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.

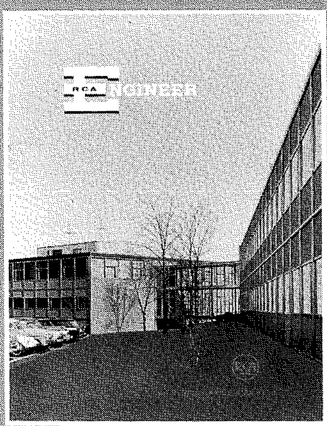
To serve as a medium of interchange of technical information between various engineering groups at RCA.

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.



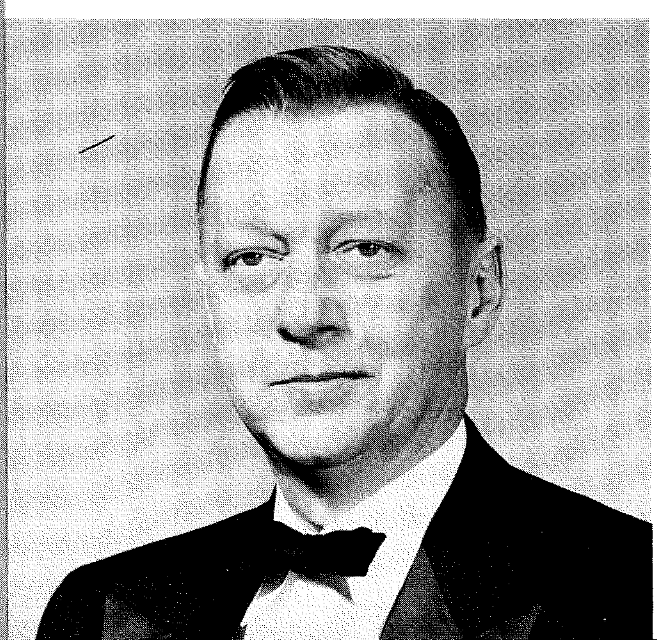
OUR COVER

This issue features a view of RCA buildings at Cherry Hill, N. J. Housing facilities include five interconnecting buildings which accommodate engineering and home office activities of RCA Service Co., RCA Victor Television Division, and RCA Victor Radio and "Victrola" Division. See article this issue by S. C. Starr.

A HERITAGE—A FUTURE

Some sixty years ago, when Eldridge Johnson invested his entire capital in advertising a new "Talking Machine," doubtless he had no idea that he was bidding for partnership in a long line of developments leading to the home entertainment business of today. Throughout the life of the acoustical phonograph, he carried on an aggressive engineering program of improving the reproduction of sound by way of disc records and the "Victrola" phonograph. The advent of radio and the vacuum tube amplifier opened up an entirely new and exciting avenue of further improvement. Some thirty years ago, RCA purchased the entire facilities of the Victor Talking Machine Company, including the heritage of science and engineering thus far developed. Progress was rapid and it was soon evident that, though radio for a while almost displaced the "Victrola" phonograph as a home entertainment device, there was room for both. The engineering strides made in radio added to the perfection of the "Victrola" phonograph. Soon a new engineering marvel—Television—entered the field, adding sight to sound. Again for a while, the newcomer bid for and attained first place in home entertainment.

Engineers continued working in a constantly broadening field, in order to present information more accurately to the ears and eyes of the user and also to make these products available to more people through lower production costs. Lately, there has been added another vast improvement —High Fidelity recording and reproduction. The ultimate success of High Fidelity is a tribute to the perseverance of the engineers in the area of recording as well as in Electronics and Acoustics. What of the future? Already there are signs that we have not reached the limits of possibility. Stereophonic sound is immediately before us, and the small success of this newest addition to the family of accomplishments, as thus far developed through the medium of magnetic tape, bids fair to blossom out in many directions. The engineering heritage of the past not only points a finger in the direction of the future, but presents a challenge which seems bounded only by the imagination. The technical superiority of our products is dependent not only upon invention and a constant search for better ways of performing today's tasks, but also upon retention of the gains made by our predecessors.



J. L. Franke

J. L. Franke
Chief Engineer
Radio & "Victrola" Division
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CONTENTS

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RCA ENGINEER

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JOHN D. ASHWORTH

HOW A TUBE ENGINEER IS DEVELOPED

by

Dr. L. B. HEADRICK

Staff Engineer

Kinescope Engineering

Electron Tube Division

Lancaster, Penna.

TO BETTER UNDERSTAND the need for training and development of the particular skills which contribute most to the development of the electron tube engineer, it is desirable to review briefly what an electron tube engineer does. The development and manufacturing engineering of electron tubes involves problems in essentially all of the important fields of applied science and engineering. Within the Electron Tube Division this engineering is divided into seven major functions: Advanced Development, Process Development, Materials and New Process Development, Equipment Development, Product Development, Application Engineering, and Manufacturing Control Engineering. Each of these functions involves many specific types of engineering and special problems.

The above phases of engineering are carried out between research and production and may extend over a period of several months to several years depending upon the complexity of the problems involved. The diagram below shows the relative timing of the various phases of engineering. The advanced development phase is difficult to schedule and is usually scheduled only in its latter stages. As indicated by the lines under each activity, there is some overlap between all parts of a program and some phases are planned for parallel development.

Although college science and engineering programs include good basic training in many fields and the electron tube engineer needs the basic training in as many fields of physics, chemistry, engineering, and the humanities as he can obtain while in college, he has much to learn from experience while working in many of the above aspects of Electron Tube Development on a variety of problems.

ADVANCED DEVELOPMENT

The advanced development engineer has the responsibility for general exploratory investigation of problems before the development of a specific product is planned for production. Advanced development may apply to a specific electron tube where some new and important features have been demonstrated by research samples but not evaluated. Advanced development work includes evaluation of the new features, advantages, disadvantages, limitations, and potential for further improvement over initial demonstrated performance. Preliminary guidance cost analysis must be made to provide an economic evaluation of the over-all performance advantages over existing products which the new device might replace—or to evaluate the potential of the new device along with existing devices. Advanced development also covers problems in fields that involve many different electron tubes, such as life and performance of cathodes, thermionic, photoelectric and secondary emission, degassing of materials, different metals, ceramics and glasses, cleaning methods, washing, firing in hydrogen, air or other gases. The study of electron optics, lenses and lens aberrations, properties of electron active solids, phosphors, ferrites, semiconductors and photoconductors, the study of new materials for tube-making, metals, ceramics, glasses, glass-to-metal sealing and coating materials may also be included in advanced development. Thus, the new engineer has an excellent opportunity to apply fundamental knowledge.

PROCESS DEVELOPMENT

The process development engineer has the responsibility for the development and standardization of electron tube manufacturing processes. The results of his work must be coordinated with the other requirements of tube design by the product development engineer. Tube process development is an excellent field for a new engineer to start to get acquainted with the requirements of tube-making and design.

Closely related to tube processing is parts cleaning which begins with the raw material supplier and parts vendor. To develop a suitable parts cleaning process and schedule, the process engineer must know what kinds of drawing, rolling, spinning, and forming lubricants are used and may even have to change some of them to provide an economical cleaning process to meet the requirements of tube life and quality. Some of the processes used are trichlorethylene wash, hot alkali, acid, detergent solution, oxidation-reduction and hydrogen firing. The effect of storage time after cleaning on gas re-absorption, oxidation, and other reactions must also be evaluated. For example, parts such as bulbs having large surface areas of coating may have to be evacuated within hours after air baking to maintain a suitably low level of surface adsorbed gas for good quality control. The effect of humidity and temperature also may be important in storage.

The exhaust process must be developed to achieve the required degassing consistent with good tube life in a minimum amount of time. The temperature cycle of the whole tube and of separate parts is most important. There are always one or more limiting items for the exhaust schedule. There may be one or more parts which must have a very thorough degassing because they will have to operate at high temperature for long periods of time with little or no gas evolution, or a large interior coated surface not readily degassed which is subjected to electron bombardment at high voltage during the tube life, or possibly stress developed in parts of the bulb during the heating or cooling part of the cycle. In some cases, the limitation may be the pumping system, or some part of it such as small-diameter exhaust tubing. Whatever the limiting items are, they must be known. Then all other factors can be held safely within their limits and new development effort can be directed toward removal of the basic limitation.

After the tube is based, suitable aging, sparking, spot knocking, and similar procedures must be developed to stabilize the cathode and the tube for performance testing and evaluation. Over-all stability is usually determined after a holding period of from one to seven days by retesting production lots on a sampling basis for initial evaluation of the product quality.

MATERIALS AND NEW PROCESS DEVELOPMENT

Many tube types require new materials and new processes to handle, apply, or use the new materials most effectively. Therefore, in a Materials and Process Laboratory, groups of people who are specialists in different fields work on programs of an advanced development or applied research nature to provide new materials and processes for the development of new products. Also, work is done to provide assistance to Manufacturing Engineering.

The new product development engineer must look to these experts in the fields of physics, chemistry, metallurgy, ceramics, glasses, and the like for new and better materials applied in new and better ways. In any new tube, one or more special problems may be involved in the following fields: glass- or ceramic-to-metal seals, metallurgy, parts cleaning and vacuum treatment, electron emission, coatings, cements, plastics, luminescent, photoconductive and semi-conductive materials, special applications methods for use of these materials, and analytical methods and measurements. In some cases, there is sufficient work for several experts, with supporting technicians, in one particular field.

This work provides another fine opportunity for a scientifically trained person to start in a specialized field of materials used in electron tubes and expand his knowledge to cover essentially the entire field of materials for electron tubes. He will also learn about material and tube processing, which is a vital part of tube making. The understanding of this field leads to a better tube design.

EQUIPMENT DEVELOPMENT

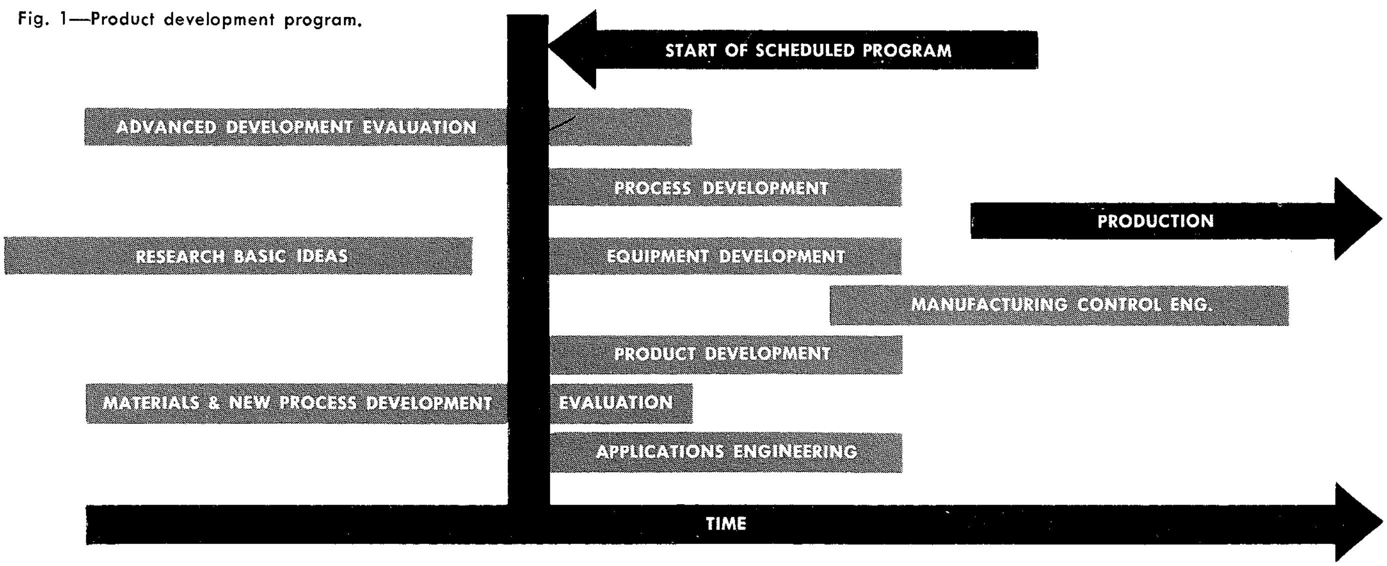
Equipment development engineering is a very important part of any new product development and manufacturing organization. New processing and fabrication equipment is needed for practically all new product developments, both for laboratory development and evaluation, and for pilot and regular production at an economical cost. In the development of equipment, flexibility, adaptability to change, unit size, and production volume become important together with the control methods, accuracy, reliability, and the like. In the Electron Tube Division new equipment is designed not only to do a job in RCA, but also to be sold like a new tube type to customers who may often be our competitors. Consequently, equipment designers must know the equipment limitations of other electron tube manufacturers so that equipment can be designed to meet their needs. Further details of equipment development operations and problems have been explained by H. V. Knauf, Administrator, Equipment Development, Electron Tube Division, in a paper entitled, "The Role of the Equipment Development Engineer in the Tube Division", RCA ENGINEER, Vol. 1, pp. 5-9, April-May, 1956.

A new engineer having interests in electrical equipment or machine design might well start with the equipment development group where he will learn directly how tubes are made and processed. To do a good job of equipment design, an engineer must know tube processing and have knowledge of properties of materials.

PRODUCT DEVELOPMENT

The product development engineer has the over-all responsibility for the development of new electron tubes or particular phases of new tubes for a given product line and also, in some cases, for advanced development, cost reduction, and quality improvement of current types. To do this work effectively, he must have years of experience in the many phases of tube engineering. After the product development engineer has gained considerable experience, he can establish the over-all engineering program for a new product development. He must be able to establish the relative importance of the various problems uncovered by an over-all analysis of the new product's expected performance and requirements. Through consultation with specialists working in the fields which deal with the various problems involved, he must estimate the engineering man-hours required to solve each problem. Then through consultation with the respective group managers, he must determine how the required engineering time can be obtained. After proper approvals are obtained he can establish a project budget and a time schedule with allowance for the solution of technical problems, procurement of new materials, equipment, and engineering effort. Tube design and construction, electrical performance characteristics, ratings, methods of tests, materials and processes should be proven, specified, and standardized before production materials and equipment are ordered for a production schedule which is based upon a sales forecast and demand. The product development engineer must also supply technical per-

Fig. 1—Product development program.



formance data and a description of product advantages and applications.

Because of the breadth of experience and judgment required of the product development engineer, it is difficult for an inexperienced engineer to start directly in this field except by working on specific problems which are a part of a major development.

APPLICATIONS ENGINEERING

While the above tube development work is being done, the applications engineer is working on specialized circuits in which the tube may be used, such as scanning and high-voltage systems for kinescope circuits, or high frequency input circuits, or cavities, waveguides, and coaxial lines for high frequency power tubes. The applications engineer must not only try to fit circuits and components to the new tube, but must also offer constructive criticism to the tube design engineer which will aid him in modifying the new tube to provide the best over-all balance of tube and circuit characteristics. New components from various suppliers are evaluated and comments and guidance are offered to suppliers on individual units. General circuit and components information must also be supplied to customers.

The applications engineer may work very closely with some customers in extended field testing of the new tube to prove its value, to determine any weak points, and to supply field life information before the tube is scheduled for production. He also has the responsibility for assisting the field engineer in informing the customer of the advantages of a new product and, thereby, of developing new business.

This circuit application work provides a good opportunity for a new engineer who has a possible interest in tubes but feels more confident in starting out in a more familiar circuit field. While working on circuit problems, he has the opportunity to learn much about tubes, and about the tube design engineer and his problems. Then if he develops interest in tube engineering, he may change to tube design engineering when an opportunity arises. The new engineer also has the opportunity of meeting field engineers and customers on occasions so that after three-to-five years of application work, he may want to transfer to field engineering with the responsibility of providing technical assistance to customers in the use of RCA products.

MANUFACTURING ENGINEERING

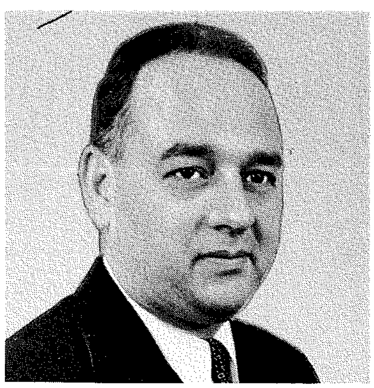
The major objectives of the manufacturing engineer are control of product quality, cost reduction through process simplification, scrap reduction, improved handling methods, the solution of day-to-day production and quality problems, cooperation with laboratory and equipment development engineers in starting new tube types and new equipment in production, and the conducting of pre-production and pilot production tests on new tube types. Manufacturing engineering, in general, involves a wide variety of short range, and often urgent, problems where time may be one of the most important factors. A broad basic engineering training is useful together with experience in recognition of the problems, the use of statistical data, obtaining the most information from a few short-time tests, and the determination of what kind of help is needed, if any, to arrive at a solution quickly. When problems are solved, it is most important to establish controls, change conditions or provide clear instructions which will eliminate or minimize recurrence of the same problem.

TRAINING FOR THE ELECTRON TUBE ENGINEER

Thus we see that Electron Tube Engineering, in all its phases, offers many types of challenging problems in many fields of science and engineering, varying from the very fundamental to the very practical with a variety of work to fit almost any engineer. Cooperation, good judgment, and the ability to use facilities and to produce results on schedule are of the essence as well as a broad and specific knowledge of technical fundamentals.

From the variety of technical work described above, it would appear that all types of technical training may be needed; this fact is essentially true. There are specialized jobs and fields which utilize technical graduates in practically all fields of Chemical, Electrical, and Mechanical Engineering, Chemistry, and Physics, including those with advanced degrees.

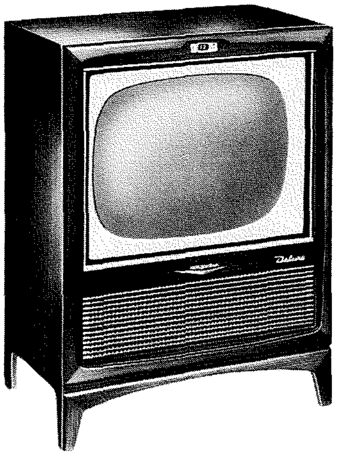
However, the background most useful to the electron tube engineer is a good broad college training in the technical fundamentals; with enough of the humanities to know how to get along well with people, learn readily from experience on a variety of practical problems, and produce results. In many locations the engineer will have opportunities to take graduate courses to meet special needs of his work. For example, at Lancaster, Franklin and Marshall College in cooperation with local industries operates an evening graduate division with a variety of special and basic courses which may be taken for graduate credit toward a Masters degree in physics or chemistry, most valuable to Lancaster engineers. After completing on-the-job training with the RCA engineering training program, a few years in advanced development, electron tube process development, equipment development, manufacturing, or applications engineering would be excellent preparation for electron tube development engineering. Therefore, the electron tube engineer should take advantage of the opportunities to supplement his basic training and experience with graduate courses to meet specific needs or for graduate work leading to an advanced degree.

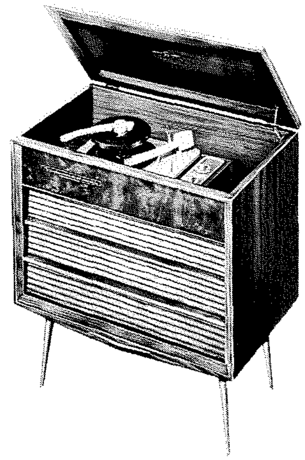


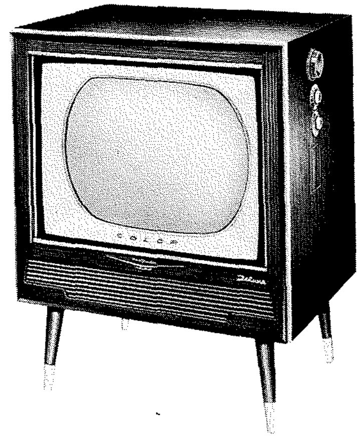
DR. LEWIS B. HEADRICK received the Bachelor of Science degree from the University of Chattanooga in 1926, and continued his graduate education at the University of Michigan, where he received the MS degree in Physics in 1928 and the Ph.D. degree in Physics in 1930. In 1930 Dr. Headrick joined Western Electric Co. as a research physicist, and in 1931 came to RCA at Harrison in the RCA Radiotron Co. In 1942 he became Manager of the Cathode Ray Tube Engineering Division of RCA Victor, and in 1954 was appointed Staff Engineer in the RCA Electron Tube Division at Lancaster.

His research fields have been in the areas of gas discharge phenomena, photoelectric devices, thermionic and secondary emission, electron optics and color TV kinescope development.

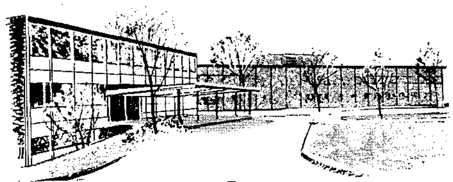
Dr. Headrick is a member of the American Physical Society, the American Association for the Advancement of Science, the Society for the Advancement of Management, and a Fellow of the IRE.







ENGINEERING ORGANIZATION AT CHERRY HILL



By
S. C. STARR, Mgr.
Engineering Services
RCA Victor Television Division
Cherry Hill, N. J.

THE RCA CHERRY HILL PLANT, located in Delaware Township seven miles east of Camden is headquarters for three major divisions of RCA: (1) the RCA Service Company; (2) the RCA Victor Radio & "Victrola" Division and (3) the RCA Victor Television Division. At this site are five interconnected buildings with 308,000 square feet of floor space and 1,900 employees . . . 250 in the Radio & "Victrola" Division, 730 in the Television Division, and the remainder in the RCA Service Company.

This article deals generally with the activities of the RCA Victor Television and the RCA Victor Radio & "Victrola" Divisions, and more specifically with the engineering departments within these Divisions. For the story on the RCA Service Company, the reader's attention is directed to Mr. Cahill's article appearing in this issue.

EARLY PLANNING

Planning for Cherry Hill was started in 1951. Prior to that time the need for more area for Engineering as well as other activities of the Radio and Television Divisions was apparent and no possibility existed for this expansion in the Camden Plant. Since the operations of these Divisions in Camden were only Home Office and Engineering functions, with manufacturing being conducted in other plants, space within the confines of the Camden Plant was not essential. A community of interest between Radio and Television as well as with the RCA Service Company (which was also facing the same problem with respect to working space) dictated a desirability for the establishment of these operations at one location.

Months of planning and many layouts of the new facilities*, and particularly those for Engineering, were required before construction of the plant was started in 1953. The first activities moved to Cherry Hill in December of 1954 with moves completed early in the following year.

ENGINEERING OFFICES AND LABORATORIES

The entire area is devoted to offices and Engineering laboratories and associated services of the three Divisions indicated above. There is no manufacturing at Cherry Hill! As a result of our intensive planning, we provided laboratories laid out for efficiency of operation and adequate working space far superior to those we had previously. Laboratory benches were uniform in style and designed for ease in movement within the area or from one area to another with a minimum of expense. Power connection to individual benches is accomplished by means of a flexible cable connected to an overhead trolley duct, easily disconnected for moving. The shielded rooms, adequate in number, were of the latest construction known to us to provide the optimum in interference attenuation. Provided also were anechoic rooms for both the Radio and the Television Divisions, unique in design and construction to provide adequate sound attenuation for audio and acoustic work. Our model shops for wood cabinets and metal parts are among the finest to be found with respect to layout, equipment, etc.

TELEVISION DIVISION ENGINEERING

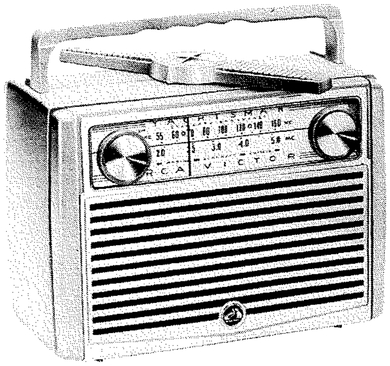
The Home Office activities of the Television Division, under the vice president in charge, include operations such as Sales, Merchandising, Product Development, Financial, Advertising, Purchasing, General Quality, Manufacturing, and Engineering. Outlined in Fig. 1 and described below are the major activities in Engineering.

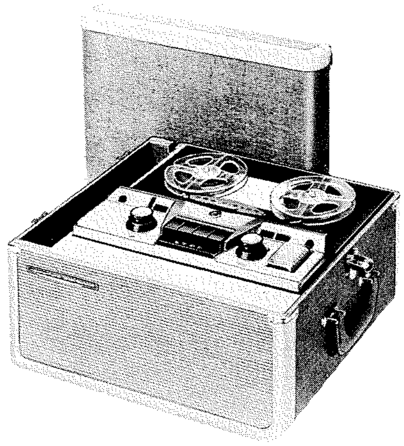
The prime objectives of both the *Black & White Television* and *Color TV Engineering* are to design and develop a line of receivers competitive in price and quality for the consumer market, keeping abreast of the art and producing the best possible sets for their respective prices.

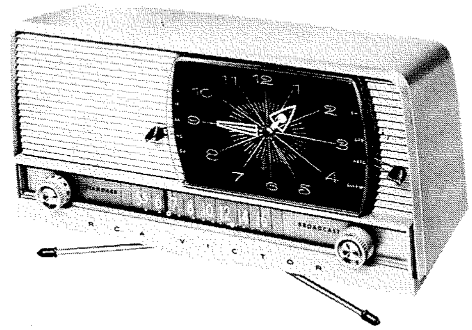
Advanced Development is concerned with developing new circuitry, applying new materials, and pioneering advances in the art which may be incorporated in future receivers.

Engineering Services is an activity covering a broad range of functions

*See Engineering at Cherry Hill by R. J. Hall, RCA ENGINEER VOL. I. NO. I.







such as budget control, engineering facilities and material procurement, electrical components engineering, tube application, design and development of deflection components, coordination with Underwriters' Labs, Packing Design, Technical Publications, Drafting Standards, Blueprint and Reproduction Service, and the Model Shop.

Resident Engineering is another important operation that provides liaison between the various Manufacturing plants (where no engineering is carried on)— and engineering at Cherry Hill (where no manufacturing is done). The only exception to this is the Findlay, Ohio plant where Ferrites are developed, designed and manufactured.

Resident Engineering supplements the basic Cherry Hill engineering development on receivers and deflection components, maintains close contact with manufacturing, solves "engineering-production" problems, and refers special problems to product engineering at Cherry Hill. A Resident Engineering activity, responsible to the Chief Engineer at Cherry Hill, is located at the receiver assembly plants at Indianapolis and Bloomington, Ind.—and at Findlay where deflection components are manufactured in addition to ferrite production.

RADIO & "VICTROLA" DIVISION ENGINEERING

Similar in organization structure to TV Division the Home Office activities of the RCA Victor Radio and "Victrola" Division, under the Vice President, include such activities as Sales, Product Planning, Advertising and Sales Promotion, Financial, Manufacturing, and Engineering. Major activities in Engineering are shown in Fig. 2, and described below.

Radio and Phonograph Engineering is responsible for developing a full line of domestic personal and portable radios (both tube and transistor), table and clock radios, "Victrola" Phonograph and tape recorder instruments. In addition, adaptations of Radio & "Victrola" products are made for International Sales. Engineering also includes minor modifications for the conversion of domestic TV receivers for foreign standards.

Record Changer Engineering has the responsibility for developing automatic record changers, manual record players, and tape recorder transports.

Advanced Development (like TV) is concerned with new circuitry, new materials, and new developments in the art. In the past two years very significant contributions were made in the transistorizing of radio receivers.

Engineering Services, as in TV, includes such activities as budget control, procurement of material, facilities arrangement, and packing design.

Electro-Mechanical Devices is responsible for the design and development of loudspeakers, phono pickup cartridges, magnetic tape recorder heads, and microphones.

Resident Engineering in the Radio & "Victrola" Division, with the same responsibilities as outlined in TV, is located in the Canonsburg, Pa. plant where radios and radio-"Victrola" combinations are produced, and in the Cambridge, Ohio plant where record changers, "Victrola" phonographs, tape recorders, and tape recorder instruments are manufactured.

HOW PRODUCTS ARE DEVELOPED

Development procedures for Radio, "Victrola" and TV are similar and will be treated on a common basis. Being in the home entertainment field, the business is different from that of other divisions in RCA. Our immediate customer is the Merchandise or Product Planning Department. The product lines of both radio and tele-

Fig. 1—RCA VICTOR Television Division Engineering

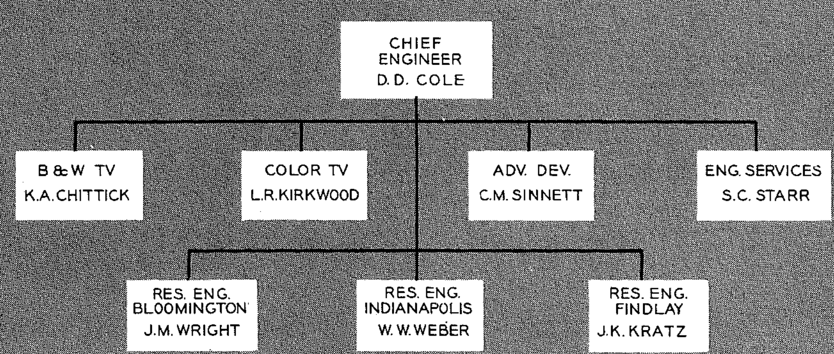
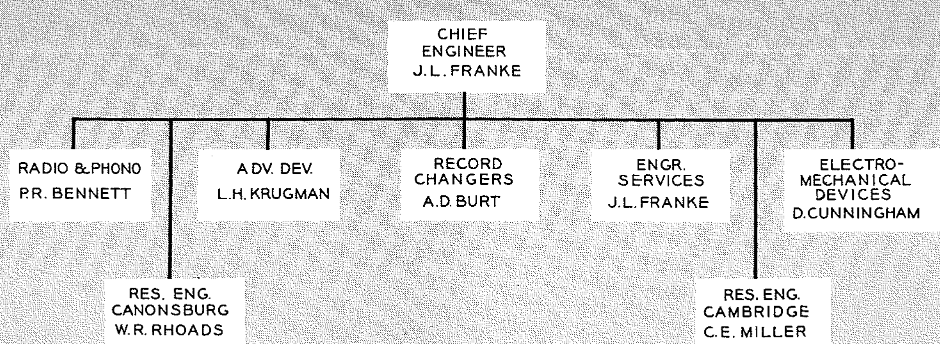
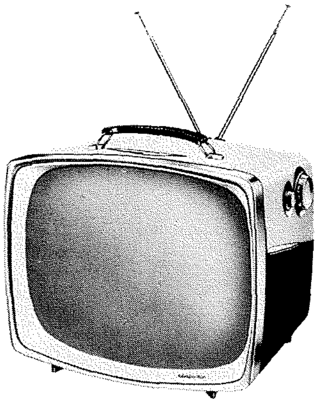
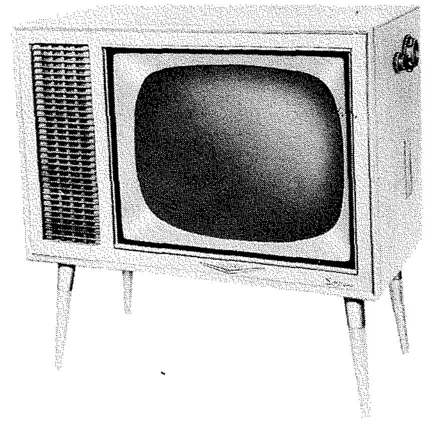


Fig. 2—RCA RADIO and "VICTROLA" Division Engineering







vision receivers are developed to meet the specifications initiated by these departments.

Once the commercial requirements for the new lines have been established, engineering and design proceeds. This is followed by the building of prototype models. In the course of development, several models may be built to achieve the desired result and prove in performance.

DOMINANT DESIGN FACTORS

In our work, the two factors that are of extreme importance to the engineer are (1) cost and (2) time. This is a highly competitive field and the goal of engineering is to create a line of instruments having good customer acceptance at a competitive price and timed for production when the consumer is in a buying mood. Merchandise lines are planned for introduction to the market at specific periods. This quite frequently means a short cycle between the introduction of the specification and completion of engineering design and development. Furthermore, the nature of the business dictates a minimum lag between engineering release and production, due to the ever-changing consumer fancies and the danger of obsolescence. When engineering is completed, the Production Control and Purchasing activities schedule and obtain materials and parts for Manufacturing.

Throughout engineering development, schedules must be adhered to so that manufacturing activities may have adequate time to start production. During the development schedule, the concept of minimum cost must always be maintained. The total engineering program includes extensive tests both in the laboratory and the field to prove the performance, the preparation of drawings and specification for manufacturing plants, and preparation of a final model for the plant as a performance standard. Instruction books and printed material for customer use must be prepared, and an instrument sent to the Underwriters' Laboratories for approval. All contributing factors in Engineering Services must help maintain schedules. For instance, Electrical Components Engineering and Deflection Components must work closely with product engineering to provide design and samples of new items required. When designs are finalized these engineers must prepare drawings and specifications of these parts, contact appropriate vendors and conduct tests and investigations required to determine acceptability of the parts for use in our receivers.

In an effort to shorten the time cycle existing between the release of engineering information and the start of production, contact is maintained with Production Control and Purchasing, advising them of possible new tooling required, and new parts or materials which might involve long time procurement.

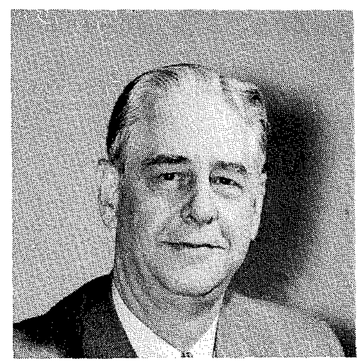
As a means of assuring economy in production, review meetings are held with Manufacturing on all new models during the development stage. When the chassis design is nearing completion, representatives of the various manufacturing activities meet with Engineering to review the model chassis. This permits suggestions to facilitate manufacture, preliminary planning of manufacturing operations, and consideration of new production test equipment which may be required.

The completion of engineering design and development includes release of drawings, specifications, and a prototype model to the manufacturing plant. After engineering release, pre-production models are built in the manufacturing plant using production parts. These are measured for performance and one or more samples sent to Product Engineering at Cherry Hill for approval prior to production.

CONCLUSION

The successful development design, and the release to manufacturing of home entertainment instruments offers many challenges to the engineer. In consumer products it is necessary that the engineer familiarize himself with mass production methods. Only in this way will the design of instruments be of maximum simplicity so that optimum manufacturing costs can be achieved. This requires a degree of skill and ability as important as that required in the actual development of more complex electronic equipment. The ability to make rapid changes in product lines to meet competition is important.

Some of the skills that the engineer must bring to his job are—the knowledge of mass production methods, the ability to simplify designs and reduce cost, and the versatility to make rapid changes to meet an ever-changing consumer market.



STANLEY C. STARR is a graduate of Purdue University, class of 1925. He joined the General Electric Company as a student engineer and subsequently worked in Transformer Development and Design, both in the Ft. Wayne and Schenectady plants. He came to RCA Victor Co. in 1931 in charge of transformer design and later was made supervisor of components activity involving transformers, capacitors, and RF-IF coils. In 1946 he was made manager of Engineering Services in Home Instrument Engineering, a position which he now occupies with the Television Division.

MAGNETIC DEMODULATORS FOR COLOR TV RECEIVERS

by

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He is a member of the IRE, Tau Beta Pi, and Eta Kappa Nu.

THE COMPOSITE COLOR signal contains, in addition to the brightness variation signal transmitted in black and white TV, two other components carrying the color information. These are the so-called in-phase (I) and quadrature (Q) components which amplitude-modulate 3.58 mc subcarriers. The phase difference between these two subcarriers is 90°.[1]

In the receiver, the I and Q components are separated from one another by a phase-sensitive detector called a demodulator. This is done by mixing the color signal with the reference subcarrier (an unmodulated 3.58 mc signal transmitted in the form of bursts) in a non-linear device. The I, Q, and brightness components are then matrixed (recombined) to recover the red, green, and blue signals required for the color scene.

Present color TV receivers use vacuum tubes as color demodulators. These demodulators and their associated matrix circuits are somewhat complex in structure and are subject to variation due to tube and component aging. Since the main purpose of the tube is to provide a non-linear element in the circuit to obtain the demodulation of the color signal, it is possible to replace the tube by some other form of non-linear element, i.e., ferro-magnetic material which has excellent stability and reliability. In addition, magnetic demodulator techniques offer possibilities for the complete elimination of the matrix circuits, thus assuring more reliable color reception. It is the purpose of this article to show how magnetic materials can be used as color TV demodulators.

1. Wentworth, J. W., "Color Television Engineering," McGraw-Hill Book Co., Inc., pp. 205-245, 1955.

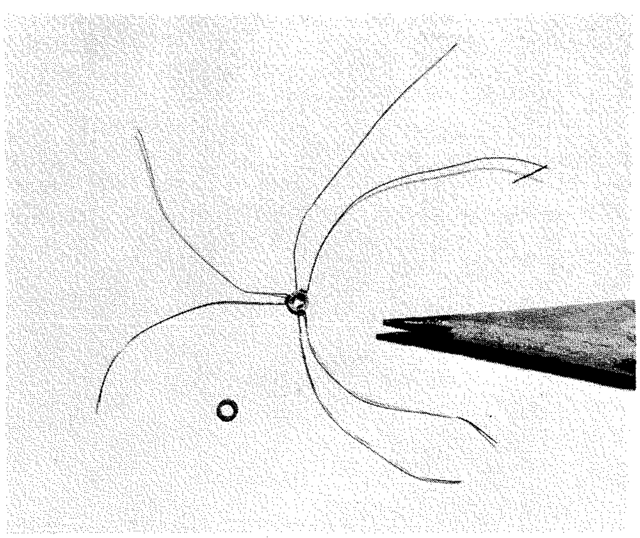
BASIC MODE OF OPERATION

The basic component used in magnetic demodulation is a ferromagnetic toroid as shown in Fig. 1. The toroid has three windings—an input winding to which the color signal is applied, a control winding to which the reference signal is applied, and an output winding from which the demodulated signal is obtained. The function of the other components will be explained later.

The actual and idealized characteristics of the magnetic toroid of Fig. 1 are shown in Fig. 2. This is the well-known hysteresis loop common to magnetic materials. Fig. 3 shows a graphical analysis of the basic mode of operation. Here, for the purpose of simplification, the idealized hysteresis loop of Fig. 2 is used and shown in Fig. 3(a). For reasons to be explained later, the reference frequency is made ½ the subcarrier frequency. This is illustrated in Fig. 3(b) where the ampere turns of the I subcarrier, Q subcarrier, and the reference signal are plotted as a function of time. The relative amplitudes have been exaggerated for the purpose of illustration. Actually, the amplitude ratio of the reference signal to the I or Q component is made at least 10:1 to prevent excessive distortion. It has also been assumed that the currents due to the reference signal and color signals are sinusoidal. This is not a necessary condition of operation but is chosen to simplify the analysis.

The total ampere turns acting on the core is the sum of the ampere turns of each signal. Since the ampere turns are produced by a-c currents, the hysteresis loop is traversed in a sequence indicated by the arrows.

The flux produced by each signal is shown in Fig. 3(c). Inspection of Fig. 3(c) will reveal that the average flux produced by the reference signal is zero, since the areas during the positive and negative cycles of the reference signal flux are equal. Flux contributions from the I or Q signal can only come during the time intervals ΔT, since at any other time the maximum flux is already established by the reference signal and the core is saturated. Again, an inspection of Fig. 3(c) will show that the average flux produced by the Q component is zero and that only the flux produced by the I component has an average value other than zero. Consequently, if the subcarriers are amplitude-modulated, the average flux would follow the envelope of the I component.



An experimental magnetic demodulator for color receivers is shown with a toroid before the windings are put on. This demodulator is designed to replace the presently used tube demodulator and associated matrix circuits. Pencil shows a comparison of size.

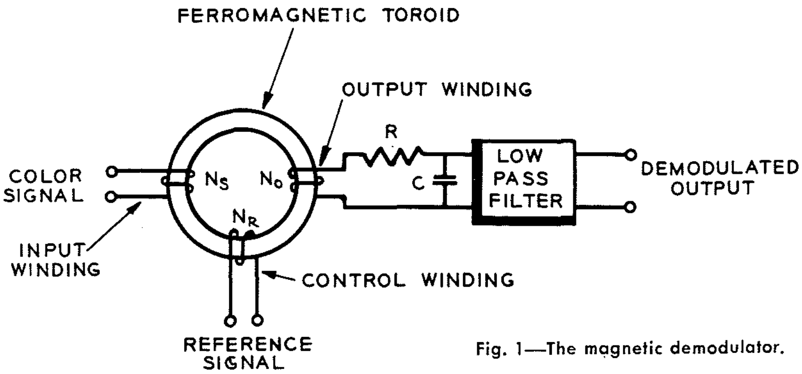


Fig. 1—The magnetic demodulator.

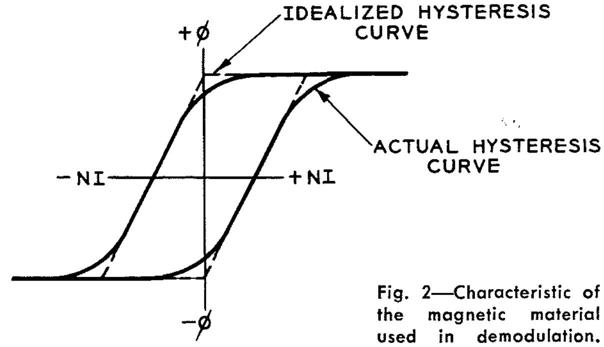


Fig. 2—Characteristic of the magnetic material used in demodulation.

The reference signal saturates the core *twice* during *its* cycle, once in the positive and once in the negative flux region. When the core is saturated, the *I* and *Q* signals cannot change the total flux. Thus, in order for the *I* signal to produce flux only *once* during *its* cycle, the reference signal frequency has to be ½ the subcarrier frequency. If the reference signal frequency were equal to the subcarrier frequency, the *I* signal would produce flux *twice* during *its* cycle, once in a positive and once in a negative direction, resulting in zero average flux and no demodulation. However, if the core is d-c magnetized, the manner in which the reference signal saturates the core changes and a 1:1 frequency ratio can be used.

In addition to the demodulated voltage in the output, there are other undesirable voltages due to the reference signal flux and harmonics of the color signal flux. These undesirable voltages, whose lowest frequency is ½ (3.58 mc) = 1.79 mc, are removed by a low-pass filter (see Fig. 1). This filter cuts off at 1.5 mc, which is the bandwidth of the color signal.

EFFICIENCY

It is important to note that so far the demodulated information is available in the form of a flux containing either *I* or *Q* information. In order to be useful, the demodulated information must be in the form of a voltage to drive the grids of the kinescope. The voltage induced in the output winding, N_o of Fig. 1, by the demodulated component of flux, Φ_d, is

$$e_o = N_o \frac{d\Phi_d}{dt}$$

The voltage output is, therefore, the time derivative of the desired voltage and must be integrated. Such an integrator is formed by the RC network of Fig. 1. As a result of the integration, the output drops by 40 db which makes the demodulating efficiency poor.

MATRIXING

To obtain the red, green, and blue color signals, two such demodulators are used, one to demodulate *I* and the other to demodulate *Q* information. The *I* and *Q* information is then matrixed to form the three color signals. The matrixing scheme used with magnetic demodulators is shown in Fig. 4. This figure shows two demodulators, each having a control, input, and three output windings. Both input windings are driven from the same color source, while the two control windings are driven from reference sources of different phase. This difference in phase is adjusted so that one core demodulates *I* and the other demodulates *Q* information. By properly fixing the ratio and phasing of the output windings, the three color signals are obtained. Each color signal is then followed by an integrating network and a low-pass filter.

SIGNAL SOURCES

The color signal and reference signal of Figs. 1 and 4 are supplied from current sources whose impedances are large compared to the impedances of the input and control windings. This is a necessary step to prevent the two windings from loading each other. The loading of the output winding can be reduced sufficiently by making the integrator input impedance high. If loading occurred, the core flux would be reduced, making it almost impossible to saturate the core.

CONCLUSIONS

Experiments and calculations have established that it is possible to use nonlinear magnetic materials as color demodulators. Since magnetic materials do not age with time or period of use, a magnetic demodulator can be expected to offer improved performance and reliability to color TV.

Another advantage of magnetic demodulation is the stability and simplicity of its matrixing scheme. Matrixing is accomplished on the cores (Fig. 4) by properly choosing the number of turns of each winding. This means that no additional elements for matrixing are required. Once the windings are adjusted, the color ratio would stay constant since both the core and turns upon which matrixing depends do not age with time.

The most serious limitation of the magnetic demodulator is its inefficiency. Its output is too low to make its application to color receivers practical at this time. This is due partly to the integration of the output and partly to a lack of materials that saturate at 3.58 mc. When a more efficient method for integration is found and the desired materials become available, these limitations may become less serious.

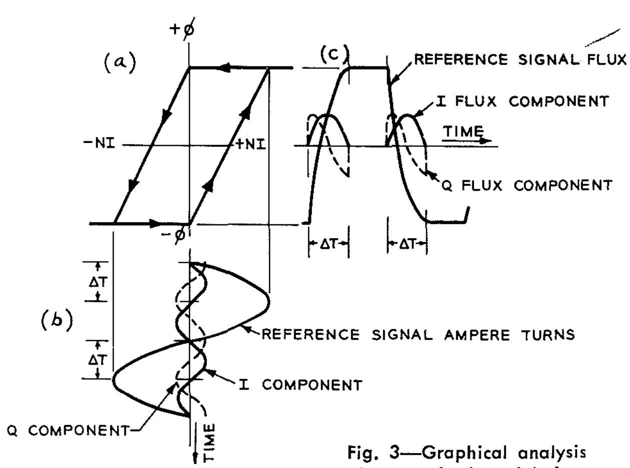


Fig. 3—Graphical analysis of magnetic demodulation.

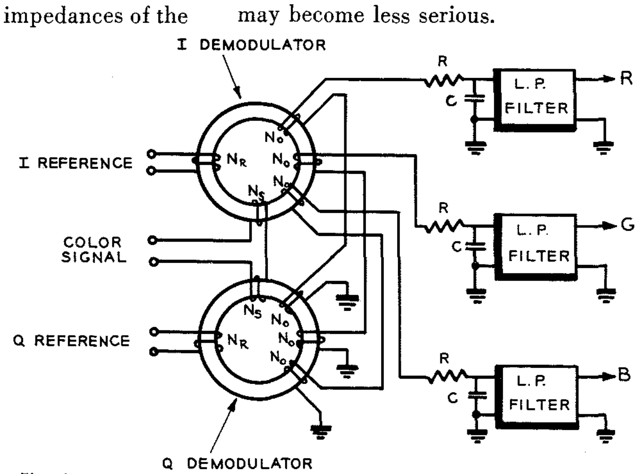


Fig. 4—Matrixing scheme used with magnetic demodulators.

PRACTICAL DESIGN ASPECTS OF UHF TELEVISION TUNERS

by **SEYMOUR LYNN**

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The Federal Communications Commission (FCC) recently proposed that the television industry consider discarding the VHF channels and using only a part of the UHF spectrum (470-890 mc) for television service in 70 channels. This program, if adopted, would transpire over a period of many years so as not to obsolete existing VHF equipment too quickly. Every TV receiver would then require a UHF tuner which would probably accelerate further development for better performance and customer utility. A brief discussion of the present status of UHF tuner design may be of interest to the readers of the "RCA Engineer."

Fig. 1 is the schematic diagram of RCA's current UHF tuner. The component circuits of the tuner will be discussed in the paragraphs that follow.

PRESELECTOR CIRCUITS

The commercial UHF-TV tuner at the present time employs a double-tuned preselector circuit, rather than an r-f amplifier stage as in VHF-TV tuners. The reason is economically sound since a good UHF amplifier tube may cost several dollars, and the improvement in performance over that using good high Q tuned coaxial preselectors does not warrant the additional cost at this time.[1]

Physical Configurations

Short-circuited quarter-wave coaxial type structures are commonly used today for UHF preselector circuits. The lines may have the shape of rods, bars, channels or rectangles. The lines are the inner conductors of coaxial cavities and also function as stators in sections of a variable capacitor. A short-circuited coaxial line is resonant at a frequency whose wavelength is four times the electrical length of the coaxial line. At lower frequencies, the coaxial line is inductive, and will resonate when capacity is added to the open end of the line. The reactance of a coaxial line as a function of wavelength is given by[2]

$$X = j\,Z_o \tan\left(2\pi \frac{l}{\lambda}\right) \qquad (1)$$

where

X = reactance of the line—ohms

Z_o = characteristic impedance of the line—ohms

$\frac{l}{\lambda}$ = wavelengths

Therefore, with a variable capacitor rotor assembly tuning the open end of the short-circuited line, the frequency of the quarter-wave resonance may be changed to cover the entire UHF TV spectrum from 470 mc to 890 mc. This is accomplished with 180° rotation of the tuning capacitor's rotor assembly as shown in Fig. 2.

The stator and rotor assemblies are usually silver or copper plated to increase the conductivity and the unloaded Q of each circuit. Equation (2) shows the relationship between theoretical unloaded Q of a coaxial circuit and frequency, and inner and outer conductor radii.[2]

$$Q' = 0.0839\sqrt{f}\,b \cdot H \qquad (2)$$

where

f = frequency—cycles/sec.

b = radius of outer conductor—cm.

H = factor given in Fig. 3

Q' = theoretical unloaded Q of a copper coaxial cavity

Since most of the current flows in a thin surface layer at the frequencies we are concerned with, a good plating of copper or silver over steel is sufficient for good high Q cavities.

Insertion Loss

The insertion loss of a tuned circuit is given in Eq. (3) as a function of unloaded and loaded Q's.[3]

$$L_i \doteq \left| \frac{\frac{Q'}{Q}}{\frac{Q'}{Q} - 1} \right|^2 \qquad (3)$$

where

L_i = insertion loss

Q' = unloaded Q

Q = loaded Q = $\frac{\text{Resonant Frequency}}{\text{3 db Bandwidth}} = \frac{f_o}{\Delta f}$

A curve of the above equation is plotted in Fig. 4. It is seen here that a ratio of 9 for Q'/Q gives an insertion loss of 1 db per circuit or approximately 2 db for a double-tuned circuit. Since it is of vital importance that the insertion loss be kept to a minimum for good UHF TV reception in weaker signal areas, high Q' circuits are a necessity.

For commercial coaxial circuits Q' of 1000 at 470 mc and Q' of 1400 at 890 mc are representative. Let us assume a 3 db bandwidth of 10 mc for all UHF channels.

At 470 mc

$$Q = \frac{f}{\Delta f} = \frac{470}{10} = 47$$

and

$$\frac{Q'}{Q} = \frac{1000}{47} = 21.3$$

Insertion loss = 0.4 db per circuit.

At 890 mc

$$Q = \frac{890}{10} = 89$$

and

$$\frac{Q'}{Q} = \frac{1400}{89} = 15.7$$

Insertion loss = 0.5 db per circuit.

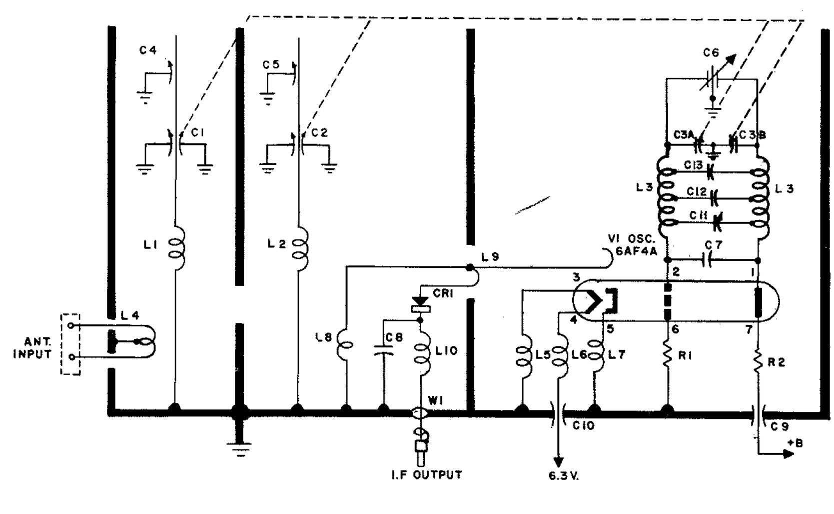


Fig. 1—Schematic diagram of a commercial UHF tuner

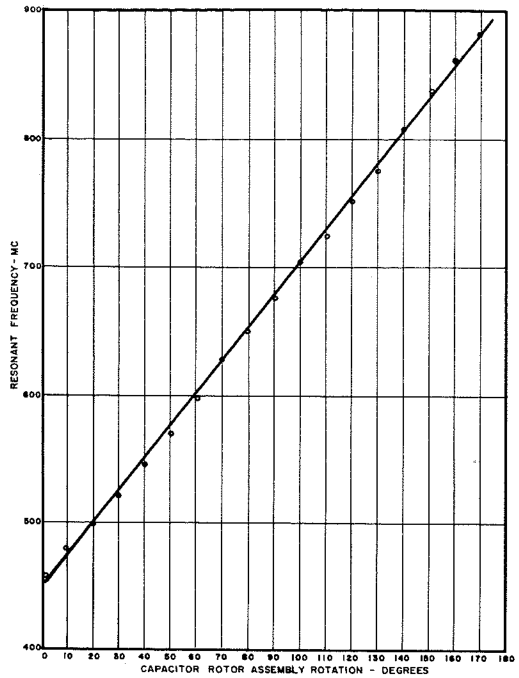


Fig. 2—Resonant frequency of short-circuited quarter-wave preselector line in a commercial tuner vs. capacitor rotor assembly rotation

If lumped circuits were used instead of coaxial circuits, the unloaded Q's would be approximately half of the cavity Q's above.

At 470 mc

$$\frac{Q'}{Q}=\frac{500}{47}=10.6$$

Insertion loss = 0.8 db per circuit.

At 890 mc

$$\frac{Q'}{Q}=\frac{700}{89}=7.9$$

Insertion loss = 1.1 db per circuit.

The use of high Q coaxial cavities is one of the most economical and best methods for increasing the usable signal, and improving the overall performance of the UHF receiver.

From the above discussion it can also be seen that the loaded Q may be decreased by widening the response curve which in turn will reduce the insertion loss. Unfortunately, as the selectivity curve becomes wider, the rejection of undesired signals is reduced and the oscillator radiation through the antenna increases. In the superheterodyne system many undesired responses are formed, such as the image response, ½ i-f response, etc.[4] Image rejection in UHF tuners is about 40 db and is usually the undesired response with the least attenuation.

Bandwidth

The bandwidth of the double-tuned circuit is determined by the coupling between the cavities, and the loading from the antenna and the mixer circuits. Although it is desirable to maintain a bandwidth of between 6 and 8 mc for all the UHF channels, maintaining the picture and sound carriers on the flat portion of the response curve becomes difficult. Consequently, for ease of tracking and to allow for some "springback" of knifed capacitor plates and possible slight frame deformation which may affect the original alignment, the response curve is designed wider than is necessary to receive the UHF signal.

Coupling between cavity compartments is usually accomplished with a rectangular aperture in the compartment wall near the shorted end of the lines.[5] Essentially constant coupling throughout the UHF spectrum is possible by determining the correct size of the window and the correct distance of the window to the shorted end of the lines.

The 300-ohm antenna may be coupled to the primary coaxial circuit with a coupling loop or may be tapped at a low impedance point on the tank inductor. Similarly, the crystal mixer circuit may be coupled to the secondary coaxial circuit through a coupling loop or may also be tapped at a low impedance point on the secondary tank inductor.

Besides insertion loss due to power dissipation in the coaxial circuits, there is a mismatch loss between the theoretical 300-ohm antenna signal source and the impedance that appears at the input terminals of the UHF tuner. Some of this mismatch loss is due to the coupling impedances of the input and output loops changing with frequency, and some of the loss is due to the variation in crystal impedance through the UHF spectrum which in turn is reflected to the antenna input. A VSWR of 2 to 1 at the antenna corresponds to a mismatch loss of 0.5 db and is usually attainable with good design.

UHF MIXER CIRCUITS

From Fig. 5 it is seen that several circuit arrangements are possible in the design of a UHF tuner. If cost were no consideration, a good UHF amplifier and UHF triode mixer, Fig. 5 (a), would probably give the best overall performance.

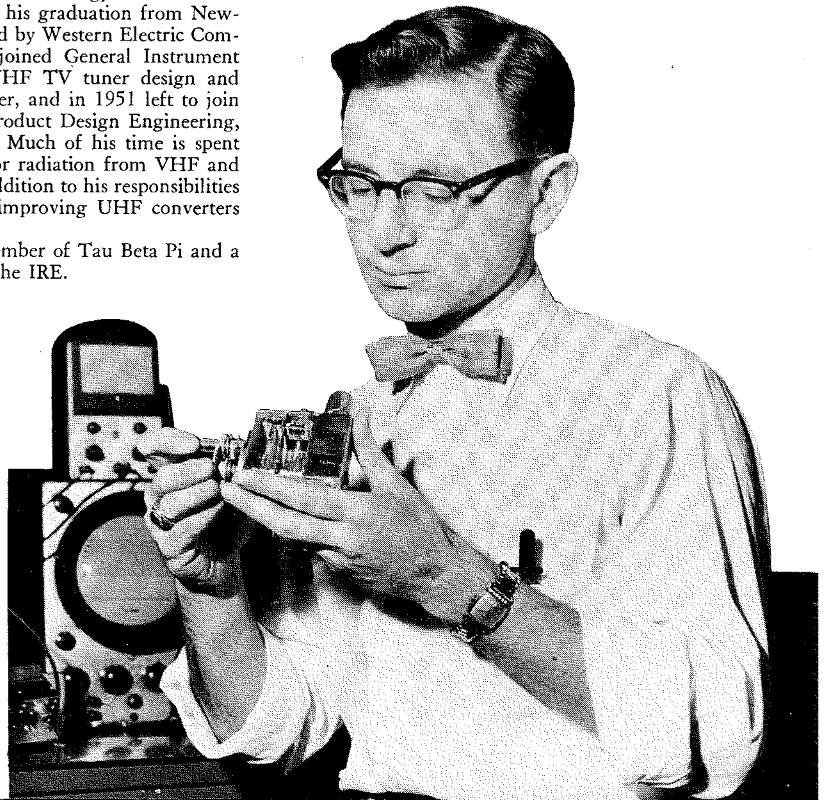
A triode mixer stage has a conversion gain of 6 db or higher instead of a conversion loss of approximately 6 db for a typical crystal mixer. However, at UHF, triode mixers using low cost tubes usually generate a greater amount of noise than crystal mixers. Also, because of a higher level of oscillator injection required for a triode mixer over a crystal mixer, the chassis oscillator radiation increases. The oscillator radiation through to the antenna, however, probably decreases because of the buffer amplifier stage.

Noise Figure

The sensitivity of a television receiver is usually limited by its noise figure which may be defined as the ratio of total noise power output from the network with a thermal source to the noise power output from the thermal source.

SEYMOUR LYNN was graduated from Newark College of Engineering with a BS degree in EE in 1946 and received the MSEE degree from Stevens Institute of Technology in 1950. For two years following his graduation from Newark he was employed by Western Electric Company. In 1948 he joined General Instrument Corporation as a VHF TV tuner design and development engineer, and in 1951 left to join RCA's RF Tuner Product Design Engineering, Television Division. Much of his time is spent in reducing oscillator radiation from VHF and UHF receivers, in addition to his responsibilities in developing and improving UHF converters and tuners.

Mr. Lynn is a member of Tau Beta Pi and a Senior Member of the IRE.



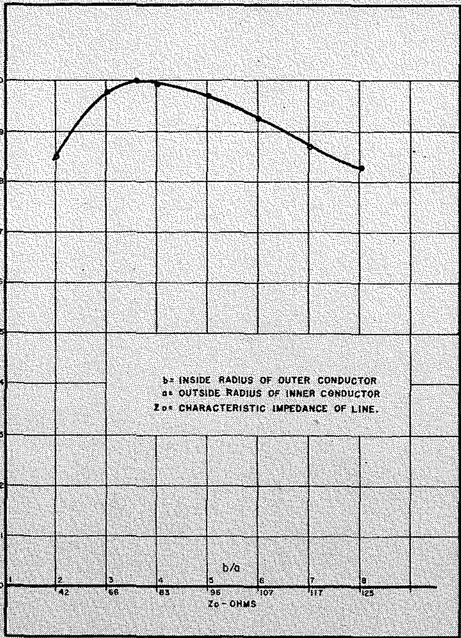


Fig. 3—Factor H used with equation (2) in calculating theoretical unloaded Q of a resonant coaxial line

The total noise figure of a receiver is given by

$$F_{rec} = F_1 + \frac{F_2 - 1}{G_1} + \cdots \quad (4)$$

where

F_{rec} = total receiver noise figure
F_1 = noise figure of first stage
F_2 = noise figure of second stage
G = available power gain of first stage

When a low-noise, high-gain amplifier is used, Fig. 5 (a), for the first stage of the receiver, the total noise figure is not affected appreciably by the second term of Eq. (4). Consequently the increased noise generated in a triode mixer can be tolerated when the amplifier has sufficient available gain to make $(F_2 -)/G_1$ insignificant with respect to F_1.

Fig. 5 (b) shows the use of a crystal instead of a triode mixer. With this arrangement less mixer excitation power is required from the oscillator which reduces the oscillator radiation, but as previously mentioned, a conversion loss instead of gain will result. The noise figure equation for this case is modified as follows:

$$F_{rec} = F_1 + \frac{L_o\,(F_{i\text{-}f} + t - 1)}{G_1} + \cdots \quad (5)$$

where

F_{rec}, F_1, and G_1 are defined above
L_o = conversion loss of crystal mixer
$F_{i\text{-}f}$ = noise figure of first i-f amplifier stage
t = noise temperature of crystal

The conversion loss of the crystal mixer is the loss in signal power when the signal is converted to i-f. The noise temperature t is defined as the ratio of actual noise power generated by the crystal to the noise power generated at room temperature by a resistance equal to the mixer output resistance. Fig. 6 shows the manner in which conversion loss and noise temperature vary with oscillator excitation.[6]

The total noise of the receiver using Fig. 5 (b) will usually be slightly lower than the receiver using Fig. 5 (a).

In Fig. 5 (c) without a UHF amplifier, the total noise figure becomes

$$F_{rec} = L_i\,(F_{mix} - 1) + \frac{F_{i\text{-}f} - 1}{G_{mix}} + \cdots \quad (6)$$

F_{rec}, and $F_{i\text{-}f}$ are defined above
L_i = mismatch and insertion loss of preselector circuits
F_{mix} = noise figure of mixer
G_{mix} = conversion power gain of mixer

The total noise figure of this system is the poorest of the four arrangements. Fig. 5 (d) presents the generally accepted circuit for the best compromise between performance and cost. The noise-figure equation for Fig. 5 (d) is

$$F_{rec} = L_i L_o\,(F_{i\text{-}f} + t - 1) + \cdots \quad (7)$$

Let us proceed to determine the overall noise figures for UHF receivers using each of the four arrangements discussed, at a midband frequency of 700 mc.

Noise Figures of Four Basic Circuit Arrangements

Assume the following numerical quantities:

F_1 = 8 db or 6.31×
G_1 = 14 db or 25.12×
F_{mix} = 14 db or 25.12×
G_{mix} = 6 db or 3.98×
L_i = 1.5 db or 1.41×
L_o = 6 db or 3.98×
t = 1.5×
$F_{i\text{-}f}$ = 3.5 db or 2.24×

Circuit Arrangements Fig.	*Receiver Noise Figure Equations*	*db*
5 (a)	$F_1 + \frac{F_{mix} - 1}{G_1}$	8.6
5 (b)	$F_1 + \frac{L_o\,(F_{i\text{-}f} + t - 1)}{G_1}$	8.3
5 (c)	$L_i\,(F_{mix} - 1) + \frac{F_{i\text{-}f} - 1}{G_{mix}}$	15.4
5 (d)	$L_i L_o\,(F_{i\text{-}f} + t - 1)$	11.9

We can see from the total receiver noise figures of the four examples that Fig. 5(c) is the least desirable and either Fig. 5(a) or 5(b) the most desirable for low noise figure. However, as mentioned previously, Fig. 5(a) or 5(b) are not commercially feasible at this time. This leads to the adoption of Fig. 5(d) for commercial television receivers. The reduced UHF gain of 5(d) can be compensated for by additional i-f gain in the receiver.

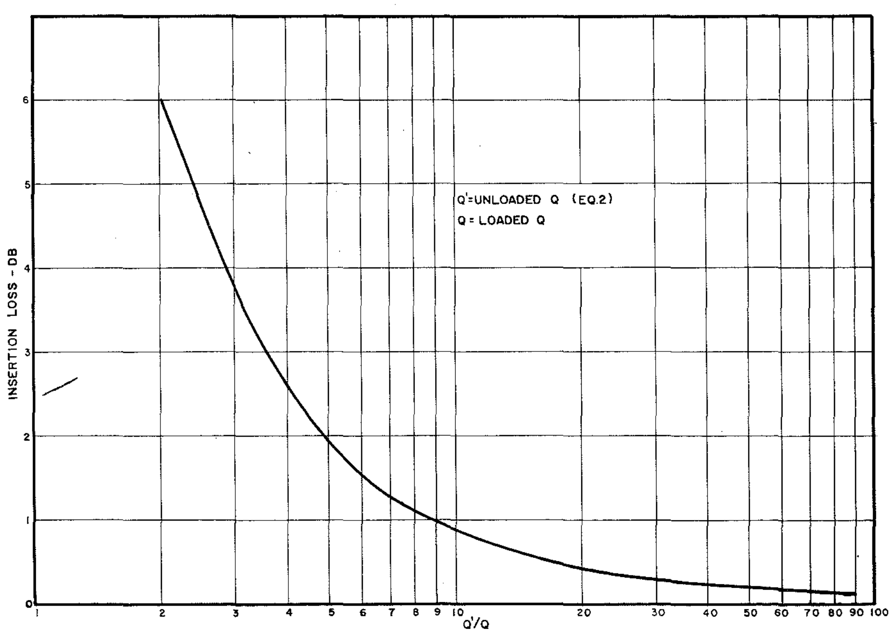


Fig. 4—Insertion loss for one tuned circuit vs. unloaded to loaded Q

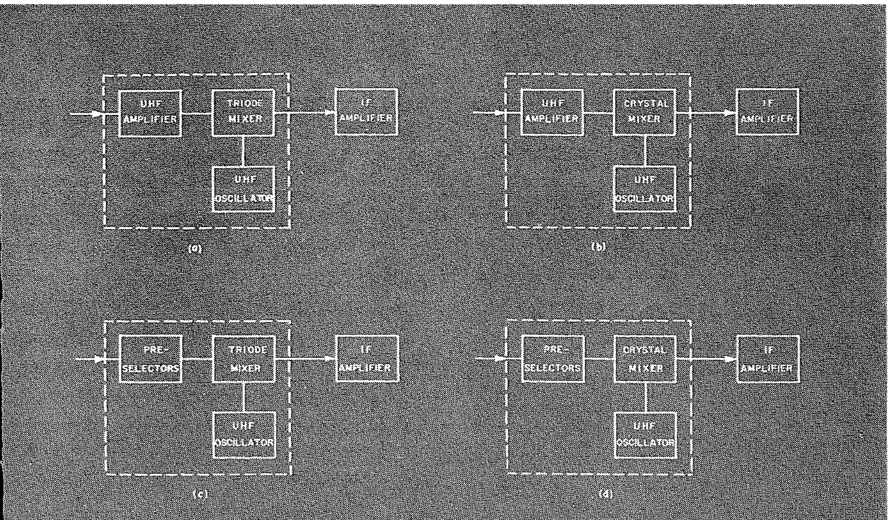


Fig. 5—Several possible UHF tuner circuit arrangements

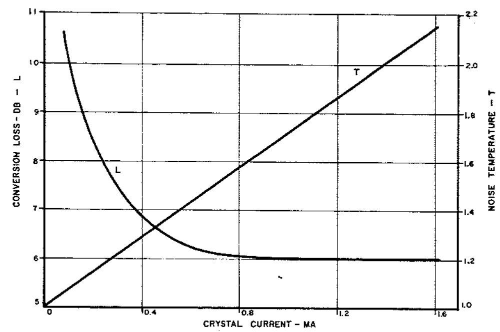


Fig. 6 — Conversion loss and noise temperature of typical mixer crystal vs. oscillator injection

Mixer Impedance

From Fig. 7 we get a general idea of the impedance variations one can expect at i-f from the crystal mixer circuit in a typical tuner. Oscillator injection and rectified crystal current may vary 2:1 or more and will affect the i-f impedance. Other crystals in the same tuner or different tuners will present other impedances. Because of these variations, it is difficult to maintain uniform response curves over the entire UHF band.

The requirements of the color TV receiver have made it necessary to follow the mixer circuit with a grounded-grid amplifier since the crystal impedance variations do not manifest themselves working into a low impedance load. Good i-f noise figure (3.5 db or better) and uniform response curves are obtainable with a grounded-grid i-f amplifier.

LOCAL OSCILLATOR

The 70 UHF channels allocated by the FCC cover a frequency spectrum from 470 mc-890 mc. If the same intermediate frequency (41 mc-47 mc) amplifier is to be used at UHF as VHF with single conversion, then the local oscillator must operate on the high-frequency side of the incoming signal. The oscillator frequency range is then 517 mc to 931 mc.

Oscillator Tubes

At the present time, the best commercial miniature type tube available for local oscillator operation, in this spectrum, is the 6AF4A for parallel heater strings and either the 2AF4A for 600 milliampere or 3AF4A for 450 milliampere series heater strings. The 6T4 is comparable to the 6AF4A. Other VHF tubes such as the 6BQ7A or 6J6 will oscillate satisfactorily up to approximately 600 mc.

With a balanced or unbalanced quarter-wave coaxial circuit, a voltage of approximately 65 volts on the plate of the oscillator tube and a plate current of 10 milliamperes will develop between 3-10 volts across a 10K ohm grid resistor. This oscillator is sufficiently strong to provide adequate injection with loose coupling to the mixer crystal and operates satisfactorily at ±10% of nominal line voltage with minimum frequency shift. A stronger oscillator is undesirable from the standpoint of oscillator radiation.

Oscillator Radiation

The reduction of oscillator radiation is one of the most difficult design problems in the entire UHF tuner development.[7] The FCC has set a maximum limit of 500 microvolts per meter (μv/m) (temporarily relaxed to 1000 μv/m) for all UHF TV local oscillator frequencies above 470 mc.

All TV receivers must be certified for compliance with the FCC spurious radiation requirements which have been adopted from the IRE Standard #51, IRE 17S1 and supplements. Local oscillator radiation is usually a combination of oscillator power fed through the r-f preselector circuits to the antenna terminals and induced voltages in the chassis caused by circulating currents at holes, slots, and cracks. A great amount of work has been done to reduce the chassis radiation to reasonable quantities. The oscillator tube socket has been completely redesigned to eliminate all openings at the socket and base where the circulating ground currents are the heaviest. Tubular feed-through capacitors for bringing power to the oscillator tube have been found to have parallel resonances, which increase coupling impedance, in the UHF spectrum. One company has developed a disc type feed-through capacitor which has moved the resonances out of the UHF band. See Fig. 8. Power leads are consequently no longer carriers of oscillator energy. Additional internal shielding has also contributed greatly to the decrease of chassis radiation.

Antenna radiation is affected by preselector bandwidth, mixer r-f bypassing, and resonances in the antenna and mixer coupling circuits. At the present time, the UHF tuner radiation from RCA TV receivers is within limits, but without satisfactory safety factor to take care of all production variations and measurement variations. However, engineering effort is continuously being applied so that oscillator radiation may be reduced to much lower levels.

Frequency Stability

An important consideration in local oscillator design is the frequency drift with temperature. The total drift is made up of short-time and long-time components. Short-time drift is usually due to the oscillator tube elements changing their relative spacing as the tube heats up. Long-time drift is usually caused by circuit components slowly changing value as the ambient temperature rises.

Frequency drift of commercial tuners without compensation is in the order of 1 mc at the higher UHF channels. Color receiver requirements made necessary a great reduction of oscillator frequency drift and a study was made to determine what was needed to keep the drift below 200 kc.[9] Among other things, it was found that the brass rotor shaft had to be replaced with a steel shaft to keep the rotor thermal expansion close to the steel tuner frame expansion for consistent drift characteristics.

With two negative temperature coefficients and one positive temperature coefficient capacitor spaced at definite intervals along the lines, a frequency drift of less than 200 kc was achieved.

THE RCA UHF TUNER

The two major improvements in our new UHF tuner which will go into pro-

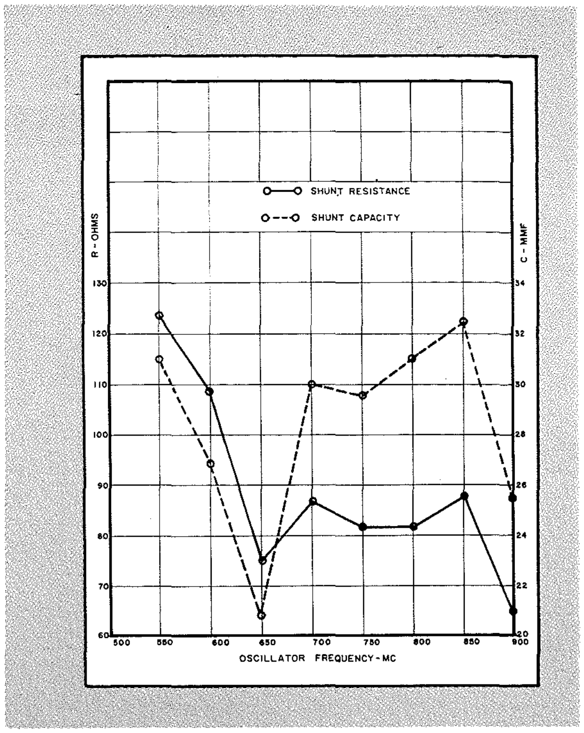


Fig. 7—I-F impedance at UHF tuner i-f output jack vs. oscillator frequency

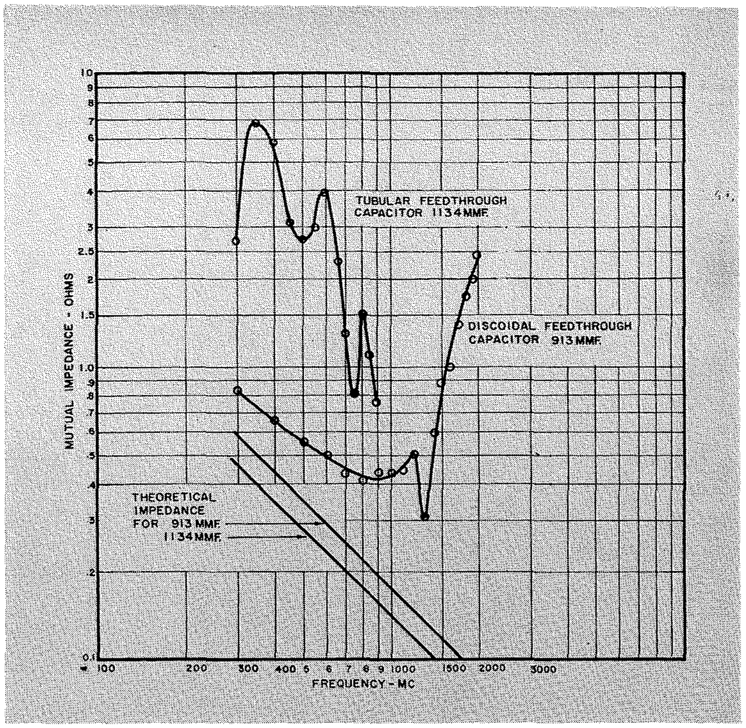


Fig. 8—Coupling impedance for discoidal and tubular feed-through capacitors

duction very shortly are smaller size and reduced cost at no deterioration in performance. Fig. 9 shows the relative size of these two units.

It appears as though we would only accrue diminishing returns if the size were reduced any further. Closer spacing between stators and rotors would be necessary to help compensate for the loss of capacity due to the smaller plate areas. At the same time a 3/16 inch diameter shaft, instead of 1/4 inch diameter would be needed to help keep the minimum capacity low and maximum to minimum capacity ratio high.

Unfortunately, the closer spacing and smaller shaft diameter make the tuner more susceptible to alignment change with relatively slight frame and shaft distortion, with rotor plate "spring-back" after knifing, and with humidity and temperature change.

Further reduction in size may also increase labor costs, as it becomes more difficult to work in tighter spaces. We believe the new tuner will offer the stability of the larger tuner and sufficient miniaturization needed for portables and table model receivers.

SUMMARY

At the present stage of the art, most UHF tuners contain two coaxial preselector circuits, a crystal mixer and a triode oscillator. The overall performance, while not the ultimate, is excellent (commensurate with cost) and is constantly being improved.

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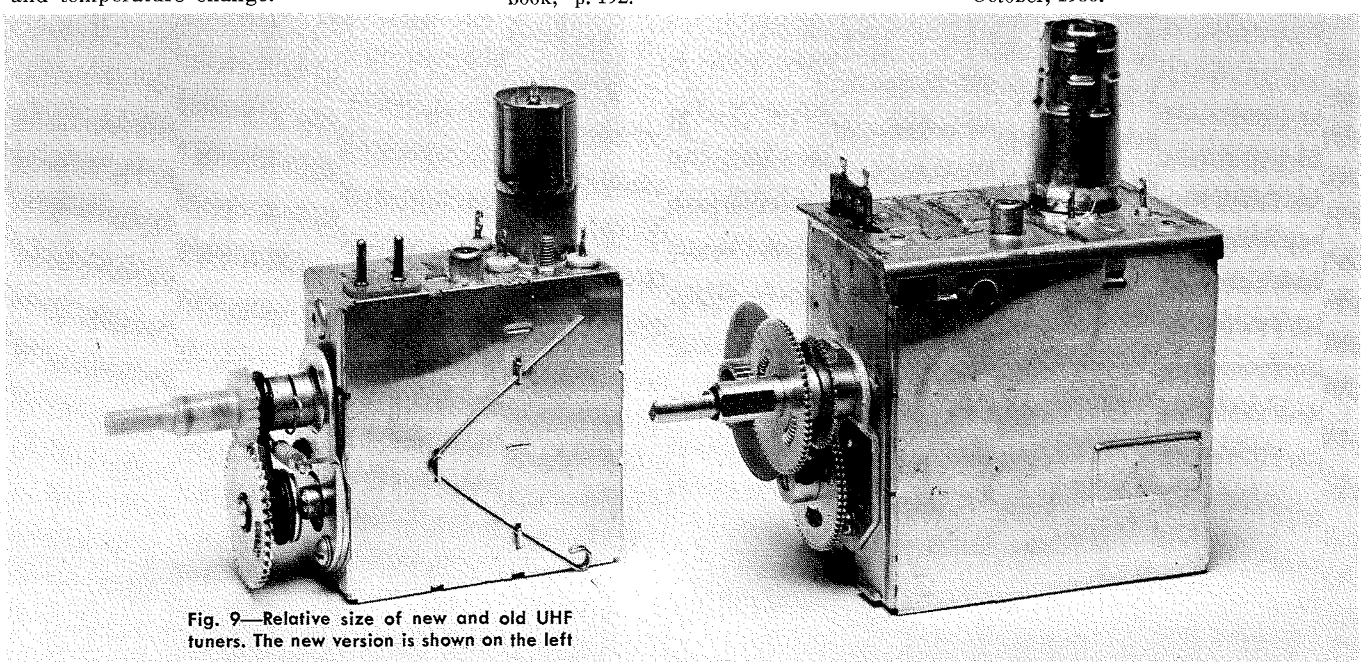


Fig. 9—Relative size of new and old UHF tuners. The new version is shown on the left

A LOCKED OSCILLATOR–QUADRATURE GRID FM DETECTOR

By **J. RICHARD ORR**
Black and White Television Engineering
RCA Victor Television Division
Cherry Hill, N. J.

A NEW FM DETECTOR called the locked oscillator-quadrature grid detector was developed at the RCA Industry Service Laboratory[1] and was first used in the RCA KCS102, a 14″ portable television receiver. It has since appeared in many of the RCA receivers. This detector is ideally suited for TV intercarrier sound service, where there is no change in the carrier frequency at the sound detector due to fine tuning adjustment. The following is a brief description of the circuit, some of the design considerations, and advantages of the system. Also, the alignment of the circuit will be discussed.

1. See License Bulletin, LB1000, "A Low-Cost Sound Detector for Television Receivers" by Jack Avins and Thomas J. Brady.

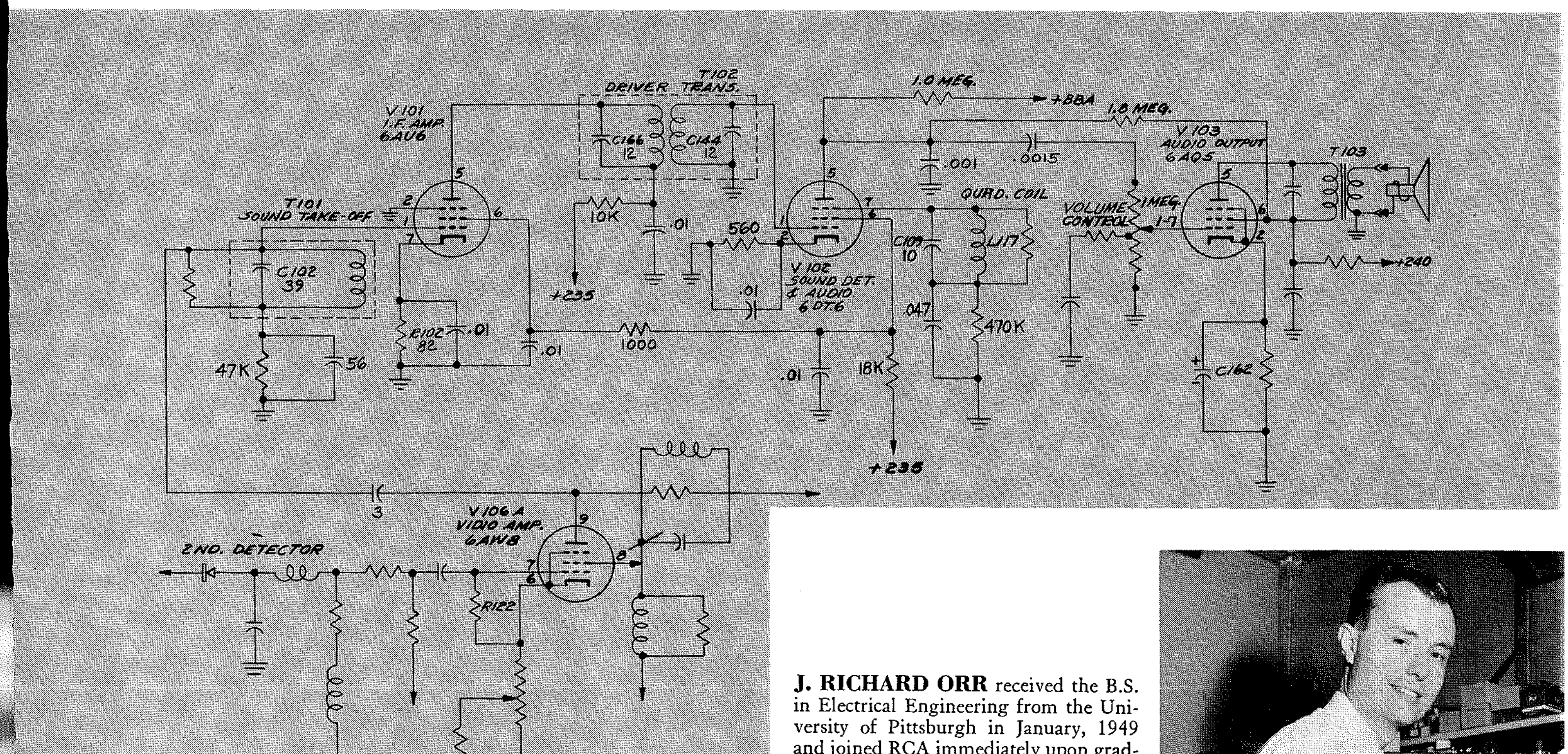
METHOD OF OPERATION

The detector circuit is shown in the schematic diagram, Fig. 1, with the associated 4.5 mc amplifier circuits and audio output stage. The detector uses a 6DT6 pentode having a sharp-cutoff suppressor-grid characteristic (V102 in Fig. 1). This circuit has two modes of operation; the directly driven quadrature mode which occurs on relatively strong signals, and the locked oscillator quadrature mode, operating on relatively weak signals.

Referring to the vector diagram, Fig. 2, a 4.5 mc signal is injected into the system from the video amplifier plate circuit, and a voltage E_1 appears from g_1 to ground in the 6DT6 circuit, Fig. 1. The voltage is coupled to g_3 by space charge coupling and appears from g_3 to ground across the No. 3 grid impedance as E_2 in quadrature with the voltage E_1. The vector E_1 effectively leads the vector E_2 by 90°, since the dispersed current by virtue of space-charge coupling is proportional to $-d_q/d_t$ and the charge "Q" is in phase with E_1.

The g_3 tank circuit is tuned to 4.5 mc, and when the incoming signal is exactly on 4.5 mc, the voltage appearing across the g_3 impedance will be 90° out of phase with respect to E_1. The voltage E_2 will change in phase with respect to E_1 as the incoming frequency varies. If the frequency is above 4.5 mc, the g_3 circuit impedance will appear capacitive and E_2 will lead the resonant vector in phase, and if the frequency is below 4.5 mc, the E_2 voltage will lag the resonant vector. The resultant plate current and therefore the resultant plate voltage E_3 will vary according to the combined effect of the voltages on the two control grids (g_1 and g_3), and can be indicated as the scalar product of E_1 and E_2. Graphically this is the projection of

Fig. 1.—The locked oscillator—quadrature grid detector and associated circuits.



J. RICHARD ORR received the B.S. in Electrical Engineering from the University of Pittsburgh in January, 1949 and joined RCA immediately upon graduation. His engineering work has been with Black and White Television Receiver Design, principally in i-f circuits, sound i-f, fm detectors, printed circuits, coils, etc. Mr. Orr is a member of the IRE, Eta Kappa Nu and Sigma Tau.

E_2 on E_1, see Fig. 2. E_3 will now vary according to the incoming frequency changes, which in turn represent the original audio modulation. There will be, in addition, an average component E_{av} not depending on the incoming signal due to the tube polarizing voltage.

Locked oscillator operation occurs when the signal applied to g_1 decreases in level to a point where g_1 circuit impedance becomes high enough to support oscillation. The detector tube (6DT6) has approximately .09 $\mu\mu$f capacitance between g_1 and g_3, and a gain of 3 from g_1 to g_3. With a high impedance tank circuit in the g_3 circuit tuned to 4.5 mc and a high impedance in the g_1 circuit, the circuit will oscillate at 4.5 mc. When a relatively weak frequency modulated signal is applied to the g_1 circuit, the circuit will continue to oscillate. Assuming first that the incoming signal is above 4.5 mc, OA in Fig. 3 represents the oscillator current across the tank circuit and AB represents the injected current of the incoming signal. Since the injected incoming signal is above 4.5 mc, the tank circuit impedance will look capacitive and this current will lead the oscillator current in phase. This injected current can be indicated in the form of its resistive and reactive components, AC and CB. The current vector AB, therefore, has a component CB at 90° leading with respect to the oscillator current OA and the result is the same as though additional capacity had been connected across the circuit. The effect is a change in the resonant frequency of the tuned circuit which means a change in the oscillator frequency. When the incoming signal goes below 4.5 mc, the opposite effect takes place and the lagging current in the tank circuit appears as though capacity has been subtracted from the circuit and the oscillator frequency again changes. The incoming signal which is varying in frequency according to audio modulation will lock this oscillator and change the frequency of this oscillator with incoming frequency variations. The resultant plate voltage E_3 will now follow the control grid variations at the original audio modulation rate.

An increase in sensitivity is realized due to the fact that a relatively strong oscillator is controlled by a weak incoming signal. When the deviation of the incoming signal swings beyond the lock-in range, a beat occurs between the oscillator and the incoming signal. This is called *"breakout"* and the resultant waveform is used to advantage in aligning the circuit during locked-oscillator operation.

DESIGN CONSIDERATIONS

A double-tuned circuit is used as the driver circuit because of the improved AM rejection over a single tuned circuit. The AM rejection of the system from the video grid will average 30 db, which is adequate even with the added possibility of cross modulation in the video amplifier. The coupling should be adjusted for slightly under critical for stable locked oscillator operation. The operating Q of the quadrature coil is adjusted for the proper bandwidth with the required bias developed across the suppressor grid resistor. The cathode resistor is r-f bypassed and is not critical for cathode degeneration of amplitude modulation on the incoming signal.

Referring to the schematic Fig. 1, the screens of the 6AU6 and the 6DT6 are connected together and fed from a common dropping resistor. This is done to improve the limiting on strong signals and the gain on weak signals by applying the 6DT6 screen grid current regulation to the 6AU6 screen grid circuit. The "B" voltages in a TV receiver drop on weak signals due to additional current being drawn by tubes on AGC bias, and rise on strong signals which is the opposite of the desired condition for the driver screen grid circuit. However, the

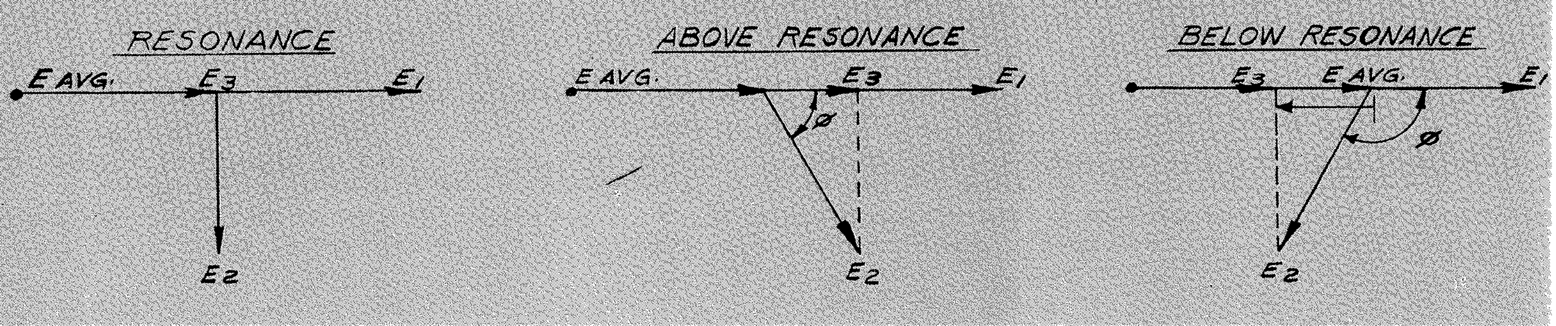


Fig. 2—Vector diagram of detector input—output voltages.

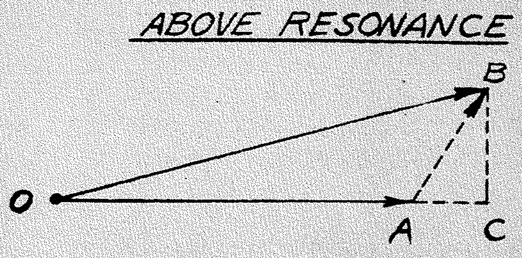


Fig. 3—Vector diagram explaining oscillator frequency change.

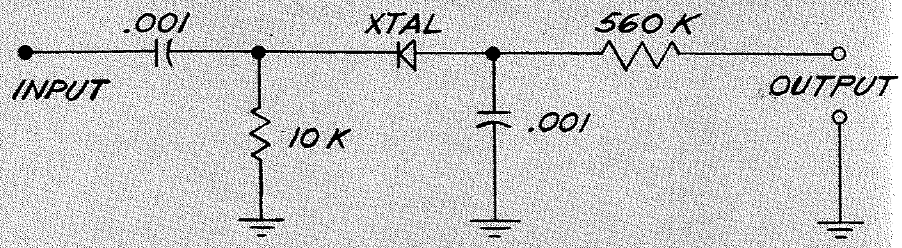


Fig. 4 — Test circuit used in the alignment procedure.

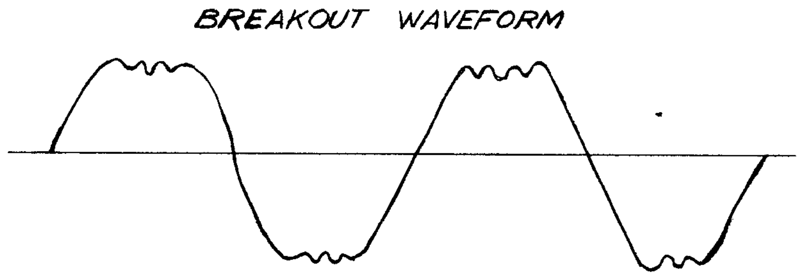


Fig. 5—"Breakout" characteristic waveform.

6DT6 screen grid current drops when the circuit oscillates, which is under a weak signal condition, and therefore the screen grid voltage rises. This change in voltage with signal level is applied to the 6AU6 screen grid and results in improved operation of this amplifier.

In the KCS102 the 6DT6 plate circuit has a 1.8 megohm resistor connected to the +240 supply voltage in addition to the 1.0 megohm plate load resistor to the "+BBA" supply, to prevent a blocking oscillation at an audio rate from occuring during the warm-up cycle of the receiver by supplying some plate voltage until the "+BBA" has reached its operating level.

Receivers with printed circuit versions will have screen grid neutralization in the 6AU6 circuit, with the value of the screen bypass selected so that the bridge formed by the C_{gp}, $Cg_1\ g_2$, C_o and C_n is balanced.

$$C_o/C_n = \frac{C_{g1p}}{C_{g1g2}}$$

The overall circuit has been temperature-compensated with capacitors having negative temperature coefficients in the sound take-off tank, the driver circuit, and the quadrature coil.

CIRCUIT ALIGNMENT

The alignment procedure is somewhat different than previous FM systems. With a 4.5 mc signal fed into grid No. 1 of the video amplifier tube (V106A), the test circuit shown in Fig. 4 connected to grid No. 3 (Pin #7) of the 6DT6, and a "VoltOhmyst" connected to the output of the test circuit, T101 and T102 primary and secondary are tuned for maximum. The input level during alignment is adjusted to maintain between 1.0 and 1.5 volts when finally peaking each circuit. The test circuit is removed and the 4.5 mc signal is frequency-modulated with 400 cycles having a 7½ kc deviation, and adjusted for approximately 200K μv. The quadrature coil, L117, is now tuned for maximum 400 cycle output at the voice coil. With an oscilloscope across the voice coil the input signal level is decreased to a point where the modulation deviation just swings beyond the lock-in range. The waveform that occurs at this point is called the break-out characteristic and is shown in Fig. 5. T101 and T102 primary and secondary are repeaked, if necessary, for maximum gain and symmetrical break-out.

It is possible to use the detector circuit as an audio amplifier by lifting the ground end of the grid #3 bypass capacitor and coupling in a low-level audio signal at this point. The 4.5 mc oscillator must be completely suppressed so that no bias appears on grid #3.

CIRCUIT ADVANTAGES

The circuit, as shown in Fig. 1, on an average will accommodate a modulation frequency deviation of ±75 kc, and with 7.5 kc deviation will deliver approximately 9.0 V. rms demodulated output. Distortion and capture ratio are comparable to the ratio detector. The present RCA black and white television receivers incorporating this circuit will average better than 5.0 μv sensitivity for 30 db quieting. From a manufacturing standpoint the circuit is reasonably uncritical to build. The coils are simplified, easy to test and adjust as compared to the more complicated ratio detector, which has very critical lead dress and coupling adjustments for proper AM rejection. In addition to a definite cost saving, the most important advantage of the circuit is the greatly improved limiting characteristic. This feature virtually eliminated the changes in sound output due to both fine tuning adjustment and selective fading conditions of the r-f carriers. Field experience to date has been very good under all conditions.

THE RCA SERVICE COMPANY-A VITAL LINK IN ENGINEERING

By **E. C. CAHILL, President**
RCA Service Company
Cherry Hill, N. J.

A BUSY HOUSEWIFE thinks of the RCA Service Company in terms of the technician who fixes her automatic washer, dryer, television set or room air conditioner. A theatre owner thinks of us as the field engineer who maintains his motion picture equipment. To a laboratory scientist, it is the engineer who helps him get the most exacting performance out of his RCA Electron Microscope. And BIZMAC owners know us as the men who maintain these wonders of the business world. Beverage bottlers think of the men who maintain their automatic inspection machines. To broadcasters, we are the men who help maintain their RCA transmitters and studio equipment. Truckers, highway patrols and pipe line operators picture us as the men who maintain their RCA mobile and micro-wave communications systems. A stateside manufacturer of packaged food products may think of us as the company that keeps his automatic weight-checking machines working with hair-line accuracy. Around Cape Canaveral, Florida, RCA Service Co. means the engineers and technicians who handle ground instrumentation activities at the Air Force missile test center and its lonely island stations far out on the range.

A military man stationed in any one of twenty-eight foreign countries may think of us primarily as Factory Service Representatives, Field Engineers and Technicians who supply installation supervision, on-the-job training and maintenance. To an Arab in faraway Casablanca we are the people who gave him his first glimpse of the magic of television. And an operator aboard an ocean liner knows us as the men who repair his communications gear.

Value to the Engineer

All RCA engineers, and particularly those engaged in product development, design and manufacturing, should recognize the importance and the far-reaching effect of the RCA Service Company's wide range of activities. RCA Service Company personnel may be thought of as a link between the engineer and the customer—a vital link that has reciprocal values of sizeable importance. It is for these reasons that I have sought this opportunity to acquaint you more fully with our organization and the scope of our activities. Besides giving you a fuller understanding of the things we do and how we are organized to do them, it is my hope that this will also suggest to you more ways in which we can be of mutual help in making our respective activities more successful.

No Newcomer to RCA

There are many people—including a sizeable number in RCA—who believe that the RCA Service Company as an operating organization is a relative newcomer in the RCA family—that it was founded in the post-war era for installing and servicing RCA Victor television receivers. The truth is it goes back even earlier than World War I. All that is new is our name. As you undoubtedly know, our present identification—RCA Service Company, a Division of Radio Corporation of America is as new as the newest New Year's Day. Before that—since 1944—it was RCA Service Company, Inc., a Subsidiary of Radio Corporation of America. Before 1944 it was the Installation and Service Department of RCA Manufacturing Company, Inc., the subsidiary in which all of RCA's manufacturing activities were once consolidated.

But the actual beginnings of the RCA Service Company are found in the Service Department of Victor Talking Machine Company, in the field service activities of RCA from the days of its founding, through the "Radiola" period of the 1920's, and in the installation and service activities of another one-time RCA subsidiary, RCA Photophone, Inc. Our present day staff numbers men and women from every one of these predecessor organizations—people who have made a lifetime career of service—as well as those who have joined us in bringing

Fig. 1—Typical RCA Service Company factory branch shop facilities for TV service. Shop technicians are provided with adequate test equipment and special tools and parts for diagnosis and analysis of difficult service problems.

about the expansion of RCA Service Company in the post-war era.

CONSUMER PRODUCTS SERVICE DEPARTMENT

The principal function of the Consumer Products Service Department is the installation and service of RCA Victor television receivers. But it also has a growing appliance service business. It has a Commercial Service activity which is responsible for preparation of all RCA Victor service data (radio, "Victrola", Hi-Fi, tape recorder, etc., as well as television), for technical liaison with RCA distributors, for field surveillance of RCA product quality, and for technical assistance to dealer and independent servicemen. And it also has a Purchasing activity which serves all of RCA Service Company.

Branch Support Functions

Backing up the service branch organization is a variety of supporting services at the home office. To mention some, there are: Engineering, which develops better service techniques and tools and looks into recurring service problems (more about engineering contributions later); a Material Control group which sees to it that the right varieties and quantities of materials are on hand; Training, which works out and administers training programs; Sales and Merchandising, to provide adequate sales programs and sales training; and Purchasing, which, as already mentioned, serves the entire RCA Service Company.

Commercial Service

For the most part, the services of this activity are performed on behalf of the RCA Victor Television Division and the RCA Radio and "Victrola" Division. Through 20 technical representatives who travel constantly among the 85 RCA Victor domestic distributors and their dealers it imparts on-the-spot technical training and assistance. These men also administer the RCA Victor Warranty policy. They conduct distributor-sponsored service clinics and workshops for dealer and independent servicemen. The magnitude of the latter activity may be gauged by the fact that since the war alone, these men have conducted over 2800 meetings with total attendance of several hundred thousand. These men resolve unusual customer complaints, through direct contact, if necessary. They supply quality and performance data to the respective RCA Victor Divisions.

Still another very important function of Commercial Service is the preparation and printing of RCA Victor Service Data manuals of which some 1700 different editions have been edited and distributed in the post-war era alone. In quality of information, they are recognized as outstanding.

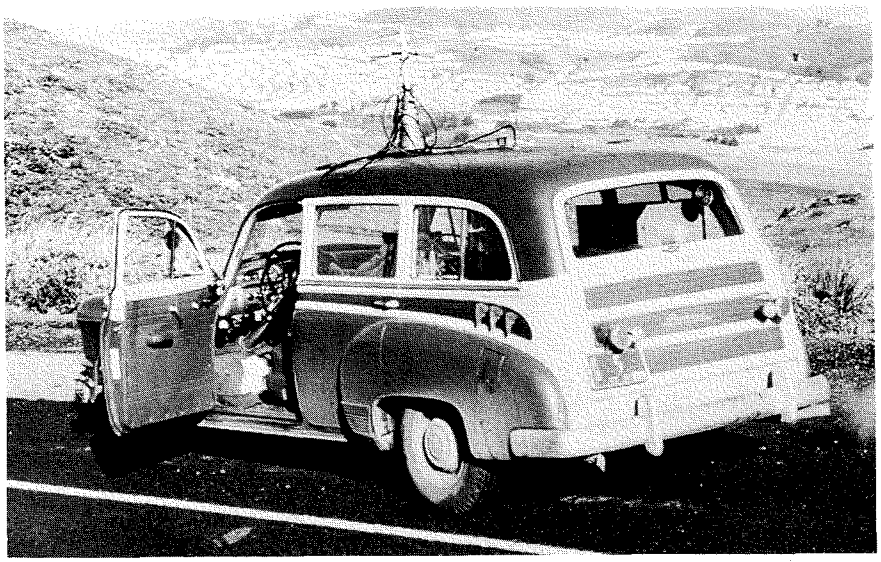


Fig. 2—Survey vehicle equipped by RCA Service Company for conducting TV propagation studies across the country. Photograph was taken atop Mt. Sutro—San Francisco, Cal.

TECHNICAL PRODUCTS SERVICE DEPARTMENT

Here is the easiest way to describe the scope of Technical Products Service Dept.: If the products you are creating are not for the home or the military, then they are products which our Technical Products Service Department is servicing. That, obviously, means it must handle a wide variety of product services.

For years its backbone has been the service of motion picture equipment. But industrial and scientific equipment services have steadily been gaining. Both remain important elements, but they will shortly be eclipsed by services for one of your newer products, RCA Electronic Data Processing equipment.

Technical Products field service activities are administered through eight Regional Managers. In a typical Region, there are also a Manager of Theatre and Industrial Service, a Manager of Mobile and Microwave service, and a Manager of Radiomarine Service. Four of the Regions also have a Manager of Communications Service.

Fig. 3—RCA Service technicians checking matrix on color receivers at the RCA Color Laboratory, Astoria, L.I. Here receivers were prepared for public and industry demonstrations in the New York area.

Mobile and Microwave Services

Mobile and Microwave services are performed by specialized technicians, many equipped with special trucks that are in reality mobile repair shops. Also, there are mobile and microwave service branches for the many customers who can drive their vehicles to the branch for service.

Mobile and Microwave service business is highly competitive, with customers who demand maximum performance of equipment and speed of service. We have revamped and expanded our facilities and trained our field organization to be sure that we provide the quality of service that will give potential equipment purchasers an extra incentive to buy RCA equipment.

Broadcast Transmitter and Studio Equipment Services

Television and radio transmitter and studio equipment installation and service is also handled by specialists. These men must be well qualified engineers, and they must be carefully schooled on the set-up, adjustment, and service of the apparatus. Our biggest problem results from the variations in our installation supervision workload which comprises by far the greater portion of this particular service.

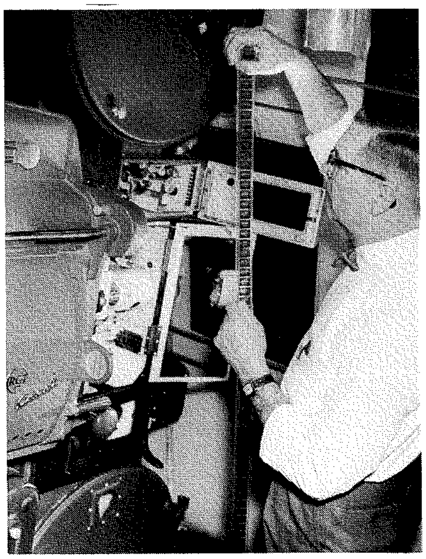
Radiomarine Services

Radiomarine services are also performed entirely by specialists. These services, incidentally, were performed by RCA Radiomarine, a subsidiary of RCA until 1955. For the performance of these services, which involves the repair of RCA marine communications gear in virtually every port of the U.S., our company presently employs a staff of approximately 125 technicians and has facilities at 51 coastal and inland waterway ports. Also, we have a well equipped shop in the New York area where complete overhauls can be efficiently handled.

Industrial and Theatre Services

RCA Electronic Data Processing's BIZMAC installation and service, too, is handled exclusively by specialists. Direction of this activity is still centered in our home office at Cherry Hill.

Fig. 4—Working "behind the scenes" in theatres throughout the nation, the Service Company engineers make use of a complete "library of special test film" to assure and maintain Academy approved sound reproduction.



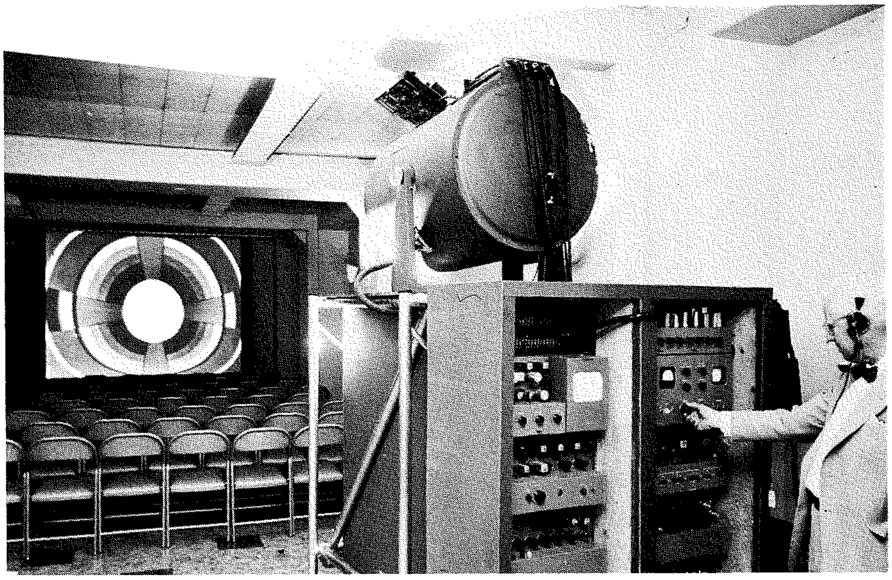


Fig. 5—The development of Theatre Closed-Circuit Television made available another mass entertainment medium for the public. Technical Products has the largest group of trained theatre television specialists in the country for handling such telecasts.

Where concentration makes it economically feasible, theatre and industrial services are performed by specialists. For example, some field engineers devote all or practically all of their time to the RCA Electron Microscope. Others may be occupied almost entirely with Beverage Inspection Machines at Coca-Cola, Pepsi-Cola, and 7-Up bottling plants. But a substantial part of our industrial services are performed by field engineers who deal with a variety of industrial products in addition to theatre equipment. Thus, a given field engineer might list on his service schedule Beverage Inspection Machines, RCA Metal Detectors, RCA Electron Microscopes, several types of electronic weighing machines, RCA Theatre Television, Industrial Sound Systems, RCA Industrial Television, and motion picture installations of a variety of makes and models. The versatility this requires and the extent of the training problems can be imagined.

You may have noted reference to non-RCA product services. The principal example is found in our theatre service activity. Most theatre chains prefer to have a single source of service. This has required that we be able to accommodate all makes of motion picture and theatre television equipment.

Also, various industrial equipment manufacturers who have found it uneconomical to maintain an installation and service organization of their own have availed themselves of our facilities. Such companies include the Exact-Weight Scale Company (which manufactures a high speed, electronically-controlled, machine for checkweighing of packaged commodities), Howe Scale (which has an electronically-controlled device for printing weight slips at remote locations), and Cox and Stevens (manufacturer of railway and traffic scales).

GOVERNMENT SERVICE DEPARTMENT

The Government Service activity of RCA Service Company was started years before it was given departmental status in 1950. But its biggest growth, by far, has come about since that time.

The activity goes back to pre-war years when our field service engineers supplied installation supervision when required under apparatus contracts awarded to the Engineering Products Department. Such apparatus was primarily sound communications equipment for Naval vessels.

The war, of course, led the RCA Manufacturing Company, Inc., into new military electronics fields such as Search Radar, Fire Control Radar, Shoran, Loran, Sonar, Block (military airborne TV) etc. As a result, RCA Service engineers were called upon to supply installation supervision, main-

Fig. 6—For the past quarter century the Broadcast service engineers have played an important role in the growth of the broadcast industry. Here the Technical Products Broadcast field engineer makes last minute visual inspection of TF-12AH antenna prior to erection.

Fig. 7—Technical supervision services for the televising of many important national and international events is made available through the Public Demonstration Services of Technical Products.

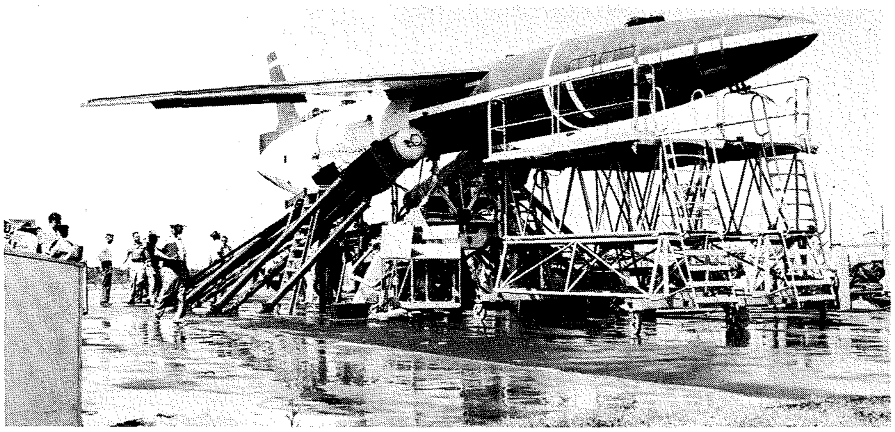


Fig. 8—Northrop "Snark" being readied for launch at Cape Canaveral, Florida where many RCA Service Company Engineers and Technicians are assigned.

tenance services, and operation and maintenance training in practically every theatre of war, as well as at shipyards and military establishments throughout the United States.

Missile Test Project

Of today's various activities in this department, the biggest and most exciting is the Missile Test Project at Patrick Air Force Base, Florida. Here, skilled personnel provide services which include the planning, engineering, operation and maintenance of all ground instrumentation for the missile test range having its launching site at Cape Canaveral. This includes manning of the down-range instrumentation stations on islands in the Caribbean and far out into the South Atlantic. Performance data for missiles under test is acquired, transmitted and reduced. Technical and fiscal information is also compiled for use by the Air Force in the procurement of equipment and materials. The RCA Service Company operates this project under a sub-contract from Pan-American Airways. It was selected on the basis that it offered the best overall qualifications. Personnel requirements include top skills in the electrical, electronic, mechanical and optical arts, and range all the way from technicians to scientists with Ph.D.'s.

RCA-Defense Electronic Products Services

Providing services required by contracts awarded to RCA-Defense Electronic Products is still a major activity of the Government Service Department. These activities are handled by a group known as Defense Electronic Products Services.

Field representation in this activity is through Factory Service Representatives. They conduct training programs covering installation, operation and maintenance. If the occasion demands, they set up and operate service shops and depots where RCA-manufactured apparatus can be modified to meet special needs. They "feed back" much valuable information to RCA-DEP engineers.

DEP-Services also conducts reliability programs, under which it provides complete data reduction, processing and computing services requiring employment of engineers, statisticians and mathematicians.

Another program of DEP-Services is the assignment of Engineering Service Representatives to assist the design engineers of RCA-Defense Electronic Products. These are carefully selected specialists who have had extensive field experience with military electronics. Their function is to provide the field service background needed for the design of equipment having the maximum "maintainability."

Technical Services Contract Activities

RCA Service Company is a leading technical services contractor for the military. As such, it is currently supplying field engineers under contracts requiring installation supervision, maintenance engineering and training services at Army, Navy and Air Force bases throughout the United States and in twenty-eight foreign countries. These services involve as many as 500 types of airborne, shipborne and land-based equipment. Similar services are performed for the Civil Aeronautics Administration, the International Co-operation Administration and the Atomic Energy Commission.

One of the contracts of this type provides for contractor maintenance at the more than 40 Aircraft Control and Warning sites operated by the Central Air Defense Force of the Air Defense Command, Here RCA Service engineers and technicians provide around-the-clock maintenance of the communications, radar and diesel power equipment.

Other Government Service Activities

Government Service instructors are currently assigned to many of the country's leading military training centers. They are also assisting in the preparation of curricula at training centers in the United States and overseas. Training activities have included design and production of a number of types of RCA Electronic Trainers which have been sold to American schools as well as to the military.

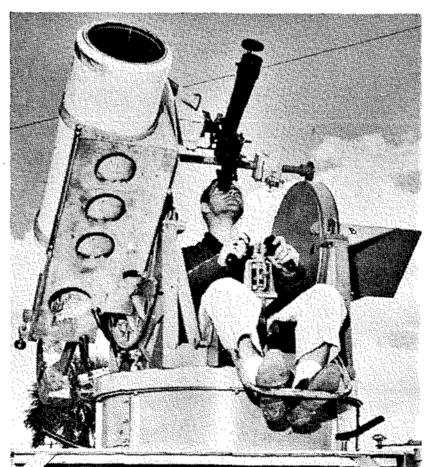
The preparation of engineering reports, technical manuals and publications is another substantial activity, one which requires the services of substantial numbers of engineers, writers, artists, photographers and draftsmen.

But the most unusual is our venture into the newest field of all—Atomic Services — wherein we have been awarded a contract to design and construct an atomic reactor simulator for military training purposes.

OUR PEOPLE AND THEIR CONTRIBUTIONS

Efficient field service calls for imagination, ingenuity and resourcefulness as well as specific product knowledge. The exercise of these talents quite often leads to valuable contributions in the way of faster or better service methods, or suggestions on new and useful products, or suggestions on how to build a better product. I should like to cite just a few specific examples: When RCA prepared to launch the prewar test of its newly developed all-electronic television system, our organization was asked to assign six of our best qualified field engineers to install and maintain the receivers. At this point there existed no television test equipment suitable for field use. These men

Fig. 9—RCA-MTP Technician operating M-45 tracking camera at AFMTC—Cape Canaveral, Florida.



designed and built the r-f and i-f sweep oscillators used throughout the test. They also designed and fabricated the receiving antennas.

When the earlier post-war television transmitters were being installed, the antenna and matching adjustments could be made only by a long drawn-out series of point-to-point measurements. An RCA Service engineer foresaw how a sweep oscillator, delay line and oscilloscope could be employed to provide an instantaneous picture of the transmitting antenna's performance over its entire transmitting band. The immediate result was a huge saving in installation time and better performance of the system.

An RCA Service engineer on a war-time Government Service assignment developed a relatively simple method for checking the performance of airborne radar without requiring that it be installed in a plane. This contribution resulted in a U.S. Government Presidential Citation.

An engineer in the home office Engineering Section of Consumer Products Service Department made these three exceedingly valuable contributions toward color television: A method and equipment for transmitting as part of a regular black-and-white picture two auxiliary color stripes which enables a field technician to check the color performance of a color receiver and antenna installation; a dot generator for checking convergence adjustments; a low-cost, portable color bar generator setting up a color receiver.

An engineer in the RCA Service Company's quality laboratory at Brown's Mills developed the cathode

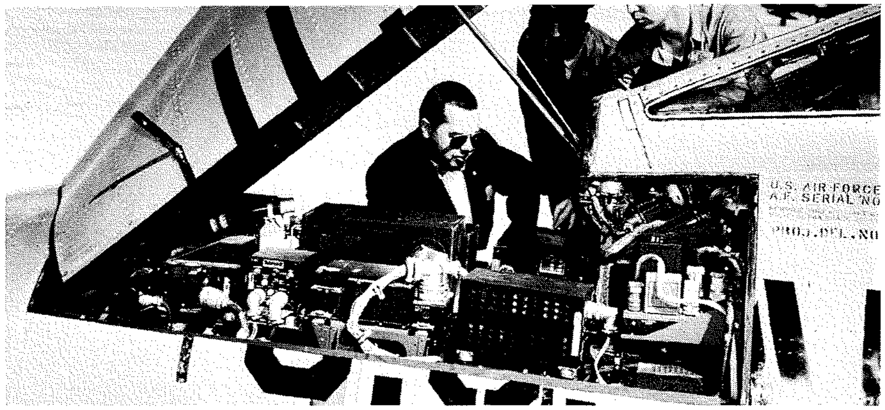


Fig. 10—Anson L. Herrinn (left) RCA Field Engineer at George AFB, California explains AN/ARC-34 installation in F-100 type aircraft to 1/LT. Daniel Alexander, Electronic Officer for the 434th Fighter-Day Squadron; and A/IC Paul Linn. The 434th Fighter-Day Squadron is part of the 479th Fighter Day Wing—TAC's first super sonic wing.

emission rise time method for evaluating kinescope life characteristics—a method now having industry-wide acceptance.

An RCA Service engineer developed a 13-channel television signal simulator which was of tremendous value for the installation of receivers in the early days of television when stations were on the air only intermittently during the daytime hours.

An RCA Service engineer years ago developed a unique method for connecting a record player attachment to a radio receiver without disturbing any of the receiver circuitry, a method which is still exemplified in kits sold by competing manufacturers.

An RCA Service engineer conceived and built the first "Dynamic Demonstrator" which set the pattern for all sorts of electronic trainers in use today.

An RCA Service engineer in the Government Service Department showed how, for certain communications services, a portable tuned loop antenna and receiver with pulse type detector could be made to perform as well or better than a normal receiver fed by a costly rhombic antenna installation.

A Technical Products service engineer developed and patented the "buzz-track" film which is used universally for adjusting sound motion picture recording and reproducing equipment. Another service engineer developed the first Frequency Modulated Audio Frequency Oscillator used to calibrate flutter measuring equipment; also designed and developed the first portable flutter indicator merchandised by RCA.

Naturally, many of our technical contributions are suggestions covering some equipment component or feature which our people sincerely believe it would be to RCA's advantage to change or improve.

We are grateful for the open-minded attitude with which these are generally received. I am sure you understand that they are always offered in good faith with the welfare of RCA and its customers in mind.

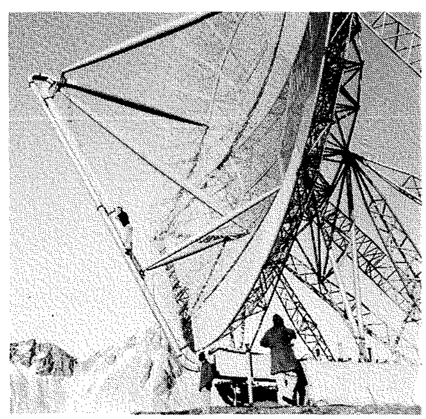
In conclusion, I should like to say it is my sincere belief we can be of even more help to one another than in the past. I am confident we will all find ways to bring this about.

EDWARD C. CAHILL'S career is a testimony to the fruits of establishing challenging goals and applying the hard work and diligence necessary to attain them. Born in Glasgow, Montana (1950 pop., 3800), he came to work on the Great Northern Railroad after a tour with the U.S. Army in World War I. During his five years of employment with the railroad he became a journeyman electrician, and his work served to convince him of the great future of the electrical industry. Enrolling in the Milwaukee School of Engineering, he worked his way through school and graduated with a BS in EE in 1928. His school recently elected him a member of the Board of Regents, and presented him with an Honorary Professional Degree.

Mr. Cahill joined RCA on graduation as a field engineer in RCA Photophone, servicing RCA motion picture and sound equipment in the Midwest. When the Photophone activities were merged with RCA Victor in 1932, he became Chicago District Manager. His rise was rapid. He was appointed Central Regional Manager in 1934. In 1937 he became National Service Manager, and in 1938 Manager of the Photophone Sales Division.

In 1943, RCA formed the RCA Service Company to handle all phases of RCA product installation and service, and Mr. Cahill was elected its President.

Fig. 11—RCA Service Company technician A. A. Guzzi climbs waveguide to make final adjustments on 60 foot tropospheric antenna in North Iceland. This antenna is part of the RCA FRC-39 scatter communications system for the Icelandic Air Defense Forces of the U. S. Air Force.



CHEMICALLY-ACTIVATED FUSES PROVIDE IMPROVED RELIABILITY

by **K. G. WEABER**
Engineering Services
RCA Victor Television Division
Cherry Hill, N. J.

THE SUCCESSFUL development of a reliable and economical fusing device has been a problem facing equipment manufacturers since the concept of television. Proper fusing, as may be expected, is a requirement set forth by the Underwriters' Laboratories in order to avoid fire hazard. From the manufacturers' viewpoint, proper fusing protects major components, and is mandatory to avoid expensive repair bills and protect the customer's investment. To perform this function the fuse should give reliable, continuous service under all operating conditions except those endangering the receiver. The ideal fuse must successfully remain in operation during current surges and momentary phenomena that do occur, and subsequently clear up during receiver operation. Because conventional fuses have not performed this function satisfactorily, receiver service has been continually interrupted, accounting for a substantial percentage of all component failures. In this paper, the design and development of a new, effective, chemically-activated fuse will be described, following a brief review of the construction, design, and reliability of conventional fuses previously used.

CONVENTIONAL-FUSE SPECIFICATIONS

Conventional low-amperage fuses are made to specifications less exacting than is generally recognized. Design engineers tend to have an unwarranted confidence in commercial fuses that are publicized as having received Underwriters' Laboratories inspection and approval.

The Underwriters' Laboratories has set up the following requirements for both the quick-acting and thermal-lag types of cartridge fuses:

1. Fuses must carry 110 per cent of their current rating indefinitely.
2. Fuse must have an average blowing time of 1 hour or less at 135 per cent of rating.
3. Fuse must have an average blowing time of 2 minutes or less at 200 per cent of rating.

In addition to the above, the thermal-lag type must hold a 200 per cent load for an average of 12 seconds minimum.

In practice, these requirements are less stringent than a strict interpretation would suggest. For example, in point (1) above, Underwriters' Laboratories permit up to a 40 per cent failure rate on the 110 per cent load requirement and "indefinitely" means the few hours necessary for the temperature of the fuse link to reach a maximum and level off. The word "average" in requirements (2) and (3) does not demand that suppliers maintain uniform quality. From an engineering viewpoint, these specifications are very "loose." Reliability cannot be expected of complex electronic equipment when components are so specified.

CONVENTIONAL-FUSE CONSTRUCTION

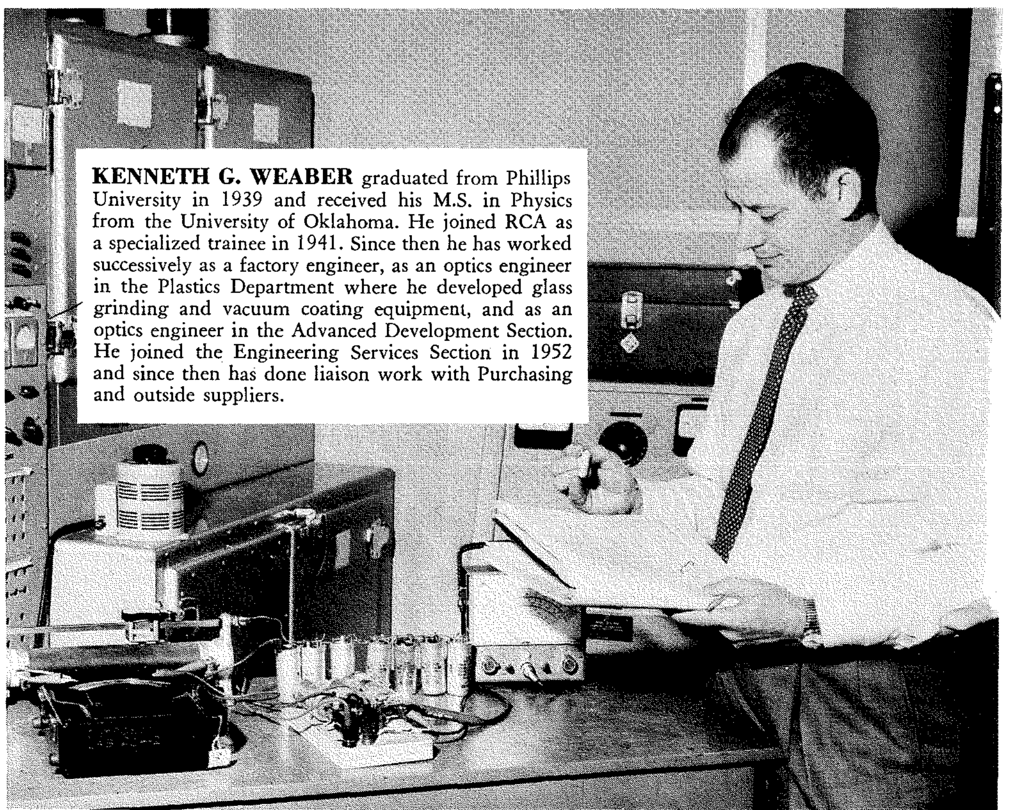
The conventional fuse consists of a link of fusible metal encased in a flame resistant cartridge. The fuse-link is stretched between ferrules enclosing each end of the cartridge. This fine-wire link melts or pulls apart when carrying current in excess of the fuse rating. Figs. 1 and 2 show sectional views of the two main types of conventional fuses. In a quick-acting ¼-amp. fuse, the fusible link has a diameter of approximately .0012″ and a melting point of 1200-1500°C. Such fuses must be used with care in electronic circuits because the fine link, which normally operates at a high temperature, is subject to cyclic fatigue during surge-current operation. This type has relatively short life when operated close to its rating.

The thermal-lag type fuse contains a heavy fusible link and a wire-wound or carbon resistor assembled under spring tension. The fusible link is designed to hold transient currents and open in a few seconds at high-level overloads. Low-level protection is obtained in a matter of minutes when the heated resistor softens the solder that connects the resistor and the link. The pre-stretched spring then separates these parts to give an open circuit.

CONVENTIONAL-FUSE RELIABILITY

Television manufacturers have done extensive testing of low-amperage fuses. The RCA Television Division has found it necessary to invoke more stringent requirements than those of the Underwriters' Laboratories. Fuse standards vary between suppliers, and quality varies between successive lots from the same supplier. Only a "small-percentage" test of each lot is reasonable since all fuses tested are destroyed. Therefore, incoming inspection tests cannot readily control fuse quality.

Long-time life tests under steady-state current loads indicate the following reliability from both quick-acting and time-delay types of conventional fuses. Small amperage fuses have an average reliability of 98½ per cent to 5,000 hours when used at 60 per cent



KENNETH G. WEABER graduated from Phillips University in 1939 and received his M.S. in Physics from the University of Oklahoma. He joined RCA as a specialized trainee in 1941. Since then he has worked successively as a factory engineer, as an optics engineer in the Plastics Department where he developed glass grinding and vacuum coating equipment, and as an optics engineer in the Advanced Development Section. He joined the Engineering Services Section in 1952 and since then has done liaison work with Purchasing and outside suppliers.

of their rating. This compares to 90 per cent reliability when used for the same period at 85 per cent of rating. Reliability at full rating is poor. Tests were discontinued at 1,600 hours when 50 per cent of the fuses had opened.

Reliability less than that indicated above, is experienced when fuses are used in electronic circuits. Quick-blow fuse failure rates are substantially higher in circuits with transient currents arising from tube flash-over or corona breakdown. Time-delay fuses handle transient currents better than do quick-blow fuses. However, reliability of time-delay fuses at an ambient temperature of 55°C or higher, is much less than that of the quick-acting fuse. At instrument ambients of 65°C, failure frequently results in a few hundred hours from cold flow of the heated solder connecting parts of the spring-loaded link. Another weakness of the time delay type fuse is its occasional tendency to fail closed, voiding instrument protection. Laboratory reliability test results are well confirmed by actual field experience.

REQUIREMENT FOR AN IMPROVED FUSE

As mentioned previously, an improved fuse for television receivers had been sought for years. Prior to the chemically-activated fuse, fuse failures were responsible for a large share of all TV receiver service calls. Improved fuse reliability was important to our Sales and Merchandising groups to maintain the RCA reputation for high quality and low maintenance costs. This has always been an important sales advantage. A more reliable fusing device was equally important to the RCA Service Company in order to maintain customer satisfaction and to reduce the cost of servicing sets maintained under yearly contracts.

REASONS FOR FUSE FAILURE

Many fuse failures occurred in receivers that were found to be in normal operating condition after the fuse was replaced. Examination showed that a large percentage of these failures were due to high surge currents. This was evidenced by complete vaporization of the fuse-link element. Fuses which fail from ordinary overload currents have a short gap burned in the fuse element. Circuit analysis suggested and experiment confirmed that these high-current failures were caused by internal flash-over within the tubes. Breakdown between the plate-grid-cathode elements in the horizontal or vertical deflection circuits allowed the large filter capacitors in the low-voltage power supply to discharge through the fuse. Occasional transient currents up to 100 amperes were measured.

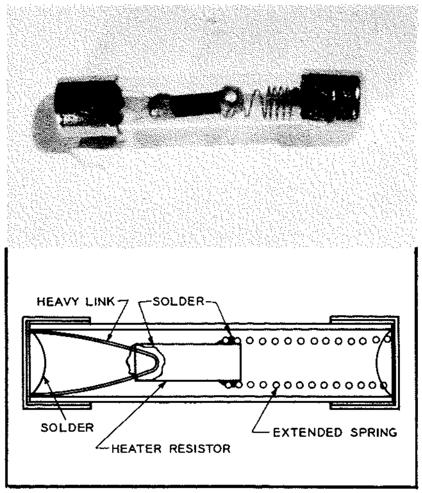


Fig. 1—Slow-Blow or Conventional Time Delay Fuse. Cross Section shows assembly of fusing link, heater and spring.

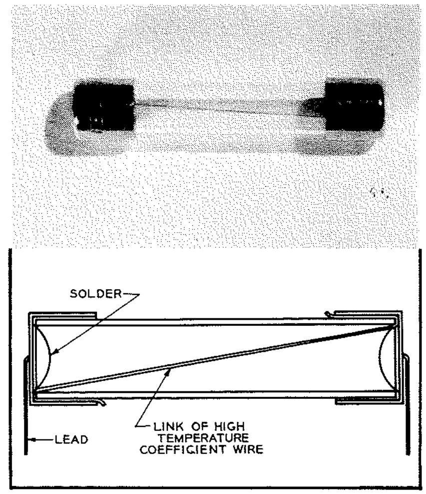


Fig. 2—Conventional Quick-Blow type of Fuse. Section shows stretched link of fusible wire.

The exact nature and duration of this transient current was difficult to determine. A very low percentage of tubes flashed-over and the resulting arc frequently burned off the cathode flake or lint causing the flash-over. Occasionally a tube would unpredictably flash-over at intervals of days or months. The RCA Service Company replaced many tubes "on suspicion." These momentary currents caused fuses rated up to 5 amperes to open. The Underwriters' Laboratories determined that a fuse rated at 0.3 amperes maximum was required to minimize fire risk to an acceptable degree.

Our fuse suppliers were consulted on the problem. Available fuse designs which would give receiver protection either had unsatisfactory life characteristics or failed to protect against high transient currents. It was found necessary to limit surge currents before a satisfactory fuse could be developed.

DEVELOPMENT OF CURRENT LIMITING RESISTORS

A fixed resistance of 50 ohms in series with the fuse reduced these 100 ampere transient currents to 5 amperes. However, this resulted in a loss of 7 to 10 volts of B+ and adversely affected receiver performance. To minimize voltage drop across the resistor with normal operating current and still reduce surge currents, a resistor with a high positive temperature characteristic was developed.

This resistor was made of high temperature coefficient wire, wound on a fluted ceramic coil form. Minimum contact of wire with coil form was required to give fast temperature build-up in the wire. A temperature change from 100°C to 1000°C was required within 500 microseconds in order to limit the current. This resistor changed in value from 10 ohms under normal operating conditions to 50 ohms under tube flash-over conditions.

Peak transients were effectively reduced to about 5 amperes but the duration of this surge was increased. Available commercial time-delay fuses which gave receiver protection and held this reduced surge were shown by life test to have unsatisfactory life expectancy. Circuit breaker designs were examined and manufacturers in this field were contacted. Both lines of inquiry proved negative. A fusible resistor of the "fusistor" type was not found feasible. A new type fuse was required!

CHEMICALLY-ACTIVATED FUSES

Chemically-activated fuses are briefly described in European periodicals and in certain British and German patents. However, engineers in this country had considered them unreliable and these types of fuses were not available in this country prior to our requirement for them.

Chemical fuse design allows the use of a fusing element with up to 10 times the cross-sectional area of that used in a conventional fuse. This element was found heavy enough to withstand our transients. In this type fuse, the element is coated with a low-firing chemical. The thermal inertia of the element prevents it from firing during short duration surges, but a sustained overload heats the wire to a temperature that fires the chemical. The resultant energy released burns the wire and opens the circuit.

The Bel Fuse Company suggested the chemical type fuse for our application and supplied several designs for evaluation by the Receiver Design groups. After life tests in the Components Laboratory, several hundred fuses of a promising design were life tested in television receivers at the Browns Mills

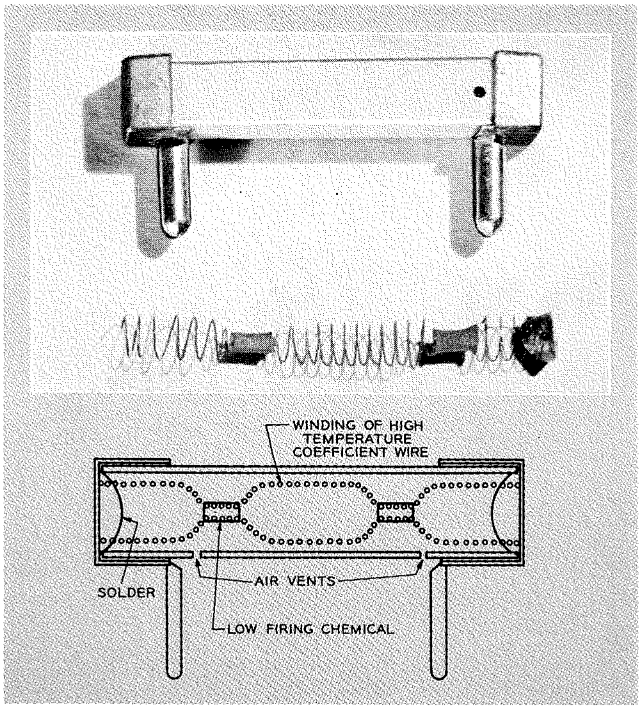


Fig. 3—Chemically-Activated Fuse with Surge Limiting Feature. Chemical is located on reduced-diameter areas of spiral winding (surge limiter resistor) as shown in sketch, and by removed element in photo above.

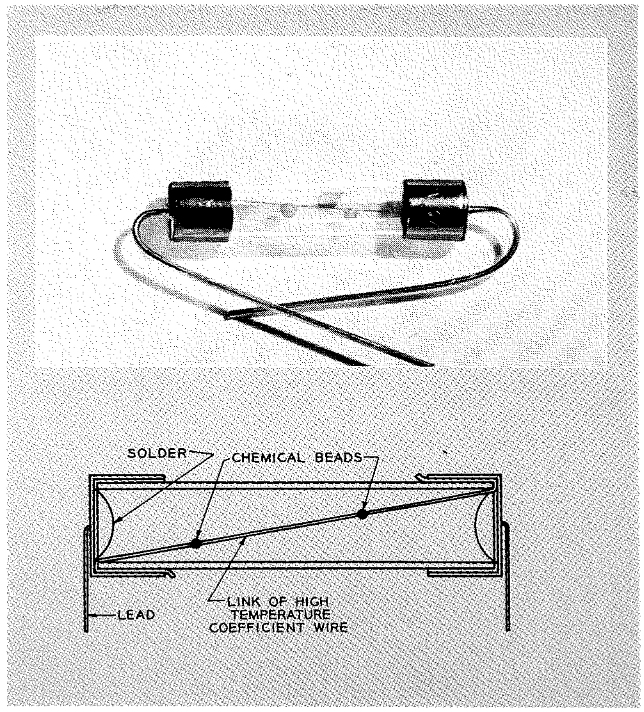


Fig. 4—Chemically-Activated Fuse without Surge Limiting Feature. Chemical is spotted directly on the straight filament.

location. These fuses did not show the expected improvement in protection against tube flash-over surges. The RCA Service Company developed a trigger circuit which allowed surge currents to be photographed on an oscilloscope. These data established that the internal impedance of the fuse was critical in the monochrome receiver. The chemical fuse, because of its heavier fusing link, had about ¼ the impedance of a conventional fuse. Since the fuse constituted most of the effective resistance during flash-over, the surge through the chemical fuse was several times as great as that through a regular fuse. It was surmised that the problem would be solved if the resistances could be equalized.

FUSIBLE SURGE LIMITERS FOR MONOCHROME RECEIVERS

A positive temperature coefficient resistor and a chemically activated fuse were required for adequate instrument protection. Their combination in a single package was indicated for cost reasons. It was important to minimize resistance under steady-state conditions. To obtain this result and still have the full effect of the resistance climb, the resistive unit should have minimum contact with its support. Tests with the temperature coefficient resistors wound on a fluted coil form showed that even this minimum contact required an increase in resistance of 30 per cent at steady state to achieve the same limiting effects under surge conditions.

The final mechanical version for this "fusible surge limiter" is shown in Fig. 3. The square ceramic tubing is capped at each end with die-cast ferrules which incorporate the mounting pins. The pins are spaced farther than is standard for fusistors to prevent these two devices from being used interchangeably. The tubing is vented as shown to allow the gas to escape. Approximately 12 inches of high temperature coefficient wire (.0035 diameter) is used to obtain the surge limiting characteristic. The wire is wound in a spiral of spaced turns. The cross-sectional view (Fig. 3) shows two areas which have closer spaced turns of reduced diameter. The chemical is applied in these areas.

The fusible surge limiter was designed as a part of a mass-produced monochrome receiver. The fuse failure rate was much lower on the chassis . . . enough so that the Merchandising Section insisted that all monochrome chassis be modified to incorporate this fuse and its holder. Several months of field experience indicates that fuse replacements in RCA's current line of TV receivers is but a small percentage of that previously experienced.

THE CHEMICAL FUSE USED IN COLOR RECEIVERS

The fuse circuit in the color TV receiver had higher impedance and surges were limited to about 10 amperes. The ¾-ampere conventional quick-blow fuse previously used occasionally failed on these surges. This fuse acted quickly enough to prevent fires but did not give true instrument protection on prolonged overload. Tubes and components were permanently damaged before the fuse opened.

A chemical fuse was then designed to better handle these surges and open at a lower overload current. The fuse was of a simpler construction, as shown in Fig. 4, since the surge limiting feature was not required. The chemical was applied in two beads directly on the straight fuse link of high temperature coefficient wire. Two beads were found to give the most consistent blowing characteristics.

FEATURES OF THE CHEMICALLY-ACTIVATED FUSE

1. Ability to carry currents reliably within 25 per cent of that value at which they will open within 30 seconds. Note: Conventional fuses must be de-rated 50 per cent to have comparable life and require 200 per cent of rated current to open within 30 seconds.
2. Lower resistance than conventional fuses since a heavier link is used.
3. Ability to hold transient currents 10 to 20 times heavier than that current at which they will open in 30 seconds.
4. Surge limiting characteristics with nominal resistance under normal operating conditions.
5. Longer life since the fuse link operates at a lower temperature.
6. More uniformity in blow characteristics than conventional fuses. The use of a larger wire diameter reduces the effect of kinks and bruises in the fuse-link.
7. Satisfactory reliability in ambients of 75°C. Note: Conventional time-lag fuses have poor life expectancy in ambients of 60°C and higher.

URETHANE FOAM RESINS

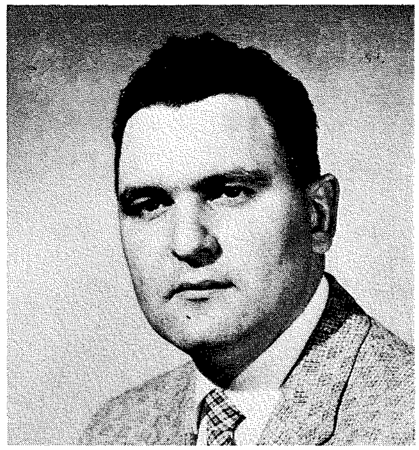
By

JAMES C. DZOMBA.

Chemical and Physical Labs.
Components & Materials Div.
Camden, N. J.

JAMES C. DZOMBA graduated from La Salle College with a degree of Bachelor of Arts in Chemistry in 1952. He was employed as a chemist for the Philco Corporation for two years after graduation and then joined the Rohm and Haas Company as a research chemist in high polymer. Mr. Dzomba joined RCA in 1956 as an engineer in the Chemical and Physical Laboratories, where he is now employed as a member of the Polymer Group.

Mr. Dzomba is a member of the American Chemical Society.



THE FIELD OF foamed plastics is one of the most rapidly growing areas of resin chemistry. It has been estimated that by 1960 Americans will be using 300 million pounds of foamed plastics per year. These plastics, which are uniformly porous or cellular polymers, are readily adaptable for filtration, packaging, cushioning, and for construction in a variety of insulation applications. There is hardly an industry in the United States today that will not eventually use some form of foamed resin.

Of the many types of plastic foams currently being manufactured and sold, the most widely known and publicized are the urethane foams, such as *Lockfoam, Selectrofoam, E. P. Fome,* and *Koolfoam.* Urethane foams are available in several forms. They may be purchased as the finished product in sheets of flexible or rigid foams, or they may be obtained as two- or three-component systems and foamed in place on a production line.

HISTORY OF URETHANE FOAMS

Urethane foams had their beginning in the 1930's. They are the result of a German-American research race, which began with Wallace Carothers' research on bifunctional acids and alcohols. Shifting his interest to bifunctional acids and amines, Carothers discovered nylon. Efforts of the I. G. Farbenindustrie to avoid du Pont nylon patents led to the German development of the basic long-chain polymers from glycols and diisocyanates. Bell Telephone Laboratories, du Pont, Monsanto, and Lockheed were some of the firms which pioneered the American urethane-foam research program. Although European commercial production of foams was started in 1951, their American manufacture was delayed until recently pending the construction of facilities for producing aromatic isocyanate compounds.

CHEMISTRY OF URETHANE FOAMS

The preparation of urethane foams involves the reaction of an aromatic diisocyanate with a polyester resin (usually one having a low acid number) to form a polyurethane resin prepolymer. Water is then added in the presence of an amine catalyst; this addition simultaneously liberates carbon dioxide and forms a cellular urethane polymer. Carbon dioxide is the foaming agent. Its effect on the resin prepolymer is similar to the effect of baking powder on cake batter.

The character and proportions of the original ingredients determine the properties of the end foam. Long, straight, chain-type polyesters having fairly high molecular weights produce elastic, rubber-like foams. Polyfunctional, branched, low - molecular - weight - type polyesters yield rigid foams. The amount of carbon dioxide released (which determines density) can be controlled by altering the amount of excess diisocyanate and water used in the formulation.

APPLICATION OF URETHANE FOAMS TO ELECTRONICS

Urethane foams can be of great value to the electronics industry for several reasons. They combine light-weight with good mechanical strength, properties of great importance, particularly in the field of aviation electronics. Urethane foams will assume the shape of the mold in which they are foamed and will encapsulate an object placed in the mold, regardless of the shape of the mold or the complexity of the object. Urethane foams have good electrical properties and good impact strength over a temperature range from −60 to plus 150 degrees centigrade.

Foams are well adapted for use as insulating agents against heat and sound. Because of their excellent adhesion to most surfaces, and the fact that they can be foamed in place they reduce costs by elimination of cutting and fitting and the use of cements or adhesives.

ENCAPSULATING ELECTRONIC COMPONENTS

The most apparent use to which urethane foams would be applicable in electronics is as an encapsulating medium for components. For this application, foams offer the advantage of (1) a rapidly reacting material which can be removed from the mold within thirty minutes after mixing, and (2) a material that is 90 per cent cured after twenty-four hours at room temperature or fully cured after a short time in an oven at moderate temperatures. Foams should, therefore, be especially suited for electronic components that cannot be subjected to the high temperatures so often required for curing ordinary encapsulating resins.

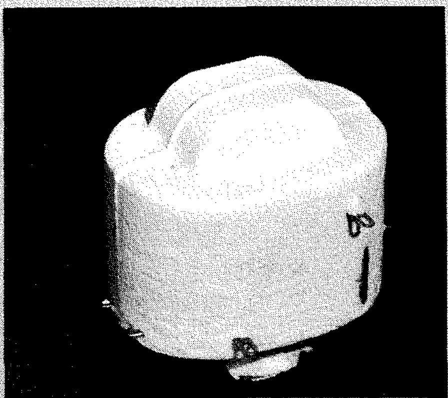
In the field of component encapsulation, urethane foams are capable of competing successfully with epoxy resins where extreme light weight and great mechanical strength are required. Urethane foams will not replace epoxies as the standard encapsulating medium since the epoxy resins offer the best combination of properties for general encapsulating uses. Although there is not much difference in relative cost, savings with urethane are possible, since less of the compound is needed per encapsulation.

Though the present use of urethane foam for encapsulating is still limited, the trend toward the use of lightweight materials in the aircraft and missile fields should increase the demand for urethane foams.

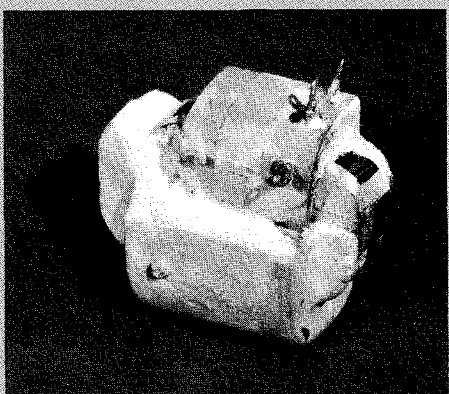
Urethane foams are also suitable for use as reinforcing cores on structural parts. In this regard, foams are extremely useful as a reinforcing medium for radomes since they do not interfere with the passage of radar waves. Their mechanical strength permits construction of lightweight rugged structures which will withstand considerable stress. The use of foams enables structures to be constructed of thin-gauge metal or plastic, thereby reducing both material and labor costs.

TECHNIQUES IN THE USE OF FOAMS

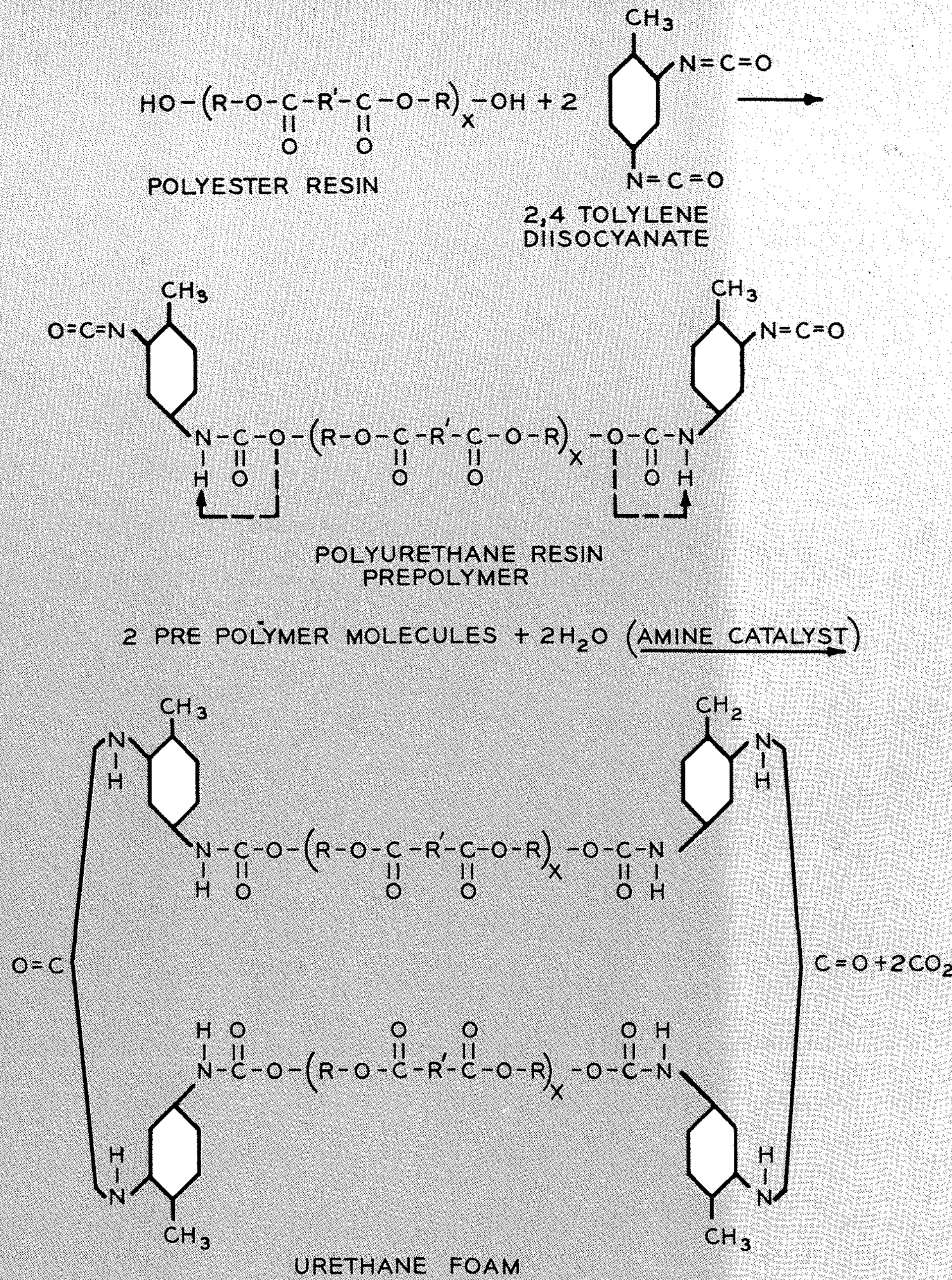
Commercially available foamed-in-place compositions are of two basic types: the



Transformer encapsulated in Urethane Foam.



Same Transformer with layer of foam cut away.



Chemically, the preparation of Urethane Foams is described by the equations above. The photos inset alongside equations show a typical output transformer encapsulated in Urethane Foam.

one-shot and the prepolymer systems. One-shot foams are produced by the reaction of a suitable amount of diisocyanate with a selected alkyd or polyester resin which has been properly catalyzed. The prepolymer system involves use of a diisocyanate which has been reacted with the resin (either completely or in part) to form a prepolymer. The prepolymer is then foamed by addition of the catalyst.

Urethane foams, whether they are of the one-shot or prepolymer types, are usually supplied as a two-component system. The two components of the one-shot system are (a) the diisocyanate and (b) the polyester, water, and catalyst. The two components of the prepolymer system are (a) the prepolymer mix and (b) water and catalyst. The components are mixed in the proper proportion and poured into the cavity to be filled. Thorough mixing of the two components is an absolute necessity if optimum results are to be obtained. Most urethane foams allow a mixing period of a minute before the foaming action commences. Although the two components are usually light yellow in color after a thorough mixing, they change to a white-colored material having a texture of heavy cream.

The particular urethane foam used in the evaluation tests made by the Chemical and Physical Laboratories was supplied by the Nopco Chemical Company. The trade name of this product is "Lockfoam," and it is a one-shot-type foam.

"Lockfoam" was foamed by the Chemical Laboratory in many different molds of various sizes, shapes and constructions. The size and shape of the mold neither inhibited or enhanced the final product. Because of the excellent natural adhesion of urethane foams to most materials, the use of a mold lubricant is necessary. Satisfactory mold lubricants for urethane foams are the various commercial Silicone products available from Dow-Corning and Union Carbide and Carbon. It was found, however, that the foam was difficult to remove from one-piece molds regardless of the mold lubricant used. Excellent release is obtained with molds that can be separated into two or more sections.

When the mold has a surface area of more than six square inches, certain difficulties arise which do not allow the foam to fill the cavity completely. One difficulty is that the theoretical calculation of the required amount of foam may not hold true. Another difficulty is due to the fluidity or lack of fluidity of the foam mixture. The fluidity of the mixture may be such that time does not permit the foam mixture to flow into all corners of the mold before foaming begins, with the result that the final product will not be uniformly thick. The procedure to be used in cases such as this is as follows: (1) determine the required weight of foam mixture that will produce sufficient foam to fill the cavity, and (2) position the mold in such a way that the foam mixture has the smallest possible volume to fill and the expansion process has to fill the largest volume of the mold.

If at all possible, molds that are used with foams should have a small opening to allow air above the foam mixture to escape, otherwise the trapped air will act as a counter pressure and prevent a full volume of foam.

If removal from the mold is neither required nor desired, any material with sufficient strength to withstand the pressure of the foam can be used for a mold.

Preheating of the mold to 50 to 60 degrees centigrade shortens the reaction time and insures a full volume of foam.

The method of calculating the amount of each component necessary to produce the desired foam can be illustrated by an example. Assume that the volume of a mold 0.25 cubic foot, and that the required density of the resulting foam is ten pounds per cubic foot. Then the total weight necessary to produce the desired foam is 0.25 by 10 or 2.50 pounds. However, a five to ten per cent excess total weight should be used to produce an overflow for flushing out the cavity. If a ten per cent excess is desired, the total quantity for unit pour will be 2.75 pounds.

If it is assumed that the formulation requires 55 parts of the resin component and 45 parts of foaming agent, the amount of each required would be:

$2.75 \times 0.55 = 1.51$ pounds resin component

$2.75 \times 0.45 = 1.24$ pounds foaming agent.

A mix made in accordance with the preceding calculation will provide sufficient foam to fill the subject mold plus an excess of one to two inches overflow. This method may also be used to determine the amount of each component necessary when a prepolymer-type foam is used.

When the foam is used to encapsulate electronic components, an overflow of material out of the mold is not desirable. For this type of work, a closed mold is used to contain the foam within the confines of the mold. If the mold is of the type in which the cover is not fastened in place by screws or some other locking device, a pressure of 15 to 25 pounds per square inch must be exerted on the cover of the mold in order to confine the foam.

PHYSICAL PROPERTIES OF URETHANE FOAMS

The physical properties listed in the following tables apply to the "Lockfoam" used. However, the same properties are applicable to the other commercial urethane foams which are currently being manufactured.

TABLE I

Dielectric Constants

Sample	Temp °C	Freq KC	K
1	25	500	1.15
2	50	500	0.98
3	25	500	1.23
4	50	500	1.15

TABLE II

Twenty-Four Hour Water Absorption

Sample	Mold Lubricant	% Gain in Weight
1	Johnson's Wax	4.70
2	Dow-Corning DC-7 Grease	2.78
3	Dow-Corning DC-20 Grease	2.34
4	Polyethylene	1.73

TABLE III

Exotherm Temperatures

Time Elapsed After (minutes) Reaction Starts	Cold Mold °C	Mold @ 60°C
1	45	51
5	80	112
15	61	85
30	48	60
60	40	40

GENERAL TESTS

Coefficient of Linear Thermal Expansion:

Temperature Range	*Expansion Per °C*
0°C to 60°C	3.5×10^{-5} inches
25°C to 70°C	3.9×10^{-5} inches

Coefficient of Linear Thermal
Operating Temperature Range
for Urethane Foam
= −60°C to plus 150°C

Three transformers were encapsulated in "Lockfoam." One transformer was kept at a constant humidity of 94 per cent for eight weeks, the second was subjected to heat in the order of 135 degrees centigrade for eight weeks, and the third was kept at a temperature of −18 degrees centigrade for four weeks. Resistance measurements on the transformers were made once a week and the following values were recorded. (1) At 94% humidity the initial resistance was 2×10^5 megohms—after 8 weeks the resistance dropped to 30 megohms. (2) After exposure to 135°C for eight weeks, the resistance measurements decreased from an original value of 1.5×10^5 to 2.4×10^4. (3) At a temperature of −18°C for a period of four weeks, there was little effect on the initial value of 2.5×10^5 megohms.

CONCLUSION

The data accumulated show that urethane foam is a unique material which offers many advantages, particularly from the standpoint of light weight in combination with mechanical strength.

One-shot type foams offer materials which are, in most cases, superior in all around properties, to prepolymer type foams. The two exceptions to this superiority are the lower exotherms and easier handling of prepolymer type foams. The one-shot foams are much stronger mechanically, better electrically and can operate at much higher temperatures for longer periods than prepolymer type foams.

The most important fact to remember when foams are used is that unless the foam components are thoroughly and completely mixed, many of the advantages offered by urethane foams will be lost.

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FERRITE TRANSDUCERS FOR ELECTROMECHANICAL FILTERS

by
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One of the properties of a magnetic material is the change of its physical dimensions in the presence of a magnetic field. This effect is known as magnetostriction. If, for example, a d-c field is passed longitudinally through an elongated body of ferrite, there will be a minute change in the length of the ferrite. The length may increase or decrease depending upon the composition.

One very interesting application for this property of a ferrite is in an electromechanical filter. Such a filter, which can be an extremely selective band-pass device, consists of an input transducer, a section of mechanically coupled resonant elements tuned to a specific frequency, and an output transducer. In this device the ferrite rods or cores are used very effectively as the input and output transducers. Assume that a small ferrite rod having relatively high magnetostrictive characteristics is placed in a coil in such a manner that the rod is free to vibrate. Then a small permanent magnet is placed near the coil assembly to supply a biasing effect on the core. If the coil assembly is excited with an a-c signal, it is possible to tune the circuit with a capacitor so that the coil energy is absorbed by the core. The core is mechanically resonant and the energy of the coil is used to provide mechanical motion to the core.

Such a device is a transducer converting electrical energy to mechanical energy. A reversal of energy conversion can also take place. If the core is provided with mechanical motion, it will induce a current in the coil at the same frequency as the mechanical motion of the core.

COUPLING COEFFICIENT

In any magnetostrictive transducer, the efficiency of operation depends upon the magnetostrictive activity of the core or resonator material. One useful way to express this efficiency is by the coefficient of coupling between a given coil and the associated core. The coil with core in place may be represented by the equivalent circuit shown in Fig. 1. In this figure, L is the inductance of the coil with resonator in place, K is the coefficient of coupling, and C is the distributed capacitance of the coil plus any external capacitance necessary to resonate the coil. The anti-resonant frequency of the parallel branch of the circuit is the same as the natural frequency of the resonator; the Q of the parallel branch is the same as the mechanical Q of the resonator. The impedance of the parallel branch may be expressed as:

$$Zp = \frac{J\omega K^2 L}{1 - \omega^2 K^2 LC} \tag{1}$$

For the frequency where the circuit is series resonant, the total impedance Z will be equal to zero, neglecting the resistance of the coil.

Let ω_2 be the series resonant frequency; then

$$Z = J\omega_2 L + \frac{J\omega_2 K - L}{1 - \omega_2{}^2 K^2 LC} = 0 \tag{2}$$

$$1 + K^2\,(1 - \omega_2{}^2 LC) = 0 \tag{3}$$

$$\text{and } K^2 = \frac{1}{\omega_2{}^2 LC - 1} \tag{4}$$

Let ω_1 be the frequency at which the parallel branch of the circuit is at resonance (anti-resonance condition); therefore:

$$LC = \frac{1}{\omega_1{}^2 K^2} \tag{5}$$

Substituting the value of LC from equation (5) in equation (4),

$$K_2 = \frac{1}{\omega_2{}^2\left(\frac{1}{\omega_1{}^2 K^2}\right) - 1} \tag{6}$$

$$K^2 = \frac{\omega_2{}^2 - \omega_1{}^2}{\omega_1{}^2}$$

$$K = \sqrt{\frac{(\omega_2 + \omega_1)\,(\omega_2 - \omega_1)}{\omega_1{}^2}} \tag{7}$$

If it is assumed that $\omega_2 \approx \omega_1$ then

$$K = \sqrt{\frac{2\omega_1\,(\omega_2 - \omega_1)}{\omega_1{}^2}} = \sqrt{\frac{2\,(\omega_2 - \omega_1)}{\omega_1}} \tag{8}$$

$$K = \frac{1}{\sqrt{\frac{\omega_1}{2\,(\omega_2 - \omega_1)}}} = \frac{1}{\sqrt{\frac{f_1}{2\,(f_2 - f_1)}}} \tag{9}$$

The coefficient of coupling K, therefore, can be determined with equation 9 from f_2, the series resonant frequency of the circuit, and f_1 the natural resonant frequency of the core.

NATURAL RESONANT FREQUENCY AND VELOCITY OF PROPAGATION

The resonant frequency of the ferrite core is a function of the velocity of propagation of sound through the body, Young's modulus, the length of the

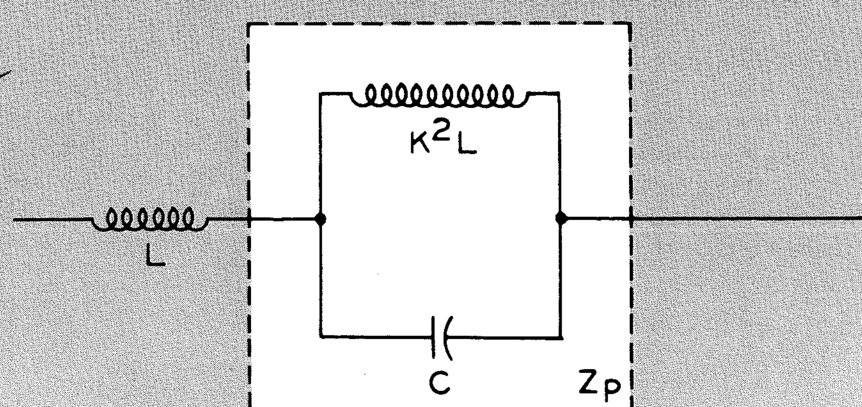


Fig. 1—Equivalent circuit for magnetostrictive resonator.

core, and the density of the core material. For rods vibrating in the longitudinal mode, this frequency is expressed by this relation:

$$f_1 = \frac{n}{2l}\left(\frac{E}{\rho}\right)^{1/2} \qquad (10)$$

where f_1 is the frequency in cycles per second, n is a small integer, (for the fundamental frequency, $n = 1$; for the second harmonic, $n = 2$, etc.) l is the length of the rod in meters, ρ is the density of the rod in kilograms per meter cubed; and E is Young's modulus in Newtons per meter squared. The expression $\left(\frac{E}{\rho}\right)^{1/2}$ is equal to the velocity of propagation in meters per second.

Because the rod is not affixed at either end, it is free to vibrate as a half-wave resonator. The velocity of propagation of sound through the ferrite medium, therefore, is given by:

$$v = f_1 \lambda \qquad (11)$$

Where v is the velocity of propagation, f_1 is the resonant frequency, and λ is the full-wave length $2l$ in meters.

$$\lambda = 2l \qquad (12)$$

TESTING PROCEDURES

The coefficient of coupling may be measured by means of the circuit arrangement shown in Fig. 2. The frequency of the signal generator is adjusted until the voltmeter reading is a minimum. This reading indicates the anti-resonant condition, that is, the impedance of the coil is a maximum and the current is a minimum. This frequency is recorded as f_1. The frequency of the signal generator is then increased until the voltmeter reading is a maximum. This reading indicates the series-resonant condition, that is, the impedance of the coil is a minimum and the current is a maximum. The frequency at this point is recorded as f_2. The coupling coefficient may then be calculated from equation 9.

The coefficient of coupling depends to some extent upon the coil design. Such factors as how close the winding is to the core, how long the coil is with respect to the core, and how the cores fit into the coil form affect the coefficient values.

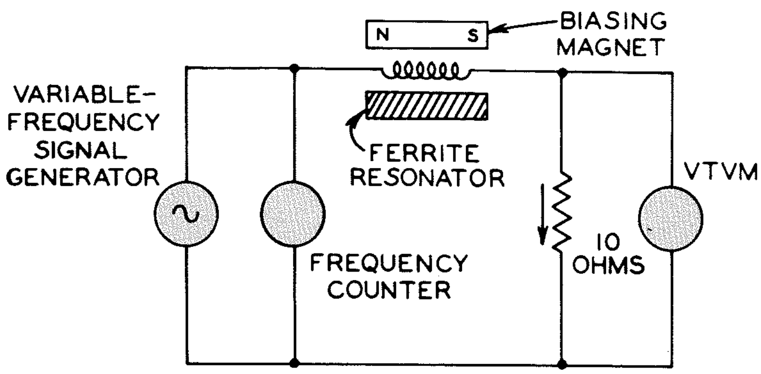


Fig. 2—Circuit arrangement for measurement of coefficient of coupling.

INITIAL PERMEABILITY

Another characteristic of importance is the initial permeability of the core material. Because of its relationship to the termination of a filter using ferrite transducers, the permeability of the ferrite must be controlled within very close limits. Since the ferrite is in the form of a rod instead of a ring, this property can be controlled by measuring the effective permeability in place of the actual ring permeability. The effective permeability is defined as the ratio of the inductance of the coil with core inserted to the inductance of the coil with an air core. This effective permeability (μ_{eff}) is measured with a Q-meter and may be expressed by:

$$\mu_{eff} = \frac{C_{\ (coil\ only)}}{C_{\ (coil\ with\ core\ inserted)}} \qquad (13)$$

The capacitance C indicated on the meter for both conditions is measured at the same frequency.

FREQUENCY STABILITY

Also of great importance is the frequency stability of the core with changes in temperature. This stability depends on the change of permeability of the ferrite resonator with temperature as well as the magneto-

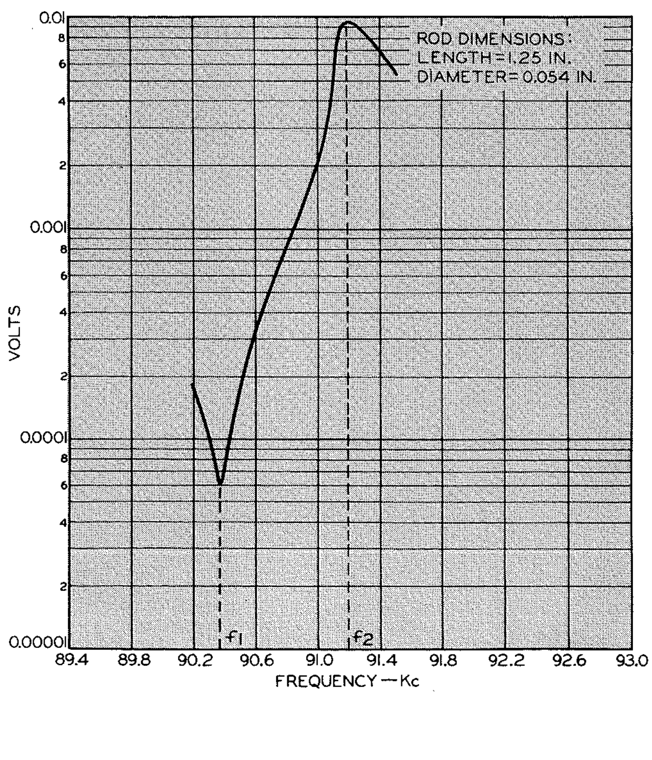


Fig. 3—Frequency response characteristic of a 200-kilocycle ferrite resonator.

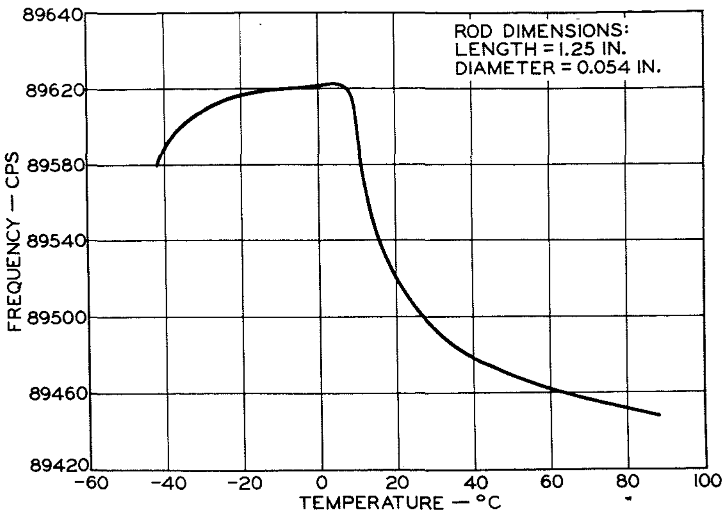


Fig. 4—Temperature stability characteristic of a 100-kilocycle ferrite resonator.

strictive quality. The exact extent of this change, expressed as a temperature coefficient, depends upon the composition and processing conditions. This temperature coefficient is most easily determined by measurement of the resonant frequency of the ferrite resonator at different temperatures. The coefficient is expressed as follows:

$$a = \frac{f(t_2) - f(t_1)}{(t_2 - t_1)\, f(t_1)} \times 10^6 \tag{14}$$

Where "a" is the temperature coefficient in (cycles/°C/mc), $f(t_1)$ is the resonant frequency at room temperature t_1, in degree centigrade and $f(t_2)$ is the frequency at any other temperature, elevated or reduced, t_2. The resonant frequency for determining the temperature coefficient is measured in the same way that the resonant frequencies for the coupling coefficient measurement are determined.

EXPERIMENTAL RESULTS

Fig. 3 shows a typical frequency-response curve of a ferrite resonator core. The ratio of the peak voltage to minimum voltage is about 150 or 200 to one. As previously stated, the anti-resonant frequency, f_1, of the parallel branch is the natural resonant frequency of the core. The series resonant frequency, f_2, is about 1000 cycles above frequency f_1. The greater the difference between f_1 and f_2, the greater the coefficient of coupling.

Five ferrite rods having different compositions or firing conditions, each 0.510 inch long and 0.037 inch in diameter are designed for operation in the vicinity of 200 kilocycles were tested for the parameters: coupling coefficient, resonant frequency, Young's modulus, velocity of propogation, effective permeability, and density. The results are given in Table I. With the addition of small amounts of impurities, the coefficient of coupling increases. This increase continues until somewhat over the 1% impurity point is reached, then it decreases. The value of Young's modulus increases with addition of impurities. The velocity of propagation decreases slightly with small additions of impurities, but further impurity additions cause an increase in velocity. The values of effective permeability increase with the addition of impurities regardless of the change in firing conditions. The density of the various samples shows tendencies toward a slight decrease with the addition of impurities.

Table II lists the various parameters for two 100-kilocycle ferrite rods produced under different conditions. There is a considerable difference in almost every parameter, but the two that stand out most are the values for the effective permeability and density.

The frequency vs. temperature characteristics of a 100-kilocycle transducer rod are given in Fig. 4. The temperature range studied was —40 to 85° C. It will be noted that the frequency increases with increase in temperature

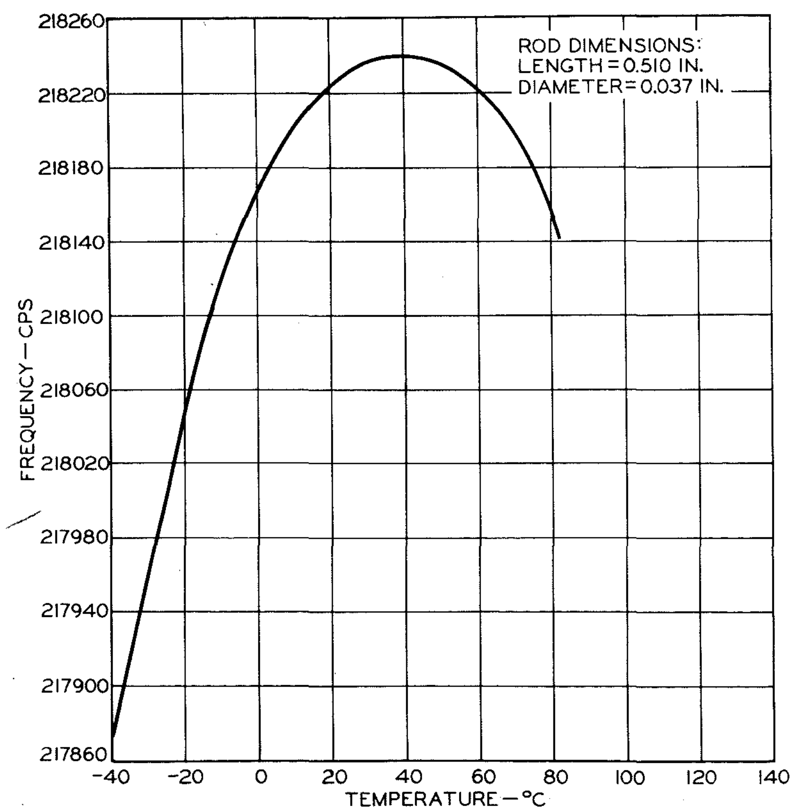


Fig. 5—Temperature stability characteristic of a 200-kilocycle ferrite resonator.

until a temperature of 4° C is reached. At this temperature, the frequency decreases quite rapidly and then shows a tendency towards leveling off. The coefficient is positive between —40 and 4° C and negative for temperatures above 4° C.

A similar frequency-temperature study, made for 200-kilocycle rods, is given in Fig. 5. The same general trend exists except that the curve rises faster and peaks at a higher temperature than does the curve for the 100-kilocycle rods. There is no indication of a tendency for frequency response to level off as it does for the 100-kilocycle rod.

Although the 100-and 200-kilocycle rods were made of the same compounded material extruded in the same manner, they have different characteristics due, undoubtedly, to differences in extrusion pressures for each size.

Another interesting feature of this magnetostrictive material is the effect of the biasing force on the coefficient of coupling. Fig. 6 shows the results of a typical core subjected to different biasing forces produced by changes in the position of a permanent magnet. With a very weak field, the coefficient of coupling is low. As the field is increased, the coefficient increases then levels off. A further increase in bias causes the coefficient to increase at a very rapid rate. The maximum value is limited only by the effective resistance of the circuit. With still further increase in the biasing force, the coefficient of coupling again drops off. Thus, it can be seen that there are bias limits within which the rod vibrates most efficiently. The extent of this range depends on the composition and processing conditions of the rod.

USE AS TRANSDUCER IN MECHANICAL FILTER

The best proof as to the effectiveness of these ferrites as transducers is how they perform in an actual filter. A complete filter was built using transducer elements having a coupling coefficient of 0.14 to 0.17, an effective permeability of 2.46 ± 3%, and a temperature coefficient of ± 35 cycles/°C/mc. Fig. 7A is a schematic diagram of the filter and Fig. 7B is a photograph. The filter was tuned by means of capacitors C_1 and C_3 for a 200-kilocycle center frequency. After

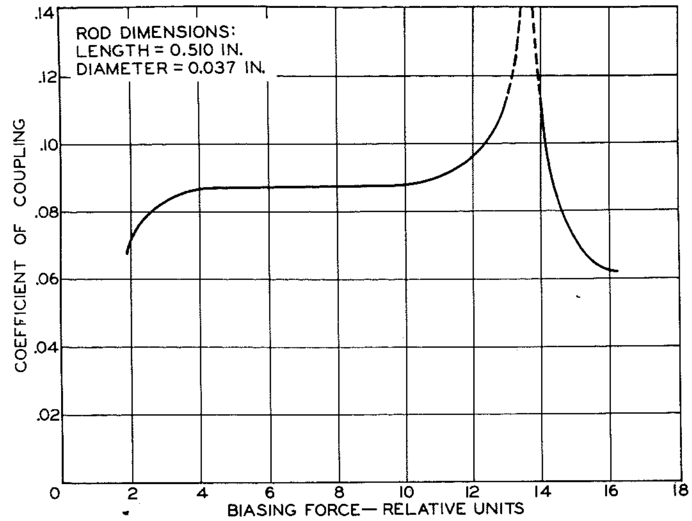
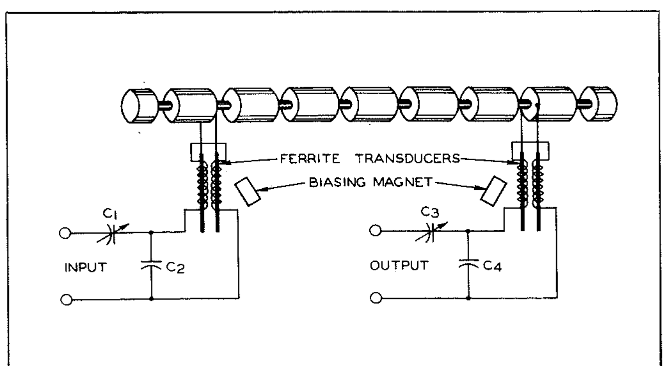


Fig. 6—Effect of change in biasing force on coefficient of coupling.

the tuning, the capacitor received no further adjustment for the remainder of the tests. Several response curves were taken at various temperatures. The filter was placed in an oven for elevated temperature tests and in a ventilated box with dry ice for the tests below room temperature. The frequency response of the filter is given in Fig. 8. The bandwidth, measured at the —6 db point, is a little over 3,000 cycles. The peak-to-valley variations is not more than 2 db over the passing range. The sides of the curve are quite steep as far down as —50 to —60 db.

Fig. 9 shows the temperature characteristics of this filter for temperatures ranging from —50 to +85 degrees C. The greatest peak-to-valley variation occurs at a temperature of 50° C; however, the value is not more

Fig. 7A—Schematic diagram of electromechanical filter using Ni-span filter elements and ferrite tranducers.



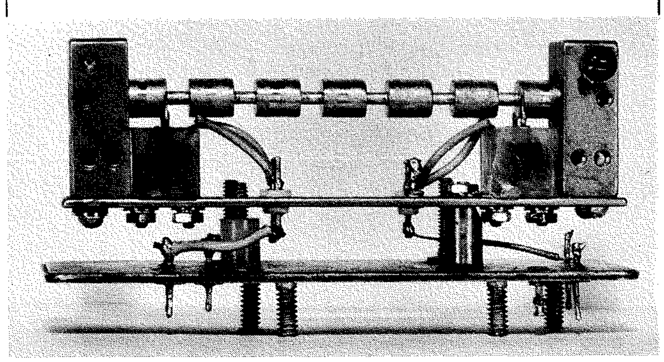


Fig. 7B—Photograph of developmental 200-kilocycle electromechanical chanical filter.

than 2 db. The bandwidth is approximately the same for all temperatures although the center frequency shifts to the lower end by a small amount.

ACKNOWLEDGEMENT

The author wishes to express his appreciation to Messrs. George Katz and R. E. Hurley who made the magnetostrictive ferrites; to R. D. Hunter who conducted the tests on the rods and filter; and to L. Dimmick who built and supplied the filter.

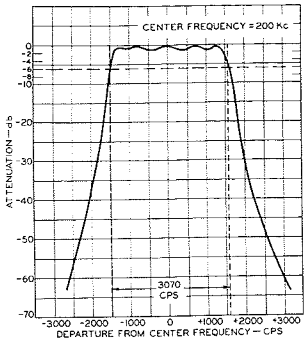


Fig. 8—Frequency response characteristic of 200-kilocycle electromechanical filter.

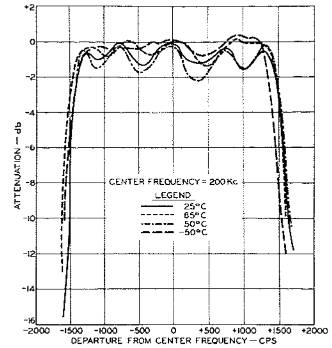


Fig. 9—Temperature stability characteristic of 200-kilocycle electromechanical filter.

TABLE I

Ferrite Rods for 200 kc. Electromechanical Transducer

Composition	Coef. of Coupling K	Resonant Frequency f_1 (cps)	Young's Modulus E (Newtons/m²)	Velocity of Propagation v (m/s)	Eff. Perm. μ eff.	Density ρ kg/m³
Ni Ferrite	.1253	219899	1.65×10^{11}	5,740	2.45	5.30×10^3
Ni Ferrite with ⅓% impurity added	.1450	217903	1.681×10^{11}	5,680	2.74	5.21×10^3
Ni Ferrite with ⅓% impurity added. Fired under different conditions than above	.1495	218052	1.692×10^{11}	5,690	2.66	5.23×10^3
Ni Ferrite with 1% impurity added	.1593	220358	1.718×10^{11}	5,750	2.82	5.19×10^3
Ni Ferrite with 2% impurity added	.1389	222941	1.765×10^{11}	5,820	3.02	5.21×10^3

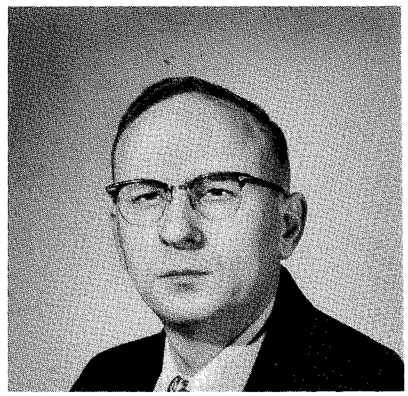
Parameters for different ferrite rods 0.510 inch long and 0.037 inch in diameter designed for operation at approximately 200 kilocycles.

TABLE II

Ferrite Rods for 100 kc. Electromechanical Transducer

Composition	Coef. of Coupling K	Resonant Frequency f_1 (cps)	Young's Modulus E (Newtons/m²)	Velocity of Propagation v (m/s)	Eff. Perm. μ eff.	Density ρ kg/m³
1. Ni Ferrite ..	.1445	90406	1.700×10^{11}	5,760	7.66	5.12×10^3
2. Ni Ferrite ..	.1288	91381	1.815×10^{11}	5,800	4.60	5.39×10^3

Parameters for two 100-kilocycle ferrite rods 1.25 inch long and 0.054 inch in diameter produced under different conditions.



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From 1943 to 1946 he served as an aircraft maintenance officer in the Armed Forces. From 1946 to 1948, Mr. Hipskind was associated with G.E.'s Fort Wayne works in the fractional horsepower motor developmental test section. He joined RCA in 1950, and is presently associated with Ferrite Engineering in the Television Division.

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UNUSUAL ELECTRON-TUBE EFFECTS OF CONCERN TO CIRCUIT DESIGNERS

By

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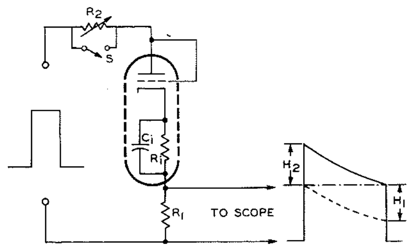


Fig. 1—Effect of cathode interface layer on current.

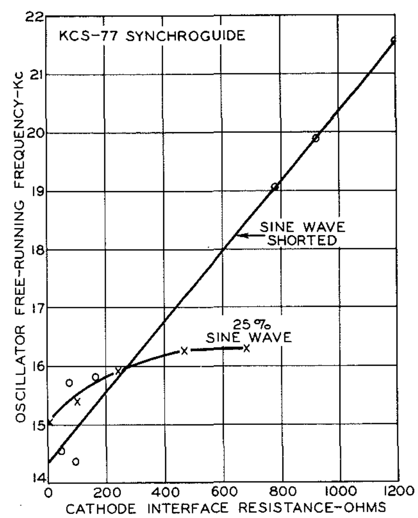


Fig. 2—Free-running frequency as a function of interface resistance for "Synchroguide" type of oscillator circuit.

DESIGNERS OF ELECTRONIC equipment usually consider the electron tube as simply another circuit component. Tube characteristics are defined by curves and tabulated data supplied by the manufacturer. In general, tube performance can be calculated with reasonable accuracy from the published characteristics.

At some time or other, however, many circuit designers experience the feeling that electron tubes are part gremlin. This feeling is caused by some of the peculiar effects noted in certain circuits. These effects are not mentioned in data supplied by tube manufacturers, nor described in textbooks on tubes or circuits.

Equipment designers and manufacturers have reported these peculiar effects to tube manufacturers at various times. In many cases, investigations by tube manufacturers have determined their causes. In some cases, changes in tube construction, design or processing eliminate the effects. In other cases, however, no way can be found to change the tube characteristic causing the effect. Thus, circuit changes are necessitated.

This paper discusses the causes of unusual circuit problems in the hope that they may be eliminated in future circuit designs. It also describes some of the problems which face electron-tube manufacturers in making tubes at a reasonable cost to satisfy an endless variety of applications. Continued cooperation between equipment designers and electron-tube manufacturer should tend to alleviate these problems and result in production of equipment with better performance and greater reliability.

"SLEEPING SICKNESS"

Perhaps the most attention by tube manufacturers and circuit designers in the last few years has been given to an effect termed "sleeping sickness." This effect has been most serious in computer circuits, where a tube may operate for long periods with plate current cut off. In many cases, when a problem is put to the computer which requires the tube to pass a pulse of current, nothing happens. The tube just will not conduct.

The "sleeping sickness" effect is caused by the formation of a resistance layer, known as cathode interface layer, between the cathode base metal and the cathode coating. This very thin layer acts as a dielectric for a capacitor in which the cathode base metal is one plate and the cathode coating is the other. This capacitor has a capacitance of the order of 0.01 microfarad and is shunted by the resistance of the interface layer.

The effect of the cathode interface layer is shown in Fig. 1. When a rectangular pulse is applied to the tube, the capacitance C_i acts as a direct short across the interface resistance R_i for an instant. The initial plate current of the tube, therefore, is determined solely by the magnitude of the applied pulse, and by the perveance of the tube. During the flat portion of the pulse, however, the capacitance

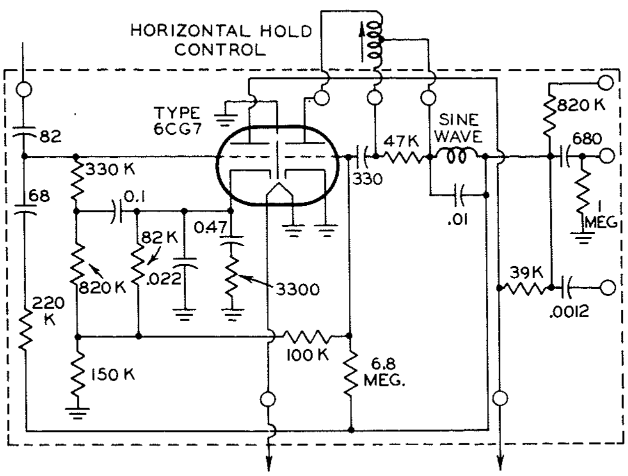


Fig. 3—Circuit compensation used to improve frequency stability.

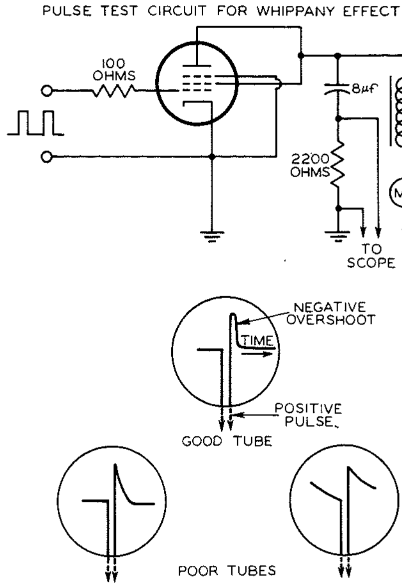


Fig. 4—Pulse test method for "blackout", and typical oscilloscope displays.

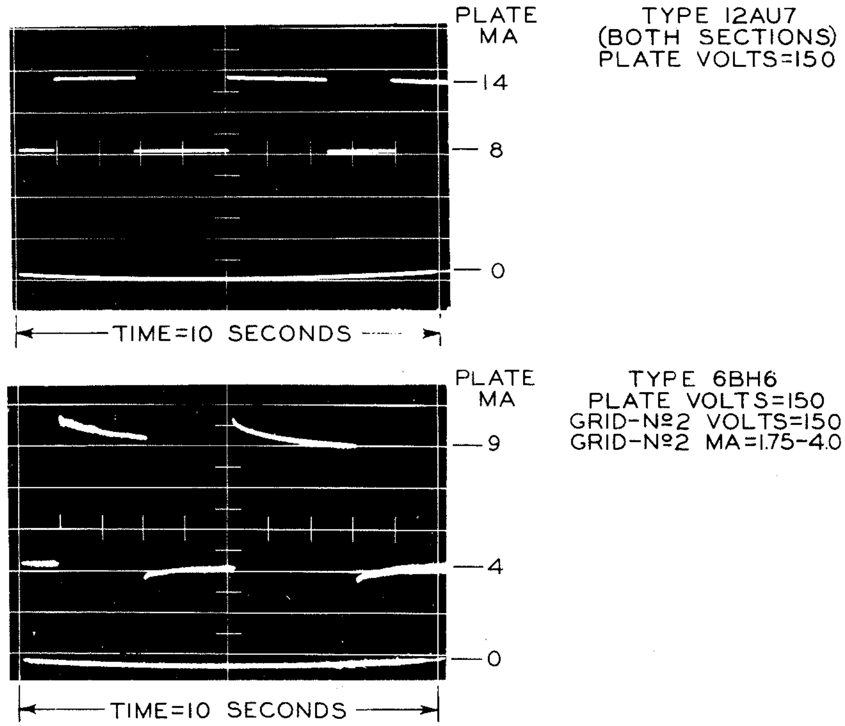


Fig. 5—Plate current of good tube (12AU7) and tube having "d-c shift" effect (6BH6) when very-low-frequency square-wave signal is used.

charges up and the current begins to decay exponentially toward a value determined by the interface resistance.

Although the interface resistance is normally close to zero in a new tube, it can increase to several hundred or even a few thousand ohms after many hours of life with plate current cut off. The magnitude of the interface resistance can be determined by the use of a calibrated variable resistor, R_2, in series with the pulse supply. The height of the trailing edge of the output pulse, H_1, is first measured with R_2 set at zero. The value of R_2 is then increased until the leading edge of the output pulse, H_2, has the same amplitude that the trailing edge had when R_2 was at zero. This vaue of R_2 is equal to the interface resistance.

CATHODE-INTERFACE PROBLEM

What is the cause of the formation of cathode interface? It is the direct result of the efforts of tube manufacturers to make tubes having a high value of emission at a reasonable cost. While tubes are being evacuated the carbonate mixture which forms the cathode coating is broken down into oxides. Subsequently, during "aging" of the tubes, the oxides are broken down to form a surface layer of pure barium. A reducing agent is required at this step to assure that the oxides produce pure barium without liberating oxygen. This reducing agent consists of minute impurities (less than 1 percent) added to the cathode base metal.

The impurity used as a reducing agent in most cathodes is silicon. Silicon forms the compound barium orthosilicate as an interface layer during periods when the barium is not being used to supply electrons for emission. In tubes designed especially for applications where "heater-only" or "plate-current cut off" operation will be used, cathode material having an extremely low silicon content is used to limit the formation of an interface layer. These tubes can operate for thousands of hours with negligible interface development. However, because the amount of reducing material available is small, factory processing of such tubes is much more difficult than that of tubes using cathodes with a higher silicon content.

In applications requiring long periods of standby operation, either biased to cutoff or with only heater voltage applied, it is advisable to use tubes designed for computer service. It is recommended that some small amount of plate current be maintained at all times to delay formation of interface.

INTERFACE IN ENTERTAINMENT TUBES

In many cases, it has also been found desirable to use low-silicon cathode material in receiving tubes designed for home-entertainment uses. For example, low-silicon cathodes are used in the RCA-6SN7-GTB medium-mu twin triode, a horizontal deflection oscillator for tv receivers. Most horizontal oscillator circuits tend to exhibit frequency drift, and thus loss of "sync," if the oscillator tube develops interface.

Fig. 2 shows the free-running frequency as a function of interface resistance for the "Synchroguide" type of oscillator circuit used in many tv receivers. A similar curve can be obtained with the stabilized multivibrator type of horizontal oscillator. The upper curve (sine wave shorted) shows the frequency drift when no attempt is made to compensate for tube variations. The second curve indicates the improvement in frequency stability achieved by circuit compensation. The compensation used in the "Synchroguide" circuit is shown in Fig. 3. The sine-wave stabilization coil, or ringing coil, tends to pull the oscillator frequency back to its proper value when changes in the tube or other components tend to change the frequency.

Although sine-wave stabilization in "Synchroguide" circuits reduced frequency drift considerably, performance was still not considered satisfactory. Therefore, the cathode base metal of the 6SN7-GTB oscillator tube

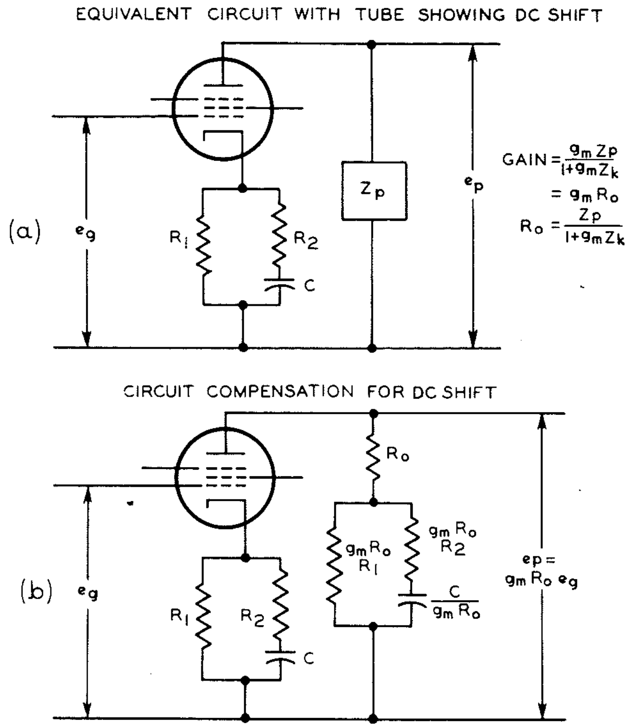


Fig. 6—(a) Equivalent circuit of tube having "d-c shift" in amplifier circuit. (b) Circuit compensation for "d-c shift." (Illustration by courtesy of Dr. Nergaard, RCA Labs, Princeton, N. J.)

was modified to a lower silicon content. Since this change was made, field troubles due to cathode interface have been non-existent, even after several thousand hours of operation.

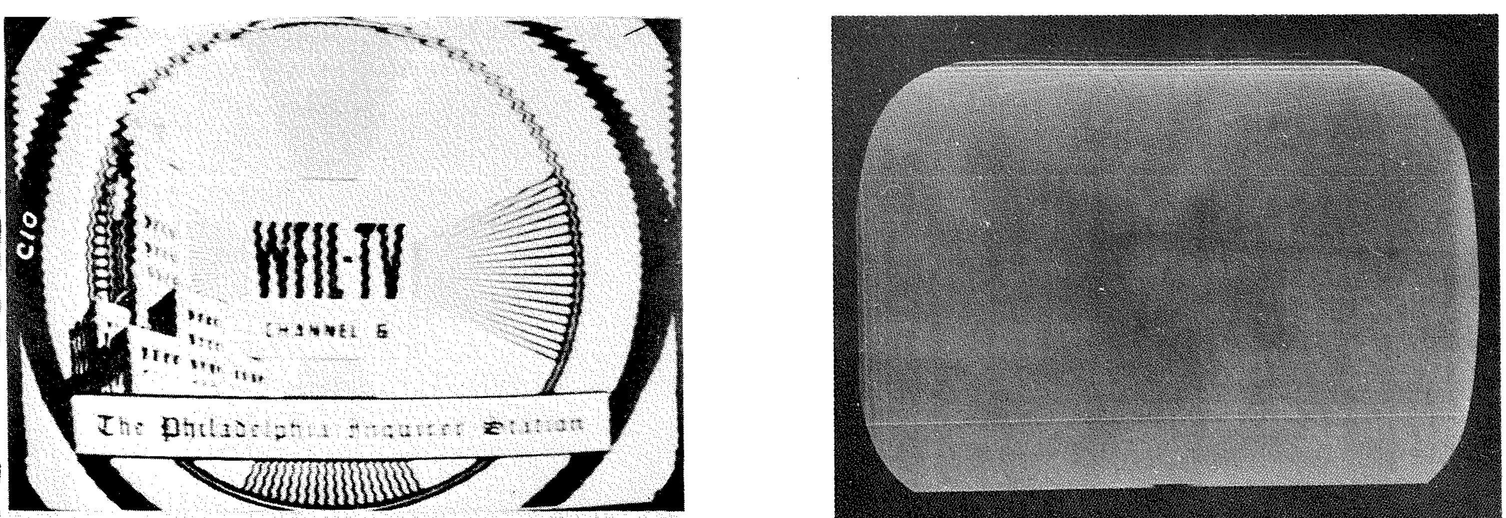
"BLACKOUT"

Another effect, in many respects related to cathode interface, has been called "blackout," or "Whippany Effect." This was first noted early in World War II, when the transmitted pulse of a radar equipment would get back into the radar receiver and the receiver would go completely dead.

"Blackout" shows up only when the control grid is driven positive. During the manufacture of a tube, a semi-insulating layer is deposited on the surface of the control grid wires. This layer acts as the dielectric of a capacitor in which one plate is the grid wire, and the other is the layer of electrons collected on the semi-insulating surface (with grid driven positive). The tube then develops its own bias inter-

Fig. 7—(a) "Cogwheel" effect produced by bulb or mica charge in horizontal deflection amplifier tubes. (b) "White line" produced by bulb or mica charge in vertical deflection amplifier tubes.

(a) (b)



nally, as in the familiar grid-leak or grid-resistor method of biasing an oscillator or class C amplifier.

Fig. 4 shows one method for determining whether a tube has "blackout." In this method, the plate voltage of the tube under test is first adjusted for some given level of plate current, and a positive pulse of sufficient magnitude to drive the grid into appreciable grid current is then applied to the control grid. If the tube has no "blackout" effect, plate current will probably rise slightly. However, if "blackout" is present, plate current will drop sharply. This change in plate current can be observed on an oscilloscope or a d-c milliameter. Oscilloscope displays obtained with a tube having no "blackout" and with two tubes having different degrees of "blackout" are shown in Fig. 4.

The resistance layer on the control grid has a negative temperature coefficient; consequently the blackout effect will usually disappear in about five minutes. The negative temperature characteristics of the resistance can produce some very annoying effects. For example, in the multivibrator type of horizontal oscillator circuit, it may be impossible to hold the oscillator in sync for several minutes after the tv set is turned on. Because resistance varies as the tube heats up, the horizontal frequency also changes and the picture drifts in the horizontal direction for several minutes every time the set is turned on. Similarly, frequency drift or detuning can occur in a local oscillator or class C amplifier stage, because of this effect.

Tube manufacturers have not as yet developed a process for preventing this effect, nor for eliminating it once it has developed. Fortunately, however, normal processing techniques produce tubes which are generally free from this effect, and most applications do not drive the control grid positive.

"D-C SHIFT"

Another effect, similar in many respects to cathode interface and "blackout," is known as "d-c shift." In amplifiers using tubes with "d-c shift," the amplifier gain is less for d-c signals than for a-c signals. In oscilloscope amplifiers, therefore, the usual a-c calibration signal is not reliable if the oscilloscope is to be used for d-c measurements.

The "d-c shift" effect can be demonstrated dramatically by the use of a very-low-frequency square-wave signal (Fig. 5). If the tube has no "d-c shift," plate current remains at a constant level during the flat portion of the pulse. If the tube has "d-c shift," however, the plate current drifts about 5 to 10 percent over a period of about 2 seconds.

The "d-c shift" problem, investigated by RCA in the tube laboratories at Harrison and Princeton, has been found to be inherent in tubes with close spacings. It is caused by the resistance of the cathode coating itself and can only be eliminated by development of a new cathode material. This resistance differs from cathode interface in that it has a time constant of the order of 1 or 2 seconds, instead of a few microseconds.

Fig. 6 (a) shows the equivalent circuit of a tube displaying d-c shift in an amplifier circuit. If the average plate-current level is maintained constant in a particular application, and departures from average are not too great, it may be possible to correct for most of the effect by a relatively simple compensating circuit such as that shown in Fig 6 (b).

BULB OR MICA CHARGE

TV receiver deflection circuits also produce many peculiar effects. Some of the most mysterious are caused by bulb or mica charge, resulting in jitter of portions of the picture. In horizontal deflection tubes, such charge may produce streaks or jitter of the entire raster, and in the extreme case an effect called "cogwheel" or "pie crust." Fig. 7 (a) shows an unusually severe case of "cogwheel"; usually the effect is barely visible. In the vertical circuit, mica charge produces an effect known as "white line" or "bright line," as shown in Fig. 7 (b), or it can also produce a "black-line."

Bulb charge can be minimized with carbonized bulbs and by a tube structure designed so that electrons cannot strike the bulb. Carbonized bulbs are rarely used, because loose carbon particles inside the tube can be more troublesome than the bulb-charge effect. Troubles due to mica charge are minimized by mica designs incorporating slots which interrupt leakage paths, and by use of a high-resistance material such as alundum on mica surfaces. Equipment designers can help to reduce problems caused by bulb or mica charge by designing deflection circuits so that the peak voltages of the tubes are well within ratings.

"SPOOK" INTERFERENCE

"Spook" interference is another pecul-

Fig. 8—Typical appearance of "spook" interference.

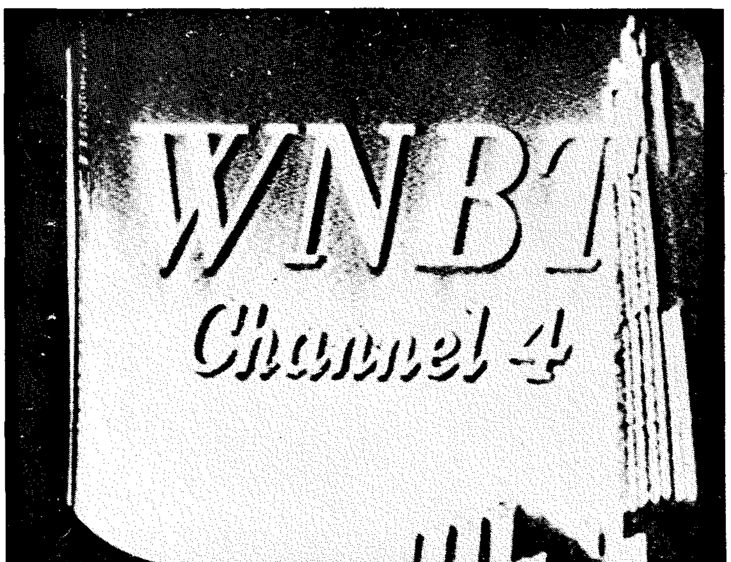
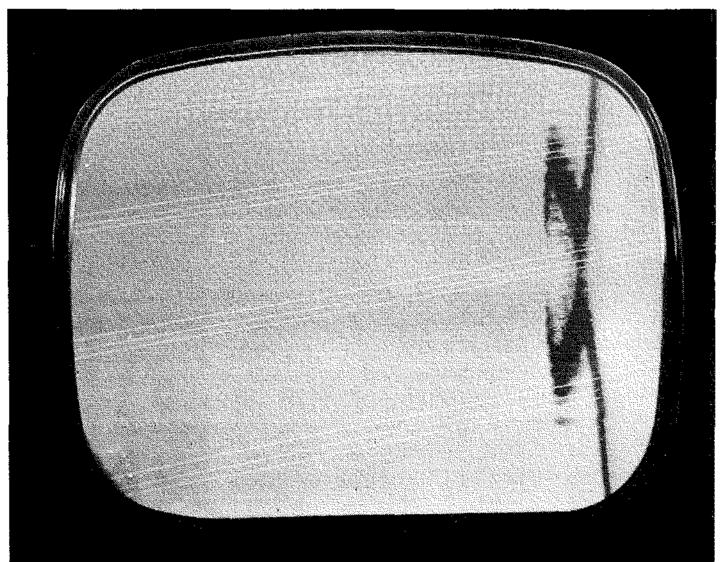


Fig. 9—An example of "snivets" interference in horizontal deflection circuits.



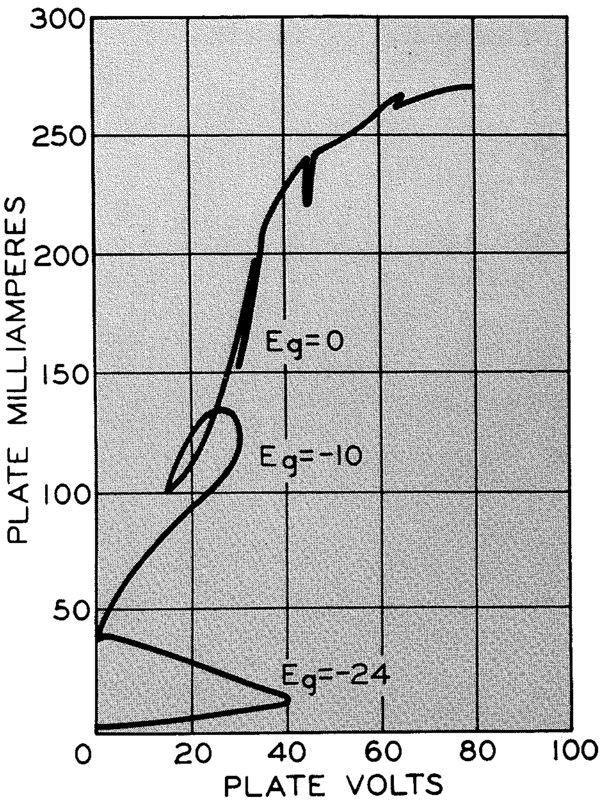


Fig. 10—Plate-current, plate-voltage characteristic of a horizontal deflection tube at zero bias.

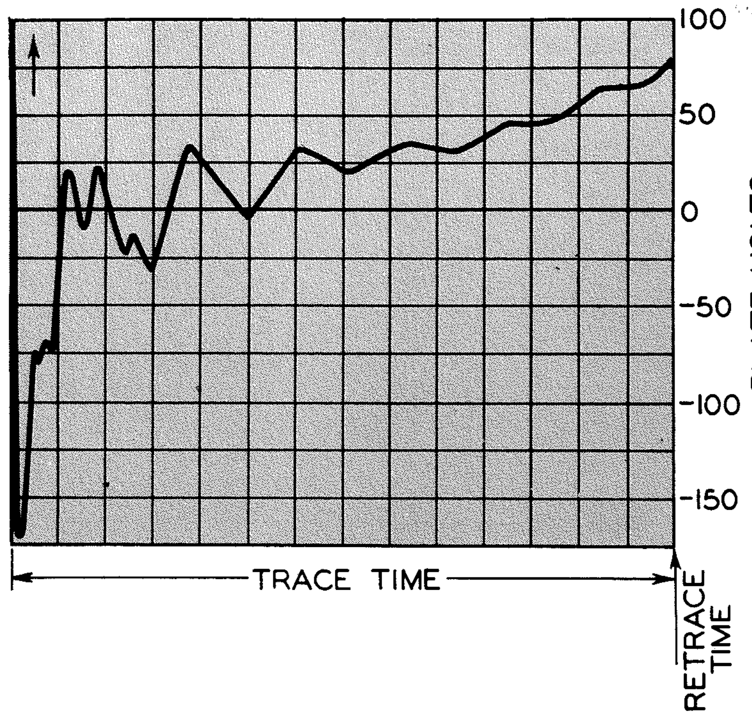


Fig. 11 — Load line of a typical horizontal deflection tube (RCA-25CD6-G) in a television receiver which exhibited "snivets."

iar effect associated with the horizontal deflection circuit (see Fig. 8). The name stems from the seemingly mysterious nature and because its cause eluded explanation for so long. The interference appears as a vertical line or band at the extreme left edge of the raster. In cany cases, it may not be visible at all, because of overscan of the raster or because it is in the blanked region. Sometimes "spook" interference is picked up from a neighboring receiver and may go flitting mysteriously back and forth across the screen; service technicians have referred to this behavior as "windshield wiper" effect.

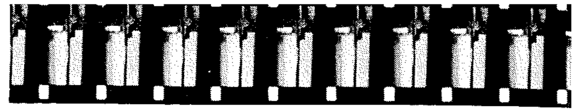
"Spook" interference is generated by the damper tube. The plate current of this tube rises from zero to several hundred milliamperes in a very short time, about 0.1 microsecond. This rapidly increasing waveform produces many higher-order harmonics of the horizontal scanning frequency which lie within the television frequency band. In addition to producing the vertical line at the left edge of the raster, these harmonics often get into the sync circuits and cause picture instability.

It is impossible to eliminate the harmonics produced by the rise of current in the damper tube. However, if r-f chokes are placed in the damper leads at the tube socket, interference is limited to that radiated by the tube itself. In some cases, it may also be necessary to put a shield around the damper tube to eliminate radiation from the tube structure.

"SNIVETS" INTERFERENCE

A very familiar kind of interference from the horizontal deflection circuit is the "snivets" type, shown in Fig. 9. One possible cause of "snivets" interference is illustrated in Fig. 10 which shows the plate-current, plate-voltage characteristic of a deflection tube at zero bias. When the plate current rises from zero to very high values, it follows a smooth curve. However, when it decreases from very high values toward zero, there is a discontinuity in the curve. This sudden change in plate current produces harmonics which can be picked up by the r-f amplifier and produce interference.

Another theory holds that "snivets" interference is caused by a form of Barkhausen oscillation. This theory is logical because the plate voltage swings appreciably below the screen grid (grid No. 2) voltage in many receivers. This condition is especially severe in modern "flyback" transformer designs which drive the plate voltage as far into the "knee" region as possible. An examination of the load line of a horizontal deflection tube illustrates this phenomenon quite well. The most familiar load line to most engineers is that drawn for resistance-coupled amplifiers, which is simply a straight line. If the load is reactive, the load line then becomes an ellipse. In contrast to these conventional load lines, Fig. 11 shows the load line of a typical deflection tube (RCA-25CD6G) in a television receiver which exhibited very strong "snivets." Is it any wonder that interference resulted?



THE HIGH-SPEED MOTION-PICTURE CAMERA AS AN ENGINEERING DIAGNOSTIC TOOL

by

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Equipment Development
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PRODUCTION MACHINERY presents many provocative problems to the design engineer. He frequently finds himself assigned, for example, the job of redesigning an existing machine with a view towards improving certain motions, lessening maintenance and "down" time, increasing its rate of production, or improving the quality of the product. Such an assignment often necessitates an exhaustive analysis of the machine involved, after which the engineer may still have to "feel" his way in arriving at correct decisions.

THE HIGH-SPEED CAMERA

Until recently, the machine-design engineer seeking the solution for a particular problem had depended primarily on the familiar but laborious diagnostic procedures of kinematic, kinetic, and dynamic analysis. He now has at his disposal, however, a new and amazingly useful tool which enables him very quickly to detect and diagnose ailments common to many machines as well as many which have hitherto been obscure. This tool is the high-speed motion-picture camera. It slows down high-speed motion (which normally is seen merely as an indistinct blur) to a slow crawl in which the behavior of a particular mechanism or part during an entire operation or at any instant is clearly visible. Equally important, it allows the slowed-down operation to be viewed simultaneously by a great many observers.

It enables the engineer to study dynamic forces in action; to observe the effects of inertia of masses of machinery, and, for example, the effects of improperly designed cams in generating motions. Intelligent appraisal of the information provided by the high-speed camera can lead the engineer toward solutions he might never have visualized without the aid of this new engineering tool.

The high-speed motion-picture camera thus aids machine-design engineers in the same way that a televised operation aids groups of prospective surgeons, and has the added advantages that it not only slows down motion and provides unlimited repeatability, but also can greatly magnify the area under observation.

This new tool has proved extremely valuable in the electron-tube industry, where a great variety of high-speed automatic and semi-automatic machines are employed for the fabrication and assembly of delicate and complex tube components.

The RCA Electron Tube Division in Harrison, New Jersey, has had particular success with a model which takes pictures at speeds up to 3200 frames per *second*. This figure represents a time magnification of 200 when the film is projected at the normal rate of 16 frames per second.

What does a time magnification of 200 mean? It means that an action which actually takes place in one second will appear to take place over a period of 3 minutes and 20 seconds. It means that the behavior of a jet plane crashing the sound barrier can be seen as clearly as if the plane were traveling at a speed of approximately 3 miles per hour. It means that a shaft turning at a speed of 400 RPM appears to make one revolution in approximately 30 seconds.

The camera (shown in Fig. 1) is a 16-mm unit operating on 115 volts a-c or d-c. It takes a 100-foot roll of film containing 4000 frames, and is provided with a rheostat speed control. A variety of lenses are available for this camera, including a 120-mm, f:2.7 lens which provides tremendous magnification.

At a speed of 3000 frames per second the entire reel flicks past the gate in approximately $1\frac{1}{2}$ seconds. Although an automatic shut-off switch stops the camera motor instantly when the film ends, the last 3 or 4 feet of film are literally shattered.

When the camera is set for a speed of 3000 frames per second, the film reaches 80% of this speed within one-third second (approximately 25 feet), and accelerates to full speed gradually over the remainder of the run. Since

KODAK HIGH SPEED CAMERA
750 TO 3200 F.P.S.

Subject	Frames /Sec.	f Stop	Lens	Lights	Distance (L. to S.)
#1 Stem Machine	1000	5.6	102mm.	3000W.	12"
#2 Spade Winder	3000	3.5	63mm.	3000W.	12"
#3 Automatic Welded Grid Machine	1700	5.6	102mm.	3000W.	16"
#4 Lead Tinning Machine	2000	3	63mm.	3000W.	24"
#5 Heater Spacer Coil Winder	1200	4.5	102mm.	3000W.	12"

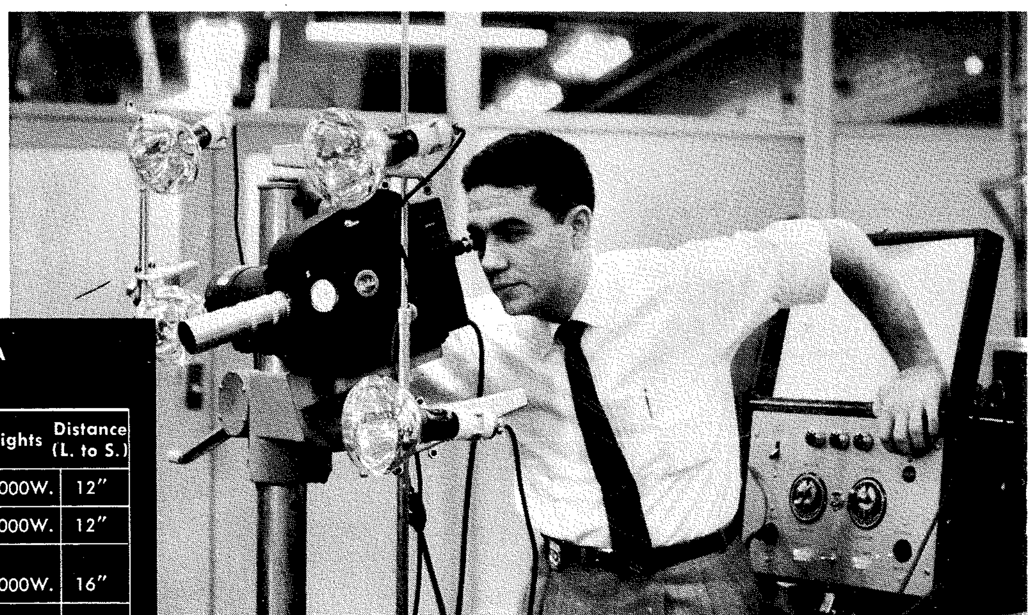


Fig. 1—The high-speed motion picture camera in use. The auxiliary timer-synchronizer unit designed by RCA is shown behind the operator, Frank Marmorato, Equipment Development Machine designer.

DON COLASANTO received his education at New York University and the City College of New York. He joined the Electron Tube Division of RCA in Harrison, N. J. in 1952 as a mechanical engineer in the Equipment Development activity. Since September 1956 he has been Manager of Mechanical Design in the same activity.

the first 25 feet of film passes through the gate much more slowly than the remainder, the beginning of the film will be overexposed. The camera is, however, provided with a built-in synchronization switch which can be used to control external lighting so that actual photography does not begin until the film has reached a predetermined speed.

The camera also contains a timing lamp which flashes at intervals of 1/120 of a second when the camera is operated on 60-cps a-c, and provides visible markers along the edge of the film strip. At a speed of 3000 frames per second, therefore, these markers are exactly 25 frames apart.

TIMER-SYNCHRONIZER UNIT

To eliminate guesswork and human error in the use of the camera, the Equipment-Development Activity at the Harrison plant developed a special timer-synchronizer unit which automatically triggers the camera at the proper moment in the machine operating cycle. This unit is shown behind the operator in Fig. 1. The camera is plugged into this timer-synchronizer unit and is not touched by the operator until the film has been run.

The timer is triggered by a Microswitch which is installed by the photographer in the machine so that it is actuated at the desired point in the operating cycle. When the Microswitch is tripped, the timer assumes full command. It turns on a cluster of four 750-watt photo-flood lamps, waits for the light to attain full intensity, then starts the camera. When the roll of film has been run, the camera is automatically shut off, the lights go out, and the operation is over.

APPLICATION

An important consideration in the use of the high-speed camera is determination of the film speed which will best provide the desired information when the film is projected. Although high speed is desirable to record as many details as possible of the operation under study, excessive speed may make it difficult to isolate visually the action of maximum interest.

The following formula is used to determine the optimum frame frequency:

$$\frac{40 \times \text{speed of the subject in inches per second}}{\text{Total width of lens field in inches}}$$

The denominator is obtainable from a table for a lens of a given focal length.

Example:

Speed of subject = 100 feet per second = 1200 inches per second

Width of lens field = 15 inches

$$\text{Frame frequency} = \frac{40(1200)}{15} =$$

3200 frames per second.

With proper techniques, velocities and accelerations can be accurately measured. For example, a proportional correlation between the distance traveled by the object in motion and the number of frames required to photograph that motion can be obtained by photographing the object against a suitable scale. The picture frequency may be determined by use of the built-in timing lamp.

EXAMPLES OF USE

A number of studies using the high-speed camera have been made by the Harrison Equipment-Development Activity. The most dramatic of these studies from the viewpoint of the engineer seeking to solve a particular problem were the following:

#1—STEM MACHINE

A stem machine (machine which performs a series of operations necessary to form the stem of an electron tube) was subjected to a kinematic analysis with a view towards increasing its

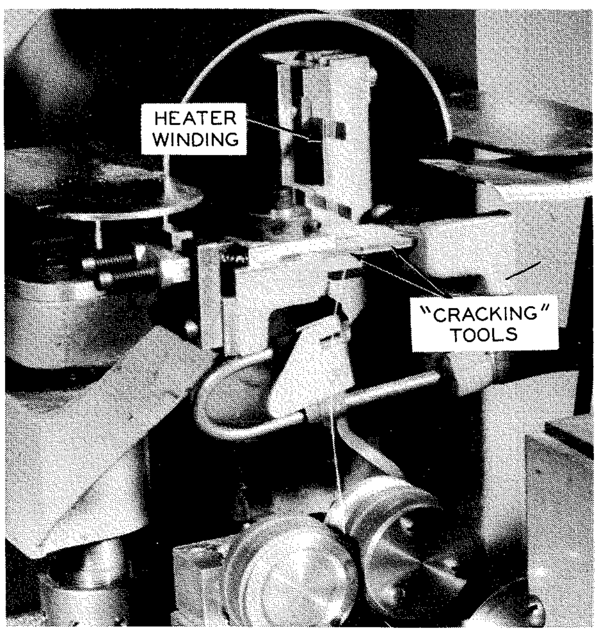


Fig. 2(a)—"Spade" winder mechanism at the start of the winding operation.

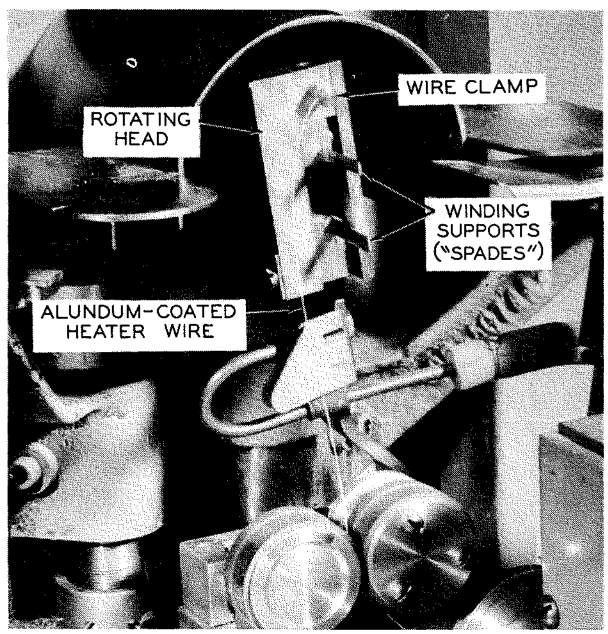


Fig. 2(b)—"Spade" winder mechanism at the end of the winding operation, showing head containing "cracking" and cutoff tools in operating position.

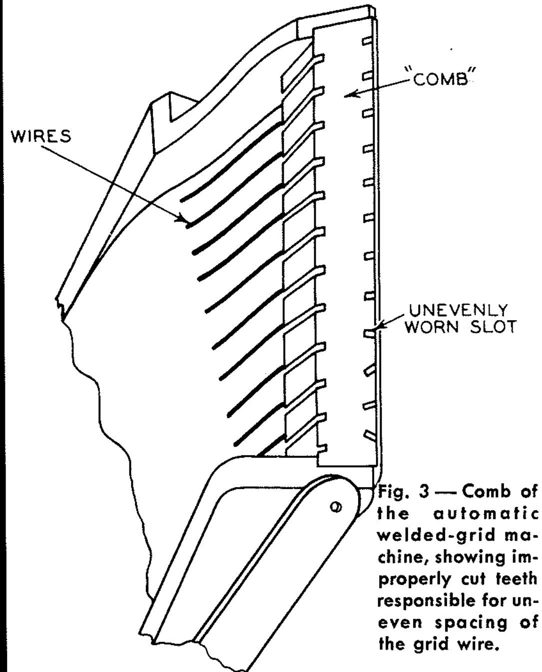


Fig. 3 — Comb of the automatic welded-grid machine, showing improperly cut teeth responsible for uneven spacing of the grid wire.

rate of production by increasing its indexing speed. In order to determine the performance during the indexing operation a carpenter's flexible-steel tape was attached to the periphery of the horizontal steel turret so that it would appear in the film. The film showed that the turret decelerated properly up to a point near the end of the indexing cycle. At that time, it was evident, the turret actually stopped, then moved forward slightly, stopped again, and then bounced back about 1/16 inch.

Obviously, the design of the commercial roller-gear indexing unit was faulty in that the rollers in the drive mechanism lost contact with the indexing cam near the end of the cycle. As a result of these findings, the manufacturer of the roller-gear drive was informed of the erratic action.

#2—"SPADE-WINDER" MACHINE

A "spade winder" is a machine used to form cathode heaters of the "folded" type to the desired configurations. Its name is derived from the flat blades or "spades" around which the alundum-coated heater wire is wound during the forming operation. (see Fig. 2a). The free end of the wire is gripped by a clamp set into the head containing the "spades." The head revolves, pulling the wire around the spades until the required number of turns have been formed. As the head stops, an arm carrying "cracking" and cutoff tools swings into the position shown in Fig. 2b. These tools then strike the ends of the wire, removing the alundum coating for the desired distance and cutting the ends to the desired length. The action of these tools is much too fast for the eye to follow.

Irregularity in the operation of the spade-winder led to a decision to undertake a redesign. In order to obtain the necessary information a series of high-speed films was made. These films showed:

(a) excessive slack in the wire during the first revolution.
(b) sidewise vibration of "spades" supporting the winding
(c) uneven stopping of the head
(d) breakoff of alundum chips at the apices of the folds, and the paths followed by these chips.

The excessive slack showed that the wire-tensioning device was not properly designed for the speeds at which the spade winder was required to operate. The vibration of the winding-support blades was caused by lack of rigidity in the head. The operating cam design required redesign to provide smoother movement and stopping of the head.

#3—THE WELDED-GRID MACHINE

The automatic welded-grid machine is used to produce parallel-wire grids for electron tubes. The required number of lateral wires are drawn through a "comb" (see Fig. 3) and welded to two side rods. During the drawing operation a retractable mandrel is inserted between the side rods to give the lateral wires an elliptical contour. Uneven spacing of the lateral grid wires prompted an investigation, leading to the taking of high-speed motion pictures. From the films, two reasons for the difficulty were immediately apparent:

1. Some of the slots in the comb through which the lateral wires are threaded before welding to the side rods were improperly cut or unevenly spaced, causing the wires to be improperly spaced in relation to each other;
2. When the mandrel withdrew after the lateral wires were welded to the side rods, it dragged some of the lateral wires with it, deforming them slightly and changing their spacing. (Fig. 4)

The problem of uneven spacing was solved by fabrication of a new comb. The problem of the mandrel is undergoing further study.

#4—TRANSISTOR-LEAD-WIRE TINNING MACHINE

A machine for tinning the lead-wires of transistors simulates the manual operation in which the lead wires are

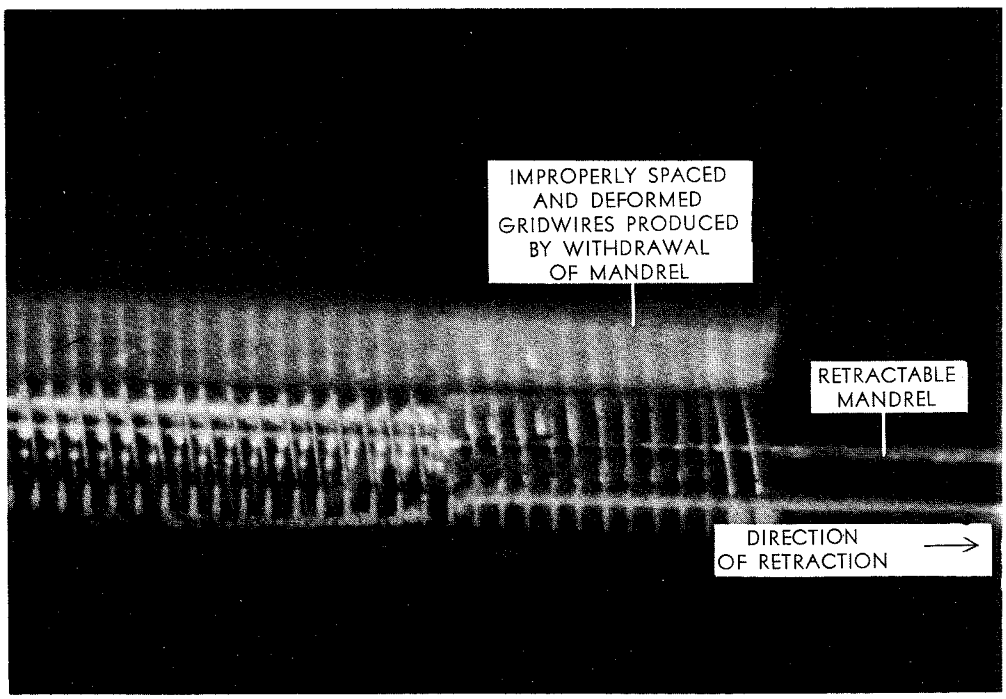


Fig. 4—Frame from high-speed film of grid-assembly operation, showing deformation caused by withdrawal of mandrel.

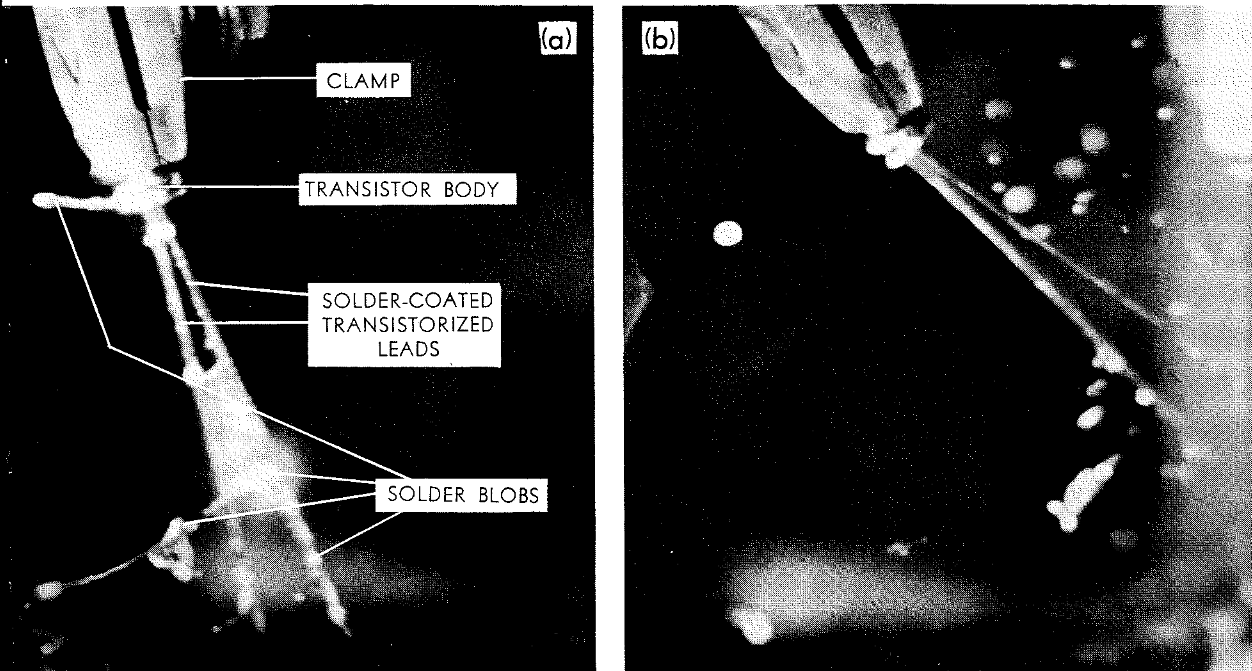


Fig. 5 — Frames from high-speed film of lead-wire tinning machine operation: (a) shows blobs of excess solder thrown off at start of snapping motion; (b) shows thrown-off solder re-landing on lead wires after snapping motion has stopped.

dipped into solder and then shaken with a snapping motion to throw off the excess solder.

The leads of the machine product, however, retained tiny globules of solder, and, consequently, did not have the smooth appearance desired in a good-quality product. To everyone's amazement, films taken by the high-speed camera revealed that the excess solder left the leads in blobs at the *beginning* of the snapping stroke (Fig. 5a), instead of at the end, where the transistor is stopped with a shock. These films also disclosed that the cast-off blobs of solder, because of their momentum, caught up with the stopped leads and sprayed them with tiny globules. (Fig. 5b)

As a result of this study the snapping motion was modified and the condition remedied.

#5—HEATER-SPACER COIL-WINDING MACHINE

A heater-spacer coil-winding machine winds tungsten wire—a wire with a nasty temperament—into small coils which are subsequently coated with insulating material and used to prevent contact between unipotential cathodes and their internal heaters. It also forms a leg or "tail" at one end of the coil, which provides a means for gripping the coil during the cataphoretic coating process.

The machine, however, failed to form the tails consistently to the same angle.

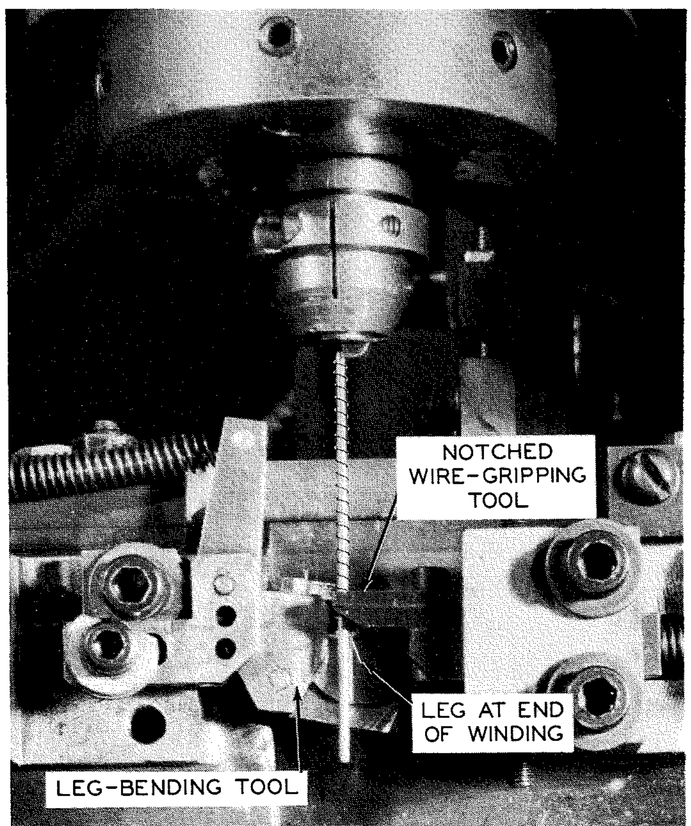
The high-speed camera showed that the notched tool used to grip and bend the tail permitted the tail to escape from its notch before the bend was completed.

This problem was solved by a redesign of the bending tool to assure retention of the tail throughout the bending operation.

CONCLUSION

This article has attempted to show the potential of a very useful device to the engineer. With the availablity of the high-speed camera, the engineer is in a position similar to that of the doctor who just realized the value of an available instrument — the microscope. Both devices make it possible to probe the unknown — one by magnifying dimensions alone, the other by magnifying time and dimensions.

Fig. 6 — Head of heater-spacer coil-winding machine.



THE "THYRISTOR"—A NEW HIGH-SPEED SWITCHING TRANSISTOR

By **C. W. MUELLER and J. HILIBRAND**
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THE USE OF THE transistor as an electrical switch has long been attractive. In fact, the point-contact transistor was generally a better switch than an amplifier to the dismay of circuit engineers seeking amplification. The point-contact transistor has a current transfer ratio (alpha) greater than unity and this characteristic can be utilized in circuits to provide a negative resistance and bistable operation. When junction transistors having an alpha less than unity were developed, their use vastly improved the stability of amplifiers.

Junction devices having alphas greater than unity have been described and include the avalanche transistor[1,2,3] and the p-n-p-n hook transistor.[4,5] More recently a silicon diode p-n-p-n switch in which the alpha increases above unity with current due to the saturation of recombination centers was discussed in considerable detail.[6] The device discussed in this article also has a current transfer ratio which becomes greater than unity with increasing current. In the present case this behavior depends on a new type of semiconductor contact that collects holes at low current densities and injects electrons at high current densities.

Because of its thyratron-like properties the device has been named "Thyristor." The "Thyristor" however, is markedly superior to the thyratron in many of its properties and comes close to having the attributes of an ideal switch. For example, the unit can be turned off by the base with low energy pulses in about 0.1 microsecond, and the total voltage drop across the unit during conduction is a few tenths of a volt.

"THYRISTOR" GEOMETRY AND FABRICATION

A cross section of the "Thyristor" is shown in Fig. 1. Arsenic is diffused into a p-type germanium wafer to form an n-type base region. A circular mask is applied and the unnecessary n-type skin is etched away, thus forming a circular plateau. Up to this point the structure is similar to that described by Lee.[7] An emitter junction and an ohmic base connection are soldered to this plateau. The area of the base connection is determined by the size of the wire used and the amount of solder present. The amount of material used must be accurately controlled to prevent shorting through the thin base layer. However, after the operations are properly set up, reproduction of the units can be accomplished readily..

The collector connection is made by soldering a nickel tab to the germanium of the collector with an alloy of lead, tin and indium. The connection may cover the entire area of the germanium wafer and does not involve any difficult or exact mechanical process. However, the physical nature of this contact has an important bearing on the "Thyristor" characteristics as discussed later.

If desired, the "Thyristor" can be used as a normal, non-regenerative, transistor switch by restricting the collector current to values below the breakover current. However, the new and interesting mode of operation occurs when the collector current is allowed to rise above a designed critical value. As the collector current is increased, the total current transfer ratio, α_{ce}, increases. When α_{ce} becomes greater than unity, for the grounded-emitter connection, a large increase of current occurs and the voltage across the unit drops to a very low value as shown in the characteristic curves[8] of Fig. 2(a) and (b). A short pulse, approximately 50 millimicroseconds in length, may be used to switch to the high conductivity mode. The transition to this mode is regenerative. After reaching the high current region, the base current can be removed without affecting the collector current. However, by the use of a reverse voltage between emitter and base, the high current can be turned off. This possibility, a highly

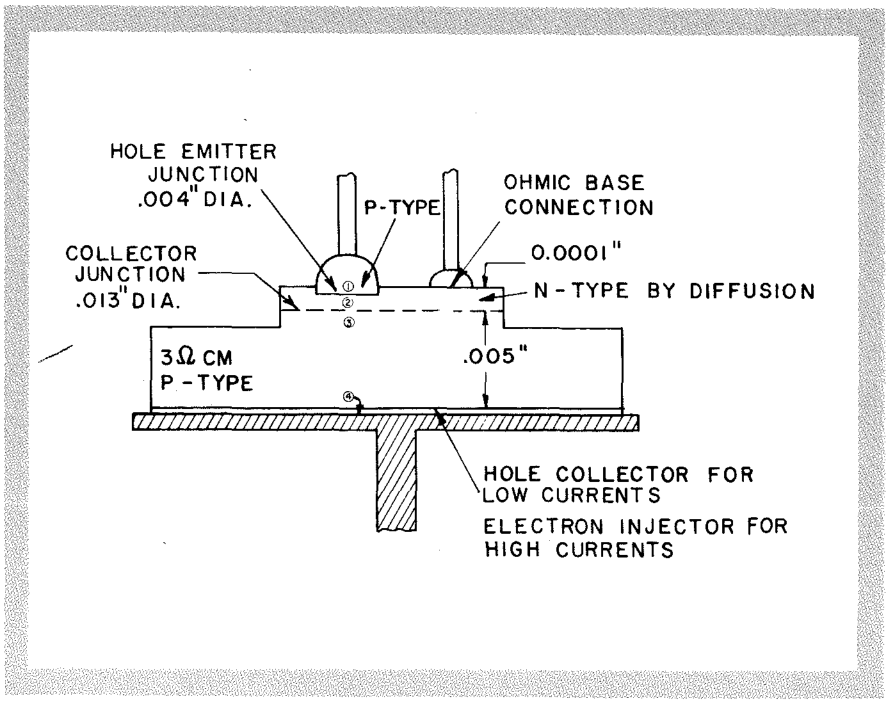

Fig. 1—Cross section showing Thyristor construction.

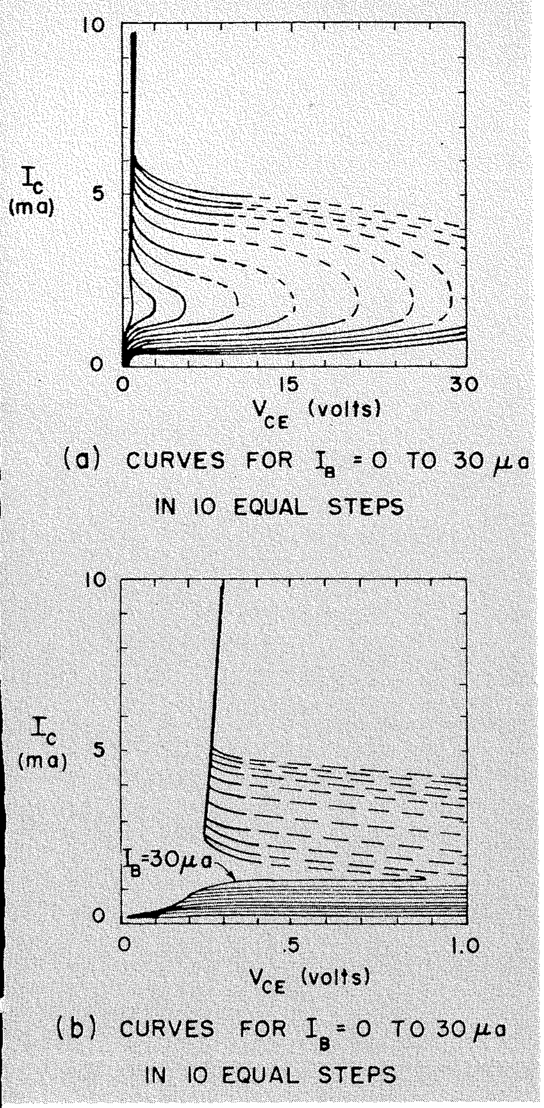

Fig. 2—Collector characteristics.

important feature for a switching device, distinguishes the "Thyristor" from a thyratron.

The "off" current is about 2 microamperes at room temperature and collector-to-base breakdown occurs at about 60 volts. In the high conductance mode the device displays a series resistance of about 3 ohms, between emitter and collector and for 100 milliamperes of collector current the voltage drop is only 0.5 volt. The small power dissipation in the high conductance mode is to be noted. The important parameter determining the transition to the high conductivity mode is the collector current. The transition value of this current is called the breakover current.

In Fig. 3, α_{ce} is shown as a function of emitter current. Since collector current is inversely proportional to $1 - \alpha_{ce}$ with the emitter grounded, the collector current would tend to rise to infinity when α_{ce} equals unity. Under this condition the device enters the high conductance mode and the current must be limited by external resistance. Note that when α_{ce} begins to rise, it increases very rapidly with emitter current. This total α_{ce} can be broken up into two parts, α_{holes}, which expresses the hole current-transfer-ratio across the base for holes injected at the emitter, and $\alpha_{electrons}$, the electron current transfer ratio across the collector body for electrons injected at the special collector connection. To measure the hole and electron alphas separately, a special transistor was constructed as sketched at the top of Fig. 4. The hole alpha (Fig. 4) shows the familiar shape and falls off at high current density. The electron alpha, plotted in Fig. 5, is small at low values of I_E. However, it increases rapidly with I_E. Between 1 milliampere and 5 milliamperes an increase of two orders of magnitude occurs. The electron alpha exhibits a power law dependence on the current. This power law relationship is a desirable feature because it gives a sharp threshold to the turn-on current.

It has been shown that when $\alpha_{ce} \geq 1$ the device will break over into the high conductance mode. In this mode the junctions have effectively disappeared. There is injection of holes from the emitter and injection of electrons from the collector contact in very nearly equal numbers. The flow in the intermediate regions (2 and 3 in Fig. 1) is due primarily to the electrical field (which no longer appears only at the collector junction). A linear voltage-current relationship is observed in this condition in which the resistance presented by the transistor (collector to emitter) is about 3 ohms.

RESPONSE TIMES OF THE "THYRISTOR"

One of the most important parameters in a negative resistance switching device is the speed of response. Measurements reported here were restricted to times of 20 millimicroseconds in length or longer, because of equipment limitations. The "Thyristor" is characterized by two types of switching response times, one for the linear mode and one for the bistable operation. In the linear mode the transistor displays the rapid response expected from a device with an alpha cutoff frequency of about 100 mc. The rise and fall times in a grounded-emitter circuit were better than 20 millimicroseconds. Storage times were not in evidence because the unit was not driven into the saturation region in attaining these speeds.

A slow response for the transition time into the high conductance mode might be expected because the transport of electrons (minority carriers) across the 5-mil collector body, (region 3 of Fig. 1) is involved. The expected transport time, if due to diffusion, would be

$$T_d = w^2/2D_n = 0.75 \text{ microseconds.}$$

Actually, however, the electron transport is primarily due to an electric field. The expected transit time for this is $T = w^2/\mu V = 0.1$ microsecond. This is approximately equal to the measured time required to switch into the high conductance mode. The energy required to turn on the unit with pulses is small, about 10^{-4} ergs.

The time required to switch off the high conductance mode involves storage effects. The high charge densities, corresponding to a current of the order of 10^3 amp/cm^2 in the active region under the emitter must be altered to apply a reverse bias at the emitter junction. The base lead resistance hinders this effort. The pulse energy for turning the unit off is about 0.1 erg. The time required is of the order of 0.1 microsecond.

CONTRAST WITH p-n-p-n STRUCTURE

In a p-n-p-n structure a rectifying barrier exists between the final p and n region. To test for a rectifying barrier between the collector body and the electron injector, special devices were made with an additional contact as sketched in Fig. 6. The V-I characteristic of the same figure shows that there is no ordinary rectifying p-n junction at the electron injector interface. Note that positive and negative voltages are plotted. The contact is ohmic (~100 ohms) until electron injection becomes significant.

The relationship of the "Thyristor" geometry to the p-n-p-n hook structure[4,5,6] is of considerable interest. The hook structure can also give a negative resistance characteristic. Although the form of the characteristic

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curves is the same, the breakover current, switching speed, and the operating temperature range can differ considerably. These differences stem from the nature of the electron injector.

To observe p-n-p-n hook operation with the "Thyristor" geometry, units were built similar to the unit shown in Fig. 1. The collector connection, however, was the lead-arsenic eutectic alloyed at 600°C. Thus, an n-type germanium region was produced at (4). With this structure, breakover to the high conductivity mode occurred at low currents. Typical values for the point of breakover under d-c conditions are: $I_B=1$–10 microamperes; $I_{CB}=10$–50 microamperes.

This low breakover current causes two practical difficulties. First, the allowable temperature range is greatly reduced because of the increase in I_{co} with temperature. Since breakover occurs at a low value of collector current, for example, the top operating temperature with zero base current is low, about 35°C compared to 65°C for typical "Thyristors." It is possible to operate both types of transistors at higher temperatures by using a reversed base bias. Operation up to 85°C has been observed. For this type of operation the p-n-p-n unit is a "normally closed" or "on" switch; a base current and stand-by power are necessary to hold it open at temperatures above 35°C.

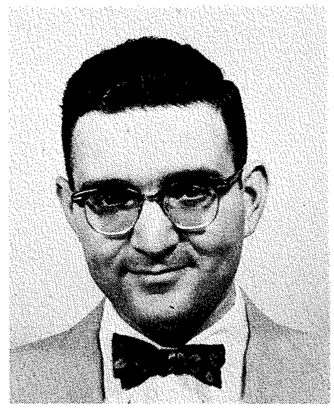
Secondly, since the low value of the breakover current is accompanied by a very small field across the collector body, the field acceleration of the minority carriers through the collector will not be very effective. The speed of response then depends upon diffusion flow. To obtain fast transit times with diffusion flow a much thinner collector body is necessary.

SUMMARY OF PROPERTIES

The advantageous features of the "Thyristor" are summarized below.

1. The device is capable of switching times of the order of 100 millimicroseconds.
2. It has a low sustaining voltage, of the order of one-half volt at 100 milliamperes. This results in low power dissipation in the high conductivity mode.
3. The structure can dissipate high powers.
4. The negative resistance characteristic allows the use of simple circuitry for switching.
5. Fabrication and alignment are simple and can be carried out with ordinary diffusion and alloy techniques.
6. Transistors that do not have a high conductance mode, or that enter this mode at any desired current level, can be made by simple changes in a soldered contact.

The novel feature of the "Thyristor" is the electron injection at the collector contact. For best operation and device reproducibility, the electron injection should increase rapidly with current. A novel contact is used that exhibits this desired characteristic, giving a power law increase of electron injection as a function of current.



JACK HILIBRAND received the B.S.E.E. degree at City College of New York in 1951. At M.I.T. he was a National Science Foundation Fellow for two years and a Research Assistant at the Research Laboratory of Electronics for two years. In 1956 he received the Sc.D. degree from M.I.T. for work in the analysis of excess physical noises.

Since graduation he has been a member of the staff at the RCA Laboratories in Princeton, New Jersey, where he is now engaged in semiconductor device development.

Dr. Hilibrand is a member of Eta Kappa Nu, Tau Beta Pi, and Sigma Xi.

APPLICATIONS OF THE THYRISTOR

The inherent advantages of the "Thyristor" will undoubtedly lead to many applications[9] by circuit engineers that are not evident at the present time. However, two classes of application can be foreseen. One is the field of computer applications where a small, high-speed, low-current switch or storage element is required. The other field is that of the control of high currents and high powers presently accomplished with thyratron gas tubes.

The negative resistance characteristics of the "Thyristor" are similar in many respects to those of the point contact transistor and many of the circuits developed for the point contact transistor can be used for the "Thyristor." The "Thyristor," however, has the stability and reliability of a junction device. For computer applications the "Thyristor" can be used as a single element storage device that can be rapidly turned on and off by a low-power input circuit. Since the active volume is small an extremely small unit that can be directly inserted into printed circuit boards is feasible.

The "Thyristor" (TA1693)[10] described here is designed for low-power, high-speed applications. The design, however, can readily be adapted for high power and thus will be capable of use in a wide variety of high-power control applications now being handled by various gas tubes. The high current density and low voltage drop in the high conductivity mode make the "Thyristor" highly efficient. Among the many applications are: control applications for ovens, welding, relaxation oscillators, frequency converters, inverters, motor control, etc.

The circuit possibilities of the "Thyristor" are large and limited only by the skill and imagination of the circuit engineer in applying this new device to specific problems.

ACKNOWLEDGMENT

The collaboration of L. E. Barton in discovering and measuring the switching characteristics is gratefully acknowledged. The fabrication of the units was carried out by Mrs. E. Moonan. D. O. North contributed many fruitful discussions.

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8. The characteristics of Fig. 2 are taken from photographs of 60 cps oscillograph traces.
9. L. Barton, "The Thyristor—Some of its Characteristics and Applications." *Electron Design*, Mar. 19, 1958.
10. The TA1693 Thyristor can be obtained from the Semiconductor Division, Somerville, N. J.

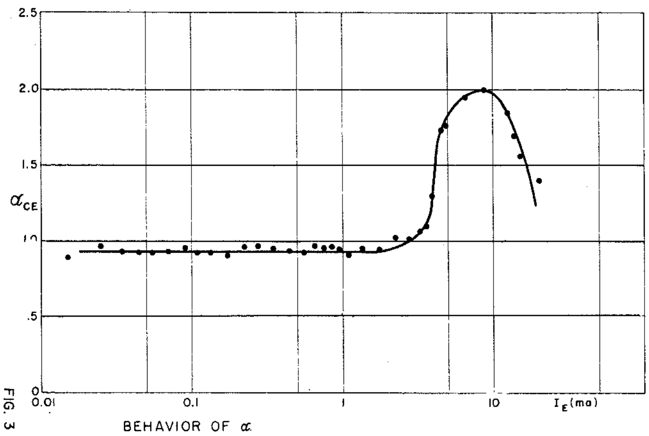


FIG. 3

Fig. 3—Behavior of α_{ce}.

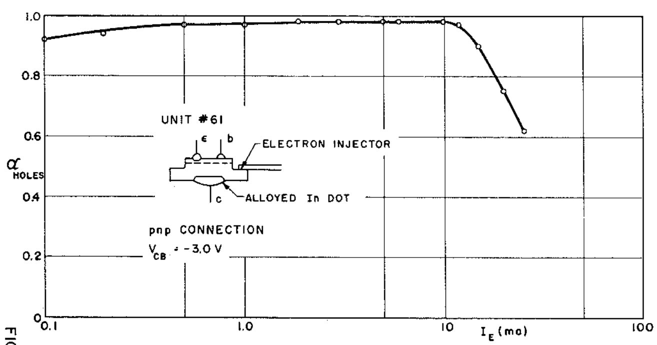


FIG. 4

Fig. 4—Behavior of α_{holes}.

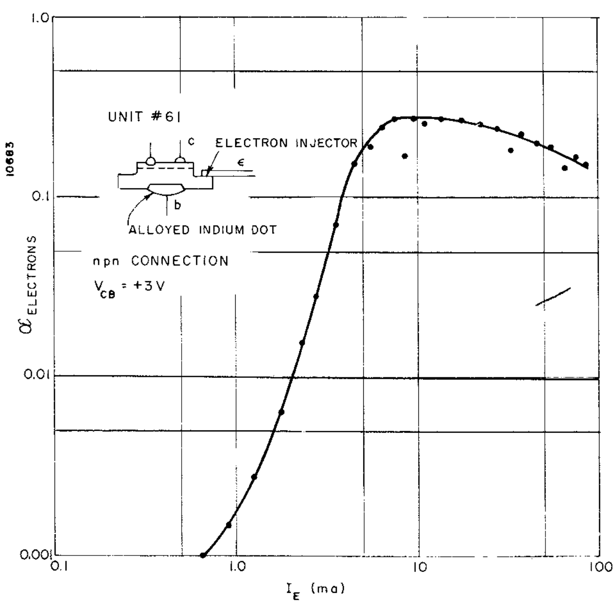


Fig. 5—Behavior of $\alpha_{electrons}$.

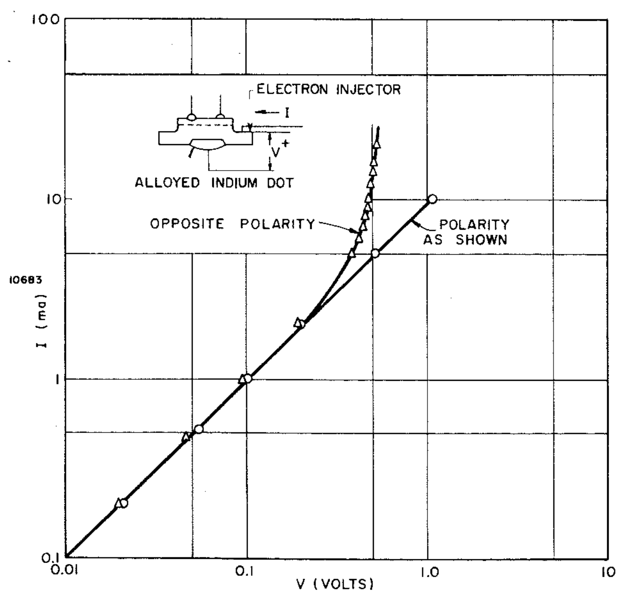


Fig. 6—Voltage-current characteristics of electron injector.

Patents Granted
TO RCA ENGINEERS

BASED ON SUMMARIES RECEIVED OVER A PERIOD OF ABOUT TWO MONTHS

DEFENSE ELECTRONIC PRODUCTS

Camden, N. J.

Signal Responsive Circuit
Pat. No. 2,785,305—granted March 12, 1957 to H. N. Crooks, Camden and Linder C. Hobbs and B. A. Kaelin, Jr., no longer employed by RCA.

Card Reader Device
Pat. No. 2,818,212—granted December 31, 1957 to R. A. Oberdorf.

Card Reader Device
Pat. No. 2,819,020—granted January 7, 1958 to R. A. Oberdorf, DEP, Camden and J. S. Baer, IEP, Camden.

Internal Drag Roller
Pat. No. 2,819,069—granted January 7, 1958 to W. R. Isom.

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

Electronic Counter Systems
Pat. No. 2,820,153—granted January 14, 1958 to H. J. Woll.

Los Angeles, Calif.

Shutterless Direct Positive Sound Recording System
Pat. No. 2,784,260—granted March 5, 1957 to J. L. Pettus, Los Angeles and E. P. Ancona, Jr., no longer employed by RCA.

System for Generating a Bar Pattern on a Cathode Ray Tube
Pat. No. 2,818,526—granted December 31, 1957 to J. F. Sterner, Los Angeles and J. R. Meagher, Electron Tube Div., Camden.

RCA VICTOR TELEVISION DIVISION

Cherry Hill, N. J.

Deflection Yokes
Pat. No. 2,799,798—granted to W. H. Barkow, Cherry Hill, and J. K. Kratz, Electron Tube Div., Findlay.

Cathode Ray Tube Deflection Apparatus
Pat. No. 2,817,782—granted December 24, 1957 to W. H. Barkow, Cherry Hill and D. P. Over, Electron Tube Div., Findlay.

Electrical Circuit
Pat. No. 2,819,442—granted January 7, 1958 to H. C. Goodrich.

Tri-Color Kinescope Beam Convergence System
Pat. No. 2,820,174—granted January 14, 1958 to H. C. Goodrich.

Television Receiving Systems
Pat. No. 2,820,092—granted January 14, 1958 to C. W. Hoyt and L. P. Thomas, Jr.

Ultra-High Frequency Television Converter with Decade-Tuning Turret Having Unit-Tuning Vernier
Pat. No. 2,821,624—granted January 28, 1958 to W. R. Koch.

Deflection Yoke
Pat. No. 2,821,671—granted January 28, 1958 to M. J. Obert, Cherry Hill and J. K. Kratz, Electron Tube Div., Findlay.

INDUSTRIAL ELECTRONIC PRODUCTS

Camden, N. J.

Card Reader Device
Pat. No. 2,819,020—granted January 7, 1958 to J. S. Baer, IEP, Camden, and R. A. Oberdorf, DEP, Camden.

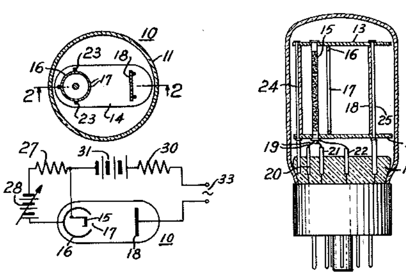
Electron Microscopy
Pat. No. 2,819,403—granted January 7, 1958 to J. H. Reisner.

Frequency Division Multiplexing
Pat. No. 2,819,344—granted January 7, 1958 to L. E. Thompson.

SEMICONDUCTOR DIVISION

Somerville, N. J.

Gas Discharge Device
Pat. No. 2,792,527—granted May 14, 1957 to Dr. L. Malter, W. M. Webster, Jr., and E. O. Johnson, RCA Labs, Princeton.



Malter, Webster & Johnson
Pat. No. 2,792,527

ELECTRON TUBE DIVISION

Harrison, N. J.

Electrode Cage for Electron Discharge Devices
Pat. No. 2,778,968—granted January 22, 1957 to F. J. Pilas, R. K. Wolke and J. A. Chase.

Combination Beam Plate and Outer Shield
Pat. No. 2,820,169—granted January 14, 1958 to C. M. Morris.

Lancaster, Pa.

Cathode-Ray Tube
Pat. No. 2,806,162—granted September 10, 1957 to R. J. Kistler, Lancaster, and H. R. McQuillen, no longer employed by RCA.

Induction Heating Device
Pat. No. 2,814,707—granted November 26, 1957 to J. C. Turnbull and L. W. Morgan.

Manufacture of Color-Kinescopes, Etc.
Pat. No. 2,817,276—granted December 24, 1957 to D. D. Van Ormer, Lancaster, and D. W. Epstein and P. E. Kaus, RCA Labs, Princeton.

Method of Coating Phosphor Particles
Pat. No. 2,817,599—granted December 24, 1957 to G. E. Crosby, Lancaster, and T. W. Edwards, no longer employed by RCA.

Photocathode for a Multiplier Tube
Pat. No. 2,818,520—granted December 31, 1957 to R. W. Engstrom, and M. E. Craig, Lancaster, O. W. Thuler, no longer employed by RCA.

Means for Obtaining a Uniform Evaporated Deposit
Pat. No. 2,818,831—granted January 7, 1958 to B. H. Vine.

Tunable Cavity Resonator
Pat. No. 2,820,176—granted January 14, 1958 to W. P. Bennett.

Carburized Thoriated Tungsten Electrode and Method of Enhancing its Emissivity
Pat. No. 2,819,991—granted January 14, 1958 to W. E. Harbaugh.

Findlay, Ohio

Cathode Ray Tube Deflection Apparatus
Pat. No. 2,817,782—granted December 24, 1957 to D. P. Over, Findlay, and W. H. Barkow, RCA Victor Tel. Div., Cherry Hill.

Deflection Yokes
Pat. No. 2,799,798—granted July 16, 1957 to J. K. Kratz, Findlay, and W. H. Barkow, RCA Victor Tel. Div., Cherry Hill.

Deflection Yoke
Pat. No. 2,821,671—granted January 28, 1958 to J. K. Kratz, Findlay, and M. J. Obert, RCA Victor Tel. Div., Cherry Hill.

Camden, N. J.

Frequency Marker
Pat. No. 2,782,380—granted February 19, 1957 to R. S. Coate and J. R. Meagher.

System for Generating a Bar Pattern on a Cathode Ray Tube
Pat. No. 2,818,526—granted December 31, 1957 to J. R. Meagher, Camden, and J. F. Sterner, DEP, Los Angeles.

RCA STAFF

Camden, N. J.

Color Television Systems
Pat. No. 2,820,844—granted January 21, 1958 to Dr. G. L. Beers.

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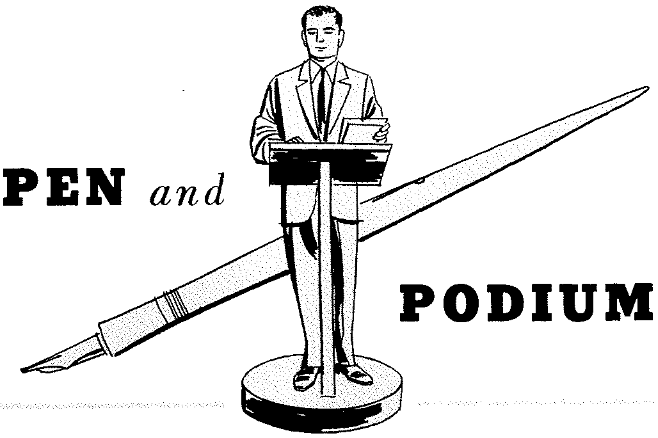


BASED ON REPORTS RECEIVED OVER A PERIOD OF ABOUT TWO MONTHS

ELECTRON TUBE DIVISION

Lancaster, Pa.

Black Level, the Lost Ingredient in TV Picture Fidelity
By R. G. Neuhauser: Published in JOURNAL OF SMPTE, Oct. 1957. This paper describes television-system improvements instituted in recent years which produce and maintain the ability to reproduce proper black level (or d-c restoration) in television receivers.

An Image-Converter Tube for High-Speed Photographic Shutter Service
By R. G. Stoudenheimer and J. C. Moor: Presented at SMPTE Convention, Phila., Pa., Oct. 4-9, 1957. Image-converter tube with low gating and deflection-power requirement is described. Resolution is better than 22 line-pairs per millimeter.

High-Voltage Regulator Tubes for Color Television Receivers
By R. E. Byram: Published in IRE TRANSACTIONS ON ELECTRON DEVICES, July, 1957. This paper describes the RCA-6BD4-A and RCA-6BK4 low-current beam triodes of the sharp-cutoff type designed specifically for regulation of the high-voltage supply in color television receivers.

Recent Developments in TV Camera Tubes
By F. S. Veith: Published in IRE Transactions on Broadcast and Television Receivers, Dec., 1957. Advantages of micromesh and superdynodes, characteristics of new image orthicon with high photocathode sensitivity, and new vidicon having increased sensitivity are described.

Creation of Light
By G. E. Crosby: Presented at Father-and-Son Banquet, Brickerville, Pa., Feb. 19, 1958. The magnitude of details implicit in biblical quotation "Let there be light—" is emphasized. Various methods of producing light are then demonstrated.

Quantitative Estimation of Graphite in Refractory Carbon Deposits by X-Ray Technique
By P. G. Herold: Published as Letter to the Editor in NATURE, Dec. 1957. This paper presents two curves which permit a quantitative estimation of graphite by use of an X-ray Spectrometer. Use of the curves in determining graphite content of several large samples of carbon deposits is given.

Will Success Spoil the Traveling-Wave Tube
By W. R. Beam, Princeton, N. J.: Presented at Northern New Jersey Chapter Meeting of IRE Professional Group on Microwave Theory and Techniques, Montclair, N. J., Jan. 15, 1958. This paper describes recent advances in the design of traveling-wave tubes which will make them more successful and more useful as part of complex systems.

Recent Work on Photoemission and Dark-Emission Problems
By R. W. Engstrom, D. A. Bly, H. L. Palmer, and R. G. Stoudenheimer: Presented at Scintillation Counter Symposium, Washington, D. C., Jan. 27, 1958. This paper describes recent work on multiplier phototubes having wider spectral responses from the ultraviolet to the infrared region, higher absolute sensitivity, and lower dark emission. Discussion includes the reflective-substrate type of cathode, cathodes for the infrared and ultraviolet regions, and the new multialkali photocathode.

Status of Multiplier Phototube Development for Scintillation Counters
By W. Widmaier: Presented at Scintillation Counter Symposium, Washington, D. C., Jan. 27, 1958. This paper describes several new multiplier phototubes which permit improved pulse-height resolution and shorter time discrimination in scintillation counter applications.

Electrical Engineering as a Vocation
By C. P. Smith: Presented at Reynolds Junior High School, Lancaster, Pa., Feb. 11, 1958. This paper gives a general description of the field of electrical engineering, and points out the educational requirements, necessary abilities and other personal qualifications, rewards, and ways of "getting started" in the field.

Harrison, N. J.

How to Use High-Speed Motion-Picture Cameras
By Don Colasanto: Published in MACHINE DESIGN, Jan. 1958. This paper describes the use of the high-speed motion-picture camera as an engineering diagnostic tool for detection and diagnosis of ailments common to many machines.

The VTVM . . . Its Care and Repair
By Rhys Samuel: Published in RADIO-ELECTRONICS, Dec. 1957. This paper describes simple preventive maintenance techniques which can be used to minimize VTVM "down-time," as well as methods for analyzing and localizing trouble in defective instruments. General troubles are pointed out, and probable causes and solutions are given.

An Unusual Color TV Problem
By M. B. Knight: Published in RCA RADIO AND TELEVISION SERVICE NEWS, Dec. 1957. This paper describes the use of an improvised "demagnetizer" to "degauss" a color television receiver which became magnetized during a heavy thunderstorm. The improvised tool uses an RCA-202D1 focus coil with an a-c plug attached to its leads.

Unusual Electron-Tube Effects of Concern to Circuit Designers
By W. E. Babcock: Presented at IRE Section Meeting, Fort Wayne, Indiana, Jan. 2, 1958. In many electron tube applications, the circuit designer may be unaware of unusual phenomena peculiar to certain tubes. Their effects and methods of minimizing difficulties are described.

Sync and Sweep Selection in CRO Applications
By Rhys Samuel: Published in RCA RADIO AND TELEVISION SERVICE NEWS, Dec. 1957. This paper describes special sync and sweep features incorporated in service-type oscilloscopes and discusses their application to signal tracing, response-curve observation, and other measurements. Proper use of sync and sweep switches avoids erroneous evaluation of waveshapes.

On the Quality of Color-Television Images and the Perception of Color Detail
By O. H. Schade, Sr.: Presented at IRE Section Meeting, Montclair, N. J., Feb. 5, 1958. This paper describes the dynamic transfer characteristic of present color television picture tubes, and shows that their luminance range of several hundred results in better color space utilization than obtained in conventional motion pictures and permits a linear reproduction of normal high-contrast color transparencies.

Photographing C-R Tube Images
By Rhys Samuel: Published in RADIO-ELECTRONICS, Dec. 1957. This paper describes the problems involved in photographing TV pictures or oscilloscope traces, and shows how these problems can be solved with specific techniques and conventional equipment.

Some Automation Concepts
By W. E. Bahls: Presented at Metropolitan Section of American Ceramic Society, New York, New York, Jan. 24, 1958. This paper attempts to justify some automation concepts by means of a step-by-step synthesis of a simple systems model.

COMPONENTS DIVISION

Camden, N. J.

Designing Relays for High Reliability
By D. H. Cunningham: Published in IRE WESCON RECORD, Dec. 1957. An objective for a component reliability of 99.99% is emphasized. Engineering effort put forth and the areas in which further work can be done are described.

SEMICONDUCTOR DIVISION

Somerville, N. J.

Variation of Transistor Parameters with Temperature
By C. R. Eshelman: Published in SEMICONDUCTOR PRODUCTS, Jan. 1958. This paper presents a theoretical discussion of

the quantitative variation with temperature of transistor hybrid-equivalent-circuit parameters, and also presents data showing experimental variation of these parameters for the RCA-2N77 alloy-junction transistor.

The Transistor, a New Electronic Device
By D. H. Wamsley: Presented at Community School for Leisure Learning, Somerville, N. J., Feb. 12, 1958. This paper describes the general principles of the transistor, its applications, and some of the manufacturing processes involved in the production of these tiny electronic devices.

Design of a High-Speed Transistor Decimal Counter with Neon-Bulb Read-out
By R. D. Lohman: Published in IRE WESCON RECORD, Dec. 1957. This paper discusses design for high-speed transistor decimal counter and gives design equations for circuitry that will provide high reliability of triggering and d-c stability.

INDUSTRIAL ELECTRONIC PRODUCTS

Camden, N. J.

Electronic Digital Computers— Their Impact on Data Processing
By J. W. Leas: Presented at Air Force Reserve Officers Meeting, Jan. 23, 1958, at Dayton, Ohio. A typical electronic digital computer system for data processing and the range of applications for it were described.

Radio Systems—ULH, HF, VHF, UHF and SHF
By N. C. Colby: Presented to AIEE Study Group, N. Y. City, Jan. 20, 1958. A description of radio communications systems common to each service named is given.

An Automatic Communications Switching System
By J. A. Brustman, L. S. Levy and I. Cohen: Presented at AIEE Winter Meeting, N. Y. City, Feb. 2-7, 1958. An electronic data processing system for a Central Telegraph Office which receives, switches, stores, transmits, conditioned messages and keeps a file of traffic handled.

Class C and Harmonic Amplifier Charts
By R. A. Henderson: Published in RCA DEP-IEP Engineering News letter. Article presents curves which relate plate efficiency to duration and shape of plate current pulse. Amplifier, doubler, and tripler curves are given.

A Case History of the Application of Human Engineering
By J. L. Owings: Presented at American Management Association Meeting, Nov. 25, 1957, N. Y. City. The RCA Bizmac System for the Ordnance Tank and Automotive Command is shown as an example of how human engineering results in workability, reliability, and economy.

The Operating Range of a Memory Using Two Ferrite Plate Apertures per Bit
By M. M. Kaufman and V. L. Newhouse: Presented at Magnetism and Magnetic Materials Conference, Nov. 21, 1957, N. Y. City. Techniques are described which compensate for non-uniformity (from hole-to-hole) found in experimental plates. A successful switch-driven ferrite plate memory is covered.

Digital Data Transmission Between Dissimilar Processing Centers
By J. A. Brustman, I. Cohen, H. P. Guerber: Presented at AIEE Winter Meeting, Feb. 6, 1958, N. Y. City. The requirements and problems in designing equipment for transmission of data from small satellite computing centers to a central processing center are described.

DEFENSE ELECTRONIC PRODUCTS

Camden, N. J.

A Systems Approach to Air Traffic Control
By I. Maron: Presented at Lancaster IRE Meeting, Nov. 26, 1957. Paper outlines manner of aircraft operations control and tells what will be adequate for 1965 era.

Component Part Failure-Rate Information in Reliability
By M. P. Feyerherm: Presented to IRE Professional Group on Reliability and Quality Control, Phila. Chapter, Jan. 23, 1958. It is shown how numerical reliability prediction can be made by use of applicable charts and curves.

Effect of Elastic Racks on Vibration Mounted Equipment
By R. A. DiTaranto: Published in Journal of Applied Mechanics, Dec. 1957. This paper shows the change of natural frequency of electronic equipment on vibration mounts due to elasticity in racks.

Transistor Bilateral Switching
By W. M. Cook and P. L. Bargellini: Presented at Transistor and Solid State Circuits Conference, Phila., Pa., Feb. 21, 1958. Basic transistor properties required for efficient bilateral switching is discussed. Operational data are given for several high-frequency switching circuits.

Effect of Radiation on Vidicon Performance
By R. A. Davidson and B. H. Rosen: Presented by R. A. Davidson at IRE (PGNS) meeting, Oct. 31, 1957, N. Y. City. This paper covered the operation of the RCA Vidicon in the Brookhaven Reactor under severe "radiation-field" conditions.

Moorestown, N. J.

Trend to Modularization, Standardization and Miniaturization of Electronic Equipment
By G. W. K. King: Presented at Johnsville NADC (PGMIL) IRE Meeting, Jan. 23, 1958. The motivating forces of time, complexity, and cost and their relation to trends and progress are discussed.

Weapon System Reliability
By M. M. Tall: Published in March, 1958, Electronic Equipment Magazine. An analysis is given of the effect of a failure on overall system performance, as a basis for directing reliability efforts.

Are You Creative?
By G. W. K. King: Presented to Society for Advancement of Management-Industrial Engineering Group, Dec. 10, 1957. Historical background and present thinking on creativity are presented. Obstacles thwarting creativity are pointed out—and a test is given to the audience.

Development of Talos Land-Based System
By D. B. Holmes: Presented at Institute of Aeronautical Sciences Symposium, N. Y. City, Jan. 28, 1958. Some of the ground-to-air defense problems utilizing a missile system are described, as are solutions to these problems by Talos.

The Training Aspects of Design Reviews
By H. C. Bryson: Presented at fourth National Symposium on Reliability and Quality Control, Jan. 6-8, 1958, Wash., D. C. It is shown how design reviews raise competence level by increasing awareness of many aspects of inactive product design.

Talos Defense Unit
By H. W. Phillips: Presented to Moorestown Kiwanis Club, Nov. 21, 1957 and Medford Rotary, Dec. 10, 1957. A description is given of TALOS, an automatic system capable of dealing with the threat, as shown by a short film picturing a "Talos" intercept of a jet target.

Waltham, Mass.

An Approach to Systems Integration for Manned Systems
By D. C. Beaumariage: Presented to IRE Professional Group on Military Electronics and Human Factors Society of America, Phila., Pa., Dec. 3, 1957. One approach is presented to solve the problem of developing a modern system.

RCA VICTOR TELEVISION DIVISION

Cherry Hill, N. J.

IRE Fellows Predict
By W. Y. Pan: Published in March 1958 Tele Tech. Author predicts how the importance of TV to every day living will continue to grow and expand into many new services, aside from entertainment.

RCA SERVICE COMPANY

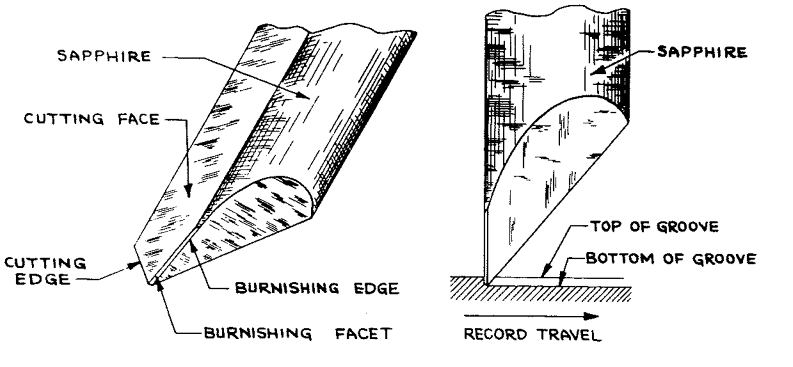
Cherry Hill, N. J.

Monochrome TV Picture Reproduction on a Tricolor Kinescope
By E. R. Klingeman: Published in Jan. 1958 Service Magazine (Vol. 27, No. 1). Author shows how modern color TV receivers, properly adjusted, also give excellent black and white pictures.

RCA VICTOR RECORD DIVISION

Indianapolis, Ind.

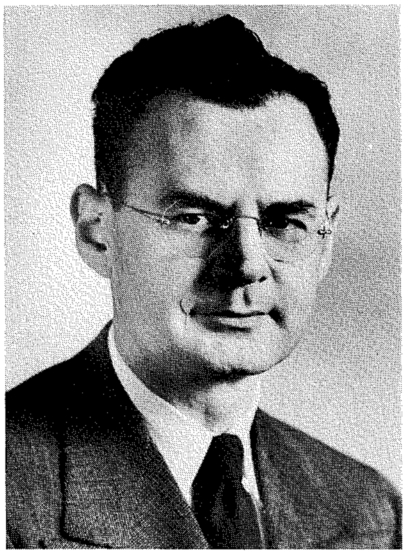
Mechanical Recording
By R. C. Mayer and H. E. Roys: Delivered by B. J. White to Audio Engineering Society, Jan. 2, 1958, N. Y. City. Mechanical recording, as used in making phonograph records, involves the cutting of a groove of a particular size and shape in a suitable medium. The equipment required to cut the groove, the precautions to be observed, and methods of evaluating the equipment and overall results are discussed.



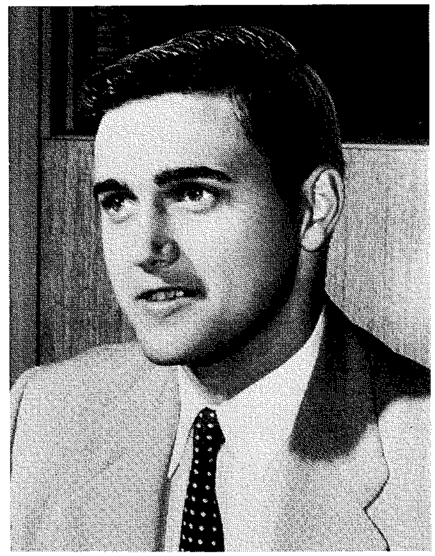
Sapphire Recording Stylus
—R. C. Mayer and H. E. Roys

Engineering NEWS *and* HIGHLIGHTS

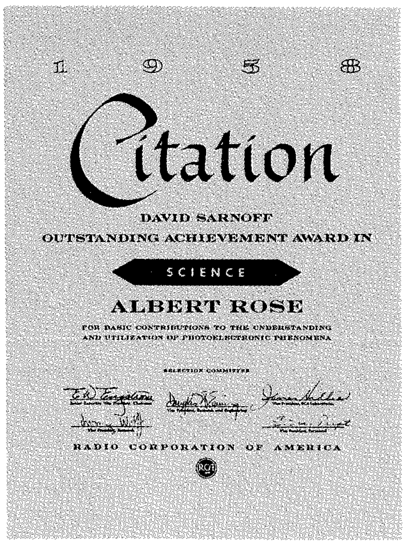
BARTON AND ROSE GET RCA'S FIRST DAVID SARNOFF AWARDS



Dr. Albert Rose



David K. Barton



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Citation

DAVID SARNOFF
OUTSTANDING ACHIEVEMENT AWARD IN

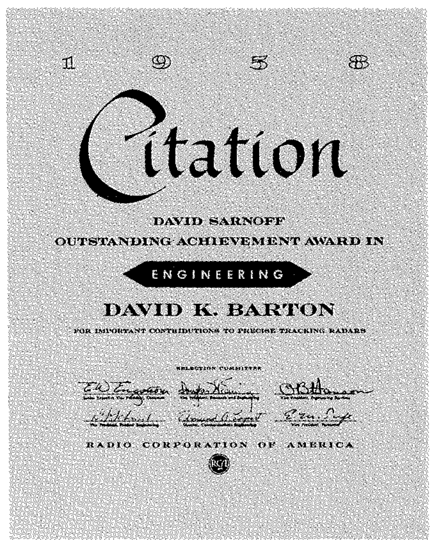
SCIENCE

ALBERT ROSE

FOR BASIC CONTRIBUTIONS TO THE UNDERSTANDING AND UTILIZATION OF PHOTOELECTRONIC PHENOMENA

SELECTION COMMITTEE

RADIO CORPORATION OF AMERICA



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Citation

DAVID SARNOFF
OUTSTANDING ACHIEVEMENT AWARD IN

ENGINEERING

DAVID K. BARTON

FOR IMPORTANT CONTRIBUTIONS TO PRECISE TRACKING RADARS

SELECTION COMMITTEE

RADIO CORPORATION OF AMERICA

The Citations as awarded

The first David Sarnoff Outstanding Achievement Awards in Science and Engineering were presented to Albert Rose of the technical staff of RCA Laboratories, and David K. Barton of the engineering staff of RCA Defense Electronic Products (See brochure distributed with RCA ENGINEER Volume 3, Number 4).

The two awards, to be made annually to the outstanding scientist and the outstanding engineer of the Radio Corporation of America, were established in September, 1956, to commemorate the fiftieth anniversary in radio of Brig. General David Sarnoff, Chairman of the Board of RCA. Each of the awards consists of a gold medal and a citation.

Dr. Rose is cited "for basic contributions to the understanding and utilization of photoelectronic phenomena." Mr. Barton's citation specifies, "for important contributions to precise tracking radars."

The medals were presented to both men by General Sarnoff in March.

Concerning the awards, Dr. Engstrom said:

"The selection of Dr. Rose and Mr. Barton as the first recipients of the David Sarnoff Outstanding Achievement Awards is a tribute to their exceptional accomplishments in fields of basic importance to electronic progress. Dr. Rose has been responsible for a series of important discoveries and applications in the fields of photoconductivity and photosensitivity, including basic contributions to the development of the Orthicon, Image Orthicon and Vidicon television tubes. His work has materially improved television for home and industry.

Mr. Barton played a major part in the development of the most precise instrumentation tracking radar known, and has been responsible for an imposing list of contributions relating to radar and guided missile technology. His work has aided in the improvement of missiles for national defense.

The awards themselves give fitting recognition not only to the accomplishments of the RCA technical staff, but also to the inspiration and unswerving support given to research and engineering over a period of many years by David Sarnoff.

Dr. Rose, who has been associated with RCA research since 1935, is best known for his work on television pickup tubes. A graduate of Cornell University in 1931, he received a Ph.D. in physics from Cornell in 1935. With RCA, he was first associated with tube research at Harrison, New Jersey, and was transferred to Princeton, New Jersey, at the opening of the new RCA Laboratories research center there in 1942.

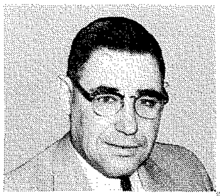
About ten years ago, Dr. Rose became interested in the relative limitations in the light sensitivity of photographic film, television pickup tubes, and the human eye. His studies in this field from 1946 to 1953 led to his widely recognized work on the mechanism of the photoconductive process and current-flow in insulators.

From May, 1955, to July, 1957, Dr. Rose headed the research activity of the newly-established RCA Laboratory at Zurich, Switzerland. Upon his return to Princeton last summer, he resumed research relating to the study and application of photoelectronic phenomena.

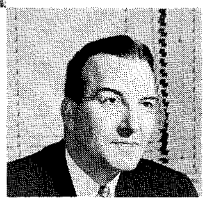
Mr. Barton, a member of the Missile and Surface Radar Department of RCA Defense Electronic Products at Moorestown, New Jersey, joined RCA early in 1955. He was graduated from Harvard University in 1949. With RCA, Mr. Barton played a major role in the formulation of specifications for a new type of tracking instrumentation radar and in testing and proving its unprecedentedly high accuracy. In addition to his contribution in the development and acceptance of this equipment, Mr. Barton has been responsible for a number of outstanding achievements in related areas, including the interpretation of radar information, the use of electronic data correction systems in connection with radar, and guided missile test range instrumentation.

ENGINEERS IN NEW POSTS

Dr. G. H. Brown has announced his staff as IEP Chief Engineer: **E. I. Anderson,** Staff Engineer; **C. O. Caulton,** Mgr. New Products Administration; **G. A. Kiessling,** Mgr. Engineering Standards & Services; and **J. N. Marshall,** Mgr. Advanced Development. . . .



W. J. Zaun



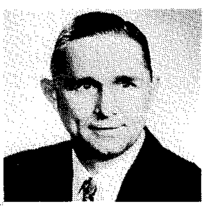
S. H. Watson

S. H. Watson has announced **C. C. Kimber** as Administrator of Industrial Finishes Standards in his Corporate Standardizing activity. . . .

Service Company has appointed two V.P.'s —**S. D. Heller** becomes Vice President, BMEWS Service, and **K. M. McLaren** replaces Heller as V.P. of the Missile Test Project, Cape Canaveral—both will report to **A. L. Conrad. . . .**

W. J. Zaun becomes Operations Mgr. for Conrad's Government Service Dept. **T. Y. Flythe** moves up to Quality Control Mgr. for Service Co. reporting to **E. C. Cahill.**

J. M. Spooner, Mgr. of the Somerville Semiconductor Plant announces his staff as follows: **D. C. Bayless,** Mgr. Plant Quality Control; **G. J. Feder** Mgr. Entertainment Manufacturing; **A. L. Gorman** Plant Engineering Mgr.; **T. A. Holmes,** Purchasing Mgr.; **J. W. Ritcey,** Mgr. Production Engineering; and **W. H. Wright,** Mgr. Industrial/Computer Manufacturing.

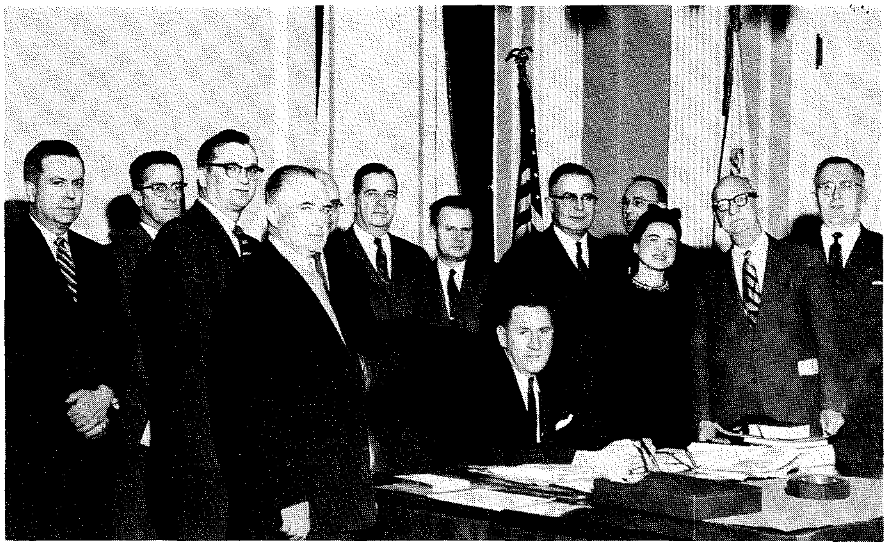


J. M. Spooner

J. W. Ritcey

Former engineer **D. G. Koch** becomes Mgr. of Eastern District, Industrial Sales, for Electron Tube Div. . . . also in the Tube Div., **J. G. Woehling** has announced the organization for his Advanced Equipment Development in the Entertainment Tube Products Dept. . . . **W. T. Engel,** Mgr. Mechanical Advanced Development, **F. J. Yannott,** Mgr. Electrical Advanced Development, and **H. Hermanny,** Mgr. Cage and Mount Equipment Design.

MASSACHUSETTS GOVERNOR HONORS RCA ENGINEER



Governor Foster Furcolo—Seated at Desk; J. H. McCusker of the Materials Advanced Development Laboratory—To the left of the U.S.A. flag pole.

Joseph H. McCusker, Materials Advanced Development Laboratory, Needham, Mass., was recently honored with a Certificate of Meritorious Service, presented by His Excellency, Governor Foster Furcolo. The Certificate was awarded for his efforts, through the Citizens' Participation Program, in establishing a program of apprenticeship training in the electronics field.

The on-the-job work and study program, the first of its kind in the country designed specifically to train electronics technician journeymen, has become available for Massachusetts electronics firms, according to a recent announcement by Gov. Foster Furcolo.

A report on the program has been received by the Governor from Commissioner Ernest A. Johnson, Commissioner of Labor and Industries in the Commonwealth.

Under the plan, devised by electronics experts and Department of Labor and Industries officials, electronics firms are provided with a basis for establishing and conducting their own trainee projects with guidance of a work process outline. The outline prescribes courses for on-the-job training and related technical instruction which ultimately would qualify a trainee as an electronics technician journeyman.

Hubert L. Connor, Director of the Division of Apprenticeship Training, is spearheading efforts now being made in the electronics industry in the state to activate the program.

They comprise an Industry Advisory Committee which was formed last year upon request of the Department of Labor and Industries to assist in mapping out all phases of the program.

Receiving certificates were: Joseph H. McCusker, Materials Advanced Development Laboratory, Radio Corporation of America of Needham; Dr. Ward Low, Missiles Systems Laboratory, Sylvania Electric Products of Waltham; Charles Barrett, Engineering Model Shop, American Machine and Foundry Company, Boston; Walter B. Driscoll, Electronics Processing Equipment Department, Raytheon Company, of Waltham; John H. Winant, Employee and Community Relations, Sprague Electric Company of North Adams; Herbert C. Ryan, CBS-Hytron, of Danvers; and Luke L. Lomartire, Apprenticeship and Training Improvement, Raytheon Company, of Waltham.

196 STUDENTS GRADUATED BY RCA INSTITUTES

FIVE CITED FOR TOP HONORS

One hundred and ninety-six students were graduated by RCA Institutes recently at exercises held in the auditorium of the School of Education, New York University.

Highest honors went to three men from New York, one from Massachusetts, and one from the Bahama Islands.

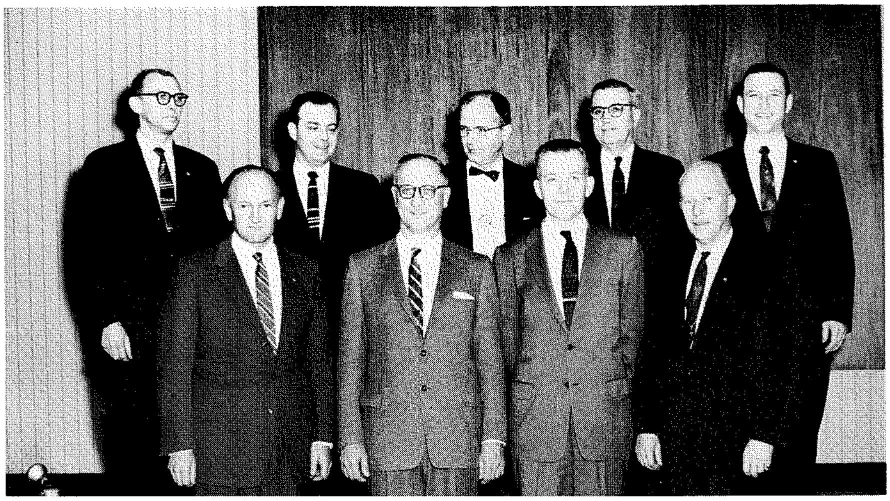
Included among the graduates, who have completed courses in advanced electronics, television and general electronics, and radio and television servicing, are residents of eight states, the Bahamas, Colombia and Haiti. Fifty-five per cent of the class are veterans.

Dr. Otto Klitgord, President of the New York City Community College, delivered the commencement address.

At the conclusion of the exercises, George F. Maedel, President of the Institutes, made special awards to the five students who completed their courses with the highest academic standing.

They were: Robert E. Bowlby, Waltham, Mass.; Eugene K. Jansen, New York, N.Y.; Michael A. Jarrett, Brooklyn, N.Y.; Carl Mark Bethel, Nassau, N.P., Bahamas; and James Leland, East Meadow, N.Y.

1957 ANNUAL PRODUCT ENGINEERING REVIEW AT LANCASTER



Speakers and special guests at the Tube Division's Annual Product Engineering Review: left to right, R. W. Engstrom, F. S. Veith, C. W. Thierfelder, E. E. Spitzer, L. P. Garner, G. G. Carne, D. F. Schmit, D. Y. Smith, and C. P. Smith.

Approximately 500 RCA engineers and guests attended the 1957 Annual Product Engineering Review held at Lancaster on February 6, 1958. E. E. Spitzer, Manager, Industrial Tube Products Engineering opened the program and presented the Engineering Highlights for Industrial Tubes. He summarized overall progress and introduced other speakers who related the Engineering Achievements by product line. These speakers included F. S. Veith, Manager, Camera, Oscillograph and Storage Tube Development; G. G. Carne, Manager, Industrial Receiving Tube Engineering at Harrison; R. W. Engstrom, Manager, Phototube and Image Tube Development; L. P. Garner, Manager, Power Tube Development and Application; and H. K. Jenny, Manager, Microwave Tube Design and Development at Harrison. Then C. P. Smith, Manager, Kinescope Engineering, reviewed the activities of Color Kinescopes, after which he introduced C. W. Thierfelder, Manager, Black and White Kinescope Engineering at Marion, who summarized the achievements of his activity. The program coordinators were W. G. Fahnestock and D. G. Garvin.

Special guests from several plant locations included Mr. D. F. Schmit, Vice President, Product Engineering, RCA Staff, and Mr. D. Y. Smith, Vice President and General Manager, RCA Electron Tube Division, who spoke briefly of engineering accomplishments and objectives and the vital relationship between engineering and other Electron Tube Division functions.—*D. G. Garvin*

J. M. TONEY APPOINTED TV DIVISION V.P.; THREE NEW VICE PRESIDENTS ELECTED

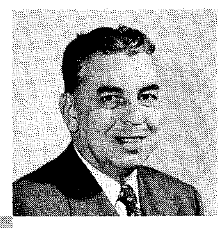
In a recent organizational move, J. M. Toney, formerly Vice President of the Radio and "Victrola" Division, has been appointed Vice President of the RCA Victor Television Division. Mr. Toney has been with RCA since 1943, where he started as an expediter in the Purchasing Department in Chicago.

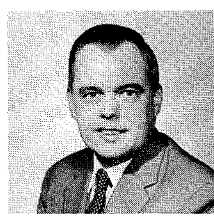
J. M. Toney

Three New Vice Presidents Elected

According to a recent announcement by John L. Burns, RCA's President, Dr. James Hillier was elected Vice President, RCA Laboratories, of which he has been general manager since January 1957. Raymond W. Saxon, formerly Director, Regional Operations, was elected Vice President and General Manager, RCA Victor Radio and "Victrola" Division, replacing J. M. Toney. Joseph M. Hertzberg was elected Vice President, Defense Marketing, DEP, of which he has been manager since July, 1957.

R. W. Saxon





Dr. J. Hillier

J. M. Hertzberg

TUBE DIVISION ELECTS NEW REPRESENTATIVE

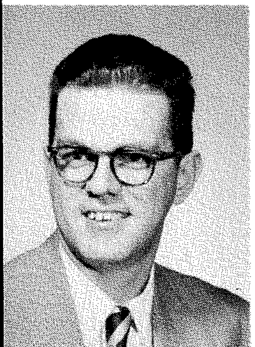
Herbert J. Wolkstein has been appointed Editorial Representative for the RCA ENGINEER, representing Industrial Tube Products in Harrison, according to a recent announcement by John F. Hirlinger, Editorial Board Chairman, Electron Tube Division.

Mr. Wolkstein received the BS degree in Electrical Engineering in 1953 at Newark College of Engineering and is presently working toward an MS degree in the same field. In 1945 and 1946 he served with the Air Force as a radar operator (technical) with Army Airways Communications System. In 1948 he became a member of the Research Laboratories of National Union Electric Corporation where he worked as project engineer on the design of special purpose beam deflection and computer tubes. He joined RCA Microwave Engineering in 1955 where he has since been engaged in the development of traveling-wave tubes. In this area he had made outstanding contributions on electron-beam-focusing periodic magnets, and the design of slow-wave structures. He has been awarded several patents in the electron tube field and other patents are pending. In addition he is the author of a number of articles which have been published and presented at technical conferences. Mr. Wolkstein is an Associate Member of the Institute of Radio Engineers.

COMMITTEE APPOINTMENTS

Dr. George R. Arthur has been re-elected first vice-president of the American Astronautical Society at its annual convention in New York City on January 29-31, 1958. Dr. Arthur, Manager of Airborne Infrared and Television Design in DEP's Airborne Radar and Missile Engineering, was also selected as an assistant editor of the *Journal of the Astronautical Sciences,* the official publication of the Society.—*J. F. Biewener*

L. Wolin, ASTRA Project, DEP, has been elected chairman of the Philadelphia Chapter of the IRE Professional Group on Automatic Control.—*T. P. Canavan*



G. A. Arthur

L. Wolin

R. H. Zachariason

L. Siepietowski

R. H. Zachariason, Manager, C & P Lab., Color Kinescope Engineering was re-elected for another term as Chairman of the Manheim Twp. Zoning Board of Adjustment. —*M. Slater*

L. Siepietowski, Equipment Development Engineering in Lancaster, is serving as Chairman of the Lancaster County Multiple Sclerosis Committee.

This organization has a country-wide education program with speaking engagements involving 20 service clubs, church groups, social groups, etc. Countless newspaper articles publicize their efforts and make the public more aware of this progressively crippling disease, of which there is no known cause or cure.

M. S. most often strikes young people between the ages of 20 and 40. More than 500,000 Americans suffer from this disease and closely related diseases of the central nervous system.

The Committee's first fund-raising campaign—1957—was well organized and exceeded a projected goal of $5,000 by $2,000. —*D. G. Garvin*

REGISTERED PROFESSIONAL ENGINEERS

The following names have been added to the RCA ENGINEER list of registered Professional Engineers:

Name	*State*	*Licensed As*	*License No.*
Electron Tube Division, Harrison			
J. S. DiMauro	N. J.	Prof. Engr.	A-7656
RCA Victor Television Division, Indianapolis			
R. P. Crowner	Ind.	Prof. Engr.	6879
E. Montoya, Jr.	Ind.	Prof. Engr.	6584
J. Osman	Ind.	Prof. Engr.	3731

ENGINEERING MEETINGS AND CONVENTIONS

April-May, 1958

APRIL 2-4
Conference on Automatic Optimization Sponsored jointly by IRE, ASME, AIChE, ISA, U. of Delaware, Newark, Del.

APRIL 8-10
IRE Electronic Wave Guides Symposium, Engineering Society Building, New York, N.Y.

APRIL 10-12
IRE S.W. Regional Conference & Show, Municipal Auditorium, San Antonio, Tex.

APRIL 14-16
AIEE Automatic Techniques Conference, Hotel Statler, Detroit, Mich.

APRIL 14-17
ASME Design Engineering Conference, Chicago, Ill.

APRIL 21-26
SMPTE (Closed Program), Ambassador Hotel, Los Angeles, Calif.

APRIL 22-24
Electronic Components Conference, Ambassador Hotel, Los Angeles, Calif.

APRIL 24-26
URSI Spring Meeting, Willard Hotel, Washington, D.C.

APRIL 27-MAY 1
National Association of Broadcasters, Baltimore and Statler Hotels, Los Angeles, Calif.

APRIL 27-MAY 1
American Ceramic Society, 60th Annual Meeting, Penn-Sheraton Hotel, Pittsburgh, Pa.

APRIL 30-MAY 2
IRE 7th Region Technical Conference & Show, Hobbies Building, State Fair Grounds, Sacramento, Calif.

MAY 5-7
IRE PGMT&T National Symposium, Stanford University, Calif.

MAY 6-9
Western Joint Computer Conference, Ambassador Hotel, Los Angeles, Calif.

MAY 12-14
National Aeronautical and Navigational Electronics Conference, Dayton, Ohio.

MAY 26-28
American Society for Quality Control, National Meeting, Boston, Mass.

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EDITOR, RCA ENGINEER
Radio Corporation of America
Bldg. 2-8, Camden 2, N. J.

RCA ENGINEER

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Street or Bldg. ______________________________

City and State or Plant ______________________________

INDEX

TO VOLUME 3

June-July 1957 to April-May 1958

The number preceding the dash denotes the issue. The number following the dash indicates the page number in that issue. Issue numbers are as follows:

1 June-July 1957
2 October-November 1957
3 December 1957-January 1958
4 February-March 1958
5 April-May 1958

Occasionally an (ED) will be noted following an article title, with no page reference. This is an editorial on the inside front cover of the issue indicated.

RCA ENGINEER EDITORIAL REPRESENTATIVES

The Editorial Representative in your group is the one you should contact in scheduling technical papers and arranging for the announcement of your professional activities. He will be glad to tell you how you can participate.

DEFENSE & INDUSTRIAL ELECTRONIC PRODUCTS

Editorial Representatives, Defense Electronic Products

I. N. BROWN, *Missile and Surface Radar Engineering, Moorestown, N. J.*

T. P. CANAVAN, *Airborne Fire Control Engineering, Camden, N. J.*

H. R. DYSON, *Technical Administration, Camden, N. J.*

R. W. JEVON, *Airborne Systems Laboratory, Waltham, Mass.*

DR. D. G. C. LUCK, *Airborne Systems Equipment Engineering, Camden, N. J.*

C. MCMORROW, *Aviation Communications and Navigation Engineering, Camden, N. J.*

J. H. PRATT, *West Coast Engineering, Los Angeles, Calif.*

L. M. SEEBERGER, *Special Systems and Development, Camden, N. J.*

E. O. SELBY, *Surface Communications Engineering, Camden, N. J.*

W. W. WAGNER, *Camden Engineering Personnel, Camden, N. J.*

H. L. WUERFFEL, *Engineering Standards and Services, Camden, N. J.*

Editorial Representatives, Industrial Electronic Products

I. F. BYRNES, *Radiomarine Engineering, New York, N. Y.*

H. E. HAYNES, *Advanced Development Engineering, Camden, N. J.*

C. E. HITTLE, *Hollywood Engineering, Hollywood, Calif.*

C. D. KENTNER, *Broadcast Transmitter and Antenna Engineering, Camden, N. J.*

T. T. PATTERSON, *Electronic Data Processing Engineering, Camden, N. J.*

J. H. ROE, *Broadcast Studio Engineering, Camden, N. J.*

J. E. VOLKMANN, *Theater and Sound Products Engineering, Camden, N. J.*

B. F. WHEELER, *Communications Engineering, Camden, N. J.*

RCA LABORATORIES

Editorial Representative

E. T. DICKEY, *Research, Princeton, N. J.*

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