulting in objectionable distortion.

The power sensitivity of the 12K5 however, is inherently low. Higher-gain transistors are necessary, and a greater signal swing is needed to secure adequate drive. Also, the large structure utilized in the 12K5 to obtain high currents increases the possibility of microphonics. The wattage (5.6 watts) resulting from the current required for the space-charge grid (75 milliamperes) and from the heaters (400 milliamperes) was high enough for grid emission to be a factor.

Later, tetrode and pentode drivers were developed for greater power sensitivity, but their higher plate resistance tends to increase the size and cost of the driver transformer. Transistors having lower gain could be used, but then the range of variation in input impedance that was possible without objectionable distortion was significantly reduced. From the standpoint of microphonics and dissipation, little or no advantage over the 12K5 was achieved. The pentode and tetrode types did not gain wide acceptance, but were employed in some receivers.

In 1956, electron-tube manufacturers began to supply tubes specifically designed for 12-volt B+ operation. Tubes are now made for the r-f and i-f stage which have a transconductance exceeding 4000 micromhos. Still other tubes are available in which the cutoff voltage of the signal grid is greater than the plate and screen-grid supply voltages. Altogether, more than twenty-five commercial tube types have been registered and made available since the inception of the program.

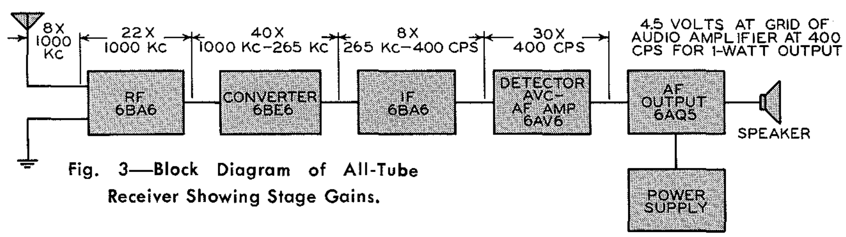


Fig. 3—Block Diagram of All-Tube Receiver Showing Stage Gains.

Generally, these tubes have higher transconductance than earlier tubes but lower transconductance than conventional tubes. The loss in gain in the r-f and i-f stages is made up by higher gain in the audio stages. Fig. 3 shows voltage gains and transconductance of a typical all-tube automobile receiver at normal voltages and at the lower potentials. Fig. 4 shows how gains may be distributed to meet the same requirements in the "hybrid" receiver.

By the beginning of 1958, the low-potential tubes and the techniques employed had improved to such an extent that the first audio-amplifier stage could be omitted. The avc diode and the detector diode were incorporated in the same envelope with the driver tube so that the receiver includes only four tubes and a transistor. Measurements made by the writer on one of these receivers indicated that the performance was comparable to that of the five-tube-and-one-transistor set.

AREAS FOR IMPROVEMENT

The change from normal voltages and all-tube complements to low-B+ potential tubes with a transistor output solved the power-supply problems but introduced others. Some of the principal problems are:

1. The limited voltage swing permitted by the reduced signal-grid base of the transfer characteristics makes the handling of large signal voltages difficult. In the r-f and converter stages severe distortion from overloading may occur with strong signal inputs. The last i-f stage may be overdriven at high carrier levels or with high percentages of modulation in either the input or the output circuits.
2. It is difficult to obtain adequate avc voltage and effectively apply it to the controlled stages. In order to obtain adequate avc voltage, the carrier voltage is taken from the top of a tapped primary coil of the last i-f stage; thus, the reflected loading of the avc diode tends to restrict the plate impedance of this stage. Two general approaches have been used for effective gain control of the input stages.

   In the first method, the r-f stage is cut off rapidly by the signal input. The residual transmission (through grid-plate capacitance) of the tube as a passive element is utilized to furnish the receiver output. For higher signals, avc voltage developed by residual transmission is applied to the converter grid after a properly instituted delay.

   The second method employs a tube having a remote cut off characteristic in the r-f stage. The avc voltage is applied to the input stages in the same manner as in the higher-voltage receivers. In this method, distortion due to non-linearity may be intensified because the signal swing is applied to a large portion of the transfer characteristic.
3. Theoretically, the maximum audio gain is limited by audio stability and by low signal distortion in the second detector. However, in practice, microphonics and distortion in the driver stage introduce problems long before the occurrence of the theoretical limitations.
4. Perhaps the greatest difficulty has been experienced in maintaining the input and/or output impedances of the tubes high enough to avoid a loss of gain or excessive distortion.

The present hybrid receiver is not considered the ultimate by any manufacturer. The preceding paragraphs outline some of the existing problems which in turn indicate the possible directions of future designs.

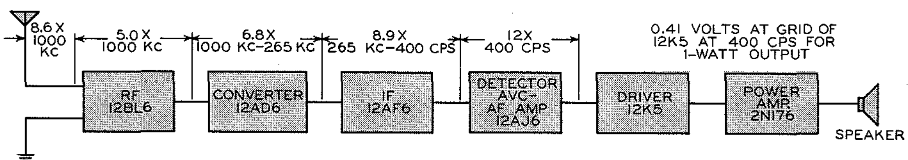


Fig. 4—Block Diagram of Transistor—Output Receiver Showing Stage Gains.

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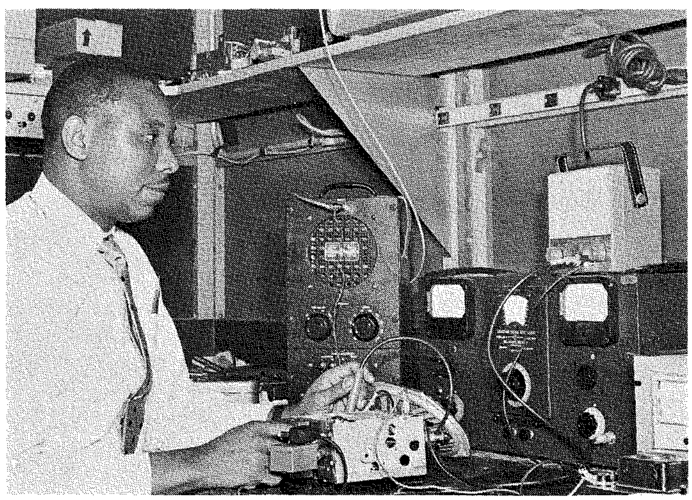
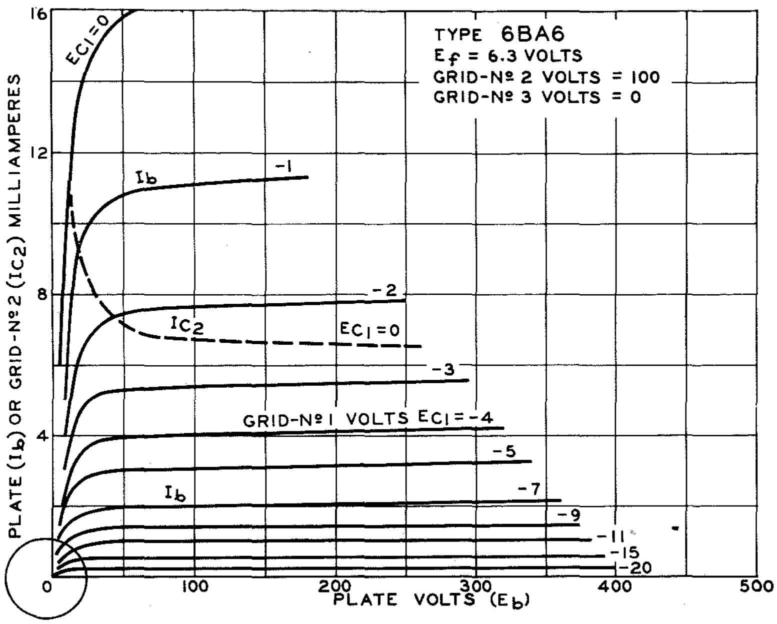


CAMBELL GONZALEZ received the B.S. degree in Electrical Engineering from Howard University in 1949. Prior to that time, he served as a 1st Lieutenant in the U. S. Army for three years. He joined RCA as a specialized engineering trainee immediately after graduation. At the completion of his training program, he was assigned to the Receiving Tube Application Laboratory of the Electron Tube Division at Harrison. He worked with the Customer Service group until 1955, and in the development activity of the Laboratory since then. His work is primarily concerned with r-f and i-f tubes for operation at plate and screen-grid potentials of 12 volts and with mixer-oscillator types for use at conventional supply voltages.

Mr. Gonzalez is a Member of the Institute of Radio Engineers.

Fig. 1—Plate-Characteristics Curve of 6BA6

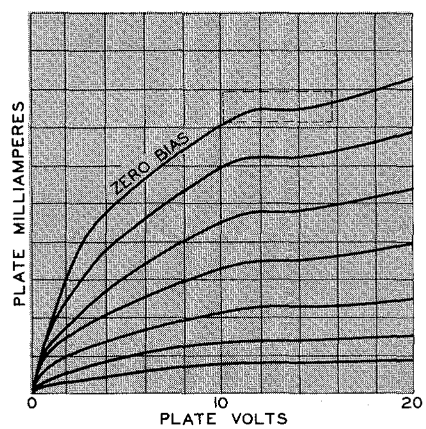


LOW-VOLTAGE RECEIVING TUBES

by

T. M. CUNNINGHAM

Receiving Tube Engineering
Electron Tube Division
Harrison, N. J.



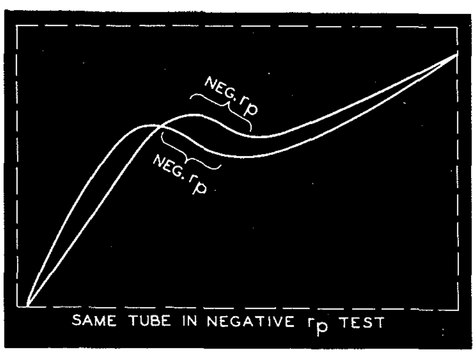


Fig. 2—Negative Dynamic Plate Resistance (r_p)

THIS PAPER DESCRIBES the major considerations involved in the design of tubes intended for low-voltage applications. The development of electron tubes designed to operate in the range from 10 to 20 volts has been stimulated by the possibility of their use in conjunction with semiconductor devices in automobile receivers.

Hybrid radio receivers utilize transistors in the audio-output stage and electron tubes in all other stages, and are operated directly from the 12.6-volt electrical supply system of the automobile. This type of receiver can deliver from two to five watts to a speaker without the use of a vibrator and high-voltage supply.

The economic attractions of the hybrid design have resulted in the development of a line of receiving tubes intended specifically for automobile receivers. However, these tubes should also be considered in the design of future portable receivers, portable record players, and portable television where the ability of the semiconductor device to provide a large power output at low voltages and the relative low cost of the receiving tube can be combined to advantage.

REASONS FOR LOW-VOLTAGE TYPES

The advent of the low-voltage receiving types may have raised questions in the mind of the set designer, such as, "Why develop new tubes to operate from low-voltage supply? Why not, except where special problems arise, employ existing tubes and operate them in the low-voltage region?"

Actually, it is possible to use existing tube types and operate them in the low-voltage region in some cases. For example, twin-diode triodes for use as AVC detectors and audio-frequency amplifiers can be used in low-voltage radio receivers with no essential changes in tube design. However, it is necessary to redefine the electrical characteristics of the tube for operation in the low-voltage region and to provide additional production controls.

Fig. 1 shows the E_b-I_b curve of the familiar 6BA6 or 12BA6 pentode amplifier over the normal voltage range. The small section of the operating range which is important in low-voltage applications is shown by the circled portion. Thus, though it may be possible to use a conventional tube in the low-voltage region, the tests and characteristics control considerations of the tube have to be redefined for operation in this region.

The new tube designs that are required for low-voltage operation are seemingly very simple and, in effect, involve nothing more than modification of existing tube designs or design principles. Some of the reasons low-voltage applications require new tube designs are the following:

1. Tubes intended for this type of operation must have uniform characteristics over a relatively wide range of operation and reasonably low and controlled signal-grid contact potential.
2. Low-voltage tubes must be specially designed and processed in manufacture to suppress secondary emission effects.
3. Some applications require new radio-frequency amplifiers having very remote-cutoff characteristic to prevent overload and cross-modulation distortion with large signal and voltage variations.
4. Higher stage gain is required in converter and voltage amplifier stages than that afforded by conventional tubes.
5. Audio power amplifiers having sufficient power output and power sensitivity to drive semiconductor-device output stages are required.

SPECIAL PROBLEMS

The special problems associated with low voltage receiving tubes of primary importance are those of contact potential and the so-called "ten-volt effects." However, before these special problems are considered, the increased importance in low-voltage operation of the general problem of supply-voltage variation should be noted. For example, a variation of one volt at ten-volt operation represents a much larger percentage of the total than at 100-volt operation. In an automobile, the nominal regulator voltage in some cases is 14.4 volts for 90 per cent of the time, and has a low of 10.0 volts or a high of 16.0 volts for 10 per cent of the time. Under these conditions, tubes are made to operate over a range of plus or minus 23 per cent of the mean value. In amplifier stages, the gain must remain relatively constant over the entire range of operation. Therefore, the tube characteristics at the low and high ends of the operating range are of the utmost importance in equipment design.

One of the major problems in the development of tubes for low-voltage operation in receivers was learning how to process tubes having low contact potential. When no AVC is applied, the control-grid operating point is determined by the bias developed across a resistor connected between the grid and the cathode. The bias is developed primarily as a result of the difference in contact potential between the grid and cathode. In effect, the tube has its own bias supply. When the tube is operated at high voltages, this difference in contact potential is relatively unimportant, but at low voltages it represents a sizable percentage of the plate voltage. It can vary between 0.5 and 1.5 volts depending on the materials employed and the manner in which the tube is processed. High contact potential results in a large developed bias which can cause low gain, particularly in the amplifier and converter stages.

Contact potential in tubes is due to the difference between the work functions of the cathode and of the control grid. During tube activation, the control grid becomes progressively more electropositive as barium metal is evaporated from the cathode and deposited on the grid. It has been determined that minute surface contaminations exert a profound effect on the work function and, therefore, on the contact potential. In low-voltage receiving tubes, contact potential is controlled by the judicious selection of grid materials and by special tube processing methods. In practice, the tube is processed at a very high heater voltage for a very short time at the end of activation to apply the correct amount of barium on a clean signal-grid surface.

Two "ten-volt effect" problems have been experienced in the development of low-voltage receiving tubes. One is the "ten-volt slump" effect, and the other is the "high-speed ten-volt effect." Both problems have received attention in the RCA Laboratories in Princeton by Nergaard and Matheson.[1] The ten-volt slump effect is a result of oxygen released by contaminated electrodes when they are bombarded by 10-volt electrons. The bombardment of metal oxides by 10-volt electrons releases oxygen which migrates to the cathode. The cathode is particularly vulnerable to oxygen poisoning and therefore the emission can be decreased and the coating resistance increased.

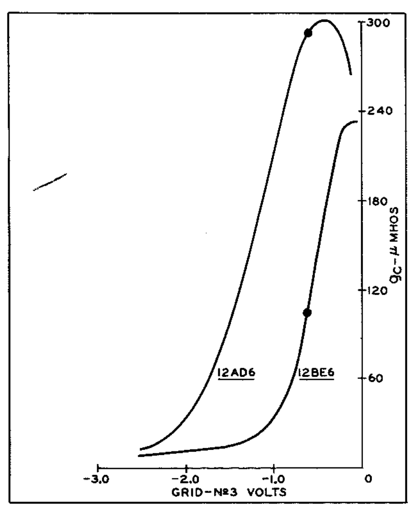


Fig. 4—Comparison of Electrical Characteristics of 12BE6 and 12AD6

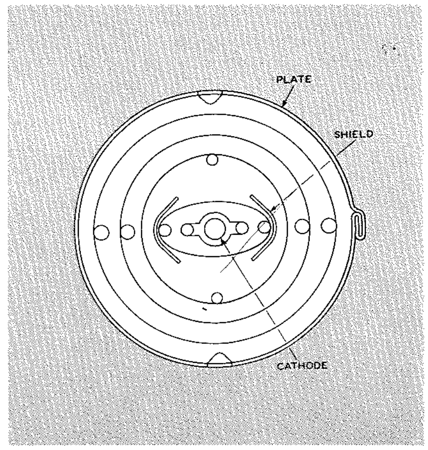


Fig. 3—Cross-Sectional View of 6BE6 and 12BE6

The 10-volt slump effect has not been a problem of any practical concern in conventional tubes because of the use of oxide free parts. However, high-speed ten-volt effects have been very evident in tubes designed for low-voltage operation. The high-speed ten-volt effect can cause objectionable irregularity in the E_b-I_b curves for tubes operating in the ten-volt region. An example of this irregularity, which is commonly called negative dynamic plate resistance, is shown in Fig. 2. Uncontrolled "kinks" in the tube characteristics curves can of course result in signal instability and signal distortion in receiver applications. This effect can occur in all types of receiving tubes that operate in the ten-volt region, whether they be diodes, triodes, tetrodes, pentodes, or heptodes. Negative r_p has been observed to occur between 8 to 14 volts. Dr. Nergaard and Mr. Matheson explain the effect as follows:

> In summary, the small, stable deviations from the 3/2 law found in tubes with oxide cathodes are due to a layer of extraneous material on the anode. Secondary electrons from this layer increase the charge in the interelectrode space, depress the potential minimum, and reduce the space current below that predicted by the 3/2 law. Evaporation experiments and secondary yield data indicate that the layer consists of barium oxide evaporated from the cathode. The apparent sudden onset of the effect is then explained by the rapid rise of secondary yield of barium oxide in the neighborhood of 10 volts.[1]

In practice, the spray of secondary electrons is reduced by making the plate

[1] R. M. Matheson and L. S. Nergaard, "High Speed Ten-Volt Effect," *RCA Review*, Volume XII, pp. 258-268, June 1951.

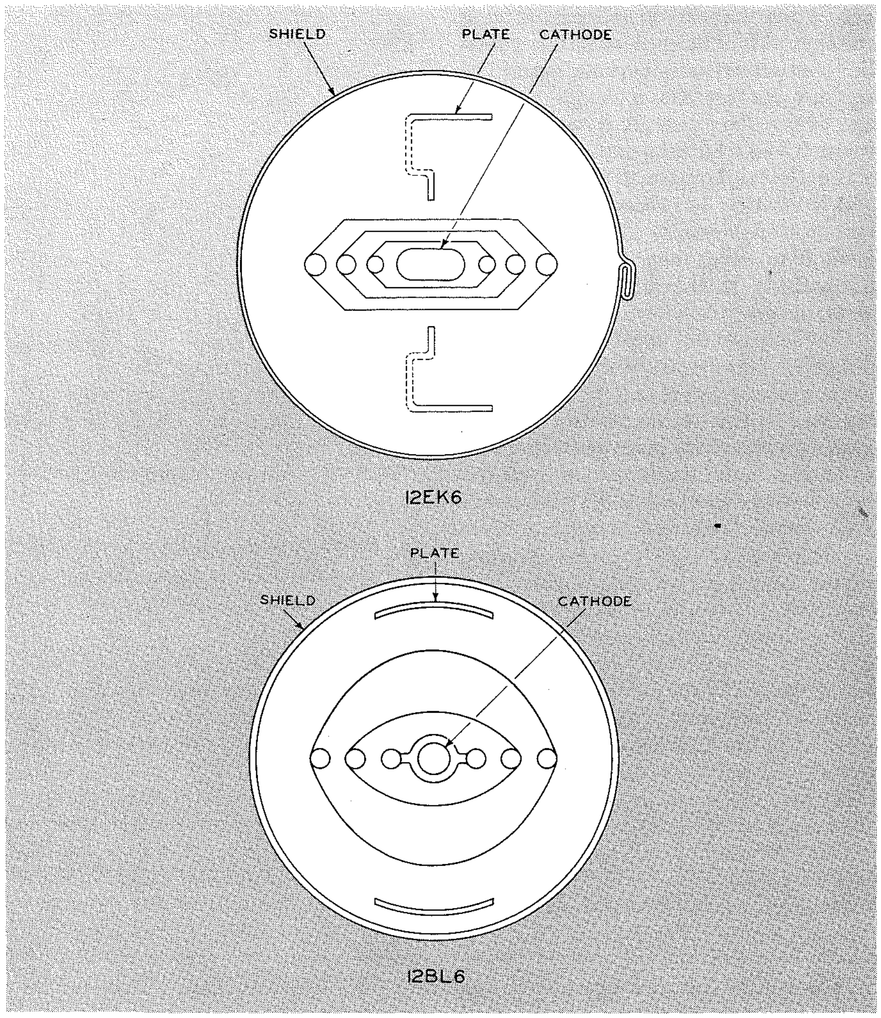


Fig. 5—Cross-Sectional View of 12BL6 and 12EK6

surface rough, (for example, by the use of a carbonized plate material) and by keeping the barium oxide content to a minimum through the judicious use of tube activation schedules. In the design of tubes which employ suppressor grids, careful consideration must be given to the region of the tube between the screen grid and the plate in order to minimize the possibility of a negative dynamic plate-resistance condition. Obviously, this problem can be avoided if the equipment designer centers the tube operating region well away from the ten-volt region.

THEORETICAL DESIGN CONSIDERATIONS

Before any actual tube design problems are considered, an investigation of the application to low-voltage tubes of one of the formulas employed to transpose electrical requirements into tube design parameters may help to illustrate some of the problems that are peculiar to the design of these tubes.

The formula shown below is a derivative of the well known Childs-Langmuir 3/2 law for plate current and is used to determine the signal-grid-to-plate transconductance of a triode.

$$g_m = \frac{3.51 \times 10^{-6} Ak\left(\frac{E_b}{\mu} + E_c + \varepsilon\right)^{1/2}}{d_{cg}^{2}\left[1 + \frac{1}{\mu}\left(\frac{d_{cp}}{d_{cg}}\right)^{4/3}\right]^{3/2}}$$

In this equation, Ak is the cathode area, d_{cg} is the spacing between grid and cathode, and d_{cp} is the spacing between plate and cathode.

As can be seen, if the value of the amplification factor μ is greater than the plate voltage (which is not too uncommon at low-voltage conditions), the expression for g_m becomes imaginary, a so-called "unreal number." To allow for this situation, a correction factor, ε, must be determined and added to the quantity inside the bracket in order to obtain reasonably close calculations. Electrons usually have velocities below 0.5 volt when leaving the cathode. The initial velocity of the electrons determines the potential minimum point, or, in other words, the position of the virtual cathode. Because the electron velocity influences the apparent tube geometry, its combined effect adds to the electrode voltage. The signal-grid-to-cathode contact potential also adds to the electrode voltage and is accounted for by the correction factor.

The pentode transconductance can be determined from the formula for triode g_m if the screen grid is considered as the plate, and the value derived thereby is multiplied by the ratio of plate to screen current.

MAJOR TUBE DESIGN CONSIDERATIONS

In the remainder of this paper, the design and processing of several low-voltage types used as converters, i-f and r-f voltage amplifiers, and audio-power amplifiers will be discussed. Because most of the work to date has been done expressly for the automobile receiver manufacturer, the design considerations that are discussed apply, for the most part, to amplitude-modulated receivers operated in the broadcast band.

1. Converters

Fig. 3 shows the physical layout of the 6BE6 and 12BE6 pentagrid converters which are used in practically all amplitude-modulated receivers. Fig. 4 shows the electrical characteristics of the 12BE6 as compared to those of a new low-voltage tube, type 12AD6. When the 12AD6 is operated normally, 12.6 volts is applied to the grid No. 2, grid No. 4, and the plate. The circled points shown on the curves refer to the operating point as established for each tube by the bias developed across a 2.2-megohm grid resistor. The conversion transconductance, and therefore the gain of the 12AD6, is considerably higher than that of the 12BE6 in low-voltage operation. A conversion transconductance as high as that of the type 12AD6 can be obtained by the following modifications of the 12BE6: 1) lower turns per inch (or higher pitch) of grid No. 1, the control grid of the oscillator section, in order to increase the oscillator plate current and transconductance; 2) a 40-turns-per-inch constant pitch instead of a variable pitch for grid No. 3 in order to optimize the g_c at the developed bias point; 3) smaller mean outside dimensions for grids No. 2 and No. 4 in order to increase the plate current and g_c under low-voltage operating conditions.

The manufacture of this type has been particularly difficult. Contamination of the signal grid by barium from the cathode is necessary in order to keep the contact potential down. An excess amount of barium causes contamination of the plate by free barium and barium oxide, and results in problems due to negative dynamic plate resistance. The problem can be avoided only by judicious selection of plate material and by proper activation procedures.

2. R-F and I-F Voltage Amplifiers

Because of the automatic-gain-control problem, receivers which operate from low-voltage supplies often require r-f amplifiers having a "super-remote" cutoff characteristic to reduce the possibility of overload and distortion. A high-gain antenna input system can cause signal voltages to be quite large at the r-f amplifier. This condition is apt to occur in the vicinity of broadcast stations. In fact, the amplified signal voltage can be equal to the plate voltage. In some cases, the agc problem is solved by the use of a pentagrid converter having agc on grid No. 1 and the signal on grid No. 3. However, the more recent pentode r-f amplifiers for 12-volt operation have a cutoff point of between −6 volts and −19 volts instead of a cutoff point of −4 volts such as the 12BA6 has.

The popular high-transconductance 12BA6 is, of course, the general purpose high-gain voltage amplifier that is used at normal voltages in AM as well as FM and television receivers. Because it was originally designed for FM and television applications, the capacitances, especially the grid-plate capacitance, are quite low. Tubes which are operated in the broadcast band do not necessarily have to operate with high load impedances or very low grid-cathode capacitances in order to provide satisfactory stage gains.

Fig. 5 shows a cross-sectional view of two r-f and i-f pentodes specifically designed for 12.6-volt operation, the 12BL6 and 12EK6. Table I shows the important electrical characteristics associated with each design. As it can be seen, both dynamic plate resistance and grid-plate capacitance are sacrificed in the higher-transconductance versions. The design of the 12BL6 is essentially the same as that of the 12BA6 except that the control grid and screen grid have been modified to give a 50 per cent increase in g_m at low-voltage operation. Without any detailed explanation, it can be seen that the progressively higher transconductance tubes generally are obtained by increasing the active area of the cathode and by decreasing the electrode spacings. However, a grid No. 1-to-cathode spacing that is less that 5 mils can cause "noise-when-tapped" quality problems in mobile or portable equipment.

The electrical characteristics of the tubes listed in Table I satisfy both low-load-impedance and high-load-impedance circuit requirements. Although type 12EK6 has a very low dynamic plate resistance, it is used in some applications where the inductance of the plate resonant circuit is tapped. The tank inductance becomes an auto-transformer which, when tied into a diode circuit, develops a larger agc voltage than can be obtained otherwise. In addition to allowing close spacings without excessively increasing grid-plate capacitance, the odd shape of the 12EK6 plate permits the use of 12BA6 shielding and thereby saves parts-tooling costs. An obvious contribution would be the design of a tube having high transconductance, high dynamic plate resistance, and reasonably low grid-plate capacitance in order to satisfy the requirements of low-impedance and high-impedance circuits with one tube design.

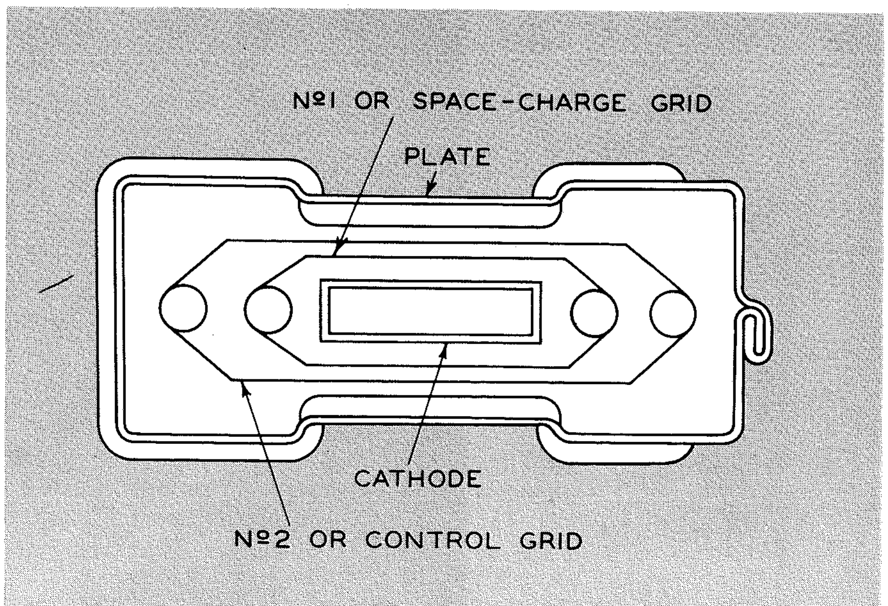
3. Audio Power Amplifiers

For any audio-power-amplifier work that is to be done by tubes, the beam power tube is usually considered first. When operated at a plate voltage of 12.6 volts, practically all of the conventional high-voltage beam power tubes deliver less than 10 milliwatts power output into an optimized load impedance. The 6AU5-GT delivers approximately 7.5 milliwatts and the 6AQ5 delivers approximattely 2.0 milliwatts at 12.6-volt operation. For low-voltage operation, the space-charge tetrode invented by Irving Langmuir in 1913 can deliver more power output than a beam power pentode. The type 12K5, a tetrode of the space-charge type developed especially for new automobile radio receivers, can deliver an output of approximately 40 milliwatts. However, in applications where power sensitivity is important, the beam power tube is more sensitive than the space-charge tetrode at output levels in the order of 15 milliwatts.

Fig. 6 shows a cross-sectional view of a space-charge tetrode, the 12K5. In the operation of this tube, the total positive potential supplied by the automobile electrical system is applied to grid No. 1, the space-charge grid. Between grid No. 1 and the plate, the tube operates as if it were a triode (grid No. 2 acts as the control grid). A Langmuir space-charge grid is inserted between the control grid and the cathode to increase the flow of electrons from the cathode. The basic reason for this arrangement is that the field due to the space charge near the cathode is partially neutralized by the field of the positive grid. Thus, a larger percentage of the total number of electrons emitted by the cathode is utilized in space current, and the "virtual cathode" in effect is transferred from a space-charge cloud or sheath surrounding the cathode to a considerably larger space-charge cloud or sheath surrounding grid No. 1. The position of this virtual cathode surrounding grid No. 1 is determined by the plate and grid No. 2 potentials.

Because of this operation, the total density of the space charge is reduced, but the effective cathode area is greatly increased. When 12.6 volts is applied to the space-charge grid, this grid draws approximately 80 milliamperes, which amounts to about 1-watt dissipation for grid No. 1. Although this current is wasted space current so far as useful

Fig. 6—Cross-Sectional View of 12K5



operation of the tube is concerned, the emission capabilities of the cathode are such that sufficient plate current flows without saturation. Moreover, the perveance of the tube is greatly increased by the use of a space-charge grid, and the internal plate impedance is greatly decreased. This type of operation, therefore, accounts for the relatively high transconductance and power output of the 12K5.

In the 1930's, this type of operation was considered wasteful of space current at high operating potentials, and therefore discarded in favor of beam power tubes. For power amplifiers having high voltage readily available, it was found more economical and efficient to meet the demand for increased power output by increasing the plate voltage rather than by increasing the plate current. However, the plate voltage is fixed at a rather low value in new automobile receiver designs, and for this type of operation, the space-charge tetrode has a considerable advantage.

Normally, 10 to 15 milliwatts is sufficient power to drive an output transistor in audio radio receivers. The 12K5 is capable of delivering approximately 35 milliwatts at 10 per cent distortion into a load resistance of 800 ohms. Recently, the 12DS7, a twin-diode space-charge tetrode intended for low-voltage applications, was announced for detector-automatic volume control-transistor driver applications. The space-charge tetrode unit of the 12DS7 is identical to that of type 12K5.

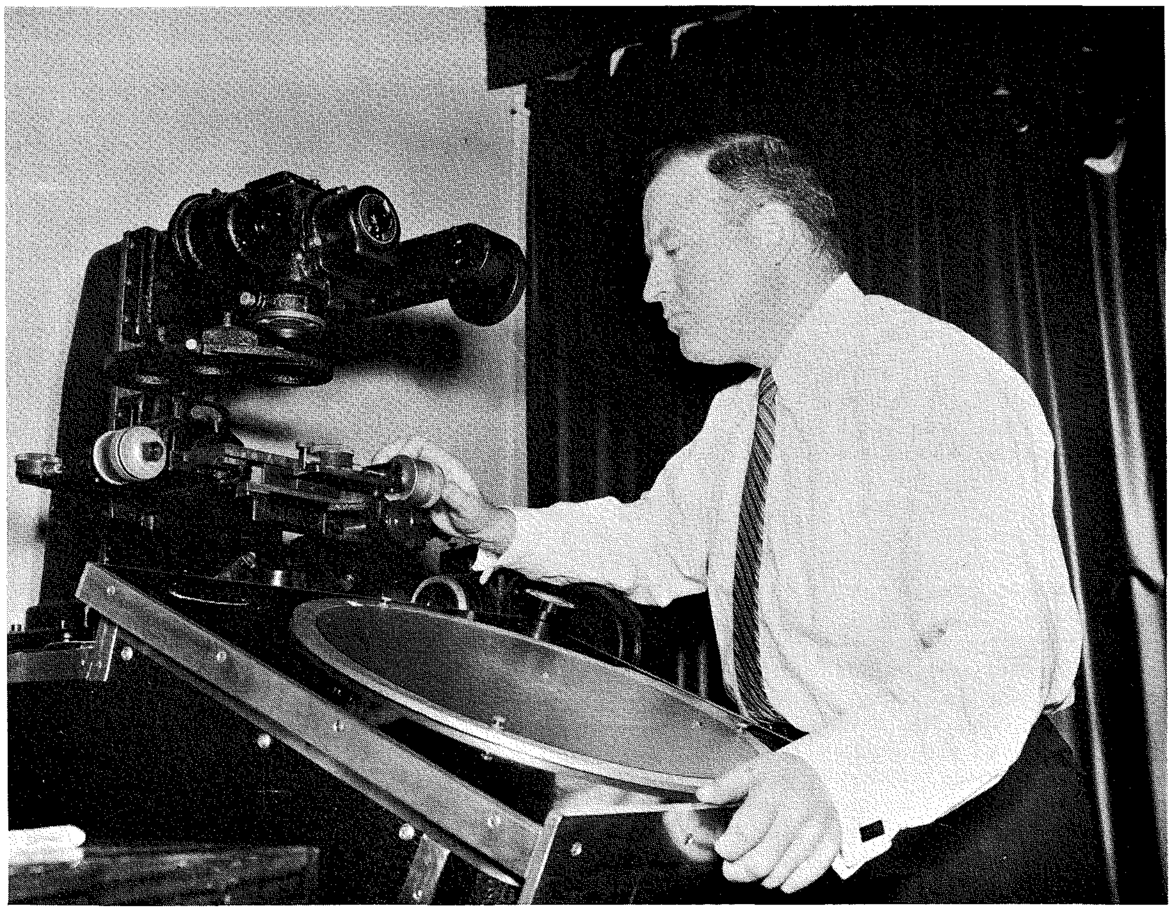
As mentioned previously, the beam power tube is more sensitive than a space-charge tetrode. Two to three times greater power sensitivity can be realized with a beam power tube design. However, the maximum power output is one-half to one-third that of a space-charge tetrode. In addition, the higher-sensitivity beam power tubes require an optimum load resistance three times that required for space-charge tetrodes.

TABLE I

Electrical Characteristics of Low-Voltage R-F and I-F Amplifiers

	12BL6	12EK6	
E_f	12.6	12.6	volts
E_{bb}	12.6	12.6	volts
E_{cc2}	12.6	12.6	volts
i_f	150	200	milliamperes
g_m	1350	4200	micromhos
r_p	500,000	40,000	ohms
I_b	1.35	4.4	milliamperes
I_{c2}	0.50	2.0	milliamperes
E_{c1} (at 10 micromhos)	−6.0	−4	volts
C_{gp} (maximum)	0.006	0.032	microfarads
R_{g1}	2.2	2.2	megohms

TIMOTHY M. CUNNINGHAM served in the United States Navy from 1942 to 1947 in the field of communications. He received the B.S. degree in Electrical Engineering from Purdue University in 1951. Since 1951, he has been associated with the engineering section of the Electron Tube Division of RCA in Harrison, New Jersey. His work consists primarily of the design and development of receiving tubes. Mr. Cunningham is a member of Eta Kappa Nu.



TECHNIQUES FOR MEASUREMENTS AT UHF

By **LEOPOLD A. HOROWITZ**

Black and White Television Engineering
RCA Victor Television Division
Cherry Hill, N. J.

THE ULTRA-HIGH-FREQUENCY spectrum extends from 300 to 3,000 megacycles, with corresponding wavelengths in free space ranging from 100 to 10 centimeters. In designing electronic equipments for operation at these frequencies one finds that the size of components often exceeds the dimensions of a wavelength in this frequency interval. Correspondingly, it can be seen that measurement of circuit parameters requires some rather specialized techniques.

To illustrate this point, at frequencies somewhat lower than UHF, circuit parameters such as resistance, inductance and capacitance are considered as appearing in lumped form. But at UHF, these parameters appear in distributed form because of the relative component size with respect to wavelength. Voltage and current consequently vary not only as a function of time but also with physical position.

The change from lumped to distributed circuitry is gradual as frequency increases, and as a result both types must be employed in circuit design at the lower end of the UHF spectrum.

The measurement techniques considered in this paper are of a general nature and apply to the whole of the UHF spectrum. However, emphasis is placed on techniques associated with the design of r-f tuners for the UHF Television Band, from 470 mc to 890 mc.

IMPEDANCE MEASUREMENTS

Due to the relatively wide frequency range of the UHF spectrum, there is a considerable variety of components differing in size, form, and application. Measurements of coaxial elements are relatively simple, since radiation and stray capacity effects are negligible. For other types of components, shielding may be necessary in order to reduce radiation losses and the influence of unpredictable surroundings. Frequently measurements are complicated by the inherent construction of the device. UHF amplifiers are built, in general, in a form that permits connection to the tube elements with short leads. Some tubes have enough inductance and capacitance due to pins and socket construction to form a complicated network. Measurements of the input impedance under those circumstances becomes quite difficult. A different but not less complicated problem is the measurement of the r-f impedance of a UHF mixer diode. It is a function of the injected power from the local oscillator, the conversion loss, the termination at image and intermediate frequency. In this application the diode with its two terminals has an equivalent circuit representation of a six-terminal network.

Slotted Line

The slotted line is a device that is adaptable for accurate impedance measurements over a wide frequency range. It consists of a uniform transmission line of finite length. The characteristic impedance is given by the following relationship of inductance and capacitance per unit length:

$$Z_o = \sqrt{\frac{L}{C}} \qquad (1)$$

where Z_o = characteristic impedance, L = inductance/unit length, and C = capacitance/unit length.

A movable probe samples the field along the line. The probe is provided with a high-frequency detector and the rectified voltage is a measure of the field distribution. To register the position of the probe in respect to the load, a calibrated scale is added parallel to the transmission line. A signal source and the measured specimen are connected to the opposite ends of the line.

The voltage distribution on the transmission line is determined by the load. The resulting ratio of the maximum to minimum voltage defined as VSWR (voltage standing wave ratio) and the distance of either extreme from the load permit an evaluation of the unknown impedance.

Standard connectors, normally 50 ohms, are provided at either end of the slotted line. Several factors limit the accuracy of measurements: con-

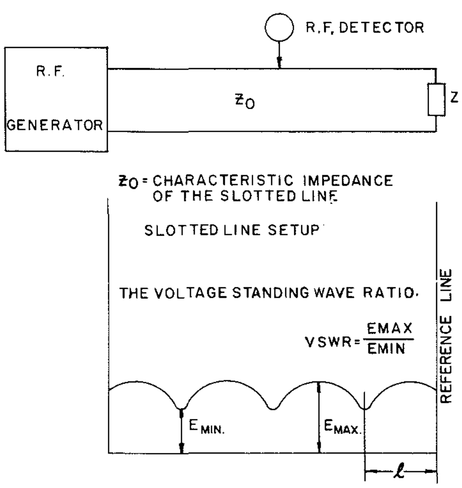


Fig. 1—Measurements on a slotted line

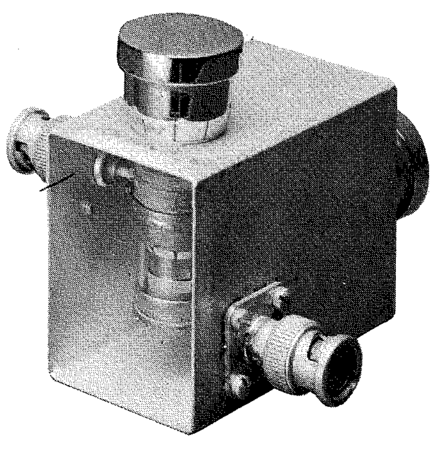


Fig. 2—A UHF universal impedance matching transformer for coupling non-standard impedances

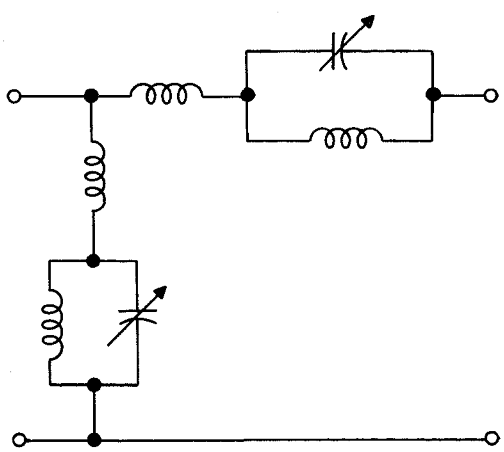


Fig. 3—L-section of the universal impedance transformer

nectors, loading of the line by the detector probe, characteristic of the detector, and mechanical stability of the line. The slot in the line effects a change in characteristic impedance, since it reduces the capacitance per unit length. In lines of special construction, the field change due to the slot is negligible.

The Admittance Meter

The admittance meter is a bridge type measurement device. It consists of four short coaxial sections joined together at one point. The unknown admittance is connected to the end of one section and a conductance standard and susceptance standard to the ends of two other connectors. A signal generator coupled to the fourth section supplies radio-frequency energy to the other three branches. Three loops sample the fields in the unknown and reference branches. The combined output from the loop probes is detected and a zero output, obtained by rotating the coupling loops, indicates a balance of fields due to unknown and reference admittances. Scales associated with each loop permit a direct reading of the unknown admittance.

The Z.D.U. Z-g Diagraph

Impedance measurements with slotted line or admittance meter are time consuming. The *Z-g* diagraph is an impedance measuring instrument which permits direct reading of the measured components without computation or calibration of the equipment. The result of measurements is displayed on a Smith chart, located on the front panel of the instrument. The principle of operation is based on the use of directional couplers. Two couplers, one for the reference cable, the other for the line terminated with the unknown impedance are employed.

Transformers

The most frequently used coaxial elements in the UHF band have a 50-ohm nominal impedance. They are provided with proper connectors designed for ease of assembly and low VSWR; but other impedances are not uncommon, like 75-ohm unbalanced or the 300-ohm balanced line, popular in the TV UHF band. Disregarding the physical difficulty of joining connectors, which differ in types and nominal impedance, a serious mismatch or unbalance would result from connecting them without proper matching elements. At low frequencies, transformers are used for impedance transformation. They are also used in UHF although the physical appearance and principle of operations are often different. Transformers that permit the connection of balanced and unbalanced impedances are called baluns.

Quarter Wavelength Transformer

The input impedance Z_i of a lossless transmission line is:

$$Z_i = Z_o \frac{Z_l \cos \beta l + jZ_o \sin \beta l}{Z_o \cos \beta l + jZ_l \sin \beta l} \quad (2)$$

where $\beta = \frac{2\pi}{\lambda}$
λ = wavelength
l = length of the transformer line
Z_o = characteristic impedance of the transmission line
Z_l = load.

If the line has a length equal to an odd integral number of quarter waves, then

$$Z_i = \frac{Z_o^2}{Z_l}.$$

To match two impedances Z_1 and Z_2, the quarter-wave matching section should have a characteristic impedance equal to the geometric mean of the two impedances to be connected.

$$Z_o = \sqrt{Z_1 Z_2} \quad (3)$$

A quarter-wave line is frequency selective, since its electrical length is a function of frequency. The quarter-wave transformer loaded with pure resistance R_l has a Q factor

$$Q = \frac{\pi}{4}\left(r_v - \frac{1}{r_v}\right) \quad (4)$$

where $r_v = \frac{R_l}{Z_o} =$ VSWR.

The bandwidth of this transformer can be increased considerably by the use of multiple section construction.

Universal Impedance Transformer

The quarter-wave transformer is practical for restricted impedance ratios and levels. A practical transformer which permits matching or coupling of non-standard impedances in a frequency range from 490-900 mc is shown in Figs. 2 and 3. It employs two "L" sections with reactive components. The limited range of the variable capacitor is extended by the use of series and parallel inductances, permitting each arm of the "L" transformer to vary its impedance to a very high value at parallel resonance and low value at series resonance. Each extreme depends on the Q factor of the circuit elements. The range

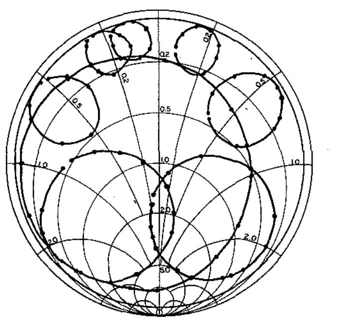


Fig. 4—Transformation Region for the impedance matching transformer

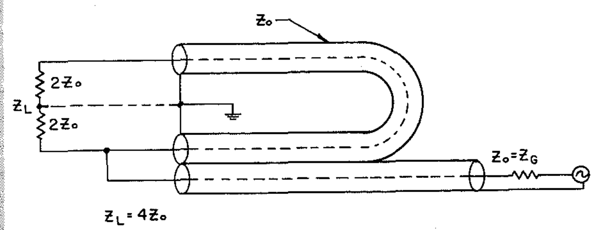


Fig. 5—Half-wave balun

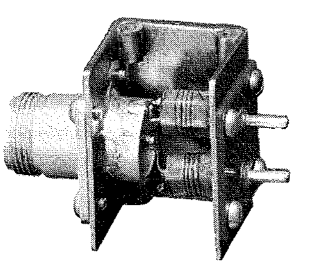


Fig. 6—A broad-band impedance transformer for UHF

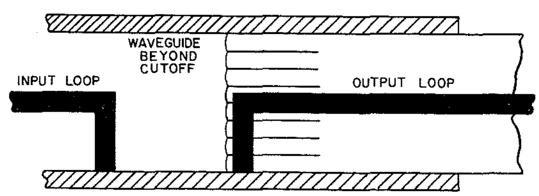


Fig. 7—Piston attenuator

A NEW METHOD FOR ETCHING COPPER

by
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THE CUPRIC-ION-ACID process described in this paper is a new method for etching copper in which a constant etching rate can be maintained indefinitely. This process employs conventional etching equipment, but uses an acidified solution of cupric chloride rather than fresh ferric chloride in the etching bath. The new method eliminates the sludge ordinarily accumulated during the etching process and, consequently, the "down time" usually required for cleaning the etching equipment. Because the cupric ion is formed continuously during the process, etching characteristics of the bath can be kept constant by the periodic addition of a suitable acid.

BACKGROUND

For at least one hundred years, the process for etching copper has involved the use of an unregenerative etching bath of ferric chloride. More efficient etching machines have been built, and purer and less expensive ferric chloride has been developed, but the fundamental method has remained the same.

The detailed reactions of ferric chloride with copper are still not completely known. It is known, however, that an oxidation-reduction reaction takes place in which free copper is oxidized to the cuprous ion and iron is reduced from the ferric to the ferrous state. It was, therefore, thought possible to regenerate the spent etching bath with an easily controllable oxidizing agent such as gaseous chlorine. Accordingly, an investigation into the reactions and mechanisms involved in setting up a completely automatic regenerating system for a ferric-chloride etching bath was started.

Among the many things learned, the following two items seemed to be the most important:

(1) It is theoretically possible to set up a completely automatic system for etching copper by a regenerative ferric chloride bath, and several parameters of such a system have been determined. Such a system is quite complex, however, because of the variations in the reactants and the products. The products are various hydrated compounds of both copper and iron in different oxidation states. The process requires close control of the chlorine supply as a function of the pH of the bath and continuous filtration to remove sludge from the bath.

(2) The amount of copper etched by a given ferric chloride bath is considerably in excess of that predicted by the stoichiometric values of the postulated reactions.

The latter fact has been known for some time, and many etchers have prolonged the life of the etching bath by the addition of free hydrochloric acid. Acid can be added only once, as a rule, because of the accumulation of sludge in the bath. It was decided to investigate this limited regeneration of the etchant bath more thoroughly.

EXPLORING THE PROBLEM

Several hypotheses were advanced to account for this increase in etchant life. Of these, the following two seemed to be the most logical:

(1) air oxidation of the ferrous ion to the ferric state, influenced by the pH of the solution as modified by the addition of the acid,

(2) effect of other ions present in the solution as influenced by the change in pH.

It has been shown previously that gaseous chlorine would oxidize the ferrous ion to the ferric state. The effect of air was tested by bubbling oxygen through ferrous chloride solutions of varying acid concentrations, and testing the resulting solutions on copper. No regeneration of the etchant bath could be obtained with oxygen. These results showed that the first hypothesis was untenable.

The second hypothesis received a great deal of study. If a system could be devised whereby an ion other than iron could be used, the regeneration of the etchant might possibly be accomplished without the complexity that had been found for the ferric chloride system. Therefore, the various ions present in the spent bath were determined and simple solutions of these various ions were prepared. These solutions were then carefully checked for their effect on copper in pure water and in hydrochloric acid of varying concentrations.

It was found that a solution containing a concentration of the cupric ion of approximately 100 grams per liter and a hydrochloric-acid concentration of approximately 125 grams per liter etched copper at a rate equivalent to that of fresh ferric chloride.

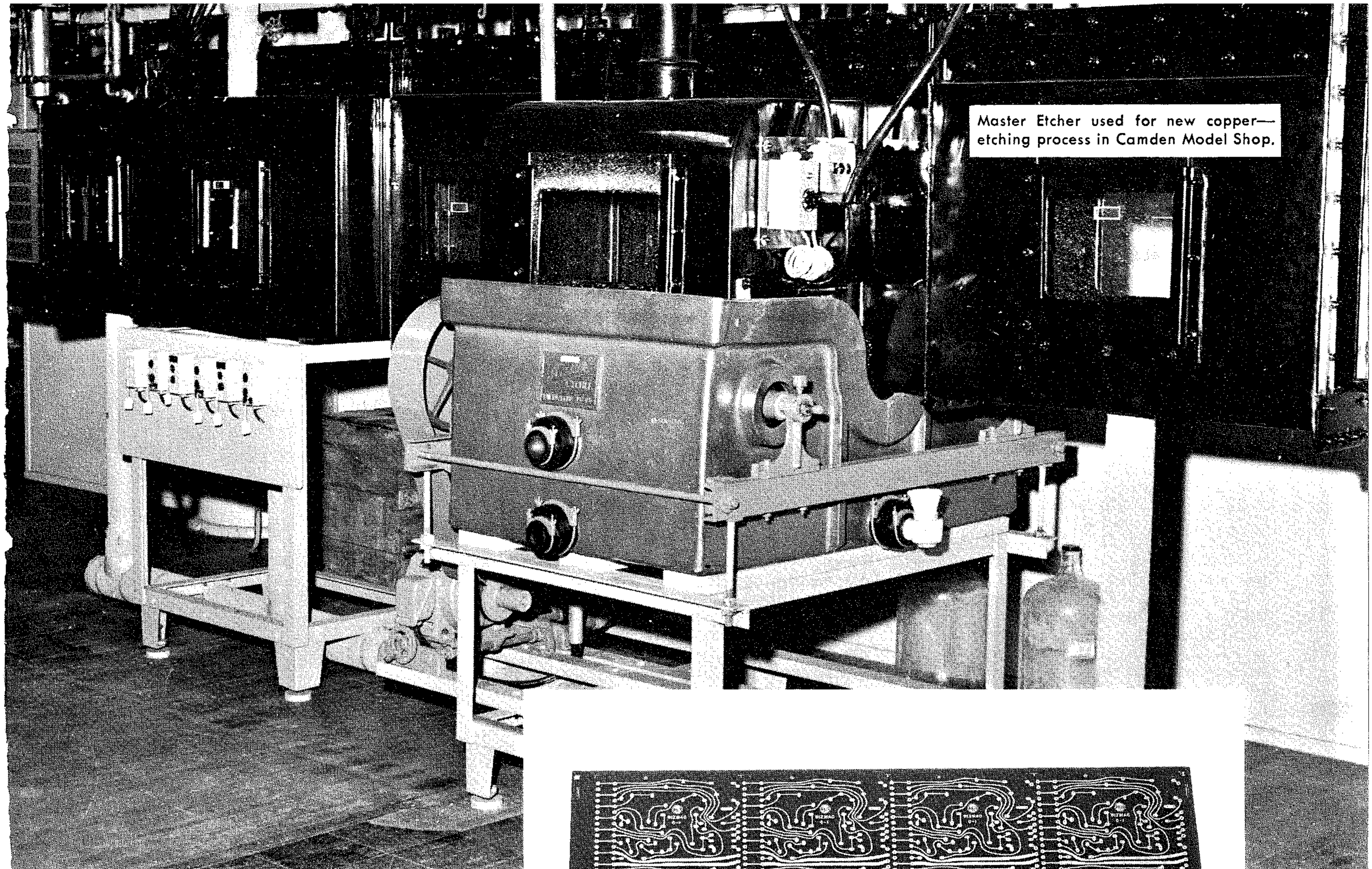
Experiments with this solution determined that the cupric ion was reduced to the cuprous state, and the copper was oxidized to the cuprous state. The surprising part of the reaction was that, with continued use, the cuprous ion was oxidized back to the cupric state. Only a small amount of the copper, 20 per cent or less, remained in the cuprous state. This percentage was found to depend on rate of use, acid concentration, and copper concentration.

THE NEW SYSTEM

Spontaneous re-oxidation of the cuprous to the cupric ion showed the way to the development of a simple regenerative system for etching copper. In this system, the only metal ion present is copper. No sludge is formed, because both cuprous and cupric chloride are quite soluble in acid. The only reagent that has to be added is hydrochloric acid, which is necessary to maintain the proper hydrogen-ion concentration. The cupric ion maintains itself.

Further investigation showed that there is an optimum range of cupric-ion concentration, and that the rate of etching is roughly proportional to the hydrogen-ion concentration. The upper limit of acid concentration is determined by other factors, such as fuming and the effect on materials other than copper which may be present.

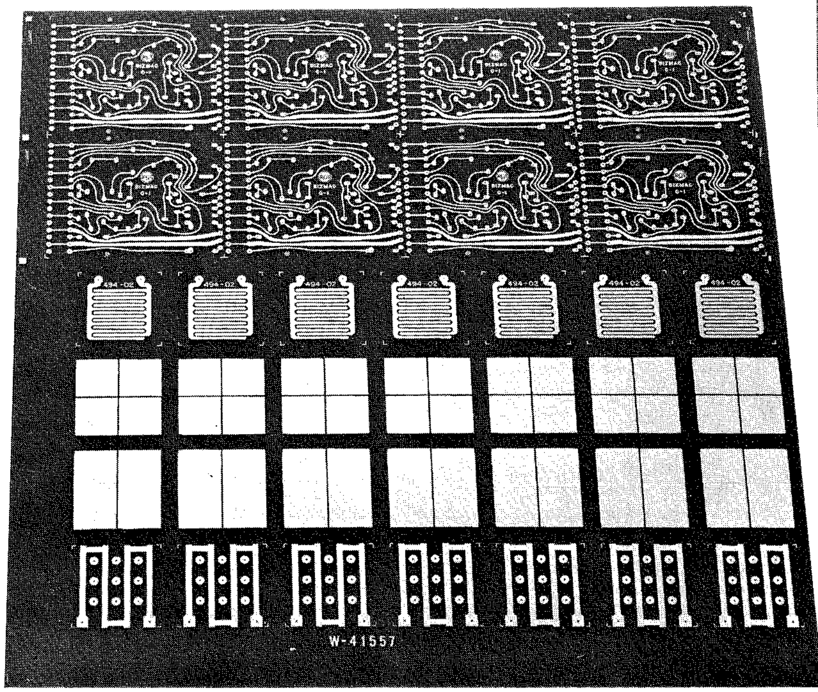
For a pilot-plant run, an acid concentration of about 150 grams per liter and a cupric-chloride concentra-



Master Etcher used for new copper—etching process in Camden Model Shop.

tion of 200 grams per liter were chosen. Hydrochloric acid was selected because it is inexpensive (approximately 3.1 cents per pound in 140-pound carboys), easily handled, and readily obtainable. Cupric chloride was chosen to furnish the cupric ion so that the chloride ion would be common to the acid and the salt.

The pilot plant has been in operation in the Printed Circuit Model Shop since July 10, 1956, and no difficulties have been encountered. The etching rate has been maintained at less than three minutes for 0.00135-inch-thick copper foil. Three liters of etching solution are removed and two liters of concentrated hydrochloric acid plus one liter of water are added for every ten 18-by-18-inch boards. This process keeps the volume of the etchant bath constant, and decreases the cupric-ion concentration at a rate that just matches the rate of concentration increase due to the formation of more cupric ions. The cupric ion maintains itself in the optimum concentration range, and the fresh hydrochloric acid maintains the hydrogen ion constant. "Drag-out" of the solution by the boards is made up by the addition of a solution of acid and water having the same concentration.

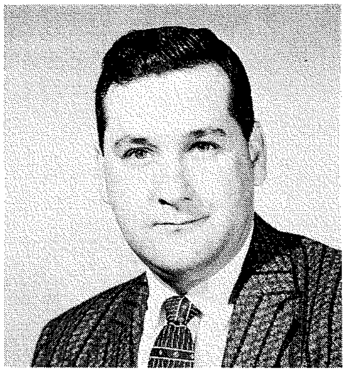


Phenolic board containing typical printed circuit etched by new cupric-ion-acid process.

Thorough testing has shown that the quality of the etch is equivalent to that of ferric chloride, and that the concentration of hydrochloric acid presently used has little or no effect on the phenolic board itself. It is necessary, however, to wash the boards very thoroughly to remove all traces of acid. The pumice scrubbing needed to remove the photosensitive resist and a one-hour soaking in clean running water have been found sufficient.

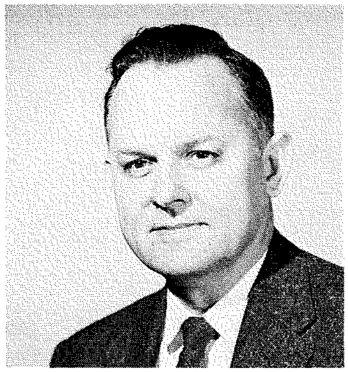
THERMODYNAMICS OF THE REACTION

The thermodynamics of the over-all reaction can be investigated by postu-



LEONARD H. CUTLER received the B.S. in Chemistry in 1949 from the Philadelphia College of Pharmacy and Science, and the M.S. degree in Physical Chemistry in 1950 and the Ph.D. degree in Physical Chemistry in 1952 from the University of Delaware. He held a Research Fellowship at the University of Delaware from June 1949 to July 1952. From July 1952 to December 1953 he was employed by the U. S. Steel Corporation in Pittsburgh, Pa., as an electrochemist working on problems involving the corrosion of metals, underground cathodic protection, and electrochemical methods of analyzing oxide films on tin plate. In December 1953 he joined the Chemical and Physical Laboratory of RCA at Camden, New Jersey and has worked on such projects as the development of a new copper-etching solution for printed circuits. Since November 1956 he has worked on the development of an N-halogen reserve battery for the Signal Corps as Senior Project Engineer. He has presented several technical papers at society meetings, had a number of technical articles published, and has several patent disclosures which are now being processed.

Dr. Cutler also served in the U. S. Navy from March 1943 to January 1946, and was honorably discharged with the rank of Electronics Technician's Mate First Class.



OTIS D. BLACK received the B.A. degree in 1938, the M.Sc. degree in 1939, and the Ph.D. degree in 1942, all from Ohio State University, his field of specialization being Physical Chemistry.

Upon graduation, he joined RCA in the Chemical and Physical Laboratories in Camden as a research and development engineer. He has been engaged in a number of studies involving plastics, ceramics, rubber, and allied fields, mycology, as well as mathematical analyses of various problems. For the past several years he has been primarily engaged in research and development of materials and processes involved in the manufacture of printed circuits.

Dr. Black has contributed to various technical publications and has a number of patents, either granted or in process. He is a member of Sigma Xi, Phi Beta Kappa, and Phi Lambda Upsilon.

lating a mechanism for the reactions involved. Such a mechanism might be as follows:

$$Cu^{++} + Cu^{\circ} \xrightarrow{acid} 2\,Cu^{+}$$

$$2\,Cu^{+} + \tfrac{1}{2}\,O_2 \xrightarrow{acid} 2\,Cu^{++} + O^{=}$$

$$2\,H^{+} + O^{=} \longrightarrow H_2O$$

When these reactions are added, the over-all reaction obtained is:

$$Cu^{\circ} + \tfrac{1}{2}\,O_2 + 2\,H^{+} \xrightarrow[(Cu^{++})]{(acid)} Cu + H_2O$$

Note: It is probable that in strong hydrochloric acid the cupric ion is bound to four chloride ions to give the complex ion $(Cu\,Cl_4)^{=}$. The over-all reaction would then be:

$$Cu^{\circ} + \tfrac{1}{2}\,O_2 + 2\,H^{+} + 4\,Cl^{-} \longrightarrow (Cu\,Cl_4)^{=} + H_2O$$

This reaction would not appreciably change the thermodynamic considerations.

Quantitative measurements show that the amount of acid used is correct for the above equation. If this equation is correct, the steps in the process are not important and the free energy of the reaction can be determined by use of steps for which the free energies are known.

The reactions and free energies in Table I are taken from Latimer[1]

Under the right conditions, therefore, the reaction as written will occur, and will have a fairly large driving force in the right direction. Thermodynamically, the intermediate steps are unimportant. The necessary conditions seem to be the presence of a sufficient concentration of cupric and hydrogen ions.

COMPARATIVE COST

A cost comparison of the ferric-chloride process with the cupric-ion-acid process shows a decided advantage for the latter. The cost of etching an 18-by-18-inch copper-clad phenolic board in the Master Etcher in the Model Shop by the ferric-chloride process is about 55 cents. The cost of an equivalent etching by the cupric-ion-acid process is about two cents. The following cost-comparison data are for the particular type of etching system used in the Camden plant. It is recognized that there are counter-current, flow-type etching systems used in which no down-time at a given time interval is required for cleaning the etching equipment. However, the cost comparison for the raw materials, ferric chloride, and hydrochloric (muriatic) acid is valid.

	Ferric Chloride	*Cupric Ion-Acid*
Etchant, per board	\$0.10	\$0.02
Cleaning etcher..	0.45	0.00
Down time......	4 hr/100 boards	None
Recovery of by-products...	None	Possible

The by-product of the process is an acid solution of copper chloride, comprising about 30 grams per liter of cuprous chloride and 190 grams per liter of cupric chloride. As the solution stands, some of the cuprous chloride oxidizes to the cupric state. This by-product has a definite market value which is undetermined at the present time and which will depend somewhat on the amount produced.

SIGNIFICANCE

The use of this process is not limited to the manufacture of printed circuits. It is applicable to any process for etching copper in which ferric chloride is used. It can find wide application in the photoengraving trade because it is simple, straightforward, clean, and economical. The process can easily be made completely automatic by the addition of equipment to remove solution and add acid at controlled intervals.

1. Oxidation Potentials, W. M. Latimer, Prentice Hall Book Co., 1952.

TABLE I

(1) $\tfrac{1}{2}\,O_2 + \tfrac{1}{2}\,H_2 + e^{-} \longrightarrow OH^{-}$ $\quad \Delta F = -37{,}595$ cal.

(2) $2\,H^{+} + 2\,OH^{-} \longrightarrow 2\,H_2O$ $\quad \Delta F = -38{,}187$

(3) $H_2 + \tfrac{1}{2}\,O_2 \longrightarrow H_2O$ $\quad \Delta F = -56{,}690$

(4) $Cu^{\circ} \longrightarrow Cu^{++} + 2\,e^{-}$ $\quad \Delta F = 15{,}530$

By doubling (1), adding to (2) and (4), and subtracting (3), the equation obtained is:

$$Cu^{\circ} + \tfrac{1}{2}\,O_2 + 2\,H^{+} \longrightarrow Cu^{++} + H_2O \quad \Delta F = -41{,}387 \text{ cal.}$$

SOUND REPRODUCING SYSTEMS DEFINED

Monaural Monophonic Binaural Stereophonic

By

DR. HARRY F. OLSON

RCA Laboratories

Princeton, N. J.

THERE ARE LARGE NUMBERS of different types of systems employed for the reproduction of sound. In this connection, sound reproducing systems in use today may be classified as follows: monaural, binaural, monophonic and stereophonic. There appears to be considerable confusion in the proper use of these terms in designating the four fundamental types of sound reproducing systems. The result is an almost indiscriminate application of the terms to unrelated systems. Therefore, it is the purpose of this paper to define and describe the characteristics of monaural, binaural, monophonic and stereophonic sound systems.

A MONAURAL SOUND SYSTEM is a closed circuit type of sound reproducing system in which one or more microphones, used to pick up the original sound, are connected to a single transducing channel which in turn is coupled to one or two telephone receivers worn by the listener. (Fig. 1.)

A BINAURAL SOUND SYSTEM is a closed circuit type of sound reproducing system in which two microphones, used to pick up the original sound, are each connected to two independent corresponding transducing channels coupled to two independent corresponding telephone receivers worn by the listener. (Fig. 2.)

A MONOPHONIC SOUND 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 (Fig. 3).

A STEREOPHONIC SOUND SYSTEM is a field type sound reproducing system in which two or more microphones, used to pick up the original sound, are each coupled to a corresponding number of independent transducing channels which in turn are each coupled to a corresponding number of loudspeakers arranged in substantial geometrical correspondence to that of the microphones (Fig. 4).

Following the definitions of monaural, binaural, monophonic and stereophonic sound[1] the next consideration will be a description of some of the characteristics of the four systems.

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 without frequency discrimination all of 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 should be approximated in the reproduced sound.
4. The spatial sound pattern of the original sound should be preserved in the reproduced sound.

A schematic diagram of a monaural sound reproducing system is shown in Fig. 1. The most common example of a monaural sound reproducing system is the telephone in which there is, in general, a single source of sound, one microphone, a transducer and one telephone receiver coupled to one ear of the listener. In most local applications, the carbon microphone is coupled directly to the telephone receiver. In long distance telephony, vacuum tube and transistor amplifiers may be used between the microphone and telephone receiver. For other more limited applications, as for example, monitoring purposes, the transducer may be a radio transmitter and receiver, a television sound transmitter and receiver, a disc phonograph recorder and reproducer, a sound motion picture recorder and a reproducer and/or a magnetic tape recorder and reproducer. In some applications, there may be more than one sound source. One or more microphones may be used. In some applications two telephone receivers may be used, transmitting the same program to each of the ears of the listener. The monaural sound reproducing system is of the closed-circuit type in which the ear of the listener is transferred to a microphone location by means of the microphone, transducer, and telephone receiver combination. The acoustics of a single room are involved in the reproduction of the sound, namely, the studio in which the microphone is located. The monaural sound reproducing system may be constructed so as to satisfy conditions 1, 2 and 3 on realism of sound reproduction. It cannot, under any conditions, satisfy condition 4.

A schematic diagram of a binaural sound reproducing system is shown in Fig. 2. There is no widespread use of the binaural sound reproducing system. The use is limited to specific applications. The binaural sound reproducing system consists of two separate channels. Each channel consists of a microphone, transducer and telephone receiver. The microphones are mounted in a dummy simulating the human head in shape and dimensions and at the locations corresponding to the ears of the human head. The transducer may be an amplifier, a radio transmitter and receiver, a television sound transmitter or receiver, a phonograph recorder and reproducer, a motion picture recorder and repro-

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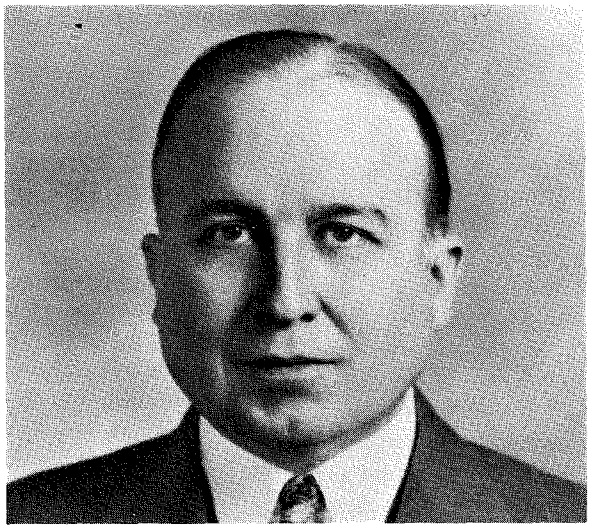
1. The definitions of the terms monaural, binaural, monophonic and stereophonic, as defined, substantially agree with those of modern dictionaries. In addition, the terms binaural and stereophonic as defined in this paper have been standardized. As a result, the incorrect usage of binaural to designate a stereophonic system is disappearing. Monaural is still incorrectly used to designate a single channel field type sound reproducing system. Monophonic is a relatively new term, which has been introduced to supply a void in terms to describe the four fundamental sound systems. Monophonic and stereophonic are harmonious and congruent terms which complement each other and have a common relationship in describing field type sound systems. Monaural and binaural are also harmonious and congruent terms which complement each other and have a common relationship in describing closed circuit type sound systems. In view of the agreement with dictionary definitions and the preceding logic, it is only a question of time until all of the terms will become standardized.

reproducer, a sound motion picture recorder and reproducer, a television transmitter and receiver, and/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.

A schematic diagram of a stereophonic sound reproducing system is shown in Fig. 4. The stereophonic sound reproducing system is the field type. Sound is picked-up by two or more microphones coupled to a corresponding number of independent transducing channels, which in turn are coupled to corresponding number of loudspeakers arranged in substantial geometrical correspondence to that of the microphones. 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, and/or a magnetic tape recorder and reproducer. Two channels are used in the disc phonograph and radio. Two and three channels are used in the magnetic tape reproducer. Two, three and more channels are used in sound motion picture reproducers. 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. Stereophonic sound is rapidly being commercialized. The first wide-scale use was in sound motion pictures. This was followed by the magnetic tape reproducer. The stereophonic disc phonograph will be commercialized this year. Experiments are now being conducted in the transmission and reproduction of stereophonic sound by means of a radio system. In one arrangement, the two channels are transmitted on two separate radio links, one by a frequency modulation system and the other by an amplitude modulation system. In another arrangement, the two channels are transmitted and reproduced by a multiplex frequency modulation system.

To summarize: The four fundamental types of sound reproducing systems (monaural, binaural, monophonic and stereophonic) have been defined and described in this paper. The terms monaural and binaural are used to designate closed circuit type sound reproducing systems. The terms monophonic and stereophonic are terms used to designate field type sound reproducing systems. Monaural and binaural (or monophonic and stereophonic) are mutually harmonious and congruent terms which complement each other in describing closed circuit type (or field type) sound reproducing systems. The definitions as presented in this paper substantially agree with modern dictionaries. The terms binaural and stereophonic have been standardized. In view of this and the logic presented in this paper it is only a question of time until all four terms, monaural, binaural, monophonic and stereophonic are standardized.



HARRY F. OLSON received the B.S. degree in 1924, the M.S. degree in 1925, the Ph.D. degree in 1928 and the E.E. degree in 1932 from the University of Iowa. From 1928 to 1930 he was in the Research Department of Radio Corporation of America; from 1930 to 1932, in the Engineering Department of RCA Photophone; from 1932 to 1941, in the Research Division of RCA Manufacturing Company; since 1941, with the RCA Laboratories. He is Director of the Acoustical and Electromechanical Laboratory of the RCA Laboratories.

One of Dr. Olson's early contributions during his career with RCA was the velocity microphone, the first microphone with uniform directivity, which became standard for broadcasting use. Subsequently, he pioneered in several other directional types of microphones, including the uni-directional types now used in television broadcasting and sound motion picture filming. He also has made pioneering contributions to loudspeaker development, including the duo-cone speaker for high fidelity sound reproduction, and to the development and improvement of phonograph pickup and recording equipment, underwater sound equipment, and sound motion picture and public address systems. In addition, he has guided and contributed substantially to the development of electronic noise reducers, stereophonic sound systems, magnetic tape recorders for sound and television, the electronic music synthesizer, and the phonetic typewriter.

He was a lecturer in Acoustical Engineering, Columbia University, New York City, from 1939 to 1943.

Dr. Olson is a member of Tau Beta Pi and Sigma Xi. He is a Fellow of the Society of Motion Picture and Television Engineers, the American Physical Society, the Institute of Radio Engineers, the Acoustical Society of America, and the Audio Engineering Society. He is a past president of the Acoustical Society of America. He is a past chairman of the Administrative Committee of the IRE Professional Group on Audio.

He holds more than 80 U.S. Patents. He is the author of 75 papers and the books, "Elements of Acoustical Engineering," "Acoustical Engineering," "Dynamical Analogies," and "Musical Engineering."

For his contributions in the field of audio engineering, Dr. Olson has received the following honors: the Modern Pioneer Award of the National Association of Manufacturers in 1940, the John H. Potts Medal of the Audio Engineering Society in 1952, the Samuel L. Warner Medal of the Society of Motion Picture and Television Engineers in 1955, the John Scott Medal of the City of Philadelphia in 1956, and the Achievement Award of the Professional Group on Audio of the Institute of Radio Engineers in 1956.

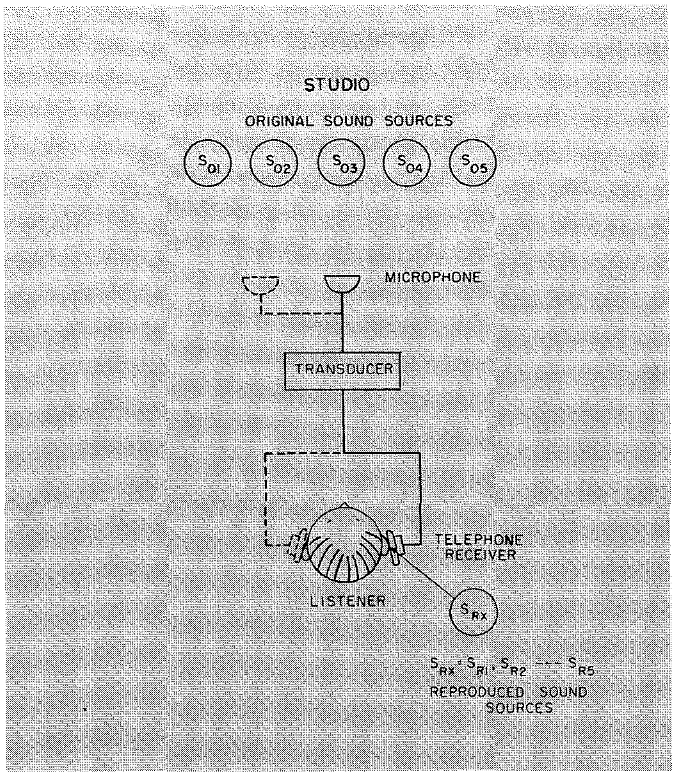


Fig. 1—A schematic diagram of a monaural sound reproducing system consisting of one or more microphones connected to a single transducer which in turn is coupled to one or two telephone receivers worn by the listener.

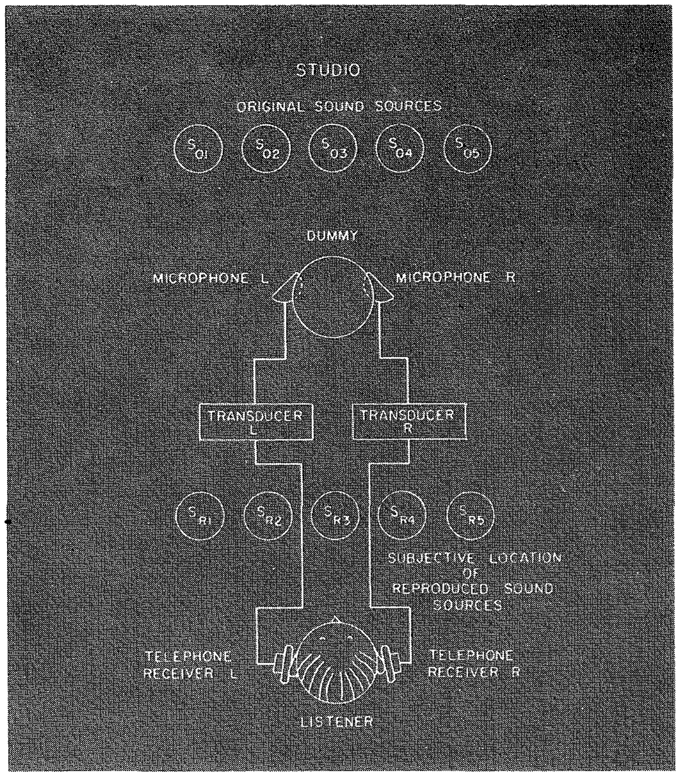


Fig. 2—A schematic diagram of a binaural sound reproducing system consisting of two channels, each channel consists of a microphone, transducer and telephone receiver.

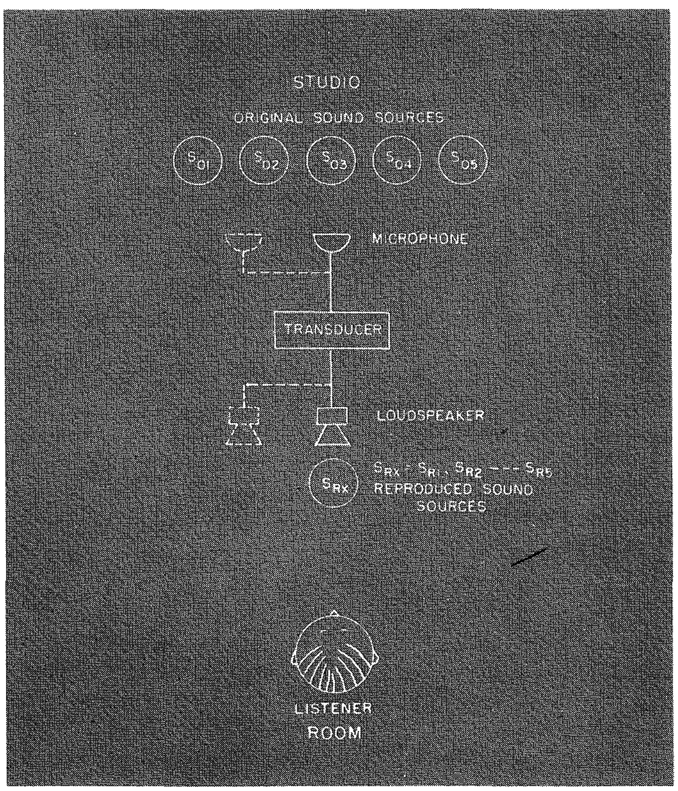


Fig. 3 — A schematic diagram of a monophonic sound reproducing system consisting of one or more microphones connected to a single transducer which in turn is coupled to one or more loudspeakers.

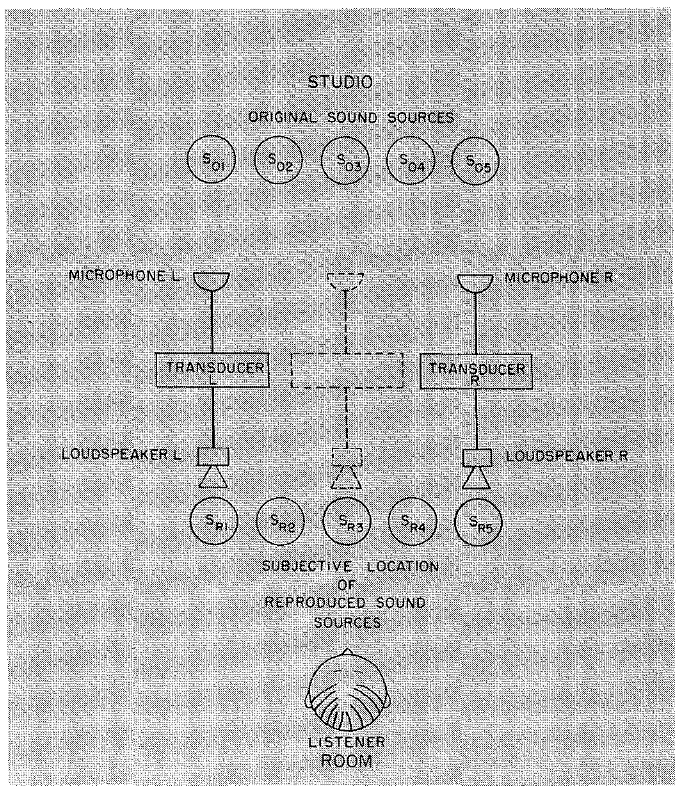


Fig. 4—A stereophonic sound reproducing system consisting of two or more channels, each channel consists of a microphone, transducer and loudspeaker.

ETA KAPPA NU

by
FRANCIS J. HERRMANN
Manager, Scientific Instruments
Industrial Electronic Products
Camden, N. J.

FOR THOSE READERS who have had no previous knowledge of the Eta Kappa Nu, perhaps the best introduction is to quote from the preamble to its constitution.

"That those in the profession of Electrical Engineering, who by their attainments in college or in practice, have manifested a deep interest and marked ability in their chosen life work, may be brought into closer union so as to foster a spirit of liberal culture in the engineering colleges . . . and to mark in an outstanding manner those who, as students in electrical engineering, have conferred honor on their Alma Maters by distinguished scholarship, activities, leadership and exemplary character . . . and to aid these students to progress through association with alumni who have attained prominence, we do hereby ordain and establish the following Constitution."

Eta Kappa Nu was founded in 1904 at the University of Illinois. Until 1935, its growth was relatively slow, averaging less than one chapter a year. Between 1935 and the present this rate of growth has nearly tripled, reaching a total of 79 chapters (College and Alumni).

LOCAL AND ALUMNI CHAPTERS

The *local chapters*, within the framework of the Association's Constitution, are autonomous. The experience gained by members in conducting their chapter affairs and directing its activities is part of the broad "living" experience needed to develop these men and women who are being trained for broad technical and administrative responsibilities. Local chapters are active in a wide variety of "campus-community" projects. These vary from serious services such as organizing slide-rule classes, and operating tutoring services for students needing assistance . . . to activities such as assisting at school "open houses," and social gatherings.

Alumni Chapters provide the means for the Eta Kappa Nu member, after graduation, to extend service to his profession and the Community at large through continued activity within the Association. The member, who strengthens an Alumni Chapter through serving others, ultimately benefits himself. The Chapter gatherings provide the occasion to meet fellow electrical engineers on a social plane, as well as for purposes of technical discussions concerning professional engineering problems.

MEMBERS AND EMINENT MEMBERS

The Association's activities are presently carried on through sixty-seven college chapters and twelve alumni chapters (alumni chapters do not have the power to confer membership). The membership which is approaching the thirty thousand mark consists of two classes which are designated as members and eminent members.

To be eligible *for induction as a member*, a candidate must be either a student at an institution having a chapter, a teacher or administrator at a recognized school or an Electrical Engineer who has done meritorious work in practice of his profession. Juniors in Electrical Engineering curricula must be ranked in the upper quarter of their classes to be eligible for election while Seniors must be in the upper third in order to be considered. With proper qualifications Graduate Students may be elected.

Eminent membership is reserved for outstanding leaders in the field of electrical engineering. In order to be eligible for eminent membership, the candidate must be counted among the great benefactors of mankind. Our own Dr. Vladimir K. Zworykin was so honored. Dr. Vannevar Bush and Dr. Lee de Forest are two other typical eminent members of the Association.

ADMINISTRATION

Affairs of the Association are administered at the "National" level through officers serving on the National Executive Council and the Board of Directors. Their acts are subject to review by a National Advisory Board whose members are elected by the various Chapters.

Annual elections are held by mail ballot, and Conventions are held by actual assembly every five years. In this way, all important questions are decided or ratified. Thus guided and helped by his teachers and by the older established members of his profession, the young electrical engineer is introduced to parliamentary procedure and "Democracy in Action." In this world, one of whose features is the growing participation of the engineer in public life, more and more of this experience should be made available to students.

BENEFITS ARE NUMEROUS

Continued contacts between Alumni Chapters and undergraduates, individually, or on a "chapter-to-chapter" basis, benefit both parties. On the one hand, alumni gain a better understanding of the youthful viewpoint with its refreshing, original thinking. On the other hand, undergraduates benefit from the mature attitudes and experience of the older graduates.

Alumni Chapters implement these contacts by supplying speakers, who are specialists in their fields, to College Chapters. Ladies' Auxiliaries are among the many innovations which have developed as a result of social programs. Successful dinners, picnics, dances and other social functions provide a lighter and extremely pleasant side to Chapter activities.

EDUCATIONAL MOVIE AVAILABLE

The activities of Alumni Chapters range over a broad spectrum. One Alumni Chapter helped in guiding the production and handled distribution of a movie, "Engineering—A Career for Tomorrow." This film presents the factual side of the profession to students considering the study of engineering. There have been times, such as during the depression of the thirties, that a great service was performed by Alumni Chapters maintaining employment services for their members.

ASSOCIATION PUBLICATION

The Association publishes a quarterly magazine, "Bridge of Eta Kappa Nu." This magazine, as is also true of the emblem of the organization, is named after the Wheatstone Bridge. The magazine serves as a medium of communication, tying together the far-flung local and alumni chapters, as well as those alumni who are not presently active in any Chapter. In addition, the magazine publishes professional papers of technical importance, and articles of general interest to electrical engineers in their roles as wide awake citizens. Two of the seven articles in the Spring 1958 issue illustrate the wide range of interests. Admiral Rickover writes on "Balance Sheet on Education," while Arthur E. Ruark of the A.E.C. writes on "Thermonuclear Breakthrough."

THE "ETA KAPPA NU" AWARD

Our company like all other large scale employers of professional people recognizes the importance of nationally accepted awards and honors as an incentive to furthering individual and group development. Nothing contributes to satisfaction of individual and group pride in achievement more than such an attainment. One of the most generally sought after awards is the ***Annual Eta Kappa Nu Recognition of Outstanding Young Electrical Engineers.*** This award is made to a young man rather than to an older man who has reached the peak of his success. Its rules provide that the candidate must have been graduated not more than ten years and must not be more than thirty-five years old. Nominations may be made by all accredited colleges, AIEE or IRE sections, and larger employers of E.E. graduates such as RCA. The Jury of Award is appointed from leaders in industry, the profession and in educational institutions.

Robert P. Crago of International Business Machines Corporation's Military Products Division accepted this year's award with obvious humility. Our own Dr. Walter R. Beam of the David Sarnoff Research Center won honorable mention, along with Glenn W. Stagg of American Gas and Electric. Dr. Beam is not the first RCA man to be so honored and we know that the future holds the opportunity for many more of our capable young engineers and scientists to secure this recognition for themselves and their associates.

THE PHILADELPHIA CHAPTER

RCA has many members of the Eta Kappa Nu Association among its engineers. They are contributing in their own way to benefit our country, our company and their engineering profession. But to those members who have not already considered it, the writer would like to point out that all the aforementioned opportunities and many more are available to those obtaining membership in the Philadelphia Alumni Chapter of Eta Kappa Nu. Monthly luncheon meetings are held at the Engineers Club in Philadelphia on the first Wednesday of every month, except during the summer. Please phone the author or address a note to Bldg. 15-5, Camden, for further information.

FRANCIS J. HERRMANN, Manager of Scientific Instruments, joined RCA in 1940 after nine years with a member firm of the New York Stock Exchange and a short period at sea as a marine radio operator. Mr. Herrmann received the B.E.E. degree from the Polytechnic Institute of Brooklyn and the M.S. in E.E. from Drexel Institute of Technology. He is presently a candidate for the M.S. (Physics) at Drexel. He attended company courses as well as courses at M.I.T., N.Y.U. and Columbia.

Starting with RCA as a radio tester, by 1945 he was Supervisor of Test Process Engineering for the Camden plant. From 1945 to 1952 he was with RCA International Division where he worked on the planning of a number of large communications systems. As Manager of Sound, Scientific and Industrial Sales, he designed sound installations for schools, hospitals and many famous luxury hotels.

In 1952 Mr. Herrmann returned to Camden where he is a member of RCA's engineering and marketing team that has carried our Electron Microscope to a new high in scientific acceptance. This same group has worked on a product line of non-destructive test equipment in the fields of diffraction and spectroscopy.

Mr. Herrmann is a senior member of IRE, a member of Electron Microscope Society of America, New York Society of Electron Microscopists and Philadelphia Electron Microscope Society. He is a member of Tau Beta Pi and Eta Kappa Nu. Recently, he was elected Secretary, Phila. Alumni Chapter Eta Kappa Nu.

THE "STRATO-WORLD" ALL-WAVE TRANSISTOR PORTABLE

By

E. CORNET and H. B. STOTT

RCA Victor Radio & "Victrola" Division
Cherry Hill, N. J.

THE RECENT INTRODUCTION of the new "Strato-World" All Transistor Portable marks the successful conclusion of cooperative development and design by the RCA Victor Radio and "Victrola" Division, the RCA Semiconductor and Materials Division, and RCA Laboratories.

Prior to the development of the Strato-World, commercial transistor receivers had been limited to coverage of the broadcast band, since suitable transistors for higher-frequency operation were not available. Design and production of the RCA germanium P-N-P drift transistors (RCA-2N370, -2N371 and -2N372) broke the frequency barrier that previously existed. The new drift transistors for r-f amplifier, r-f local oscillator, and r-f mixer applications, including shortwave bands, are welcome additions to the low-frequency units previously available.

Early development and design programs on the receiver circuitry and on the high-frequency drift transistors were carried on simultaneously, and these parallel efforts were mutually beneficial. Following this, final production of both transistors and receivers proceeded concurrently.

LIGHTWEIGHT AND LOW DRAIN

The final multi-band transistor set, which is housed in a simulated black lizard case, has greater output, weighs less than 15 pounds . . . and represents a considerable reduction in size over its predecessor, a tube portable. The set operates on nine standard flashlight batteries. Reduced battery drain is realized when either of the following two features are in operation; a front-panel earphone jack for personal listening, and a "back-apron" phono-jack that silences radio . . . giving interference-free disc reproduction. A spring loaded switch controls momentary dial illumination for ease in tuning during late evening listening.

GENERAL DESCRIPTION

The new receiver includes 9 transistors in a superheterodyne circuit (see Fig. 1). New transistor circuit developments are shown in later figures which include simplified portions of the receiver circuit.

A tuned r-f stage precedes the separate mixer and oscillator, followed by two i-f stages, a transistor-detector-AGC stage, audio driver and a Class "B" power output stage. The receiver covers seven bands: "A" band (standard broadcast) 540 to 1600 kc; "B" band 2 to 4 mc; "C" band 4 to 8 mc; and also four short-wave spread bands (31, 25, 19, and 16 meters). A large extended slide rule dial contains all the frequency calibrations. A collapsible vertical rod antenna is used for all bands except standard broadcast which employs a large flat loop antenna contained in the front-panel lid.

There are four front-panel controls: a continuously variable low-cut, high-cut, tone control; a compensated loudness control; vernier tuning; and dial lighting.

GOALS ESTABLISHED

The historical success of preceding tube portable receivers (3BX671 and 7BX10 Strato-World types) with proven performance and established features set a definite challenge for the all-transistor, multiband receiver. The objective was to design a transistor receiver, within a competitive price range, and maintain performance characteristics equal to or better than the former tube receivers.

OVERALL DESIGN CONSIDERATIONS

An important criterion in receiver performance, signal-to-noise ratio, is dependent upon the design of the antenna, r-f and mixer stages. Practical as well as theoretical compromises are necessarily involved in determining selectivity, image rejection, stability and sensitivity requirements.

For example, a sensitivity of approximately 25 microvolts-per-meter for a 50-milliwatts listening level is satisfactory for "A" band. Likewise, 2- to 5-microvolts to a short capacitance-type rod antenna is considered ample signal for shortwave bands. There is no need for higher sensitivity because weaker signals are accompanied by fading and poor signal-to-noise ratio.

The detector circuit signal level and its effect on the automatic gain control system are major considerations. The

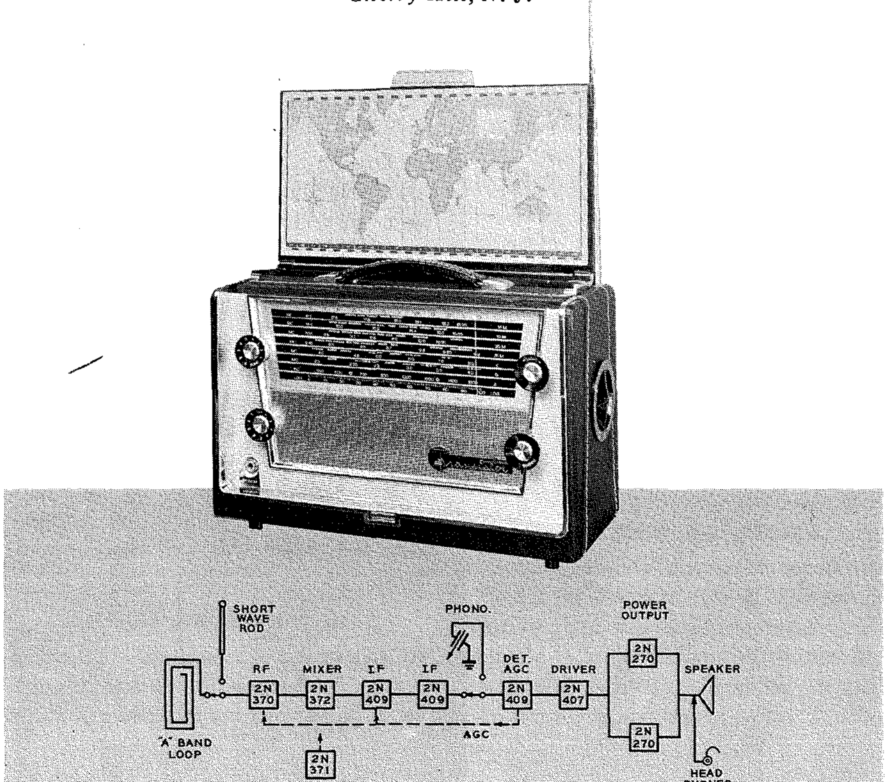


Fig. 1—Receiver Block Diagram (due to complexity and size, the complete schematic is not included). A view of final receiver is inset above.

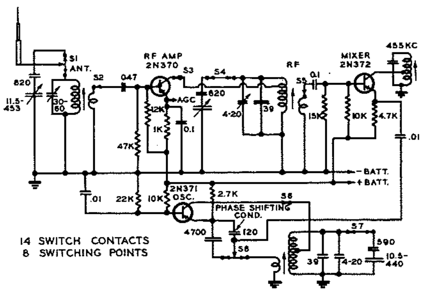


Fig. 2—Schematic showing the "C" Band coil switching. Note that complexity of the transistor 7-band tuner requires eight switching points instead of only four needed in the tube receiver.

2nd and 3rd harmonic tweet interference, detector efficiency and distortion are also influenced by signal level. Volume and tone control circuits assure sufficient loudness adjustment from strong to weak signals. All stages must be temperature stabilized, and output stage design must not exceed the transistor ratings.

The overall power gain requirement (from antenna to loudspeaker) is determined, keeping all these factors in mind. How this overall gain is distributed in r-f, i-f, audio and power output stages is quite important, and the method is influenced by practical design limitations of coils and other components, including the transistors.

As a part of the general considerations outlined above, there were many specific and interesting problems solved during design of the individual stages of the receiver. Some of these, such as i-f and audio design, r-f amplifier stability, band sensitivity equalization, coupling effects and factors affecting tuner design, are described.

TUNER

The shunt-loading effects of transistor input and output conductances upon the resonant circuits influence coil designs in all stages. In the tuner, this loading results in coil operating Q's much lower than those of like tube circuits. To compensate for this, most of the new coils were designed to have nearly double the unloaded Q of similar tube-tuner coils. This made it possible to attain image ratios comparable to those of tube receivers. The necessity of using secondary windings and taps on the transistor-set coils also greatly increased the complexity of switching. (See Fig. 2) Some other interesting factors affecting the tuner design are described later.

ANTENNA COUPLING

In transistor receivers, the antenna acts as an r-f signal power source. Maximum antenna input power available depends upon both antenna design and signal field strength. The actual r-f power supplied to the transistor input is a function of this maximum available power, less the losses of the matching network. Optimum signal-to-noise is obtained by reducing these losses to a minimum.

SPREAD BAND ANTENNA COUPLING

The rod-antenna capacitance is in parallel with the antenna-circuit tuning capacitor on all short-wave bands. As shown in Fig. 3a the antenna winding, L_a, requires a secondary winding, L_s, to match the high-impedance antenna circuit to the low value of transistor base input resistance. Reactive components of the transistor input impedance are tuned out at resonance. In the equivalent circuit, Fig. 3b, the rod-antenna capacitance, C_a, represents a low fixed capacitance in series with a voltage generator.

As shown in Fig. 4 the four high-frequency or "spread" bands, 31, 25, 19 and 16 meters, have a tuning range of less than 5% of nominal frequency. Therefore, since a small tuning increment is essential, and a maximum tuned circuit impedance is required to minimize transfer losses, special low-capacitance tuning sections are used.

On the contrary, for the lower-frequency bands, higher capacitance tuning sections are required due to the greater frequency ratios. Because of this, transfer losses are increased somewhat at the low end of "A," "B," and "C" bands, resulting in less available signal power from the antenna for a given field strength. These additional losses are only partially compensated by the characteristic increase in available power gain of the r-f transistor as frequency is lowered. This problem is solved by "frequency-variable" input coupling.

"FREQUENCY-VARIABLE" B-BAND COUPLING

The optimum coupling coefficient of the antenna input circuit varies with frequency. However, the usual inductive coupling (see Fig. 3b) is constant over the tuning range, resulting in excessive tuned-circuit loading or undercoupling as the receiver is tuned. Thus, "frequency-variable" coupling from the antenna to r-f transistor input is used.

Referring to Fig. 5, the tuned inductor, L_A, is mutually coupled to L_S, a second inductor. L_S is connected so that its induced voltage is series aiding with that voltage due to the common bottom coupling, C_c. Coupling due to C_c is a minimum at the high-frequency end of the band, and predominates at the low end. The total coupling vs. frequency slope is thus determined by the relative amounts of mutual and common bottom coupling. With this method, optimum coupling may be obtained over a wide frequency range.

LOOP ANTENNA COUPLING

As shown in Fig. 6a, a new type of loop-coupling network is used to match the loop antenna to the r-f transistor base input. Formerly, three leads were needed from a "primary-secondary" type loop-antenna to provide connection to the receiver chassis. With the new method, the two hinges on the front-panel lid serve as loop connections to the chassis and tuner.

Fig. 6b shows the equivalent circuit. L_M is a common reactance which may be varied to adjust the coupling of the transistor input resistance to the tuned-loop circuit, so that the coupled resistance will equal the tuned-loop antenna series resistance, R_a.

Series resistance reflected by the transistor into the tuned-loop circuit is:

$$\text{Equivalent } R \text{ Reflected} = \frac{\omega^2 L_M^2}{R_{IN}} \quad (1)$$

Since the generator voltage, E_a, does not change with loading, maximum power will be obtained when,

$$(\text{For Max. Power}) \ \frac{\omega^2 L_M^2}{R_{IN}} = R_a \quad (2)$$

Rearranging to obtain L_M in terms of the other parameters, and for the

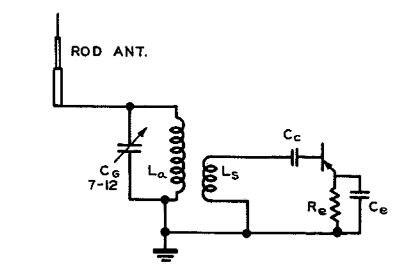


Fig. 3a—Spread-Band Antenna Input Circuit.

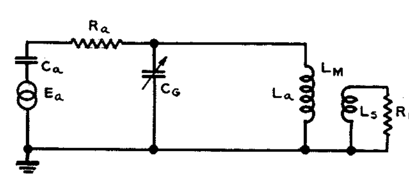


Fig. 3b—Spread-Band Equivalent Input Circuit.

Band	Frequency Coverage	Frequency Ratio
'A'	532 KC - 1620 KC	3.045
'B'	1.97 MC - 4.05 MC	2.056
'C'	3.9 MC - 8.1 MC	2.077
31 Meter	9.45 MC - 9.9 MC	1.048
25 Meter	11.55 MC - 12.1 MC	1.048
19 Meter	14.9 MC - 15.55 MC	1.044
16 Meter	17.5 MC - 18.25 MC	1.043

Fig. 4—Table showing Frequency Coverage and Ratios.

maximum input power:

$$L_{M\ (P\ MAX)} = \sqrt{\frac{R_a R_{IN}}{\omega}} \quad (3)$$

This formula might seem to indicate that L_M is independent of L_a, the loop inductance, since L_a does not appear. However, since $R_a = X_{La}/Q_{La}$, the loop series resistance will vary directly with the loop inductance, assuming constant loop Q. Thus, L_M is a function of the loop inductance.

Referring to Fig. 6b the resonant rise in voltage that appears across the entire inductive branch is given by $E_R = E_a Q_L$. Then, according to the value of L_M, a portion of this voltage will be applied across the transistor input resistance, R_{IN}. When the magnitude of L_M is such that the voltage across L_M is equal to $\frac{1}{2}E_a\sqrt{R_{IN}/R_a}$, maximum available power input to the transistor is obtained.

R-F AMPLIFIER STABILITY

The r-f transformers perform the function of matching the relatively high collector impedance to the low mixer-input impedance. This is done in the manner described below which results in maximum selectivity for the required circuit stability.

On the 31, 25, 19, and 16 meter spread bands, the r-f amplifier is inherently stable because of the relatively high input and output conductances of the transistor at these frequencies. However, on "A," "B," and "C" bands these conductances, when matched, tend to cause regeneration. For a single-stage unneutralized amplifier, the stability factor* is:

$$p = \frac{2(g_{11} + G_G)\ (g_{22} + G_L)}{M(1 + \cos\theta)}$$

where g_{11} = the input conductance
g_{22} = the output conductance
G_G = the source conductance
G_L = the load conductance
$M = Y_{12}Y_{21}$
$\theta = \underline{/Y_{12}Y_{21}}$

Since g_{11} and g_{22} are fixed by the particular transistor being used, the stability factor (p) is improved by increasing the source or output-load conductances. Either the mismatching method or increasing the tuned-circuit transfer losses (constituting a large portion of the interstage losses) may be used to vary the conductances G_G and G_L. It can be stated that, in general, maximum stable gain may be obtained by employing equalized mismatch ratios. Nonetheless, it is preferable on "A," "B" and "C" bands to provide stability by increasing the interstage transfer losses through tuned-circuit "tapping-down" adjustments. Otherwise, mismatching would degrade the signal-to-noise ratio, and could decrease selectivity.

*Stern, A. P., "Stability and Power Gain of Tuned Transistor Amplifiers" *Proc. IRE* (March, 1957) 335-343.

BAND SENSITIVITY EQUALIZATION

Inasmuch as the available gain of the presently used drift transistors decreases at the higher frequencies, it was necessary to determine the best way of equalizing gain from band-to-band. Many different methods were considered. The idea of introducing gain-equalizing losses in the antenna coupling networks was discarded because this degrades the signal-to-noise ratio. Gain equalization by interstage mismatching resulted in either poorer r-f selectivity or possible instability.

Therefore, the most advantageous means of equalization was to introduce losses by tapping down on the r-f interstage transformer. Lower tank-circuit tap positions increase losses as the bands become lower in frequency. Shunt conductance losses in the tank circuit are thus increased from band-to-band to equalize gains.

This method of equalizing results in maximum image rejection ratio due to higher circuit Q. Moreover, on the spread bands where tank and tuning capacitances are lowest, the effect of transistor parameter variations upon alignment is greatly reduced.

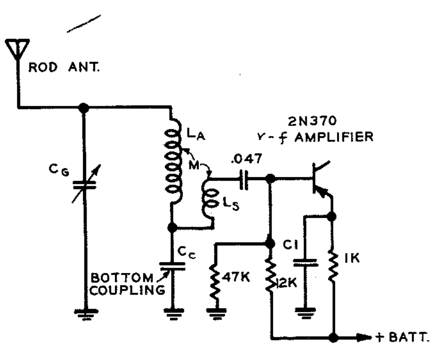


Fig. 5—"Frequency-Variable" input coupling—"B" Band.

OSCILLATOR STAGE

It is desirable to make the oscillator frequency independent of variations in the transistor parameters. This is achieved by designing the oscillator coils for maximum coupling efficiency and adjusting the secondary reactance so that its reflected reactance will vary with parameter changes in a manner that is equal and opposite to the reactive shift of the collector capacitance.

To maintain oscillation over the highest-frequency band, transistor phase shift must be compensated. As may be noted in Fig. 7 a relatively low value, 120 $\mu\mu$f, capacitor is in series with the feedback winding on the spread bands. This capacitor introduces a phase shift in the feedback network which counteracts the increased phase shift in the transistor on the higher frequencies. This phase shift compensation is necessary to obtain oscillation on the highest-frequency bands. On the lower-frequency bands, this capacitor is shunted by a much larger capacitor which has the primary function of isolating the d-c voltage on the oscillator emitter.

A new method of oscillator injection (Fig. 7) is accomplished by returning the 0.1 mfd. mixer-emitter bypass capacitor to the high side of the oscillator feedback windings. This simplifies the switching by eliminating the need for separate injection windings or taps. The d-c operating point of both oscillator and mixer transistors is critical. Also, oscillator-coil transfer losses must be kept to a minimum on the higher-frequency bands because available transistor gain is lowest. The mixer-oscillator circuitry was found to result in negligible oscillator "pulling" on the h-f bands.

TWO-STAGE I-F AMPLIFIER

The two-stage i-f amplifier is designed (See Fig. 8) for a desired overall selectivity and gain. Both are dependent on basic factors which govern stability, namely, source and load resistance, feedback capacitance, and transistor characteristics.

Maximum power gain occurs when the input and output impedances of the coupling transformers are matched to the input and output impedances of the transistors (conjugate match). However, instability may exist. The design of the i-f transformers was aided by a published paper.* It de-

*Holmes, D. D., and Stanley, T. O., "Stability Considerations in Transistor I-F Amplifiers," *Transistors I* (Princeton, N. J., 1956) 403-421.

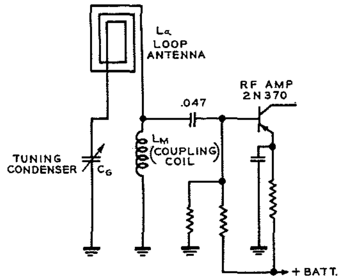


Fig. 6a — Loop-antenna coupling circuit—"A" Band.

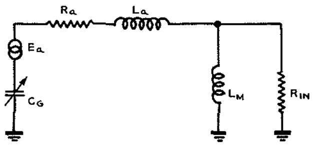


Fig. 6b—Equivalent Loop Antenna Coupling.

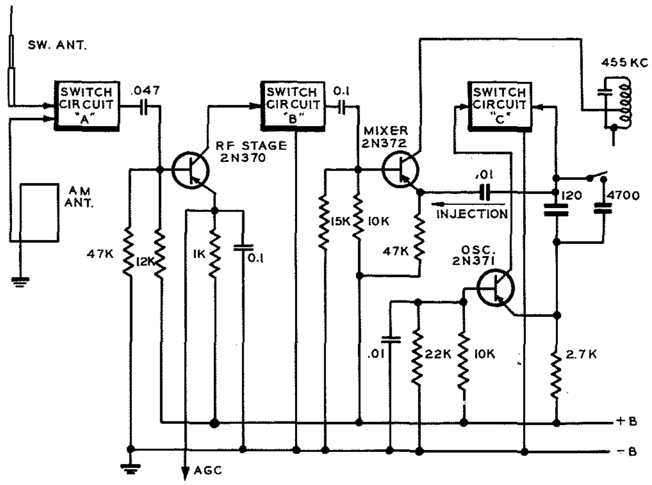


Fig. 7 — Block diagram of transistor tuner showing d-c bias, stability circuitry, and method of oscillator injection.

scribes a method for determining the insertion loss required to effect stability with a minimum loss in power sensitivity or gain. Insertion loss and stability factor are intimately related, and prescribe the ratio of transformer-loaded-Q-to-unloaded-Q for a desired selectivity, matching impedance, and neutralizing requirement. From this procedure and by use of a universal selectivity curve, the required operating "Q" of each transformer was derived. A selectivity, 6-db down at 8-kc bandwidth, or 2-db down for each transformer was desired. Also, the unloaded "Q" of the primary and secondary windings and the single-tuned winding was obtained using average operating characteristics of the transistors (1-ma collector current in the first i-f stage, and 3 ma in the second). The second stage is designed to furnish sufficient power drive for the transistor detector AGC system so that strong signal overload is avoided. Gain of the two-stage amplifier is 58 db.

DETECTOR AND AGC

The transistor detector in performing its function features emitter-current rise with signal-carrier increase and is used as the AGC control. As shown in Fig. 8, emitter-current control is applied to the r-f and to the first i-f stages. They are "constant-emitter-current" biased for the zero-signal condition at 1.5 ma. An increase in the detector emitter-collector current produces a proportional decrease in the collector currents of the controlled stages. The AGC curves (Figs. 9a and b) show this and the desired delay in the AGC action at low signal level. The system is effective in preventing strong signal overload and develops an AGC figure of merit of 63 db on the broadcast band.

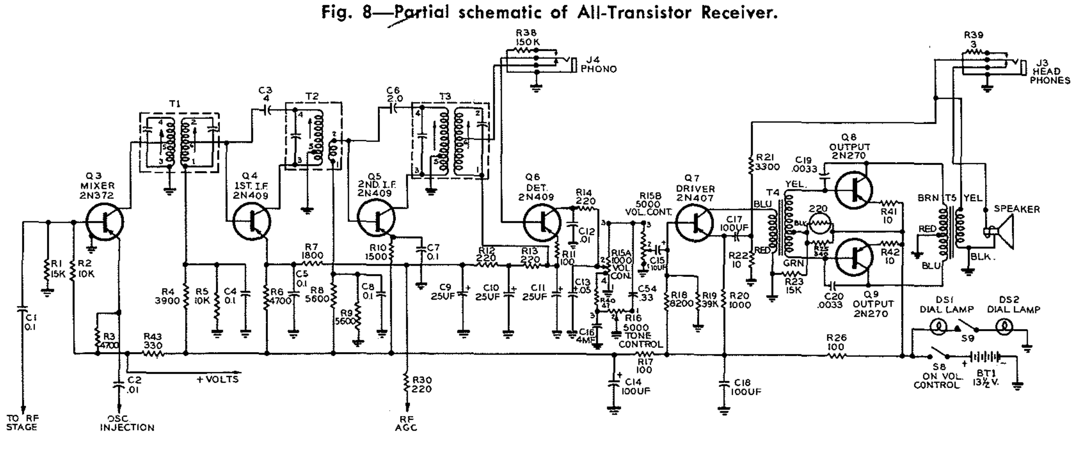
The RC networks (Fig. 8) R12, R13, C9, C10, and C11 in the emitter circuit of the detector provide filtering of r-f and audio components of the AGC current generated in the detector. The relative degree of AGC control in the r-f and i-f stage is proportioned by the resistance value of R7 and R30. The RC network R14, C12, and C13 eliminates i-f and harmonics from the audio system. In addition, the stage functions as a preamplifier for phonograph application by plugging into J4. This opens the base input lead and applies resistor R38 to bias the stage to an adjusted 2.5 ma. The AGC system is actuated, effectively cutting off the r-f and i-f stages to provide complete radio silencing.

AUDIO DRIVER

The audio output of the detector (see Fig. 8) is applied via the dual-element volume control (R15A, R15B) and the coupling capacitor, C15, to the base of the driver transistor, Q7. The current available for driving the stage is proportional to the resistance introduced between the volume control sliders and ground. The dual-element circuitry features wide-range loudness adjustment without sacrificing dynamic output of the detector stage and the AGC. This avoids adding higher resistance in the collector circuit, which would lower the available voltage on the collector. The collector current increases with carrier-signal level, and AGC figure of merit is dependent on the collector voltage.

The high-cut, low-cut tone control, R16, (see Fig. 8) is seen in combina-

Fig. 8—Partial schematic of All-Transistor Receiver.

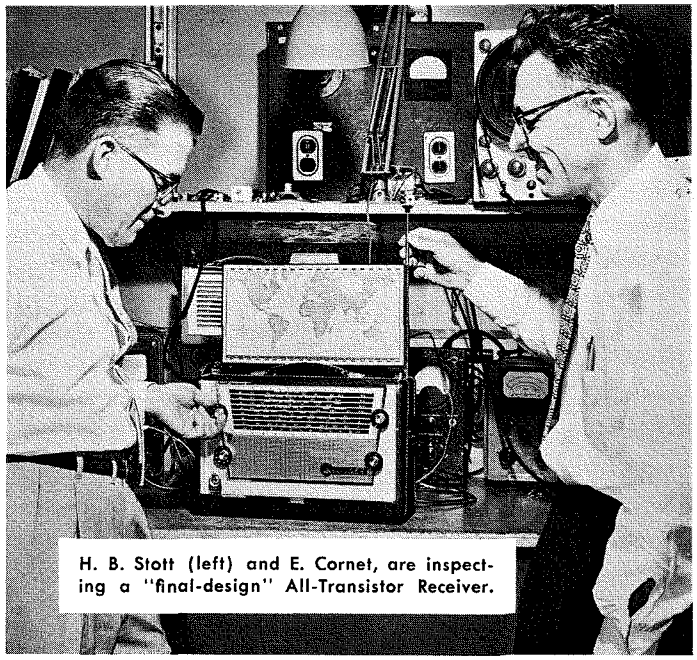


EDWIN CORNET, who attended evening school at Wentworth Institute, began his career in 1930 as a designer for Browning and Drake Corp. In 1932 he was employed by the Pilot Radio and in 1934 headed up Auto, All-Wave and A-C/D-C receiver design at Automatic Radio Corp. In 1938 Mr. Cornet was made engineering supervisor of the Philco Coil Lab., and in 1945, was in charge of portable, AM/FM and A-C/D-C receiver design at Bendix Corp. In 1947, Mr. Cornet came with RCA, as an AA Electrical Design Engineer, in the radio-phonograph section. Since 1956 he has been with Advanced Development, Radio & "Victrola" Division.

Mr. Cornet is a Senior Member of IRE.

HAROLD B. STOTT was first employed in 1926 by G. E. Co. where he did mechanical and electrical layout of automatic switchgear, and in 1932 joined RCA. In 1934, after having completed seven years of study in the Drexel Evening School, Mr. Stott graduated with a diploma in E.E. Following this, Mr. Stott worked in the RCA Record Engineering and in the Radio and Television Advanced Development. In 1944, he transferred to the present RCA Radio and "Victrola" Division as a Design Engineer, where he works on both transistor and tube circuitry.

Mr. Stott is a Senior Member of IRE.



H. B. Stott (left) and E. Cornet, are inspecting a "final-design" All-Transistor Receiver.

tion with the compensated volume control. Operating current of the class "A" driver stage is controlled by the base bias bleeder in conjunction with the emitter resistor, R20, and is adjusted to 2 ma. The driver transformer acts as a phase inverter and impedance coupling device for the push-pull output stage. The impedance reflected to the driver collector is low enough so that driver overload does not occur before overload of the output stage. An impedance ratio of 8000-to-1500 is used. The d-c resistance of the primary is low enough so that the loss of driver supply voltage is tolerable. The secondary winding halves are bifilar wound to avoid transient voltage effects when current shifts between output transistors.

AUDIO OUTPUT

The audio output stage (see Fig. 8) incorporates a matched pair of RCA 2N270 transistors operating Class "B" in a grounded-emitter configuration. Over 300 milliwatts (10%) undistorted output is obtained efficiently while operating within the maximum peak current and dissipation rating of the transistors. This requires an output load impedance of 715 ohms from collector-to-collector with the 13½-volt battery used. Temperature stabilization is accomplished by a thermistor-regulated voltage-divider bias network, R23, R25, RT1. Special output transformer design combines low d-c resistance and high open-circuit primary impedance for battery economy plus good low-frequency response. Cross-over distortion prevalent in Class "B" operation is minimized by precise adjustment of base-to-emitter bias to permit a collector current of approximately 2 ma. at zero signal. The remaining distortion is reduced by the use of collector-to-base negative feedback, C19, C20, and by R41, R42 un-bypassed emitter resistors. Voltage clipping occurs beyond the 300-milliwatt output level. Approximately 6 db of negative feedback is supplied from the secondary of the output transformer to the driver stage emitter, lowering the overall audio system distortion. The output stage plus driver-stage power gain is 70 db.

OVERALL PERFORMANCE

Results indicate performance equivalent to or greater than that of the former tube receiver, Model 7BX10. Improved sensitivity particularly on the "B" and "C" bands, along with increased power output and much greater battery life, were achieved. The overall performance of this receiver is shown in the following table.

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Band	Freq.	Sensitivity for 50 mw. Out.	Image Attenuation	20 db "S-to-N" Sensitivity
'A'	600 kc	20 µV/m	57 db	58 µv/m
	1400	15	61	50
'B'	2 mc	2 µV	74 db	10 µV
	4	1	56	4
'C'	4	2	47	10
	8	1	26	3
31 Meter	9.6	1	26	2
25 Meter	11.8	1	22	3
19 Meter	15.2	2	12	2
16 Meter	17.8	3	16	2

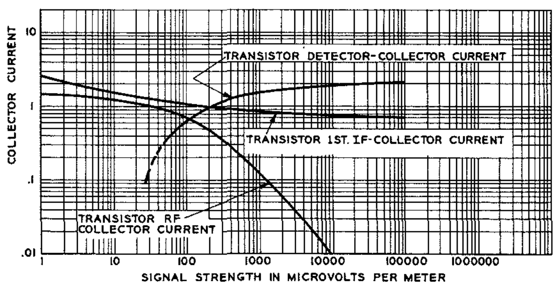

Fig. 9a—Curves showing developed AGC Bias currents.

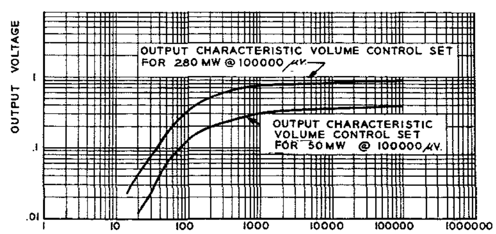

Fig. 9b—AGC Typical Output Characteristic Curves.

THE CATHODE AND ITS ENVIRONMENT

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WHILE IT IS GENERALLY recognized that the thermionic performance of cathodes is influenced to some extent by the environment in which the cathode operates, it is seldom appreciated that the environment is quite as important as the cathode structure itself in determining thermionic performance. This article will briefly review some properties which are inherent characteristics of all cathodes and attempt to show by simple arguments and examples that optimum thermionic performance can only be obtained when a favorable environment exists. In particular, it will be shown that to obtain optimum cathode performance all traces of potential oxidizing agents must be removed from the tube; furthermore it will be shown that, the better the cathode, the more stringent the requirements it places on its environment.

ALL CATHODES ARE REDUCING AGENTS

The statement that all cathodes are reducing agents becomes obvious if one recalls the definitions of oxidation and reduction. Pauling states "Oxidation is the removal of electrons from an atom or group of atoms. Reduction is the addition of electrons to an atom or group of atoms" and "an atom, molecule, or ion which takes up electrons is called an oxidizing agent, and one which liberates electrons is called a reducing agent."[1] He further points out that "every electron reaction involves an oxidizing agent and a reducing agent, which are closely related to one another." Thus, according to these definitions, the passage of an electron from the cathode to the anode of a diode is an oxidation-reduction process. To consider electron emission as an oxidation process may seem somewhat strange, but it has the advantage of calling attention to the fact that on an atomic scale physical and chemical forces are indistinguishable. Furthermore, it emphasizes the point that the physical process of electron emission is also a chemical process and may therefore alter the properties of the cathode.

It is worthwhile to examine the properties of a reducing agent using essentially 'chemical' arguments and to see how these properties are pertinent to the process of electron emission. The 'strength' of a reducing agent is measured by its chemical activity, a quantity which determines, in part, the extent to which the agent will reduce (i.e. react with) another substance. The law of mass action provides the means of computing the results of a reaction. Consider the reaction

$$aA + bB \rightleftharpoons cC + dD.$$

When the reaction has reached equilibrium, and provided that no reactant is exhausted before equilibrium is reached, the mass action law states that

$$\frac{[C]^c\,[D]^d}{[A]^a\,[B]^b} = k.$$

k is the equilibrium constant and is given by

$$k = e^{\Delta H/kT}$$

where ΔH is the heat of reaction. The brackets indicate the activity of A etc. For ideal systems, the activities are proportional to the concentrations or partial pressures of the reactants and end products relative to a standard reference state. It is convenient to use concentrations relative to the "density of states" in the gas phase as activities, i.e.

$$[n] = \frac{n}{N_c}$$

where the density of states in the gas phase,

$$N_c = 2\left(\frac{2\pi\, m\, kT}{h^2}\right)^{3/2}$$

This procedure is equivalent to making the free energy of the system a minimum.

As an example of the use of this procedure, consider a set of electron donors D, of concentration N_D, lying at an energy ε below the bottom of the conduction band of an insulator and in equilibrium with the electrons in the conduction band. The reaction between the electrons and the donors is:

$$D \rightleftharpoons D^+ + e$$

where $D+$ indicates an ionized or oxidized donor. Then the mass action law states that

$$\frac{[D+]\,[e]}{[D]} = \frac{\left(\frac{N_D^+}{N_c}\right)\left(\frac{n}{N_c}\right)}{\left(\frac{N_D}{N_c}\right)} = e^{-\varepsilon/kT}$$

Since the material is an insulator, the number of ionized donors N_D^+ is equal to the number of free or conduction electrons n, so

$$n = \sqrt{N_D\,N_c}\quad e^{-\varepsilon/2kT}$$

The same result may also be obtained from solid state theory and is valid provided $n << N_D$, i.e. when the donors are not exhausted before equilibrium is reached.

In this example the electrons were treated on the same basis as the other reactants and products and their activity was written n/N_c. The activity of the electrons in the solid is then:

$$a'_e(s) = \frac{n}{N_c} = \sqrt{\frac{N_D}{N_c}}\; e^{-\varepsilon/2kT} = \sqrt{\frac{N_D}{N_c}}\; e^{-\mu'/kT}$$

and it will be recognized that μ' is the Fermi energy measured with respect to the bottom of the conduction band. Since the absolute activity is the activity referred to the gas phase, it is necessary to adjust the heat of reaction μ' by adding to it the energy (x) necessary to remove an electron from the bottom of the conduction band into the gas phase or to the "vacuum level." Therefore, the absolute activity of the electrons in the solid is

$$a_e(s) = a'_e(s)\,e^{-x/kT} = \frac{\sqrt{N_D}}{\sqrt{N_c}}\quad e^{-\frac{\mu'+x}{kT}}$$

Here x is the electron affinity of the insulator and $\mu' + x = \phi$ is the Fermi energy measured with respect to the "vacuum level," i.e. the work function of the insulator. Thus it can be seen that the absolute activity of the electrons in the solid is determined largely by the work function of the solid. If the number of donors is made large so that N_D becomes equal to N_c, as is the case in a metal, then the activity is determined solely by the work function.

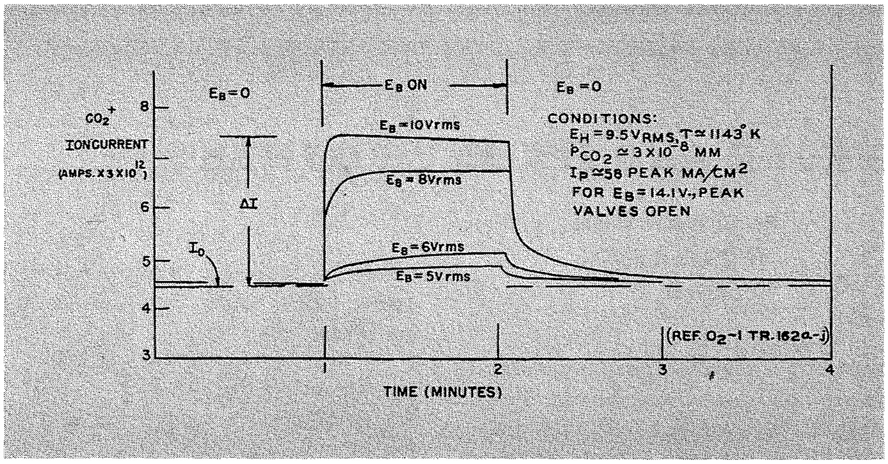


Fig. 1—CO_2 Evolution from an Oxide Cathode

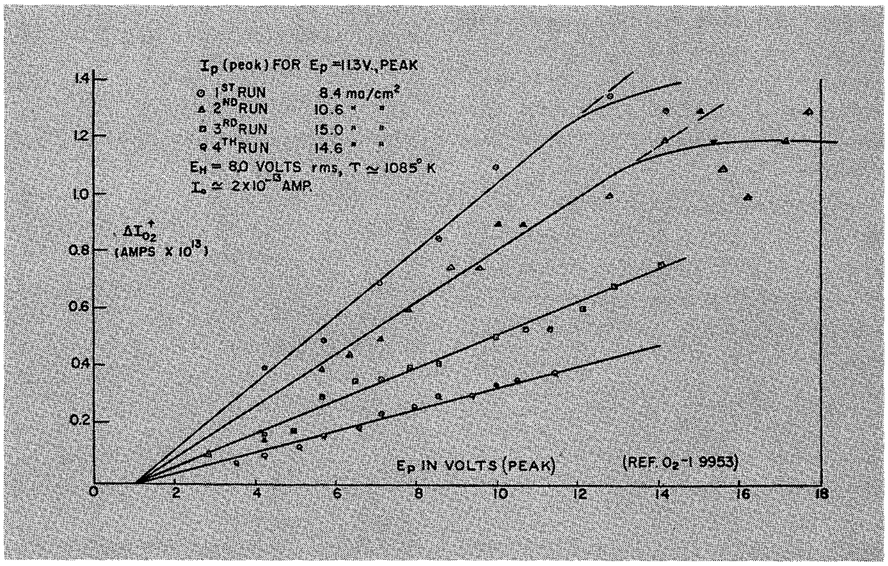


Fig. 2—O_2 Evolution from an Oxide Cathode

Recalling that the 'strength' of a reducing agent is measured by its chemical activity, it now becomes obvious that: Every cathode is a reducing agent, and at a given temperature its chemical activity increases in direct proportion to its emission.

This conclusion is of prime importance because it shows that the better a cathode is, the more likely it is to react with oxidizing agents and so lose its activity. This indicates clearly that environment is a vital factor affecting the performance of a cathode.

EVERY CATHODE LIVES IN EQUILIBRIUM WITH ITS ENVIRONMENT

Having recognized the fact that every cathode is an active chemical reducing agent, the next step is to determine what it can react with. It can react with its support and with the gaseous ambient which surrounds it. Since the ambient gases arise in part from the other electrodes, leads, insulators, the envelope, and even from the cathode itself, the cathode is, in effect, in equilibrium with the entire tube. If the envelope is not completely impervious, it is in equilibrium with the gases surrounding the envelope. This equilibrium is not a thermodynamic equilibrium because the system is not all at one temperature and all possible reactions have not run to completion. However the system is in an apparent equilibrium; that is the rates of all the reactions in progress are so low that the system appears stable on a time scale of hours or even of thousands of hours. Obviously if this apparent stability did not exist, vacuum tubes would have no utility. Conversely, it might be argued that, because tubes are stable for long periods, no reactions at all take place. If this were indeed the case, then tubes would last indefinitely, a condition contrary to fact.

The reaction of the cathode with its supports is usually controlled or made trivial by choosing inert supports. With metallic cathodes this source of reaction is held to the absolute minimum. In the case of the oxide cathode, the coating is usually placed on an inert support such as nickel or platinum, neither of which reacts significantly with the oxide at normal operating temperatures. However the support usually contains impurities which may diffuse and consequently may react with the cathode. These impurities are frequently reducing agents such as the metals silicon and magnesium. They may be present by accident or by intent, and usually play a major role in determining the performance of the tube. Their function and significance will be discussed in more detail later.

The cathode contributes to the ambient not only by direct evaporation of its own constituents but also by virtue of reactions of its constituents with the impurities from its support and with some components of the ambient. In the case of metallic cathodes, the direct evaporation of metal usually plays a small role in establishing the ambient. The evaporated metal condenses quickly on the envelope, leads, and other electrodes and because of its low vapor pressure at the temperature of these surfaces remains there. Reaction between metallic cathodes and components of the ambient may be important. A well known example is the water cycle with tungsten which results in the rapid destruction of the cathode accompanied by the appearance of heavy deposits of tungsten throughout the tube. In the case of cathodes such as the oxide cathode and the L cathode both Ba and BaO evaporate. The Ba probably reacts with the oxidizing gases of the ambient to form BaO. While the vapor pressure of BaO is not very large at room temperatures, it may re-evaporate if the electrode on which it lands runs hot during operation. In addition it is known that BaO dissociates under electron bombardment releasing O_2 and Ba. The O_2 can oxidize the cathode and reduce its activity. The Ba may return to the cathode and thus enhance its activity. However, due to its lower vapor pressure, the Ba is less likely to reach the cathode than the O_2 and is likely to be reoxidized by some component of the ambient. The dissociation mechanism is not understood and the large number of possible reactions of the dissociation products with the ambient renders the situation very complex.

The importance of the ambient can be shown in a rather striking fashion by computing the number of atoms which impinge on the cathode surface during the life of a tube. Vacuum tubes are usually pumped to a pressure of 10^{-7} mm Hg. At this pressure, several times 10^{14} atoms strike each square centimeter of cathode surface each second. This number is equivalent to the number of atoms in one tenth of a monolayer. If all these atoms adhered to the surface and did not re-evaporate subsequently, the cathode thickness would increase by about 0.005 cm per thousand hours. Since this material amounts to more than 10 percent of the total material originally present in the coating of an oxide cathode, it is seen that this possibility of damaging reactions is not to be ignored.

In a well designed and well pumped tube the ambient gases which surround an oxide cathode are for the most part H_2, CO, and N_2; smaller quantities of A, CH_4 and H_2O and traces of O_2, CO_2, C_2H_2, and other hydrocarbon fragments are almost invariably present[(2) (3)]. It has been clearly demonstrated by Plumlee that these ambient gases do react with the cathode. Using a mass spectrometer he studied the partial pressures of the various species of the ambient in contact with an oxide cathode as a function of temperature, total pressure, and the voltage applied to the diode of which the cathode was a part. Fig. 1, taken from Plumlee's paper[(2)], shows the variation of CO_2 partial pressure with time when anode voltage was applied to the diode. It will be noted that the CO_2 partial pressure increases with anode voltage and that saturation sets in at the higher voltages.

Similar behavior is displayed by the ambient O_2. Fig. 2, also from Plumlee's paper, shows the variation of O_2 partial pressure as a function of voltage applied to the diode. Both of these effects are examples of the increase in chemical activity of a charged reactant in the presence of an electric field and may be compared directly with anodic oxidation in electrolysis. In both cases the oxide coating is reduced, raising the Fermi level, and the cathode is rendered more active both chemically and thermionically. The significance of this reduction mechanism in practical cathodes will be discussed in the next section.

Sometimes the ambient may be, in part, established by direct evaporation from electrodes other than the cathode. Evidence has been obtained that evaporation of reducing metals from the anode of a tube may affect the activity of the cathode [(4) (5)]. In these experiments spectrographic analysis of aged oxide coatings revealed traces of magnesium which could have come from the anode which contained 0.09 percent magnesium either during the outgassing of the anode or during the life test if the anode ran at a temperature of 350°C or higher[(6)]. However the magnesium reached the cathode, it is a strong reducing agent and its presence must have contributed considerably to keeping the cathode in an active state. That such an effect occurred in tubes designed by careful experimenters specifically to minimize cathode contamination indicates clearly the importance of considering the properties of all tube elements in evaluating cathode performance.

The effect of a small change in the composition of the ambient is shown in Fig. 3. In this instance Ba ions, selected by a mass spectrometer, were deposited on the cathode. It can be seen that deposition of Ba at a rate which was equivalent to a 0.1 percent change in the composition of the gaseous ambient resulted in a nearly tenfold increase in the activity of the cathode in a period of less than three hours.

In practical tube structures it is usually difficult to establish unambiguously which effects are due to the gaseous ambient. A clear cut example of such an effect in a double triode (6SN7) is shown in Fig. 4. This figure shows the change in cathode resistance

Fig. 3—Effect of adding a trace of Ba ions to the gaseous ambient.

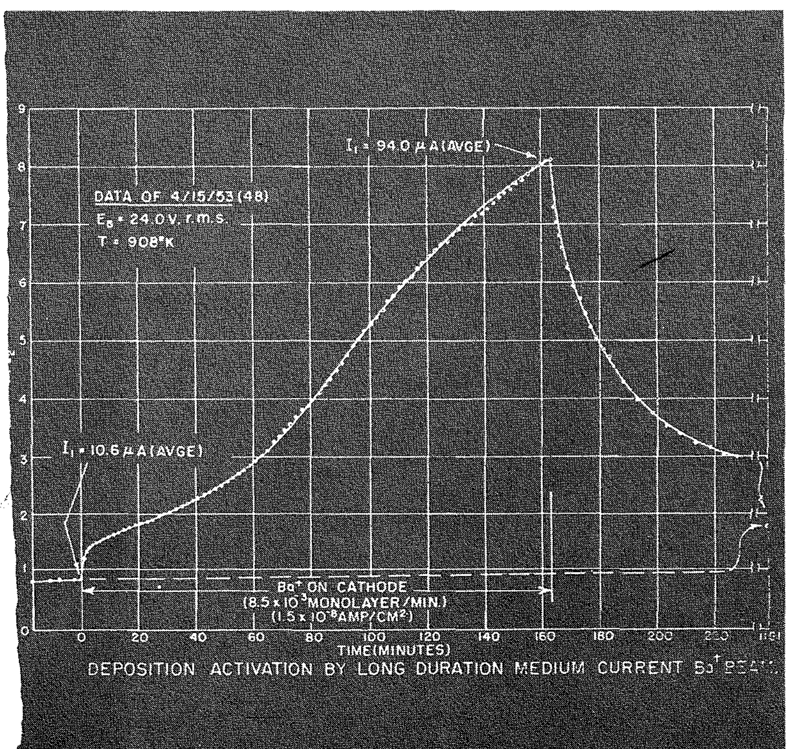
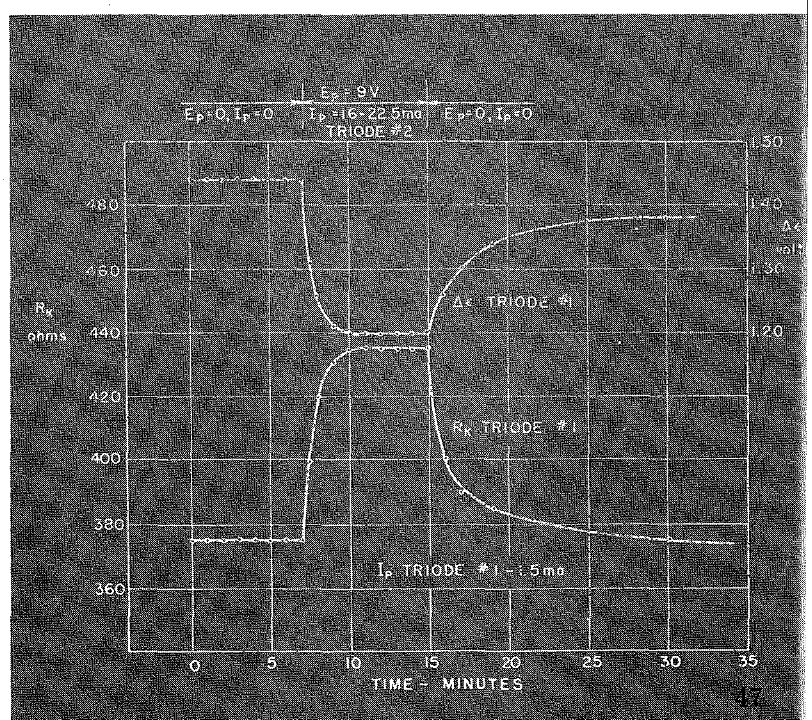


Fig. 4—Interaction of the two units of a double triode via the gas phase.



(R_K) and contact potential (ε) in triode unit I of this tube when current was drawn in unit II. When plate voltage was applied to unit II its cathode activity rose; this was indicated by the rise in its plate current during the period of application of plate voltage. The change in the gaseous ambient resulting from this activation caused the change of cathode resistance and contact potential of unit I. The combined effect of change of cathode resistance and contact potential was, in this instance, equivalent to a change of 0.3 volts in grid bias.

The purpose of this section has been to show that a cathode cannot be considered as an element apart in a vacuum tube. It interacts with every other part of the tube, and its life and performance during life depend as much upon the composition and condition of the other electrodes and the envelope of the tube as upon its own initial composition. It follows that it is fruitless to produce a better cathode unless all other electrodes are improved simultaneously because all electrodes including the cathode will find a common level and the performance of each will be determined by all the others.

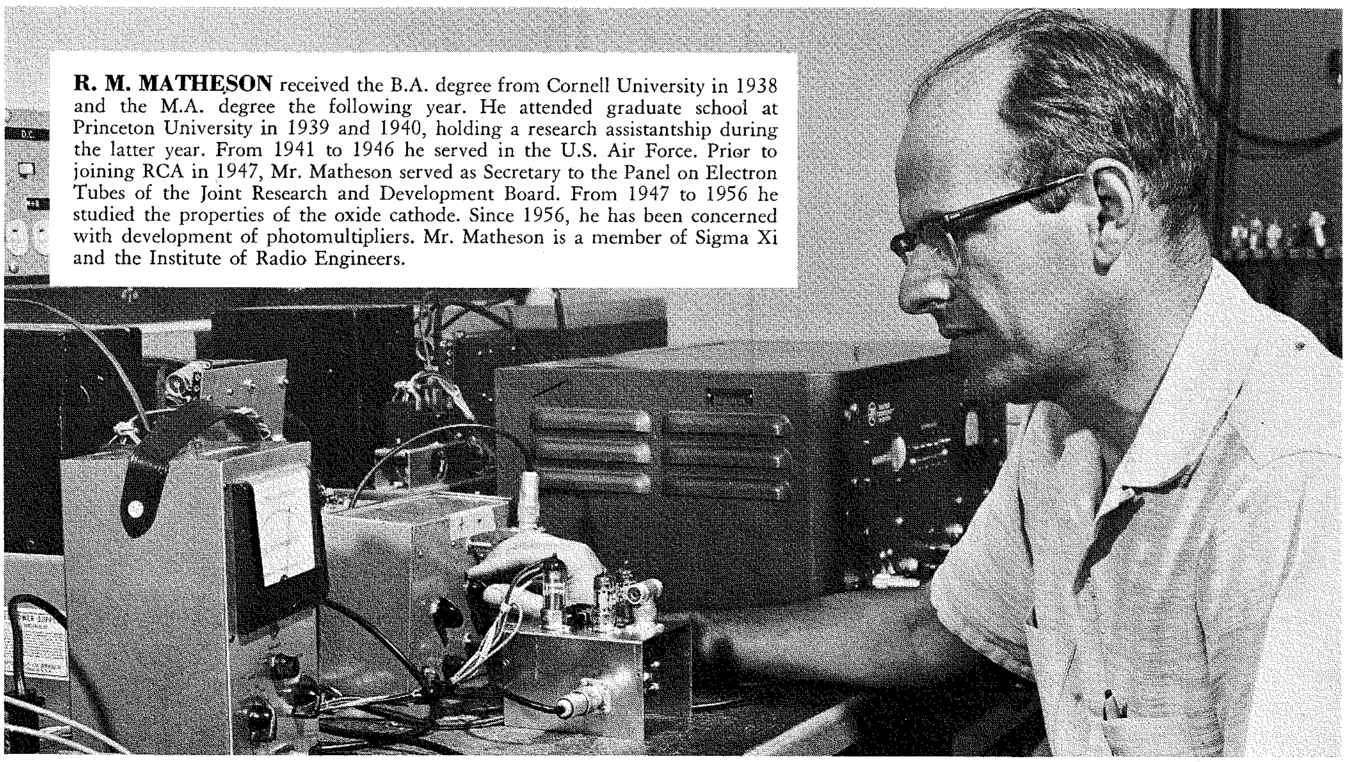
ALL CATHODES ARE DISPENSER CATHODES

Because a vacuum tube is a system which has not achieved thermodynamic equilibrium, chemical reactions are proceeding at a low but finite rate. Since the gaseous ambient is to some extent an oxidizing agent, and since the cathode must be maintained in a reduced state, it is essential to provide a source of reducing potential to counteract the influence of the gaseous ambient. Consequently, to keep the cathode active, a reducing agent must be continuously supplied to the cathode. Cathodes in which the source of supply of reducing potential is obvious are called dispenser cathodes. However, although it is often far from obvious, the means for maintaining a highly reduced state are incorporated in all practical cathodes.

In the case of pure metallic cathodes, such as tungsten filaments, the metal provides its own reducing potential. It can be readily seen that this is the case. A metal is a reducing agent, i.e. it has a large number of nearly free electrons. Since the concentration of the metal is great and the temperature is high the mass action law indicates that the metal will remain unoxidized even in the presence of substantial pressures of oxygen.

In the thoriated tungsten cathode, the mechanism is more complicated, but the great bulk of pure metal still provides the reducing potential. In the interior a quasi-thermodynamic equilibrium exists, and due to the large ratio of concentrations the mass action law indicates that some of the thoria will be reduced. This thorium metal diffuses to the surface continuously and consequently maintains the surface in a reduced state. At the normal operating temperature the reduction-diffusion process just balances the surface losses which are largely due to evaporation and to oxidation by the ambient.

In cathodes which operate at lower temperatures the processes are usually less obvious and frequently more intricate. The notable exceptions are cathodes where a reducing-potential dispenser is mechanically incorporated into the cathode. Some time ago Hull invented a 'dispenser cathode,' so-called because the dispenser function is obvious[7]. Recently this type of cathode has been greatly refined in the form of the L-cathode. The emitting surface of this cathode consists of porous sintered tungsten coated with an extremely thin layer of BaO. This BaO surface is continuously replenished from a reservoir of BaO located behind the sintered tungsten. The reservoir may be filled with BaO, or by various Ba compounds and suitable reducing agents which, at the operating temperature, react at such a rate that the active surface of the cathode



R. M. MATHESON received the B.A. degree from Cornell University in 1938 and the M.A. degree the following year. He attended graduate school at Princeton University in 1939 and 1940, holding a research assistantship during the latter year. From 1941 to 1946 he served in the U.S. Air Force. Prior to joining RCA in 1947, Mr. Matheson served as Secretary to the Panel on Electron Tubes of the Joint Research and Development Board. From 1947 to 1956 he studied the properties of the oxide cathode. Since 1956, he has been concerned with development of photomultipliers. Mr. Matheson is a member of Sigma Xi and the Institute of Radio Engineers.

is continuously replenished. Here the dispenser function is quite obvious and the mode of operation has been thoroughly studied[8][9].

In the ordinary oxide cathode, the source of reducing potential and the dispenser function are much less obvious. The base metals, nickel and platinum, are more inert, i.e. are less powerful reducing agents, than tungsten as can be seen from their position in the periodic table. However they do in general contain impurities, many of which are present in a highly reduced state. It is now generally accepted that these impurities (e.g. silicon, magnesium, carbon) constitute an important source of reducing potential. Diffusion of these impurities out of the base metal and into the overlying coating results in a continuous reduction of the coating. The properties of these impurities and of their diffusion rates have been and are being actively studied[10][11][12][13]. With increased knowledge of these properties it may be possible before long to develop base metals which will maintain an oxide cathode at an acceptable level of activity over very long periods of time.

While reducing agents dispensed by the base metal of an oxide cathode are useful in effecting the initial reduction of the oxide during activation and in maintaining activity subsequently, they are not necessary, either to activate or to maintain activity. This is indicated by the use of 'passive' nickels (i.e. nickels containing the irreducible minimum of reducing agents) for base metals and by the achievement of active cathodes supported on ceramics[14]. In these instances the oxide itself serves as a dispenser and the primary source of reducing potential is the anode power supply. As was noted in the preceding section, the partial pressure of O_2 and CO_2, both oxidizing gases, depends on the anode voltage applied to the tube. It may be seen that this is an example of reduction by electrolysis. The O_2 and CO_2 are electrolysed to the anode, in this case the vacuum boundary of the cathode, and consequently the partial pressure of these gases in the ambient increases. The barium reduced by electrolysis remains within the cathode until it escapes by diffusion either into the vacuum or into the base metal. Since the diffusion process is relatively slow compared to electrolysis (electrolysis may be, to some extent, viewed as field directed and accelerated diffusion) an increased level of cathode activity can be achieved and maintained by electrolysis. It was stated just above that the Ba 'escapes' into the base metal. It should be noted that this Ba is not lost but rather increases the reducing potential of the base metal and consequently serves to assist in maintaining the reduced state of the cathode. In fact with passive base metals, the initial activation process may be primarily associated with establishing a sufficient level of reducing potential within the base metal.

It will be noted from Fig. 2 that the rate of oxygen evolution diminished on successive runs as the cathode activity increased. Thus this activation mechanism tends to be self-limiting and the cathode seeks a level of activity appropriate to the demands on it. This variation in cathode activity with current demand is quite conspicuous in some transmitting tubes where the total cathode area is relatively large compared to the volume of the envelope. When unused for an extended period, the cathodes in these tubes may become quite inactive. However, operation at reduced power level restores the cathode to normal activity in a few minutes.

Thus it may be seen that every practical cathode has within it a source of reducing potential. This potential may be made effective in producing cathode activity either thermally, as is the case with metallic and dispenser cathodes with diffusion sources, or electrically as is the case with the ordinary oxide cathode.

SUMMARY AND CONCLUSIONS

This article has pointed out that, in all cathodes, the thermionic and chemical activity are directly and intimately related. Consequently the thermionic performance of a cathode is directly influenced by anything which affects its chemical structure. By determining the composition of the gaseous ambient, which can react with the cathode, all elements within the vacuum envelope directly influence the thermionic performance of the cathode. Consequently the best performance from any cathode can be obtained only by providing it with a suitable environment. Further, better cathodes will inevitably impose even more stringent requirements on the composition of the gaseous ambient and hence on the other elements of the tube structure.

In conclusion the writer would like to point out that the arguments advanced herein result from the work of many people. The writer is particularly indebted to his colleagues in cathode work, L. S. Nergaard and R. H. Plumlee.

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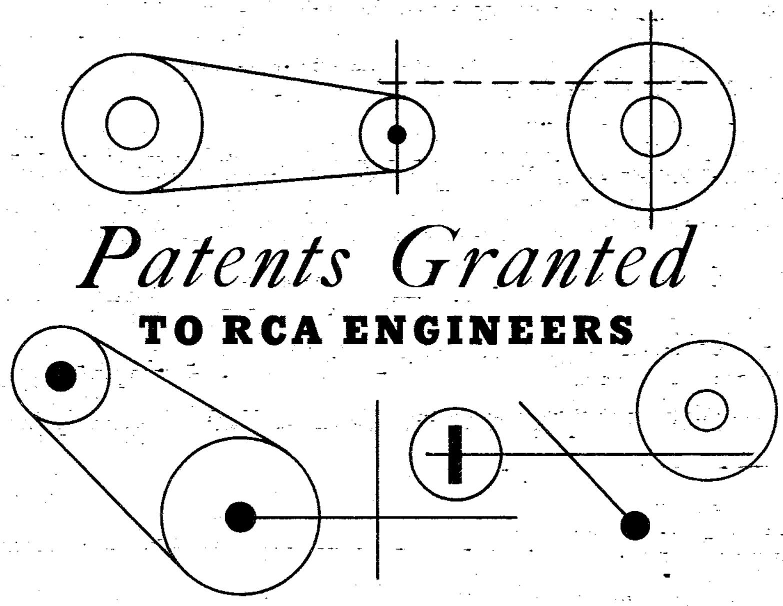


Patents Granted

TO RCA ENGINEERS

Based on Summaries Received over a period of about two months

DEFENSE ELECTRONIC PRODUCTS

Moorestown, N. J.

Coaxial Transmission Line Connecting or Termination Device
Pat. No. 2,836,647—granted May 27, 1958 to Herbert E. Strauss and Daniel T. Rockwell, IEP, Camden, N. J.

Transmission Line Termination
Pat. No. 2,839,730—granted June 17, 1958 to A. L. Rosenberg, Jr.

Voltage Regulator
Pat. No. 2,839,717—granted June 17, 1958 to M. M. Mandelkehr and C. L. Olson.

Transmitter Interlock Circuit
Pat. No. 2,840,693—granted June 24, 1958 to H. E. Strauss.

Camden, N. J.

Capstan for Magnetic Recorders
Pat. No. 2,819,349—granted Jan. 7, 1958 to James R. Hall.

Motor Control Circuit
Pat. No. 2,833,935—granted May 6, 1958 to W. J. Hannan.

Los Angeles, Calif.

Power Type Selsyn Motor Control System
Pat. No. 2,833,972—granted May 6, 1958 to C. E. Hittle and J. J. Askins, Jr.

RCA VICTOR TELEVISION DIVISION

Cherry Hill, N. J.

Extended Range High-Frequency Tuning Device & Circuit
Pat. No. 2,773,194—granted Dec. 4, 1956 to W. F. Sands.

Signal Filtering System for Color Television Receiver
Pat. No. 2,831,919—granted April 22, 1958 to R. K. Lockhart.

Cathode Ray Tube Adjunct
Pat. No. 2,834,901—granted May 13, 1958 to W. H. Barkow and J. K. Kratz, Findlay, Ohio.

Television Deflection Apparatus
Pat. No. 2,834,913—granted May 13, 1958 to L. Dietch.

Frequency Selective Circuit Structures
Pat. No. 2,834,948—granted May 13, 1958 to W. Y. Pan and D. J. Carlson.

Electric Wave Amplitude Clipping Circuit
Pat. No. 2,834,882—granted May 13, 1958 to R. W. Sonnenfeldt.

Television Receiver with Color Signal Gate
Pat. No. 2,835,728—granted May 20, 1958 to R. D. Flood and L. R. Kirkwood.

Television Receiver with Color Signal Gate
Pat. No. 2,835,729—granted May 20, 1958 to R. D. Flood.

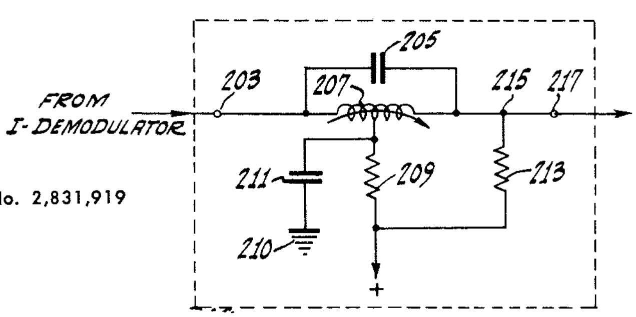
V.H.F./U.H.F.—Tuner System
Pat. No. 2,835,798—granted May 20, 1958 to G. C. Hermeling, Jr. and S. Lynn.

Electro-Magnetic Deflection Apparatus
Pat. No. 2,837,674—granted June 3, 1958 to W. H. Barkow.

Color Synchronization
Pat. No. 2,837,574—granted June 3, 1958 to B. R. Clay.

Cathode Ray Beam Deflection Apparatus
Pat. No. 2,837,692—granted June 3, 1958 to B. E. Denton.

Uni-Control Tuning Mechanism for Multi-Band Signal Receivers and the Like
Pat. No. 2,839,936—granted June 24, 1958 to E. D. Dawson.



Lockhart, Pat. No. 2,831,919

RCA VICTOR TELEVISION DIVISION

Findlay, Ohio

Cathode Ray Tube Adjunct
Pat. No. 2,834,901—granted May 13, 1958 to J. K. Kratz and W. H. Barkow, Cherry Hill, N. J.

INDUSTRIAL ELECTRONIC PRODUCTS

Camden, N. J.

Wave Generating Systems
Pat. No. 2,83,804—granted May 20, 1958 to A. C. Luther, Jr.

Coaxial Transmission Line Connecting or Termination Device
Pat. No. 2,836,647—granted May 27, 1958 to D. T. Rockwell and H. E. Strauss, DEP, Moorestown, N. J.

Web Drive Mechanism
Pat. No. 2,838,250—granted June 10, 1958 to A. Stavrakis and C. J. Kennedy.

Input and Output Coaxial-Type Circuits for Double Ended Vacuum Tubes
Pat. No. 2,840,647—granted June 24, 1958 to L. L. Koros and M. V. Hoover, Lancaster, Pa.

ELECTRON TUBE DIVISION

Lancaster, Pa.

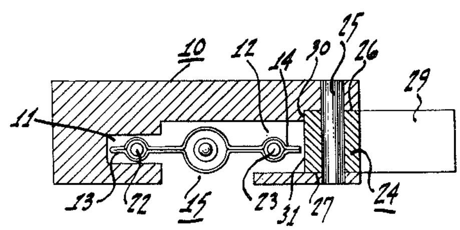
Automatic Racking Apparatus
Pat. No. 2,829,477—granted April 8, 1958 to J. L. Folly.

Cathode Ray Tube Manufacture
Pat. No. 2,836,751—granted May 27, 1958 to J. C. Turnbull and R. D. Faulkner.

Input and Output Coaxial-Type Circuits for Double Ended Vacuum Tubes
Pat. No. 2,840,647—granted June 24, 1958 to M. V. Hoover and L. L. Koros, IEP, Camden, N. J.

Harrison, N. J.

Safety Release for Automatic Mounting Apparatus
Pat. No. 2,831,239—granted April 22, 1958 to F. J. Pilas, R. K. Wolke and J. A. Chase.



Pilas, Wolke and Chase—Pat. No. 2,831,239

Apparatus for Automatically Mounting Spacer Plates in Electrode Assemblies
Pat. No. 2,831,238—granted April 22, 1958 to J. A. Chase, F. J. Pilas and R. K. Wolke.

Electron Tube Mount
Pat. No. 2,836,746—granted May 27, 1958 to R. K. Wolke and F. J. Pilas.

RADIO & "VICTROLA" DIVISION

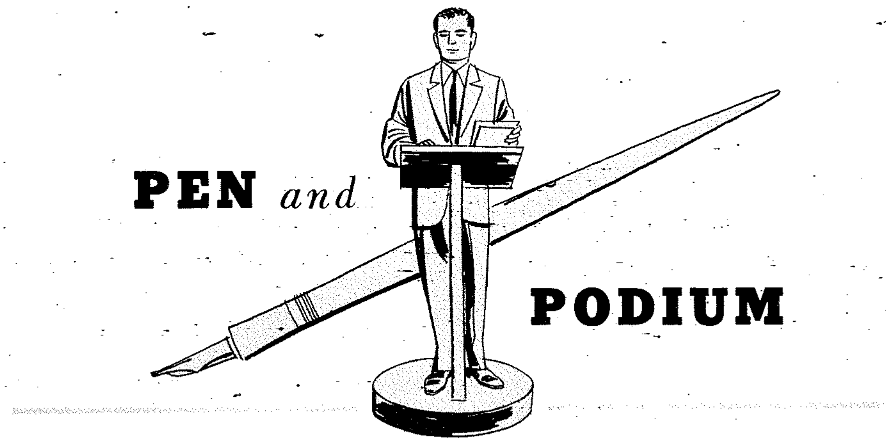
Cherry Hill, N. J.

Electronic Limiter Circuit
Pat. No. 2,836,714—granted May 27, 1958 to D. R. Andrews.

RCA INSTITUTES

New York City, N. Y.

Selective Calling System
Pat. No. 2,811,708—granted Oct. 29, 1957 to I. F. Byrnes, Mr. Myers and Mr. Zettler.



BASED ON REPORTS RECEIVED OVER A PERIOD OF ABOUT TWO MONTHS

ELECTRON TUBE DIVISION

Harrison, N. J.

RCA Color Picture Tubes
By W. M. James: Presented at Tokyo, Japan, April 10, 1958; and at Osaka, Japan, April 17, 1958. The development of color picture tubes for use in the RCA compatible color television system is described. The design of the 21CYp22 is discussed and advantages compared with earlier tubes.

Low-Noise Traveling-Wave-Tube Preamplifiers
By A. G. Hogg and R. W. Kissinger: Presented at Southwestern IRE Conference, Dallas, Texas, April 10, 1958. The use of low-noise traveling-wave tubes as preamplifiers for microwave receivers is discussed, and useful design information is given. Suitable circuitry and a method for increasing dynamic range is discussed.

Business Systems Simulation in Production Planning
By W. K. Halstead: Presented at Institute of Management Science, New York City, April 14, 1958. The dynamic nature of the business system is outlined, and a system plan is described which promises to give substantial gains through improvements in information flow. Use of a computer to reduce planning time from ten days-per-month to one day or less was discussed.

A Sequential Method for Screening Experimental Variables
By C. H. Li: Presented at American Statistical Association, New York City, April 15, 1958. A sequential method is described for determining the important variables in a given experiment with maximum efficiency. Tables showing optimum designs and total number of tests or samples required are included.

What The V.T.V.M. Can Do For You in the Ham Shack
By Rhys Samuel: Presented to Amateur Radio Club, Livingston, N. J., April 18, 1958. Meters and their proper application in the ham shack are discussed, and basic measurement techniques are described. Advantages of vacuum-tube voltmeters over non-electronic meters in amateur measurements are shown.

A Small, Light-Weight Traveling-Wave Tube for Military Applications
By H. J. Wolkstein, R. Pekarowitz, and E. H. Diamond: Presented at IRE National Convention on Military Electronics, Washington, D. C., June 16-18, 1958. An amplifier chain for the 2000-to-4000-Mc band consisting of two packaged traveling-wave tubes is described. Design features and operating techniques which permit small size, light weight, and good electrical performance and stability are discussed.

Considerations for the Reliable Use of Receiving-Type Tubes in Class "C" Circuits
By A. Dzik: Presented at IRE National Convention on Military Electronics, Washington, D. C., June 16-18, 1958. Effects of class C operation on receiving-type tubes are analyzed, and circuit-design techniques which can be used to improve equipment reliability are described.

Fix Your Scope
By Rhys Samuel: Published in RADIO-ELECTRONICS, April 1958. Typical defects encountered in oscilloscopes are analyzed, and techniques for locating the cause and correcting the defect are described.

Worksheet Gives Optimum Conditions
By C. H. Li: Published in CHEMICAL ENGINEERING, April 7, 1958. A worksheet is described for rapid planning and analysis of efficient exploratory tests. The worksheet is based on modern statistical principles. Examples of its use in development and in production are given.

A Low-Cost Hi-Fi Amplifier
By L. Kaplan: Published by RADIO & TV NEWS, May, 1958. A simple, low-cost hi-fi using only 3 tubes is described. The amplifier uses a 6BH8 in the input and phase-inverter stages and two 6973's in the push-pull output stage. It has a total harmonic distortion of 0.5 per cent and a sensitivity of 0.98 volt at an output of 15 watts.

Why Don't You Write A Paper?
By E. M. McElwee: Published in Northern New Jersey IRE NEWSLETTER, May 1958. Engineers are encouraged to write papers for publication, and some helpful hints are given on getting started, organizing material, choosing illustrations, and submitting the finished paper.

A Transistorized Grid-Dip-Meter
By C. A. West: Published in HAM TIPS, June 1958 and April 1958. A grid-dip meter utilizing a high-frequency drift transistor and a semiconductor diode is described. Details of construction are given, and the operation and use of the meter are discussed.

Lancaster, Pa.

Sensitivity and Speed in Television Camera Tubes
By R. G. Neuhauser: Presented at SMPTE Convention, Los Angeles, Calif., April 21, 1958. Speed and sensitivity in television camera tubes are compared with equivalent properties in photographic film. Effective speeds of various camera tubes are evaluated in terms of ability to stop motion. Effects of over-exposure and under-exposure on speed are illustrated.

Phosphors in the System Magnesia-Cadmium Oxide-Zinc Oxide-Silica
By P. G. Herold: Presented at Electrochemical Society, New York City, April 29, 1958. Four new compounds in the subject four-component system were isolated and identified. The relationships of these compounds on a weight-per-cent basis are described, and their compositions and X-ray diffraction patterns are shown.

Advances in High-Power Grid-Controlled Tubes, Techniques and Applications
By M. V. Hoover: Presented at I.E.E. International Convention on Microwave Valves, London, England, May 19-23, 1958. Design features and techniques are discussed for triode and tetrode tubes for vhf and uhf operation. Features and applications of seven developmental and commercial super-power tubes are described.

Improved Power Fault Protection
By J. T. Mark: Published in ELECTRONIC DESIGN, March 3, 1958. A simple high-speed fault-protection circuit which provides both "dump-tube" and rectifier-blocking protection is described. The circuit can be used for high-, medium-, or low-power equipment.

SEMICONDUCTOR AND MATERIALS DIVISION

Somerville, N. J.

A 25-Watt Transistor Hi-Fi Amplifier
By R. C. Janzow: Presented at the IRE Section Meeting, Milwaukee, Wisc., April 22, 1958. A transistorized high-fidelity amplifier using RCA commercial transistors is described. The 4-transistor preamplifier incorporates bass and treble tone controls, a level set, and loudness controls.

Mechanical Standardization for Transistors
By R. B. Janes: Presented at Electronic Components Conference, Los Angeles, Calif., April 22-24, 1958. The need for standardization in the transistor field is discussed, and the work of JETEC committees is reviewed. Examples are given of progress made on various items.

Transistor Design and Manufacture
By R. E. Rist: Presented at Student AIEE Branch, Newark College of Engineering, Newark, N. J., May 1, 1958. Basic transistor design considerations are discussed, including materials, mechanical design, and manufacturing processes. Engineering fields existing in the semiconductor industry are described.

The Thyristor—Design and Applications
By I. H. Kalish and A. J. Bosso: Presented at Metropolitan Chapter of IRE Professional Group on Electron Devices, New York City, May 8, 1958. Construction of the Thyristor, a new semiconductor switching device, is described. Electrical characteristics are presented, and the unique switching action is analyzed. Typical circuits are shown for using the Thyristor in flip-flops, ring counters, and shift registers.

Transistors
By A. Kerken: Presented at Amateur Radio Club, Babylon, L. I., N. Y., May 19, 1958. A general review is given of semiconductor

theory, transistor design, ratings, operating considerations, and circuits. Special emphasis is given to amateur equipment that can be transistorized.

The Effect of Material Characteristics In Transistors
By W. M. Webster and S. Lederhandler: Presented at International Conference on Solid-State Physics, Brussels, Belgium, June 2-7, 1958. The role of dislocations and strain in diffused-silicon diodes and transistors is described. The infrared equipment used in the correlation study and the measurement techniques employed are also discussed.

Camden, N. J.

Microminiature Modules
By D. Mackey: Presented at IRE Professional Group on Component Parts, Phila., Pa., May 20, 1958. "Modularization" is described as a new technique of component manufacture in which single-function components will gradually be replaced by multi-function miniaturized components. Several examples of possible constructions for various components are given, and some of the problems encountered are discussed.

RCA VICTOR TELEVISION DIVISION

Cherry Hill, N. J.

Time Domain Synthesis
By M. S. Corrington: Presented at a lecture series in New York City on March 3, 1958. Sponsored jointly by IRE, New York Section Professional Group on Circuit Theory, IRE American Institute of Electrical Engineers, Basic Science Division. Methods for equalizing a network to produce a desired transient were described in detail. Techniques for solving the integral equations and a comparison of minimum and non-minimum phase networks were given. It was shown that linear-phase systems have symmetrical transients, and that they can be synthesized with delay-line filters.

Tracing Distortion in Stereophonic Disc Recording
By M. S. Corrington and T. Murakami: Presented at the IRE National Convention, New York City, March 25, 1958 and at an ASA meeting, Wash., D. C., May 10, 1958. The theory of the vertical-lateral, and the 45°-45° stereophonic disc records was derived. The equations for the stylus motion were solved to obtain the harmonic and cross modulation distortion for each system. Curves showing the tracing distortion were computed for various stylus radii, recording levels, and groove velocities. It was shown that the stylus radius and the recording levels should be reduced below present limits for LP records to make sure the distortion does not exceed tolerable limits.

DEFENSE ELECTRONIC PRODUCTS

Camden, N. J.

A New Head-Set Microphone for Military Use
By M. L. Touger: Presented at Acoustical Society of America Meeting, Wash., D. C., May 9, 1958. This paper describes the H-157 (XA)/AIC, a new headset-microphone combination which was developed by the Transducer Engineering staff of RCA Defense Electronic Products for the Air Force under a contract with the Communication and Navigation Laboratories at Wright Air Development Center.

A Night Television System
By Charles Shelton, Earle Townsend, and B. F. Walker: Presented at the Professional Group for Military Electronics Meeting in Washington, D. C., July 16, 1958. The co-authors are all engineers in Section 599, Airborne Radar and Missile Engineering.

Moorestown, N. J.

Equipment Manufacturer's Requirements for Hydrogen Thyratrons Used in Missile Tracking Transmitters
By C. Pappas: Presented at the 5th Hydrogen Thyratron Symposium on May 22, 1958 at Fort Monmouth, N. J. This paper sets forth four principal requirements for hydrogen thyratrons for the modulators of transmitters used in missile tracking systems of ground-based equipment.

Outline of Some Practical Aspects of Quality Control as Applied at the Missile and Surface Radar Department of RCA
By Eugene West: Presented at Phila. Ordnance District Office, Phila., Pa., May 2, 1958. This outlines how quality is controlled at M&SR; the government inspector's role in M&SR quality control; special quality problems in small-quantity, large-systems manufacture; how our system is self-correcting by feedback and that an adequate system assures quality.

A Guidance Radar for Satellites, Space Vehicles and Ballistic Missiles
By E. A. Mechler, J. W. Porter and R. O. Yavne: Presented at the 2nd National Convention on Military Electronics (IRE) Wash., D. C. on June 17, 1958. Ballistic missiles, satellites, and space vehicles for lunar navigation require a very precise measurement of velocity. Angular rates at 1,000,000 feet range must be measured to better than 10 microradians/second. A tracking radar, the AN/FPS-16, has this capability and is already in the field. The design of the radar and the various instrumentation methods for achieving this measurement are discussed.

Digital Ranging System
By A. J. Lisicky: Presented at the 2nd National Convention on Military Electronics, Wash., D. C. on June 17, 1958. An all electronic range tracking unit for pulse radars has been developed which utilizes both analog and digital techniques. The electronic range tracking unit possesses many advantages over its electro-mechanical counterpart.

Computation of Cross-Correlation Function
By H. Rosenthal: Presented at the 650 Technical Computing Seminar in Phila., Pa., in February, 1958. Cross-correlation coefficients have been found to be useful in comparing the characteristics of one time distribution with several others. A description of a program for computing cross-correlation coefficients will be given in flow-chart form, details being outlined where necessary.

New York City, N. Y.

Reduction of Bandwidth Requirements For Radio Relay Systems
By A. Mack and A. Meyerhoff, DEP, New York and D. L. Jacoby and R. H. Levine, U. S. Army Signal Eng. Labs., Fort Monmouth, N. J.: Presented at the 1958 IRE Convention, March 24-27. A comparison is made between the minimum bandwidth requirements for *ppm*, binary *pcm*, and quaternary *pcm* signals. Use of bipolar *pcm* results in additional reduction in bandwidth requirements, as well as an improvement in noise threshold when compared with conventional *pcm*. A reduction of 12-to-1 in receiver bandwidth has been achieved relative to existing systems.

INDUSTRIAL ELECTRONIC PRODUCTS

Camden, N. J.

On the Behavior of Ear Protection Devices Below 1000 CPS
By A. L. Witchey: Presented at the Spring Meeting of the Acoustical Society of America, Wash., D. C., May 8, 1958. An experimental study of the maximum possible sound exclusion provided by ear protection devices was presented and included such parameters as environment, boundary, clamping, shell volume, pad and flange.

An Automatic Communications Switching System
By R. E. Montijo: Presented at the 7th Region IRE Conference, Sacramento, Calif., May 2, 1958. This paper was also presented by James L. Owings for R. E. Montijo at the Armed Forces Communications and Electronics Association Annual Meeting in Wash., D. C., on June 5, 1958. The paper describes a system of electronic equipment designed to collect and distribute the large masses of communication information required as input and output by electronic data processing centers. Featuring flexibility and the facilities for expansion, this system performs automatic transceiving, categorizing, routing, switching, and editing of digital communications data for a range of applications and traffic loads.

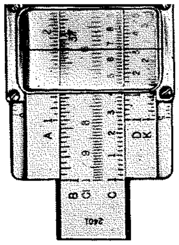
The RCA 501—A Transistor Computer System
By G. E. Poorte and A. S. Kranzley: Presented at the Western Joint Computer Conference, Los Angeles, Calif., May 7, 1958. This paper describes a new transistor Computer System developed by RCA to fit a wide range of applications. Higher tape and data speed, completely variable item and message length, parallel data transfer and exceptional flexibility in handling magnetic tape input-output are a few of the features.

The Analysis of Programming Techniques and Their Relationship to Computer Structure
By John H. Waite, Jr.: Presented at the AIEE Summer General Meeting, Buffalo, New York, June 27, 1958. This paper describes some of the programming techniques which have resulted in computer design changes, such as simultaneous input-compute operations, minimum latency conversion routines, column addressing techniques, address generation techniques, relative addressing techniques and others.

ASTRO-ELECTRONIC PRODUCTS DIVISION

Hightstown, N. J.

An Extremal Problem With Infinitely Many Interpolation Conditions
By J. Minker, Astro-Electronic Products, B. Epstein, Univ. of Pa., and D. S. Greenstein, U. of Michigan: Published in the ANNALES ACADEMIAE SCIENTIARIUM FENNICAE JOURNAL. In this paper we first consider a specific domain D_6 together with a certain denumerable set of joints (z_k) and obtain a necessary and sufficient condition on the prescribed values (a_k) in order that there may exist a quadratically integrable function which satisfies, $f(z_k) = a_k$, and thus assures the existence of a minimizing function. When this condition is satisfied, the extremal function is obtained. Finally, the method employed is modified so as to be applicable to somewhat more general domains.

Engineering  NEWS *and* HIGHLIGHTS

EARL ANDERSON APPOINTED CHIEF ENGINEER

Mr. Anderson has recently been appointed Chief Engineer of IEP Communications Equipment Department. This includes all of RCA's non-military communications equipment and is composed of the mobile radio, microwave equipment and systems, and Radiomarine Divisions.

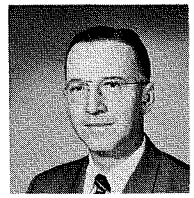
He joined what is now the RCA Industry Service Laboratory in New York in 1937 as an engineer and was Engineer-in-Charge of that Laboratory when he left in February of this year to join the Communications Department. During this time he was closely associated with the rapidly advancing Television receiver field. He was given a Fellow Award by IRE in 1954 for his contributions in this area. He also holds some 30 patents. He has been a member of the Administrative Committee of the Professional Group on Broadcast and Television Receivers almost since the inception of the group and has served as its vice-chairman and chairman as well as editor of its Transactions.

During the War he was in charge of the Shoran project from its inception to its actual use in battle in Europe. In addition, he designed for the U. S. Navy what is believed to be the first successful doppler effect speed indicator.

He got his first ham ticket at the age of 12 (present call W2UE) and has been active since. He was one of the pioneers in ham single sideband, having used this form of transmission since 1950.

ENGINEERS IN NEW POSTS

Dr. Alan Glover announces the organization of Engineering in the Semiconductor and Materials Division—With Dr. Glover acting as Chief Engineer, his managers are **B. V. Dale,** Mgr. Modules Engineering, **Dr. F. E. Vinal,** Mgr. Materials Engineering and **D. H. Wamsley,** Mgr. of Semi-conductor Engineering . . . **J. J. Newman** becomes Defense Planning Mgr. for S & M Division at Somerville.



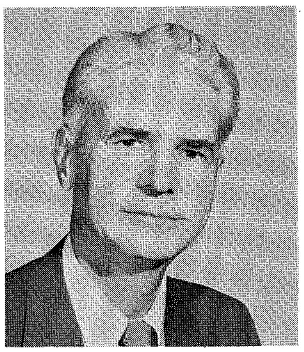
B. V. Dale

In IEP, **J. C. Walter** becomes Mgr. of High-Power Radar Transmitter Engineering of Broadcast and TV Equipment Dept., Telecommunications Division.

In the Electron Tube Division, **R. F. Dunn,** Mgr. of Entertainment Tube Development, appoints **R. C. Fortin** as Mgr. Entertainment Tube Design-Current Products, and **M. Bondy,** Mgr. of Entertainment Tube Design-New Products.

S. H. Watson, Mgr. Corporate Standardizing, appoints **D. Drusdow** Administrator, Electrical Standards.

J. BURGESS DAVIS RETIRES



Long associated with technical writing and editing, J. Burgess Davis retired May 30, 1958. At the time of his retirement, Mr. Davis was Engineering Editor and Technical Papers Coordinator for Defense Electronic Products. He had been associated with the RCA ENGINEER since its inception as Engineering Editor for Industrial Electronic Products and DEP.

Mr. Davis attended Bloomsburg State Normal School and Albright College, and has been closely affiliated with radio and television for more than thirty years, twenty-five with RCA. He has served as technical advisor in extension courses with RCA Institutes, technical writer and lecturer for RCA Service Division, and technical writer and editor for Special Apparatus and Engineering Products Divisions.

His most recent professional society activities include Editor of the IRE Bulletin, Philadelphia Section, and member of the New Jersey Industrial Editors' Association.

The Editors are grateful to Burgess Davis for his invaluable assistance and cooperation. His efforts on the RCA ENGINEER will be missed.

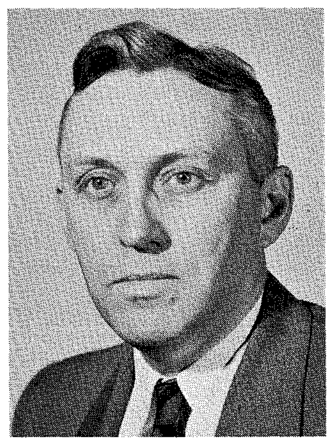
FRANK TALMAGE DIES AFTER PROTRACTED ILLNESS

F. E. Talmage was Manager of the Low Power Transmitter Design Section in the Broadcast Transmitter Engineering Department before his recent death. Born on May 14, 1911, he received his B.S. in E.E. from Georgia Institute of Technology in 1934. He was employed by RCA in Camden, New Jersey since 1935. The last sixteen years were in the Engineering Department working primarily on the design of AM, FM, and TV Transmitters.

Mr. Talmage was an outstanding engineer in the department and achieved an excellent record of accomplishments not only in the field of equipment and circuit design but also in securing the utmost in cooperative effort from those who worked in his group. Frank was particularly active in the formulation of the initial line of RCA FM Transmitters, contributing in a major way to the design of these units.

He will be remembered by most broadcasters for his masterfully written papers and articles on FM transmitter operating and measuring techniques, which became basic reference material in the field. This material enabled Broadcasters to perform required FCC "Proof-of-Performance" tests simply and easily. His contributions in the design and operating techniques of television transmitters were no less important, and included high-power as well as low-power television transmitting equipments. All of Frank's transmitter designs are popularly accepted and used throughout the Broadcast Field.

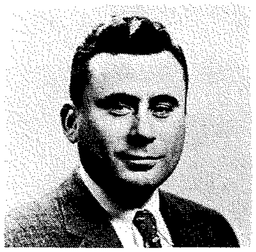
He was active as an RCA representative in various industry committees on broadcast equipment, where he made many friends outside the Company, and earned a reputation for objective thinking and constructive accomplishments. He was highly regarded and much consulted by the many Broadcast Station engineers and customers who knew him. He was particularly well liked and respected by his many coworkers throughout engineering, Marketing, Sales and Production Departments. His integrity and devotion to his work throughout the years established an example which will be an inspiration to all who knew him. —*C. D. Kentner*



ENGINEER IS APPOINTED TO DREXEL STAFF

John J. Nagle, engineer in Missile and Surface Radar Engineering at DEP's Moorestown Plant, has been appointed Adjunct Assistant Professor at Drexel Institute of Technology. Mr. Nagle will teach engineering at the Evening College (for his biography, see Mr. Nagle's article in the RCA ENGINEER, Vol. 2, No. 3.).

ASTRO-ELECTRONIC PRODUCTS DIVISION APPOINTS RCA ENGINEER REPRESENTATIVES



Sidney Sternberg appointed member, Advisory Board

E. A. Goldberg appointed Editorial Representative

The appointment of **Sidney Sternberg** as Chief Engineer of the Astro-Electronic Products Division to replace Arthur W. Vance, who is leaving the company, became effective on August 1, 1958. Mr. Sternberg has been with RCA for eight years, first at the RCA Laboratories and lately as project engineer for the Juno Project in the AEP Division. He was graduated from City College, New York City in 1943 with a BS in Physics. He continued studies at MIT, and in 1949 received a MEE degree from NYU. During this time he was employed at the Office of Naval Research where he worked on radar, sonar and related fields. During his years at the Laboratories he made important contributions to the development of the Typhoon computer for the Navy and the Dynamic Systems Synthesizer for the Air Force. For his work on the latter he received the RCA Laboratories award of merit. He is a senior member of IRE, a member of Sigma Xi, and of the American Rocket Society.

Edwin A. Goldberg received the degrees of B.S. in Electrical Engineering in 1938 and M.S. in Electrical Engineering in 1940 at the University of Texas. He joined the RCA Manufacturing Company in 1940 and was assigned to the Research Division in 1941. He became a member of RCA Laboratories Division when it was established in 1942, where he engaged in the development of electronic analog computers and computer components for fire control, missile simulation, and guided missile control. He also did circuit development work in color television. He is presently serving as a staff engineer for the Chief Engineer of the Astro-Electronic Products Division with the title of Manager, Engineering Administration.

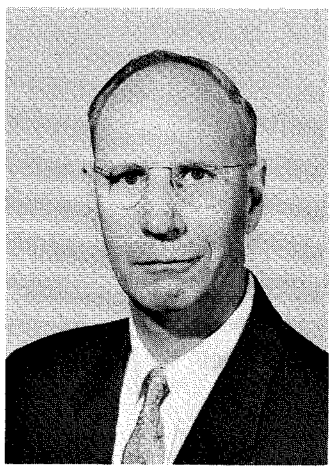
Mr. Goldberg has twenty issued patents. He is a member of Sigma Xi, Tau Beta Pi, Eta Kappa Nu, and the American Institute of Electrical Engineers.

FRANK WHITMORE APPOINTED ENGINEERING EDITOR FOR DEP

F. D. Whitmore has recently been appointed Technical Publications Administrator for Defense Electronic Products, replacing J. Burgess Davis on the latter's retirement. Among Mr. Whitmore's duties are Engineering Editor for the RCA ENGINEER, representing DEP.

Mr. Whitmore graduated from Oglethorpe University in 1935 with an AB degree in Liberal Arts. He joined RCA in 1936 as a transmitter tester, and transferred to International Sales in 1938 as a service engineer on the Russian television system contract. In 1941 he became head of the Instruction Book department of Special Apparatus.

In 1957 Mr. Whitmore became Manager of Administrative Services in DEP, where he served until his present appointment. Mr. Whitmore has been active in Amateur Radio since 1930. His call letters are W2AAA.



ASSISTANT EDITORIAL REPRESENTATIVES APPOINTED AT HARRISON

Henry E. Stumman and **William T. Kelley** have been appointed Assistant Editorial Representatives for Industrial Tube Products at Harrison by Herbert J. Wolkstein, Editorial Representative.

WILLIAM T. KELLEY received the BS in Mathematics and Economics from Bethany College in 1950 and joined the RCA Tube Division in parts preparation engineering. He received further training in the Signal Corps during the Korean War and returned to RCA as a Manufacturing Engineer at Harrison, currently in Production facilities planning.

For biography of H. E. Stumman, see RCA ENGINEER Vol. 2 No. 3.

ASSISTANT EDITORIAL REPRESENTATIVE APPOINTED AT DEP NEW YORK

In March of this year, **Miss Audrey M. Arzinger,** Librarian at DEP Surface Communications Systems Laboratory, 75 Varick Street, New York, N. Y., was appointed Assistant Editorial Representative.

Miss Arzinger joined the Radio Systems Research Laboratory of RCA Laboratories Division in New York, N. Y., in 1942, as statistician on terrestrial magnetism, solar and key-circuit performance investigations. She went on to work in literature searching and to edit the Engineering Memorandum on the RCA Mux/ARQ-1 Terminal. Her transfer to the SurfCom Systems Lab was effected on January 1st, 1957.

COMMITTEE APPOINTMENTS

Tube Division, Harrison

Rhys Samuel of the Commercial Engineering activity of the Electron Tube Division, Harrison, has been appointed Managing Editor of the Newsletter for the Northern New Jersey Section of the IRE.

Markus Nowogrodzki, Manager, Microwave Tube Development at Harrison, has been re-appointed to the IRE Committee for High Vacuum Microwave Tubes. In addition, he also serves as Chairman of the Subcommittee on Non-Operating Characteristics of Microwave Tubes.

Willis F. Beltz, Manager, Microwave Tube Quality Control, has been reappointed to the JETEC Industry Committee for Microwave Tubes.

Marvin J. Ungar of Microwave Tube Application Engineering has been appointed Chairman of the JETEC Subcommittee on Traveling-Wave Tubes.

Max Magid, of Microwave Tube Application Engineering, has been appointed to serve as a member of the JETEC Subcommittee on Standardization of Magnetrons Within the Industry. —*H. J. Wolkstein*

IEP Camden

J. C. Walter has been appointed Chairman of the Registration of Engineers Committee for the Philadelphia Section of the American Institute of Electrical Engineers. This is a newly formed committee to promulgate the registration of professional engineers and to cooperate, upon request, with the State Boards of Registration in the development of adequate written examinations. —*C. D. Kentner*

DEP Camden

At the April meeting of the Philadelphia Section of the American Institute of Electrical Engineers, **Mr. T. H. Story** of the DEP Surface Communications Engineering Department, Camden, was elected Manager for a term of two years beginning with June, 1958. He has also been appointed chairman of the Committee on Arrangements for the 1959 Electronics Conference jointly sponsored by the AIEE, the IRE, the EIA, and the WCEMA. Mr. Story has also been made a member, for a two year term, of the Committee for the AIEE National Prize Paper. —*E. O. Selby*

Tube Division, Marion

New Officers appointed to the Marion Chapter of the National Industrial Management Club include **T. J. Morris,** Manufacturing Engineer, as Program Chairman, and **M. Jefferson,** Manufacturing Engineer, as Publicity Chairman.

The retiring officers of the organization included **M. Massey,** Manufacturing Engineer, and **D. Collins,** Manufacturing Engineer, who served as President and as Treasurer, respectively.

C. Lattimer, Manager, Marion Chemical and Physical Laboratory, Electron Tube Division, has been appointed Vice President of the Indianapolis Chapter of the Electro-Chemical Society. —*J. deGraad*

RCA Service Company

Edward Stanko, Manager, Engineering Section, Technical Products Service Department, RCA Service Company, has been appointed as a member of the SMPTE Screen Brightness Committee.

MEETINGS, COURSES & SEMINARS

AMA Workshop

G. G. Carne, Manager of Industrial Receiving Tube Engineering recently attended an American Management Association workshop seminar at Colgate University on "Managing and Measuring Engineering Performance" at Colgate University.
—H. E. Stumman

American Ceramic Society

Howard E. Cooper, Ferrite Engineering, Television Division, Findlay, Ohio, attended the convention of the American Ceramic Society in Pittsburgh, April 28-30. *—H. P. J. Ward*

Color Seminars

Two TV seminars held at Hollywood Roosevelt Hotel on April 24-25 and May 2-3, each attended by 60 to 70 technical and managerial people from broadcast stations, universities, telephone companies, etc. Speakers: J. W. Wentworth, A. F. Inglis, H. N. Kozanowski, B. F. Melchionni, J. H. Roe, R. E. Jose and A. H. Lind of Broadcast Studio Engineering, IEP, Camden. *—J. H. Roe*

Communications

R. F. Kolar, Television Division Advanced Development Engineer at Cherry Hill, spoke on the subject of a Free-Field Room at a recent Seminar on Modern Communications at RCA Laboratories, Princeton.
—M. C. Kidd

Computing Systems Course

On April 29, 1958, the first group of Service Computing Systems Engineers was graduated. Certificates were presented to the graduates by Edward Stanko, Manager, Engineering Technical Products, following a dinner at Compton's Log Cabin. The graduates were addressed by J. Wesley Leas, Chief Engineer of the Electronic Data Processing Division.

Those graduating were R. Heacock, D. Phelps, W. Davids, D. den Boef, J. McKinney, P. Rhodes, J. Wentz, R. Woodbury and H. Srolovitz. R. Heacock and D. Phelps were given special recognition as the honor men in the class.

The course instructors were: J. Anderson, G. Kropp, L. Gallo, T. Seetoo and B. Swedloff. *—E. Stanko*

Creativity

C. M. Sinnett, Mgr. of Advanced Development, Television Division at Cherry Hill, gave a talk to the American Management Association Symposium on May 15, 1958. His talk was, "Creativity: Motivation of Engineers." *—M. C. Kidd*

Disc Recording

On June 12 **Mr. B. J. White,** of Engineering, RCA Victor Record Division, Indianapolis, was the guest speaker at an Electronics Seminar sponsored by Indiana Technical College, Fort Wayne, Indiana. Mr. White's lecture was presented as part of the open house and dedication ceremonies commemorating the formal opening of the new Dana Science Building.
—S. D. Ransburg

IRE Award for Audio Paper

James J. Davidson, Advanced Development Engineering, Radio and "Victrola" Division received the 1956-1957, IRE Professional Group on Audio Award for his paper entitled 'Low Noise Transistor Microphone Amplifier' delivered at the 1957 IRE Convention in New York City.
—W. S. Skidmore

Recording Techniques

On June 2, 3 and 4 an RCA Victor Record Interplant Plating Meeting was held in Indianapolis for the purpose of discussing record recording and process problems. Such topics as stereophonic quality and process techniques, improved recording lacquer cleaning methods, plating equipment development, and impurity analysis for plating solutions were reported by the engineers attending this session.
—S. D. Ransburg

Sound Recording

H. E. Roys, Manager of Record Engineering, Indianapolis, attended the International Electrotechnical Commission Meetings on Sound Recording in Stockholm, Sweden, July 7-9.

At the meetings, which were attended by the foremost recording engineers of Europe, standards pertaining to disc and magnetic recording will be established.

Mr. Roys who is Chairman of American Standards Association Sectional Committee Z57 Sound Recording, served as a delegate of the U. S. National Committee.

Transistor Applications

An in-plant course on the applications of transistors to television circuits was inaugurated in Broadcast Studio Engineering, IEP, in May. **R. N. Hurst** and **A. C. Luther** are preparing the course material and presenting the lectures. *—J. H. Roe*

IRE VISITS SOMERVILLE

The Princeton IRE Sub-section visited the Somerville operations of the Semiconductor and Materials Division on May 8. Approximately 150 members were present for a talk on RCA transistors by D. H. Wamsley, Manager, Semiconductor Engineering, and for a tour of the manufacturing area.

The Monmouth IRE Sub-section also visited Somerville on June 18. Approximately 75 members attended a talk by members of the Sales Department. Following a tour of the manufacturing area, a question and answer session was held with a panel of Semiconductor and Materials Division engineers. *—R. E. Rist*

ETA KAPPA NU VISITS MARION PLANT

Forty-five members of the Eta Kappa Nu Chapter of Purdue University were the guests recently of the Electron Tube Division at Marion. The group was welcomed by L. Gillon, Marion Plant Manager, who was followed by W. Harrington, Manager, Development Shop, speaking on "Electrical Engineering in the Cathode Ray Tube Industry."

Following a dinner, the group was taken on a tour of the operation by R. Salveter, R. Whitlock, R. Konrad, J. Bumke, W. Blankenship, and M. Calvin, all Purdue University Engineering graduates.
—J. deGraad

LANCASTER TRAINING PROGRAM IN CREATIVITY

The first Training Program in Creativity based on the new outline developed by the RCA Engineering Training Committee was completed recently in Lancaster. Objectives of the Program are:

- To make managers and engineers more aware of their creative ability.
- To help managers recognize their responsibility for stimulating creativity in their engineers.
- To study the creative process and certain techniques which should help managers and engineers use their own creative talent more effectively.

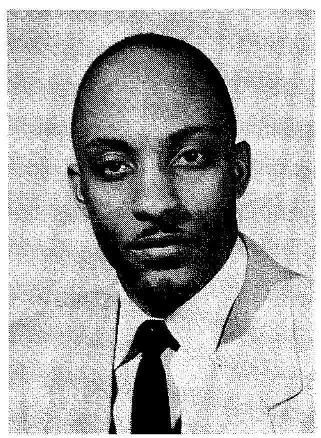
Lancaster was most fortunate in obtaining Mr. C. M. Sinnett, Manager of Television Engineering Advanced Development at Cherry Hill, to conduct this first series of sessions. For many years Mr. Sinnett has been active in the development of creative thinking, having served officially at numerous national industrial and educational conferences.

The course was covered in eight weekly sessions of one-and-one-half hours each. At the first session, Mr. P. C. Farbro, Manager of RCA Staff Training and Personnel Research, summarized events leading up to the inception of the course, outlined the background of the series planned, and expressed the interest of RCA management in the successful introduction of training in creative thinking. He explained the selection of the Lancaster location for introducing this work was due to the very active interest there for the past several years.

The course was developed and Mr. Sinnett's services were obtained through the efforts of the Lancaster Training Manager, and the members of the Lancaster Engineering Education Committee and its Subcommittee on Creativity. *—D. G. Garvin*

HI-FI SERIES IN CAMDEN "RCA FAMILY"

In glancing through the Camden editions of the RCA FAMILY issued over the past two years, we have noticed the periodic appearance of some interesting articles on high fidelity. The slant, of course, is to the layman but we are impressed by the lucid style and broad informative approach to the subject.



The author of this series is Sidney Sykes, Jr., on the technical writing staff of Section 571, IEP Technical Publications, Camden. Formerly a tester in IEP Broadcast Communications, he has studied at Philadelphia Wireless School and Temple University.

The current popularity of high fidelity, without a doubt, owes much to articles such as these. The hi-fi fans among our readers might find it profitable to look into them.

ENGINEERING DEGREES

DEP New York

William M. Mazer, Surface Communications Systems Laboratory, DEP, New York, was awarded a Doctorate in Electrical Engineering from the Polytechnic Institute of Brooklyn on June 11, 1958. He received his B.E.E. from City College of New York in 1947, and his M.M.E. from the Polytechnic Institute of Brooklyn in 1950.
—*A. M. Artzinger*

DEP Moorestown

N. I. Korman, Chief Systems Engineer, Missile and Surface Radar Engineering, DEP Moorestown, received his PhD degree from the University of Pennsylvania, June 11, 1958. Dr. Korman received his BSEE in 1937 from Worcester Polytechnic Institute, where he was graduated with "highest distinction." As an undergraduate at Worcester Polytechnic Institute, he was elected a member of Sigma Xi.

Robert N. Casolaro received the Masters Degree in EE from Drexel Institute of Technology on June 14, 1958.

The following Engineers of the R-F, Video & Computer Mech. Engineering Unit, DEP Moorestown have completed degrees as shown:

Walter Robinson, B.S. in ME, Drexel Institute of Technology.

Ervin Bruzel, Missile and Surface Radar Engineering; Diploma in Mechanical Engineering, Drexel Institute of Technology.
—*I. N. Brown*

DEP Camden

W. F. Meeker, Audio & Transducer Engineering, DEP Surface Communications Dept., received the MSEE Degree at Univ. of Penna. on June 19, 1958.

G. J. Rauscher, DEP Surface Communications Engineering, received the BS degree in Mechanical Engineering at Drexel Institute of Technology, June 14, 1958. During his degree program, Mr. Rauscher won the following distinctions: Academic Achievement Award, G. W. Childs Honorary Scholarship, Alpha Sigma Lambda Honorary Fraternity.
—*E. O. Selby*

Tube Division, Lancaster

John Wallen Gaylor and **John Kolostyak,** Industrial Tube Products Engineering, also **John Evans, Jr.,** Color Kinescope Engineering, received Masters of Science Degrees from Franklin & Marshall College on June 9, 1958.
—*D. G. Garvin*

Tube Division, Harrison

L. P. A. DeBacher and **J. Gutowski** of Industrial Receiving Tube Engineering at Harrison received Master of Science degrees in June 1958 from Stevens Institute of Technology.

J. A. Olmstead has returned to Industrial Receiving Tube Engineering at Harrison for the summer. Mr. Olmstead has been on a leave of absence to work toward a PhD degree in Electronic Math. at the University of Buffalo.
—*R. L. Klem*

IEP Camden

Albert Feller, IEP Broadcast Transmitter Engineering, received his MSEE degree from Moore School of Electrical Engineering, Penn.
—*C. D. Kentner*

Alfred G. Jones, Electronic Data Processing Engineering received his MSEE from the University of Pennsylvania on June 11.
— *T. T. Patterson*

Semiconductor & Materials Division

Degrees have been granted to the following engineers: **Semour Dansky** received the BSEE degree from Newark College of Engineering; **George Granger** and **Philip Kuznetzoff** both received the MS degree from Stevens Institute of Technology; **Haig Goshgarian** received the MSEE degree from Newark College of Engineering.

Walter Kunnmann of the Materials Engineering Laboratory, Needham has been granted a Teaching Fellowship in the Department of Chemistry with the Polytechnic Institute of Brooklyn. Mr. Kunnmann plans to pursue a Teaching Fellowship to obtain a doctor's degree in chemistry.
—*T. A. Richard*

EDWARD SCHNEIDER RETIRES

Edward Schneider, field engineer with the Technical Products Service Department of RCA Service Company, has recently retired after thirty-three years with RCA. He joined the Victor Talking Machine Company as a tool maker in 1925, moving to the RCA Service Company in 1942 as a field engineer. In 1948 he transferred to the Public Demonstration group where he has aided in TV demonstrations around the world. His work took him to Berlin, Milan, Karachi, Djakarta, New Delhi and extensive traveling in both North and South America.

Mr. Schneider was presented with an RCA clock radio at a dinner given in his honor.
—*E. Stanko*

ENGINEERING MEETINGS AND CONVENTIONS

August-October, 1958

AUGUST 6-8
IRE-AIEE Special Technical Conf. on Non-linear Magnetism, Hotel Statler, Los Angeles, Calif.

AUGUST 13-15
IRE-AIEE-NBS Electronic Standards and Measures Conference, Boulder, Colo.

AUGUST 19-22
WESCON, Ambassador Hotel, Pan Pacific Auditorium, Los Angeles, Cal.

SEPTEMBER 22-24
IRE-PGTRC National Symposium on Telemetering, Americana Hotel, Miami Beach, Fla.

SEPTEMBER 24-25
IRE-AIEE Industrial Electronics Conference, Rackham Memorial Building, Detroit, Mich.

OCTOBER 1-2
4th Conference on Radio Interference Reduction, Armour Research Institute, Chicago, Ill.

OCTOBER 1-2
IRE Engineering Writing & Speech Symposium, Biltmore Hotel, New York, N. Y.

OCTOBER 6-8
Symposium on Extended Range and Space Transmission, George Washington University, Washington, D. C.

OCTOBER 8-10
IRE Canadian Convention, Exhibition Park, Toronto, Canada.

OCTOBER 13-15
National Electronics Conference, Hotel Sherman, Chicago, Ill.

OCTOBER 20-22
IRE 4th Annual Symposium on Aeronautical Communications, Hotel Utica, Utica, New York.

OCTOBER 21-22
URSI Fall Meeting, Penn State University, University Park, Pa.

OCTOBER 23-25
National Simulation Conference, Dallas, Texas.

OCTOBER 27-29
IRE-EIA Radio Fall Meeting, Sheraton Hotel, Rochester, N. Y.

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