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RCA ENGINEER

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OBJECTIVES

To disseminate to RCA engineers technical information of professional value.

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

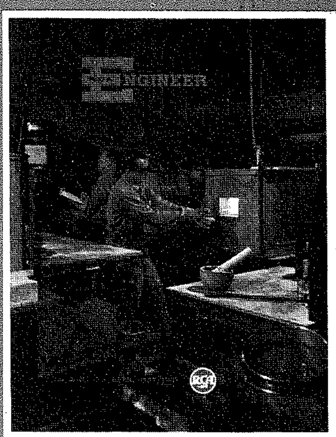
To serve as a medium of interchange of technical information between various engineering groups at RCA.

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

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

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

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



OUR COVER

Our cover this issue features the Ferrite Laboratory of the Components Division in Camden, N. J. Chemical engineer George Katz is shown removing an experimental ferrite sample from one of the electric kilns, while engineer John Simpkiss checks temperature recording equipment.

COMPONENTS ENGINEERING

The responsibility for developing and perfecting new and better materials and parts rests with the components engineer. New components must be designed so that they are simpler to make, more efficient to operate, and less expensive than their predecessors.

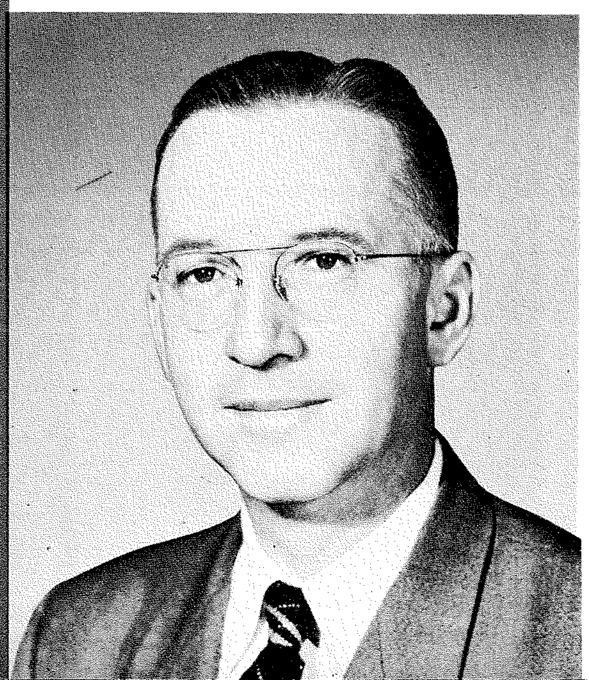
In accomplishing these objectives, the components design engineer, like many other engineers, must work in the fields of analysis, selection, standardization, design, performance testing, and application engineering. To a great extent, however, his success depends on his ability to communicate with others. He must cooperate effectively with other engineers in resolving design problems, and must work closely with customers who will use his product, as well as with manufacturing personnel who will make it. It is through good communication, and the accompanying good understanding, that his plans and ideas will be converted into new products. In this way the components design engineer can be assured that his contributions will result in the effective utilization of the component.

Today we are on the threshold of a revolution in electronic materials and components. Looking backward, we can trace the history of electronic materials almost without exception to their roots in the electrical industry, which grew up around electric-lighting and power-generating equipment requirements. Because these materials, or adaptations of such materials, are no longer the answer to the needs of the electronics industry, new materials must be developed in order that this dynamic industry will continue to grow. One of the significant material developments in this revolution is ferrite, which is featured in this issue of the RCA Engineer.

Ferrites are assuming an important role in commercial, industrial and military equipment of all kinds: computers, receivers, laboratory equipment, special military control devices, radar, and magnetics in rotating machinery. Closely following ferrites will come the materials still in the research and development laboratories — thermoelectrics, ferroelectrics, titanates, and others.

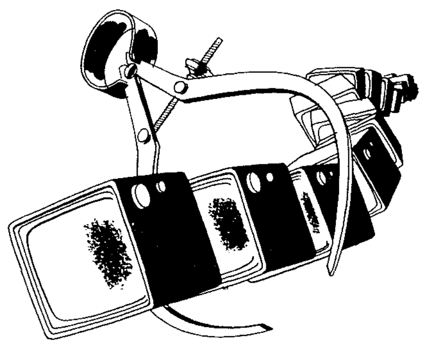
The revolution will not be confined to materials. They will contribute, in turn, to the development of radically new components. The components of the future, now in development, will perform multi-functions, will embrace modular construction and miniaturization, and will be produced by automation techniques. This new development approach requires of the components engineer a bold new concept in component design.

With this concept of major change in the near future, it becomes clear that circuit designers become more and more dependent on the components and materials engineers. In the pursuit of new developments, we must remember, "An electronic chain is no stronger than its weakest component."



B. V. Dale
Chief Engineer
Components Division
Camden, N. J.

STANDARDS AND THE ENGINEER



By
S. H. WATSON, Mgr.
Corporate Standardizing
Camden, N. J.

THE ENGINEER'S MOST important personal asset, from an engineering viewpoint, is his creative ability. His time and effort are best spent in developing and applying this asset. Engineering projects abound with factors that tend to divert the engineer into channels leading only to a belated rediscovery of things long since established through standardization. Time and effort wasted along such non-productive avenues delay the completion of creative tasks, increase costs and are likely to retard professional advancement.

Standardization is a major defense against influences that compromise the effective utilization of engineering talent. It is one of the most valuable tools available to the engineer, yet it is too frequently neglected early in his career. Engineers who become adept in the full exploitation of standards acquire a substantial performance advantage over those who do not.

HOW "STANDARDS-MINDED" ENGINEERS STANDARDIZE

In product design, advanced development and even in research, standards-minded engineers can usually meet 50 to 90 percent of their needs by employing the following practices: (1) never create a special item until it is determined that there is no existing standard that will satisfy the requirement. (2) When "parts peculiar" are required, make full use of standard materials, finishes and standardized design parameters. (3) When new materials and finishes, electrical or mechanical components are required enlist the specialized skills of the materials, industrial finishing, and components standards engineers in the product division and Corporate Standardizing Division. (4) When new standards are introduced, quickly and critically evaluate them, recognize their merits, and employ them at every good opportunity. (5) Discontinue the use of older standards that have fallen into obsolescence.

Through careful adherence to these practices in engineering, many RCA products, up-to-the minute in every practical respect, appear in the hands of the customer in a remarkably short time.

STANDARDS SAVE TIME AND MONEY

An excellent example of what can be accomplished with a comprehensive standardization program when time is a limiting factor is contained in the following description.

Shortly after the end of World War II, RCA experienced an influx of orders for a variety of equipments. They were urgently needed by RCA customers to expedite conversion to peacetime commercial pursuits. Many orders were filled within one or two weeks. This was possible only through the availability of a well-planned collection of standards in the hands of competent and ingenious product engineers. Part of the planning in anticipation of the inrush of post-war orders was the design of the now well-known standard RCA cabinet and rack. When the cabinet program was completed in mid 1945, six RCA product groups pooled an order for 1500 units, saved $200,000 through tooling and volume production, and had cabinets in finished goods stock when the rush came. The use of the standard RCA cabinet, in this manner, continues today; 4000 have been manufactured and sold in the past two years. Although this shows the great potential value of using standards, every engineer is encouraged to inquire into them in terms of his own engineering needs.

SOME FACTS ABOUT STANDARDS

In making a personal evaluation of standards and what they can do for him, the engineer must be realistic. He must make his approach on an "I want to know the facts" basis and with a willingness to accept reality and plot his course accordingly. Too frequently, standards are thought to stifle progress; they are accused of being restrictive, inhibitive and of creating an unhealthy state of fixation. Actually, this is never true. Invariably, the only restrictions and compromises the engineer should countenance and live with are those dictated by common sense and good judgment; they stem from economic considerations, law and regulation or limitations in the current state of a particular art.

ADOPTING NEW STANDARDS —ABANDONING OLD

Our own RCA pioneering experience with the 45 RPM phonograph record and companion record changer provides an excellent illustration of how engineers should challenge old, outmoded standards and adopt new ones when the time is right.

For over forty years the industry and millions of phonograph customers had lived with the small center hole and 78 RPM speed. A variety of automatic record changers had been introduced through the years, each one compromised in complexity and expense due to the economic considerations which dictated adherence to the standard. Finally, RCA engineers envisioned a combination product with potential of sufficient attractiveness to justify advanced development. The initial work was highly successful and prompted preliminary product design and production prototypes. At this point, a decision of far-reaching significance had to be made. It was a question requiring astute judgment in weighing the merchandising possibilities of the new products and the impact of introducing a radically new standard where one of long standing was deeply entrenched. As is frequently the case, engineers alone could not finalize the decision; they joined with merchandizers and top management and launched two new products involving new standards. The outstanding success of the 45 RPM record and record changer is due to the combined excellence of engineering and merchandising. Those who participated can be justly proud of their wisdom and vision.

As described in the foregoing example, an engineer whose projects reflect maximum benefits from standardization, is one who not only makes maximum use of standards but also applies vision and good judgment in selecting new approaches.

TAKE ADVANTAGE OF NEW STANDARDS

Another factor of vital importance to the engineer is alertness to take every advantage of the features made available in newly introduced standards. For example, in 1951, the Standardizing Division, following the lead of a farm equipment manufacturer, introduced the "roll-pin" as a general purpose standard fastener. It was destined to eliminate or greatly reduce the use of the taper pin, a well established RCA standard, which had served dependably for many years in RCA operations. The taper pin, however, requires a drilled pilot hole in the two parts to be joined, followed by a slow and expensive taper reaming operation. The roll pin requires only a drilled hole. A year and a half later a follow-up revealed that the economies and performance advantages of the new standard had not been widely recognized; thousands of assemblies were being processed into manufacturing burdened with the unwarranted cost and delay of taper reaming.

One product group, however, had adopted the new standard one-hundred percent. The reason is interesting. The product engineers were engaged in the design and development of an equipment that operated at high speed. At 12,000 RPM, taper pins, predominantly heavy at one end, would disengage and throw out. The new standard fastener completely solved the performance and reliability problem and introduced a substantial reduction in cost.

OPPORTUNITIES ARE UNLIMITED

Just as in the example of the "roll-pin" and the 45 RPM player there are scores of similar interesting cases that could be cited not only by RCA engineers, but by personnel in every RCA function: all demonstrating conclusively the terrific potential in standards to expedite the development and production of RCA products. Whether he is engaged in research, advanced development or product design, the engineer has unlimited opportunities to make use of standards. Standards are being applied every day in routine fashions with scarcely a realization that the standard is being put to work. Other, not so obvious, opportunities to use standards are fascinating and challenging and often result in new and ingenious applications of proven standards.

There is, therefore, a strong motivation and a responsibility for the engineer to become thoroughly familiar with RCA engineering standards and to develop a close working relationship with the standards engineers in the product division and those in the Corporate Standardizing Division.

The RCA standards books available to engineers in RCA operations throughout the world, contain a wealth of thought provoking information and the answers to thousands of design needs.

Standards engineers devote their entire time to standards and to the problems solved with existing or newly developed standards. In working with them, frequently you will find that a seemingly new and unique problem has already been solved and the answer is waiting for you. Frequently, also, you will be a contributor to the advancement of standardization; the ingenuity you have applied in meeting a challenging situation with standards may well be an important story to be told and made available to countless other engineers.

SAMUEL H. WATSON entered the General Electric Company, Schenectady, N. Y., in 1922 where he specialized in calculating weights, stress and strain. He entered the G. E. Engineering School in 1923 and graduated in 1927. In 1929, Mr. Watson transferred to RCA in Camden, N. J., and engaged in design and field engineering on automotive and aircraft receivers until the spring of 1941. From 1941 until 1944 he was engaged as mechanical project engineer on armed forces communications equipment. He was appointed manager of the Corporate Standardizing Division in 1944.

Mr. Watson currently represents RCA on the American Standards Association Company Member Conference. He was chairman of the conference in 1949 and again in 1952. He is a senior member of the IRE and a charter member of the Standards Engineers Society.

A REVIEW OF FERRITES AND THEIR APPLICATIONS

by

G. S. HIPSKIND

Components Division
Camden, N. J.

ALTHOUGH FERROMAGNETIC spinels, or "ferrites," were known in ancient times, it was not until the late 1930's that they came into their own as a magnetic material. Up to that time the history of magnetic materials had progressed from a solid soft-iron pole piece used by Edison in his first generator to the laminated sheet steel used in modern rotating machinery. In radio and television, however, where higher and higher frequencies are encountered, laminated materials are not satisfactory because of high eddy-current losses.

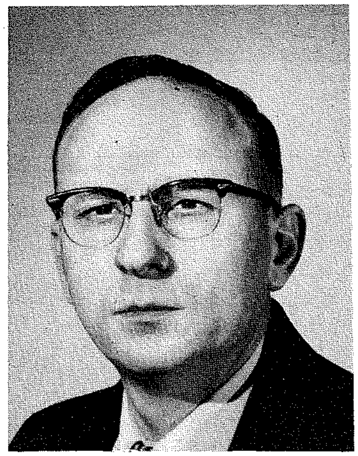
The next magnetic material to appear on the scene was powdered iron. Because the iron particles were finely divided and insulated from one another, the eddy-current losses were greatly reduced. There was, however, one great disadvantage in this development: The non-magnetic insulating material formed air gaps between the magnetic particles and thus reduced the effective permeability of the iron.

Modern ferrite materials have several unique advantages over other magnetic materials including relatively high permeability, very high resistivity, and low eddy-current loss. In addition, ferrite is a solid material which does not require laminating.

PRODUCT DEVELOPMENT AND THE MARKET

As a result of continued research and development on this new magnetic material, it was possible by the end of 1949 to market ferrites for use in deflecting yokes and flyback transformers. Several years later, the frequency range of ferrite material was extended to include radio frequencies, and ferrite antennas appeared in a number of portable radios. By 1954, "rectangular-loop" ferrites had been developed for use in the electronic computer field. In 1955, ferrites exhibiting a high degree of magnetostrictive activity were employed in the manufacture of electro-mechanical filters. Also in 1955, ceramic (ferrite) magnets were developed for use in deflecting yokes for color television receivers.

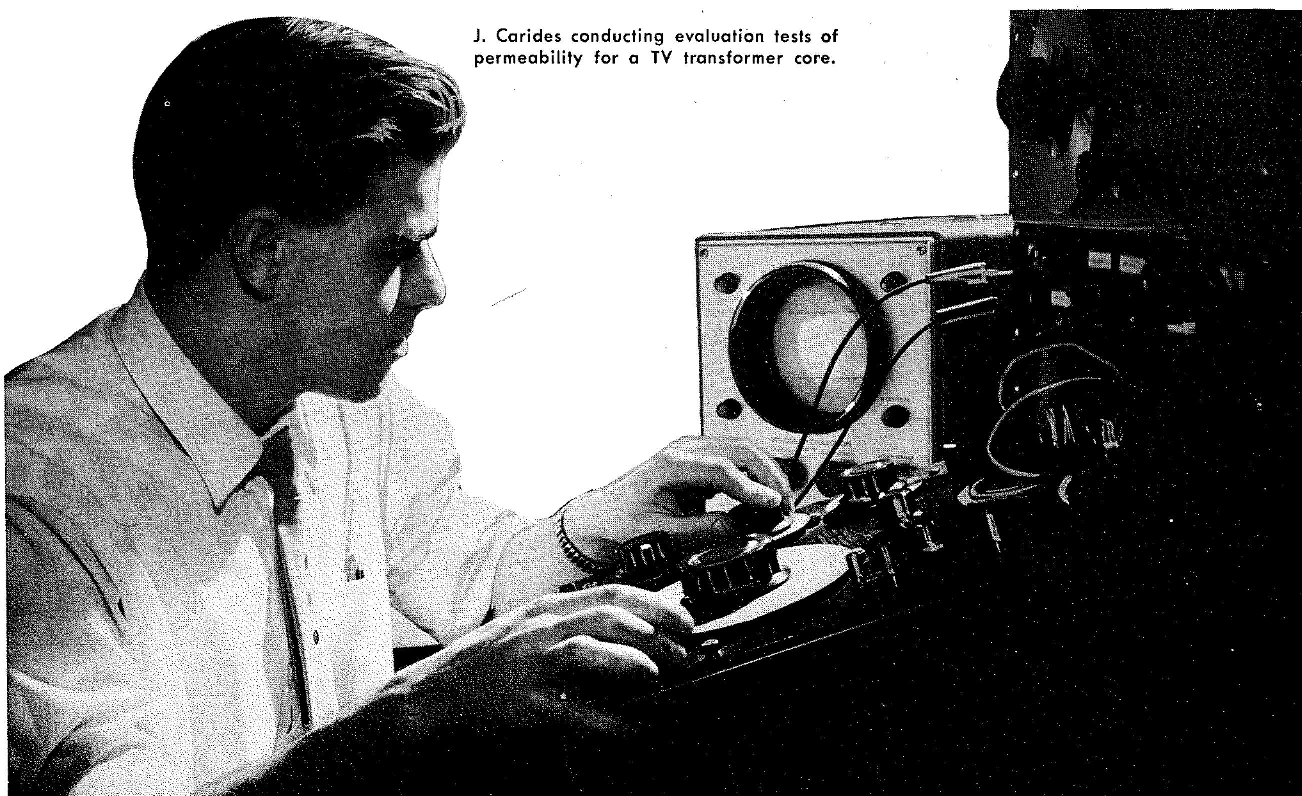
It is interesting to speculate on other applications in which ferrites may be used. Metallic magnetic materials have been developed over a long period of time, during which their frequency range has been gradually



GLYNDON S. HIPSKIND received the B.S.E.E. Degree in 1942 from Indiana Technical College, and continued his studies in the graduate school at the University of Notre Dame.

From 1942 to 1943, he worked in the Plant Engineering Section of the Fort Wayne works of the General Electric Co. and 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 horse power motor developmental test section. He joined RCA in 1950, and is presently associated with Ferrite Engineering in the Component Division.

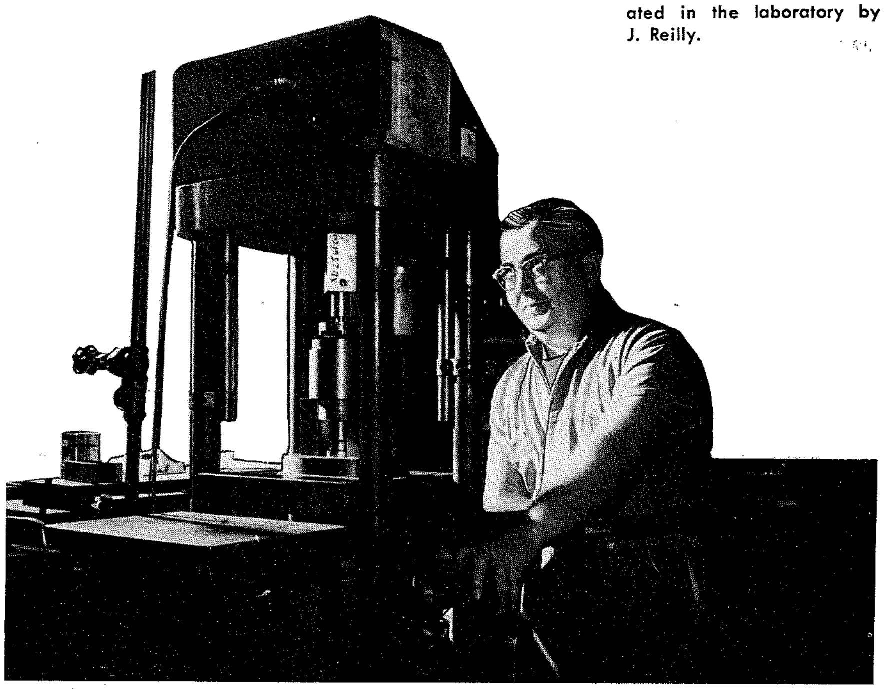
Mr. Hipskind has worked on such projects as Deflection Ferrites, Ferrite Memory Cores, Transducers and Ceramic Magnets.



J. Carides conducting evaluation tests of permeability for a TV transformer core.

extended and their losses have been reduced. It can be expected that the development of ferrite magnetic materials will follow the same trend, but at an accelerated rate. Ferrite materials have already been developed for use in microwave applications. As their permeability-temperature characteristics are improved, and higher permeability and lower losses are achieved, these materials will be useful in the miniaturization of both commercial and military equipment. Rectangular-loop ferrites will also undoubtedly find new uses in the computer and business-machine fields.

Ceramic magnets are presently being used in speakers, refrigerator and cabinet-door latches, and various other applications. Table I shows the major types of ferrites commercially available at RCA, their characteristics, and some suggested applications. One of RCA's greatest advantages in this field is its ability to produce most of these ferrites in very large quantities and, at the same time, to maintain good, uniform quality.



A molding press for TV transformer cores is being operated in the laboratory by J. Reilly.

PROSPECTS FOR THE FUTURE

Because of the nature of the chemistry of these materials, it may soon be possible to produce ferrites having better temperature-permeability characteristics, lower losses, higher permeability, and higher resistivity. With the development of new processing techniques, improved mechanization, and increased volume of production, a reduction in the cost of these improved materials will undoubtedly be realized.

Type	Typical Characteristics	Applications
A1	Soft magnetic material having high permeability, high resistivity, low eddy-current and hysteresis losses, relatively good temperature characteristics. Frequency range 1 to 100 kc.	TV deflection components, pulse transformers; inductors for telephone loading coils; and i-f transformers.
A2	Soft magnetic material having medium-high permeability, very high resistivity, low eddy-current and hysteresis losses, good temperature characteristics. Frequency range 1 to 50 Mc.	Antenna rods and wave guides.
B	Hard or permanent magnetic material having permeability near unity, high resistivity, high coercive force, high energy products.	Color deflecting yokes; traveling-wave tubes; and focusing coils.
C	Rectangular-loop material having square B-H corners, high dB/dH slopes, medium permeability, medium coercive force, high resistivity, low eddy-current loss.	High-speed coincident-current memory elements; switching applications; shift register, and flexoprinters.
D	Magnetostrictive material having high permeability, high resistivity, low eddy-current and hysteresis losses, high degree of magnetostrictive activity, good frequency-temperature coefficient.	Transducers for electro-mechanical filters.

MATERIALS ADVANCED DEVELOPMENT LABORATORY

by
DR. F. E. VINAL and J. H. McCUSKER
Components Division, Needham, Massachusetts

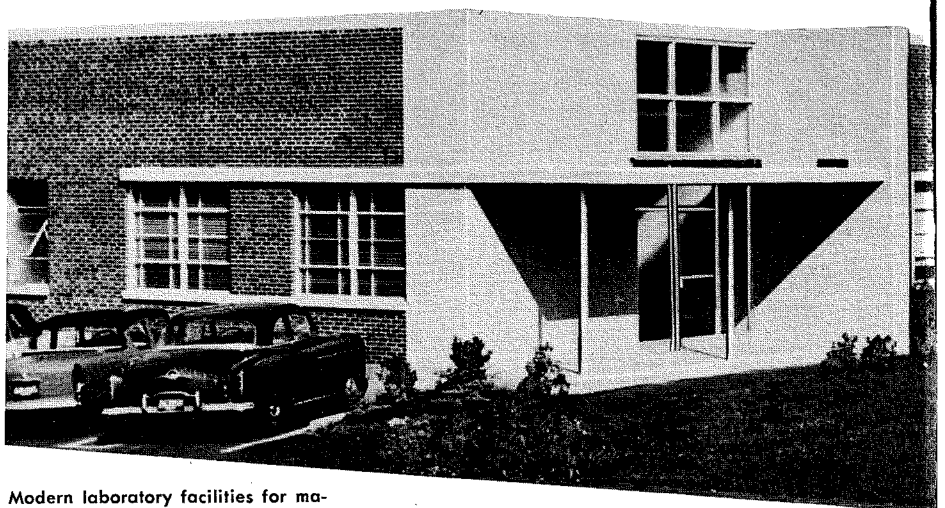
THE USE OF solid-state materials for electronic components has become increasingly attractive in recent years because of the growing need for rugged, long-lived, highly reliable components, preferably of low cost and simple manufacture, which exhibit a high degree of uniformity and reproducibility. Because such components can be only as good as the materials from which they are derived, a materials development phase is necessary to achieve basic improvements and new components.

REQUIREMENTS FOR DEVELOPMENTAL WORK

Today the areas of most intense activity in the development of materials for components include magnetics, dielectrics, insulating materials, luminescent materials, thermistors, transistors, thermoelectrics, glass and ceramics, metal seals, peizoelectrics, rectifiers, photoconductive materials, and superconductive materials. The scope of the current activities of the Components Division encompasses several of these classes of materials, and the activities of the Materials Advanced Development Laboratory are directed to these particular classes.

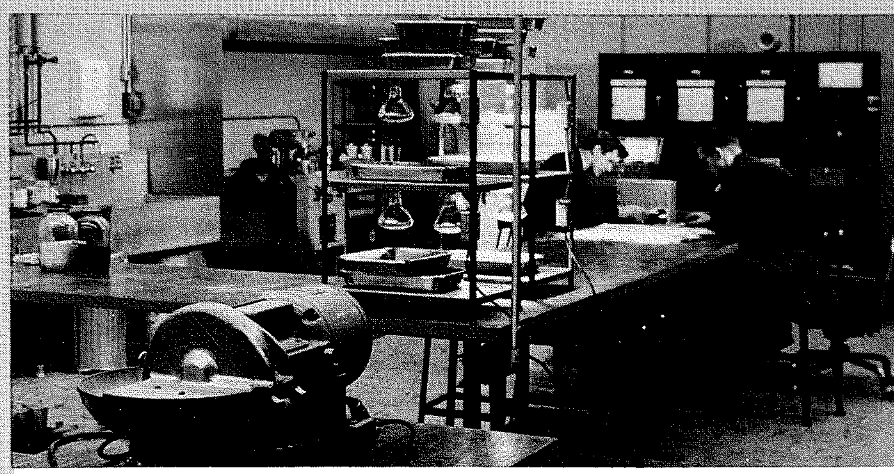
Solid-state materials for components are usually of an inorganic chemical character and are often processed by ceramic techniques and evaluated by physical and electrical measurements for use as circuit elements. Their behavior as circuit elements depends upon the solid-state physical properties. Because persons with the necessary breadth of background to handle competently all these different phases of material development are virtually non-existent, a working team of persons having diverse skills is a prerequisite. A further need for such developmental work is proper facilities. Because the daily tasks run a gamut from basic physics and chemistry through processing to precise electrical evaluation, diverse and precise instrumentation is also a necessity.

An additional need, which is perhaps not so easily anticipated, is breadth of scope. Although the activity is primarily of a development character, the scope should include sufficient latitude to permit such physical and chemical considerations of a fundamental nature as may be re-



Modern laboratory facilities for material research at Needham, Mass.

Processing Laboratory



Crystal Structor Laboratory

quired for a sound working basis. Likewise, processing studies should be carried far enough to assure a feasible process.

NEW LABORATORY

The realization of these needs led to the establishment in mid-1956 of the Materials Advanced Development Laboratory for the Components Division. The Laboratory is located in the New England Industrial Center in Needham, Massachusetts. This "garden-type" industrial development provides an excellent atmosphere for a laboratory and has been a considerable factor in the employment of highly-skilled technical personnel. The activity is housed in a new, one-story, brick-and-cinder-block building 20,000 square feet in area. Of this area, 10,000 square feet have now been fitted out for laboratory work; the remainder is occupied by the Tube Division as a distributing center.

At the present time the non-metallic magnetic materials (ferrites) represent the greater portion of the activity at this Laboratory, but work on dielectric and thermoelectric materials has recently been started. The magnetic materials will be used for illustrative purposes in the consideration of the type of problems which are encountered and how they are approached. The typical project outlined below has been considered, but is not at present an active part of the program.

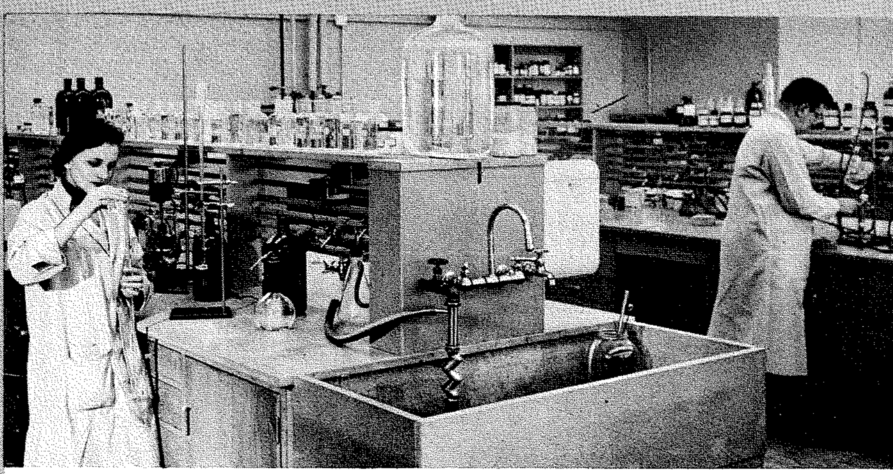
TYPICAL DEVELOPMENT PROJECT: MAGNETIC AMPLIFIER MATERIALS

Although the use of magnetic amplifiers at radio frequencies has often been proposed, to date the materials used have not been satisfactory at frequencies above 100 kilocycles. Magnetic metals are of interest because of their low coercivity and high flux values, and their consequent high permeability. However, they exhibit rather large losses, the best understood of which are eddy-current losses.

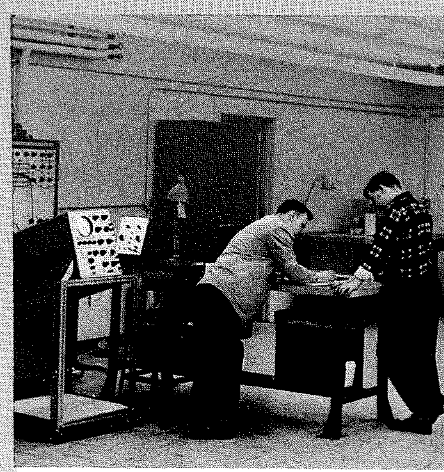
It appears that improved performance of ferrite materials could be expected from higher magnetization values, I_s; lower threshold fields, H_o; and lower switching parameter, S_w. These factors, however, are so interdependent and tied in with Curie temperature and thermal effects that no simple approach is possible. The most likely general areas, therefore, for development of improved magnetic materials for magnetic amplifiers are as follows:

1. Compositional studies of materials likely to have square hysteresis loops and possess high values of I_s and low values of S_w.
2. Processing studies to reveal the significance of grain size and grain perfection on S_w and H_o.
3. Processing studies to ascertain the effects of annealing methods on significant magnetic parameters such as H_o and the B_r-to-B_s ratio.

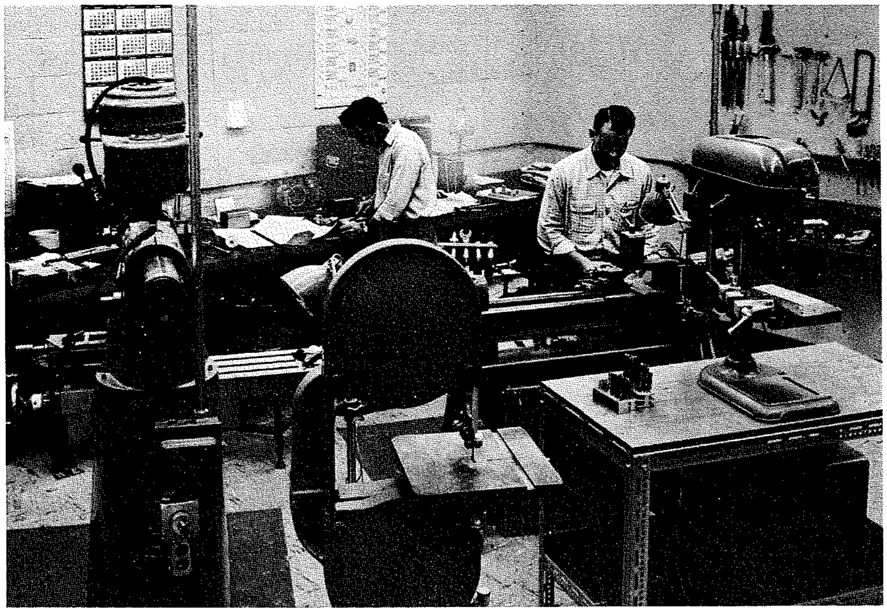
After preliminary investigation of the literature to determine the important parameters, a point is reached where experimental work is called for from persons having diverse skills. An inorganic chemist will judiciously select the proper ions to occupy particular lattice sites in the crystal structure, and syntheses will be made to achieve this structure. An analyst will



Chemical Laboratory



Measurement Laboratory



Model Shop

check by chemical methods to ascertain that the intended stoichiometry is correctly achieved. A crystallographer will then examine the crystal lattice by X-ray diffraction and crystallographic techniques to be sure of the structure and to provide new information where a highly original material has been synthesized. The processing chemist then converts the new substance into useful sizes and shapes, and the electrical engineer and physicist evaluate the degree of success (or failure) to meet the desired objectives.

When a promising material has been made, a period of optimization will usually increase its performance by a factor of two or better. After this optimization period, the material is turned over to the product engineering activities for use in component designs.

PRESENT AND FUTURE ACTIVITY

It may occur to some readers that the pertinent parameters discussed in this paper are derived from theoretical considerations, and that specific materials to realize these improved properties are not enumerated. The discussion has deliberately been handled in this manner because of the preliminary nature of this program.

Although most of the current projects are sponsored by the Components Division, three are supported by the Applied Research Program of the Princeton Laboratory and two receive Corporate Funds support. In addition, two proposals have been made to government agencies and are now under consideration. During recent months, the staff of the Materials Advanced Development Laboratory has been instrumental in the addition of two new materials to the ferrite product line, the high-speed memory core, 221M1, and the low-drive memory core, 222M1. The staff enjoys the challenge offered by the various technical projects, and looks forward to reporting to the readers of the *RCA Engineer* future developments of new and interesting materials.

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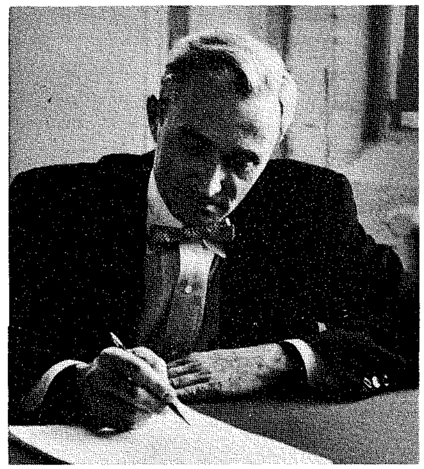
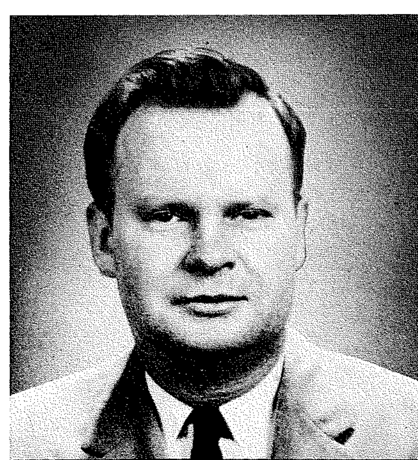
DR. F. E. VINAL received the B. A. degree in Chemistry in 1936 and the M. A. degree in chemistry in 1938 from Wesleyan University, and the Sc. D. degree in inorganic chemistry from M. I. T. in 1941. He also completed two years of evening study at the Georgetown University Law School.

During the war years he was attached to the National Defense Research Committee, serving on the headquarters staff and on various projects concerned with vesicants, automotive lubricants, liquid oxygen, and uranium purification techniques. He returned to M. I. T., in 1946 to serve on the faculty as Assistant Professor of Ceramics. When the M. I. T. Lincoln Laboratory was established, Dr. Vinal transferred to that group to establish and supervise the chemistry section of the Computer Division. Dr. Vinal joined the Components Division of RCA in 1956 to establish the Materials Advanced Development Laboratory of which he is now Manager.



J. H. McCUSKER received the B. S. degree in electrical engineering from Northeastern University in 1947 and the M. S. degree in electrical engineering from M. I. T. in 1949. From 1944 to 1946, he served as an engineer for the U. S. Atomic Energy Project, developing high-vacuum physical techniques associated with mass spectrometers, ionization chambers, and isotope determinations. In 1949 he became an instructor in Electrical Engineering at Pennsylvania State University. He returned to M. I. T. in 1951 as Chief of the Materials Evaluation Section for the Computer Division, M. I. T. Lincoln Laboratory.

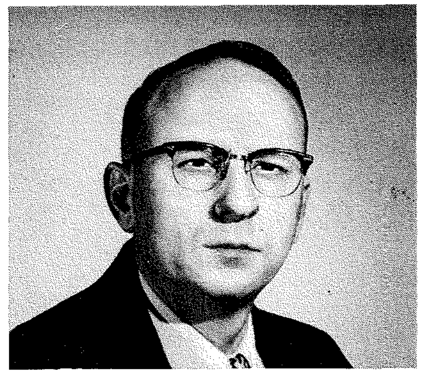
Mr. McCusker joined the Components Division of RCA in May of 1956, and has since devoted his time to the establishment of the electrical measurements laboratory for the Materials Advanced Development Laboratory at Needham. He is presently a Leader of the Technical Staff for electrical measurements.



PROCESSING AND TESTING OF RECTANGULAR-LOOP FERRITE CORES

by **GLYNDON S. HIPSKIND and THEODORE Q. DZIEMIANOWICZ**

Components Division, Camden, N. J.



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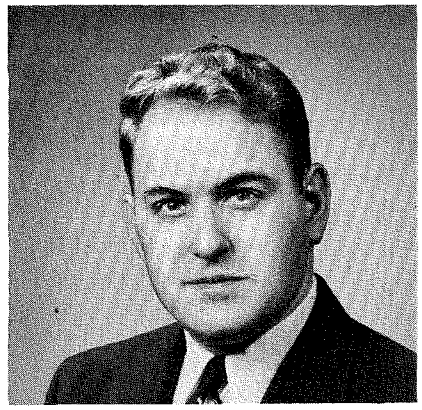

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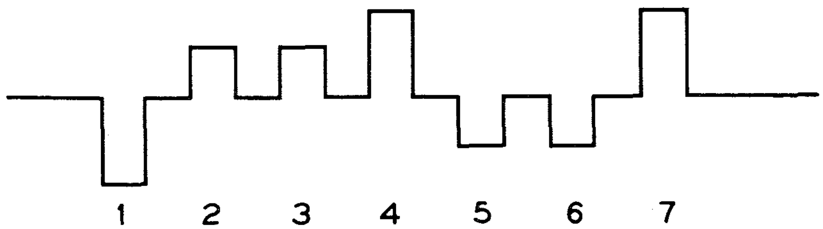


Fig. 1—Magnetizing pulse program simulating operation of a core in a coincident-current magnetic memory.

MATERIALS HAVING RECTANGULAR hysteresis loops are used in applications such as storage devices for digital computers, magnetic amplifiers, and magnetic switching devices.

The need for such materials for use in a double-coincident-current memory cell prompted the Ferrite Development activity to start an extensive development program to obtain a suitable ferrite core. The problem was to develop a small ring-shaped ferrite core having suitable "rectangular" *B-H* characteristics. The core should operate so that its flux polarity reverses only when the correct combination of two magnetizing windings are excited coincidentally.

Only a core which retains a large percentage of remanent flux (B_r) of the proper polarity, in spite of repeated "non-selecting" disturbances, can be used as a coincident-current magnetic memory unit. The following material characteristics are necessary for coincident-current operation: B_r/B_m ratio approaching unity, sharp loop corners, low coercive force, high saturation flux density, and high differential permeability dB/dH. The manner in which these characteristics are obtained will be discussed later.

TESTING TECHNIQUE

A magnetizing pulse pattern which simulates the actual operation of a core in a Matrix is shown in Fig. 1 Pulse No. 1 writes a "one"; Nos. 2 and 3, interspersed between the "write" and "read" pulses, disturb the state of the written "one" (pulse No. 3 may be repeated as many as 64 times if desired). Pulse No. 4 reads the "disturbed-one" and, at the same time, places the core in the "zero" state. Pulses 5 and 6 disturb this "zero" state (pulse No. 6 may also be repeated as many as 64 times), and pulse No. 7 reads the "disturbed-zero" output. When this pulse pattern is repeated at a rate of 2 kilocycles per second, the voltage outputs can be observed on an oscilloscope.

The photographs in Fig. 2 show the voltage response of two typical cores having different coercive forces and requiring different values of current drive. The large positive trace is the "read-undisturbed-one" output. This value is slightly higher than the "disturbed-one" output. The small positive trace is the "read-disturbed-zero" output. The large negative trace is the result of the "write-one" pulse. The larger of the two small negative traces is due to the first "disturb" pulse, and the smaller of these traces to the second "disturb" pulses. The signal ratio is the ratio of the peak value of the "disturbed-one" or "undisturbed-one" output to the peak value of the "disturbed-zero" output.

THE NATURE OF FERROSPINELS

Ferrospinels, or ferrites, as they are commonly known, encompass a class of certain oxygen-dominated iron-containing solids which crystallize in spinel structures. The original spinel was a mineral specimen of magnesium aluminate, $MgAl_2O_4$. Compounds which have the same structure as $MgAl_2O_4$ are classified as spinel structures. For work in coincident-memory and low-loss operation at radio frequencies, it is essential that crystal structures be as isotropic as possible. Consequently, only stable iron compounds which crystallize in the cubic system were considered. In the first ferrospinel, therefore, the alumina (Al_2O_3) of the original spinel was replaced with the trivalent oxide of iron (Fe_2O_3). Ferrospinels are now generalized by the formula M Fe_2O_4, where M is a metallic cation nominally assigned the valence of 2+.

GLYNDON S. HIPSKIND'S biography appears on page 4 of this issue. The editors would like to acknowledge Mr. Hipskind's assistance in coordinating many of the ferrite articles in this issue.

THEODORE Q. DZIEMIANOWICZ received a Certificate in E.E. in 1944 from the University of Cincinnati, and B.S. Degrees in Chemical and Ceramic Engineering in 1948 and 1949, respectively, from the Missouri School of Mines and Metallurgy. He is currently working for his M.S. Degree in Industrial Management at Temple University.

Following graduation, he worked as a control engineer on porcelain enamels and research chemist on decalcomanias. In 1950, he accepted a position as research engineer at the Institute of Science of Technology, Fayetteville, Ark.

Prior to joining RCA in 1953, he served as head of the Crystal Chemistry Section at the Frankford Arsenal, Phila.

Since 1953, he has worked on the development of magnetic materials for square-loop application in the Ferrite Development activity of the Components Division.

He is a member of Alpha Chi Sigma, the American Chemical Society, and the Institute of Ceramic Engineers.

SYNTHESIS

Most of the computer cores presently available are synthesized from four basic oxides: (a) ferric oxide (Fe_2O_3), (b) manganous oxide (MnO), (c) magnesium oxide (MgO), and (d) zinc oxide (ZnO). The quantity of each component used depends primarily upon the electrical characteristics desired of the end product. This four-component system can produce computer cores having optimum drives ranging from 300 to 1100 milliamperes and signal-to-noise ratios ranging from 4:1 to 12:1.

The synthesis of ferrospinels is both a simple and a complex process—simple in that basic unit operations are employed, but complex in that each unit operation introduces from one to three variables which directly or indirectly may affect the electrical and magnetic characteristics of the end product. Ferrospinels are generally synthesized in seven distinct operations, as follows: (See Fig. 3)

1. *Mixing*—Pure fine-particle oxides in predetermined proportions are prepared in a water slurry and are intimately mixed by wet ball milling (tumbling with hardened steel balls in a closed steel jar). The mixed slurry is dried and then sieved through a coarse mesh screen.
2. *Calcining*—The dry powder is packed loosely in fire-clay saggers and heated in an electric furnace at a temperature of about 1800° F. This operation may be eliminated in certain cases, depending upon the oxides selected.
3. *Grinding*—The calcined material is ground to a fine powder by wet ball milling. The calcine slurry is then dried and sieved to a fine powder.
4. *Addition of binder and/or lubricant*—Binders are added to the finely ground calcine so that the powder particles will cohere after they are pressed into shape. Lubricants are sometimes also added to facilitate molding.

   Three types of binders are in general use: (a) modified natural rosins; (b) organic gums; or (c) fatty acids. When rosins are used, 3 to 5 per cent by weight (based on the dry weight of the calcine) of the selected rosin is added to the calcine, and sufficient organic solvent is introduced to form a heavy viscous slurry. The binder, calcine, and solvent are mixed together to obtain a uniform distribution of the added organics.

   When organic gums or fatty acids are used, 5 to 8 per cent by weight of the organics is added to the calcine, together with ½ per cent by weight of lubricant. A sufficient amount of hot water is introduced into the system to form a mass having the consistency of stiff mud. The binder, lubricant, and calcine are mixed together as described above for the rosin binder. The water or solvent is evaporated to a low liquid content by heating at a temperature of about 135° F, and the calcined mass is broken up into small lumps.
5. *Classifying*—The dry, lumpy material is classified according to particle size through a series of sieves weighted down with steel balls, and the selected pellets are fraction-retained for the molding operation.
6. *Molding*—On a single-action tablet press, the selected pellet fraction is molded in a polished steel mold to a toroid shape having a 0.025-inch cross-section, a 0.094-inch outside diameter, and a 0.059-inch inside diameter. A weight of about 0.0065 gram for each pellet, pressed at about 3,000 pounds total pressure, produces a square cross-section.

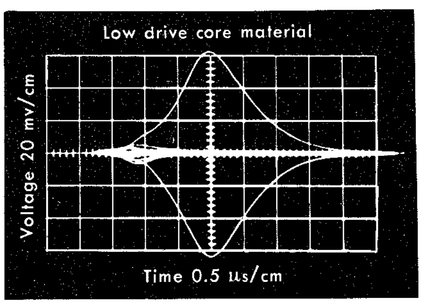
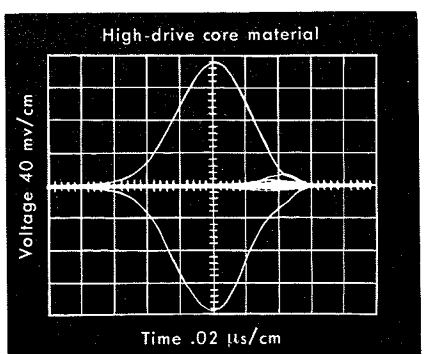


Fig. 2—Voltage response of two typical cores having different coercive forces and requiring different values of current drive.



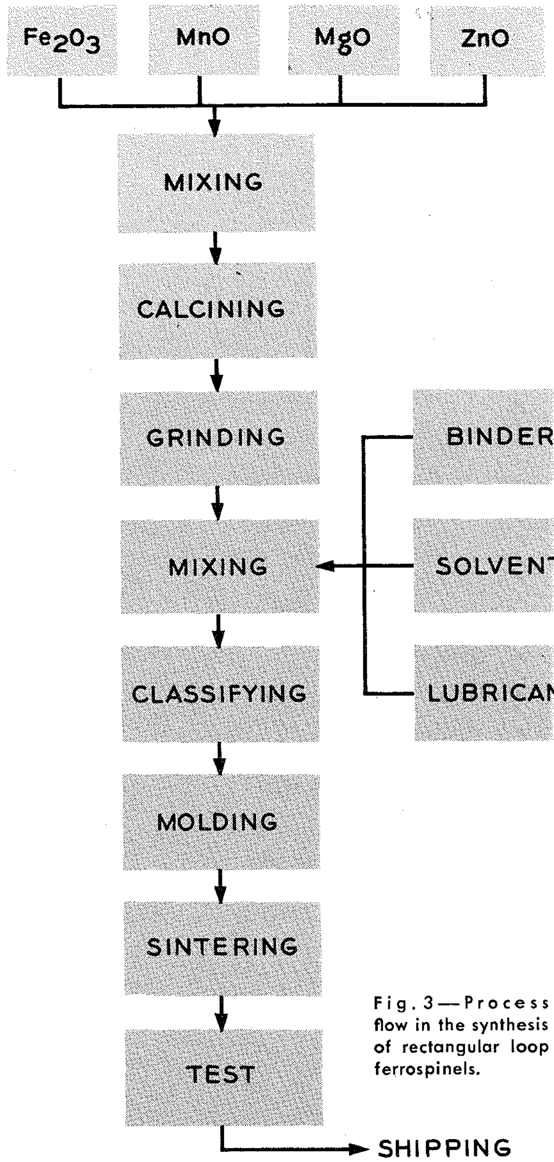


Fig. 3—Process flow in the synthesis of rectangular loop ferrospinels.

7. *Final Heat Treatment*—The molded toroids are placed on high alumina, mullite, or cordierite refractory in uni-layer fashion, and are heated in an electric furnace to volatilize the binder, lubricant, and solvent. The refractory and toroids are then placed in an electric furnace at a predetermined temperature and held there for a predetermined period of time. At the end of this time, the matured toroids are withdrawn from the furnace and either "quick-quenched" in air or "slow-cooled" on the refractory. Curing temperatures and times, as well as cooling cycles, depend on the chemical composition, as well as on the electrical characteristics desired of the end product.

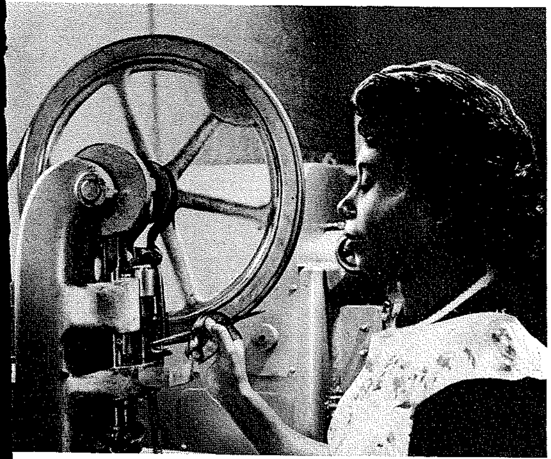


Fig. 4—A molding press producing computer toroids.

PROCESS CONTROL

The electrical and magnetic characteristics of square-loop ferrites are often affected by minor deviations in composition, raw-material purity, molded density, and sintering-time-temperature relationships. Because of errors introduced by the human element, and processing variables introduced by equipment, two successive batches of processed molding powder rarely yield identical electromagnetic parameters when sintered to the same time-temperature cycle. Fortunately, minor deviations introduced through process variables can be compensated for by adjustment of sintering times and temperatures during the final heat-treatment operation. This method, however, requires that each new batch of processed molding powder be test fired before being approved for production runs. This procedure can become quite costly and time-consuming. To minimize the number of test firings required, and to insure a uniform and reproducible product, it is desirable to establish processing control points along the routes of material flow. Some of the critical areas so monitored are:

1. Batching

Because composition defines the optimum electromagnetic characteristics attainable in the end product and governs the type of time-temperature relationships employed during the final heat-treatment operation, critical control of batch compounding is of prime importance. Each component of the batch should be weighed separately on a laboratory-type balance to a maximum tolerance of ± 1 gram. Care should be taken in material-transfer operations to minimize contamination of one component by another.

In some cases, it may be possible to compound a batch sufficiently large to yield a moldable fraction capable of supporting a sustained production schedule through its entirety. This type of procedure, however, is often limited by equipment capacity.

2. Raw material sources of basic oxides

The selection of raw materials for ferrospinels is dependent upon three properties: (a) purity, (b) quantity and nature of contaminants, and (c) particle size and uniformity. Because raw-materials suppliers will not guarantee material uniformity from one lot shipment to the next, processing techniques must sometimes be modified to compensate for raw-material non-uniformity. The raw materials used for ferrospinel synthesis should be of the highest purity available. Certain commercial grades of Fe_2O_3 and ZnO having a parity of 99 per cent or better yield excellent results. Chemically pure (C.P.) grades of $MnCO_3$ or MnO_2 having a purity of 93 per cent or better are recommended as a raw-material source for manganous oxide. C.P. $MgCO_3$ and MgO having a purity of 98 per cent or better have been successfully used as a source of MgO. In the latter two cases, the carbonates appear to yield better electromagnetic properties.

Na_2O, K_2O, and SiO_2, even in minute quantities, tend to destroy rectangularity and radically impair other electromagnetic parameters of computer cores. For this reason, the raw materials used for ferrospinel synthesis should be as free as possible of these common oxide contaminants. The maximum limit of these impurities which can be tolerated is approximately 0.1 per cent on an individual component basis.

Better composition homogeneity during and after mixing is obtained when the raw materials used for synthesis are finely sub-divided and uniform in particle size. Raw material control, therefore, becomes another important link in the control chain. A complete chemical analysis and particle size determination must be made on each new lot of raw material received. When the new lot of raw material is first incorporated into a standard batch mix, the batch composition must be adjusted appropriately to compensate for raw-material impurities. As another step in raw-material control, materials should be stored in closed containers in dry, dust-free areas to minimize the possibility of contamination and chemical deterioration.

3. Calcining and Grinding

The calcining and grinding operations serve three main functions: (a) control of shrinkage and porosity, (b) facilitation of molding, and (c) control of coercive force.

Calcining tends to increase the density of the synthesized molding powder. The denser the powder, the less is the shrinkage experienced by the molded piece during the final curing stage. By proper control of shrinkage, products of uniform size, shape, and electrical characteristics are obtained. Because of their increased density, calcined molding powders tend to flow more uniformly during the molding operation, thereby insuring a more uniform cavity fill and a more uniform end product from one pressing to another.

The function of the grinding opera-

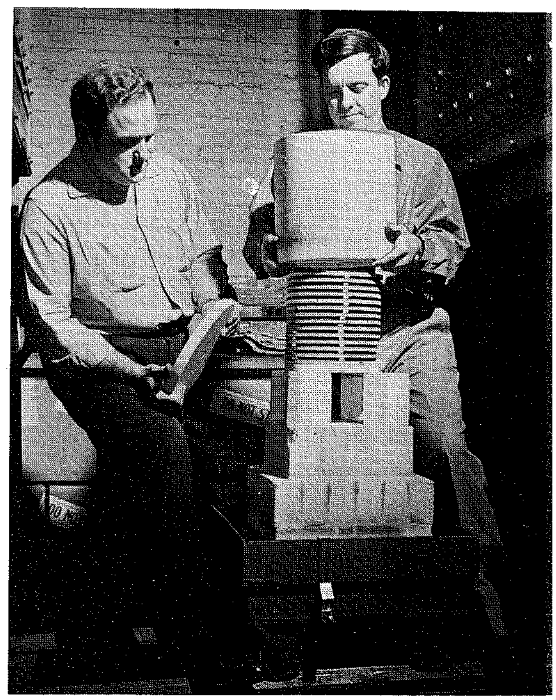


Fig. 5 — T. Q. Dziemianowicz (left) and J. Saylor loading memory cores in a refractory for firing. Discs of ceramic each holding a layer of cores are stacked on the fire-brick base. The base is then rolled under the oven and raised into it for firing.

The function of the grinding operation is to reduce large agglomerates of calcine to a finely sub-divided moldable powder. It also tends to control porosity, curing time, and temperature. In the molding of a fine-particle fraction, individual particles tend to become more closely packed and to have a greater number of contact points with adjacent particles. This packing tends to reduce porosity and electromagnetic discontinuity during the final heat treatment so that a finished toroid of higher rectangularity results. Because their total reactive surface area is greater, toroids molded from a fine-particle fraction tend to mature in a shorter time and/or at lower temperatures than toroids molded from a coarser-particle fraction.

4. Binder

Binders should be added only in sufficient quantities to permit each calcined particle to become coated with a thin film of the binder. The binder should be added in such a manner that a thoroughly homogeneous mass, free from lumpy agglomerates, results. When an excess or globule of binder is incorporated into a molded structure, a void results during the pre-fire or volatilization stage which may fail to close during crystal growth in the final heat treatment, causing a porous or discontinuous electrical path and decreasing the rectangularity of the toroid.

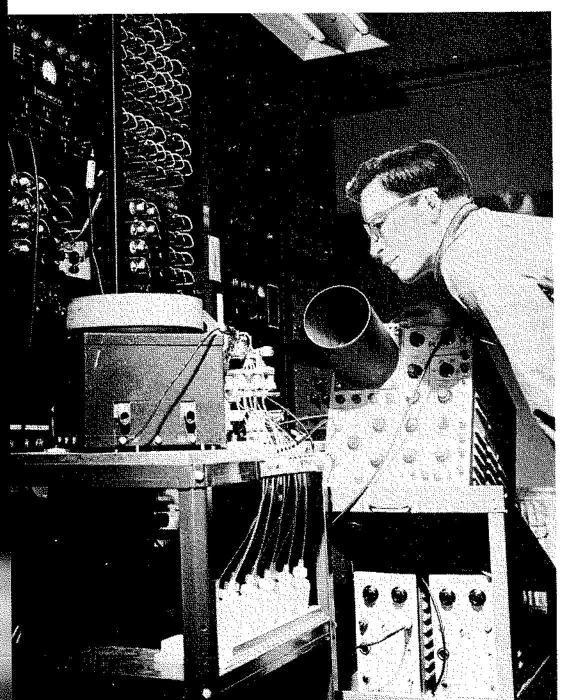


Fig. 6—J. T. Hicks observing an automatic testing machine for ferrite memory cores. The machine tests electrical characteristics of each core and sorts them according to characteristics.

5. Molding

Tool wear necessitates close control of molded thickness, diameter, and weight during the molding operation because all of these physical variables have a pronounced effect on the electrical properties of the finished product. To insure electromagnetic uniformity and high production yields, molded weights and heights should be controlled to tolerances of ± 1 per cent and ± 0.005 inch, respectively. When it is considered that the average molded weight of a standard RCA 80-mil (O.D.) computer toroid is between 0.0055 gram and 0.0065 gram, this desired high degree of control may seem to be well outside of rated tolerances for standard commercially available presses. By the modification of certain mechanical portions of standard commercially available presses, however, the Camden Plant has been able to achieve this high degree of molding control. One of the presses currently in use is shown in Fig. 4.

FINAL HEAT TREATMENT

The function of the final heat treatment or sintering operation is to initiate crystal growth, and to control this growth until the desired electromagnetic properties are attained in the end product.

The sintering operation, the batch composition, the molding process, and the raw-material source comprise the four most critical control areas in the synthesis of ferrospinels. The sintering kiln is the heart of the ferrite operation in that it is the major instrument for controlling the quality of the end product. For this reason, the selection of the proper kiln for a particular type of ferrospinel is of the utmost importance. Because square-loop ferrites are extremely sensitive to even minor deviations in established time-temperature relationships during final heat treatment, the kilns selected for the sintering operation should have the following characteristics:

1. High degree of control
2. Flexibility
3. Instantaneous response to temperature and power adjustments
4. Temperature gradients no greater than 2° C laterally and 5° C vertically
5. Broad temperature operating range

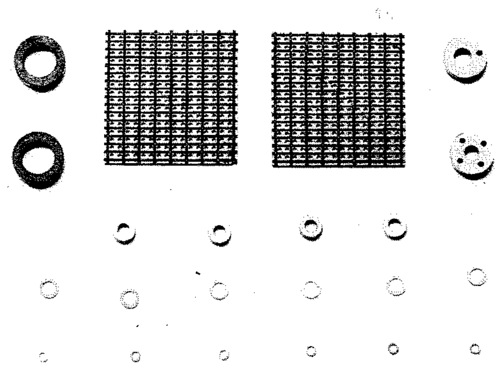


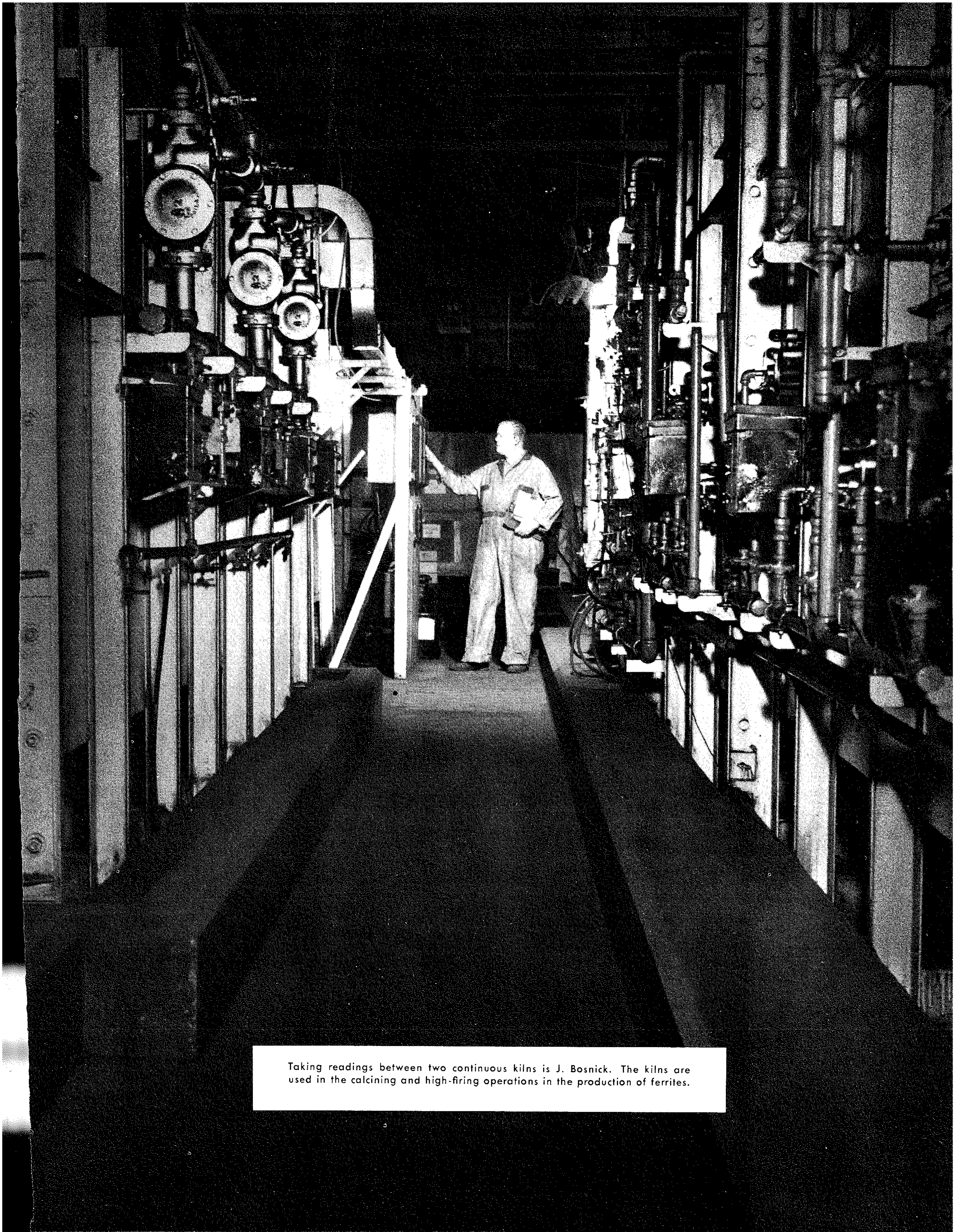
Fig. 7—A display of typical ferrite products.

Square-loop ferrites are made to customers' specifications. Because these specifications vary from customer to customer, the manufacture of square-loop products has become a specialties field. Consequently, kilns selected for sintering square-loop ferrospinels must be flexible. Periodic rather than continuous kilns adapt themselves quite readily to this type operation. A typical kiln is shown in Fig. 5.

The degree of control exercised over the sintering temperature during the "soak" period should be $\pm 1°$ C. This control can be accomplished by the use of multi-couple control and sensitive instrumentation.

FACILITIES

The manufacture of ferrites is a precise and highly specialized science. In the past six years, the Camden Plant has acquired the knowledge, experience, and skill necessary to manufacture square-loop ferrospinels successfully in varied sizes, shapes, electromagnetic parameters, and for varied applications (see Fig. 7). In the Camden plant, an area of approximately 1700 square feet is devoted to the manufacture of square-loop ferrites, and another 3400 square feet to development laboratories.



Taking readings between two continuous kilns is J. Bosnick. The kilns are used in the calcining and high-firing operations in the production of ferrites.

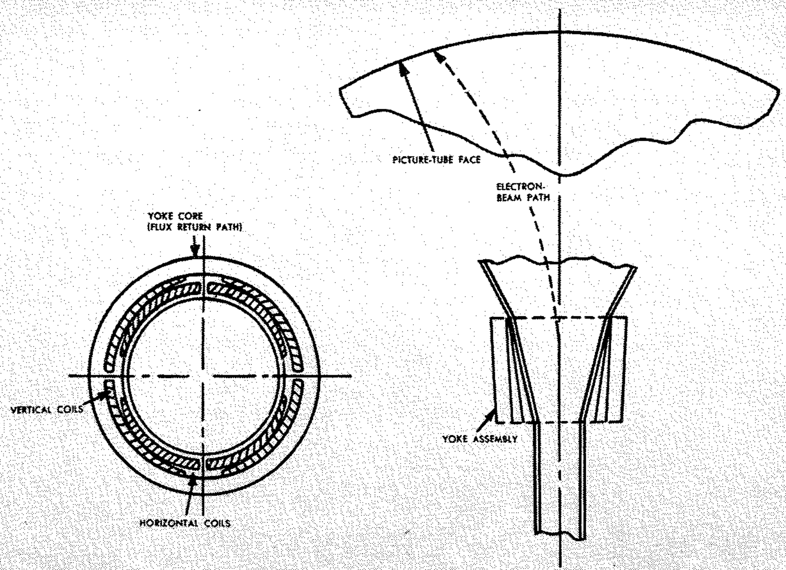


Fig. 2—Yoke described in Bowman-Manfield patent (2,148,398), filed Oct. 23, 1935.

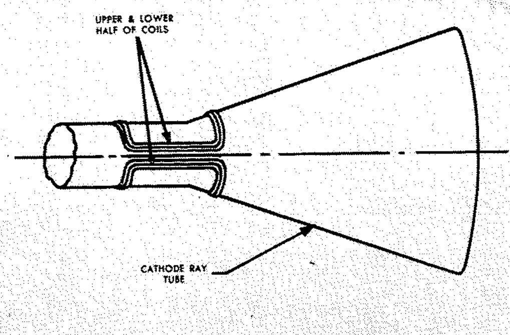


Fig. 3—Yoke described in Federman patent (2,172,733) filed March 28, 1935.

HISTORICAL SURVEY OF THE DEVELOPMENT OF TELEVISION DEFLECTING YOKES

by
M. J. OBERT, Mgr.
Electro Magnetic Devices Engineering Components Division, Camden, N. J.

THE CATHODE-RAY tubes used as display devices in early television receivers were electrostatic-deflection types. These types were used because the simple plate electrodes of an electrostatic-deflection system could be conveniently incorporated in electron-gun structures and because the deflection power required for the relatively small tubes then in use could be easily provided by existing receiving equipment. One of the limitations of an electrostatic-deflection system, however, is that the deflection obtainable is inversely proportional to the beam-accelerating voltage (ultor voltage). Consequently, as progress in the television art created a demand for larger and larger picture tubes requiring higher and higher ultor voltages, it also created new problems with respect to methods of obtaining the required deflection power economically.

The search for possible solutions to these problems indicated that substantially higher deflection sensitivity could be obtained by use of an electromagnetic system, since deflection in this type of system is inversely proportional to the *square root* of the ultor voltage. Electromagnetic deflection was also found capable of providing more uniform focus over wide deflection angles, reduced field aberrations, and substantially better raster symmetry than electrostatic deflection. It was evident, therefore, that successful development of the television art required the adoption of electromagnetic deflection. All present-day commercial television receivers employ magnetic-deflection picture tubes.

SOME PRINCIPLES OF ELECTROMAGNETIC DEFLECTION

The distance an electron beam is deflected by a magnetic field is proportional to the strength of the field, and the direction in which the beam is deflected is at right angles to the direction of the magnetic flux lines producing the field. These relationships are shown diagrammatically in Fig. 1, and may be expressed mathematically by

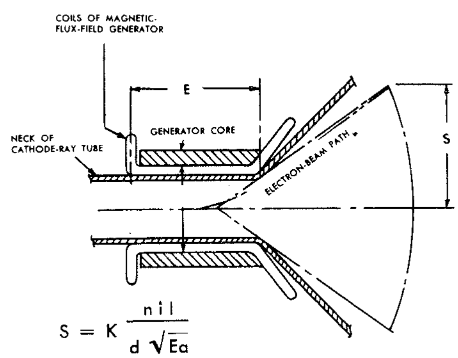


Fig. 1—Schematic representation of relations in electromagnetic-deflection cathode-ray tube.

$$S = K \frac{n\hat{\imath}\,l}{d\sqrt{E_a}}$$

where S is the distance the electron beam is deflected,
l is the effective length of the applied magnetic field, as determined by a plot of the field flux,
K is a constant,
$n\hat{\imath}$ is the peak value of the magnetizing force in ampere-turns,
d is the average diameter of the deflecting flux field,
and
E_a is the electron-beam accelerating voltage (ultor voltage).

The magnetic-flux-field generators used with electromagnetic deflection cathode-ray tubes are known as "deflecting yokes." The beam deflection requirements of a tube and the quality of the resulting display are determined by the characteristics of the yoke and of the tube itself.

In order to produce the simultaneous horizontal and vertical deflection required for television displays, a yoke must have separate horizontal and vertical windings designed and positioned so that their magnetic fields are at right angles. These windings should

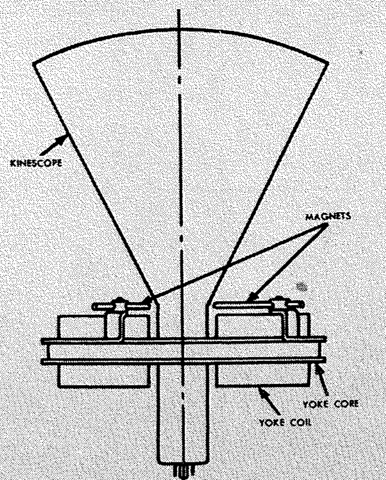


Fig. 4—Yoke described in Maloff patent (2,157,182) filed Dec. 31, 1935

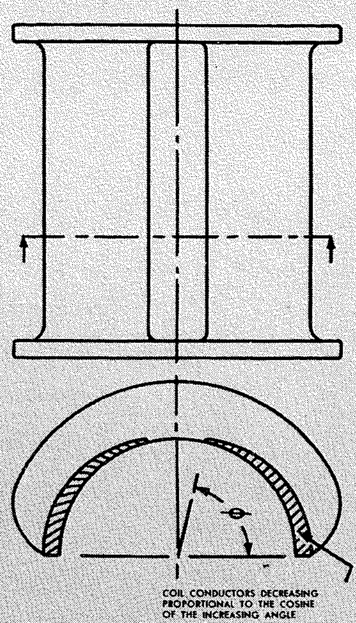


Fig. 5—Yoke described in Grundmann patent (2,395,736) filed May 30, 1944.

Patent History of T.V. Deflection Yokes

A detailed listing and discussion of patents in the deflection art is beyond the scope of this paper. Some of the flavor of early work, however, may be derived from the following references. One of the early patents (D-2,148,398) which indicated understanding of the principles of electromagnetic deflection was filed on October 23, 1935, by Bowman Manfield. This patent describes a yoke (see Fig. 2) designed to provide uniform flux fields in the area traversed by the electron beam without the expenditure of magnetizing energy in producing a field elsewhere. It includes the use of a magnetic sheath or "core" around the coils to obtain high efficiency by provision of a low-reluctance return path for the magnetic flux.

A subsequent patent (D-2,172,733) applied for March 28, 1935 by W. Federmann et al., described deflection coils "in part-arranged on the cylindrical tube neck and in part on the part of the tube forming the frustum of a cone" (see Fig. 3).

In December, 1935, I. G. Maloff filed a patent (2,157,182) which included means for obtaining a substantially uniform deflecting field by the use of permanent magnets adjacent to the deflecting coils (see Fig. 4).

U. S. Patent 2,395,736 filed in May, 1944 by G. Grundman, described a magnetic deflecting yoke for producing a uniform deflecting field "—— with conductors decreasing in number proportional to the cosine of the increasing angle." (see Fig. 5).

have high efficiency at the corresponding scanning frequencies, and be designed so that their fields produce negligible defocusing of the electron-beam spot over the entire scanned area of the picture-tube screen. An essentially constant width-to-height ratio (aspect ratio) of 4/3 is required to control "pincushion" or "barrel" field distortion. Coupling between the horizontal and vertical windings should be as small as possible to minimize field interactions which might result in ringing distortion of the scanning lines.

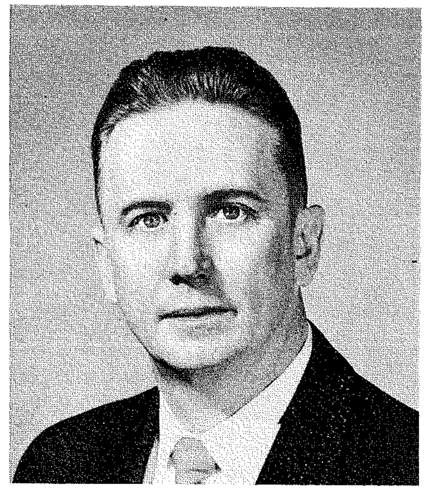
HISTORICAL DEVELOPMENT OF YOKE-COIL CONFIGURATION

The earliest RCA yokes used rectangular coils shaped as shown in Fig. 6a so as to conform to the contour of the tube neck. Coils of this type permitted control of the flux-field configuration by variation of turns spacing and/or of the thickness of the straight sections.

The first post-war production-type RCA yoke employed coils shaped like those shown in Fig. 6b. This yoke (Type 201D1) was designed for use with tubes having horizontal deflection angles of approximately of 52 degrees such as the 7DP4 and 10BP4. The turned-up ends provided substantially greater effective length and sensitivity than those of the yoke shown in Fig. 6a, and minimized the Z-direction field produced by the ends of the windings in the region traversed by the electron beam, thus reducing field distortion and defocusing.

Following the success of the RCA 630TS and other receivers using 10-inch picture tubes, larger 52-degree picture-tubes such as the 12AP4 and 16AP4 were introduced. The continued demand for still larger tubes, however, coupled with economic considerations and styling trends which demanded limitations on cabinet depth, resulted in the development of 70-degree picture tubes. This group includes the round 16GP4 and 19AP4, and a variety of rectangular types up to the 21-inch size which is still the volume leader. The yoke-coil design developed for use with these tubes is shown in Fig. 6c. The problem of maintaining good focus over a 70-degree deflection angle was solved by the use of distributed windings. Proper distribution of the vertical-coil turns also minimized pincushion effects, and made it unnecessary to use external correcting magnets.

As the result of a continuing demand for still larger picture tubes and for more compact equipment, development of 24-inch, 27-inch, and smaller types, design for 90-degree deflection was undertaken. Preliminary studies of the deflection requirements of these tubes indicated that two-tube (in par-



MAXIMILIAN J. OBERT attended Drexel Institute of Technology from 1929 to 1932, and received the Diploma in Electrical Engineering from the Evening School in 1939. He started with RCA in 1933 in transformer manufacturing, becoming a process engineer in 1937. In 1940 Mr. Obert became a Manufacturing Development Engineer and advanced through Engineering and Managerial ranks to his present position as Manager, Electro Magnetic Devices Engineering. His primary interest in the past eight years has been in the field of Television Deflection Components. His designs have been accepted as industry standards in both black and white and color television. He is a Senior Member, IRE, and received the RCA Award of Merit for 1954 for his contributions in his chosen field.

allel) horizontal-deflection output amplifiers would be required to provide adequate deflection power unless the tube neck was made smaller than the currently used diameter of 1-7/16 inches. It was soon determined, however, that adequate deflection power could be obtained from one-tube amplifier stages without reduction of kinescope neck diameter by proper expansion of the yoke front end, so as to move the center of deflection forward, and thereby permit the use of a longer coil and core structure having correspondingly greater sensitivity. This improved coil design, shown in Fig. 6d, is used in the RCA Type 220D1 deflecting yoke and in practically all other 90-degree yokes now in use.

In recent years, the greatly expanded market for portable television receivers and more compact home receivers has resulted in substantial reductions in over-all picture tube length. This has been brought about by the development of 110-degree deflection types, such as the 21CEP4. This tube utilizes a new gun and a small-diameter (1-1/8-inch) neck facilitating the design of yokes having very high deflection sensitivity. The yoke-coil design developed for use with these tubes is shown in Fig. 6e. Both the contour of the picture-tube funnel and the shape of the yoke coils were optimized with respect to the actual path of the electron beam in the funnel region.

Fig. 7 shows the over-all design of the 110-degree yoke which uses the coil design described above. As shown, the 110-degree yoke (RCA Type XD3142), follows the glass contour closely, and combines very high sensitivity with low cost and weight.

The significant mechanical differences between the four basic yoke types are listed in Table 1.

The results achieved by the introduction of RCA ferrite cores in the design of horizontal-deflection-output and high-voltage transformers and deflecting yokes are shown in Table 2. For example, the Type 211T1 52°, 9-kilovolt transformer, which used electrolytic-iron cores, weighed 0.951 pounds total, and required 33.6 watts of power, whereas the Type 230T1 ferrite-core 65° transformer provided 18-kilovolts, weighed only 24 per cent as much as the 52-degree transformer, and required 18-per cent less power.

The total copper weight of the Type XD3142 110° yoke is 21 per cent less than that of the Type 220D1 90-degree yoke, and the ferrite core weight is 2 per cent less. The significant improvements in efficiency obtained in the new 110° system are due largely to the development of picture tubes having a neck diameter of only 1-1/8 inch, as compared with 1-7/16 inch for the older types, and partly to the incorporation in the yoke of four ferrite permanent magnets which provide some scan boost as well as pincushion correction.

Fig. 8 shows the successive reductions in the over-all length of large screen picture tubes achieved by the use of wider deflection angles. The reduction in cabinet depth permitted by the introduction of 90-degree tubes was sufficient to cause obsolesence of the 70° types.

The over-all length of the new RCA 21CEP4 permits a 5-5/8 inch reduction in cabinet depth from that required for present 90°, 21 inch receivers. The new length is considered satisfactory for aesthetically correct cabinet styling, and it is expected that 90° deflection systems will rapidly become obsolete, except perhaps in the smallest sizes of portable receivers.

110° DEFLECTION CIRCUIT

A typical horizontal-deflection and high-voltage circuit for a 110-degree system and its operating characteristics are shown in Fig. 9. With suitable components and modifications this circuit can also be used for 14-, 17-, 21-, and 24-inch 110-degree picture tubes.

PATENTS AS AN ENGINEERING TOOL

The improvements in deflecting components and picture tubes described here were the result of intensive engineering effort. Some of the design

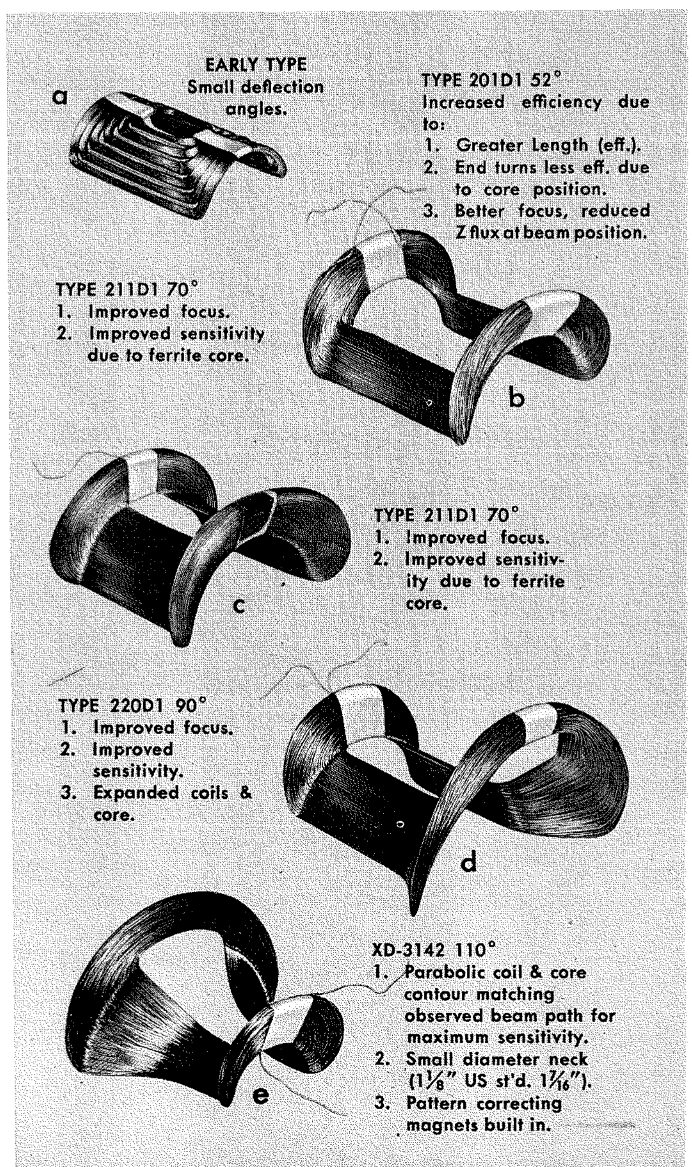
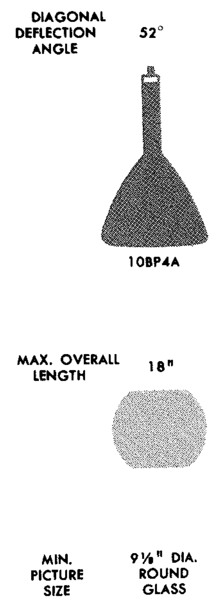


Fig. 6—Photographs showing changes in the form of yoke windings with increases in deflection angle.



principles used in the latest types of yokes were approximated in an early form in certain of the patent disclosures described. It will be recognized, therefore, that the patented art is a fruitful source of reference material for design engineers, since the patents show not only the historical development of the art, but also may indicate further areas in which engineering effort may effectively utilize principles developed earlier.

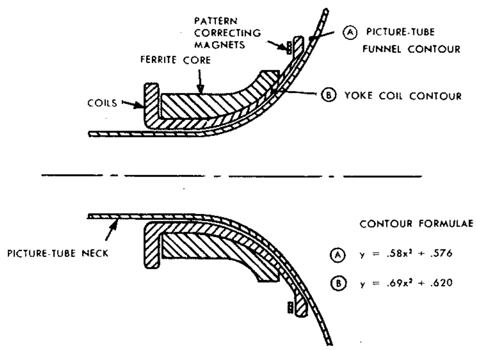


Fig. 7—Details of the RCA Developmental Type XD-3142 110-degree yoke.

TABLE 1

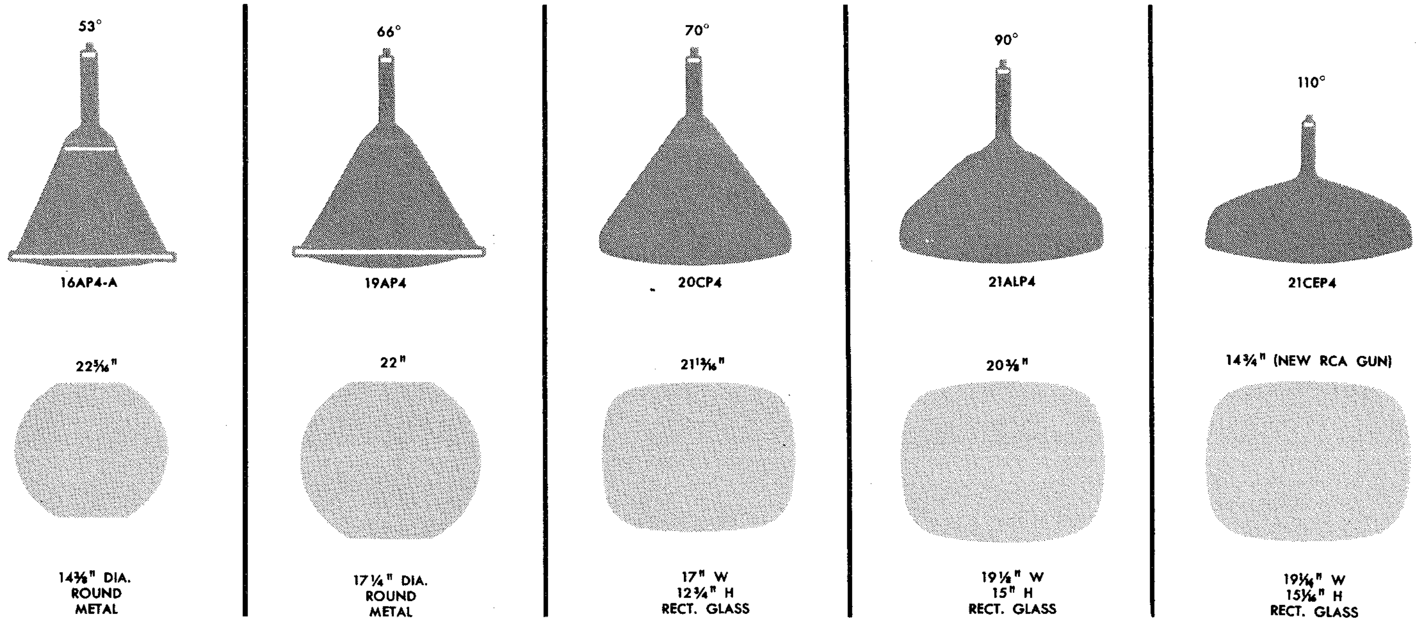
YOKE COIL DEVELOPMENT

Max. Deflection Angle	55°	70°	90°	110°
RCA Type Number	201D1	211D1	220D1	XD-3142
Core length	1.305″	.960″	1.441″	1.280″
Vertical Window length	1.500	1.152	1.730	1.295
Vertical Over-all length	2.031	1.652	1.962	1.76
Horizontal Window length	2.000	1.703	2.053	1.634
Horizontal Over-all length	2.531	2.197	2.350	2.21

TABLE 2

DEFLECTION SYSTEM COMPARISON

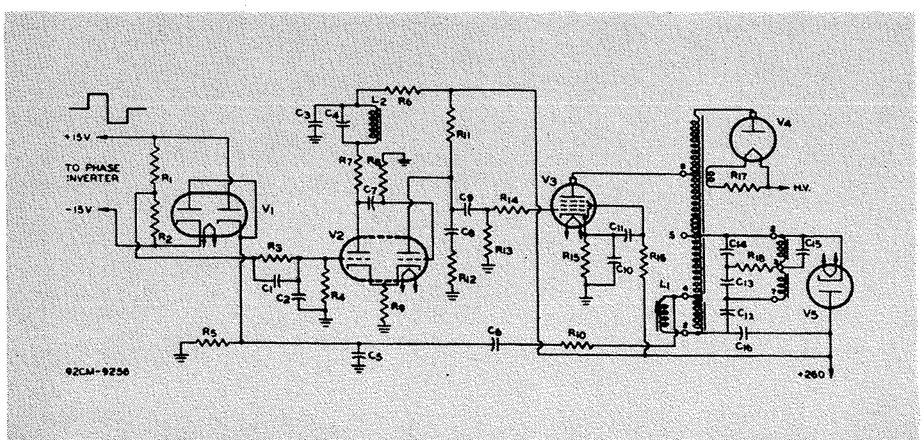
		FERRITE-CORE TYPES			
Max. Deflection Angle (degrees)		55	70	90	110
RCA Yoke Type		201D1	211D1	220D1	XD-3142
RCA Horiz.-Output and HV Trans.		211T1	230T1	235T1	XD-2830-BB
Horiz. Scanning Angle (degrees)		52	65	85	106
Yoke current for full horiz. scan (pk/pk) (amperes)		0.510	0.850	1.20	0.840
Ampere turns full scan		168.	416.	444.	393.
Ultor voltage (KV)		9.	18.	18.	16.
+B supply voltage (volts)		380.	310.	265.	260.
Power Input to Horiz. (watts)		33.6	27.6	30.5	33.8
Transformer weights	Copper weight lbs.	0.101	0.110	.133	.080
	Core weight lbs.	0.85	0.157	.308	.308
	Total lbs.	.951	.229	.441	.388
Yoke weights	Copper weight lbs.	.398	.422	.506	.400
	Core weight lbs.	.300	.291	.415	.406
	Total lbs.	.698	.713	.921	.806



NOTE: △ LENGTH FOR 21" KINESCOPE 110° VS 90° IS 4⁵⁄₁₆", INCLUDING NEW RCA GUN.

▲ Fig. 8—Mechanical comparison of popular commercial picture tubes having deflection angles from 52 to 110 degrees.

Fig. 9—Developmental horizontal deflection and high-voltage circuit for the RCA 21CEP4 110-degree picture tube. ▶



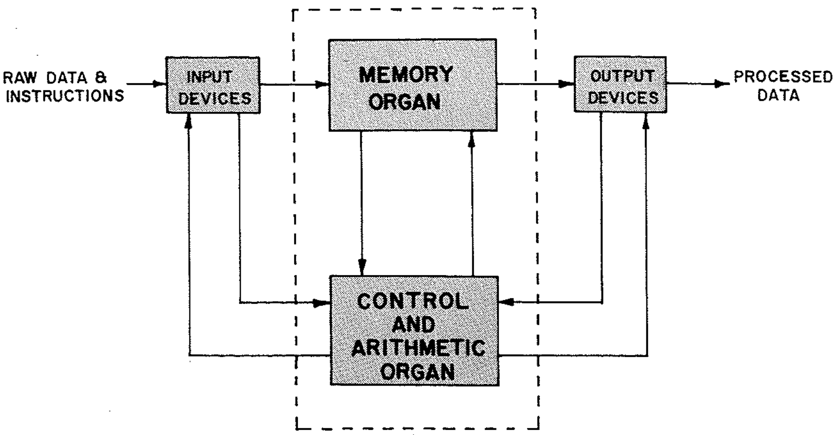


Fig. 1—Block diagram of a digital computing system.

A MAGNETIC-CORE MEMORY FOR DIGITAL COMPUTING SYSTEMS

by **A. KATZ, C. Y. HSUEH, and R. J. SPOELSTRA**
BIZMAC Engineering
Commercial Electronic Products
Camden, N. J.

OVER A CENTURY ago, Charles Babbage made public his plans for the construction of the first large-scale digital computer, the "Analytical Engine." Babbage described his machine as follows: "The Analytical Engine consists of two parts: a) The *store* in which all variables to be operated upon, as well as all those quantities which have arisen from the result of other operations, are placed. b) The *mill* into which the quantities about to be operated upon are always brought."[1] In modern parlance these correspond, respectively, to the memory organ and to the control and arithmetic organ.

The Engine was to be capable of performing arithmetic operations, of comparing quantities, and of exercising judgment based on these comparisons. Using the angular position of gears to represent quantity, its store was to have a capacity of one-thousand 50-digit numbers. Working a century before his time, Babbage spent his life in a vain effort to reproduce in metal the faculties of memory and decision. His grand vision has finally been realized in the electronic information-processor, of which the BIZMAC Computer is an example.

MEMORY DESIGN PHILOSOPHY

The digital computer is a device which, in executing a set of internally-stored instructions, accepts raw data from its environment, applies prescribed processes to this data, and supplies the finished data to its environment for further action. A simplified block diagram of such a machine is shown in Fig. 1. The functional capabilities of the computer to date have been largely determined and, indeed, severely limited by the characteristics of its memory. These characteristics are speed, capacity, cost, and reliability. Recognizing the inherent reliability of a machine, whose internal organs recognize only two rather than ten states, computer engineers have based their designs on binary or binary-coded representations of alphanumeric quantities. Since the computer can only process data which are in the form of a code having two discrete values, transcribing devices are required at its input and output. Designers of large computers have "solved" the storage problem by providing a hierarchy of memory devices as follows:

a) bulk storage, with capacities in the many millions of binary digits (or bits) and access times measured in seconds. Examples of such storage devices are punched-cards and magnetic tape.
b) auxiliary storage, with capacities in the hundreds of thousands of bits and access times measured in milliseconds. An example is the magnetic drum.
c) high-speed storage, with capacities in the tens or hundreds of thousands of bits and access times measured in microseconds. Examples are the electrostatic storage tubes and the magnetic-core store.

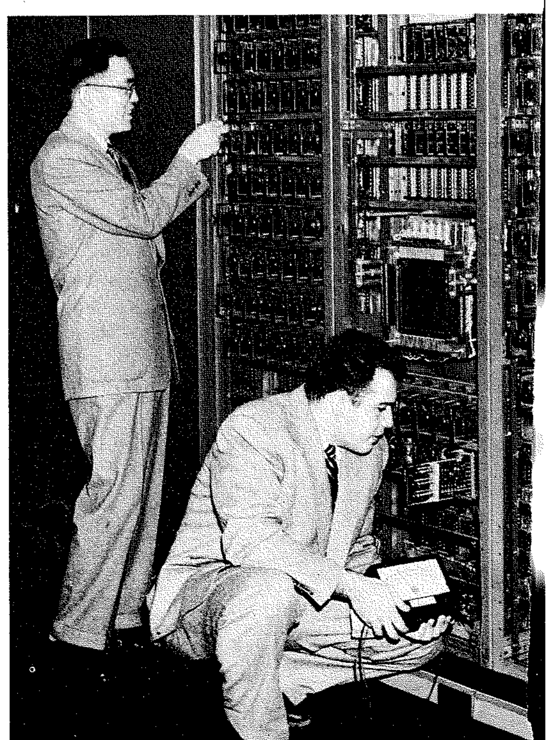
The cost-per-bit ranges from a few tenths of a cent for bulk storage to tens of cents for high-speed storage. Economic considerations dictate the relative proportions of the auxiliary and high-speed storage used as the internal memory organ of a large machine. These same considerations have to date constrained the designers of small machines to the use of a single memory device, generally a magnetic drum.

In order to limit the scope of this paper, we shall here consider the design of only one medium for high-speed storage—the magnetic core. Because of its speed, simplicity, and reliability, the core memory has become the "standard" storage medium in high-speed digital computers.

MAGNETIC-CORE MEMORIES

During the past two decades there have been several generations of

C. Y. Hsueh (standing) and R. T. Spoelstra making tests on a computer using a magnetic-core memory.



memory devices. Although many devices are capable of retaining binary information, relatively few lend themselves to rapid selection. One of these devices, the biremanent magnetic core, can serve as an elementary cell capable of storing one binary digit. As shown in Fig. 2, the core stores a "zero" when in positive remanence; a "one," in negative remanence. The memory element is relatively insensitive to an applied field H_d, but is responsive to a field H_m resulting from the coincident application of two fields, each of value H_d. By virtue of this nonlinearity, the cores provide an added degree of discrimination which greatly simplifies the selection problem.

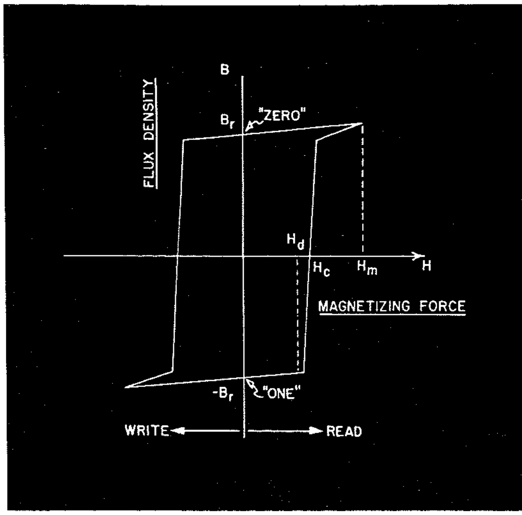


Fig. 2—Hysteresis characteristic of memory core.

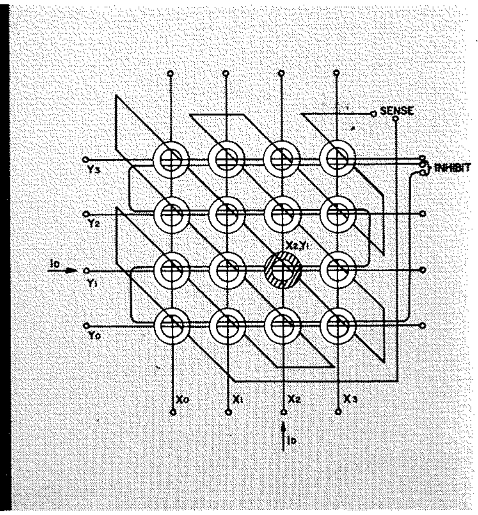


Fig. 3—Planar array of memory cores.

COINCIDENT-CURRENT OPERATION(2-4)

The principle of operation will briefly be reviewed. In the array shown in Fig. 3, each core is threaded by four windings. The Sense and the Inhibit windings are common to all cores; a particular x-coordinate and a y-coordinate access line threads each core. The content of a specific core is read by applying a drive current I_d along each of the appropriate access-line pair. Only the core at the intersection is driven by $I_m = 2\ I_d$, and only that core responds. If it contains a "1", a relatively large voltage is induced in the Sense winding; if a "0", a relatively small voltage. In Fig. 3, the content of core X_2Y_1 is being read by driving lines X_2 and Y_1.

To write information into a core, the drive currents are reversed. If a "0" is to be inscribed, a bias current having magnitude I_d and sense opposite to the drive current is applied to the Inhibit winding; if a "1", no excitation is applied. Note that the extraction of the content of a core results in destruction of the information in that core (whatever its original content, it will be "0" after reading). Hence, an access to the memory requires a "read-write" cycle if the information must be preserved for later use.

The planar arrays are arranged (see Fig. 4) to form a compact, three-dimensional lattice by interconnecting corresponding x-lines and y-lines. Each array serves as a digit plane since it stores a particular binary digit for each of the registers in the lattice. A typical memory lattice might consist of thirty such arrays, each containing 64 X 64 (or 4096) cores. Such a lattice is said to have a capacity of 4096 registers of 30-bit length. The contents of any register may be altered or examined by suitably controlling the currents in the three coordinates along the edges of the lattice. Since the selection coordinates are entirely spatial, the rate of access to any register is inherently high.

MATERIALS ASPECTS

The design of a memory system is necessarily related to the physical properties of the storage medium. Magnetic materials are particularly attractive for use as such media because they are stable and non-volatile with respect to retention of information. Cores exhibiting the hysteresis characteristic shown in Fig. 2 may be fabricated in a variety of ways including: a) ultra-thin ribbons of molybdenum permalloy metal wound on ceramic bobbins, and b) ferrospinel compounds formed as ceramic bodies. Because of its higher speed, lower cost, and greater reproducibility in manufacture, the latter have largely preempted the computer memory field. The most commonly used core has the following approximate characteristics:

a) Body dimensions:
O.D. = 0.080 inches
I.D. = 0.050 inches
Height = 0.025 inches
b) Saturation flux density = 1800 gausses
c) Coercivity = 1.5 oersteds
d) Resistivity = 10^7 ohm-cm.

When operated in a coincident-current mode, core switching time is about

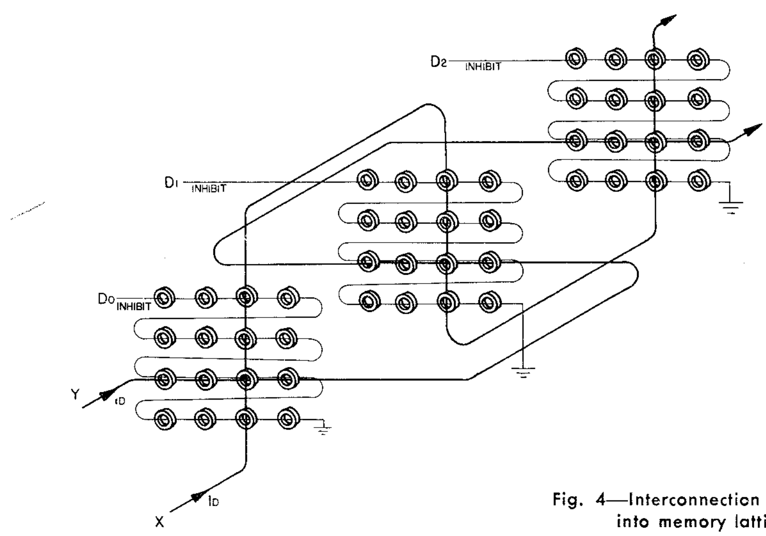


Fig. 4—Interconnection of arrays into memory lattice.

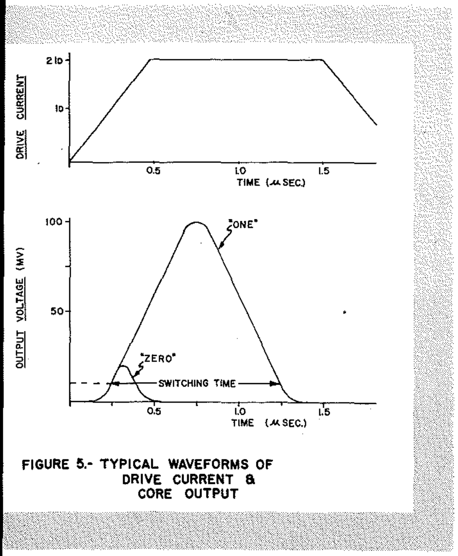


FIGURE 5.- TYPICAL WAVEFORMS OF DRIVE CURRENT & CORE OUTPUT

Fig. 5—Typical output pulse waveforms.

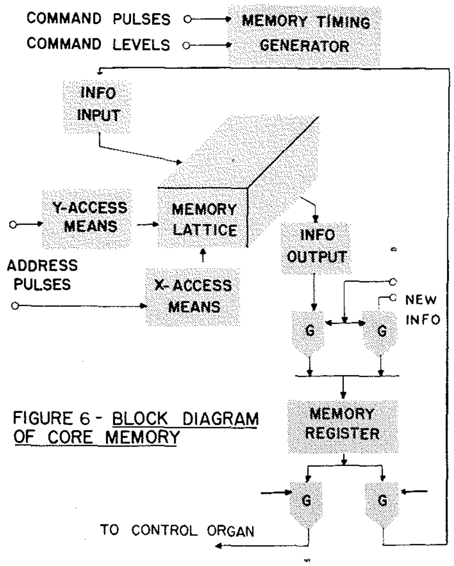


FIGURE 6 - BLOCK DIAGRAM OF CORE MEMORY

Fig. 6—Block diagram of core memory.

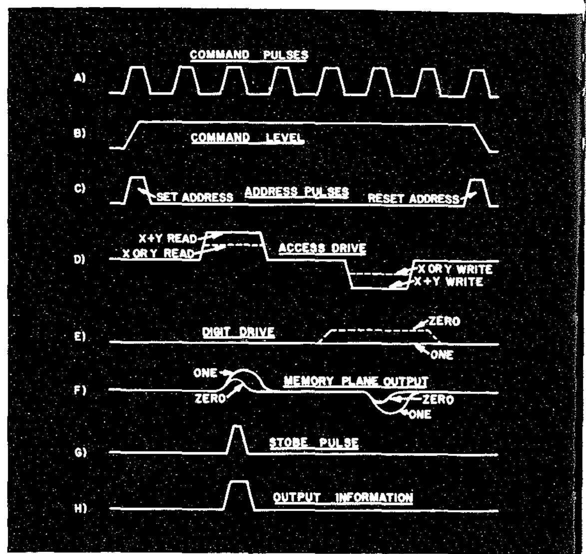


Fig. 7—Memory timing diagram.

1.25 microseconds with 0.90 ampere-turn drive (typical output waveforms are shown in Fig. 5). Other ferro-spinels available in the same core body switch in about 2 microseconds with 0.50 ampere-turn drive, or in 5 microseconds with 0.35 ampere-turn drive.

The particular material to be used depends primarily on the speed required. A memory cycle has a duration of at least twice that of the core switching time. If the delays inherent in propagating pulses through the system are added to this time, then the memory cycle for the 1.25 microsecond core becomes about six microseconds.

SYSTEM ASPECTS

Having selected the material and body particularly suited for the application, one can then proceed with the design effort. A block diagram of the basic memory system is shown in Fig. 6. A particular register is selected by the X-Access and Y-Access means in accordance with the address specified by the programmed instruction. Each of these identical means consists of a selection system and an access drive system. Information is read out by the access means, and later inscribed by the digit drivers operating in conjunction with the access means. The remainder of the information channel consists of sensing amplifiers, pulse standardizers, a memory register, and a network for gating information to and from the memory. There is also a memory timing generator which converts the basic machine commands into pulses of a nature determined by the characteristics of the cores.

Insofar as the electronic design is concerned, the engineering effort may conveniently be divided into four areas as follows: a) generation of special waveforms, b) register selection, c) register and digit drive, and d) output circuitry. With respect to the first of these, it is worth noting that digital "thinking" processes are implemented by the presence or absence of voltage pulses in combination with command voltage levels. Since the pulses and levels are generally not suitable for actuating the cores, there is need for a system which translates conventional machine commands into a language intelligible to the memory system. An engineer must combine the appropriate digital circuits, such as gates, pulse amplifiers, delays, and flip-flops, into a logical network whose inputs are the machine commands, and whose outputs are the memory commands. Machine commands and the regime of special pulses needed for proper memory operation are shown in Fig. 7. Note that characteristics of these pulses are related to core output as follows:

a) Widths of the "read" and "write" pulses (line d) for access drive are greater than the natural switching time of the core (line f),
b) The width of the "digit inhibit" pulse (line e) is greater than those of the "write" pulses (line d),
c) Rise times of the "read" pulses (line d) are short compared to the core switching time (line f) and
d) Amplitude and time discrimination are provided by means of a "strobe" pulse (line g) which is narrow compared to core switching time, and positioned so as to optimize the signal-to-noise ratio.

Although these pulses are properly shaped and timed, they are generated at a power level too low to actuate the cores. It is the function of the access and digit drivers to supply that power.

MEMORY DRIVE

As indicated earlier, an access means consists of a selection system and an access drive system. The use of multi-coordinate selection within the memory lattice results in a rather small amount of addressing circuitry. For example, a lattice having N^2 registers of M-bit length requires N X-access drivers, N Y-access drivers and M digit drivers. The register addressing means must then select one of N drivers within each of the access means. A typical solution to the selection problem is shown in Fig. 8. This involves an address register with associated buffers and a multi-position diode matrix switch. Since the outputs of each of the three flip-flops shown can assume two states, there are 2^3 combinations of such outputs. The diode matrix converts the register binary code into a linear code. For each of the 2^3 combinations of

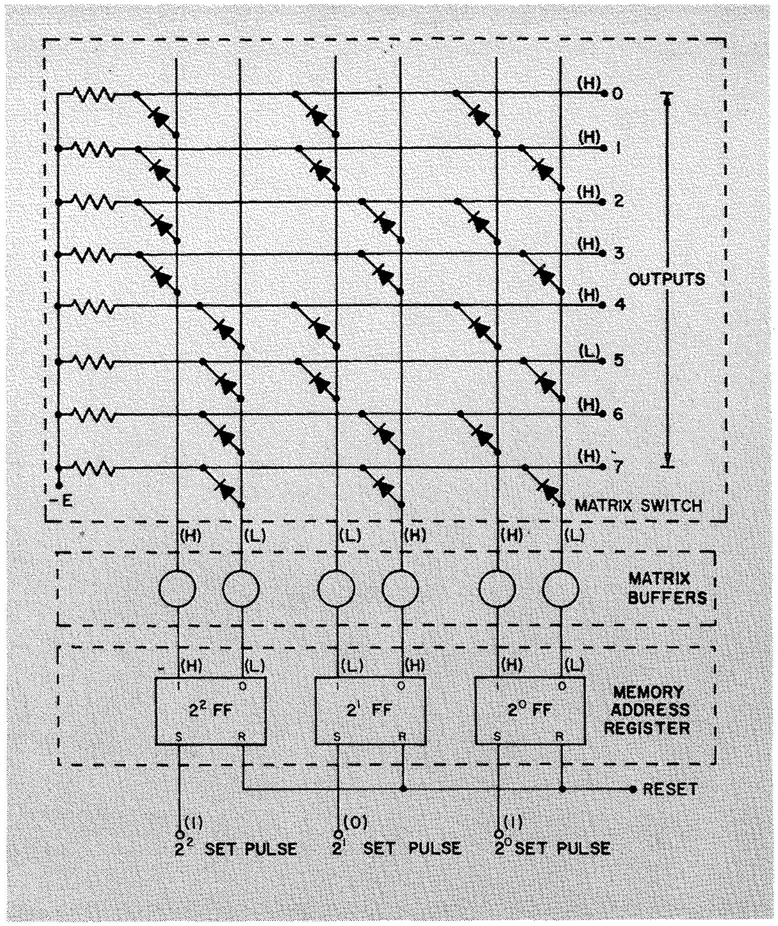


Fig. 8—Typical selection system.

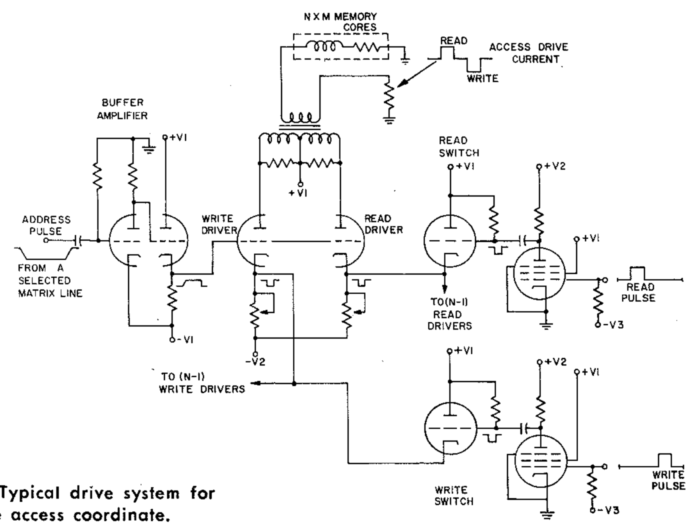


Fig. 9—Typical drive system for one access coordinate.

"switch" inputs, only one "switch" output line will be energized. By way of example, if binary code *101* were set into the register, then the flip-flop outputs would be high (H) and low (L) as shown on the diagram. Only line *5* has all of its inputs low, hence only that line assumes a low output level, indicating selection. Each of the other unselected lines remain at a high output level through the conduction of one or more of its associated diodes. Note that for 2^n switch outputs, there are required $n\ (2^n)$ diodes.

Having generated the necessary special pulses and selected the proper pair of access drivers, we may now consider the means by which the memory lattice is actually driven. Depending on the size of the memory, this load seen by a driver may be approximated by an inductance ranging from several microhenries to a tenth of a millihenry. A typical access drive system is shown in Fig. 9.

Each output line of the diode matrix is connected through a buffer amplifier to the grids of one of the "read" and "write" drivers. The address pulse appears as a wide positive pulse at the grids of the selected drivers while the other drivers are held well below cut-off. The "read" switch is conducting heavily in the quiescent stage. It supplies enough current through the common cathode resistor to keep the driver cathode potentials high enough so that the unselected and selected drivers remain "cut-off." At the appropriate time, the "read" pulse drives the "read" switch into the cut-off state, pulling down all "read" cathodes. However, only the selected driver will conduct because its grid is primed by the address pulse. At "write" time, the "write" driver is turned on in an identical manner.

The design of the digit driver presents problems quite similar to those of the access drivers. The digit driver supplies a pulse of the same magnitude but of greater width to a load having larger inductance. The requirements on rise and fall times, however, are less severe.

MEMORY OUTPUT

Considering memory output problems, one notes that all cores in the array in Fig. 3 are threaded by a common sensing winding. From Fig. 5 it will be recalled that signal voltages from a core are 100 millivolts for a "one" and 10 to 15 millivolts for a "zero." The output of the sensing winding, however, is a composite signal that consists of a voltage from the selected core as well as noise voltages from 2 (N-1) half-selected cores. Furthermore, a noise output in the order of volts is coupled into the sense winding by the action of the digit driver. Requirements on the sensing amplifier are as follows:

a) It must accept both positive and negative signals, inverting and amplifying them.
b) It must handle signals over a large dynamic range.
c) It must be insensitive to variations in the signal repetition rate.

Referring again to Fig. 5, we note that not only is there a difference in pulse amplitude between a "one" and a "zero," but also a difference in pulse width. The effective signal-to-noise ratio may greatly be increased by sampling at a time when the "zero" signal has virtually decayed. The output of the sensing amplifier is accordingly sampled and the resultant signal is then standardized for use elsewhere in the computer.

SUMMARY OF PRESENT STATUS

The coincident-current magnetic-core memory has proven to be the most reliable medium yet devised for high-speed storage in digital computers. Experience with core storage at RCA as well as at Lincoln Laboratory and at Rand Corporation, shows that one can achieve mean times between errors measured in the hundreds of hours. With respect to size and speed, core memories have been built with capacities in the millions of bits and speeds of access measured in microseconds. In sizes over one hundred thousand bits, the core memory is fully competitive on a cost-per-bit basis with the magnetic drum memory, and exceeds it in speed by several orders of magnitude.

TRANSISTORIZATION

It is fairly obvious that one could, at the present time, transistorize all the low-level circuitry in the memory. This includes the timing generator, the register selection system, and the output channels. The access and digit drive circuitry, however, present a more difficult problem. There, it is necessary to develop large current pulses with fast rise times in a load which is predominantly inductive. Depending on the size of the memory, the back voltages induced may exceed the rating on the collector voltage of the transistor. Transistors are now commercially available which are suitable for driving memories of moderate sizes and speeds. For such memories one can then realize all the advantages of transistorization, with savings in space, power, and weight. These are of special significance in military applications.

FUTURE PROSPECTS

Looking to the future, we note new developments in materials and techniques on the horizon. Use of the apertured ferrite plate and the associated switching devices developed by Dr. Jan A. Rajchman[6] at the RCA Princeton Laboratories should greatly reduce the cost of computer memories. As the cost-per-bit is brought down by improvements in design and production, the core memory will become increasingly competitive with auxiliary storage means such as magnetic drums. If this proves true, then the internal storage systems of digital computers will be progressively simplified from a hierarchy of memory devices to a single very large core memory. This trend will be further accelerated by the substitution of ferrite plates for core arrays.

Concurrently with this trend to ever greater storage capacity, there is also the demand for ever higher speed. Certain classes of problems are of such complexity that their solutions are possible only by machines having operating speeds a few orders of magnitude faster than existing machines. If these machines are not to be "memory-limited" then there must be further improvement in memory speeds. This improvement appears feasible if one exploits the magnetic viscosity phenomena[7] in cores and plates, or the switching phenomena of very thin evaporated ferromagnetic films.[8]

The appetite of computer users for storage is well-nigh insatiable. Our position in the field can be maintained only through an extensive program for discovering and applying new materials and techniques, and by a rapid exploitation of these discoveries by product design engineers.

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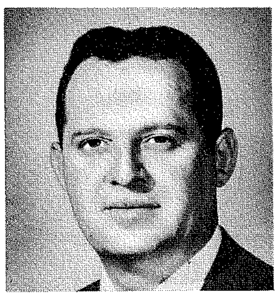
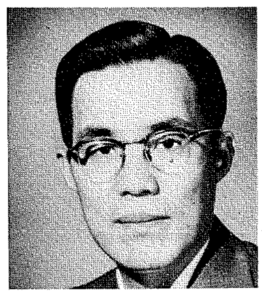
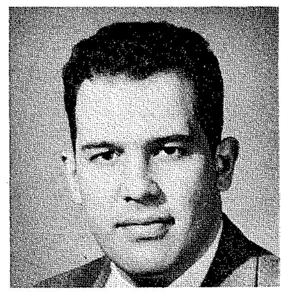


ABRAHAM KATZ received the degree of BS in EE from MIT in 1950, and an MS Degree from MIT in 1952. From 1950 to 1953 he worked at the MIT Digital Computer Laboratory, concerned with digital control systems and magnetic core devices. From 1953 to 1954 he worked at Marchant Research, Inc., in Oakland, California. In 1954 he joined Computing Systems, BIZMAC Engineering, where he worked on magnetic-core memory development. Mr. Katz was promoted to his present occupation in 1956, as head of the Computer Memory Group. He is a member of AIEE, IRE, Sigmax, and Eta Kappa Nu.



CHIA Y. HSUEH graduated from the National University of Cheikiang, China, in 1943 with the Degree of BSEE. He received the Degree of MSEE from the University of Oklahoma in 1951. Mr. Hsueh worked at the Central Radio Manufacturing Company, China as a student engineer from 1943 to 1944. In 1944 he joined the Chinese Air Force and was sent to the U.S. to receive training. Mr. Hsueh joined RCA in 1952. He has been active in magnetic-core memory engineering. He is a member of Eta Kappa Nu, Pi Mu Epsilon and IRE.



RUDOLF J. SPOELSTRA was graduated from Alabama Polytechnic Institute in 1953 with a BSEE Degree. He joined the Shell Oil Company as a Seismologist for an exploration party. He next returned to Alabama Polytechnic Institute to work towards obtaining a Master Degree. He joined RCA in 1955 as an Engineer in the High-Speed Memory Group of BIZMAC Engineering. Mr. Spoelstra has been engaged in the design and development of circuits for BIZMAC memory systems. He is a member of AIEE, IRE, Tau Beta Pi, Eta Kappa Nu, and Phi Kappa Phi.

APPLICATION OF POWER TRANSISTORS TO CLASS A OUTPUT STAGES OF AUTO RECEIVERS

By

ROBERT MINTON

Application Laboratory, Semiconductor Division
Somerville, N. J.

Mr. Minton's article is a continuation of the series of semiconductor articles featured in the last issue of the RCA ENGINEER. This article will be published in two parts. The first is devoted to class A audio output applications of power transistors, and the second, to appear in the next issue, will discuss class B audio applications.

Because power transistors can be operated efficiently at low supply voltages, their use in the output stages of automobile receivers make it possible to achieve considerable savings in circuit components. For example the vibrator and vibrator transformer are eliminated, saving not only the cost and expense of installation of these components, but also eliminating the problem of vibrator hash or buzz encountered in many present radios. With the commercial availability of power transistors, the circuit designer can now design and develop audio power-amplifier stages capable of delivering considerable amounts of power output. This paper describes the use of power transistors in audio frequency power-output stages for automobile broadcast-band receivers.

RCA POWER TRANSISTORS

The new RCA germanium p-n-p alloy junction transistors, 2N301 and 2N301A shown in Fig. 1, are designed especially for use in class A and class B audio output stages in automobile broadcast-band receivers and other medium-to-high-power applications. These transistors are characterized by low thermal resistance and extremely low leakage currents.* The low thermal resistance, i.e., high heat transfer efficiency from the transistor to the external case, is achieved by direct connection of the collector junction of the transistor to the external mounting flange.

*Design features of these transistors were described in the paper "Factors in the Design of Power Transistors" by A. Blicher, J. Ollendorf and I. Kalish in the February-March 1957 issue of the RCA ENGINEER.

These new transistors may be used in either class A or class B output stages. In class A, a maximum-signal power output of approximately 2.7 watts is available from a single transistor. In class B service, two transistors in push-pull can deliver a maximum-signal power output of approximately 12 watts.

POWER-DISSIPATION CONSIDERATIONS

In the design of transistor audio power amplifiers, the most important characteristic to be considered is the power-dissipation capability of the transistor. The maximum power that can be dissipated before "runaway" occurs depends on a number of factors, of which the most important is the ability to remove heat generated within the transistor.[1] When heat is removed by conduction, this ability is measured by the

ROBERT MINTON received his B.S. degree in Electrical Engineering from Howard University in 1951 and his M.S. degree in E.E. from Stevens Institute of Technology in 1956. Mr. Minton joined RCA as a specialized engineering trainee in 1951. At the completion of the engineering training program, he was assigned to Tube Test Engineering in Harrison, New Jersey from 1951 to 1953. From 1953 to 1954, he worked in Semiconductor Test Engineering Laboratory. At the present time, he is a member of the Semiconductor Application Laboratory and is engaged in the design and development of audio frequency circuits.

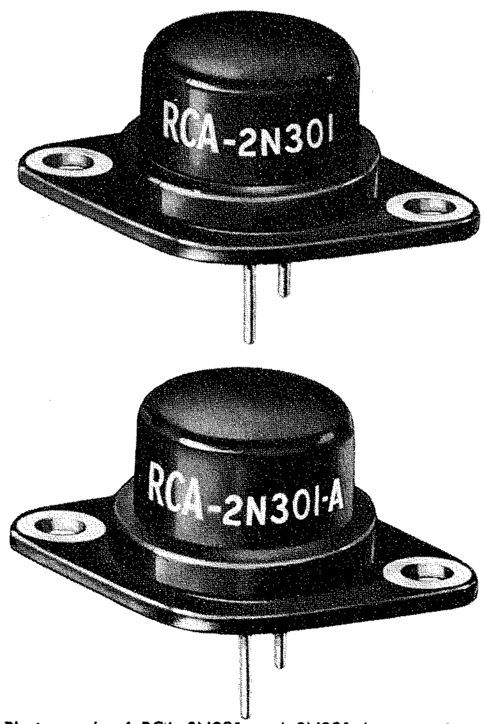


Fig. 1—Photograph of RCA 2N301 and 2N301-A power transistors.

thermal resistance, i.e., the internal temperature rise per unit of power dissipation. The lower the thermal resistance, the greater the power-handling capability. Other factors which determine the maximum power-dissipation capability are the collector voltage, circuit stability factor, reverse collector saturation current, and maximum ambient temperature.

CLASS A TRANSISTOR POWER AMPLIFIERS

Any of the three basic transistor-circuit configurations can be used as a class A power amplifier. This discussion will be limited to the base-input, common-emitter circuit because it has the greatest power gain. In a power amplifier, it is desirable to obtain as much power output as possible with a minimum amount of distortion. The power gain and maximum distortion limits for automobile receivers are usually established for a particular supply voltage and power-output level. The class A output stage must then be designed to meet these specifications.

Fig. 2 shows a typical class A audio-frequency power amplifier for use in an automobile receiver, together with curves of maximum power output at a total harmonic distortion of 10 per cent for various values of collector load impedance. Low values of collector load impedance are required to produce large amounts of power output for the supply voltages shown. The power gain of a junction-transistor class A amplifier is a function of input resistance, load impedance, and a-c current transfer ratio, and can be expressed as follows:

$$\text{Power gain} = \alpha_{cb}^2 \, (R_L/R_{IN})$$

where α_{cb} is the ac current transfer ratio, R_L is the collector load impedance in ohms, and R_{IN} is the a-c input resistance of the transistor in ohms. For the circuit shown in Fig. 2, R_{IN} is equal to $R_{be} + \alpha_{cb} R_e$, where R_{be} is the transistor base-to-emitter resistance in ohms and R_e is the emitter resistance in ohms.

In operation, with a low supply voltage, the collector load impedance is considerably lower than the output resistance of the transistor. In output stages for auto receivers, the collector load is established primarily by the maximum power-output requirement. For these receivers, a class A power stage must deliver an output of approximately 3 watts at a total harmonic distortion of less than 10 per cent. When the input resistance R_{IN} is greater than the load impedance R_L, the power gain of the class A stage will be low unless the transistor has a high current transfer ratio α_{cb}. Fig. 3 shows the variation in power gain as a function of R_L. With an R_L of 25 ohms, the circuit shown in Fig. 2 has a power gain of approximately 30 db at a power output of 3 watts when operated from a —14.4 volt supply.

DISTORTION IN CLASS A POWER AMPLIFIERS

Distortion in transistor class A amplifiers is primarily a function of power output, nonlinearity in transfer characteristics, and source impedance. Fig. 4 shows the base-to-collector current transfer characteristic for a 2N301 or 2N301A power transistor. When the input (base) current is sinusoidial, the output (collector current is fairly linear and low in harmonics. As the signal level increases, the input current traverses a greater portion of the nonlinear region of the transfer characteristic and the harmonic content of the output current increases considerably. Fig. 5 shows the total harmonic distortion as a function of power output for different supply voltages. The increase in distortion with increasing power output is due primarily to the nonlinearity in the base-to-collector current transfer characteristic. The rapid change in slope of the distortion curve at high power-output levels is due to "clipping" in the output circuit.

Fig. 2—Maximum power output of 2N-301 or 2N301-A transistors in class A operation as a function of collector load impedance for different values of collector supply voltage.

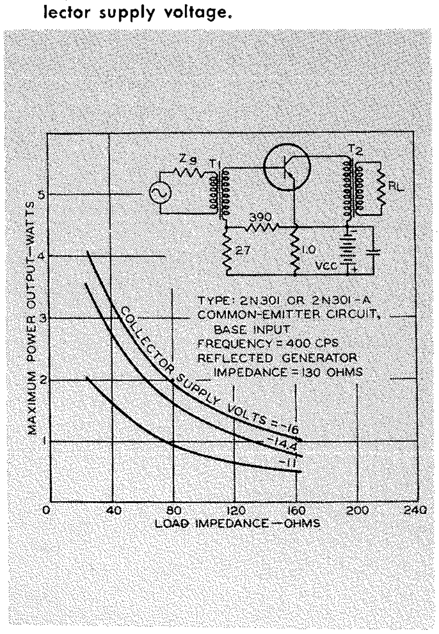


Fig. 3—Power gain of class A circuit as a function of collector load impedance.

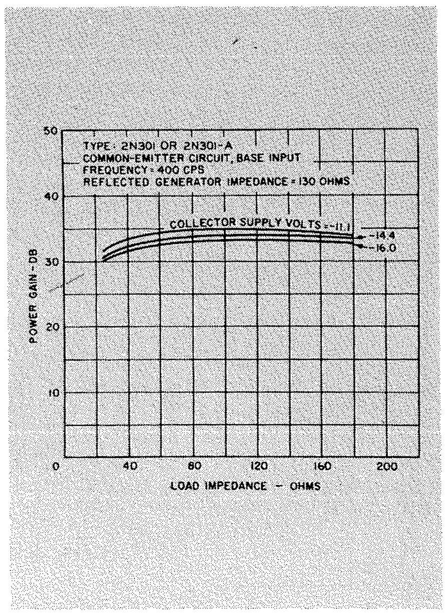
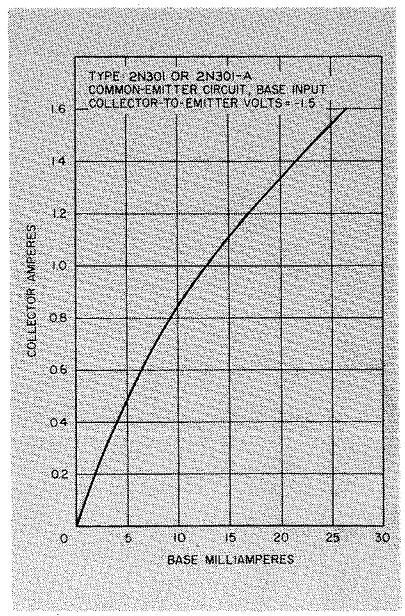


Fig. 4—Current transfer characteristic of RCA power transistors.



EFFECTS OF SOURCE IMPEDANCE ON DISTORTION IN CLASS A POWER AMPLIFIERS

The source impedance presented to the input of a class A power-amplifier stage which uses an interstage transformer depends on the type of driving device used and the impedance transfer ratio of the driver transformer. When the transferred driver output impedance is much less than the input resistance of the transistor, the class A stage is considered to be operated from a constant-voltage source. When the reflected driver output impedance is much greater than the input resistance of the transistor, the stage is considered to be operated from a constant-current source. Fig. 7 shows the variation in total harmonic distortion as a function of the ratio of reflected source impedance (Z'_g) to the input resistance of the transistor. The total harmonic distortion increases appreciably as the ratio Z'_g/R_{IN} is increased, partly because of the higher degree of nonlinearity in the current transfer characteristic. The lowest feasible value of source impedance should be used in a class A power amplifier to minimize distortion.

In some applications, it may be necessary to use negative feedback to reduce the total harmonic distortion. One method of obtaining degenerative feedback is by the insertion of resistance in the emitter lead. The amount of emitter resistance that can be used is normally limited by the power-gain requirements of the output stage.

TEMPERATURE CONSIDERATIONS FOR CLASS A POWER AMPLIFIERS

The effects of temperature changes on transistor behavior are due primarily to changes in reverse collector current, I_{co}, and d-c input conductance.[2] These parameters are highly sensitive to temperature changes, and may cause a shift in operating point. In a class A circuit having low d-c load resistance, such as a transformer-coupled stage, the collector voltage is relatively constant. The collector current in such a circuit will increase with temperature due to variations in I_{co} and d-c input conductance. The resulting increase in dissipation may cause operation beyond the maximum power ratings of the transistor. For satisfactory operation over a wide range of temperatures, some form of stabilization must be used.

The transfer characteristic curves shown in Fig. 6 illustrate the effects of temperature upon the transistor in a stabilized common emitter class A circuit. The operating point is designated by point A on the 25°C curve. If this common-emitter circuit were operated with a constant base-to-emitter bias voltage, an increase in temperature would cause an appreciable increase in quiescent collector current and a consequent increase in power dissipation.[3,4,5] In the circuit shown, however, the bias voltage is determined by the voltage drops across the emitter resistor, R_e and the parallel combination of R_1 and R_2. The voltage drop across the emitter resistor is essentially proportional to the collector current, and tends to stabilize the collector current by applying a reverse bias to the transistor. For a given value of emitter resistance, therefore, the stability of the operating point is largely dependent on the resistance of the parallel combination of R_1 and R_2.

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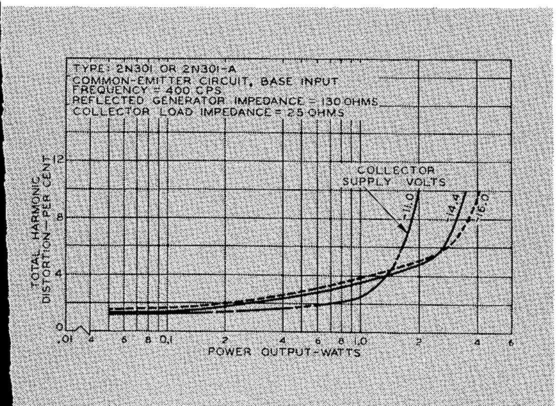
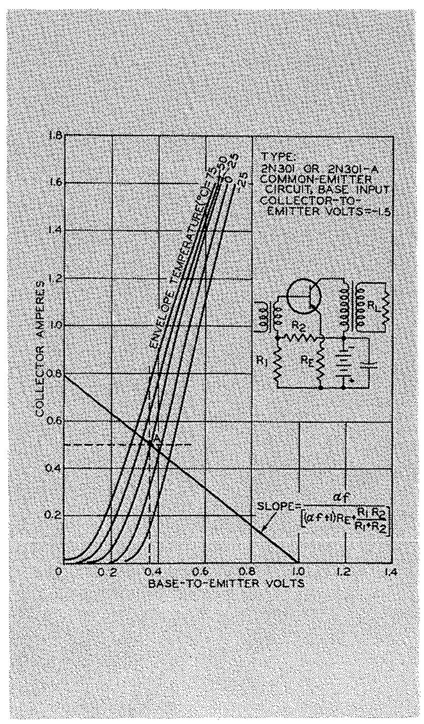


Fig. 5—Total harmonic distortion of class A circuit as a function of power output.

Fig. 6—Curves showing effects of temperature variations on performance of class A common-emitter circuit.



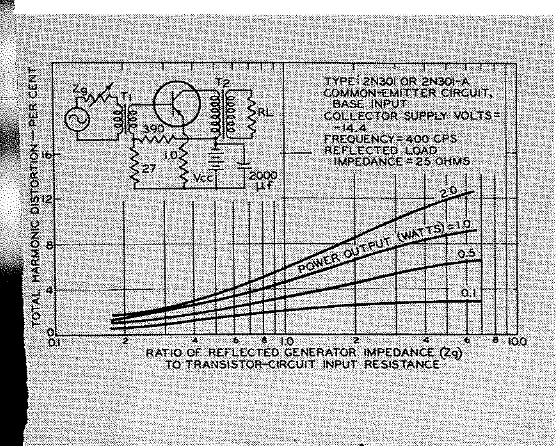
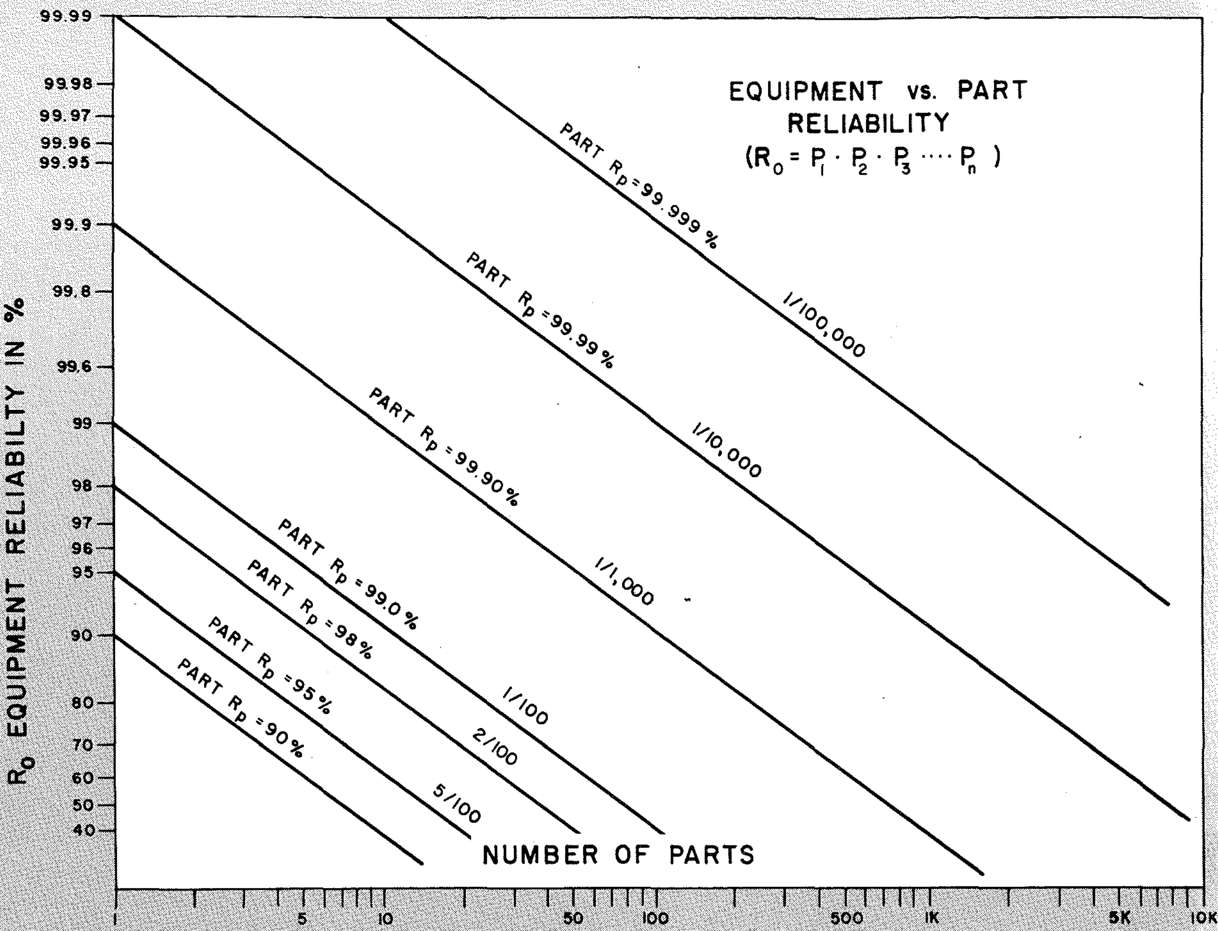


Fig. 7—Total harmonic distortion of class A circuit as a function of the ratio of reflected source impedance to input resistance.

Chart 1—Estimation of approximate equipment reliability when number and average reliability of parts are known.



RELIABILITY—WHAT IT IS AND WHAT IT DOES

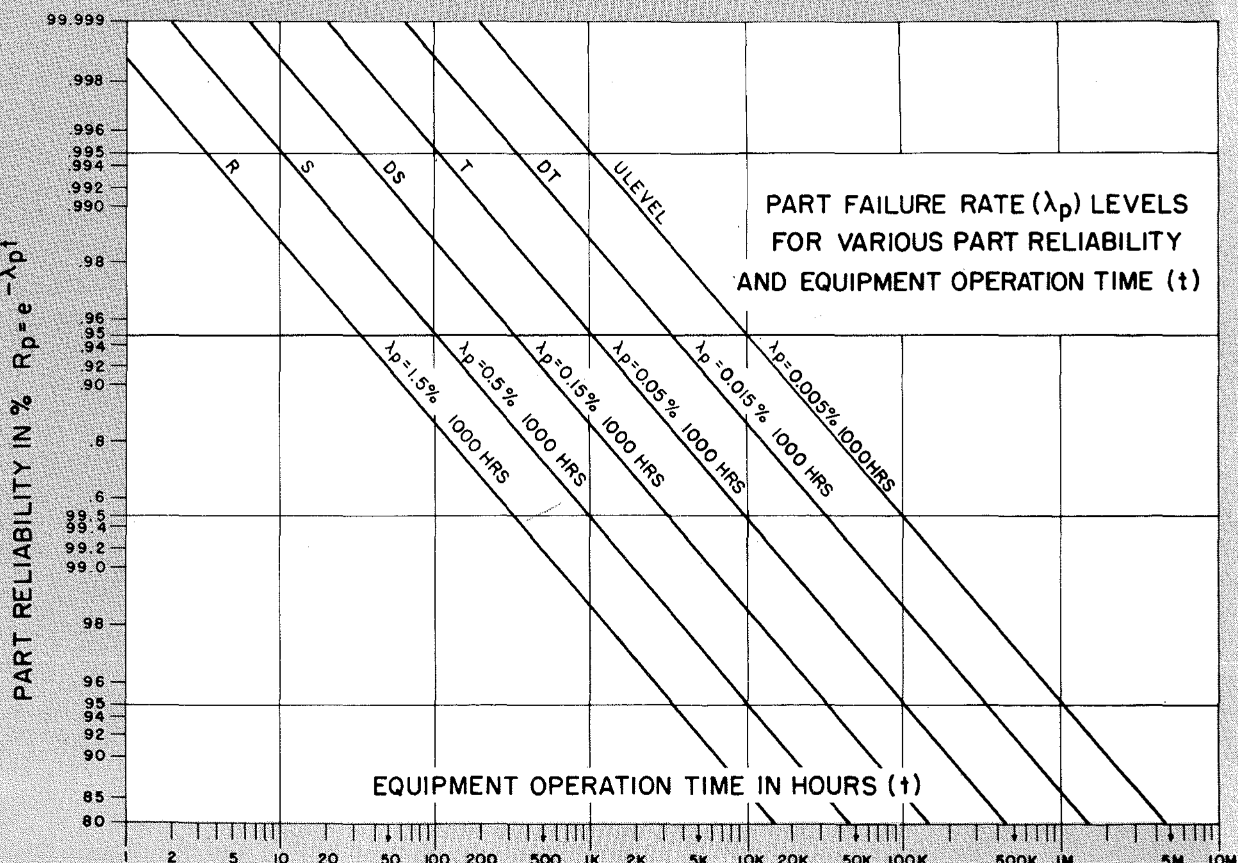


Chart 2—Required failure rate of parts for specific time periods of equipment operation.

RELIABILITY IS A frequently-used word that has much meaning . . . it suggests qualities which merit trust or confidence. Reliability, as related to sound engineering and production practice, is not new to RCA engineers who have always possessed "pride for product"!

As a matter of fact, over the years, RCA has gained an enviable reputation in the electronics field for its reliable engineering and quality products. Engineering management policies which have placed emphasis on dependability have been warranted and the success of this approach is directly reflected in today's high volume of business, good customer relations, and the general high standing of RCA in industry and with the government. Examples of this are the pinnacles attained by RCA in the broadcast and television equipment field and electron tube markets.

RELIABILITY OF CONSUMER PRODUCTS

However, the emphasis that any individual engineer might place on the reliability of a particular product depends upon the end use or commercial requirements for the product. A certain degree of reliability must be designed in all such products; TV receivers, record players, radio receivers and high-fidelity equipment. Yet today, the failure of a radio receiver will probably not disrupt the family well-being since there is usually another receiver to be turned on in its place. The interruption of service, after a reasonable time, does not panic the home receiver owner. The modern trend has been a realization by the receiver owner that an indefinite life is an impossibility at the price the customer is willing to pay. Moreover, a life extended beyond a point at which a receiver becomes out of date is not warranted.

This same general reasoning extends to most all consumer products and appliances and even to some degree to some larger industrial equipments. In these cases, the engineer must design a degree of reliability into the equipment within the dictates of cost and end use of the product. This, then, might lead the engineer to wonder, why and what is the modern concept of reliability?

C. M. RYERSON
Reliability Administrator
Defense Electronic Products
Camden, N. J.

MODERN RELIABILITY REQUIREMENTS

Aside from the consumer products mentioned above, commercial electronic equipment today is finding its way more and more into industry. Applications include automatic control, servo mechanisms and automatic machinery such as that used in the oil and paper industry and to some degree in electronics. In these cases the failure of one small component may disrupt a whole operation, tying up the entire factory for valuable minutes, maybe hours. This cannot be tolerated!

Project this same thinking to defense equipment involving guided missiles and military systems which may include thousands of individual stages or components. Now, it is easy to see why *reliability must be reviewed in a new light!* Unlike the commercial consumer product with a comparatively short yet satisfactory life, it now often becomes a necessity to provide long-life and a high degree of reliability in order to satisfy stringent defense requirements and specifications. One might question why not apply the same logic that has made RCA broadcast equipment so successful, i.e., quality equipment with reasonable amount of spares. It is true that this logic can be applied to a certain degree. However, the cost of redundancy becomes prohibitive when it involves complex and costly defense systems employing thousands of components. Moreover, space limitations in many systems will not accommodate a duplication of equipment. A further complication in modern military equipment is the extreme environmental conditions of end use.

RELIABILITY DEFINED

Because there has recently been so much publicity and difference of opinion concerning the term reliability, it seems in order to discuss a definition:

The reliability of a particular component or system is the probability that it will do what it is supposed to do for a given period of time, when used in the manner and for the purpose intended.

This is a well accepted definition and is the one proposed by RETMA. It offers the key that there is a need to cope, within cost limitations, with the control of failures and defects that occur in equipment. Picture an entire system as a chain of components which are successive links, all working together. Statistically then, the overall reliability of the chain is the mathematical product of the reliabilities of all the individual links, i.e.,

OVERALL RELIABILITY,

$R_o = P_1 \times P_2 \times P_3 \ldots P_n$ where P_1, $P_2 \ldots P_n$ are the probabilities that each of the component parts will be reliable. Suppose, for example, a simple system is made up of one-hundred different components, each of which has a reliability of 99% for a given period of time. Then, the overall reliability for the entire system is only 36½% for the same period of elapsed time. This means that two of three systems you have put together will probably fail.

Since this paper is introductory in nature, detailed mathematical treatment is not included. Nevertheless, Chart #1 shows how approximate reliability may be estimated, when the number of parts and average reliability of parts and average reliability of each are known.

Chart #2 shows the failure rate required of parts if the equipment must be reliable for specific periods of time. The level R was met by World War II equipment as reported in the Rand Report #RM1131 by R. R. Carhart. The level S is the present minimum Standard RCA design level and is approximately three times better than the "Rand" or R level. The DS level is a derated S level approximately three times better. The T level is ten times better than the S level and represents a reliability that RCA has frequently been called upon to achieve. The DT level is three times better than the T level and the U or "ultimate level" is ten times better than the T and thus one hundred times better than the S level. Even this ultimate is obtainable but very often cost consideration becomes a prohibitive factor.

Charts #1 and #2 point out that a control of components, as well as system reliability, is vital. Part reliability can be controlled by proper circuit application and the maintenance of a high quality of part design and manufacture.

Good engineering practice and good reliability are inexorably related. Good engineering must assure the attainment of a definite degree of reliability for military systems (that figure specified in the contract). Following is a list of recommended steps which will get a reliability control system operating successfully and will result in achievement of reliability figure-of-merit "bogeys."

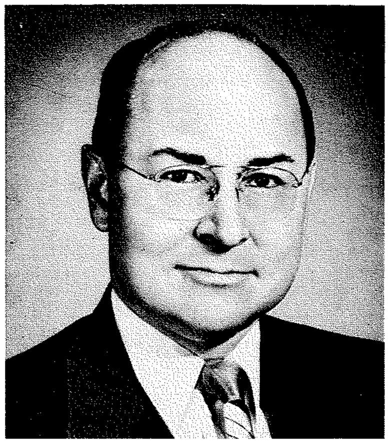
1. *Determine Requirements*—Check carefully the degree of reliability required. Determine environment, operating time, performance limits, etc., in terms of required reliability.

2. *Designate Responsibility and Design Goals*—Determine and assign responsibility for executing the reliability program at the project level. Project engineers must further designate responsibilities to subordinates in terms of specific design goals.

3. *Establish Controls* — Define and break down in terms of people, skills and facilities. Provide test procedures which show high degree of correlation with end-use condition. Set up methods for continuous accumulation of data on components and system.

4. *Analyze* — Make sure reliability requirements are being met. Establish causes of failure by analysis of data collected. Take action to eliminate causes of failure so that required level of reliability is met. Provide for proper liaison between design, test and field operation.

5. *Evaluate and Maintain Vigilance*—Accumulate information pertinent to reliability improvement, evaluate and pass on information to central Reliability Committee. The committee must further keep all project engineers and leaders aware of latest developments and techniques. Establish information feedback and institute methods for corrective action. Review and modify requirements with changing conditions.



CLIFFORD M. RYERSON received his B.S. degree from Stetson University, DeLand, Fla. He also took post graduate work in Physics at Duke University where he served 3 years as assistant to the Head of the Physics Department.

From 1941 to 1946 Mr. Ryerson was with the Naval Ordnance Lab., Washington, D. C., where he served as an electronic consultant in the Research Division. The next six years were spent with the Naval Gun Factory, Washington, D. C.

In 1952 Mr. Ryerson joined RCA as a System Project Engineer in the Missile and Radar Department and in 1954 was Reliability Coordinator for Engineering Services. He became Reliability Administrator, Defense Electronic Products in 1955, reporting to M. C. Batsel.

Mr. Ryerson is associated with the Institute of Radio Engineers, American Physical Society, and a number of honorary and social fraternities. He is a registered Professional Engineer, holds 5 patents and is active on national committees of RETMA, IRE, AIA and AGREE.

REVIEW OF METHODS USED

The foregoing procedure assumes that a required degree of reliability is designated in contract specifications for military products, or established by analysis of product end use for commercial products. Parameters such as environment, shelf life, degradation, catastrophic failure, maintenance, economy, redundancy and human error and many others must all be considered.

Concerted effort on reliability is a requirement of current necessity, especially in contracts for defense products, where specific figures of merit for reliability have been requested by the government. It is expected that this will be on the increase and extend to most all contracts in the future. Fortunately, RCA management has realized that emphasis must be placed on reliability and that it cannot be done through localized or isolated efforts.

WHAT RCA IS DOING ABOUT RELIABILITY

A central committee for reliability control in Defense Electronic Products is under the direction of Mr. M. C. Batsel, DEP Chief Technical Administrator. This committee is comprised of engineering, planning, marketing, purchasing, and quality control representatives from each DEP product line division, with the author serving as "chairman." Coordination also extends to the Service Company and other divisions of the company represented on the committee.

A service provided by the Central Reliability Committee is to circulate reprints of articles, brochures, and pamphlets to the various interested activities. A four-point plan of training courses offered during working hours has now been introduced. It is expected that these courses will further the control of reliability to a great degree.

A training course for field representatives has been in operation for many months within the Service Company.

In addition to the above courses sponsored by the Central Reliability Committee, there is an after-hour training program in progress comprising two courses in applied statistics and a third dealing with reliable design through proper application of parts.

CONCLUSION

In conclusion it is apparent that reliability has taken on a new importance in view of today's trend toward automatic procedure and in view of the urgency of our defense systems. It is also evident that a "group reliability control" of such systems is needed. This control must be all encompassing since it includes procedures, equipment and people . . . and depends upon designs, manufacturing, testing and quality. At RCA there are engineers with long and valuable experience in designing and providing quality procedures, production people with long experience at quality production, and others with long experience in various fields including management. It is with the help of these people that the overall reliability program can be made successful.

A NEW HIGH-PERFORMANCE COMMUNICATION RECEIVER

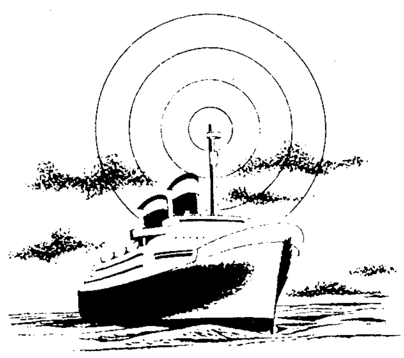
A MODERN COMMUNICATION receiver must meet more stringent requirements than did receivers of only a few years ago. With the present crowded frequency spectrum, one of the paramount needs is variable selectivity which can be adjusted to be just wide enough for the desired signal, and at the same time reject all other signals. High selectivity in turn requires excellent frequency stability so that a signal will not be detuned or lost as the receiver's local oscillator drifts. Having achieved high selectivity and stability, it is equally important to "bandspread" the tuning system so any frequency within the receiver's range can be spotted and tuned with precision.

VARIABLE SELECTIVITY FEATURE

Variable selectivity and high frequency stability are achieved through a unique application of a triple conversion superheterodyne circuit in conjunction with a tunable i-f system. The high-frequency oscillator has its circuits stabilized by means of seven built-in crystals. This, however, does not limit the receiver to spot crystal controlled frequencies because the tunable i-f system, ganged to a lower frequency variable oscillator, permits continuous tuning for any high-frequency signal.

Depending upon the frequency band in use, and the degree of selectivity desired, the circuits function as a single, double or triple superheterodyne. One of the fixed i-f stages operating at 455 kc includes a mechanical filter with a steep-sloped response, providing for high rejection of undesired signals outside its pass band. Another fixed i-f stage, operating at 45 kc, is used for narrow band reception. For still higher selectivity, the audio amplifier may be switched to a 1-kc filter which is 100-cycles wide with a 6-db bandwidth.

The features of stability and selectivity do not tell the whole story, however, as there are many exacting conditions under which a communications receiver must operate when employed for Marine service.



By **R. G. BERGE and E. W. MAHLAND**

Radiomarine Engineering
Commercial Electronic Products
New York, N. Y.

SPECIAL REQUIREMENTS FOR MARINE SERVICES

Marine communication receivers are subjected to severe environmental conditions. *First of all,* they operate under constant vibration while the ship is under way. Received signals must "stay put" so that the operator is free to run a typewriter. *Second,* materials and components are required to withstand the effects of humidity and salt atmosphere. *Third,* a shipboard receiver is subjected to high antenna voltages produced from the ship's transmitters, yet it must operate simultaneously without excessive interference, especially in radiotelephone service. Therefore, blocking and cross-modulation characteristics require special attention.

Since low- and medium-frequencies are used for ship communications, as well as high frequencies, the receiver must include all three bands to avoid the necessity of two receivers. Concerning power, many ships utilize d.c., so it is desirable to have a receiver which does not require an external inverter to provide either d-c or a-c operation. A description of how these various design features were obtained is given in the paragraphs that follow.

HOW SELECTIVITY IS OBTAINED

The Radiomarine Model AR-8516 Communication Receiver is a triple conversion superheterodyne with a frequency coverage of 80 kc to 30 mc (refer to Fig. 2). The tuning range is divided into 18 bands, 15 of these covering from 1.2 mc to 30 mc. Each of these 15 bands covers a linear 2 mc range and the remaining three low bands, 80 kc to 1300 kc, are of conventional design. To provide a high degree of selectivity on all bands three different intermediate frequencies are used; 45 kc for frequencies up to 520 kc, 455 kc and 45 kc for frequencies to 4 mc; and above 4 mc a tunable intermediate frequency of 1.09 to 3.09 mc or 2 to 4 mc in addition to the 455-kc and 45-kc systems. For frequencies above 520 kc the selection of the 45 kc intermediate frequency is optional.

The 455 kc intermediate-frequency amplifier provides selectivities in the range of 6 kc and 3 kc, the 3 kc being obtained by the use of a mechanical filter. For the 1.5-kc and 0.8-kc positions of selectivity the 45-kc is used and for frequencies above 520 kc it can be cascaded after the 455-kc i-f amplifier. The 0.1-kc selectivity position is acquired by the use of a 1000 cycle peaking circuit in the audio section. Fig. 3 shows a typical set of selectivity curves for all five positions.

STABILITY PROBLEM

Most communication receivers have a local oscillator in the same frequency range as that of the receiver, differing only by the intermediate frequency. As the frequency of the receiver increases, the problem of maintaining the stability of the local oscillator becomes more difficult.

For example, on a percentage basis of say .01% per °C stability, the deviation of a local oscillator at 1 mc over a temperature change of 20°C would be 2000 cps, which is quite stable for a simple LC type of oscillator. However at 30 mc the deviation would be 60 kc which is intolerable.

The maximum change in frequency of this receiver was limited to less than 1 kc over normal operation conditions, including warm up. The lower bands, 80 kc to 1300 kc, and all BFO's are well within this specification by using conventional LC type of oscillators. However, to meet this requirement for the frequency coverage of 1.2 to 30 mc it was necessary to depart from the conventional LC type of local oscillator and to limit the upper oscillator frequency to 3.545 mc.

In order to cover up to 30 mc it was necessary to heterodyne the frequencies above 4 mc with an appropriate crystal frequency or its harmonics to obtain a tunable intermediate frequency range of 2 mc. The local oscillator, or variable frequency oscillator (VFO), can then cover a constant frequency range which is heterodyned with the tunable i-f to produce the desired 455-kc intermediate frequency The obvious advantages of using the above system are: no coil switching of the VFO is required when changing bands; the stability of the receiver is mainly determined by the VFO oscillator, as the crystals are inherently stable. The VFO oscillator is of the series resonance type[1] and was chosen because of the following features:

(a) The elimination of the Miller capacity effect by the use of cathode feedback.
(b) The input and output of the tube are shunted with low reactances which minimize the effects of variation in tube impedances.
(c) The use of simple capacity temperature compensation at both frequency ends of the oscillator.

ELECTRICAL STABILITY

With the elimination of the electron tube as a factor in frequency stability, this leaves only the tuning capacitor and coil as the major considerations. The tuning capacitor decided upon is of steel construction because of its better temperature coefficient over that of aluminum. The coil is wound under tension on a ceramic form and is of single-layer close-wound design. Since a high Q is desirable in this type of oscillator, a powdered iron core is used, which also provides a means of tracking the VFO at the low-frequency end.

The coil is specially heat treated and baked at 275° F for maximum stability. The maximum frequency shift of this stable oscillator is less than 20 parts per million per degree centigrade (0.002% per °C). There is very little warm-up drift when the oscillator is first turned on, or long term drift after the oscillator is operating. Line voltage variations of ± 10% cause less than 25 cycles.

MECHANICAL STABILITY

When designing a receiver for shipboard use special precautions have to be taken in regard to mechanical stability, as mentioned previously. All components for our VFO, with the exception of the tuning capacitor, are mounted on a sub chassis constructed of heavy gauge steel to prevent mechanical distortion. In any receiver, the mounting of the oscillator capacitor is critical because of its susceptibility to slight mechanical changes causing frequency shift. The result of this frequency instability is to render the reception of CW and SSB signals very difficult, if not impossible. With the receiver monitoring these CW and SSB signals practical tests were made by (1) lifting the receiver by one handle to create mechanical stresses; (2) jarring the surface to which the receiver is mounted, thus creating mechanical shock; and (3) installing the receiver in a shipboard console with the motor generator running to cause vibrations in the frequency range of 30 cps.

By mounting the tuning capacitor and gear box rigidly to each other and properly bracing these units to the main chassis and front panel, it was possible to reduce frequency shift and distortion of CW and SSB signals, to a negligible value.

A NOVEL TUNING MECHANISM

A sketch of the tuning mechanism is shown in Fig. 4. For the five lowest frequency bands in which the receiver operates as a conventional superheterodyne, the tuning capacitors are actuated through a step-down gear ratio of 41.7 to 1, giving a high degree of mechanical band spread. For bands 6 through 18 it is necessary to track the r-f signal circuits to the tunable i-f circuits. In order to do this it is necessary that there be a linear relationship between the frequencies to which the r-f signal circuits are tuned and the angular displacement of the r-f tuning shaft. To obtain this linearity a special variable capacitor plate shape was developed. In conjunction with suitable shunt and series tuned circuit padding, all ranges are substantially linear. The r-f tuning shaft is mechanically coupled to the i-f tuning shaft by a detent mechanism and a step-down gear train of 3.8 to 1. Thus when the tuning knob, which drives the i-f tuning capacitor through a 41.7 to 1 step-down gear train, is rotated, the r-f tuning capacitors are also rotated. This means that when the tunable i-f is tuned through its entire range (2.0-4.0 mc) the r-f tuning capacitors have been tuned through only approximately one quarter of their range and exactly two megacycles have been covered.

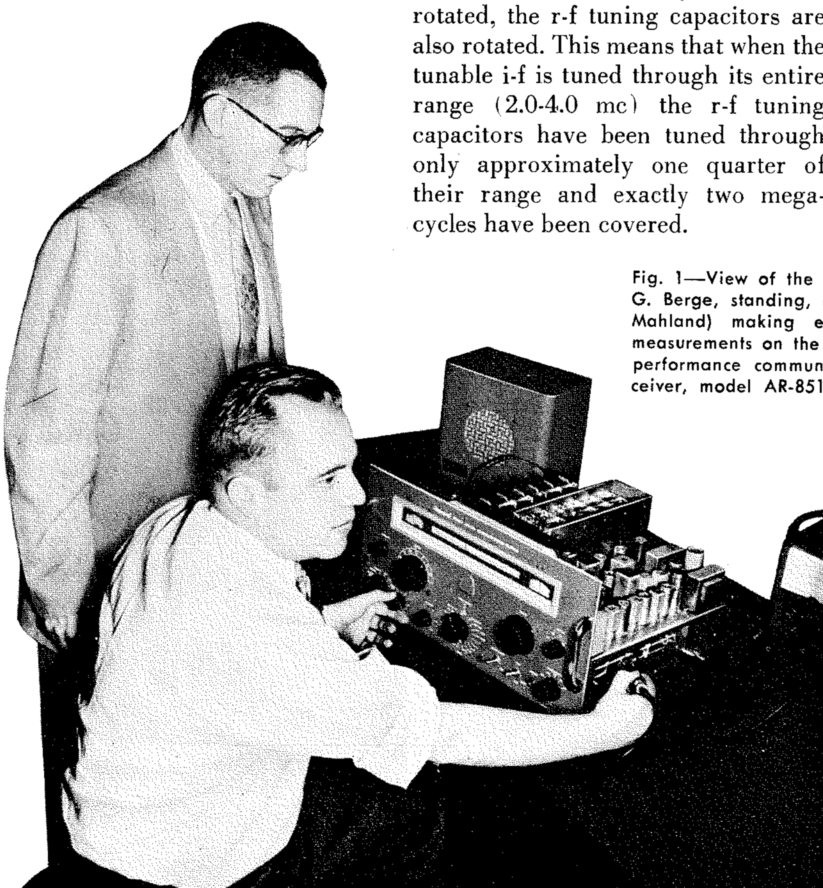


Fig. 1—View of the authors (R. G. Berge, standing, and E. W. Mahland) making engineering measurements on the new high-performance communication receiver, model AR-8516.

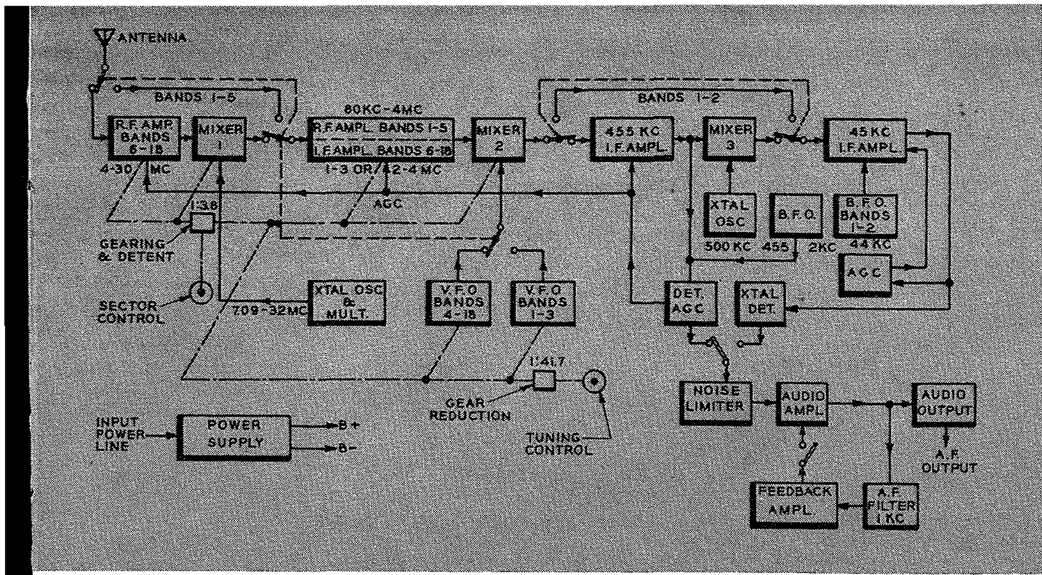


Fig. 2—Simplified block diagram of the model AR-8516 Communication Receiver.

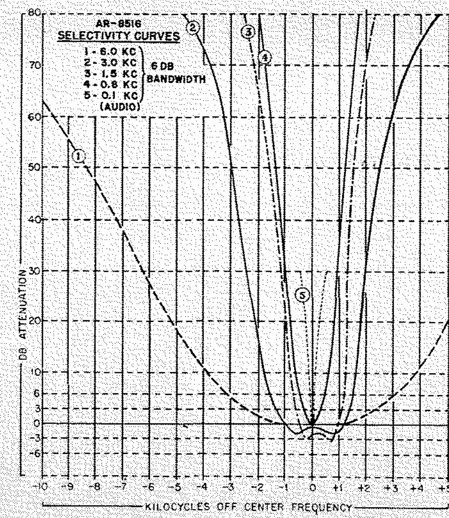


Fig. 3—A group of curves showing the selectivity for each of the five frequency positions.

The r-f tuning capacitor shaft is brought out to the SECTOR knob on the front panel. This shaft is mechanically coupled to the gear train by a four-step detent mechanism with the detents accurately located 45° apart on a plate fastened to the driving gear. The arm of the detent is fastened to the capacitor shaft. Turning the SECTOR knob moves the detent from one position to the next and results in a change in r-f tuning of two megacycles. When the BAND switch is moved to the next position, corresponding to the SECTOR selected, a crystal oscillator voltage of correct frequency is applied to the first mixer, and correct tracking is maintained between the r-f signal circuits and the tunable i-f circuits.

Considering the 13 bands above 4 megacycles, a conventional receiver would require 13 sets of r-f coils to tune the range of 4 to 30 mc in two megacycle steps. The Model AR-8516 Receiver covers this range in four sets of r-f coils by using the tuning mechanism described.

The dial drum incorporates a scale for each band. The drum rotates when the BAND switch is rotated so that the correct scale appears in the window on the front panel of the receiver. The pointer for this scale is driven from a drum attached to the i-f capacitor tuning shaft. The four sectors of the SECTOR control are marked A, B, C and D and the sector position to be used for a particular band is indicated in a small window located directly above the BAND switch. A dial light tell-tale circuit is also included. A wafer type switch is used for this with the contact arm of the switch attached to the SECTOR control shaft and the wafer connected to the gear to which the detent plate is attached. The circuit is interlocked through the bandswitch so that the dial lights only light when the SECTOR is in the correct position. Because of the tuning system employed, a signal at 30 megacycles tunes in and has the same "feel" as a signal at two megacycles. One-kilocycle intervals are shown on the vernier scale, and because of the quality spring-loaded gears used, signals are resettable to less than one kilocycle. The average accuracy of frequency settings is about five kilocycles.

SPECIAL BFO CONSIDERATIONS

When a new type of design is undertaken, problems arise which are not readily apparent at the beginning of the project. The following paragraphs are an example of such a problem and how it was solved:

In a conventional type of superheterodyne receiver, variable selectivity is often provided by changing the coupling between tuned circuits of the intermediate frequency amplifier. The beat frequency oscillator signal used to produce an audible output when receiving a CW signal is injected in the i-f system at a point just ahead of the detector circuit so that the selectivity of the i-f circuits does not affect the audio beat note or its amplitude.

This receiver provides for different degrees of selectivity by making use of two i-f systems of different frequencies. They are either used separately or connected in cascade, the higher frequency system (455 kc) is used for broad selectivity and the sharp selectivity is obtained by connecting a low-frequency system (45 kc) in cascade with the higher system. A beat frequency oscillator operating at 455 kc produces the usual audio beat note at the 455-kc detector.

However, when the 45-kc system is connected in cascade, the selectivity of the 45-kc tuned circuits causes the side bands, containing the audio beat note, to be seriously reduced at the 45-kc detector. By making use of a recombination of frequencies we were able to eliminate this effect in the 45-kc system. As can be seen from Fig. 5 the switching is arranged so that the audio output can be connected to either the 455-kc or 45-kc detectors by means of S1. The S2 switch is used to connect the 455-kc BFO for either operation with the 455-kc or 45-kc system.

The above circuitry fulfills the requirements of switching from broad selectivity to sharp selectivity without changing the amplitude or frequency of the resulting audio tone.

An additional feature is included in the 455-kc BFO to aid in the reception of SSB signals. A position is provided on the front panel marked "SSB." At this position the strength of the BFO is increased in order to minimize the possibility of overmodulation in the detected SSB signal.

DESCRIPTIVE SPECIFICATION

The final specification for the production units of the AR-8516 Receiver is summarized on the following page.

CONCLUSIONS AND ACKNOWLEDGMENTS

In the present state of radio communications the Model AR-8516 Receiver design should give highly satis-

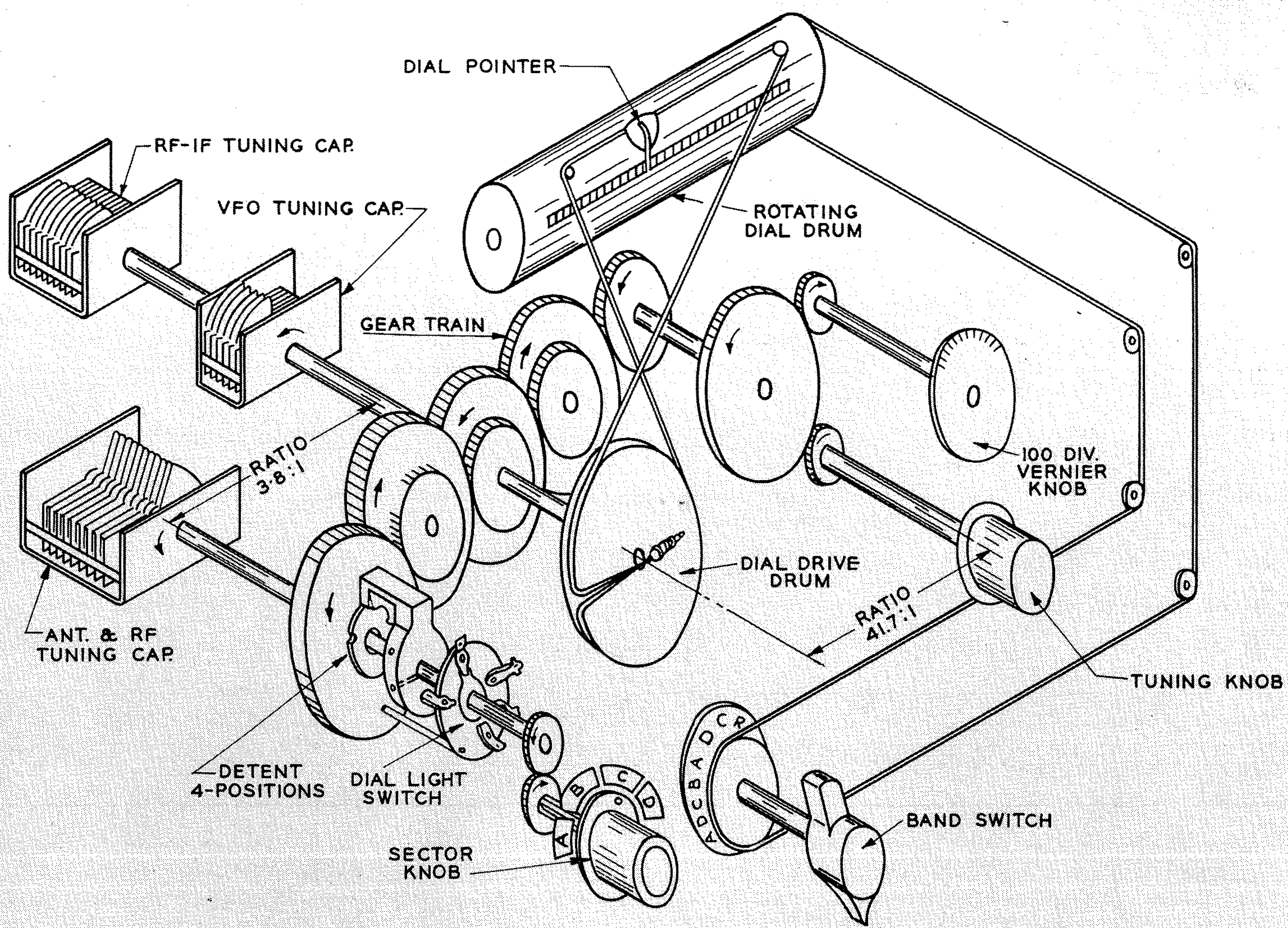
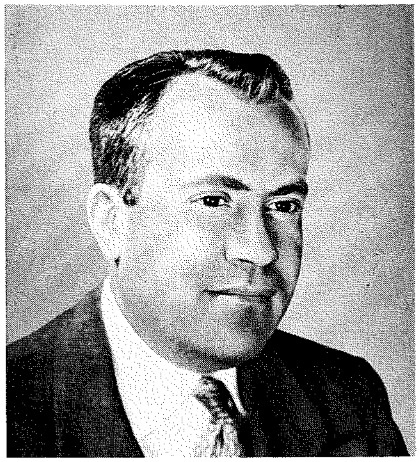


Fig. 4—View of the AR-8516 Communication Receiver with the tuning mechanism arrangement shown at top of page.

RAYMOND G. BERGE graduated from Columbia University in 1939 with a B.A. degree, engineering major. He also attended RCA Institutes and took post-graduate courses at Columbia in engineering subjects. He joined Radiomarine Corp. of America in March 1941 where he did work in test and development. Later after promotion to engineer, he designed radiotelephone receivers, radio direction finders and radio teletype equipment. Mr. Berge also designed and supervised installation of equipment for the superliner S.S. United States. He is a senior member of IRE.



EDWARD W. MAHLAND joined the Radiomarine Corp. of America, Engineering department, in October 1945. Previous to his 3 year enlistment in the U.S. Navy, he worked for Sperry Gyroscope Company in their bombsight division. He graduated from Bliss Electrical School in 1943 and Capitol Radio Engineering Institute in 1951. He has worked mainly with Radio and Radar receivers since his employment with Radiomarine and supervised the installation of remote receiving equipment aboard the SS Independence and SS Constitution. He is a member of the IRE.

factory electrical and mechanical performance for many years to come. Not only does it have the required features for marine use, but can readily be used as an all-purpose communication receiver.

The authors gratefully acknowledge the development work done by G. Grosso and Harry Mohr in the laboratory and to Bill Autry, Charles Mendelsohn and Gloria Fletcher for their work in the mechanical design and layout of the receiver. Credit is also extended to Mr. George Bradley, formerly supervisor of the project, for his many constructive and practical suggestions.

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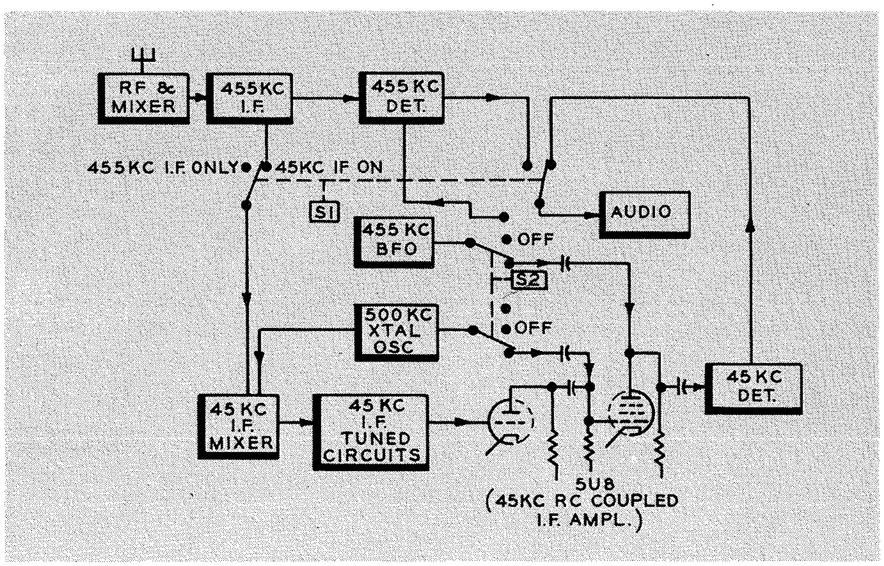
1. Radio Engineering, E. K. Sandeman, Volume 1, 1948, Chapter X1:2 page 421.



SPECIFICATIONS

Tuning Range:
80 kc to 30 mc

Intermediate Frequencies:
Tunable: 1.09 to 3.09 mc or 2 to 4 mc
Fixed: 455 kc; 45 kc
Sensitivity for 6 db $\frac{S+N}{N}$ Ratio
(400 cps modulated 30%)

80 kc — 520 kc	6μv or less	
520 kc — 4.0 mc	4μv or less	
4.0 mc — 30 mc	2μv or less	

Selectivity for 6 db Bandwidth: 6 kc, 3 kc, 1.5 kc, 0.8 kc and 100 cps, audio peaking (±200 cps at 20 db).

Antenna Input:
IRE Dummy: 80 kc to 4.0 mc.
75-300 ohms balanced: 4-30 mc.

Audio Output:
3.2 ohms, 600 ohms center tapped, and headphone jack.
1 watt, 10% or less distortion.

Fidelity (Overall):
200-3000 cps ±4 db (6 kc selectivity).

Beat Frequency Oscillator:
455 kc ±2000 cps.
44 kc (fixed), 80 kc to 520 kc.

Noise Limiter:
Effective pulse clipping with negligible effect on modulation.

Crystal Calibration:
Check points every 500 kc.

Tuning Meter:
Calibrated in db above 1 μv.

Automatic Gain Control:
Output constant to ±5 db for 10μv to 1 volt input.

Blocking and Cross Modulation:
Designed for minimum blocking and cross modulation.

Spurious Signals:
External
1st image: greater than 56 db (ave).
i-f rejection: more than 60 db (ave).
All others: greater than 70 db.
Internal
Less than 2μ volts equivalent antenna signal.

Frequency Calibration:
Resettable to 1 kc by vernier scale.

Stability:
Within 1 kc under normal operating conditions including warm-up.

Hum and Noise Level:
34 db below 1 watt output.

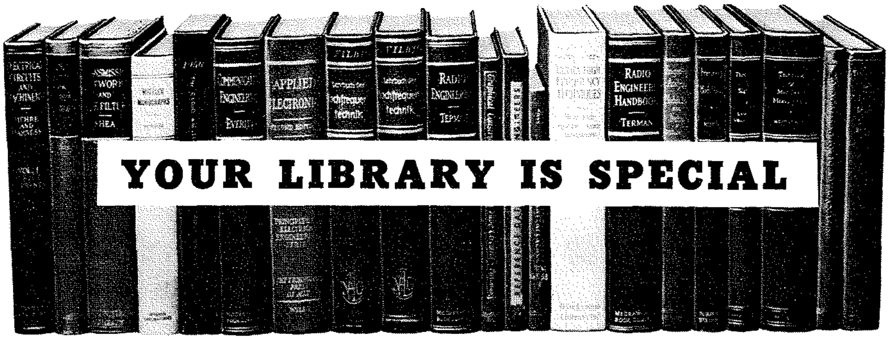
Antenna Radiation:
Below 400μμ watts.

Balance to Unbalance Ratio:
Greater than 20 db.

Auxiliary Connections:
455 kc i-f jack for FSK, or SSB adapters (0.1 volt into 1000 ohms). Standby terminals for receiver-transmitter switching.

Power Supply:
Line operated AC/DC 115 volts.
Power consumption 80 watts.

Dimensions and Weight:
19"W x 9½"H x 16"L. (Standard 19" relay rack or cabinet mounting.
Approx. 61 lbs. without cabinet.



YOUR LIBRARY IS SPECIAL

Mrs. ANITA W. JONES
Librarian—Cherry Hill

TODAY LIBRARIES HAVE become all things to all people. To some they are a formula for fun, to others a source of inspiration. But whether it's for work or play, fact-finding or escape, they supply millions of people with necessary, vital know-how. Just as the public library floodlights a whole community, the special engineering library spotlights one group or organization.

INFORMATION PRESENT AND FUTURE

In contrast to the traditional library, the special library deals primarily with the present and future. Consequently, the material of most vital importance may not be in books, often may not even be in print. So the library reaches out for information, classifies it in such a way as to make it available quickly, checks it, sees that it is pertinent, authoritative and up to date.

A wide variety of questions are asked of the more than 3000 special libraries in the United States. Not long ago, when the subject was extra hush-hush, an engineering research librarian was asked to give a correct definition of radar which would tell nothing.

One fact, which may not be obvious to the library user, is that the technical library does not attempt and does not need to possess all of the recorded information which it uses. Through interchange with other libraries, knowledge of sources are applied to reach outside its own four walls for information, and a large part of its value lies in knowing just where and in what direction to reach.

ENDLESS RESOURCES

The General Interlibrary Loan Code (as set up by the American Library Association in 1952) is used in borrowing items from other libraries. This courtesy allows material to be lent by one library to another library for the use of an individual borrower. These rules are observed by the RCA Libraries and all borrowers should request that material be located and borrowed through the library serving their group.

There are 17 organized libraries in RCA. Each library handles the functions of obtaining, classifying, arranging, safekeeping and circulating a specialized collection of books, journals, government specifications and publications, trade catalogs, patents and other published information. Each library also collects RCA reports of interest to its borrowers.

Kettering has said that "you should set up your problem, think it out, decide how it ought to be done, then go and see what has already been done on it." The RCA libraries, without stifling creative thinking, have established guideposts that will help avoid roadblocks and blind alleys in the fields which are of vital interest to the Corporation. Anyone interested can find in the library storehouses more experience than any one man alone could acquire in a lifetime! If you wanted to hunt for gold, would you search by hunch? Or would you use the geological and specialized equipment available?

The search for fact or a bit of information is like trying to find a nugget of gold. You might make a find through aimless groping, but your chances will improve if you find out where and how to look and what tools to use.

The best library in the world would be useless without careful organization. Most libraries in the United States and Canada are arranged according to subject so that any book in the collection can be found on a few minutes' notice. Learn to use one library well and you will be able to find your general way around in any library.

Thousands of research workers do not know the elementary tools for fact hunting. Actually, the rules for using them are very simple. The areas for search are the endless resources of the library, and there are many guides to enable one to work on his own if he prefers.

CARD CATALOG

The CARD CATALOG is an index of all books owned by the library. This index at Cherry Hill has books listed on white cards, other materials (reports, pamphlets, catalogs, etc.) on blue. The catalog can be used to find material by its author, its title, or its subject. Every book in the library is listed all three ways!

As you thumb through the cards in the catalog, notice the cryptic numerals and letters in the upper left-hand corner of each card. That is the "call number" which you can match with the identical number on the spine of the book. Here is positive identification, just as a license plate identifies a car. At Cherry Hill, the books are arranged on the shelves in subject order according to the library of Congress (LC) system of classification. This scheme uses both letters and numbers. The first letter indicates the class (or subject); the second a division of the class; and further sectioning is made by the use of numbers. For example, the letter Q stands for Science, QC for Physics, and QC 252 for "Heat." Other libraries may use the Dewey Decimal Classification System which divides books into ten main subject classes using numbers only. An example uses 530 for Physics; 536 for Heat; and 536.5 for the Temperature of Heat.

SPECIALIZED INDICES

There are the many SPECIALIZED INDICES. Many times you may want a fact that hasn't yet been preserved in hard covers, a fact which appeared in a magazine or journal. It is a rather hopeless task to page through stacks of old magazines to find the one fugitive fact you need. This time-consuming effort is not at all necessary for there are many guides to periodical literature. Thousands of journals keep hundreds of thousands of specialists abreast of the growth of knowledge in their fields of investigation. The Cherry Hill Library currently receives 130 different periodicals regularly. Since the journals are usually about five years ahead of books on the same subject, it becomes important to learn to use the excellent indexes of this material. Two indices which supplement each other in listing articles on technical and scientific subjects are INDUSTRIAL ARTS INDEX and ENGINEERING INDEX.

INDUSTRIAL ARTS INDEX is published monthly and cumulated finally at the year's end. The articles are indexed by subject and are taken from a selected list of engineering, trade, and business periodicals.

ENGINEERING INDEX is published annually and reviews more than 1,200 publications, many from foreign countries. Only articles dealing with engineering are selected and there is an author index at the end of each volume. Each reference has a brief summary of the article, which is of great aid in deciding if the article should be studied in detail.

RESEARCH REPORTS

Still another rich vein of information is the collection of reports written within the Company. The Cherry Hill Library has a numerical listing of the reports stored in the library, and also an author, title, and subject listing. The accumulation of these reports represents the most unique literature in a technical library. They provide all the significant details of our Company's technical past, present, and future. These research reports must be indexed meticulously to reveal work that has been done and to provide insurance against its being repeated. The RCA reports are regarded as confidential, subject to restricted circulation.

SECURITY-CLASSIFIED TECHNICAL REPORTS

RCA Libraries serving engineers working under government contract receive copies of pertinent regulations from the sponsoring agencies. Problems of military security always are present in the library handling classified reports and each engineer should check with his library concerning procedures.

REFERENCE SECTION

The REFERENCE SECTION of the library is made up of guide books, encyclopedias, handbooks and dictionaries. The librarian also keeps an information file which is a constantly-growing store of miscellaneous information. Here can be found the answers to such questions as "Who has a collection of catalogs, specifications or drawings?" "Where can I get information concerning RCA scholarships?" "Does RCA have a film library?"

LIBRARIAN WILL HELP

Suppose you do not have time to personally explore these resources for every research problem. A valuable service to any engineer is the personal assistance of the librarian. Her qualitative knowledge will save you time by directing you to the exact material you need. The good librarian tries to be aware of the contents of the many items in the library, but is not a student of the contents per se.

ANSWERS BY TELEPHONE

Quite often you may need a quick answer to a question, not a complete exploration of a topic. You will find that a telephone call to your library results in:

Information specifically requested,

Suggestions of better or more recent material,

Notification of currently published technical information.

A PRIVATE DETECTIVE

Most librarians have developed the instincts of a detective. Even MIT hasn't invented a machine of permanent memory for an infinite amount of information. "Two years ago," is so often heard, "Joe Smith wrote a small, blue-covered book about_____. May I have it right after lunch?" As soon as the smoke clears (there's no dust at Cherry Hill Library, only smoke) it is discovered that there is no Joe Smith, no blue-covered book by him, BUT Sam Hall covered the subject in an article in 1947. Lapse of memory is a universal trait, so beware of being so positive that the librarian feels that you might object if she reaches for any other than the book described!

READING LEADS TO SUCCESS

Much statistical research and devolopment can be eliminated because often the desired knowledge is available through your library and its related research. A recent survey answers the question, "How important economically is the effective utilization of recorded knowledge?" Studies were made of the use of recorded information and the financial success of various companies, as indicated by their ten-year earning records and the percentage increases in net operating profit during this same ten-year period. Two interesting correlations were observed:

Sixty-seven percent of those companies that depend primarily on personal reading of management and that depended least on the library were in the last 20 percent in earnings.

Sixty-seven percent of those companies that depend primarily on the library facilities for information were in the first 30 percent in earnings.

VISIT THE LIBRARY

If the word LIBRARY conjures up visions of dusty shelves, limp rubber plants, and dog-eared books from which the "newness" has long since departed, you are the one who should visit your technical library at once. Just one visit should dim such musty memories and introduce you to a special library which is more than just a collection of printed matter. Your library collects, integrates, and passes on to the research worker the significant and latest scientific information. Chances of repeating earlier work is thereby reduced to a minimum, and the research worker is able to plan and evaluate his own work on the basis of this accumulated knowledge. He can then devote his full energies to productive new research.

ANITA W. JONES received her A.B. Degree from the University of Kentucky and her Library Science Degree from George Peabody College. Mrs. Jones has had experience in various types of library work including public, school and county. In 1955 she began setting up the Engineering Library at Cherry Hill. She is a member of Special Libraries Association; New Jersey Library Association.

RCA LIBRARIES (March 1957)

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Lancaster	Tube	Mary Zabriskie	Brazil	Radio	Yolanda Heu
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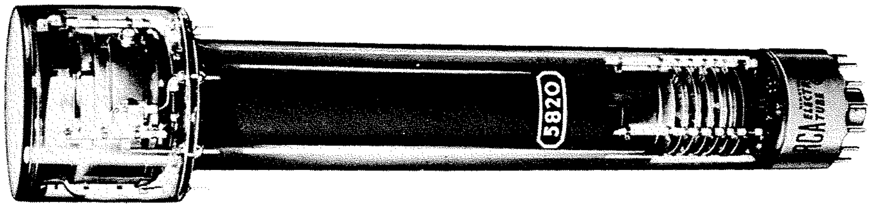

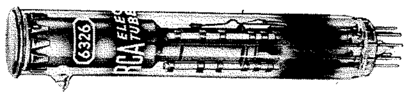

CAMERA TUBES FOR COLOR TELEVISION BROADCAST SERVICE

by **R. G. NEUHAUSER**
Cathode Ray and Power Tube Engineering
Tube Division, Lancaster, Pennsylvania

TWO DIFFERENT CAMERA tubes are used in color cameras for television broadcasting, the Vidicon, and the Image Orthicon. At present, these are the only tubes that have been found useful for producing an acceptable color picture under the requirements imposed by broadcast standards and practices. Each has desirable characteristics that make it suitable for particular conditions or applications. Neither tube at the present time is fully capable of being used for all broadcast applications. Therefore, the two tubes are used in different manners and for different service. The Image Orthicon is used in cameras for both studio and outdoor live pickup. The Vidicon is used in film and slide pickup service or in live scenes for which high light levels can be conveniently produced. In both cases, the tubes are operated in a simultaneous camera system employing three tubes to produce the color television signal.

The type of layout and optical system utilized for the two different cameras is slightly different, although the cameras have the same general layout and arrangements for light splitting and optical registry. A block diagram of each of the systems is shown in Fig. 1 and Fig. 2. In both of the systems, the primary image is focused on the plane of a condenser lens and relayed to the tube face where the proper color image is formed. This system is utilized to provide a suitable working distance between the lens of the camera or film projector and the tube faces for the light-splitting elements of the optical system.

The video signals that are derived from the three camera tubes of the color camera, when optical images are properly registered on the tube faces and the camera tubes are scanned in proper registration, represent the red, blue and green information of each portion of the scene. These signals are used to form the final color signal. Each signal represents a sharply defined image of red, blue, or green information of the original scene.

PERFORMANCE SPECIFICATIONS

Important characteristics determining directly the accuracy of reproduction of a color scene are: (1) Sensitivity, (2) Light Transfer Characteristics, (3) Black-Level Reproduction, (4) Spectral Response, (5) Resolution and Ability to Register Images, and (6) Signal-to-Noise Ratio.

A review of each characteristic illustrates its importance and significance in color television camera use.

Sensitivity. The photo-sensitivity of the tube for direct studio pickup should be very high because of light loss and absorption in the optical and color trimming system. The lens system should pick up and transfer to the camera tubes enough light to properly expose the three tubes. Depth of focus should be equivalent to that provided on double frame 35mm film with an aperture of not less than f:6.3.

Film pickup requirements are less stringent, since it is easy to obtain average illumination levels of 0.5 to 1.0 lumen on the photosensitive surface of the camera tube from the film projector. Sensitivity is no problem for a camera tube for this application, provided the tube can store the information during film pull-down time.

Light Transfer Characteristics. A camera tube for color pickup should have a predictable and constant light input versus signal output that is the exact complement of the grid-drive versus light-output characteristic of the reproducing kinescope. The desired characteristic is a signal output that varies approximately as the 1/2.5 power of the incident illumination or, in television tube terminology, a constant "gamma" of 0.4. By the use of appropriate gamma-correction circuits in the video amplifier, a video signal having practically any transfer characteristic can be modified to produce a signal having the desired signal gradient.

A *predictable* gamma characteristic is desired so that each portion of the video signal developed has an exact relationship to the light energy of the scene that reaches the corresponding portion of the camera tube. The signal should not be affected by over-all illumination level or adjacent area illumination or other modifying influences. If these conditions are

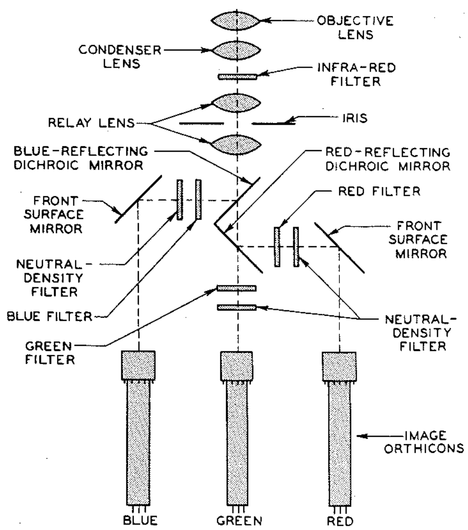

Fig. 1—Block diagram of a color television camera using Image Orthicons

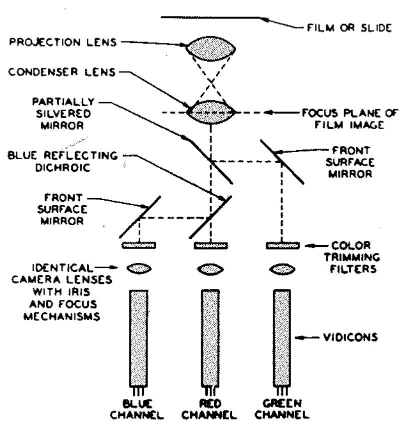

Fig. 2—Block diagram of a color television camera using Vidicons

not met, colors of different luminosity will not be reproduced in proper hue, and portions of a scene will have their hue or saturation change as a function of the over-all illumination level.

Black-Level Reproduction. This characteristic is usually considered as a separate one for a camera tube. If the requirement of predictable gamma is achieved, accurate black level will automatically result. Conversely, any tube that does not produce a signal having substantially accurate black-level information will not be suitable for simultaneous color camera operation. Small values of spurious signal developed during scan are compensated by "shading" insertion if they do not change with scene illumination.

Spectral Response. Exact duplication of a particular spectral response is not necessary from tube to tube. Spectral response curves of photosensitive devices do not usually show abrupt discontinuities. A reasonable photosensitivity over the entire visible spectrum is, therefore, the only special requirement because the shape of the spectral "taking" characteristic of each color channel can be and is controlled primarily by the light-splitting and color filter portions of the camera optical system. The amount of light transferred to each tube is controlled to compensate for its response in the particular color channel in which it is operating. In addition, one type of tube should be usable in any of the three color channels.

Resolution and Ability to Register Images. Resolving requirements of a camera tube for color operation are much the same as those of a black-and-white system. An additional factor not directly related to the tube resolving capabilities, but affecting the resolution of the final color picture, is the ability to register images in both the optical and the time-position sense. Tube geometry, optical image similarity, and deflection methods and equipment should be precise enough to enable the camera to produce three images that are well registered.

Signal-to-noise Ratio. High signal-to-noise ratios of the video signal developed by the camera tubes are essential. The requirements are probably more stringent for color than black and white, since there is some evidence that high-frequency noise beating against the color sub-carrier produces low-frequency noise which is more objectionable visibly than evidence that high-frequency noise ratios of the individual color channels should be at least 60 to 1 for good black-and-white reproduction of the color signal. Operations on the video signal, such as gamma correction and aperture correction, usually decrease the signal-to-noise ratios. This decrease is partially offset by the fact that the luminance-channel signal is derived by the addition of signals from three color channels; the signals add directly while the noise adds in quadrature, resulting in a better signal-to-noise ratio of the luminance channel than is present in any of the color channels.

CAMERA TUBE COMPARISON

Let us now compare the available camera tubes with the foregoing specification:

High-Velocity Scanning Tubes. Camera tubes employing high-velocity scanning at present do not meet the specification given above for predictable light transfer characteristics or proper black-level reproduction. The uncontrolled secondary electrons generated and redistributed in the high-velocity scanning process distort somewhat the tone rendition of adjacent areas and create spurious signals. Tubes employing high-velocity scanning are the *Image Iconoscope* and the *Iconoscope*.

Low-Sensitivity Tubes. Tubes such as the Image Dissector might be considered for color television pickup except for their lack of sensitivity. In addition, they cannot store information, necessitating constant illumination during picture scanning time.

The CPS Emitron or Orthicon type tube is a medium-sensitivity tube requiring four to five times the light required by the Image Orthicon, making it, at the present time, a marginal performer for simultaneous color pickup.

IMAGE ORTHICON AS COLOR TUBE

The Image Orthicon, as designed and operated for color pickup, meets all of the basic requirements for a camera tube for simultaneous color pickup. Operation under the "knee," i.e., limiting the highlights of the scene by iris or lighting control to the relatively linear initial portion of the curve of Fig. 3, produces a predictable light transfer characteristic that is essentially linear. Operation so that highlights of the scene are over the knee is undesirable because the image section behaves in a manner similar to a tube operated with high-velocity scanning. The secondary electrons from the target are then no longer collected by the target collector mesh but are free to travel some distance from their point of origin and, upon landing, distort adjacent area charge patterns. A loss of accurate black level at these points, or distortion of other tonal values results. For example, a human face has fairly high red light reflectivity. If the camera were operated so that the illumination of the red camera tube only was "over the knee," two things would happen. *First,* the facial tones would turn toward the blue-green because the output of the red tube would be limited in the facial highlights. This loss of red signal would cause an electron charge redistribution to the darker surroundings. The *second effect,* therefore, would be to drive the adjacent low-light areas of the red scene toward the black level, producing blue or blue-green shadows due to a deficiency of red signal from these areas. Image Orthicon tubes designed for color have a high-capacitance closely-spaced target-mesh assembly which extends the linear portion of the curve under the knee, improving signal-to-noise and contrast range.

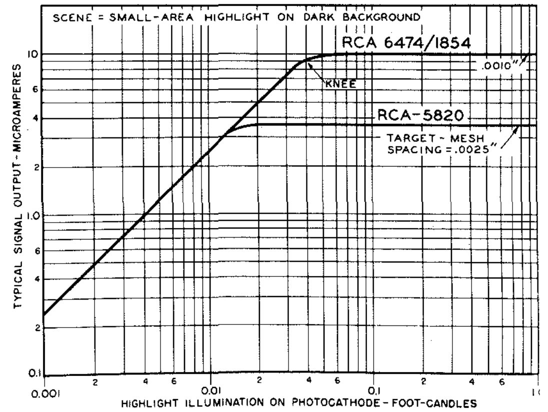

Fig. 3—Light transfer characteristic of the Image Orthicon

The sensitivity of the Image Orthicon is higher than that of any competing camera tube. When properly exposed, the Image Orthicon, as used for color cameras, is as sensitive as a photographic film having an A.S.A. speed index of 500. This comparison is valid if the "shutter" speed is considered equal to the television frame rate.

Black Level. The Image Orthicon is capable of producing a signal proportional to illumination. It is inherently capable of producing a good black-level signal during retrace that is representative of true blacks in the scene. Certain tube effects produce some deviation from true black level, but these effects are not a function of scene illumination or camera exposure. They are termed "shading" signals caused by incomplete or improper collection of the return beam and appear as a stationary pattern. Secondly,

ROBERT G. NEUHAUSER joined RCA at Lancaster as a co-op engineering student, alternating work with study from 1946 to 1949. He received the BS degree in EE from Drexel Institute of Technology in 1949 and joined the cathode-ray tube development group at Lancaster. In 1950 he was assigned to the camera, oscillograph and storage tube development activity. Since 1953 he has been engineering leader in charge of camera tube and TV oscillograph tube design.

since the return beam is partially in focus as it strikes the first dynode, the dynode surface texture may be evident in dark areas of a scene. The larger components of this spurious signal can be compensated by the addition of a fixed amount of shading signal to the video signals.

Resolution. The resolving characteristics of the Image Orthicon tube are very adequate for black-and-white broadcast television. The same degree of adequacy should apply to the Image Orthicon, as used for color.

The number associated with resolution capabilities of the tube does not tell the whole story. The pictures developed by an Image Orthicon for color and for black-and-white television are sufficiently different in appearance to warrant examination of this difference, and its effect on apparent sharpness. The difference, of course, lies in "over-the-knee" operation as used in black-and-white versus "under-the-knee" operation for color.

The knee characteristic is a result of the storage surface charging up to a potential at which further voltage build-up is limited by returning secondary electrons. In this process two things happen that modify resolving capabilities of the tube.

The first is illustrated by the amplitude response curves of the Image Orthicon as shown on (Fig.6) Here, the curve for operation "one stop over the knee" shows an increase in detail information response above a certain point. The explanation lies in the fact that small areas have an effectively higher capacitance per unit area than large areas. This difference is due to the added capacitance of the differently charged adjacent areas on the target glass.

The signal-to-noise ratio of the signal produced by the close-spaced Image Orthicon used in color television is approximately 70 to 1 (peak signal to rms noise). After suitable gamma correction and aperture correction of the video signal, the noise is below the objectionable point but has little reserve and, therefore, requires that careful attention be given to those operating factors that will maintain the best signal-to-noise ratio.

VIDICON AS A COLOR CAMERA TUBE

The Vidicon as a color camera tube meets all but one of the requirements for a universal color camera tube admirably well. The limitation of present Vidicon tubes is sensitivity, requiring rather high light levels so that lag or smear of moving images is not objectionable. This limitation results in the Vidicon being used primarily for film pickup work or direct pickup in areas having very high light levels and restricted speed of motion.

For film pickup, where light is no problem, the Vidicon meets the outlined specifications for color pickup very well. Besides being extremely predictable and unaffected by scene content, the transfer characteristic is nearly ideally suited to compensate for that of the reproducing kinescope. The shape of the light transfer characteristics (Fig. 5) is almost entirely dependent upon the photoconductive material properties and has proven to be constant from tube to tube. The low-velocity scanning process produces no secondary electrons that escape and cause image-charge distortion.

For film pickup, black represents zero signal current and is constant at all parts of the tube in the absence of light. In this respect it excels any other camera tube.

Vidicon spectral response Fig. 4. is adequate in all portions of the visible spectrum. Its response in the red regions is slightly lower than desired but has not been a problem.

The resolution of the Vidicon has proven very adequate for both color and black-and-white film pickup, especially when appropriate aperture correction is used. Full modulation in the broadcast channel in the horizontal direction is obtainable, although the effective modulation is slightly less because of the single-dimension correction process used. Although its uncompensated re-

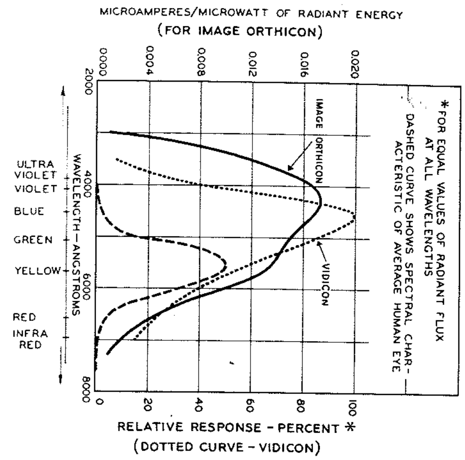

Fig. 4— Spectral response of the Image Orthicon and Vidicon

sponse is somewhat lower than that of some camera tubes, it does have response at very high line numbers.

Due to its simple construction and geometry, there is inherently little geometric distortion of the images within the tube. This feature makes registration very easy and precise and, maintains good resolving capabilities.

The signal-to-noise ratio of the Vidicon can be as high as 300 to 1. Aperture correction reduces this ratio to approximately 100 to 1. Because only a small amount of additional gamma correction is needed for film having a wide contrast range, little noise is added in this process in comparison to gamma correction for other camera tubes. The Vidicon color signal is essentially noise free even when operated with dense film stock and remains constant.

All these positive features concerning Vidicon operation lead one to assume, and rightly so, that the Vidicon is the camera tube "most likely to succeed." There is a theoretical limit to the possible Vidicon sensitivity which is many times that of the present tube. A small portion of this would amply satisfy all sensitivity needs of a camera tube for the foreseeable future.

DIFFICULTIES IN THREE-TUBE SYSTEMS

No system that is as complex as a three-tube color television system is free of difficulties. The most obvious problem is that of registration. Ideally, the three-scanning beams in the camera tubes should scan their individual scene images exactly, point by point, throughout the entire raster. Departures from this exact state show up first as loss of reso-

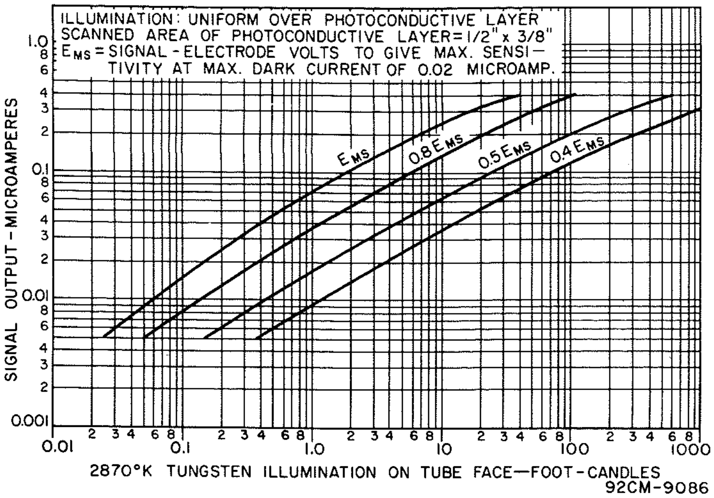

Fig. 5—Light transfer characteristics of the Vidicon

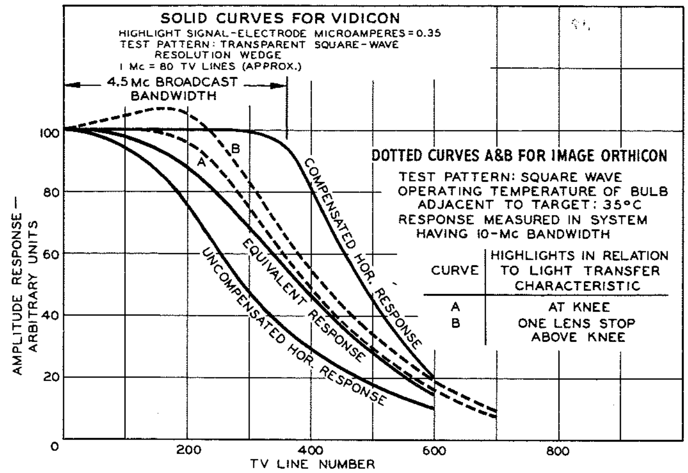

Fig. 6—Amplitude response curves of the Image Orthicon and Vidicon

lution, and finally as color fringing or multiple images of fine detail. In present cameras, registration is usually sufficiently good so that these deviations are not encountered.

The image section of the Image Orthicon provides a possible source of geometric distortion that is not present in a tube not having an image section, such as the Vidicon, and must be made as precisely as possible.

A second problem encountered in all such camera systems is uniformity of signal output or sensitivity over the raster. This problem is basic in the sense that no photosurface is ever perfect. It is a quality problem, and extremely close watch is kept on all photosurface processing. Much tighter specifications are held on the uniformity of sensitivity of tubes produced for color cameras.

Any unwanted signal added to the video signal can be considered a black-level error in the sense that it is an added signal and in the absence of light shows up as other than a true black signal and should not occur.

There are many operating devices or circuits that can be used to improve performance of camera tubes in simultaneous color systems, such as the insertion of shading signals. Black-level uniformity cannot be overemphasized because small variations in black level from channel to channel cause very pronounced color shifts of low light portions of a scene. Shading insertion should not be used to produce high light or sensitivity uniformity over the raster because such additional signals will distort the black level reproduction of the individual color channels. A circuit capable of performing the function of correcting non-uniform sensitivity is being used extensively with color Vidicon cameras.

SINGLE TUBE CAMERA SYSTEM

The desirability of a single tube capable of generating all of the necessary color video information is fairly obvious in that relatively complex optical equipment, circuits, and controls would be unnecessary.

At present the only approach that seems at all practical to the problem of producing the necessary signals to form a color picture from one tube is that described by Dr. P. K. Weimer et al. of the RCA Laboratories.

This tube, as described, is a photoconductive tube employing vertical color filter strips registered with appropriate signal output strips that are tied to the proper bus connections. It produces three simultaneous signals at three outputs. This approach uses a single scanning beam requiring no convergence or non-perpendicular beam landing incidence. Secondly, accurate timing is not required to detect color information, as is necessary with Image Orthicons.

The technology of making this type of tube with the precision required is extremely complex and difficult. The principles of operation and signal generation are sound and it has been demonstrated to perform the functions required satisfactorily. However, more sensitive photoconductors are required for satisfactory operation in live pickup.

CREDITS

The success of color television camera tube performance is due in a large part to the work of Dr. R. B. Janes, Dr. B. H. Vine, F. S. Veith, F. D. Marschka, and A. A. Rotow of the Lancaster Engineering Section, in developing these tubes for color.

Credit should be given the camera tube factory engineering personnel for their constant improvement of the camera tube uniformity, quality and performance. Many engineers under the direction of J. K. Johnson and H. M. Hambleton have contributed much over the years to the technology of camera tube manufacture that makes the use of complex color tubes possible.

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COMPONENT EVALUATION—

Brute Force vs. Statistical Reasoning

by

D. C. BOWEN, Mgr.

Electrical Standards
RCA Corporate Standardizing,
Camden, N. J.

Ever since the first electron tube was put to practical use, the circuit designer has been required to select suitable components such as resistors, capacitors, relays, connectors, coils and transformers to use in support of the tube itself. The fact that semiconductors are making appreciable progress in equipment applications does nothing to diminish the engineer's responsibilities or problems in this area. With the growth in number and variety of these extremely versatile electron devices, the engineering and production of component parts has come into its own as one of our major national enterprises. It is the purpose of this article to review progress already made in the development of techniques for evaluating component parts, to probe a few areas in which our knowledge or know-how is still notably deficient, and to suggest some future guiding principles.

SEAT-OF-THE-PANTS ENGINEERING AT ITS BEST

Our components industry was originally stimulated by the need for relatively large quantity production of radio receivers during the 1920's and 1930's. In the very early days, grid leak resistors were even made from lead pencils—it was essential to screen a supply of "lead" to find those which had the approximate resistance required. Now the standard molded composition resistor has reached a stage in its development where four companies in the United States are the sole domestic producers. Simple as they may appear, these little resistors are made by extremely complex and costly machinery. In a similar fashion many other major component lines have come from crude beginnings to a comparatively advanced state of technical development.

The preparation of specifications for the components which are assembled in our final product has become a major engineering task. This specification writing has resulted in the gradual evolution of highly standardized methods of testing for attributes to assure an adequate quality level. It has incidentally also resulted in the need for and creation of a new branch of the profession called standards engineering. Test methods have usually been divided into two distinctly different categories; the simple, non-destructive tests for rapid inspection, and the sometimes simple, sometimes complicated destructive tests which are usually limited to an engineering evaluation of the acceptability of a component type. Throughout all of these procedures, however, the prevailing philosophy has been to define arbitrary limits on the parameters being measured without regard to the actual variance or "scatter" of the data obtained in performing the tests. Table I itemizes a few of the most commonly measured parameters of capacitors and resistors and the methods used to establish their limits.

Note that most of these limits (aside from capacitance and resistance) might be called "open-ended." Any one of these individual tests can be performed on a go-no-go basis with no data recorded other than to indicate percentage of parts which failed or survived. This qualitative sort of procedure has survived a quarter of a century of field testing in its application to home entertainment type receivers. Indications are that it will be good for at least a second quarter century in this specialized area. As a means for establishing ordinary levels of reliability it is simple, effective and economical . . . a quasi-scientific procedure which rates being called "seat-of-the-pants-engineering" at its very finest.

SOME SHORTCOMINGS APPEAR

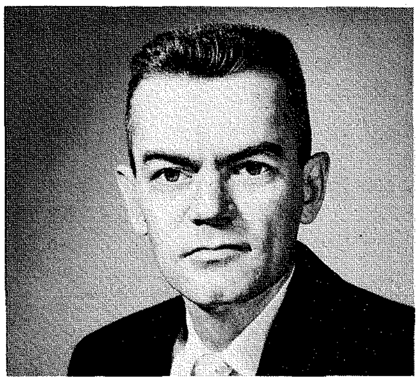
After the 1930's, the end product gradually began to change complexion. While the considerable volume of home entertainment receiver production continued to increase (except for the war years) and was even given tremendous new impetus by the commercialization of black-and-white television, other applications for electronic components began to develop at an even faster rate. These include, to name a few, radar, guided missiles, mobile communications, electronic computing machines and industrial television. This general class of equipment is made to exceptionally stringent standards of performance and reliability for the simple reason that failures become an extremely serious matter. An excessive number of outages can result in large financial losses, and even in the loss of life.

Since there is no mass consumer market for this type of product, production quantities are normally low and the corresponding quantity of any single component used is small when compared to the millions of similar parts installed in our television, radio and "Victrola" phonograph sets. Here, variety is truly "the spice of life." This situation has created problems in standardization several times more difficult than any that existed prior to 1940. Among the many engineering responsibilities, which must be re-examined in the light of these changing conditions, is the business of creating suitable component specifications. In this area of endeavor, we are now faced with such a multiplicity of parameters to be measured and environmental conditions to be met as to cause us to take serious stock of the old established methods for testing component parts. What was (and still is) an eminently satisfactory procedure for checking component quality for a production run of hundreds of thousands of television chassis may be inadequate qualitywise, and altogether too expensive when applied to a production run of a few hundred separate equipments which must have a very high degree of intrinsic reliability. Statisticians have derived some astonishing figures to show how many components must be tested without failures to assure the high component survival rates absolutely essential to the successful operation of an electronic computer. Simultaneous demands for super performance and ultra small size have done nothing to simplify matters.

WANTED: A NEW TEST PHILOSOPHY

We have rather sketchily developed the origins and purposes of the present-day "performance specification" as it applies to the component part. This procedure was born of necessity, as are most good things, and has been exceptionally well adapted to the radio and television industry for well over 25 years. It leaves something to be desired when applied to the complex industrial, commercial and military equipment designed just before, during and since World War II.

Before going on from here to develop a different concept in component evaluation, it is well to consider briefly the basic failure mechanisms which cause malfunctioning of components. If we except accidental mechanical damage to parts which may occur in the vendor's plant, during shipment, or even on our own production lines, nearly all component failures can be attributed to one of two broad categories. These are



DONALD C. BOWEN received the B.E.E. Degree in 1948 from Rensselaer Polytechnic Institute. Following his graduation, Mr. Bowen held the position as Instructor of Electrical Engineering at the California State Polytechnic College until 1951, at which time he joined the Guided Missile Division of Consolidated-Vultee Aircraft Corporation as a Senior Research Engineer. He came with RCA as Manager, Electrical Standards Section, in 1952 and continues to serve in this capacity.

Mr. Bowen is a Member of the Standards Engineers Society and a Senior Member of I.R.E., and has been active in many I.R.E., RETMA and ASA Committees. He is licensed by the FCC as a radiotelegraph and radiotelephone operator.

TABLE I

Component Parameter	Specification Limits
Capacitors	
Capacitance	+ and − tolerance
Dissipation Factor, Power Factor, (or Q)	Maximum (or minimum) allowable value specified
Insulation Resistance	Minimum allowable value specified
Dielectric Withstand Voltage (terminal-to-terminal, terminal-to-case)	Fixed voltage specified
Resistors	
Resistance	+ and − tolerance
Noise	Maximum allowable value specified
Overload	Fixed load (wattage) specified
Dielectric Withstand Voltage (terminal-to-case)	Fixed voltage specified

1. The early life failures which are caused by built-in random defects, and
2. The long life, or "wearout" failures which are caused by subtle chemical or physical changes in the constituent materials during the natural aging process.

Factors which contribute to early life failure are frequently of such a nature that visual inspection techniques may be employed to essentially eliminate their occurrence. In some cases, vacuum tubes are subjected to microscopic and X-ray examinations to locate bad welds, defective materials and improperly located electrodes. Ceramic capacitors can be visually inspected for cracks, chips, skewed electrodes, or other flaws in the dielectric material. Relays can be visually inspected for contact contamination and mechanical irregularities in spring assemblies. These practices are representative of the many similar inspection requirements now in widespread use within RCA and within our vendors' plants. Unfortunately, however, there are always some defects which cannot be detected by either visual screening or simple performance testing. Examples of these are microscopic conducting particles imbedded in capacitor dielectric tissues, minute defects in vacuum tube filament wires and the presence of small amounts of corrosive fluxes at the terminals of wire-wound resistors.

Where quality standards are very high, it occasionally becomes necessary to "de-bug" every part in an entire equipment. Depending on the circumstances, this may be accomplished during a run-in test of the equipment itself, or it may take the form of a batch-by-batch shakedown of individual components. Where the latter course is more economical, the process should preferably be conducted in the vendor's plant as a part of his final acceptance tests. The most important precaution is to avoid long, exhaustive de-bugging cycles before assembly.

The second basic failure mechanism (normal long life fatigue of materials) can presently be evaluated only on the basis of costly, time-consuming and semi-destructive accelerated life tests. The parts which are subjected to these tests usually cannot be used in production. So, we must add to direct testing costs the cost of buying and testing to destruction as many as four non-productive parts to obtain reasonable assurances that one part finally used will be adequate. In small quantities, this unfavorable ration (parts destroyed-to-parts used in production) may increase by an order of magnitude or more.

What is urgently needed is a performance test of moderate cost and duration. It should be esentially non-destructive, and result in some quantitative measure of the vendor's *process uniformity*. In addition to the conventional "open-ended" specification of parameters, we may be required to set limits on acceptable variances within lots and to establish short-term parameter stability levels.

The application of these techniques would necessitate the recording of more bits of data, require test equipment which is highly reproducible in results, and require interpretation of results with carefully planned statistical tools. It could, in return, eliminate many destructive tests, thereby improving the final yield and reducing cost per part. It could be performed in a shorter overall time cycle, improving production schedules and alleviating the critical shortage of such items as environmental test chambers. These procedures would probably not effect a significant reduction of total man-hours. In spite of a shortened time cycle for testing a single group of parts, the need for more precise measurements to replace the simple go-no-go test, the shortening of intervals between these measurements, the extensive recording of data and the final statistical analysis of this data would possibly cause a redistribution of work load rather than a net reduction. Large scale economies in man-power utilization would have to await the advent of more and better automation of test facilities. Fully-mechanized and programmed component test facilities with built-in computers for data handling are probably not "just around the corner," but may be closer to application on a widespread basis than is generally realized.

In order to make intelligent use of such a test, it would be necessary to restrict certain processes in the manufacturer's plant that have not previously been controlled by the conventional performance specification. Since we would have to deal with a statistical analysis of parameter measurements, paper capacitors produced under different impregnation cycles would not yield suitable data if they were mixed prior to testing. Capacitors made during one cycle might have a characteristic dissipation factor of about 0.35%, while those from another cycle might have dissipation factors in the order of 0.50%. To handle statistically data involving the distribution, or "scatter," of this parameter, it is essential to eliminate any extraneous factors leading to nonuniformity of results with no correlation to the actual quality of the end product. On the other hand, a few parameters do not lend themselves to any analysis of their relative dispersion. Measured capacitance and resistance values may be considered as "accidental" and the fact that in a single lot they are consistently above or below nominal, or widely scattered within their acceptable limits would not ordinarily be related to basic material stability and/or product reliability.

To illustrate these concepts, Tables II, III and IV include actual test data on a total of 72 paper capacitors—24 parts from each of 3 different vendors. These capacitors were subjected throughout the test to a dry oven temperature of 85°C. During the initial 100 hours, a d-c voltage of 150% rated voltage was applied to all parts. After the 1000-hour measurements were made, the test voltage was reduced to 125% of the rated d-c voltage. At this writing, the test is still in progress, has gone more than 4500 hours without further incident and is scheduled for another set of measurements at the 8000 hour point. To analyze this data in some more detail, the following features may be noted.

Table II samples (Bar Graph on Fig. 1) show a single failure at 9 hours on test. Following this failure, all remaining parts exhibit an exceptionally high degree of uniformity and long term stability. Cause of the one failure could not be determined, nor did the initial data show any significant abnormalities in this defective part by comparison with the remaining parts.

Table III samples (Bar Graph on Fig. 2) show a total of four failures, occurring at 8, 24, 33, and 128 hours on test. Interestingly, all four defective parts were higher in initial dissipation factor than any of the 20 remaining parts, although whether or not this differential was large enough to be meaningful is a debatable point. Cause of failures could not be determined. Long-term stability of capacitance and dissipation factor is good, although both show a large (and perhaps unacceptable) increase during the first few hundred hours on test. The range, or "scattering," of dissipation factor data is initially good (failed parts were excluded from calculations of the coefficient of variation) and actually improves with age. One part (sample 18) shows signs of non-conformance with group behavior at the 2000 hour mark.

Table IV samples (Bar Graph on Fig. 3) have exhibited no failures to date.

TABLE II

SAMPLE NO.	CAPACITANCE IN UUF				DISSIPATION FACTOR IN %			
	INITIAL	1000 HR	2000 HR	4000 HR	INITIAL	1000 HR	2000 HR	4000 HR
1	4222	4225	4278	4294	.96	1.02	.98	1.07
2	4380	FAILED @ 9 HRS. OPERATION			1.01			
3	4599	4611	4626	4649	.95	1.02	.99	1.07
4	4663	4696	4709	4739	.96	1.02	1.00	1.08
5	4382	4417	4432	4446	1.00	1.08	1.04	1.12
6	4852	4895	4906	4937	.98	1.06	1.03	1.11
7	4465	4495	4496	4519	.97	1.01	.99	1.06
8	4736	4788	4800	4823	.97	1.04	1.01	1.09
9	4574	4603	4612	4637	1.00	1.04	1.01	1.08
10	4545	4568	4570	4587	.98	1.05	1.03	1.10
11	4429	4473	4487	4505	.96	1.01	.99	1.07
12	4390	4429	4441	4464	.96	1.00	.98	1.08
13	4458	4515	4527	4548	1.00	1.05	1.01	1.10
14	4434	4496	4494	4514	.97	1.03	1.00	1.09
15	4649	4711	4720	4746	.95	1.00	.99	1.06
16	4396	4444	4450	4471	1.00	1.05	1.01	1.08
17	4176	4210	4219	4244	.98	1.04	1.01	1.10
18	4882	4927	4947	4968	.99	1.06	1.03	1.12
19	4788	4834	4844	4871	.94	1.00	.97	1.05
20	4663	4694	4704	4727	.97	1.01	.99	1.08
21	4635	4660	4670	4699	.97	1.03	1.01	1.08
22	4456	4514	4525	4546	.99	1.06	1.04	1.11
23	4280	4301	4311	4332	.99	1.02	.99	1.07
24	4698	4734	4747	4774	.96	1.03	1.01	1.09
*Averages	4538	4576	4588	4611	.974	1.032	1.005	1.085
*Coefficient of Variation					1.8%	2.1%	2.0%	1.8%

TABLE III

SAMPLE NO	CAPACITANCE IN UUF				DISSIPATION FACTOR IN %			
	INITIAL	1000 HR	2000 HR	4000 HR	INITIAL	1000 HR	2000 HR	4000 HR
1	4290	4679	4760	4790	.46	.78	.83	.89
2	4080	4434	4507	4550	.41	.76	.84	.91
3	4480	4941	5019	5059	.46	.76	.84	.89
4	4352	4664	4757	4794	.42	.75	.81	.90
5	4250	4643	4700	4766	.43	.75	.84	.90
6	4338	FAILED @ 24 HRS.			.53			
7	4296	4600	4700	4734	.44	.78	.84	.92
8	4131	4513	4551	4600	.45	.78	.82	.90
9	4297	FAILED @ 33 HRS.			.60			
10	4304	4712	4745	4828	.46	.75	.81	.88
11	4269	4635	4692	4707	.50	.80	.84	.91
12	4451	4822	4907	4981	.46	.78	.84	.92
13	4312	4698	4762	4747	.48	.84	.84	.90
14	4168	4471	4593	4597	.49	.82	.85	.91
15	4502	FAILED @ 128 HRS.			.52			
16	4209	4616	4727	4741	.48	.80	.85	.92
17	4374	4757	4873	4905	.45	.73	.82	.89
18	4377	4721	4790	4820	.44	.83	.91	.98
19	4130	4481	4540	4589	.46	.78	.82	.89
20	4065	4439	4514	4538	.46	.77	.83	.89
21	4080	4444	4489	4543	.45	.76	.83	.90
22	4120	4437	4505	4507	.47	.80	.82	.89
23	4464	FAILED @ 8 HRS.			.57			
24	4148	4502	4537	4560	.49	.82	.83	.89
Averages	4244	4610	4683	4718	.458	.782	.837	.905
Coefficient of Variation					4.9%	3.8%	2.5%	2.5%

TABLE IV

SAMPLE NO	CAPACITANCE IN UUF				DISSIPATION FACTOR IN %			
	INITIAL	1000 HR	2000 HR	4000 HR	INITIAL	1000 HR	2000 HR	4000 HR
1	4047	4071	4084	4043	.40	.48	.52	.56
2	4180	4188	4204	4196	.39	.49	.58	.63
3	4052	4094	4112	4129	.38	.50	.62	.71
4	4078	4096	4111	4104	.39	.50	.57	.62
5	4019	4039	4036	4001	.39	.47	.52	.58
6	3983	4008	4199	4001	.38	.46	.50	.52
7	4098	4128	4130	4109	.39	.49	.52	.53
8	4041	4064	4065	4014	.36	.46	.50	.51
9	4127	4162	4161	4163	.39	.49	.55	.57
10	3989	4003	4010	4002	.37	.43	.46	.48
11	4039	4028	4055	4026	.38	.50	.59	.65
12	4068	4099	4110	4100	.38	.46	.48	.48
13	4032	4057	3967	3960	.37	.45	.50	.56
14	4093	4129	4129	4114	.34	.42	.46	.48
15	4192	4221	4211	4058	.51	.76	.95	1.30
16	4193	4223	4234	4207	.37	.45	.49	.52
17	4067	4078	4092	4078	.44	.64	.75	.80
18	4124	4143	4129	4080	.36	.48	.52	.61
19	4109	4140	4150	4134	.41	.49	.52	.54
20	4144	4121	4157	4148	.42	.52	.59	.62
21	4060	4073	4088	4056	.38	.48	.55	.60
22	4062	3896	3633	3476	.38	.83	1.1	1.40
23	4196	4203	4220	4201	.43	.55	.64	.72
24	4105	4059	4058	4032	.40	.56	.65	.68
Averages	4087	4097	4098	4059	.392	.515	.589	.653
Coefficient of Variation					8.4%	20.2%	29.0%	39.5%

* Averages and Coefficient of Variation do not include parts which failed. Coefficient of Variation is defined as the ratio of standard deviation to the mean value—expressed here as a percentage.

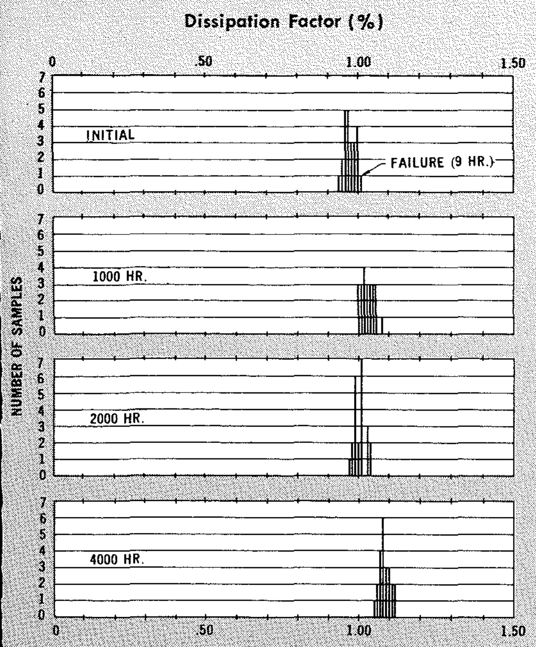


Fig. 1—Bar graph of dissipation factor data from Table II.

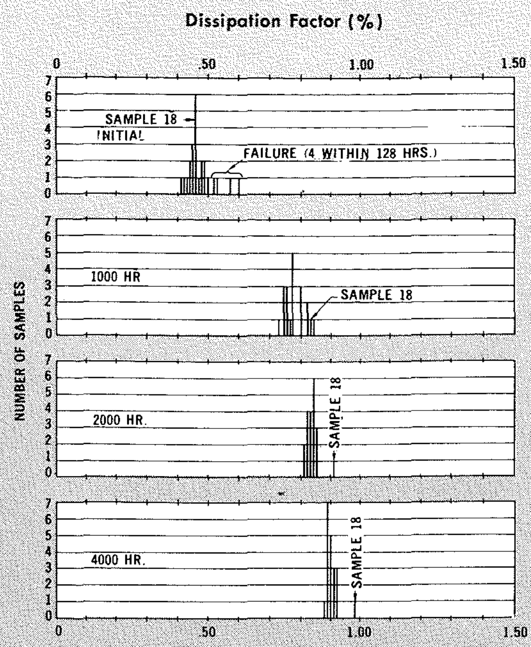


Fig. 2—Bar graph of dissipation factor data from Table III.

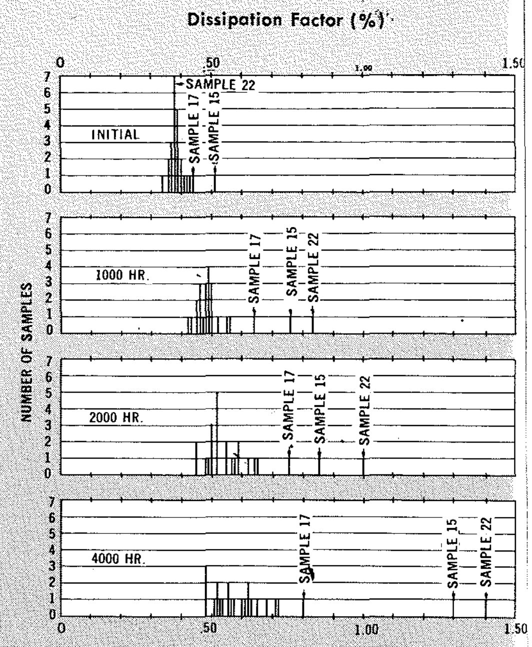


Fig. 3—Bar graph of dissipation factor data from Table IV.

Long-term capacitance stability is excellent in terms of averages, but individual capacitors—items 15 and 22 especially—show abnormally large decreases late in the test cycle. Long-term dissipation factor stability is also good, but items 15, 17 and 22 show "runaway" tendencies and are the major factors in a very poor coefficient of variation—a numerical "handle" for expressing uniformity of performance.

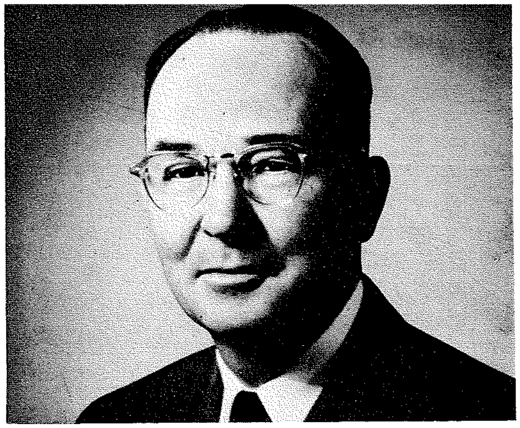
To generalize on all these results:

1. The test up to the 4500-hour point is approximately equivalent to 2 years of continuous operation at 85C and *rated* voltage.
2. All failures up to the 4500-hour point occurred within 128 hours of the start of the test—less than 3% of the total test duration. 80% (four out of five) of these failures occurred within 33 hours—under 1% of the total test duration.
3. Most significantly, *we have not learned anything new about the behavior patterns of these parts that we didn't already know at the 1000-hour mark.* We have eliminated five initially bad capacitors and have localized four others which show very definite indications of internal deterioration. Three of these questionable capacitors can immediately be picked out on the basis of the 1000-hour measurements; further aging has only served to magnify the differences.

As a result of the foregoing analysis, the reader could conceivably be trapped into jumping to hasty conclusions as to the real meaning of the data. It would be a fallacy to assume that the four "bad" capacitors just discussed will fail before any others as the test progresses. It would probably be safe to assume that they will fail relatively early, but it is most unlikely that they will be the first four. This method of data analysis develops probabilities with the usual risks that are involved in any statistical prediction technique. Its real significance in this particular test can only be determined experimentally—a process that may consume many months of work.

While all of the factual information dealt with in this article has been limited to capacitor studies to simplify the discussion, there is no technically valid reason to preclude an application of the same general principles to any other class of component. We would, of course, have to measure other parameters on other types of test equipment, with different conditioning cycles. Manufacturers of highly reliable vacuum tubes for special-purpose use have, in fact, used these concepts to good advantage already. The procedures remain to be extended to other problem areas.

This relatively new philosophy, as it matures, must be based on solid facts; not intuition or "guesstimates." Until we learn much more about basic causes of component failures and how they are related to measurable quantities, our ventures into the realm of these more logical specifications will be somewhat limited. During this interim period, however, it is encouraging to take note of the amount of work being conducted—in RCA and throughout the electronics industry—to find the necessary answers. We should have many of these answers in the near future, and perhaps a new kind of component specification will shortly become a reality.



ROBERT L. HARVEY received the B.S. degree in E.E. from the University of Tennessee in 1928 and in the same year was employed by the General Electric Company. In 1930 he transferred to the RCA Manufacturing Company and in 1942 moved to Princeton as a member of the technical staff of RCA Laboratories. Mr. Harvey has about twenty years experience in the field of magnetic materials and their application to electronic circuits. He is a Senior Member of I.R.E. and a member of Sigma Xi.

UNDERSTANDING YOUR MAGNETIC MATERIALS

by **ROBERT L. HARVEY**
RCA Laboratories
Princeton, N. J.

FOR MANY YEARS magnetic materials have been an important factor in the design of electrical equipment. It was found that iron, and the like, was useful in achieving a low reluctance magnetic path with the result that the equipment was more efficient, smaller in size, and lower in cost.

During the last decade or so, we have seen magnetic materials being used by the electronic industry for such purposes as: tuning of radio frequency circuits, adjustment of inductances, loss reduction of inductors, transducers, bi-stable memory inductors, transfluxors, rotation of microwaves, and as non-reciprocal attenuators. In addition, we find permanent magnets used in loudspeakers and other electronic applications.

The attainment of suitable magnetic materials for use at radio frequencies is the result of many man-years of work in this country and abroad. Iron, and certain alloys are ideally suited for carrying non-varying magnetic flux such as we find in d-c apparatus. When an alternating current is used to produce the magnetic flux we find certain losses occurring in the magnetic material which reduces the efficiency of the equipment. These losses are of several kinds but the most serious one, when radio frequencies are used, is the eddy current loss which increases as a square function of the frequency. At 60 cycles the eddy current loss can be effectively reduced by laminating the magnetic material. This method of loss reduction would be effective at radio frequencies if sufficiently thin laminations or wires were practical. Attempts to divide and insulate the magnetic material for use at radio frequencies resulted in the powdered iron type of cores,[1] which for certain limited applications are acceptable. Such comminuted cores always have rather high reluctance (low permeability) because the binder-insulator is a non-magnetic medium distributed throughout the core, like many tiny air gaps within the flux path.

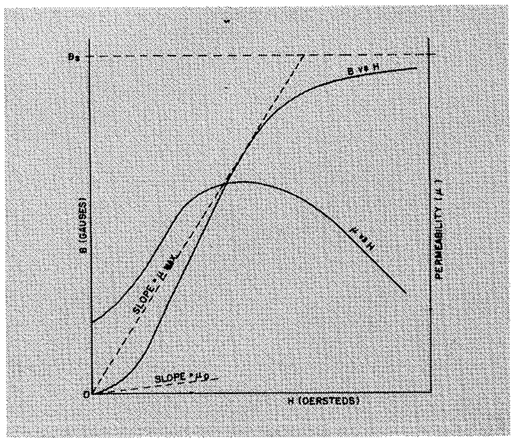


Fig. 1—The induction (B) and the permeability (μ) are not linear functions of the field strength (H).

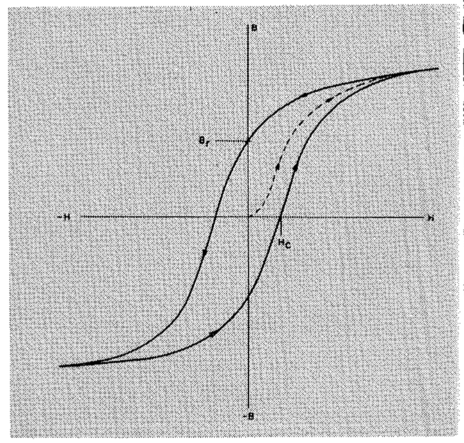


Fig. 2—The magnetic hysteresis loop showing the residual induction (B_r) and the coercive force (H_c).

The alternative way of reducing the eddy current losses is to find a magnetic material with low conductivity so that the eddy currents cannot flow. Investigation with this concept in mind has resulted in the relatively new oxidic type of magnetic material known as ferrites.[2] With the advent of ferrites the use of ferromagnetic materials in electronic equipment has shown a marked increase because for the first time a material is available with relatively high permeability and low losses at radio frequencies.

The intelligent use of magnetic materials requires some understanding of the mechanism of magnetization and the terms used to describe their behavior.

BEHAVIOR OF MAGNETIZATION

The pole of a magnet attracts, or repels, the pole of another magnet with a force that varies inversely as the square of the distance between them. A *unit pole* (by concept) is defined so that two unit poles, one centimeter apart in a vacuum, would repel each other with a force of one dyne. The strength of field of force, or *magnetic field strength* (H) one centimeter from a unit pole is one *oersted*.

In order to adequately describe the magnetic properties of materials one must have a measure of magnetiza-

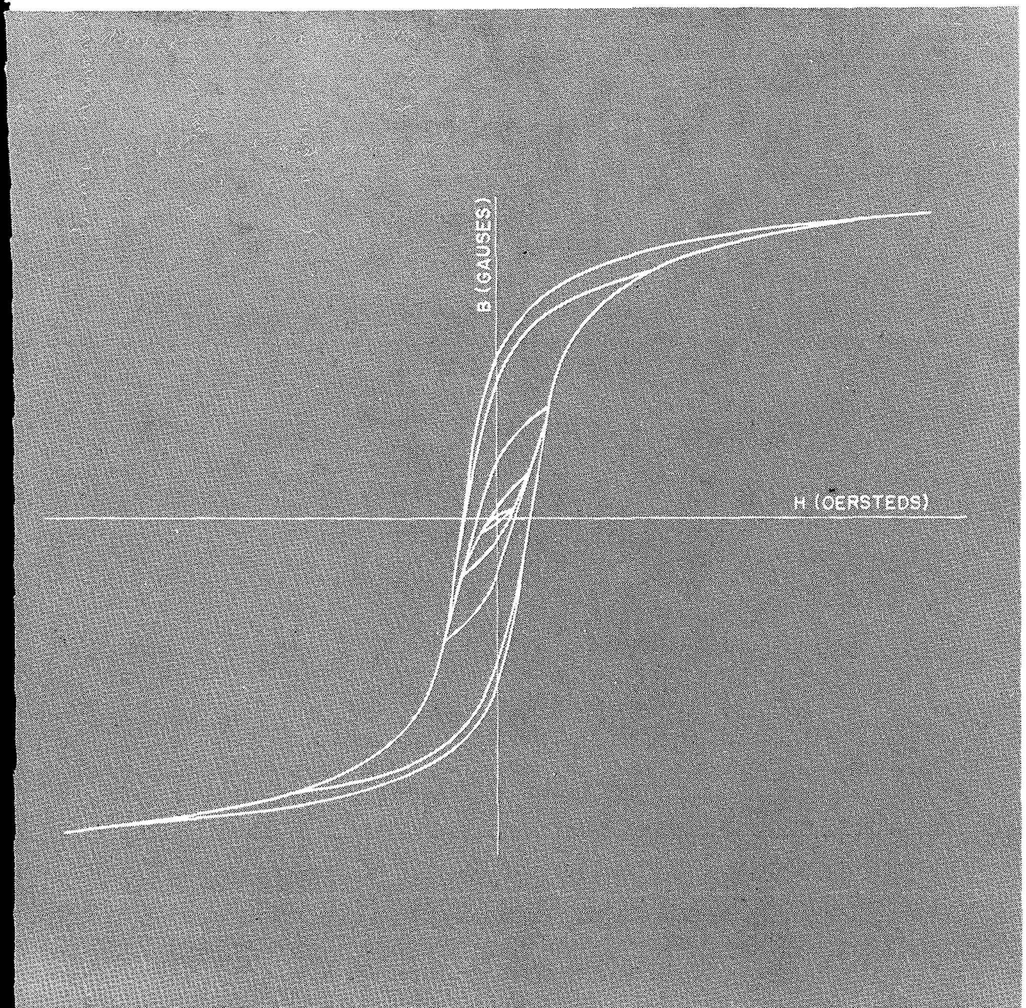


Fig. 3—A family of hysteresis loops for various values of (H).

tion. For this we use intensity of magnetization. If we have a uniformly magnetized bar of cross section (a) with (m) unit poles; the intensity of magnetization (I) is then m/a. Faraday thought of flux as a flow, and conceived endless lines of induction that represent the direction, and by their concentration, the flux flow at any point. The total number of lines crossing a given area at right angles is the flux of the area. The flux per unit area is the flux density or *magnetic induction* (B). Both H and I contribute to the lines of induction but in most materials the contribution of I is much larger. Thus we have:

$$B = H + 4\pi I$$

the addition being vectorial when I and H are in different directions.

The ratio B/H is called the *permeability* (μ) and represents the relative increase in flux caused by the presence of the magnetic material.

Fig. 1 shows that the induction (B) does not vary linearly with the field strength (H), and the slope (dB/dH) which is a measure of the permeability is also nonlinear. At the origin the slope of the B vs. H curve represents the *initial permeability* (μ_o). As H is increased the slope also increases to a maximum value representing the *maximum permeability* (μ_m). The slope then falls off to an ultimate value of unity as H is further increased. Where $B = H + 4\pi I$ attains a maximum value is called the *saturation magnetization* (B_s).

THE HYSTERESIS LOOP

We have seen how B varies as H is increased to a value so that $B = B_s$. Now if we decrease the value of H we find that B does not retrace the original (virgin) curve but lags behind, and when H is reduced to zero we have a finite value of B as shown in Fig. 2. This is called the *residual induction* (B_r). A finite value of $-H$ is required to reduce the induction to zero. This value of H is called *the coercive force* (H_c). (If the field strength is sufficient to magnetize the material to saturation, the coercive force and residual induction are called *coercivity* and *retentivity*.) By further changing the magnitude of H in a negative direction and then in a positive direction we have a closed loop as shown. This is called a hysteresis loop from the phenomenon Ewing named hysteresis. The hysteresis loop may be retraced at will so long as the original values of $+H$ and $-H$ are maintained. The original virgin curve can be found only by completely demagnetizing the material. A complete family of hysteresis loops, as shown in Fig. 3, are found if we start with a demagnetized material and successively increase the value of H after drawing each complete loop.

The magnetization curve may be divided into three portions, each characterized by a mode of magnetization.[3] Referring again to the B vs. H curve of Fig. 1, the first portion of the curve is that which lies between the origin and the instep, the slope of which follows approximately the Rayleigh relation

$$\mu = \mu_o \, v \, H$$

where v is $d\mu/dH$ and is a constant. This portion of the curve is said to be reversible because the curve is approximately retraced when the field strength is reduced. The second portion of the curve lies between the instep and the knee and has the greatest slope (2 to 100 times that of the first portion) and is said to be irreversible because the path followed by B is different when H is decreased as compared to the upward path. The third portion of the curve, that beyond the knee, has a smaller slope and approaches unity on the B vs. H plot. This third portion of the curve is reversible to a considerable extent and is approximated by the Frolich-Kennelly relation.

$$\frac{1}{\mu} = a + b\,H$$

MAGNETIC DOMAIN THEORY

The domain theory stated by Weiss[4] in 1907 is, for the most part, accepted today as the best explanation for the behavior of the magnetization curve and the character of the hysteresis loop. The theory that a ferromagnetic material is composed of many regions, or *domains*, each magnetized to saturation, has been substantiated by observations made on powder patterns by Williams, Bozorth, and Shockley.[5] The magnetic moment of any one domain is specified by magnitude and direction of its magnetization, and by its volume. The moment of a domain, and therefore the magnetization of a ferromagnetic material of which it is a part, can be changed by:

1. A change in the direction of magnetization of the domain by rotation.
2. A change in the volume of the domain by domain wall motion. The three portions of the hysteresis loop, previously discussed, may be identified with the following processes:

First portion—Reversible wall displacement

Second portion — Irreversible wall displacement

Third portion—Reversible rotation

Bozorth has shown schematically (reproduced as Fig. 4) how the domain rotation and the wall displacement occur.

To understand why the processes of magnetization are reversible or irreversible we must again consider the direction of magnetization of the domain. This direction is controlled by the crystalline structure (ease of magnetization along the crystallographic axes), strain, and the magnetic field. Each of these factors: crystal structure, stress, and field may be expressed in terms of potential energy, and the relative importance of each will determine the character of the hysteresis loop.

In a material with domains of random orientation, and in the absence of strain, the ratio of $B_r/B_s = .5$. If the crystals are aligned so that the easy direction of magnetization is parallel to the applied field the ratio of B_r/B_s can be .95 or more. Conversely, if the crystals are aligned so that the easy direction of magnetization is perpendicular to the applied field the ratio of B_r/B_s can be .1 or less. Most magnetic materials are magnetostrictive to some degree. In such materials stress occurring as a result of external or internal strain will similarly affect the ratio of B_r/B_s, the value of the ratio being dependent on whether the stress causes the domains to become more or less oriented in the direction of the field. Thus, we have seen that the hysteresis loop is greatly influenced by crystalline anisotropy and strain.

THE RECTANGULAR HYSTERESIS LOOP

In rectangular loop materials, which have become of great importance as memory storage elements, one or both of the following structure conditions exists:

1. The crystals are aligned to result in low anisotropy.
2. Stress causes the domains to be aligned in the direction of the applied field.

The mechanism responsible for the *rectangular hysteresis loop* is as follows: In a completely demagnetized material the domains are oriented, half in each of the two opposite directions. When a field is applied half of the domains make 180° reversals by displacement of the domain walls until the material is saturated. Domains of this type have great stability and when the field is reduced to zero the value of B is essentially unchanged. This condition persists even when some $-H$ is applied to the material. As the value of $-H$ is further increased a nucleus of anti-parallel magnetization is formed by 180° reversal at some place in the material. This region rapidly spreads to others until a complete reversal is accomplished.

Fig. 5—C. Wentworth loading rotary furnace with ferrite samples to be crystallized.

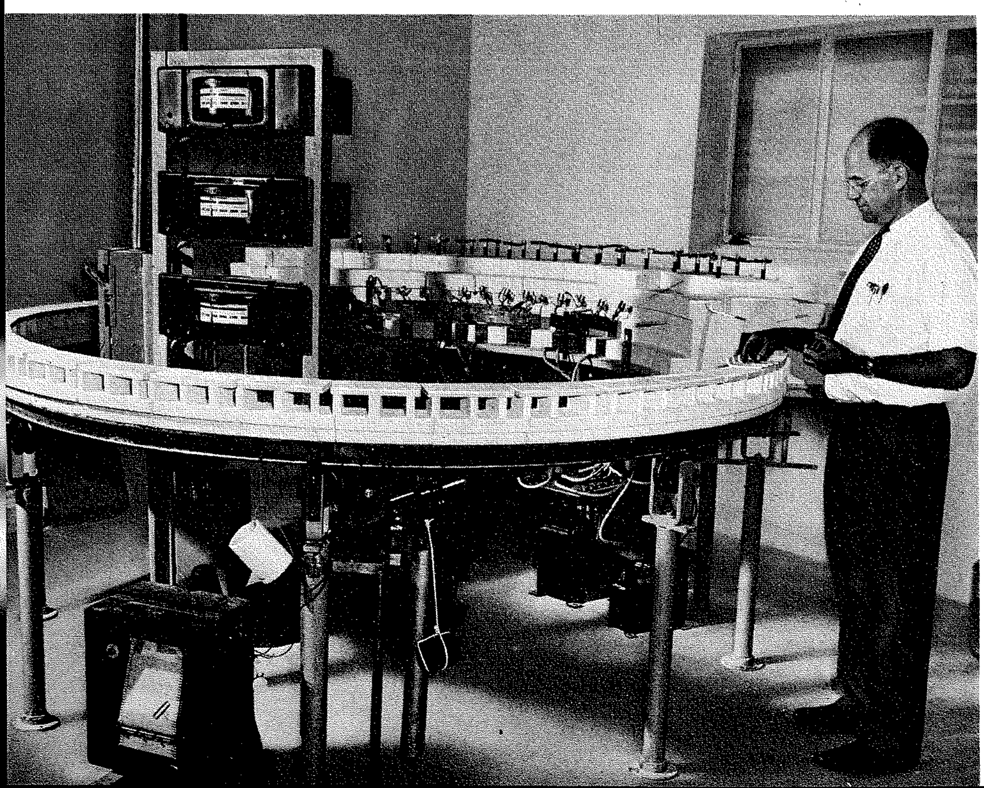
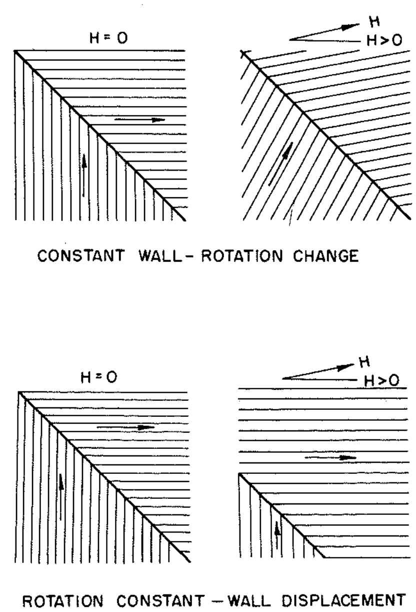


Fig. 4—A schematic representation of domain rotation and wall displacement (from Bozorth).



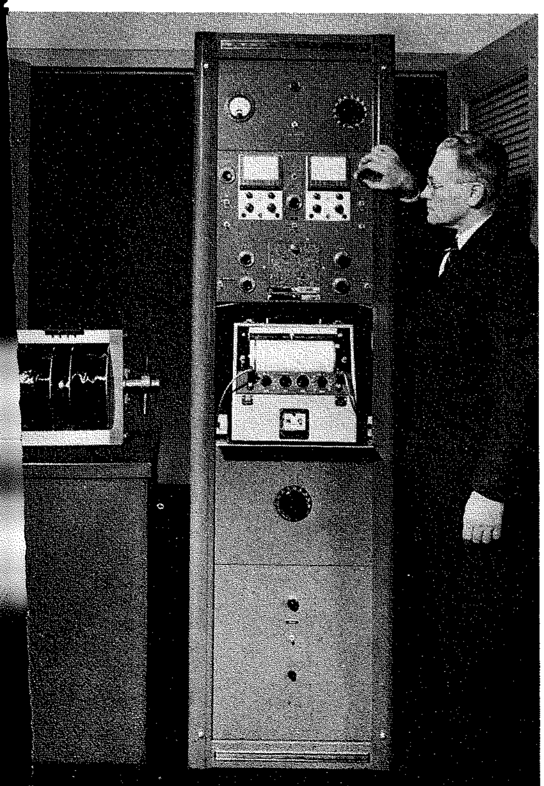
During this process the induction has rapidly changed from $+B$ to $-B$. This then is a bi-stable magnetic material and is ideally suited for information storage.

The value of the coercive force determines the *class* of a ferromagnetic material. If a material has a low coercive force it is said to be magnetically *soft*. If the coercive force is large the material is said to be magnetically *hard*. Tables I, II, III show the coercive force and induction of some of the well known materials.

WIDE LATITUDE OF FERRITES

As mentioned earlier, the advent of ferrites has permitted a much greater utilization of magnetic materials by the electronic industry. One may think of ferrites as magnetic ceramics which distinguishes them from the metallic materials. Magnetite (FeO-Fe_2O_3), which is found in nature, is a ferrous ferrite and just as elemental iron can be combined with other elements to produce a superior magnetic alloy, so magnetite can be altered to produce improved ferrites. The FeO can be replaced with some other metal oxide to produce a series of ferrites as: zinc ferrite, copper ferrite, cobalt ferrite, lithium ferrite, magnesium ferrite, manganese ferrite, and nickel ferrite. In addition there are many combinations of these ferrites which are called *mixed ferrites.*

Fig. 6—H. C. Allen using d-c hysteresograph in magnetics research.



The choice of the ferrite, or mixture of ferrites, is a determining factor in the electrical properties obtained; for example, nickel ferrite has been found to have excellent magnetostriction properties, and lithium, zinc ferrite (a mixture) has lower losses in the megacycle range of frequencies. For a more complete discussion of the composition and structure of ferrites, and the electrical properties of ferrites, references 1, 2, and 6 are suggested.

LIMITATIONS TO OVERCOME

There seems to be some basic limitations inherent to the ferrite structure. For example, the saturation magnetization is limited to about 4,500 gauss, which is about one third that found in the metals and alloys. Another limitation, predicted by Snoek[2] and since confirmed experimentally, is the magnetic resonance and associated losses when the ferrites are operated at high frequencies. One of the requirements for ferromagnetism is unpaired electron spins. These spins have a resonant frequency and when the frequency of the external flux approaches the magnetic spin frequency a procession, or wobbling, occurs which causes a high order of energy loss. The impressed frequency need not be as high as the magnetic spin resonance to cause some precession; indeed, this type of loss is sometimes evident at frequencies a decade lower than the actual magnetic spin resonance. The magnetic spin resonance may be calculated by using the formula,

$$f_r \text{ (in mc)} = 1.86\, B_s/\mu_o$$

where the saturation induction (B_s) and the initial permeability (μ_o) are static values.

Recently, Jonker, Wijn, and Braun[7] have reported a ferromagnetic material that reduces this difficulty, and is said to be useful up to frequencies of about 500 megacycles. The new compound is similar to the cubic ferrites but having a hexagonal crystal structure with the preferred direction of magnetization lying in a *plane* perpendicular to the c-axis. As a consequence of the presence of the preferred plane the magnetic resonance frequency lies about five times higher than that of ferrites. Unfortunately, the cited compounds have low permeability (approximately 10).

Much research work is continuing to better understand the complicated mechanism of certain known ferromagnetic phenomenon and also to search for new and improved materials which circumvent some of the limitations of the existing materials.

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4. P. Weiss, "Hypothesis of the Molecular Field and Ferromagnetic Properties," J. Physics, *4*, 6.
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6. R. L. Harvey, "Ferrites and Their Properties at Radio Frequencies," Proc. N.E.C., Vol. 9, 1954.
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TABLE I

PROPERTIES OF SOME MAGNETICALLY SOFT MATERIALS

Material	H_c (oersteds)	B_r (Gauss)	B_s (Gauss)
Silicon iron	.5	14000	19000
Numetal	.05		6500
Mn, Zn Ferrite	.3	1600	3600
Ni, Zn Ferrite	.1	620	1780
Pressed iron powder	15.		15000

TABLE II

PROPERTIES OF SOME MAGNETICALLY HARD MATERIALS

Material	H_c (oersteds)	B_r (Gauss)
Carbon steel	50	10000
Alnico V	640	13000
Co Ferrite	900	1600
Bismanol	3500	4500
Ba Ferrite	1900	4000

TABLE III

PROPERTIES OF RECTANGULAR LOOP FERRITES

Material	H_c (oersteds)	B_r (Gauss)
General Ceramics (S-1)	2.49	1250
RCAL (experimental)	.89	1540

MOTION CONTROL OF LOUDSPEAKERS

by **SYDNEY V. PERRY**

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

IN AN ELECTRO-ACOUSTIC reproducing system intended primarily for use in the home, the problem of attaining proper reproduction in the bass range is by no means simple. Such a system usually consists of one or more dynamically driven cone loudspeakers mounted in a cabinet, together with tuners, amplifiers, record players and associated equipment and accessories.

The cabinet forms the acoustic enclosure for the loudspeakers and with them determines the bass, or low-frequency response of the instrument. Of necessity, instruments for the average home are designed to meet the requirements of appearance, utility, and cost. Usually there is a hodge-podge of partitions, shelves, and openings in which mechanical and acoustic resonances are almost always present. These resonances in the cabinet and speaker produce over-accentuation of certain limited frequency ranges, deficient response in other ranges, transient hang-over of certain types of signal, and similar undesirable effects.

HIGH EXCURSION AND NON LINEARITY

In addition to cabinet difficulties, the reproduction at normal volumes of the lowest musical tones requires high excursion of the loudspeaker cones, well beyond the linear range of their suspension systems. This results in wave form distortion, with its associated production of both harmonic and discordant tones which were not present in the original signal. These non-linear effects, together with the cabinet and speaker acoustic and mechanical deficiencies produce defective bass reproduction, often described by such terms as 'boom,' 'one-note bass,' 'hang-over,' distortion, frequency doubling, muddy reproduction, and others even less complimentary.

Modern attempts to alleviate these conditions have consisted chiefly of the introduction of damping into the system by electrical, acoustical, and mechanical means, and of novel and often trick enclosure designs. Each method has its own faults and merits, but none of them is wholly satisfactory.

INFINITE BAFFLE AND PISTON

In order to understand the fundamental problem of acoustic reproduction in the low frequency (or bass) range, let us first consider a simple acoustical system. Assume that we have a rigid circular piston which is suspended in a plane surface of infinite extension (i.e., an "infinite baffle"), as shown in Fig. 1. Assume that it is driven (by any convenient means) with sinusoidal motion at some frequency in the audible range, and in a direction at right angles to the baffle. The motion of the piston will set up a sound wave in the air which will radiate out from the piston. The intensity of this radiated sound at some distance from the piston will depend

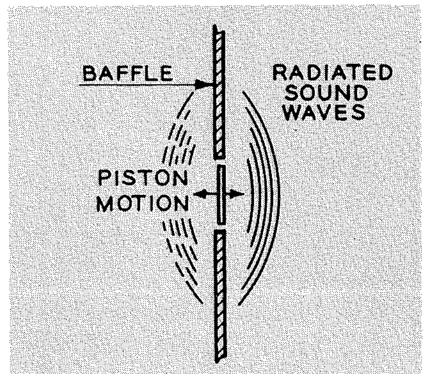


Fig. 1—Piston moving in an infinite baffle.

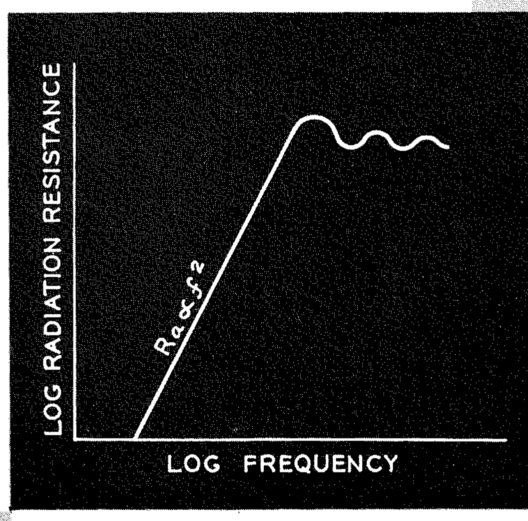


Fig. 2—Radiation Resistance vs. Frequency for a 12-inch piston in an infinite baffle.

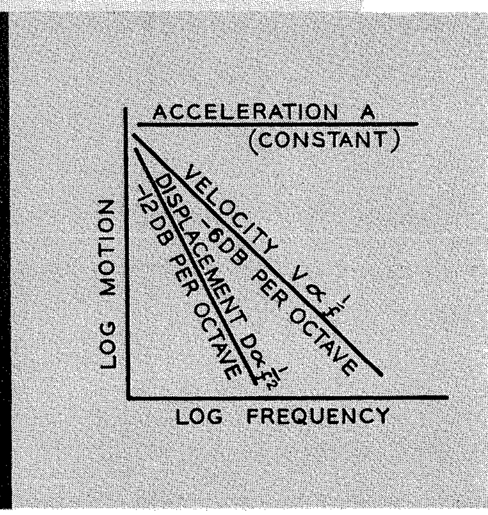


Fig. 3—Variation of Acceleration, Velocity and Displacement with frequency, of a *mass controlled* system.

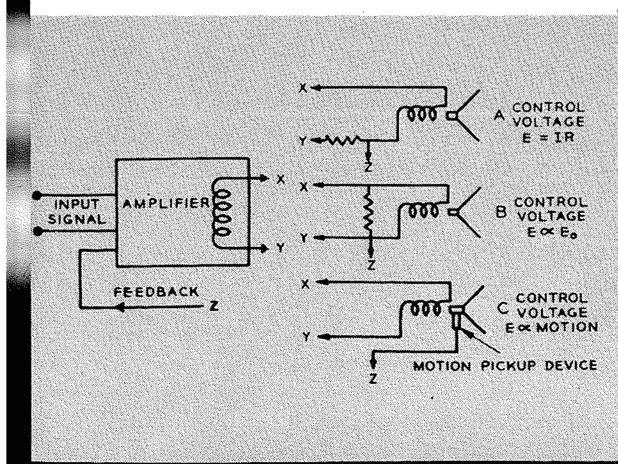


Fig. 4—Alternate constant drive systems utilizing inverse feedback. (a) Constant current drive utilizing control voltage proportional to the output current; (b) constant voltage drive with feedback voltage proportional to output voltage; (c) constant motion drive utilizing a voltage proportional to loudspeaker cone motion.

Fig. 5A—Increase in radiated acoustic power due to cone suspension resonance.

Fig. 5B, C—Impedance and current of a resonant system when driven from a constant voltage source.

upon the amount of sound energy communicated to the air by the piston. The problem is first, to determine the motion that must be imparted to the piston in order that the radiated sound energy may remain constant as the frequency is varied; and second, to determine the driving force or means necessary to produce the required motion.

The radiated sound energy will depend upon the amplitude and frequency of motion of the piston, and upon the effective resistance to motion which the air imposes on the piston. This latter characteristic of the air has been shown by classic theory[1] to be as given in Fig. 2, specifically for a piston of 12 inches diameter. Fig. 2 shows that in this case for frequencies below about 700 cycles per second the radiation resistance is proportional to the square of the frequency; i.e.,

$$R_a \propto f^2 \qquad (1)$$

in which R_a is the acoustic radiation resistance and f is frequency.

The acoustic power delivered to the air by the piston is given[2] by

$$P_a = V^2 R_a \qquad (2)$$

in which P_a is the radiated acoustic power and V is the velocity of motion of the piston.

Combining equations (1) and (2) we have

$$P_a \propto V^2 f^2 \qquad (3)$$

Equation (3) shows that since it is desired that the radiated acoustic power remain constant as frequency is varied then it is necessary that the velocity of motion be inversely proportional to frequency, or

$$V \propto \frac{1}{f} \qquad (4)$$

This is the required motion of the piston.

MASS CONTROLLED MOTION

Now, from elementary physics we know that when a sinusoidal force is applied to a system in which the only element present to impede motion is mass (i.e., a *mass controlled* system), then the force is expended in accelerating the mass, and the following relations hold:

$$F = MA = 2\pi f MV = (2\pi f)^2 MD \qquad (5)$$

in which F is force
M is mass
A is acceleration
V is velocity
D is displacement
f is frequency

From equation (5) we may deduce that if force is held constant while frequency is varied (mass also being constant), then:

$$\text{acceleration } A \text{ is constant} \qquad (6a)$$

$$\text{velocity } V \propto \frac{1}{f} \qquad (6b)$$

$$\text{displacement } D \propto \frac{1}{f^2} \qquad (6c)$$

These relations are illustrated in Fig. 3. They define *mass controlled* motion.

DYNAMIC DRIVE

If the actuating means is a dynamic driver system[3], then

$$F = Bl\,I \qquad (7)$$

in which F is force
B is magnetic flux density
l is length of conductor
I is current through the conductor

From equation (7) it follows that constant force is obtained from constant driving current.

Combining the above relations, we find that a rigid, mass controlled piston of the order of 12 inches in diameter, suspended in an infinite baffle, will radiate constant acoustic power at all frequencies below about 700 cycles per second if it is driven by a dynamic driver system which is actuated by a current held constant over the same frequency range.

A PRACTICAL SYSTEM

In a practical system, some of these requirements can be readily approximated with sufficient accuracy, while others are much more difficult to attain. The "infinite baffle" serves chiefly to separate the back wave from the front wave, and so can be approximated by a closed box. The rigid piston can be closely approximated by a paper cone, which is inherently rigid by virtue of its shape. Also its mass, combined with the mass of the air it moves, is sufficient to satisfy the "mass control" requirement.

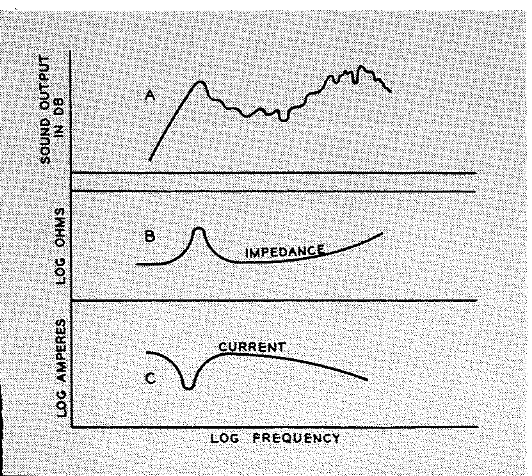
The constant current drive can be met with great accuracy by modern amplifier design techniques, as for instance the current feed-back system illustrated in Fig. 4(A), in which output current control is achieved by feeding back a control voltage proportional in magnitude to the output current, and in reversed phase.

SPEAKER RESONANCE

The one requirement which is hard to meet is in the cone suspension system. A dynamically driven paper cone must be suspended in such manner that, (1) there is negligible air leakage around its outer edge, and (2) so that its driving coil may move linearly over large amplitudes in its air gap without rubbing, and (3) will return to center when the driving signal is removed. These three requirements ordinarily result in a compliant suspension of such stiffness that mechanical resonance occurs well within the audio spectrum—usually of the order of 60 cycles per second for a 12-inch cone in open air. At and near the frequency of resonance, the cone moves much easier than at other frequencies, so that the velocity of motion, and therefore the sound power radiated, are much higher than the desired "mass controlled" value, as indicated in Fig. 5A. This high output causes over-accentuation of tones near resonance, together with transient distortion. It can be reduced by (a) adding mechanical resistance, (b) by decreasing acoustic radiation, and (c) by decreasing the driving power.

A PARTIAL CORRECTION

Decreasing the driving power is one of the simplest methods for reducing the effects of cone suspension resonance. This is because the operating impedance shows a pronounced peak at resonance[4], as in Fig. 5, curve B. If such a system is driven from a source of constant voltage over the frequency range, the current will show a pronounced dip in the region of resonance, as shown in Fig. 5, curve C. An amplifier for driving such a system with constant voltage can be readily designed by modern methods. For instance, the voltage feedback sys-



tem illustrated in Fig. 4(B), in which output voltage control is achieved by feeding back a control voltage proportional in magnitude to the output voltage, but reversed in phase. Using such an amplifier, only partial correction of the excess output is achieved. This is because the height of the peak in Fig. 5, curve B, and therefore the depth of the dip in Fig. 5, curve C, is determined by a number of factors including the motion, the flux density, the voice coil resistance, and the amplifier resistance[5]. In order that the correction approach the desired amount, it is necessary that the flux density be as high as possible, and that the output resistance of the amplifier plus the voice coil be as low as possible. These factors account for the considerable emphasis given in recent years to huge magnets, and to trick amplifiers having low output impedance, zero impedance, or even negative impedance.

STIFFNESS CONTROLLED MOTION

At frequencies well below resonance, the major factor impeding the motion of the cone is the stiffness of its suspension. From elementary physics we know that when a sinusoidal force is applied to a system in which the only impeding element is stiffness (i.e., a *stiffness controlled* system), then the force is expended in displacing the stiffness elements, and the following relations hold:

$$F = SD = \frac{SV}{2\pi f} = \frac{SA}{(2\pi f)^2} \quad (8)$$

in which F is force
S is stiffness
D is displacement
V is velocity
A is acceleration
f is frequency

From Equation (8) we may deduce that when force is held constant while frequency is varied (stiffness also being constant), then

D is constant (9a)
$V \propto f$ (9b)
$A \propto f^2$ (9c)

These relations are illustrated in Fig. 6.

In order to maintain constant acoustic power output as frequency is varied, it has been shown by equations (4) and (6b) that the system must obey the laws of mass control, i.e., the velocity of motion must rise at 6 db per octave as frequency is decreased, (see Fig. 3). It has also been shown by equation (9b) and Fig. 6 that in a stiffness controlled system the velocity of motion does not rise, but instead falls (also at 6 db per octave) as frequency is decreased. From these two relations it follows that in a stiffness controlled system, the acoustic power output will fall at a rate corresponding to the difference between these two slopes, i.e., at 12 db per octave, as frequency is decreased.

BASS BOOST AND AMPLITUDE DISTORTION

Compensation for the 12 db per octave deficiency below resonance would require 12 db per octave bass boost in the amplifier chain, below speaker resonance. No doubt this could be accomplished by suitable circuitry, but it would require rather accurate "tuning" to the speaker resonant frequency in order to avoid considerable variation due to over- or under-compensation.

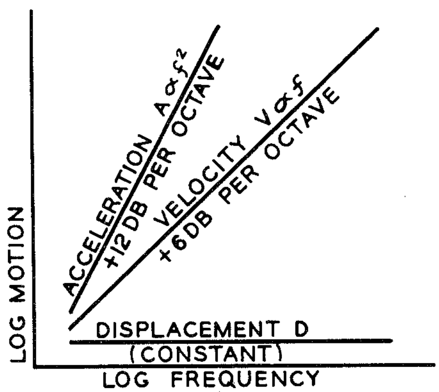


Fig. 6—Variation of Acceleration, Velocity and Displacement with frequency, in a *stiffness controlled* system.

In the low-frequency range below resonance, large amplitudes of motion —i.e., displacements—may be expected, and do indeed exist. These large displacements result in excessive wave form distortion, since the cone suspension system is usually very non-linear over large excursions. For this reason, it is not wise to introduce large amounts of bass boost without providing some means of correcting the resultant wave form distortion.

SUMMARY OF CONVENTIONAL SYSTEM

To sum up, we find that the mechanical resonance of a loudspeaker cone and its compliant suspension system causes it to deviate from the desired mass-controlled action. When driven by a constant current drive, it exhibits exaggerated response at and near its resonant frequency, and relatively sharp cut-off at lower frequencies, together with transient hang-over and wave form distortion. A constant voltage drive will partially correct these defects, but it requires large magnets and very low-impedance amplifiers to be really effective. With either drive system, excessive bass boost is required at frequencies below resonance, resulting in uncorrected wave form distortion in the cone motion. Hence, it would seem that refinements of amplifier design are not effective means of solving the problem of true undistorted reproduction in the bass range.

DIRECT CONTROL OF MOTION

A direct method of attack on the problem is to drive the loudspeaker in such a manner that its *motion* is under control, more or less independently of resonances, amplifier impedance, and similar factors. This can be done by inverse feedback methods, exactly as is commonly done in current feedback systems and in voltage feedback systems. It is required only that a control voltage be available which is at all times proportional to the *motion* of the loudspeaker cone, and in proper phase relation. This is indicated graphically in Fig. 4(C).

There are several possible ways of producing voltage proportional to motion. For example, phonograph pickups are specifically designed for this purpose. However, they are designed for use with relatively microscopic motions, hundreds of times smaller than exist in loudspeaker cones. Similarly, other electro-mechanical transducers have been designed, each for a particular use. Special designs of motion pickup devices, and means of coupling them to loudspeaker cones, are required for this application.

SOMETHING FOR NOTHING?

There is one very intriguing method of obtaining a control voltage from a dynamic speaker without attaching any mechanical device to it. This consists of using the voltage generated in the voice coil by virtue of its motion in the magnetic field. Whenever a conductor is moved in a magnetic field, a voltage is induced in it proportional to its velocity of motion, as given[6] by the equation:

$$E_g = Bl\,V \qquad (10)$$

in which E_g is generated voltage
B is magnetic flux density
l is length of conductor
V is velocity of motion

This relation holds true even though the motion be the result of the application of some other driving voltage E_d and some resulting driving current I_d which in turn sets up other voltages $I_d R_s$ and $I_d X_s$ across the resistance and reactance of the voice coil winding. It remains only to separate out the generated voltage from the driving voltages. This can be done by a bridge method, as in Fig. 7. This is by no means the only bridge circuit suitable for this purpose. It is one of the simplest to understand, and therefore it will be used here for explanatory purposes.

THE VELOCITY BRIDGE

Referring to Fig. 7A, let us assume that R_s and X_s represent the impedance of the loudspeaker voice coil in a blocked (motionless) condition. The other elements are connected as shown, and adjusted so that

$$\frac{X_s}{X_1} = \frac{R_s}{R_1} = \frac{R_B}{R_A}$$

The bridge is then balanced for all frequencies, and its output voltage $E_{F\text{-}G}$ is zero. The vector diagram of voltages is given in Fig. 7B.*

Now let us assume that an additional generated voltage E_g is inserted in series with the loudspeaker (see Fig. 8A), allowing the loudspeaker cone to move in its normal manner. This obviously unbalances the bridge, and the vector diagram now takes the form shown in Fig. 8B, in which a voltage appears between F and G, exactly proportional to and exactly in phase with the generated voltage E_g. This voltage is exactly proportional to and exactly in phase with the velocity of motion. Hence, the voltage $E_{F\text{-}G}$ is an electrical picture of the velocity of motion of the loudspeaker voice coil, and may be used as a control voltage in a Motion Control system.

A TYPICAL CASE

In a typical experiment, a 12-inch loudspeaker was mounted in a 3 cubic foot box, of rigid construction, using internal padding to reduce acoustic and mechanical resonances. The generated velocity voltage obtained by this method was as shown in Fig. 9, curve A, from a constant current drive. The peak of velocity at resonance was some 16 db above the desired "mass control" line. Below resonance, the velocity rapidly fell off, crossing the "mass control" line about 1/3 octave below resonance and continuing down to about 24 db below "mass control" at 20 cycles (which is two octaves below resonance in this case). The irregularities in the velocity curve above resonance are due to cone breakup (i.e., failure of the cone to move as a rigid piston). The whole curve A represents normal performance of a system of this construction, actuated by a constant current drive. Curve A-1 gives its performance when actuated by a constant voltage drive.

The velocity voltage, Fig. 9, curve A, was used for inverse feedback in the driving amplifier, and as expected, it resulted in practically flat velocity output, as indicated in curve B. However, flat velocity output is not what we require (see Fig. 3), but rather velocity that increases at 6 db per octave as frequency is reduced. Hence, simple RC bass boost was required, and was introduced in the pre-amplifier (before the feedback loop). This produced velocity as in curve C. This meets the desired "mass control" line at about 30 cps, and is only about 2 db down at 20 cps (an extension of its range of "flat" acoustic output of about one and one-half octaves from curve A). The increase in response at 20 cps was 22 db, above curve A. The distortion correction factor, as given by the distance between curves A and B, was 34 db at resonance, falling off rapidly on both sides of resonance to only a few db at 20 cps. While no direct measurements were made in this particular case, the improvement in both wave form distortion and transient hangover as observed by oscilloscope, was very noticeable.

It should be noted that the extension in range of "flat" response, from about 55 cps down to about 20 cps, was not a direct result of Motion Control, but was rather a direct result of bass boost, which was made practical by Motion Control.

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*A one-to-one bridge ratio is very wasteful of power. A more practical ratio, in which the loss is only 1 db, is

$$\frac{X_S}{X_1}=\frac{R_S}{R_1}=\frac{R_B}{R_A}=5 \text{ and } \frac{R_B}{R_S}=25$$

Fig. 7A—Bridge circuit balanced.
Fig. 7B—Vector diagram of balanced bridge.

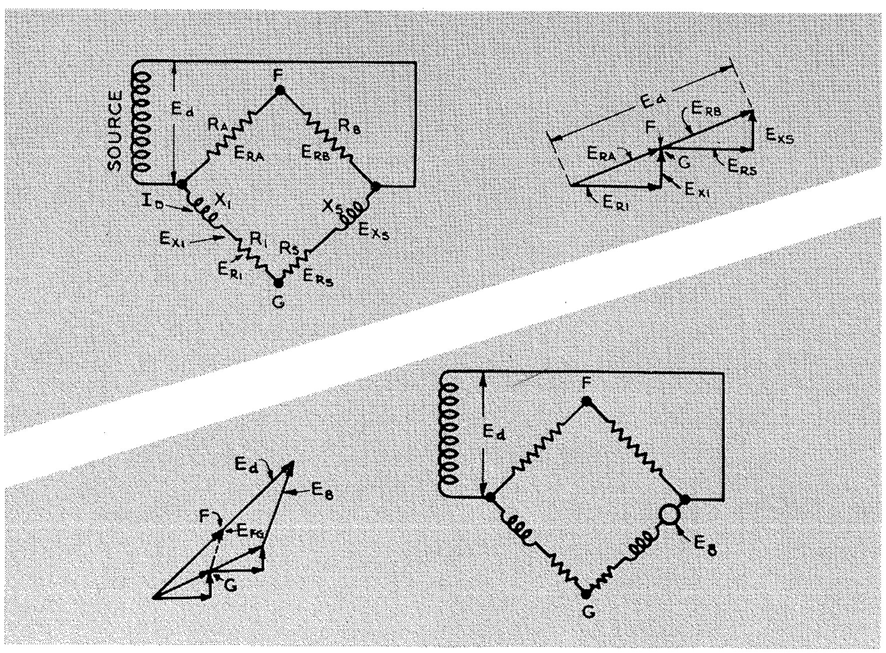


Fig. 8A—Vector diagram of unbalanced bridge.
Fig. 8B—Bridge unbalanced due to motion.

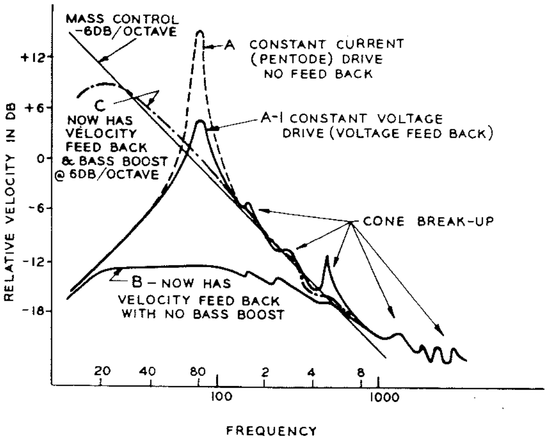


Fig. 9—Variation in velocity with frequency for (A) constant current drive; (B) velocity control; (C) velocity control and bass boost.

It should also be noted that Motion Control is effective in the lower half of the audio range, below about 700 cps. Above this frequency, the amplifier should be arranged to feed the loudspeaker system in a more conventional manner, possibly with constant voltage, or whatever may be desired.

In the particular case illustrated by Fig. 9, the effect of Motion Control was (a) to virtually eliminate loudspeaker resonance, (b) to greatly improve transient distortion, (c) to give reduction of wave form distortion, (d) to permit bass boost below resonance by simple circuitry, and (e) with bass boost, to give uniformly smooth "mass controlled" motion over the range from 20 cps to about 700 cps, or about 5 octaves. The improvement in sound output is shown in Fig. 10.

FURTHER DEVELOPMENT

In this description of a Motion Control system, the writer has been guilty of much oversimplification. While the system has some inherent advantages, it also has some problems and disadvantages. The acoustic problems of a given cabinet cannot always be resolved by enclosing the speaker in a box. Other acoustic enclosures have advantages, particularly in increased efficiency at the lowest frequencies. The problem of applying Motion Control advantageously to open back cabinets, and other acoustic enclosures has yet to be investigated. The problem of motion pickup needs considerable attention. The bridge described herein is difficult to balance. Other types of motion pickup need special development for this application. Extension of the system above about 700 cps presents special problems due to cone breakup; cutting the system off in the mid range may produce undesirable modification of the response, due to phase shift. Phase shift problems in the motion pickup device and the amplifier at extreme low frequencies tend to produce instability and oscillation. Reduction in low frequency distortion is produced at the expense of amplifier gain. Increase in low frequency output by bass boost requires more gain. In many cases, increased low frequency output may be unusable, due to excessive rumble and hum. Undoubtedly, these and other problems can be solved, but their solution will involve work, time, and expense. A modification of the system, or perhaps an extension of it, would pick up the control signal from the sound output of the speaker by means of a suitable microphone[7]. Such a system involves further problems of gain and phase shift.

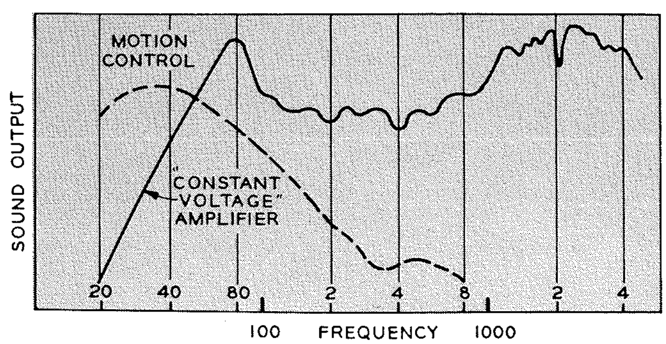
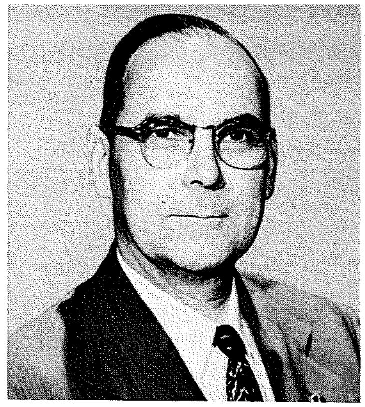


Fig. 10—Improvement in sound output.



SYDNEY V. PERRY, a native of England, was graduated from Queens University at Kingston, Ontario, Canada in 1923. He immediately joined the RCA organization through the then affiliated Westinghouse Company at East Pittsburgh, Pennsylvania. Mr. Perry has been in loud speaker and acoustic work since 1925. He is a member of I.R.E. and has several patents to his credit.

Since 1938 Mr. Perry has been concerned chiefly with the over-all audio and acoustic performance of radios, phonographs, and television instruments. He developed the "Golden Throat" tone system which included the correlation of amplifier, controls, loud speaker, and cabinet. More recently he developed the "Panoramic Sound System." He is now engaged in loud speaker and acoustic work in the Radio & "Victrola" Division.

HISTORICAL

Motion control, as outlined herein, is by no means a new idea. The writer has done work along these lines several times over a period of many years, dating back to at least 1937. M. C. Batsel and E. W. Kellogg had the system under consideration in 1937. H. F. Olson devotes a page to it in his book[7] published in 1940. It has appeared in the Radiotron Handbook[8] in 1952. More recently, R. E. Werner[9] has analyzed its action from an entirely different viewpoint—that of damping. R. L. Libbey has built several systems for field tests. Probably many others have explored this system in some form or other. The possible future use of the system will depend upon how well its problems can be solved.

REFERENCES

1. H. F. Olson, "Elements of Acoustical Engineering," D. Van Nostrand Co., New York, N.Y., 1940, pp. 80, 82.
2. Reference 1, p. 113
3. Reference 1, p. 101
4. Reference 1, p. 116
5. Reference 1, pp. 115-117
6. Reference 1, p. 102
7. Reference 1, p. 135
8. F. Langford-Smith, "Radiotron Designer's Handbook," Fourth Edition, RCA Victor Division, Radio Corp. of America, Harrison, N.J., 1952, p. 841.
9. R. E. Werner, "Loudspeaker-Amplifier System of Superior Performance," EM-4363; June, 1956.

Patents Granted

TO RCA ENGINEERS

BASED ON SUMMARIES RECEIVED OVER A PERIOD OF ABOUT TWO MONTHS

PHONOGRAPH RECORD STORAGE SYSTEM (Patent No. 2,763,524)—granted September 18, 1956 to GEORGE L. BEERS, PRODUCT ENGINEERING, Camden, N. J. A record storage box, marketable as a record container protected by a cover, is provided with a notch for engagement with a rod on a record storage shelf or in a record storage cabinet. When the boxes are used in the record storage and filing system of this invention the cover may be discarded.

ELECTROMAGNETIC FOCUS FOR CATHODE RAY TUBE (Patent No. 2,763,805)—granted September 18, 1956 to SIDNEY L. BENDELL, COMMERCIAL ELECTRONIC PRODUCTS, Camden, N. J. Invention provides an electromagnetic focus coil comprising a cylindrical form and a conductor wound thereon as a "universal winding." That is, the conductor is wound on with a certain pitch and wound back over itself with the reverse pitch. This type of winding may be performed by a conventional textile cord-winding machine and can be made quite precisely.

METHOD FOR ELECTROFORMING A COPPER ARTICLE (Patent No. 2,762,762)—granted September 11, 1956 to DANIEL J. DONAHUE, TUBE DIVISION, Lancaster, Pa. Maintaining chloride ion concentration at .025 to .045 grams per liter in an acid copper plating bath provides an electroformed film having low internal stress, and also a high degree of separability between the film and the noble metal substrate on which it is formed.

TAPE PERFORATING APPARATUS (Patent No. 2,761,509)—granted September 4, 1956 to JOHN N. MARSHALL and JOHN S. BAER, COMMERCIAL ELECTRONIC PRODUCTS, Camden, N. J. Tangential perforating drums 14, 16 can be preset before rotating into punch position. Perforators 18 may be selectively blocked at die openings 30 by interposer balls 40. Perforating speeds are limited only by the rolling speed of the drums 14, 16 and the time needed to set each die opening 30 for punch or no punch. A clearing station after the perforating station puts all die openings into a ready state.

HIGH SPEED RECORDER (Patent No. 2,762-297)—granted September 11, 1956 to JOHN S. BAER, COMMERCIAL ELECTRONIC PRODUCTS, Camden, N. J. The subject printer is a high speed device having a rotating flexible belt bearing transfer characters inked from a trough. A platen serves to support the paper sheet and printed impressions are obtained by projecting synchronously timed fluid jets to force the paper into contact with the characters.

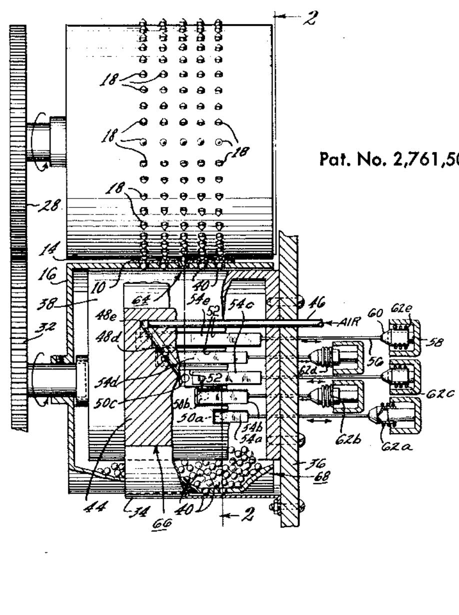
FERROSPINEL BODIES AND METHODS OF MAKING SAME (Patent No. 2,762,776)—granted September 11, 1956 to ROBERT E. HURLEY and JOHN O. SIMPKISS, JR., COMPONENTS DIVISION, Camden, N. J. A tacky, highly viscous diethylene glycol or methyl ester of rosin is dry mixed with ferrospinel-forming oxides. The mixture is pelletized and molded according to standard techniques. Pellets made thereby are stronger and mold into relatively green bodies that withstand relatively rough handling.

DIFFERENCE CIRCUIT (Patent No. 2,762,010)—granted September 4, 1956 to H. J. WOLL and HARRY E. ROSE, DEFENSE ELECTRONIC PRODUCTS, Camden, N. J. The invention consists of difference circuits applicable to analogue computers for the purpose of deriving the difference between two currents. A large incremental impedance in the form of a triode and a cathode resistor are connected in series with paralleled current sources. Error voltages are fed back through the amplifier to a computer. Computed current increments in the tube are substantially equal to and of opposite polarity to current increments in the tube. The voltage at the terminal is an accurate measure of current increments in the tube.

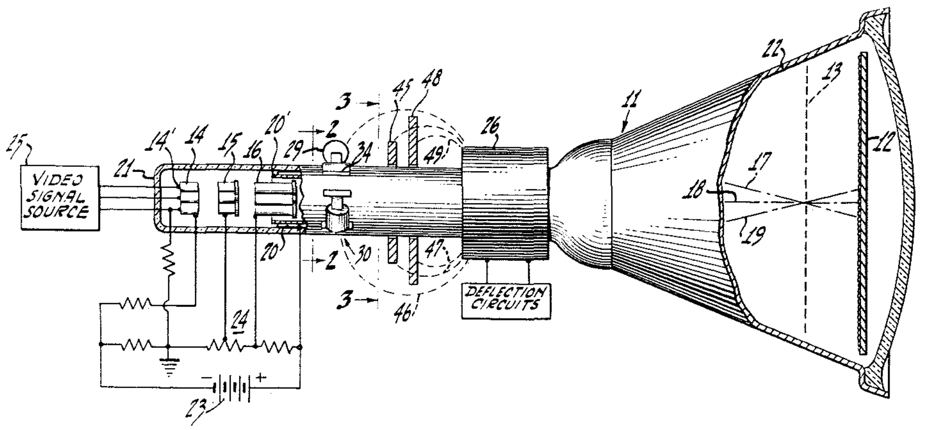
LOW FREQUENCY WAVE GENERATORS (Patent No. 2,761,970)—granted September 4, 1956 to JAMES H. OWENS, COMPONENTS DIVISION, Camden, N. J. The oscillator includes two tubes having a common cathode impedance. A low-pass RC filter is coupled from anode of first tube to grid of second tube, and second low-pass RC filter (which acts as high-pass) is coupled from cathodes to grid of first tube. Has good frequency stability and other practical advantages. Additional circuits provide constant output level.

METHOD OF MAKING A NON-DEFORMING LAMINATED ELECTRODE SUPPORT (Patent No. 2,761,197)—granted September 4, 1956 to WILLIS E. HARBAUGH, TUBE DIVISION, Lancaster, Pa. The method of forming a laminated flexible support comprising: coating with a bonding material, the end portions of each of a plurality of lamina of substantially equal length; stacking the lamina; pressing together the corresponding end portions of the stacked lamina and heating them to bond adjacent end portion coatings together whereby a structure will be formed comprising solid end blocks and a flexible section between them.

MOTOR CONTROL FOR SYNCHRONIZING WEB FEED (Patent No. 2,760,137)—granted August 21, 1956 to DALLAS R. ANDREWS, RCA VICTOR RADIO & "VICTROLA" DIVISION, Cherry Hill, N. J. Optical sync marks are placed on both members (a film and a magnetic tape) to be synchronized. Pulse circuit means detect the order of occurrence of the marks and produce an error signal to be used in controlling the speed of the members.



Pat. No. 2,761,509



Pat. No. 2,763,804

MAGNETIC PULSE RECORDING (Patent No. 2,760,063)—granted August 21, 1956 to DALLAS R. ANDREWS, RCA VICTOR RADIO & "VICTROLA" DIVISION, Cherry Hill, N. J. In order to insure simultaneous "read-out" of a plurality of simultaneously recorded data pulses, the first occurring pulse is used to simultaneously operate a plurality of coincidence gate circuits. Each of the gate circuits produces an output pulse simultaneously, regardless of slight phase differences among different data pulses.

AMPLIFIER HAVING CONTROLLABLE SIGNAL EXPANSION AND COMPRESSION CHARACTERISTICS (Patent No. 2,760,008) —granted August 21, 1956 to OTTO H. SCHADE, TUBE DIVISION, Harrison, N. J. In accordance with one form of the present invention, the cathode biasing resistor in a video amplifier is shunted by two oppositely poled diodes. Controllable bias is applied to the diodes so that their conduction on opposite extremities of a video signal produces decreased degeneration with an attendant stretching of the video signal at its extremities.

LUMINESCENT MATERIALS AND APPLICATIONS THEREOF (Patent No. 2,758,941)—granted August 14, 1956 to GILMORE E. CROSBY, TUBE DIVISION, Lancaster and THOMAS W. EDWARDS, formerly with RCA. Method comprises coating individual particles while suspending in an aqueous medium having a pH between 10.5 and 11.0 with a thin layer of calcium hydroxy phosphate. The invention includes the coated phosphor particles, method of coating the particles and luminescent screens comprising said particles.

SIGNAL RESPONSIVE CIRCUIT (Patent No. 2,757,280) — granted July 31, 1956 to ARTHUR D. BEARD, DEFENSE ELECTRONIC PRODUCTS, Camden, N. J. A shunt type gating element is employed to draw current through a summing resistor to thereby negate the effect of an input signal applied at the other side of the above-mentioned summing resistor. This principle is expanded such that a two-input gate having the logical function of "either-but-not-both" is provided by a circuit employing first and second cathode followers which have their outputs connected through buffer diodes to an output terminal and respectively cross coupled to the grids of second and first shunt type gating tubes.

APPARATUS FOR OBTAINING SYSTOLIC INFORMATION (Patent No. 2,756,741)—granted July 31, 1956 to MATTHEW J. CAMPANELLA, DEFENSE ELECTRONIC PRODUCTS, Moorestown, N. J. System, using an electromechanical transducer attached to a patient for automatically obtaining patient's blood pressure, pulse rhythm, and pulse count having means for displaying such information for easy observation by a surgeon during an operation. Display means includes a recycling counter which indicates new pulse count after a set interval.

MAGNETIC RECORDING (Patent No. 2,751,-274)—granted June 19, 1956 to DALLAS R. ANDREWS, RCA VICTOR RADIO & "VICTROLA" DIVISION, Cherry Hill, N. J. A drum or disc is provided having a number of adjacent, independent and concentric magnetic record tracks thereon. A magnetic head is pivotably mounted so as to move along an arc until indexed to stop at the desired record track.

OSCILLATION SYNCHRONIZATION (Patent No. 2,748,191)—granted June 5, 1956 to RICHARD W. SONNENFELDT, RCA VICTOR TELEVISION DIVISION, Cherry Hill, N. J. The subject invention relates to an improvement in triode type unbalanced phase comparator circuits. In a conventional triode type phase comparator circuit, sync is applied to the grid of the triode with deflection flyback pulse being applied to the anode. Phase error voltage is then developed as a function of anode current flow. Present invention returns grid of tube to a point along cathode bias resistor of tube. In this way, no error voltage is developed should there be an interruption in the application of sync to the grid of the tube.

OSCILLATION CONTROL CIRCUITS (Patent No. 2,743,369)—granted April 24, 1956 to WILLIAM F. SANDS, RCA VICTOR TELEVISION DIVISION, Cherry Hill, N. J. In accordance with the present invention, a highly stable oscillator circuit is provided through the use of a reactance tube circuit connected in frequency determining relation to an oscillator. The power supply potential versus frequency characteristics of the basic oscillator is then neutralized by providing a complementary characteristic in the reactance tube circuit. The frequency of the oscillator may be additionally controlled, as in color television color oscillator systems, by phase comparison of the oscillator with received color burst.

CATHODE RAY TUBE DEVICE (Patent No. 2,763,804)—granted September 18, 1956 to ALBERT M. MORRELL, TUBE DIVISION, Lancaster, Pa. In electromagnetic convergence type color kinescope, of the internal pole piece type, it is essential to shield the convergence region from the deflection flux. Thus, in addition to the magnetic shunt 45 of earlier Goodrich case SN. 356,620, the present invention employs a copper disk 48 between the yoke and the ferrite disk. Eddy currents set up in the disk 48 by the horizontal field "buck" and cancel the field, thereby effectively shielding the convergence region therefrom, while not introducing distortion into the field configuration.

WIDE BAND HIGH FREQUENCY PREAMPLIFIER CIRCUITS (Patent No. 2,743,323)—granted April 24, 1956 to STEVEN WLASUK, RCA SERVICE COMPANY, Cherry Hill, N. J. A broad band RF amplifier system is disclosed suitable for use as a preamplifier over both the VHF and UHF TV bands. The amplifier is comprised of a first and a second "Cascode" amplifier with the cathodes of the first tube in each "Cascode" connected together and thence through a single common cathode load circuit to ground. The input circuits of the two amplifiers are broadly tuned to the VHF and UHF bands respectively, as are their respective output circuits. The two input circuits are then connected in series with one another across a single input terminal means, for accepting an antenna. Output circuits are similarly combined to feed a TV receiver.

ELECTRON BEAM CONVERGENCE APPARATUS (Patent No. 2,742,589)—granted April 17, 1956 to HUNTER C. GOODRICH, RCA VICTOR TELEVISION DIVISION, Cherry Hill, N. J. In a three beam tri-color kinescope using internal pole piece convergence apparatus, the three beam-convergence magnets are energized conventionally by line and field frequency parabolic waves and, in addition, the red and grean beam-convergence magnets are energized by modified sawtooth waves at line frequency to correct the corner distortion of the red and green rasters.

WAVE GENERATING SYSTEMS (Patent No. 2,734,945)—granted February 14, 1956 to RICHARD W. SONNENFELDT, RCA VICTOR TELEVISION DIVISION, Cherry Hill, N. J. By comparing in a gate circuit the output pulse of a deflection blocking oscillator (or the flyback pulse of a standard deflection output stage) with arriving television sync, a variable area type of coincidence timing control signal is developed. This is used to control the frequency of the blocking oscillator. Single tube embodiment of invention provides combined sync clipping, AFC and sawtooth generation. Materially reduces number of tubes required in a television receiver.

TRANSISTOR BIAS CIRCUIT WITH STABILIZATION (Patent No. 2,762,873)—granted September 11, 1956 to HUNTER C. GOODRICH, RCA VICTOR TELEVISION DIVISION, Cherry Hill, N. J. Operating point stabilization of a transistor may be achieved by connecting a resistor between the collector and base electrodes to provide negative current feedback. In accordance with this invention, a higher degree of stability is obtained with the collector to base feedback connection by applying a fixed base bias current to the transistor. This is accomplished by connecting a resistor and a supply source in the base-emitter circuit.

DYNAMIC ELECTRON BEAM CONTROL SYSTEMS (Patent No. 2,730,651)—granted January 10, 1956 to RICHARD W. SONNENFELDT, RCA VICTOR TELEVISION DIVISION, Cherry Hill, N. J. An improved circuit for generating a parabolic type waveform useful as a convergence control signal for color kinescope is described. The primary winding of a transformer is put in series with the deflection output stage. The secondary of the same transformer is connected with a differentiating network which develops a waveform approximating the desired parabolic convergence control signal. This waveform is then combined with a small amount of sawtooth waveform signal of the same frequency to produce the final convergence control signal having the desired phase and voltage waveform.

DEFLECTION WAVEFORM GENERATOR (Patent No. 2,729,744)—granted January 3, 1956 to B. S. VILKOMERSON, RCA VICTOR TELEVISION DIVISION, Cherry Hill, N. J. This invention provides improved stability of blocking oscillator and multivibrator type sawtooth discharge generators. Improved stability of conventional blocking or multivibrator oscillators is accomplished by imposing a fixed capacitance of the order of 200 micromicrofarads between the anode and control electrode of the multivibrator or blocking oscillator tube. This provides both inverse feedback and voltage limiting action. Circuit then has much greater immunity to undesirable noise pulse such as for example the horizontal "fly back" pulse capacitively and inductively fed to the vertical deflection circuit via the deflection yoke.

TELEVISION FILM RECORDING (Patent No. 2,763,833)—granted September 18, 1956 to JOHN M. BRUMBAUGH, DEFENSE ELECTRONIC PRODUCTS, Camden, N. J. Step wave is applied to recording kinescope to develop raster comprising a series of parallel bands of different brightness levels. Photomultiplier picks up light from the respective bands after passage through a filter comprising a series of parallel strips of different densities, and photomultiplier output is displayed on oscilloscope. Densities of the filter strips are chosen so that if kinescope apparatus has the desired transfer characteristics, an equal amount of light flux is picked up by photomultiplier for all of the raster bands, and height of all the pulses on oscilloscope screen will therefore be equal. If kinescope apparatus does not have the desired characteristics, gamma, contrast, and brightness controls of recording system are adjusted until correct indication is obtained. Filter strips may be separated by opaque masking strips, or step wave may be notched, so that substantially complete phosphor decay occurs before each brightness level indication begins.

FREQUENCY SYNCHRONIZING SYSTEMS (Patent No. 2,764,686)—granted September 25, 1956 to ARCH C. LUTHER, JR., COMMERCIAL ELECTRONIC PRODUCTS, Camden, N. J. The system uses a short time constant circuit 28 between a control voltage generating circuit 18 and a control circuit 41, to allow the frequency control circuit to readily follow voltage fluctuations of a voltage generated by the control voltage generator circuit 18 during a period when the frequency is undergoing substantial change. A circuit for lengthening the time constant of the coupling circuit consisting of resistance 36 and a capacitor 38 operates when the oscillator generator is undergoing a little change and thereby renders the frequency control circuit less responsive to random signals.

ORIENTING DEVICE (Patent No. 2,752,028)—granted June 26, 1956 to ROGER E. SCHELL, COMMERCIAL ELECTRONIC PRODUCTS, Camden, N. J. and LESTER MOSKOWITZ (formerly with RCA). The orienting device comprises means to cause randomly aligned bottles moving along a track to fall between two separated and angularly disposed plates. Bottles proceeding neck-first are turned over, and bottles proceeding base-first advance in that position.

TUNABLE SIGNAL AMPLIFIER STRUCTURE AND COUPLING ELEMENTS THEREFOR (Patent No. 2,762,987)—granted September 11, 1956 to DONALD MACKEY, COMPONENTS DIVISION, Camden, N. J. The primary and secondary windings are printed side by side on an insulating support panel. Conductive washers change the inductance of the windings. In a 40 mc television i.f. amplifier, a plurality of the transformers may be supported on a chassis in alignment, each being provided with a shield can having openings which provide access to the screws from one side of the chassis. The coupling between the windings may be varied without changing their relative positions by changing the position of the terminal connection leads relative to the windings.

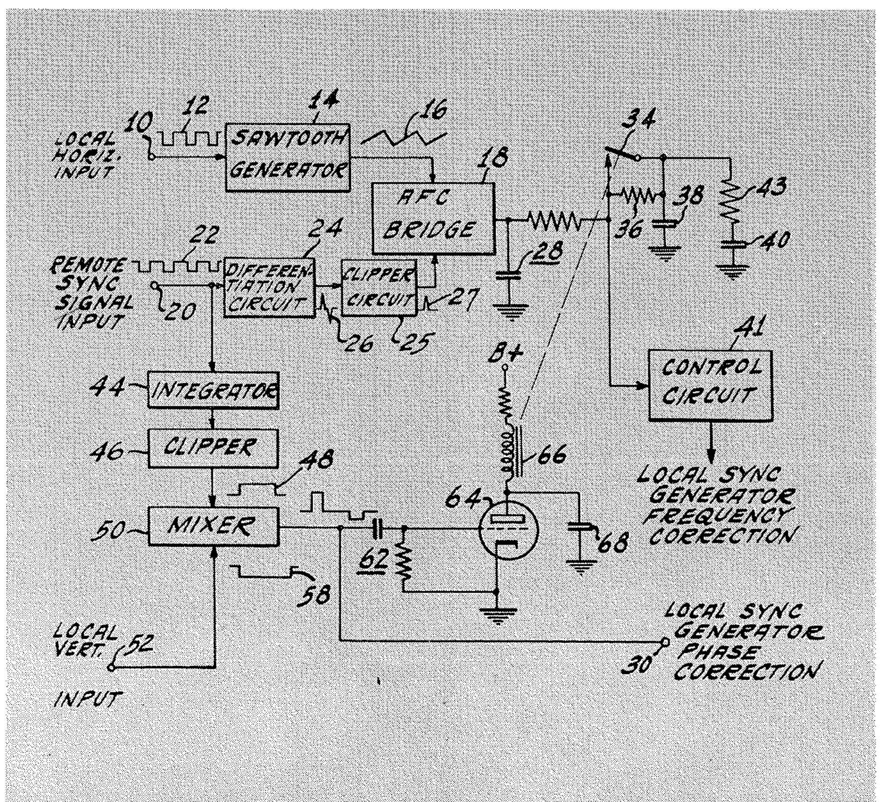
ELECTRON DISCHARGE DEVICE (Patent No. 2,749,469)—granted June 5, 1956 to MERRALD B. SHRADER, TUBE DIVISION, Lancaster, Pa. In a power tetrode side support rods of screen grid are positioned on the outside of the grid helix rather than on the inside of the helix, as is normal. This arrangement allows close spacing between control grid and screen grid. Grid turns and supports rods of each grid are aligned, giving an improved beaming action which results in lower screen current.

METHOD OF FORMING P-N JUNCTIONS IN N-TYPE GERMANIUM (Patent No. 2,761,800)—granted September 4, 1956 to NORMAN H. DITRICK, SEMICONDUCTOR DIVISION, Somerville, N. J. Indium electrode material is alloyed with 0.2 to 0.5% zinc. A flux capable of yielding hydrochloric acid is placed between the indium-zinc electrode and the germanium wafer. On heating the flux decomposes. Hydrochloric acid is formed and reacts with the zinc in the electrode to form zinc chloride, which is the flux for wetting indium and germanium. The amount and location of the zinc chloride is thus controlled.

MAGNETIC RECORDING APPARATUS (Patent No. 2,742,536)—granted April 17, 1956 to JOSEPH M. URITIS, DEFENSE ELECTRONIC PRODUCTS, Camden, N. J. To obtain accurate azimuth adjustments of a magnetic head with respect to the tape, a holder is provided. It is a four-sided element having one flexible side. This flexible side may be deformed, thereby shortening it to angularly displace the head.

CARD SWITCHING DEVICE (Patent No. 2,734,954)—granted February 14, 1956 to MARSHALL C. KIDD, RCA VICTOR TELEVISION DIVISION, Cherry Hill, N. J. A laminated data storage card is disclosed having defined within it a plurality of electrical circuit paths accessible by means of conductive deposits on surface of card or holes in surface permitting contact with conductive deposits within the card. Area of novelty includes the further provision within the card of pressure responsive switch means which alter the internal circuit paths by the application of pressure to surface of card. Data thus stored may be useful in subscription TV or Bizmac type equipment.

FREQUENCY MARKER SYSTEM (Patent No. 2,763,835)—granted September 18, 1956 to DON L. LUNDGREN, COMMERCIAL ELECTRONIC PRODUCTS, Camden, N. J. The frequency marker circuit comprises a resonant network connected to a triode, in a high Q pulse former circuit, whereby a sharp pulse is produced when a signal of the resonant frequency is applied to the network; and means to amplify, clip, and invert the output pulse.



Pat. No. 2,764,686

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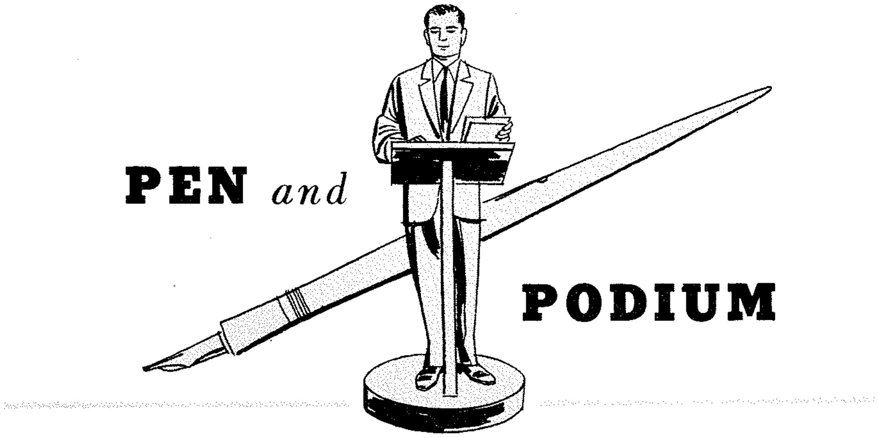


BASED ON REPORTS RECEIVED OVER A PERIOD OF ABOUT TWO MONTHS

LUMINESCENT MATERIALS . . . By G. E. CROSBY, TUBE DIVISION, Lancaster, Pa. Presented at Seminar for Chemistry Students, Fordham University, New York, on February 20, 1957. This paper emphasizes cathodoluminescence and demonstrates the many properties involved with various materials. Materials influence the efficiency of the three major processes involved in cathodoluminescence: absorption, storage, and emission of energy. Only assumptions can be made regarding the absorption of electron energy in matter. Many practical properties of the storage process can be discussed, such as build-up, decay, infrared quenching and stimulation, glow curves, and temperature breakpoints.

COMPONENT REQUIREMENTS FOR HIGH POWER AIRBORNE MODULATOR APPLICATIONS . . . By L. ANDRADE, DEFENSE ELECTRONIC PRODUCTS, Camden, N. J. Presented at the Modulator Colloquium—Knolls Laboratory, Schenectady, N. Y. on January 16, 1957. A description of Modulator work in the RCA Airborne Fire Control Section was outlined. Requirements for application in an interceptor type aircraft were described. The design approach emphasizes space, weight, and temperature requirements of the application. Component problems, available tube types and their limitations were discussed.

MULTIPLIER PHOTOTUBE DEVELOPMENTS AT RCA-LANCASTER . . . By RALPH W. ENGSTROM, TUBE DIVISION, Lancaster, Pa. Presented at Symposium on Millimicrosecond Pulse Techniques for Nuclear Counting, University of California, February 14-15, 1957. This paper describes the latest developments of multiplier phototubes at the Lancaster plant, with emphasis on tubes and characteristics useful in scintillation counting and especially those applicable to short-time resolution. Tube types discussed include the recently announced 6903 fused-silica-window tube; the 6810 fourteen-stage multiplier phototube; a developmental sixteen-stage version of the 6810; a developmental 5-inch multiplier phototube recently developed under AEC contract; a developmental ¾-inch multiplier phototube; and a developmental multialkali photocathode type and its status, spectral response, and possible use in scintillation counting.

COMPONENT RELIABILITY, ITS SPECIFICATION & MEASUREMENT . . . By I. K. MUNSON, DEFENSE ELECTRONIC PRODUCTS, Camden, N. J. Presented on January 15 at the Third National Symposium on Reliability and Quality Control, Washington, D. C. The drive for equipment reliability has placed great emphasis on improvement of component specifications. This paper deals with the necessity for techniques which will permit procurement of components of known reliability. Restrictions on materials and quality control are discussed.

A LOOK AT THE MANAGEMENT SCIENCE FOREST . . . By W. E. BAHLS, TUBE DIVISION, Harrison, N. J. Presented at Institute for Management Science, New York City, January 15, 1957. This paper discusses the correlation between various scientific disciplines and the business system in a way that is understandable to the non-technically-trained manager. Such items as automation, operations research, systems analysis, simulation, servo-mechanisms, instrumentation, electronic computers, data processings, and the like are also discussed.

THE USE OF NUMERICAL MODELS IN PSEUDO-CODE TRANSFORMATIONS . . . By J. H. WAITE, JR., COMMERCIAL ELECTRONIC PRODUCTS, Camden, N. J. Presented at the University of Pennsylvania, Moore School of Engineering, on February 6, 1957. In the development of automatic programming systems, much emphasis must be placed upon problem languages and convenient pseudo-codes. To date transformation of these pseudo-codes into machine instructions is done by various look-up table techniques. The next step is to replace these tables by numerical techniques which take advantage of desirable group properties of languages and of numerical models. A few numerical models, including a binary cyclic group, a permutation group, and binary generating functions are described.

LOW COST MULTIPLE SAMPLING METHOD . . . By RICHARD M. JACOBS, DEFENSE ELECTRONIC PRODUCTS, Moorestown, N. J. Presented on January 15, 1957 at the Third National Symposium on Reliability and Quality Control, Washington, D. C. Sampling procedures now in use call for different plans, quantities and multiple records for each class of defect. This presentation describes a system for weighing characteristics for a multiple sampling plan requiring only one record and utilizing one sampling plan and the same quantity for all defect classes. The paper suggests a system for use in acceptance inspection programs.

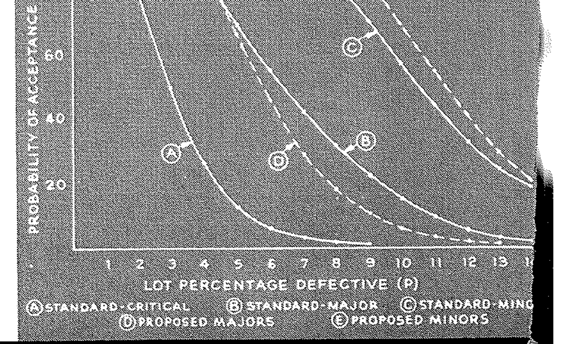
THERMISTORS COMPENSATE TRANSISTOR AMPLIFIERS . . . By A. J. WHEELER, SEMICONDUCTOR DIVISION, Somerville, N. J. Published in ELECTRONICS, January 1957. This paper describes the use of a thermistor bias circuit to compensate for temperature effects on junction transistors used in class B push-pull stages. Temperature compensation is necessary in such applications to minimize distortion and to prevent the occurrence of a runaway condition produced by changes in ambient temperature. Equations are developed for calculation of restrictions on choice of thermistor material and on the values of circiit components.

USE OF THE COMPUTER IN COMPUTER DESIGN . . . By J. H. WAITE, JR., COMMERCIAL ELECTRONIC PRODUCTS, Camden, N. J. Presented on February 1, 1957 at the Operations Research Symposium, Case Institute of Technology, Cleveland, Ohio. This paper represents an attempt to use a digital computer as a design tool in these phases of computer design and manufacture: a) Logic synthesis and optimization; b) Logic design verification; c) Wiring schedules; d) Hardware tests; e) Error identification and isolation; and f) Equipment modification and test thereof.

AN EXPERIMENTAL SUPER-POWER HARD-TUBE PULSE MODULATOR SYSTEM . . . By M. V. HOOVER, TUBE DIVISION, Lancaster, Pa. Presented at High-Power Modulator Colloquium, Knolls Research Laboratory, General Electric Co., Schenectady, N. Y., January 16-17, 1957. This paper describes a 10-megawatt experimental super-power hard-tube modulator system developed and constructed at the Lancaster plant. This equipment is intended for operation in pulse service requiring high-duty-factor power (e.g., in the order of 5 per cent). Operational pulse length is continuously variable from a minimum of several microseconds to a maximum of at least three milliseconds.

THE UTILIZATION OF DOMAIN WALL VISCOSITY IN DATA HANDLING DEVICES . . . By V. L. NEWHOUSE, COMMERCIAL ELECTRONIC PRODUCTS, Camden, N. J. Presented on February 26, 1957 at the Western Joint Computer Conference. Investigation of switching behavior of metal tape rectangular-loop cores has led to the discovery of a group of phenomena which will collectively be referred to as the Magnetic Inertia Effects. These can be explained in terms of existing theory of magnetic domains. Digital circuit applications are described. Two of these are; a technique of continuously displaying the contents of

Operating Characteristic Curves for Double Sampling Plans Letter Size K Level II—Jacobs



magnetic shift registers, and a means of operating random access memories faster than present current coincidence types.

A TRANSISTORIZED HIGH VOLTAGE PUSH-PULL SWEEP GENERATOR USING HIGH IMPEDANCE TECHNIQUES . . . By P. J. ANZALONE, DEFENSE ELECTRONIC PRODUCTS, Camden, N. J. Presented at the 1957 Transistor and Solid State Circuits Conference, Phila., on February 14. A method of obtaining an ultra-high input impedance unity gain amplifier is considered first. This isolating amplifier is then utilized in a bootstrap linear sweep generator circuit which is capable of generating a 105-volt sawtooth waveform using 120-volt breakdown transistors. The unity gain isolating amplifier is again utilized in a voltage doubler circuit which doubles the voltage swing capabilities of a 120-volt transistor. The voltage doubling circuit is used in a push-pull arrangement to obtain a positive going 210-volt sawtooth and a negative going 210-volt sawtooth waveform. These sawtooth voltages can be used for electrostatic deflection of a 5 inch P.R.T.

A RELIABILITY APPROACH TO THERMAL DESIGN AND EVALUATION . . . By T. C. REEVES, DEFENSE ELECTRONIC PRODUCTS, Camden, N. J. Published in the February 1957 issue of ELECTRICAL MANUFACTURING. The article outlines a method for estimating the cooling requirements for an electronic equipment in terms of the specified quantitative reliability goal, i.e., allowable equipment failure rate. Methods are also described for evaluating the adequacy of an existing cooling system in terms of its effect on the equipment failure rate.

RECENT DEVELOPMENTS IN HIGH-FREQUENCY TRANSISTORS . . . By A. L. KESTENBAUM, SEMICONDUCTOR DIVISION, Somerville, N. J. Presented at the Basic Science and Communications Division of New York AIEE Section on January 15, 1957. This paper discusses the relationship between the physical structure of transistors and their high-frequency behavior. In particular, the advantages of the drift transistor structure which utilizes a graded-impurity base region are described and the technique of solid-phase-impurity diffusion in semiconductors is discussed to show its applicability to the construction of high-frequency transistors.

AVALANCHE OPERATED JUNCTION TRANSISTORS IN A RING COUNTER . . . By J. E. LINDSAY, DEFENSE ELECTRONIC PRODUCTS, Camden, N. J. Presented at the 1957 Transistor and Solid State Circuits Conference, Phila., on February 14. The avalanche mode of operation for junction transistors is encountered at higher-than-normal collector voltages. In this avalanche region the junction transistor is altered due to a voltage sensitive current-multiplication at the collector junction. Current controlled N-type negative resistance characteristics suitable for bistable operation are obtained. Important features of these characteristics can be treated analytically to obtain results suitable for design purposes. The collector characteristics and emitter input characteristic obtained with avalanche operation are compared and discussed. An equivalent circuit is presented together with basic relationships useful for circuit design. Twelve experimental avalanche-operated junction transistors have been used in a decade ring counter and driver, representing a saving of two to one in semiconductor devices, as contrasted to the use of conventionally operated junction transistors for the same function.

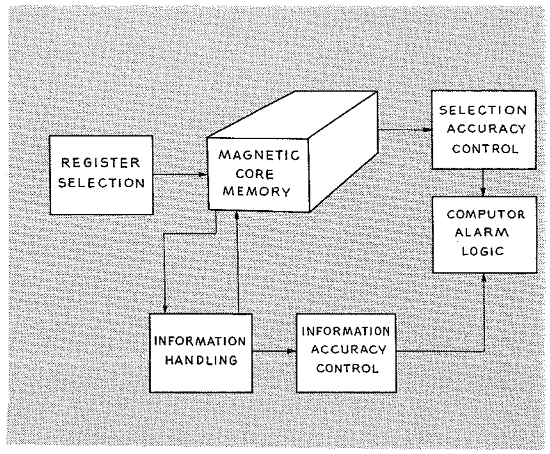
METALLOGRAPHIC ASPECTS OF ALLOY JUNCTIONS . . . By A. S. ROSE, SEMICONDUCTOR DIVISION, Somerville, N. J. Presented at the AIMME Semiconductor Symposium, New Orleans, La. on February 25, 1957. Germanium-indium phase relationships are reviewed with particular reference to the manufacture of alloy-junction transistors. Alloying is discussed as a function of such variables as temperature gradients, surface properties of germanium and indium, and edge-dislocation density of germanium. The effects of these variables on junction flatness and incomplete alloying are illustrated. Metallographic techniques for sample preparation are described. Principles and procedures for obtaining planar, completely alloyed junctions are presented for large-area alloy-junction transistors.

ARITHMETIC PROCESSES IN DIGITAL COMPUTERS . . . By E. L. SCHLAIN, COMMERCIAL ELECTRONIC PRODUCTS, Camden, N. J. Presented on February 25, 1957 at the Symposium on Computer Fundamentals, University of Pennsylvania, Phila., Pa. This paper discusses methods performing basic arithmetic operations of addition, subtraction, multiplication and division. Consideration is given to different types of arithmetic devices, both binary and decimal, and the manner in which they function relative to the rest of the computer. In connection with the Symposium Computer, (a simplified computer created by the Symposium for purposes of illustration), an arithmetic unit was devised and its use in the computer performance of addition, subtraction and multiplication was specified.

APPLICATION OF PRECISION TRACKING RADAR TO LOCATION CONTROL AND DATA TRANSMISSION FOR AN UNMANNED OBSERVATION PLATFORM . . . By D. K. BARTON, DEFENSE ELECTRONIC PRODUCTS, Moorestown, N. J. Presented on February 7, 1957 at the Third Annual Radar Symposium, University of Michigan. The conduct of a modern military operation may require several types of unmanned platforms or airborne vehicles for observation. Drone aircraft, balloons or guided missiles may be employed to penetrate tens or hundreds of miles into hostile territory. There exists a common requirement for precise knowledge as to location of the platform, control of sensing equipment or of the platform itself, and for transmission of data back to the operations center. This paper describes a new precision radar which has been designed primarily for flexibility in application and for extreme accuracy and long range.

APPROACH TO THE STANDARDIZATION OF CIRCUITS . . . By G. T. ROSS, DEFENSE ELECTRONIC PRODUCTS, Camden, N. J. Presented on January 16, 1957 at the Third National Symposium on Reliability and Quality Control, Washington, D. C. This paper covered the reasons for embarking on a circuit standardization program and the possible methods of attack. These methods include a discussion of, 1) the use and analysis of old circuits for possible standardization and, 2) the derivation of new circuits and the problems involved. The placement of emphasis whether on semiconductors or tube circuits was treated pro and con. An approach to standardization which is more acceptable to Design Engineers was given.

ACCURACY CONTROL SYSTEMS FOR MAGNETIC-CORE MEMORIES . . . By A. G. JONES, A. KATZ and G. REZEK, COMMERCIAL ELECTRONIC PRODUCTS, Camden, N. J. Presented by Mr. Katz at the Western Joint Computer Conference, Los Angeles, on February 27, 1957. Because of simplicity and reliability, coincident-current magnetic-core memory has become a "standard" storage medium. This paper describes means for the immediate detection and speedy location of faults in the memory system.



Magnetic Core Memory with Associated Accuracy Control Systems—Katz & Rezek

PHASE CONTROLLED TRANSISTOR POWER SUPPLY REGULATION . . . By D. E. DEUITCH and H. J. PAZ, DEFENSE ELECTRONIC PRODUCTS, Camden, N. J. Presented at the 1957 Transistor and Solid State Circuits Conference, Phila. on February 15. Transistors have been utilized effectively in series regulated power supplies. However, the power handling capacity and high temperature performance is restricted because of power and temperature limitations of transistors. This paper describes a regulated power supply in which regulator transistors are operated as switches. Transistor dissipation is extremely small. This enables low-power transistors to control large amounts of power and permits substantial improvement in power supply capabilities at high temperature compared to the series regulated supply. A 12 volt, 0 to 1 ampere power supply of this type is described.

POLYSTYRENE PACKAGES FOR ELECTRON TUBES . . . By RICHARD KUHLMAN, TUBE DIVISION, Harrison, N. J. Published in MODERN PACKAGING, February, 1957. This paper describes the use of molded expanded polystyrene in trays which act as internal toting units for tubes as well as packages for external shipment. These trays protect delicate projecting parts of the tubes, and are designed to accommodate unusual shapes.

AN EXPERIMENTAL INVESTIGATION OF THE EFFECTS OF NUCLEAR RADIATION ON TRANSISTORS . . . By A. J. SCHWARTZ, DEFENSE ELECTRONIC PRODUCTS, Camden, N. J. Presented on February 27, 1957 at the Symposium on Nuclear Radiation Effects on Semiconductor Devices and Materials. This paper discusses the results of a comprehensive experimental investigation of nuclear radiation effects on transistors. It was the purpose of this investigation to attempt to establish some general trends on the deterioration of transistor characteristics as a function of radiation time. Tests were run on approximately 150 transistors of sixteen different types under various levels and kinds of radiation. The effects on the various types of transistors according to classification are included. Differences encountered in making measurements under nuclear radiation environments are also included. Finally, recommendations for future work in this field are presented.

EFFECTS OF RADIATION ON TRANSISTORS AND OTHER SEMICONDUCTOR DEVICES . . . By D. B. KRET, DEFENSE ELECTRONIC PRODUCTS, Camden, N. J. Presented on February 27, 1957 at the Symposium on Nuclear Radiation Effects on Semiconductor Devices and Materials. This paper discusses the physical mechanisms of changes in semiconductor materials due to nuclear radiation. The effects of each type of radiation particle and ray are determined independently. Energy, cross section, transmutation, and lattice defects, are analyzed with respect to the application of semiconductor materials. Bulk and surface defects are considered separately wherever possible. Annealing mechanisms are also explained. An analytical discussion of the expected changes in electrical characteristics for the various types, levels, and intensities of irradiation is also included together with a comparison of actual results.

ACCURACY CONTROL IN THE BIZMAC SYSTEM . . . By I. COHEN, J. G. SMITH and A. M. SPIELBERG, COMMERCIAL ELECTRONIC PRODUCTS, Camden, N. J. Presented by Mr. Cohen on February 27, 1957 at the Western Joint Computer Conference. Very early in the development of the BIZMAC system by RCA it was recognized that large scale data handling applications presented particular requirements which would not be met by the multiplication of data processing devices alone. The size and complexity of such applications were such that several departures from the organization of prior data processing systems were indicated. Centralized and immediate control of the entire system conferred all the advantages on system operation that the programmed computer had on the interim organization of data for computation. All processing machines and data transfer media not only contain necessary internal monitoring devices, but also the ability to monitor their own system operation.

TRANSISTORS IN AIRBORNE EQUIPMENT . . . By H. J. WOLL, DEFENSE ELECTRONIC PRODUCTS, Camden, N. J. Presented on December 6, 1956 at the Dayton Chapter of the Professional Group on Aeronautical and Navigational Electronics. The present status of transistor electronic equipment was outlined. Advantages of transistor equipment over its vacuum tube counterpart because of low power drain, small size and weight, portability, better reliability, and circuit simplicity were illustrated. Design of circuits for wide temperature range operation was discussed. Particular attention was paid to new and unique circuits that are possible with transistors. A simple description was given of complementary symmetry transformerless circuits, low noise input circuits, push-pull emitter followers and symmetrical gates. Trends in the transistorization of airborne equipment were explored. A hi fidelity audio amplifier using a complementary symmetry transformerless circuit was demonstrated.

CREATIVITY IN ENGINEERING . . . By C. M. SINNETT, RCA VICTOR TELEVISION DIVISION, Cherry Hill, N. J. Presented on February 21 to the Professional Group on Engineering Management, Philadelphia Section IRE. Increasing the creative ability of engineers is of prime importance to management. Techniques and methods have been developed which can double this ability. These were discussed together with ways of overcoming some of the mental blocks to creativity. Group ideation is one method which produces quantities of ideas and was discussed in some detail.

THE SUPERVISORY TRAINING PROGRAM AT RCA . . . By S. E. CLARK, TUBE DIVISION, Harrison, N. J. Presented at the Armed Forces Management Association, New York City, on January 16, 1957. This paper describes the RCA concept of training supervisors, discussing both the real need for such training and the actual programs developed to meet this need. The steps taken in planning these programs are enumerated, and surveys, procedures, and results are analyzed.

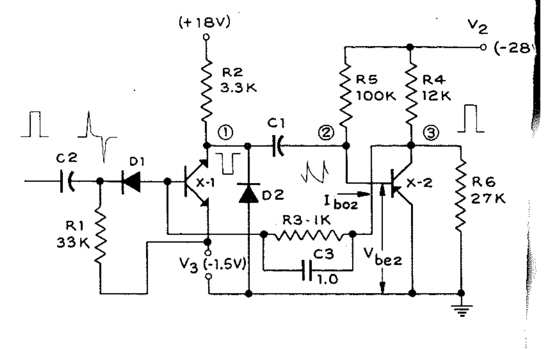
A MONOSTABLE MULTIVIBRATOR CIRCUIT USING COMPLEMENTARY TRANSISTORS . . . By C. F. CHONG and A. I. ARONSON, DEFENSE ELECTRONIC PRODUCTS, Camden, N. J. Presented on February 14 at the 1957 Transistor and Solid State Circuits Conference, Phila. A transistor monostable circuit using complementary transistors is described. Using this unique property of transistors in this application results in certain advantages compared to the transistor monostable circuit directly analogous to a tube monostable multivibrator. An analysis of circuit operation and timing is given, and the effects of temperature on circuit reliability are discussed. The circuit has operated reliably with input frequencies from 250 cycles to one megacycle.

COLOR-TV VIDEO GENERATOR FOR CONVERGENCE . . . By RHYS SAMUEL, TUBE DIVISION, Harrison, N. J. Published in the January 1957 issue of SERVICE Magazine. This paper describes the RCA WR-46A Video Dot/Crosshatch Generator designed for servicing all models of color-TV receivers. This generator provides a choice of vertical-bar, horizontal-bar, dot, or crosshatch patterns on video frequencies.

ELECTRO-OPTICAL SYSTEMS IN CASCADE . . . O. H. SCHADE, TUBE DIVISION, Harrison, N. J. Presented at the Air Force Cambridge Research Center, Boston University, Mass. on January 9-11, 1957. The Fourier spectrum of an imaging system is expressed as a function of the spatial frequency (line-number) and direction of sinusoidal plane-wave patterns, establishing a direct connection with the scanning operation (convolution) performed in measurements. Optical and Electrical system elements are represented by scanning apertures, forming two-dimensional point-images, described in the frequency domain by two-dimensional Fourier spectra. For many purposes the spectrum function can be replaced by an equivalent passband, which simplifies analysis and assessment of complex imaging systems.

A HALF-TONE DISPLAY STORAGE TUBE WITH MAGNETIC DEFLECTION . . . By M. E. CRAIG, TUBE DIVISION, Lancaster, Pa. Presented at the AIEE Winter General Meeting, New York City on January 24, 1957. This paper describes a new developmental RCA Display Storage Tube, a cathode-ray tube capable of providing a visual display of radar information at a brightness level that permits viewing under high-ambient-light conditions. Features which make the tube useful as a radar indicator are its high writing speed, good half-tone rendition, and good resolution. Basic principles of operation and storage characteristics are discussed.

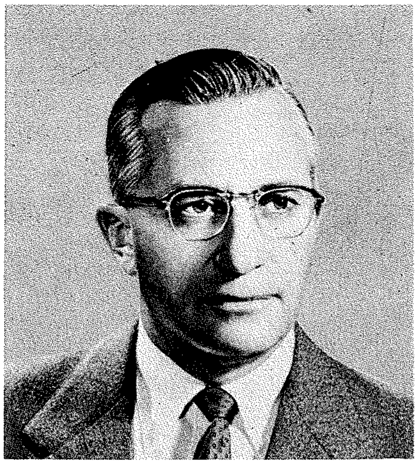
REVERBERATION CHAMBERS FOR DISC AND TAPE RECORDING STUDIOS . . . By M. RETTINGER, COMMERCIAL ELECTRONIC PRODUCTS, Hollywood, California. Presented on February 7 at the Audio Engineering Society West Coast Convention, Hollywood, Calif. Design of reverberation chambers and such factors as optimal ratio for height, width, and length of room are discussed. Curves show the variation of reverberation time with room volume for enclosures having preferred dimensions and which are treated with materials of various sound absorption co-efficients.



Monostable Multivibrator Circuit—Chong & Aronson

Engineering NEWS *and* HIGHLIGHTS

H. E. ROYS HONORED BY IRE

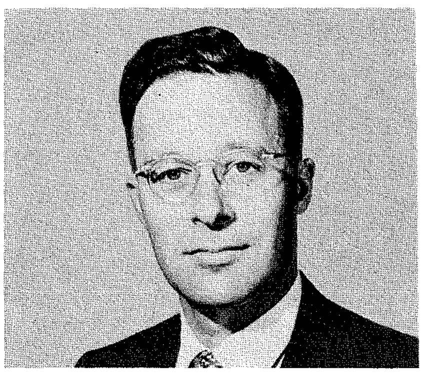


H. E. Roys, Manager of Engineering, RCA Victor Record Division, Indianapolis, has been elected to receive the Achievement Award of the IRE Professional Group on Audio. The award is based on outstanding contributions to the audio arts, sciences or technology, periodically as documented by papers appearing in IRE publications.

Mr. Roys' articles have specialized in problems related to the improvement in the quality of phonograph reproduction.

—*S. D. Ransburg*

W. K. HALSTEAD TRANSFERS TO SOMERVILLE

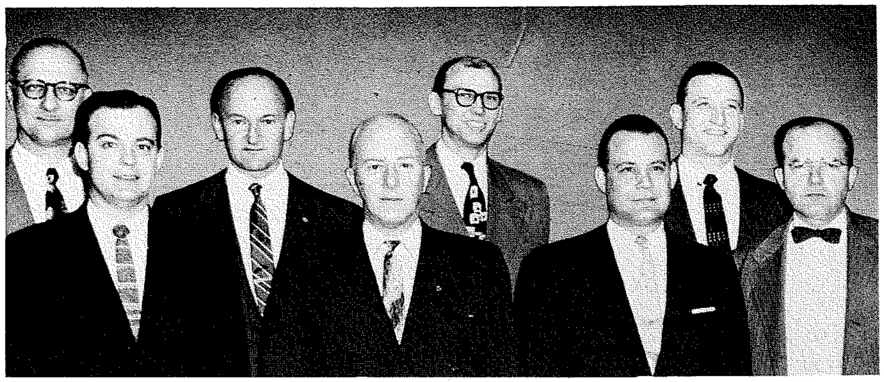


A dinner was recently held at Schillig's Black Horse Farms, Camden, N. J., for Walter Halstead, formerly Manager of Systems and Advanced Product Development, CEP BIZMAC Engineering, who is transferring to Somerville. Speeches were made by J. W. Leas, J. H. Sweer, R. A. C. Lane, M. Macchia and A. S. Kranzley. In addition, J. H. Waite recited the poem he authored for the occasion. Walter received two beautiful pieces of luggage.

Mr. Halstead graduated from MIT with a BS in EE in 1939 and from Ohio State University with a MS in 1941. From 1944 to 1947 he was employed by the Polaroid Corp., and from 1947 to 1950 as Chief Engineer for the W. S. MacDonald Co. He joined RCA in 1950 in the Advanced Development Section and became associated with the BIZMAC project.

—*T. T. Patterson*

1956 ANNUAL ENGINEERING REVIEW AT LANCASTER



Left to right: E. E. Spitzer, C. W. Thierfelter, F. J. Vieth, D. Y. Smith, R. W. Engstrom, C. C. Simeral, C. P. Smith, and L. P. Garner.

Approximately 500 engineers and RCA guests attended the 1956 Annual Engineering Review held at Lancaster Plant on January 24, 1956. C. P. Smith, Manager, Color Kinescope Engineering, opened the program and presented the engineering highlights for Color Kinescopes.

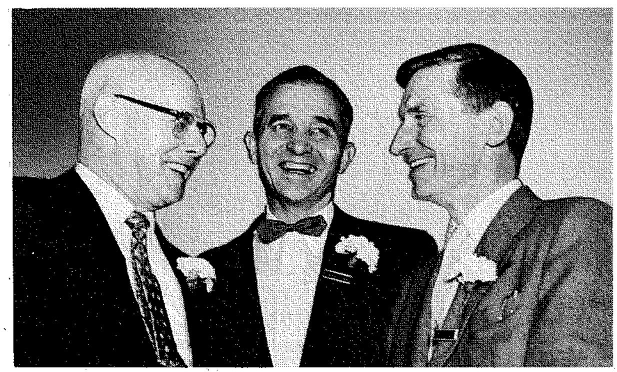
E. E. Spitzer, Manager, Cathode Ray & Power Tube Engineering, summarized overall progress and introduced other speakers who related the engineering achievements by product line. The Black and White Kinescope Engineering of Marion and Microwave Engineering located in Harrison were included.

Special guests from several plant locations included D. Y. Smith, Vice President and General Manager, RCA Tube Division, who spoke briefly on engineering accomplishments and objectives. Program coordinators were W. G. Fahnestock and D. G. Garvin.

—*D. G. Garvin*

TUBE ENGINEERS MEET AT 25-YEAR DINNER

Talking over "old times" at the Tube Division 25-Year Club Dinner are three well-known Tube Division engineering personalities. Left to right are: John Fitzpatrick, Manager, Production Engineering, Building 55 Receiving Tubes; Ted Perkins, Administrator, Field Engineering Services, and Dr. Otto Schade, Staff Engineer, Advanced Development, Receiving Tube Engineering.



TUBE ENGINEER AT GROUND BREAKING

P. D. Strubhar participated in recent ground breaking ceremonies at the site of the new Penn-Manor High School costing $3,000,000. Strubhar is President of the Penn-Manor School Building Authority. —*D. G. Garvin*

MEETINGS, COURSES AND SEMINARS

HUMAN RELATIONS

West Coast Engineering Leaders and Managers recently completed a series of six meetings on Human Relations. The instructor was Dr. Jesse Tarwater of the Rand Corporation. Dr. Tarwater is on the staff of the UCLA Extension Faculty. The course was organized by the Training Section of WCEPD Personnel Department.

—*J. H. Pratt*

HIGH POWER MODULATOR COLLOQUIUM

A High-Power Modulator Colloquium, sponsored by the Industrial Committee Working Group on Power and Gas Tubes, advisors to the Defense Department on Electron Tubes, was held at the Knolls Research Laboratory of the General Electric Company on January 16 and 17, 1957. The Colloquium was attended by many representatives of equipment manufacturers, tube manufacturers, and the Armed Services with the objective of presenting problems of the equipment manufacturers and services in the application of tubes in high-power modulators.

Missile and Surface Radar Engineering was represented by Messrs. R. M. Fisher, D. L. Pruitt, and W. I. Smith. The latter two, who are both Leaders in the Transmitter Unit, made presentations on typical problems encountered by Missile and Surface Radar Engineering in high-power modulator designs. Mr. Pruitt's presentation was on a Super Power Line-Type Pulser Using Ignitrons, and Mr. Smith's presentation was on Hard Tube and Line-Type Modulators Designed to Drive Multi-Megawatt Klystrons.

SINNETT AND FARBRO GIVE CREATIVITY LECTURES

C. M. Sinnett, Manager, Advanced Development, RCA Victor Television Division (left) and P. C. Farbro, Manager, Personnel Research, RCA Staff, answer questions raised by the Engineering leaders at the conclusion of their presentations on Creativity and Brainstorming at DEP Moorestown Plant.

RCA AFTER HOURS COURSES ON TRANSISTORS AND NUCLEAR RADIATION . . . Two ten-week courses in Transistor Fundamentals are being offered in Spring, 1957 by DEP General Engineering Development. These courses are taught by Mr. K. E. Palm and Mr. F. L. Putzrath, and will include transistor physics and basic transistor electronics. A twelve-week course in Transistor Switching Circuits, taught by Mr. D. E. Deuitch, is presently in progress. This course is for those engineers who have completed the fundamental course or who have equivalent experience in the field. A twelve-week course in Nuclear Radiation Effects has been completed. The instructor, Mr. J. E. Lindsay, presented fundamentals of nuclear physics, particle accelerators, reactor operation, and radiation effects on matter.

—*L. M. Seeberger*

RCA CONDUCTS SEMINAR FOR BROADCAST CONSULTANTS ON LATEST EQUIPMENT AND ENGINEERING TECHNIQUES . . . Latest broadcast equipment and engineering techniques, highlighted by the previewing of a new VHF transmitting antenna and coaxial transmission-line developments, were described and previewed in Washington, D. C. on February 26 in a special seminar by RCA radio and television broadcast consultants.

Technical papers were presented by Dr. George H. Brown, Chief Engineer, RCA Commercial Electronic Products; W. C. Morrison, David Sarnoff Research Center of RCA; A. F. Inglis, Manager, RCA Broadcast Studio Systems Engineering; and J. E. Young, Manager, RCA Transmitter and Antenna Engineering.

RCA SPONSORED SEMINARS AT LANCASTER

REPORT WRITING

P. D. Strubhar was instructor for a five-session course on Technical Report Writing, to review the fundamental rules of technical writing. Because of the large enrollment (77), the group was split into three sections. The five sessions were:

a. February 4: Nature and Function of Technical Reports; Getting Ready to Write a Technical Report.
b. February 11: Paragraphing and Usage; Pitfalls in Grammar, Mechanics and Punctuation.
c. February 18: Workshop Session—Sentence structure, phrasing, etc.
d. February 25: The Technical Report—Title, topic sentence, introduction, main body, abstract, etc.
e. March 4: Workshop Session—Preparation of a Technical Report.

X-RAY DIFFRACTION

An X-ray Diffraction Course has been developed by members of the Chemical & Physical Laboratory. The course has been specifically designed to present the basic concepts of X-ray diffraction and its application in research and development. The six lectures were:

a. February 20: *S. B. Deal*—Content of Lecture Series, Theory of X-rays.
b. February 27: *J. M. Schmidt*—X-ray Diffraction Instruments, Equipment and Techniques.
c. March 5: *P. G. Herold*—Use of X-ray Diffraction in Solid State Chemistry, I. Determination of Composition and Grain Size Measurement.
d. March 13: *P. G. Herold*—Use of X-ray Diffraction in Solid State Chemistry, II. Measurement of Continuous Solid Solutions and Diffraction Line Intensity.
e. March 27: *S. W. Kessler*—X-ray Diffraction and Metallurgy, II. Stereographic Projection, Pole Figures Orientation Determination, Preferred Orientation from Cold-Work, Preferred Orientation After Annealing, and Orientation in Castings and Deposited Films.

TUBE TECHNOLOGY

A series of tube technology lectures were given to engineers of Microwave Engineering at Harrison, by members of the Lancaster Chemical & Physical Laboratory. The series included:

a. January 9: *C. H. Thomas*—The Oxide Cathode.
b. January 23: *M. Berg*—Ceramics and Glass.
c. February 6: *L. P. Fox*—Parts Processing.
d. February 20—*P. D. Strubhar*—General Metallurgy.
e. March 6: *S. W. Kessler*—Aluminum Sealing Techniques.
f. March 20: *S. B. Deal*—Laboratory Analysis of Materials.

—*D. G. Garvin*

IRE CONFERENCE ON TV

IRE Conference on TV was conducted by Cincinnati Section April 26-27, in Cincinnati Engineering Society Bldg., with Dr. George H. Brown, Chief Engineer for CEP, as April 26 banquet speaker. Papers presented by RCA Engineers at April 27 meetings: "A Constant Input-Impedance RF Amplifier for VHF TV Receiver," H. B. Yin & H. M. Wasson; "Color TV Recording on Black-and-White Lenticular Film," J. M. Brumbaugh, E. D. Goodale & R. D. Kell; "Transistor Receiver Video Amplifiers," M. C. Kidd; "A Transistorized Horizontal Deflection System," H. C. Goodrich.

NAESU-RCA ELECTRONICS MAINTENANCE CONFERENCE

A conference was held on December 11, 1956, between the Navy Aviation Electronics Service Unit (NAESU) and RCA representatives at the Naval Receiving Station in Washington, D. C. The RCA personnel attending were John A. Foster of DEP Airborne Systems, Moorestown; John S. Furnstahl of DEP Airborne Fire Control, Camden; and Joseph W. Vick Roy of DEP Airborne Fire Control Engineering, Camden.

The purpose of the conference was to acquire NAESU field-experience information for improvement of future designs in both aircraft equipment and maintenance equipment. Beneficial discussions were held on thermal and vibration problems, maintenance and servicing topics, and system packaging. Above all else, the discussions pointed up the vital need for a means of rapid communication between field personnel and design engineers.—*T. P. Canavan*

COMMITTEE APPOINTMENTS

J. E. Volkmann, Theater and Sound Products Engineering, CEP, Camden, has been appointed to serve on the Audio and Electroacoustic Committee of the Acoustical Society of America. Dr. H. F. Olson, RCA Laboratories, is Chairman of this committee.

Herbert M. Gurk, DEP General Engineering Development, has been appointed Program Chairman on the Joint IRE-PGEM-SIAM Operations Research Symposium on "Mathematical Models in Management Decision Making," February 7, 1957, University of Pennsylvania.—*L. M. Seeberger*

David S. Greenstein, DEP General Engineering Development, has been appointed Treasurer, Delaware Valley Section, Society for Industrial and Applied Mathematics.
—*L. M. Seeberger*

W. E. Woods, DEP General Engineering Development, initiated a seminar series on number theory, especially tailored to the needs of the computer engineer. Binary, octal, and decimal notations were given primary emphasis. This seminar series was given for the benefit of the Digital Communication and Control Group in DEP Special Systems and Development.—*L. M. Seeberger*

Nils J. Oman, CEP Broadcast Transmitter Engineering, has been appointed to serve on an IRE Ad Hoc Committee on Measurement of Envelope Delay.—*C. D. Kentner*

Color Kinescope Engineering—Lancaster

Dr. J. C. Turnbull was re-appointed Chairman of the Membership Committee of the Glass Division of the American Ceramic Society for 1957.

Dr. M. Berg was appointed to the Program Committee of the Basic Science Division of the American Ceramic Society for 1957.

P. D. Strubhar was appointed a member of the task force to write A.S.T.M. specifications for Dumet Wire for Subcommittee 5 of A.S.T.M Committee F-1.

Alan D. Gordon, formerly of Cathode Ray and Power Tube Engineering and now the RCA International technical representative in Lancaster, was recently elected President of the Lancaster Junior Chamber of Commerce. He previously served as First Vice President and was named "Outstanding Jaycee of the Lancaster Junior Chamber of Commerce for 1955." See RCA ENGINEER, Vol. 1, No. 6, Page 64.—*D. G. Garvin*

CEP Communications Engineering

J. C. Walter, Chief Engineer, Communications Products Department, CEP, has been appointed to serve on a new AIEE Committee on Periodicals and Transactions. The Committee will deal with policy matters concerning the monthly publication *Electrical Engineering* and the *Transactions* of the Institute.

D. R. Marsh, CEP Communications Engineering, has been appointed to the National Committee on Communication Systems of the AIEE representing the Philadelphia Section.

W. J. Culp, CEP Communications Engineering, has been appointed to the RETMA TR-8.5 Committee on Mobile Selective Calling.—*B. F. Wheeler*

NEW EDITORIAL REPRESENTATIVES APPOINTED


E. J. Evans
Bloomington


T. A. Richard
Needham


M. N. Slater
Lancaster

E. J. Evans who was recently appointed editorial representative to the RCA ENGINEER for the Bloomington plant, received his B.S.E.E. from the University of Pittsburgh in 1950. He came to RCA as a student trainee and later joined the Resident Engineering Group. He is currently the group leader of black and white television engineering. He is a member of A.I.E.E.

T. A. Richard graduated from the University of Pennsylvania, Wharton School of Financing & Commerce in June, 1951, with a Bachelor of Science degree, with an accounting major. Immediately upon graduating he put in one season in public accounting with Arthur Anderson & Company. In April of 1952, he joined RCA Corporate Staff Auditing Division. In June of 1956, Mr. Richard was appointed Administrator of Development Laboratory Services for the Needham Laboratory. He is a Lt. Commander and the Executive Officer of the VF934 (jet) fighter squadron, U. S. Naval Reserve. He is a member of the Beta Alpha Psi Honorary Accounting Professional Society.

M. N. Slater, formerly Editorial Representative at Marion, Indiana, has been appointed Assistant Editorial Representative for Color Kinescope Engineering, Lancaster, replacing L. P. Fox, who was transferred to Somerville, N. J.

RCA ENGINEERS ACTIVE AT IRE NATIONAL CONVENTION

This year's IRE National Convention, held at the New York Coliseum and Waldorf Astoria Hotel in New York City, March 18 to 21, was the largest to date. Twenty-five RCA engineers presented seventeen papers at the technical sessions. Titles and authors of these papers are listed below.

Signal Mutilation and Error Prevention on Short-wave Radio-Teleprinter Services
J. B. Moore, RCA Communications, Inc. New York, N. Y.

A New Time-Division Multiplex System
W. J. Bieganski and L. M. Glickman, CEP, Camden, N. J.

The Analysis of Post-Detection Integration System by Monte Carlo Methods
R. Dilworth, California Institute of Technology, Pasadena, Calif., and E. Ackerlin, DEP, Los Angeles, Calif.

UHF High-Power Transmitting Developments
J. E. Young, L. L. Koros, and I. Martin, CEP, Camden, N. J.
Discussion

New Operational Techniques Concerning Video Test Signals
J. W. Wentworth, CEP,
Camden, N. J.

Disk and Magnetic Tape Phonograph Systems
W. H. Erikson, DEP, Camden, N. J.

New Developments in the Panel Light Amplifier
B. Kazan, RCA Labs., Princeton, N. J.

An RCA High-Performance Tape Tarnsport System
S. Baybick and R. E. Montijo, CEP, Camden, N. J.

Circuit Considerations for High-Frequency Amplifiers using Drift Transistors
J. W. Englund and A. L. Kestenbaum, Semiconductor Div., Somerville, N. J.

Design Considerations in the First Stage of Transistor Receivers
L. A. Freedman, RCA Labs.,
Princeton, N. J.

A Six-Transistor Portable Receiver Employing a Complementary Symmetry Audio Output Stage
D. D. Holmes, RCA Labs., Princeton, N. J.

Electron Tubes—General
G. M. Rose, Jr., Tube Div., Harrison, N. J.

Long Range Telemetering Reception
J. B. Wynn, RCA Missile Test Center, Melbourne, Fla.

Speech Analysis and Audio Amplifiers
Chairman: H. F. Olson, RCA Labs., Princeton, N. J.

A Low Noise Transistor Microphone Amplifier
J. J. Davidson, Radio & "Victrola" Div., Camden, N. J.

Circuit Considerations for Audio Output Stages Using Power Transistors
R. Minton, Semiconductor Div., Somerville, N. J.

Pulse-Firing and Recovery-Time Characteristics of the 2D21 Thyratron
J. A. Olmstead and M. Roth, Tube Div., Harrison, N. J.

An Image Converter for High-Speed Photography
R. G. Stoudenheimer and J. C. Moor, Tube Div., Lancaster, Pa.

HEADS NEW ELECTRON MICROSCOPE APPLICATION RESEARCH LABORATORY

Radio Corporation of America is now establishing a new Electron Microscope Application Research Laboratory in Camden, New Jersey. It will be devoted to a broad service and research program of benefit to the customers of the Industrial Products Section of RCA. J. J. Kelsch, the scientist in charge, will conduct studies in the development of new techniques as well as thorough and comprehensive investigations of new applications of the electron microscope in industrial, medical and biological fields.

The laboratory will be equipped with a new RCA EMU-3 Electron Microscope, an RCA EMD-2 Electron Diffraction Unit, two evaporators, photomicrographic equipment, a versatile setup for light microscopy, and accessory instruments. These facilities will enable its staff to render valuable service to the customers of RCA.

J. J. Kelsch attended Manhattan Colleges, Brooklyn College, and the Polytechnic Institute of Brooklyn. Bachelor's degree Brooklyn College, having majored in Biology and Geology, minored in Physics and Chemistry. He has had a life long interest in microscopy. After receiving degree, joined Electrolux Corporation, Old Greenwich, Connecticut, in Engineering Department. Set up inspection techniques using microscopy to detect winding failures, shorted commutation, etc. Joined Gulf Oil Company as reconnaissance geologist and carried a microscope on mule back through the jungles of the Republic of Colombia for two years. Joined the Interchemical Corporation Research Labs, became Chief Microscopist in 18 months and for 11 years carried on industrial research in various fields.

From 1945 to 1951 worked also in the field of cancer research and was one of the pioneers (along with Fullam, Grey, and Gessler) in the development of the first successful methods of sectioning animal and plant tissue for electron microscopy. Later was involved in virus segregation methods for electron microscopy.

Member of New York Microscopical Society EMSA, AAAS, New York Microchemical Society.

Technical advisor to a large New York advertising agency on authenticity of scientific sets in TV advertising films.

—*J. E. Volkmann*

GIVES LECTURES TO HIGH SCHOOL STUDENTS

G. E. Crosby of Color Kinescope Engineering at Lancaster, recently participated in a lecture and demonstration series presented to a total of 3,700 students in six area high schools. Mr. Crosby represented RCA in the program which was designed to acquaint high school students with the potential opportunities in science and was sponsored by the Harrisburg Chapter of the Pennsylvania Society of Professional Engineers.

—*D. G. Garvin*

205 TV AND RADIO STUDENTS GRADUATED BY RCA INSTITUTES

Two hundred and five graduates received diplomas February 21 from RCA Institutes, Inc. The commencement exercises were held in the School of Education Auditorium, New York University, 35 West 4th Street, New York City.

Graduates of this winter term class have completed courses of study in advanced electronics, radio and television broadcasting, radio and television servicing and radiotelegraph operating. More than 55 per cent of the class are veterans of the Armed Forces.

REGISTERED PROFESSIONAL ENGINEERS

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

Tube Division, Lancaster

Name	*State*	*Licensed As*	*License No.*
H. A. Stern	Ohio	Prof. Eng.	22704
L. I. Mengle	Pa.	Prof. Eng.	3778E

ENGINEERING MEETINGS AND CONVENTIONS

April-June, 1957

APRIL 22-28:
Annual Engineering Convention and Exhibition of the IRE Buenos Aires Section, Buenos Aires, Argentina

APRIL 23-25:
Fifth National Electromagnetic Relay Conference, Oklahoma A & M College, Stillwater, Okla.

APRIL 25-26:
First Annual Technical Meeting and Equipment Conference of the Institute of Environmental Engineers, La Salle Hotel, Chicago, Ill.

APRIL 26-27:
Eleventh Annual Spring Television Conference, Engineering Society Bldg., Cincinnati, Ohio

APRIL 29-MAY 1:
Third National Flight Test Instrumentation Symposium, ISA, Statler Hotel, Los Angeles

MAY 1-3:
Electronic Components Conference, Morrison Hotel, Chicago, Ill.

MAY 9-10:
Pacific Northwest Instrumentation and Automation Exhibit. Sponsored by Seattle Section, ISA.

MAY 9-10:
Symposium on Microwave Ferrites and Devices & Applications, Western Union Auditorium, New York City

MAY 12-16:
The Electrochemical Society 111th Meeting, Hotel Statler, Washington, D. C.

MAY 13-15:
National Aero. and Nav. Electronics Conference, Dayton, Ohio

MAY 13-16:
Fifth Annual Semiconductor Symposium of the Electrochemical Society, Statler Hotel, New York City

MAY 14-16:
Industrial Nuclear Technology Conference, ARF, Ill. Tech, Nucleonics Magazine, Museum of Science and Industry, Chicago, Ill.

MAY 15-16:
Age of Space Symposium sponsored by Southern Research Institute, Birmingham, Ala.

MAY 16-18:
New York State Society of Professional Engineers, 1957 Engineering Industries Exposition and Annual Convention, Statler Hotel, New York, N. Y.

MAY 20-23:
Electronics Parts Distributors Show Conrad Hilton Hotel, Chicago, Ill.

MAY 22-25:
URSI Spring Meeting, Hotel Willard, Washington, D. C.

MAY 27-29:
1957 National Telemetering Conference, AIEE, ISA, IAS, Hotel Cortez, El Paso, Texas

JUNE 6-7:
PGPT First Annual Conference on Production Techniques, Willard Hotel, Washington, D. C.

JUNE 1/-19:
PGMIL First National Meeting, Sheraton-Park Hotel, Washington, D. C.

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3 October-November 1956
4 December 1956-January 1957
5 February-March 1957
6 April-May 1957.

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.