OBJECTIVES

To disseminate to RCA engineers technical information of professional value.

●

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

●

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

●

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

●

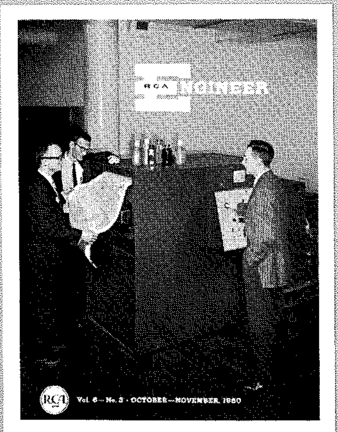
To help publicize engineering achievements in a manner that will promote the interests and reputation of RCA in the engineering field.

●

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

●

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



OUR COVER

The Electrofax five-color map printer developed by DEP Applied Research provides rapid, economical reproduction in the field of tactical Army maps from 70-mm separations. Donald J. Parker, Mgr., Applied Physics (left foreground) and Paul E. Wright examine a map, while Martin L. Levene adjusts the controls (all of DEP Applied Research). In this feasibility model, the five colors are applied by successive overprinting, one color for each uninterrupted pass of the paper through the machine.

DEP APPLIED RESEARCH

. . . translates basic research into practical techniques

For 30 years, DEP Applied Research and its predecessors have played a vital role in the growth and prosperity of RCA by transforming the findings of basic research into practical techniques. DEP Applied Research works closely with the six divisions of DEP to open doors to new products and new businesses, complementing the applied research done in these divisions for their specific needs.

An idea develops like a growing child. Regardless of their potential, both need a home where they can be nurtured through insignificant infancy and steered through frustrating adolescence. DEP Applied Research is such a home. Here, new techniques that might get lost in big business get the opportunity to grow into big business. Some of the areas that will develop into future business in the six divisions of DEP are molecular resonance, fiber optics, thermoelectrics, plasmas, superconductivity, nonlinear signal processing, integrated electronics, pattern recognition, and electrostatic printing, The cover of this issue and the articles on Electrofax, the atomic clock, and the small-signal tunnel diode appearing inside describe typical projects.

Not all ideas are successful, but all must be considered—one never knows which idea will sell the best or which approach will be most economical. An alert, aggressive, and well-rounded applied-research group can be most effective in maximizing the opportunities and in minimizing the risk and cost in exploiting the future. Recognizing, demonstrating, and selling new ideas is therefore the mission of DEP Applied Research.

H. J. Woll

Dr. H. J. Woll
Manager, Applied Research
Defense Electronic Products
Radio Corporation of America

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The Engineer and the Corporation

SYSTEMS PLANNING
The Link Between Military and Industrial Planning

by **Dr. N. I. KORMAN, *Director***

Advanced Military Systems, DEP, Princeton, New Jersey

TODAY, THERE is little question as to the desirability of advanced planning for the nation's defense effort. The question is not whether to plan, but how.

There is and has been much debate as to whether defense planning and management should reside primarily with industry or primarily with the military services. The whole answer does not lie on one side or the other of that debate; rather, the military and industry are each uniquely fitted to handle certain aspects of this planning. Coordination of their individual planning efforts is most helpful and productive.

MILITARY AND INDUSTRY PLANNING ROLES

There are areas of planning information in which the Department of Defense and its military services are and should be pre-eminent. They are best informed as to the enemy's power, capabilities, and intentions. They are also most acutely aware of our own nation's military posture. They can best judge what the enemy's total resources are and how those resources might be employed to our greatest disadvantage. They are also the best judges of what our own resources are and how these might be used to achieve the best possible defense posture for the future.

On the other hand, industry, with its research, development, design, production, and service agencies, is more aware of possibilities for military equipment that arise out of technology, engineering, and production. It has greater insight as to what might be done with weapon characteristics, performance, lead times, costs, and dates of obsolescence.

It is important to be perfectly clear as to the relationship of these planning roles. The decision for strategic offense as to the proper mix of B-52's, B-58's, Atlas', Titans, Minutemen, Polaris', etc., is properly and strictly a Department of Defense decision, subject to the policies laid down by the President and Congress. However, industry can and does provide valuable information for this decision-making by advising not only as to equipment characteristics and performance, lead times and cost, but also as to how equipment life and performance may be extended by re-engineering and refitting, and when obsolescence makes such re-engineering and refitting unwise.

SYSTEMS PLANNING

With this relationship between military and industry planning in mind, the way in which industry carries out its systems planning can be described. First, there is the way in which our source material for systems planning is obtained. Useful source material is of several sorts and is gathered in various ways. The main problem here is with the tremendous amount of material available—assembling, collating, and interpretation constitute the main problem. The planner must continually guard against accepting one-sided opinions; he must avoid forming an early opinion on fragmentary data because it is so easy to verify almost any point of view if one looks primarily for confirming data.

Types and Sources of Information

There is general background information—status of the cold war; U. S. strengths, weaknesses, and intentions versus enemy strengths, weaknesses, and intentions; U. S. strategy vis-a-vis enemy strategy; relative importance of strategic offense and defense, limited land warfare, sea warfare, etc. Such material is found in numerous periodicals and books, published statements by our political and military leaders, and analyses by our University Institutes for Foreign Affairs.

There is information on specific weapons and equipment in being, under development, and under study. Here, the trade magazines and newspapers are excellent sources not only for their day-to-day recording of events, but also for the summaries and analyses which they publish from time to time. Of course, security considerations limit the thoroughness, accuracy, and timeliness of their coverage; but they are excellent for the purpose of general guidance, and there are good ways of augmenting them for those who have a "need-to-know."

To acquire knowledge as to the capabilities, limitations, and problems with specific weapons, equipment, and systems, the three military services have information available for those who can establish the proper level of security clearance and need-to-know. For example, the Air Force *System Requirements* (SR's) documents and the Army's *Qualitative Development Requirements Information* (QDRI's) are statements of specific military operational problems available to industry for study and technical analysis. Here, the industrial planner obtains information in proportion to his willingness to give information in return. The quality and quantity of information he can receive in the long run is in proportion to the quality and quantity of work he does.

The knowledge as to scientific, engineering, and industrial possibilities and innovations must come primarily from the planners' own organization. It can be supplemented and checked by information gleaned from consultants, the proceedings of technical societies and in other ways, but unless the bulk of the experts in these fields are indigenous to the planners' own organization, that organization stands little chance of surviving in the intense competitive struggle. The planner must *recognize, utilize,* and *exploit* the skills inherent in his company. However, he must be alert to gaps in the knowledge and skills of his organization and be ready to fill them by association with a company that does have the missing attributes or by acquisition in some other way.

Applying the Storehouse of Information

The *utilization* of the scientific, engineering, and industrial know-how of the planners' organization to solve the equipment and systems problems of the military services is, in essence, the main job of the systems planner.

The planners themselves are, first and foremost, creative technical men with the broadest possible outlook—mature and known for their excellent judgment. They do not particularly aspire to the running of large organizations because they prefer not to be burdened with the associated administrative load. They are familiar with the skills, capabilities, strengths, and weaknesses of their company. They have personal abilities and reputations which enable them to tap and utilize the skills which reside in their company. They are very active in seeking an understanding of military problems in a way which will enable them to utilize the fruits of technology in the solution of these problems. Collectively, they should possess skills which cut across the entire scope of the technology they hope to utilize in the solution of the military problems.

A typical study project should not be allowed to last longer than three to six months without re-examination. After that period, it should be redefined if it is to continue. Projects are selected based upon their importance to the defense effort and upon the likelihood that they can be solved with the knowledge and skills of the company. Suggestions for likely projects come from the military services, who are usually quite happy to discuss their problems with industrial concerns whom they think might be helpful to them, from suggestions from within the company, and, most important, from the system planners themselves. This last source is most important because it is a truism that proper definition of a problem is almost tantamount to its solution. The true skill of the systems planners is largely in their ability to *define* their systems problems.

Executing the Systems Study

In the establishment of a systems-study project, the appropriate experts in the Department of Defense must be consulted to obtain the military viewpoint as to what they consider to be important attributes of a solution. This military viewpoint need not be taken too literally or adhered to too slavishly. The military people usually are only too happy to hear to what extent the industry systems planner thinks his requirements can or cannot be met. In some cases, the military viewpoint may be acquired informally; in other cases, security considerations dictate the proper degree of clearance and need-to-know. In all cases, the quality and quantity of the information obtained is dependent primarily upon the degree of confidence with which the military people believe that they will get ideas and suggestions in return for their information.

Proper backing must also be obtained from the appropriate functions in the system planners' company. Failure to obtain such backing can result in lack of support during the system study phase and, worse, lack of enthusiasm to pick up the results of the study for further implementation.

In the next phase as many ideas as possible which might be pertinent to the problem are generated and evaluated. Here, a combination of solitary and group action is beneficial. Bull sessions with bright young idea men from within the organization are interspersed with the introspective deliberations of the mature creative experts of the systems-planning function.

The ideas which survive the process are used in the synthesis of possible systems. Such systems are then subjected to analysis for reliability, performance, effectiveness, cost, lead time, enemy countermeasures, and many other factors, to determine whether any of them can indeed help solve the military problem and, if so, which solution might be best.

As outlined, the system-planning function sounds very orderly and straightforward. In real life, it is seldom so. It goes by fits and starts. The various steps are intermingled with each other, and many times, tentative solutions are found while still trying to state the problem. Often, important military constraints on the solution can only be seen as the solution itself is being formulated. In many cases, a systems study only serves to highlight other problems which need solutions.

Assuming, however, that a systems study serves to highlight an important military problem and to indicate a solution, the next step is to implement it.

FROM STUDY TO REALITY

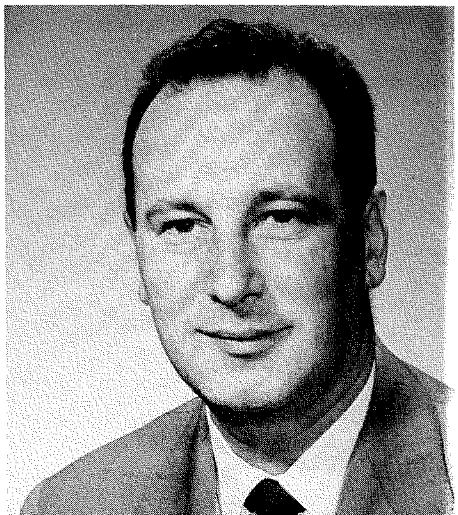
To implement the results of a system study, the system planners must first secure corporate endorsement of their work. They must establish to what extent their company will continue further studies, to what extent it will go in reorganizing to prosecute further work, and whether it will commit itself to produce the requisite equipment in the time and for the cost indicated.

Having established these points, the study results may be presented to appropriate parties in the Department of Defense, along with recommendations. In important studies, usually a number of different presentations must be made, each emphasizing those points in which the particular audience is interested. Operations people are interested in somewhat different aspects than research-and-development people, who in turn are interested in different aspects than the training or maintenance people. Oftentimes, questions arise for which ready answers are not available, necessitating auxiliary studies with subsequent exposition of their results.

As an example, in connection with the studies which preceded the BMEWS program, over fifty systems-engineering briefings were conducted by RCA over a period of a year before a decision was made to proceed.

Finally, with acceptance of the study results may come action in the form of reoriented research, initiation of development, and creation of new organizational alignments within the company, all pointed toward production of the actual system or equipment—the end product conceived and made feasible by the systems-planning synthesis of *ideas*.

DR. N. I. KORMAN received his B.S.E.E. in 1937 from Worcester Polytechnic Institute, and his M.S.E.E. from the Massachusetts Institute of Technology in 1938, where he studied as a Charles A. Coffin Fellow. He received his Ph.D. from the University of Pennsylvania in 1958. He joined RCA in 1938 as a student engineer. In his early years at RCA, he worked on advanced development of FM transmitters and microwave components, particularly as they apply to TV and radar. Dr. Korman has held positions of increasing responsibility and authority after being promoted to supervision in 1945. In recognition of his work, he was awarded the 1951 *RCA Victor Award of Merit*. In 1956, he was appointed Chief Systems Engineer of Missile and Surface Radar Engineering, and was responsible for systems engineering on such major projects as Talos and BMEWS. In 1958, Dr. Korman was appointed Director of Advanced Military Systems. He is responsible for the creation and development of new and advanced system concepts and for the initiation of corporate action to exploit these ideas and concepts. He is a member of Sigma Xi and a Fellow of the IRE. He holds 31 patents, with more still pending, and has authored many professional papers.



A NORMALIZED REPRESENTATION OF THE SMALL-SIGNAL TUNNEL DIODE

by **E. P. McGROGAN**
Applied Research,
DEP, Camden, New Jersey

THE ADVENT OF the tunnel diode has instigated many predictions of an impending electronic revolution in both digital and analog information-handling technology. Some of these claims are based on a knowledgeable evaluation of the device capabilities, while others are based merely on consideration of the salient attributes of the device without regard to some of the inherent limitations. The purpose of this article is to consider both the attributes and limitations, and to develop a set of parameters that clearly characterize the small-signal properties of the tunnel diode and permit universal small-signal admittance curves to be used in the design of tunnel-diode circuits. The parameters developed, however, will not necessarily be useful for characterization of the switching properties of the tunnel diode.

SMALL-SIGNAL EQUIVALENT CIRCUIT

The equivalent circuit in Fig. 1 accurately represents the tunnel diode over the frequency range of interest.[1] The dynamic conductance of the tunnel junction, *G,* is a function of the d-c bias and is a negative quantity when the tunnel diode is biased in its negative conductance region. The transition capacitance of the junction, *C,* may be quite high, even for small-area junctions, since the transition region in a tunnel junction may be of the order of 50 to 100 angstroms long.[2] For a concentration of 4×10^{19} carriers/cm^3 in a bulk semiconductor, the capacitance may be as high as 5 μf/cm^2 of junction area.[1] This is a capacitance of 32 pf for a junction area of one square mil. The spreading resistance, *R,* of the diode includes all losses between the junction and the external leads of the tunnel diode. The series inductance, *L,* is introduced by the diode package and any external device necessary to hold the package.

The four parameters, *L, R, G* and *C,* of the small-signal equivalent circuit completely specify the small-signal tunnel diode, but no one of these parameters, unless considered with respect to the other parameters will divulge any useful information about the small-signal capabilities of a particular tunnel diode. The cut-off frequency, $\omega_{co} = 2\pi f_{co}$, and the zero-frequency conductance, Y_o, (both explicitly related to the small-signal equivalent-circuit parameters) are a more significant measure of the tunnel-diode properties than the equivalent-circuit parameters. The tunnel diode, when biased to its negative-conductance region, exhibits a negative conductance at its terminals up to a certain maximum frequency known as the cut-off frequency; above this frequency, the conductive component of the tunnel-diode admittance is always greater than zero. The zero-frequency conductance, Y_o, is given by the slope of the static I-V characteristic of the tunnel diode at a specific operating point. This is generally assumed to be the point in the negative-conductance region where the conductance is at its maximum, although other operating points can be assumed. The actual conductance of the tunnel junction, *G,* will differ slightly from Y_o because of the effect of the spreading resistance, *R.*

The zero-frequency conductance and the cut-off frequency can be used advantageously in the normalization of the tunnel-diode small-signal admittance if the admittance is normalized so that its zero frequency value is −1 and the complex frequency, *s*, is normalized so that it is +1 at the cut-off frequency. The normalized admittance Y_N and frequency s_N are defined as:

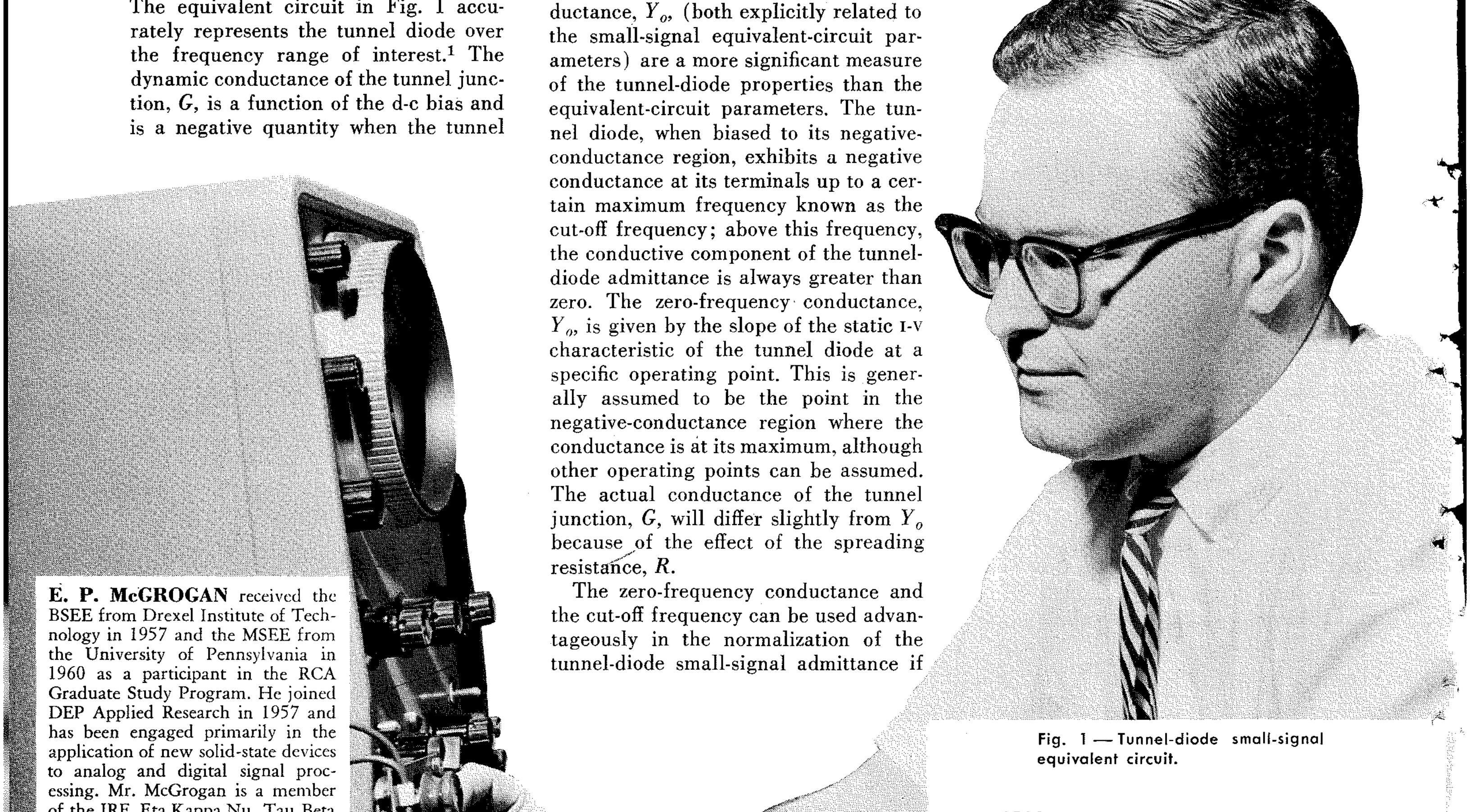
$$Y_N = \frac{Y_{in}(\omega)}{Y_{in}(o)} \qquad (1)$$

$$s_N = \frac{s}{\omega_{co}} \qquad (2)$$

The normalized admittance, Y_N, can now be written as a function of the normalized complex frequency, s_N:

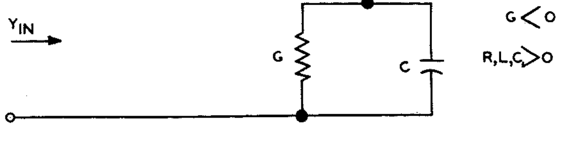
$$Y_N(s_N) = \frac{s_N\sqrt{\dfrac{1+RG}{-RG}}-1}{s_N^2\left(\dfrac{-GL}{RC}\right)+s_N\dfrac{1+\dfrac{GL}{RC}}{\sqrt{\dfrac{1+RG}{-RG}}}+1} \qquad (3)$$

As the original equivalent circuit had only four independent parameters, it is desirable that the normalized representation of the tunnel diode have only four independent parameters. Two of these parameters have already been chosen to be the zero-frequency admittance and



E. P. McGROGAN received the BSEE from Drexel Institute of Technology in 1957 and the MSEE from the University of Pennsylvania in 1960 as a participant in the RCA Graduate Study Program. He joined DEP Applied Research in 1957 and has been engaged primarily in the application of new solid-state devices to analog and digital signal processing. Mr. McGrogan is a member of the IRE, Eta Kappa Nu, Tau Beta Pi, and Phi Kappa Phi.

Fig. 1 — Tunnel-diode small-signal equivalent circuit.



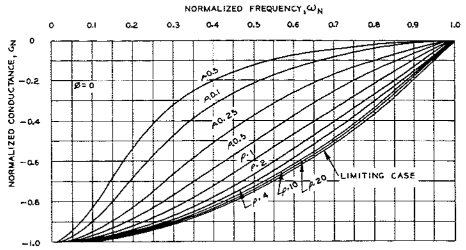


Fig. 2—Normalized conductance versus normalized frequency for zero inductance.

the cut-off frequency. The other two may be chosen by referring to Equation 3 and making the following definitions:

$$\rho = \frac{1+RG}{-RG} \tag{4}$$

$$\phi = \frac{-GL}{RC} \tag{5}$$

Substituting Equations 4 and 5 into Equation 3, the normalized admittance of the tunnel diode is:

$$Y_N(s_N) = \frac{s_N\sqrt{\rho}-1}{s_N^2\,\phi + s_N\dfrac{1-\phi}{\sqrt{\rho}} + 1} \tag{6}$$

The small-signal tunnel diode has now been characterized in terms of four parameters which are related to the four parameters of the small-signal equivalent circuit of Fig. 1. The four new parameters are Y_o, ω_{co}, ϕ, and ρ. These new parameters, which will be designated as the *normalizing parameters*, give a better idea of the capabilities of a given tunnel diode than do the R, L, G and C of the small-signal equivalent circuit. The parameter ρ may be rewritten as $\rho = (R_n - R)/R$, where R_n is the magnitude of the negative resistance of the tunnel junction, $R_n = -1/G$. The parameter ρ is seen to be the ratio of the magnitude of the negative resistance which appears at the diode terminals at zero frequency, $R_n - R$, to the positive spreading resistance of the diode, R. The resistance ratio, ρ, does not involve the inductance and capacitance of the tunnel diode and can be determined directly from the diode I-V characteristic. Equation 5 may be rewritten as $\phi = (-G/C)/(R/L)$. The parameter ϕ is called the *frequency ratio*, since it is the ratio of the critical frequency of the intrinsic tunnel junction, $-G/C$, to the critical frequency of the extrinsic tunnel diode, R/L. The frequency ratio ϕ is directly proportional to the series inductance of the tunnel diode and is a more useful measure of the effect of the inductance than the magnitude of the inductance itself. The four normalizing parameters of the tunnel diode can be expressed explicitly in terms of the small-signal equivalent-circuit parameters; these relationships are tabulated in Table I. The inverse relationships are tabulated in Table II.

Table I — Tunnel Diode Small Signal Normalizing Parameters in Terms of Equivalent Circuit Parameters

angular cut-off frequency	$\omega_{co} = \dfrac{\sqrt{-G(1+RG)}}{\sqrt{RC}}$
zero frequency (d-c) conductance	$Y_o = \dfrac{G}{1+RG}$
frequency ratio	$\phi = \dfrac{-GL}{RC}$
resistance ratio	$\rho = \dfrac{1+RG}{-RG}$

Table II — Tunnel Diode Equivalent Circuit Parameters in Terms of the Small Signal Normalizing Parameters

dynamic tunnel junction conductance	$G = \dfrac{\rho Y_o}{\rho+1}$
diode spreading resistance	$R = \dfrac{-1}{\rho Y_o}$
diode series inductance	$L = \dfrac{-\phi}{\omega_{co}\sqrt{\rho}\,Y_o}$
tunnel junction transition capacitance	$C = \dfrac{-\rho^{3/2} Y_o}{(\rho+1)\omega_{co}}$

CONDUCTIVE AND SUSCEPTIVE COMPONENTS OF NORMALIZED ADMITTANCE

The conductive and susceptive components of the normalized admittance, Y_N, at real frequencies ($s_N = j\omega_N$) are significant in the design of small-signal tunnel-diode circuits. These components are determined by replacing s_N in Equation 6 by $j\omega_N$ and rationalizing the resulting expression.

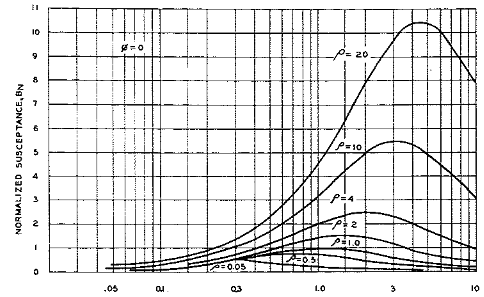


Fig. 3—Normalized susceptance versus normalized frequency for zero inductance.

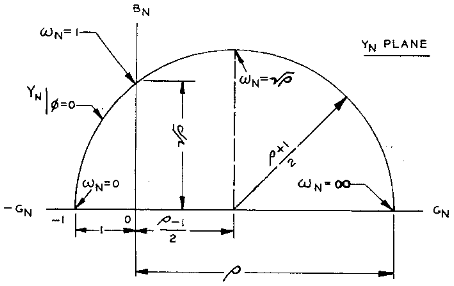


Fig. 4—General admittance plane contour for normalized tunnel diodes, $\rho > 1$, $\phi = 0$.

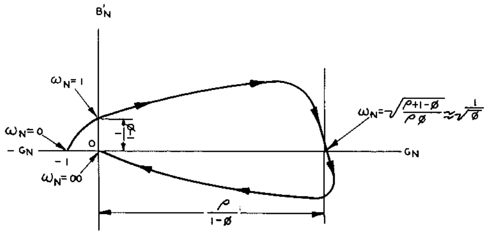


Fig. 5—General G_N — B'_N plane contour for normalized tunnel diode, $0 < \phi < 1/2$, ρ large.

$$Y_N(j\omega_N) = \frac{\omega_N^2 - 1 + j\omega_N\left[\sqrt{\rho}\,(1-\omega_N^2\phi) + \dfrac{1}{\sqrt{\rho}}(1-\phi)\right]}{\omega_N^4\,\phi^2 + \omega_N^2\,\dfrac{\phi^2+1-2\phi\,(\rho+1)}{\rho} + 1} \tag{7}$$

The normalized conductance, G_N, is then given by:

$$G_N = \frac{\omega_N^2 - 1}{\omega_N^4\,\phi^2 + \omega_N^2\,\dfrac{\phi^2+1-2\phi\,(\rho+1)}{\rho} + 1} \tag{8}$$

And the normalized susceptance, by:

$$B_N = \frac{\omega_N\left[\sqrt{\rho}\,(1-\omega_N^2\phi) + \dfrac{1}{\sqrt{\rho}}(1-\phi)\right]}{\omega_N^4\,\phi^2 + \omega_N^2\,\dfrac{\phi^2+1-2\phi\,(\rho+1)}{\rho} + 1} \tag{9}$$

Equations 8 and 9 can be used as the basis for universal tunnel-diode small-signal admittance curves, since ϕ and ρ are sufficient to specify completely the admittance characteristics of a tunnel diode, once the tunnel-diode admittance has been normalized with respect to the cut-off frequency and the zero-frequency admittance.

Universal conductance and susceptance curves based upon Equations 8 and 9 have been computed and plotted for various combinations of the resistance and frequency ratios, ρ and ϕ. These curves are presented elsewhere.[3]

SPECIAL CASES OF THE NORMALIZED ADMITTANCE FUNCTIONS

Some insight into the nature of the conductance and susceptance functions of Equations 8 and 9 can be gained by consideration of some special cases.

Zero Frequency Ratio, $\phi = 0$ (Negligible Series Inductance)

An important special case is that in which the series inductance of the tunnel diode is negligible. Neglect of the series inductance can be accomplished by equating the frequency ratio, ϕ, to zero in Equations 8 and 9. When $\phi = 0$, the normalized conductance, G_N, becomes:

$$G_N \Bigg|_{\phi = 0} = \frac{\omega_N^2 - 1}{\dfrac{\omega_N^2}{\rho} + 1} \qquad (10)$$

And, the normalized susceptance, B_N, becomes:

$$B_N \Bigg|_{\phi = 0} = \frac{\omega_N \left[\sqrt{\rho} + \dfrac{1}{\sqrt{\rho}} \right]}{\dfrac{\omega_N^2}{\rho} + 1} \qquad (11)$$

The normalized conductance and susceptance versus normalized frequency curves for the inductance-less tunnel diode are shown in Figs. 2 and 3, respectively. Each curve is drawn for a different value of the resistance ratio, ρ. When ρ is very large, the normalized conductance approaches a limiting parabola given by $G_N = \omega_N^2 - 1$. A complex frequency plane contour of the normalized admittance of the inductance-less tunnel diode is the semicircular contour shown in Fig. 4.

Large Resistance Ratio (ρ Large)

Many tunnel diodes are characterized by low spreading resistances and consequently have high resistance ratios, ρ. Typical germanium tunnel diodes with peak currents in the order of several milliamperes have resistance ratios in excess of 100. An extremely useful special case of the general admittance components, Equations 8 and 9, is that in which the resistance ratio, ρ, is considered to be relatively large. Because of the complexity of these equations, the condition that ρ is large must be applied judiciously. The same approximations are not necessarily valid at all frequencies.

If a new normalized susceptance $B'_N = B_N/\sqrt{\rho}$, is defined, the complex admittance plane, $G_N - B'_N$, plots of the normalized tunnel diode admittance are given in Figs. 5, 6 and 7. In all cases, the admittance is -1 at $\omega_N = 0$, and intersects the B'_N axis at $\omega_N = 1$. Fig. 5 shows the typical admittance contour when the frequency ratio, ϕ, is less than ½. In this case, the conductive component of admittance is a monotonically increasing function of frequency up to the cut-off frequency, and the susceptive component is capacitive at all frequencies below the cut-off frequency. Fig. 6 shows the complex admittance when $\frac{1}{2} < \phi < 1$; in this case, the conductive component of the admittance assumes values more negative than -1, and the susceptive component is still capacitive at frequencies below the cut-off frequency. When $\phi > 1$, as in Fig. 7, the conductive component of the admittance can assume values considerably more negative than -1, and the susceptance changes from capacitive to inductive susceptance at a frequency below the cut-off frequency. Diodes of the latter type, i.e., $\phi > 1$, are extremely difficult to stabilize in small-signal circuits because the input conductance can assume such large negative values.

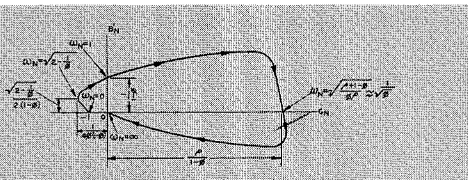


Fig. 6—General $G_N - B'_N$ plane contour for normalized tunnel diode, $\frac{1}{2} < \phi < 1$, ρ large.

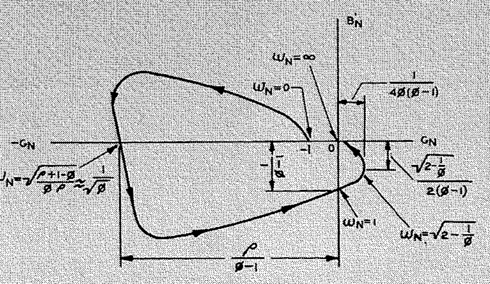


Fig. 7—General $G_N - B'_N$ plane contour for normalized tunnel diode, $\phi > 1$, ρ large.

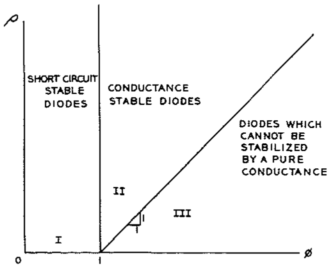


Fig. 8—Conductance stability of diodes as determined by the location of the diode in the $\phi - \rho$ plane.

STABILITY CONSIDERATIONS

The relative values of the resistance and frequency ratios, ρ and ϕ, determine what measures are necessary to stabilize a tunnel diode in a circuit. If $\phi < 1$, the tunnel diode would be stable with a short circuit across its terminals. If $1 < \phi < (\rho + 1)$, there exists a value of a purely conductive load which will stabilize the tunnel diode. If $\phi > 1$, the diode is extremely difficult, but not necessarily impossible, to stabilize. The stability characteristics of diodes specified by ρ and ϕ are indicated in Fig. 8. Many of the diodes which fall in Region III of Fig. 8 have cut-off frequencies of the order of several kilomegacycles. However, these are virtually useless as active circuit elements at these frequencies because of their series inductance, which does not enter into the formula for the cut-off frequency but makes the diodes almost impossible to bias stably.

Series inductances of a few nanohenries can place most typical tunnel diodes in Region III of Fig. 8, indicating that very-low-inductance packages are a necessity for tunnel diodes and that other circuit elements used in conjunction with tunnel diodes should also have extremely low inductances.

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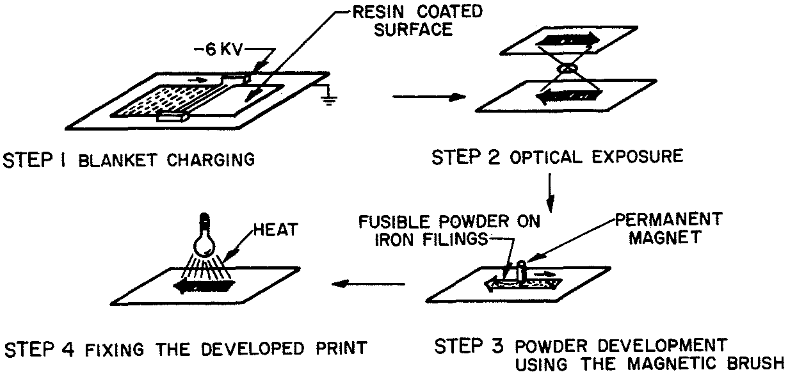

Fig. 1—Basic steps of Electrofax process.

ELECTROFAX—TODAY AND TOMORROW

by **D. J. PARKER, Mgr.**
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Electrofax is an RCA trademark for an optical printing process utilizing a photoconductive surface. The main ingredient of this surface is zinc oxide, and the surface has the property of being an insulator in the dark and a conductor when illuminated. Even in the presence of light, however, the conductivity is through the surface; there is little lateral leakage across the surface.

These properties are seen to be grossly similar to an array of element-size, insulated capacitors whose internal resistance may be made to suddenly and greatly decrease by shining light on them. Hence, electrostatic charge may be placed on opposing sides of the surface, and exposure to light will cause an internal current to flow, equalizing these charges and removing the charge from the areas of the surface thus exposed. If the light exposure is an optical image, such as a projected lantern slide, the charge remaining on the dark portions of the image constitutes an electrostatic image of the projected optical image. This electrostatic image may be made instantly visible by bringing tiny black or colored particles having an opposite electrostatic charge in contact with the surface; the particles stick to the electrostatic image but not to the exposed portion of the image. The result is a visible, positive reproduction of the projected slide.

BASIC ELECTROFAX

Fig. 1 depicts the basic steps of the Electrofax process. The photo-conductive surface is normally applied to a paper base as a thin coating. An electrostatic charge is placed across the surface in the dark. A corona discharge (fine wires at high negative potential in front of the surface, a ground plate in contact with the rear of the paper) bombards the surface uniformly with negative ions. The charged paper is then exposed to a projected image or is contact printed. The result is a latent electrostatic image. Dusting of the image with charged resin particles coated with carbon black yields an immediately visible image that can be made permanent by fusing the resin into the surface with heat.

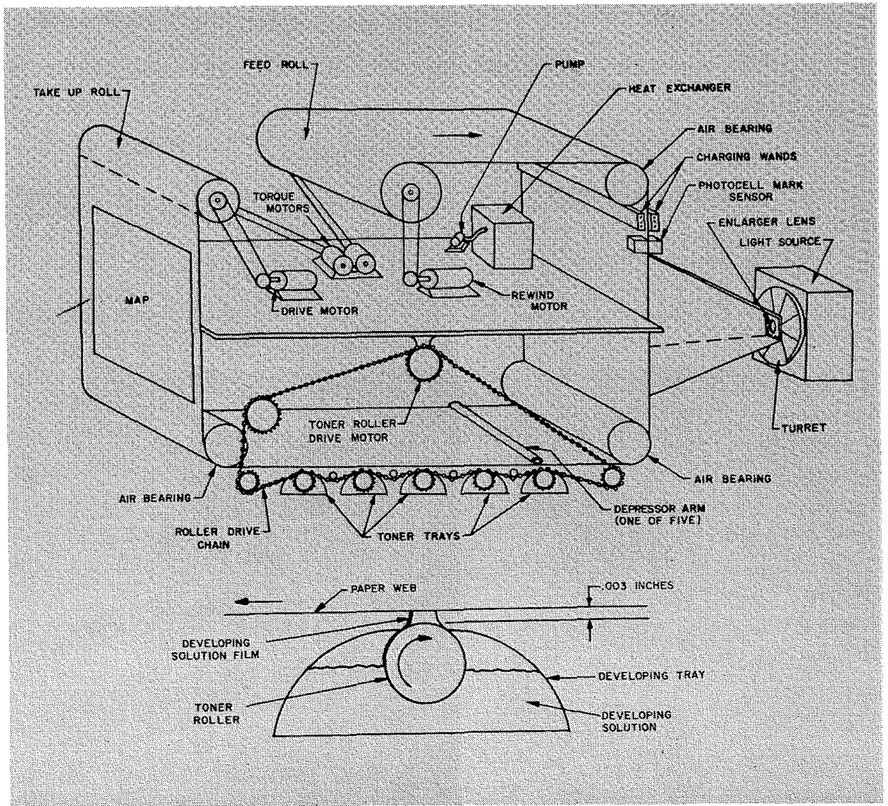
The simple behavior described above masks the complicated solid-state phenomenon producing the results. The capacitor analogy doesn't begin to explain the complete performance of the Electrofax surface. Articles that recently appeared in the *RCA Review* give an up-to-date description of the solid-state model for Electrofax. (J. Amick, "A Review of Electrofax Behavior" and "A Volume-Charge Capacitor Model for Electrofax Layers" *RCA Review*, December 1959.)

CHARACTERISTICS

Electrofax paper has two major advantages as a photographic material: rapid development of the image, and a much lower cost than silver halide and similar processes. In addition, it is an extremely versatile medium in that it can be developed positive or negative by interchanging the sign of the paper and toner electrostatic charge. After development, the unfused toner image may be transferred to another base material such as glass or plastic. Or, once an image has been fused, the paper may be recharged and other images overlaid. Other advantages are that the paper is not subject to accidental exposure during storage, since it is charged just prior to use; all the materials are nontoxic and noncorrosive. The resolution is good: 300 TV-lines/inch in normal machine development and up to 1000 TV-lines/inch with hand processing.

Excellent reproduction of multi-tonal copy may be obtained with Electrofax by the use of a halftone screen, as used in newspaper photographs. This process, in which a fine screen (e.g. 150 lines to the inch) is placed in front of the paper, changes the density varia-

Fig. 2—Operation of the five-color map printer pictured on the cover of this issue. At bottom are typical toner-tray details.



tions in the image into variations in the dot sizes produced by the screen shadowing. Screening reduces the resolution in the photograph, of course, and for this reason is not universally acceptable.

The pertinent engineering characteristics of one common Electrofax paper are:

1) In photographic terminology, the sensitivity of this Electrofax paper rates about ASA 1 for incandescent light, and about ASA 4 for light that is a better color match to the paper, which has strong blue sensitivity. P-11 phosphor and mercury arc lamps are sources giving such a color match.
2) The photographic *gamma* (slope of the density vs. log exposure curve) is steep, about 2.5 to 3, as a minimum. This has two very significant results: (a) The tonal range which may be reproduced on the paper is reduced from that available in normal input material such as photographic transparencies; reproduced tonal range (highlight to shadow) corresponds to an object brightness ratio of about 3:1. (b) The tolerance-to-exposure variation is proportionally less than with lower-gamma photographic materials—a major consideration in machine design.
3) When the paper is stored at low relative humidity (20 percent or less) its conductivity drops greatly and satisfactory charging of the paper may be difficult to obtain. This can be avoided by insuring proper moisture at the time of manufacture, and keeping the paper tightly wrapped until use. The paper base can also be made conductive permanently by other means such as metallic coatings.

APPLICATIONS

The above characteristics point up applications appropriate for Electrofax: rapid and cheap reproduction of material in black and white or color, and with successive over-prints if desired. There are several excellent military and commercial applications where these characteristics are highly desirable: 1) tactical map printing, 2) high-speed computer output, 3) letterpress and lithographic plates, 4) military large-screen displays, 5) bank-book and credit-card recording, and 6) library and office copiers.

Printing Tactical Maps in Color

The overprinting characteristics of Electrofax mentioned above made possible the design of an electrostatic color map printer (see front cover). This machine produces maps from miniature film separations, and since maps are primarily line copy with a limited gray scale, this is almost an optimum application for Electrofax.

The color map printer was built under a contract from the United States Army Engineer Research and Development Laboatories, Fort Belvoir, Virginia, as a feasibility model to demonstrate the usefulness of electrostatic map-reproduction techniques. Technical map reproduction from miniature color separations is a very attractive alternative to large-scale transport and storage of maps. The electrostatic printer allows the rapid reproduction of maps in the field on specific demand. The RCA Electrofax map printer prints 22½″ by 29″ maps in five colors by sequential optical exposure and development. The Electrofax paper is exposed to the enlarged image of a 70-mm color separation by electronic flash. The paper moves continuously through the machine at rates as high as 16 inches per second.

The map printer uses liquid Electrofax development techniques in which the developing pigments are suspended in an insulating fluid. The fluid is applied to the exposed paper surface by a simple roller technique illustrated in Fig. 2. This liquid development technique has been found to be excellent from point of view of ease of mechanization, overprinting characteristics, exposure tolerance, and background cleanliness.

DEP Applied Research is just beginning the design of a feasibility model of a shipboard map printer for the Bureau of Ships, United States Navy. This machine is designed to fulfill the same functions as the Army Printer, with the exception that the paper will remain stationary throughout the five sequential exposure and development cycles. This mode of operation will be somewhat slower than the Army machine but has two significant advantages: 1) there are no problems in registering the paper at successive exposure stations, and 2) the machine size is greatly reduced for shipboard installation.

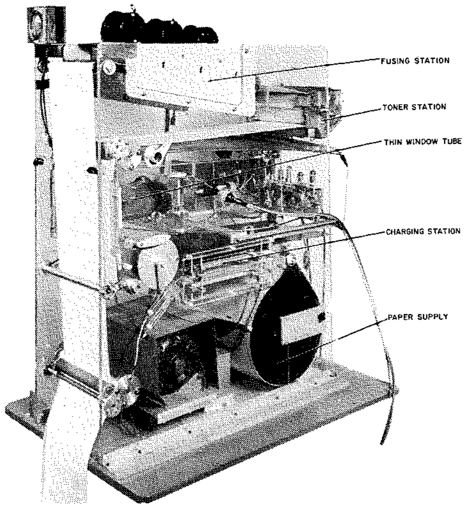
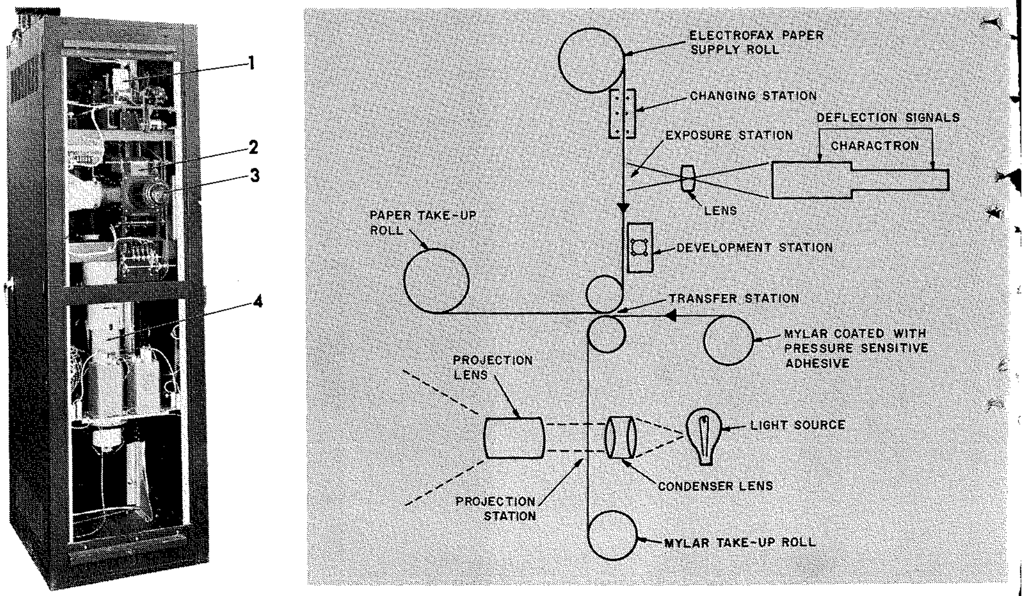


Fig. 3—Thin-window Electrofax printer.

High Speed Computer Output

It is generally recognized that data output rates from computers and communication systems are growing to the point where mechanical printers cannot operate synchronously. There are

Fig. 4—Electrofax transparency projection system. In photo; 1) Electrofax paper and process station; 2) Mylar film; 3) projection station; 4) charactron tube.



already applications for electronic printers capable of printing in the range 5,000 to 20,000 characters per second. Electrofax is a good basic tool to realize such high-speed printers. Its basic sensitivity may be effectively increased by the use of new optical tools, such as the fiber-optics high-speed printing tube described by L. J. Krolak in Vol. 4, No. 1 of RCA ENGINEER ("Fiber Optics—Valuable Engineering Principle") or by thin-window tube techniques as pioneered by Princeton Laboratories. The thin-window printer (Fig. 3) has already been operated, in facsimile printing, at rates in excess of 20,000 characters per second. Both the fiber-optics tube and the thin-window tube achieve an effective optical exposure increase of the order of 50 to 1.

The use of Electrofax as a high-speed printing medium is basically desirable because electro-optical output devices, such as the cathode ray tube, have far higher maximum writing rates than competitive electrical printing techniques.

Letterpress and Lithographic Plates

RCA has developed an Electrofax surface and a development technique which promises to be a major breakthrough in newspaper and offset lithography applications. Finished letterpress and lithographic plates are presently produced by photo-etching techniques in which photosensitive resins protect the areas of the surface which are not to be etched. The resin surface for the metal plates must be prepared at the printing plant because the resin has a very short shelf life. Since the photosensitivity of the plates is very low. the copy to be printed must be first photocopied onto a negative film. This negative film in contact with the photosensitive resin is exposed with carbon arc lamps for about four minutes. The plate is then etched to bring out the image.

The significant features of the Electrofax process are the elimination of the negative film step and the reduction of exposure time from four minutes to just a few seconds. With the Electrofax system, any hard copy can be exposed directly by contact or projection onto the plate. The electrostatic image is toned and fused, and the Electrofax coating in the nonimage areas is removed with a solvent. The plate is ready to etch in the same manner as regular plates.

Military Large Screen Displays

A major need in military systems is an automatic technique for large situation displays. Such displays must have high brightness and resolution. The information presented on display must be generated automatically and rapidly from electrical data. Electrofax fulfills all the requirements for such a medium, since it can take information photographically from electrical data in a fashion similar to high-speed printing from a cathode ray tube, and it has good resolution and rapid processing. It is not possible, however, to project the information developed on the Electrofax surface onto a large screen display because the Electrofax surface itself is not transparent. To overcome this difficulty, techniques have been developed for transferring the powder image developed on the Electrofax surface to a transparent base medium. A breadboard machine to accomplish this transfer automatically has been constructed and is shown in Fig. 4. This machine prints information onto 70-mm-wide Electrofax paper from a Charactron tube. The exposed paper is developed and the powder image then transferred to an adhesive-coated Mylar base. This base material has sufficient stability and transparency to allow bright projection on very large screens.

In this application, Electrofax is competitive with rapid-processing photographic film systems and has the advantage of large film size, low cost, and simple processing techniques.

Bank Book and Credit Card Recording

It would be very advantageous to the banking industry to be able to insert the subscribers signature in coated form into a bank book. An optical technique has been developed for scrambling the signature, and Electrofax gives the cheap and rapid processing necessary to allow economical recording of the optically scrambled signature.

Such a scrambled signature recorded on Electrofax is shown in Fig. 5. Since bank books or credit cards get extreme handling, a technique has been developed for this application in which the Electrofax surface is covered with a very thin protective Mylar sheet.

In these applications, Electrofax is extremely important, since the Electrofax surface may be printed directly into the bank book or on the credit card, the books and cards may be stored indefinitely, and yet the signature may be recorded and be available with a very short processing cycle. These characteristics are not possessed by other recording mediums.

Library and Office Copiers

Electrofax characteristics are also very suitable for use as a general copying medium. The low paper cost, rapid processing cycle, and high quality are great advantages in these applications. An outstanding example is the library copier developed by RCA Laboratories. This machine optically copies pages from books onto Electrofax paper using reflective illumination. The processing is done by liquid techniques and the finished print is thermally fused. This machine has been in use for many months. It is fully automatic, and its performance has been outstanding relative to conventional copiers.

Fig. 5—Electrofax print of scrambled signature.

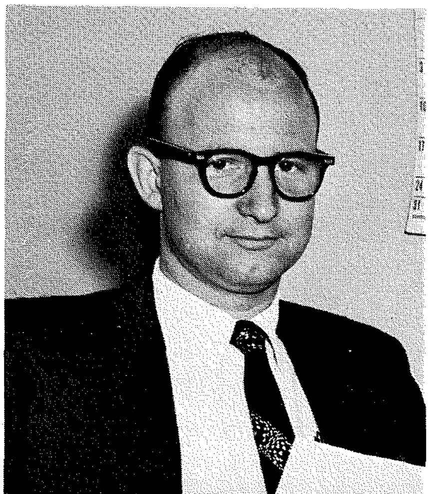
Johnny Y Johnstone

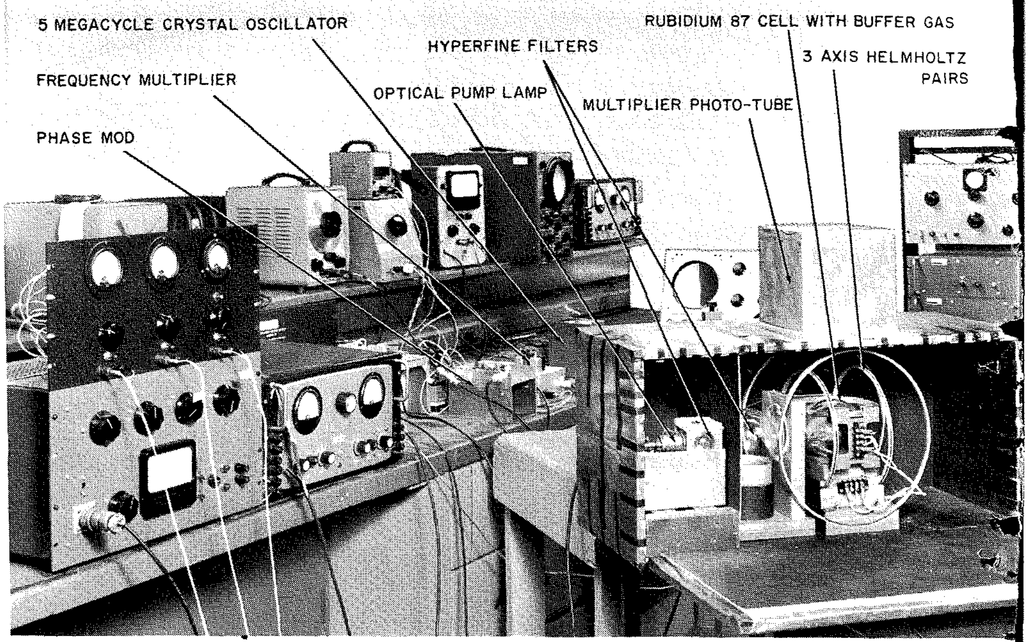
FUTURE DEVELOPMENTS

RCA has invested many man-years of research and development in the Electrofax process over the past decade. The excellent potential of the military and commercial applications referred to here gives testimony to the wisdom of this investment. The challenge now is the engineering and marketing transformation of models into products.

In the near future, there is the attractive prospect of increased capability for the Electrofax medium. Increased sensitivity, much greater tonal range, increased fidelity of color reproduction, lower-cost materials, and transparent color toners are some of the characteristics that will be available. The range of new applications will be virtually unlimited.

For Mr. Parker's biography, see Vol. 6, No. 1; p. 21.





THE ATOMIC CLOCK . . . A PRECISION FREQUENCY AND TIME STANDARD

by **L. J. NICASTRO, J. R. PARKER, and R. E. STRAUCH**
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MAN HAS LONG SOUGHT to perfect his standards of time. The earliest unit of time, quite naturally, was the *day* as established by the rotation of the earth. Shorter periods of time were determined by the period required to burn a length of candle, or for water to drip from a leaky vessel, or by similarly crude devices. An early improvement was the hour glass. Subsequent efforts generally have taken the form of an oscillator whose periods can be counted or added to measure time. Hence, there has been a parallel development of time standards and frequency standards (oscillators).

CHRONOMETERS TO CRYSTALS

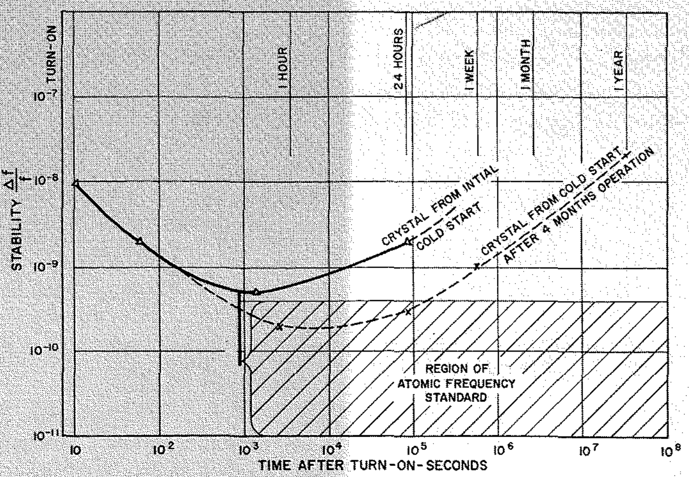
The importance of time in navigation was recognized before the days of Columbus, when it was known that large distortions and great disagreement in the maps of the day could be traced to poor measurement of time. Finally, the English government in 1714 fostered the development of a chronometer, many of whose features are incorporated in the better watches we use today. A carefully built and handled chronometer may be relied upon to within a few hundredths of a second per day if not disturbed or moved from the calibration site. With the advent of radio beacons in 1921, it became possible to superpose time signals on the beacon emission so that with proper receiving equipment, the drift and loss of time accuracy of ship-borne chronometers could be determined and corrected while at sea.

Crowded conditions in the application of radio to communications and navigation brought about stringent government assignment and control of operating frequencies. To facilitate this control, the Bell Telephone Laboratories in the 1920's developed 100-cycle tuning forks and 100-kc quartz-crystal oscillator frequency standards having good frequency stabilities. Eventually, the crystal standards could be so precisely reproduced and were so stable as to be self-consistent to within one part in 100 million per day. With the addition of electronic frequency division from 100 kc to 50 cycles and 50-cycle electric clocks, these frequency standards became precise time standards. The quartz crystals, however, suffered from the inherent long-term drift that is characteristic of all quartz-crystal oscillators and had to be corrected periodically. The correction was made whenever the indicated time departed by some small fraction of a second from astronautical time determined by the United States Naval Observatory. A further difficulty arose from the fact that the mean solar day, as determined by astronautical measurements, fluctuates by as much as one part in 30 million.

MOLECULAR AND ATOMIC FREQUENCY STANDARDS

To eliminate the above difficulties, physicists sought a system of time measurement that would not vary with time. RCA work in the early 1940's in microwave spectroscopy resulted in the development of a molecular frequency standard which was reported by Hershberger and Norton[1] in 1948. Similar work at the National Bureau of Standards was reported by H. B. Lyons.[2] Hershberger[3] at RCA disclosed atomic-beam constant frequency sources such as later adopted by Dr. J. R. Zacharias of Columbia University to make a cesium-beam frequency standard. Cesium-beam frequency standards are now internationally accepted. The atomic time scale A.1, established on January 1, 1958, is based on the cesium zero-field transition at 9,192,631,770 ±20cps. This was determined with cesium-beam measurements conducted jointly by the U.S. Naval Observatory and the English National Physical Laboratory.

Fig. 1—Stability characteristics of crystal oscillators and atomic frequency standard.



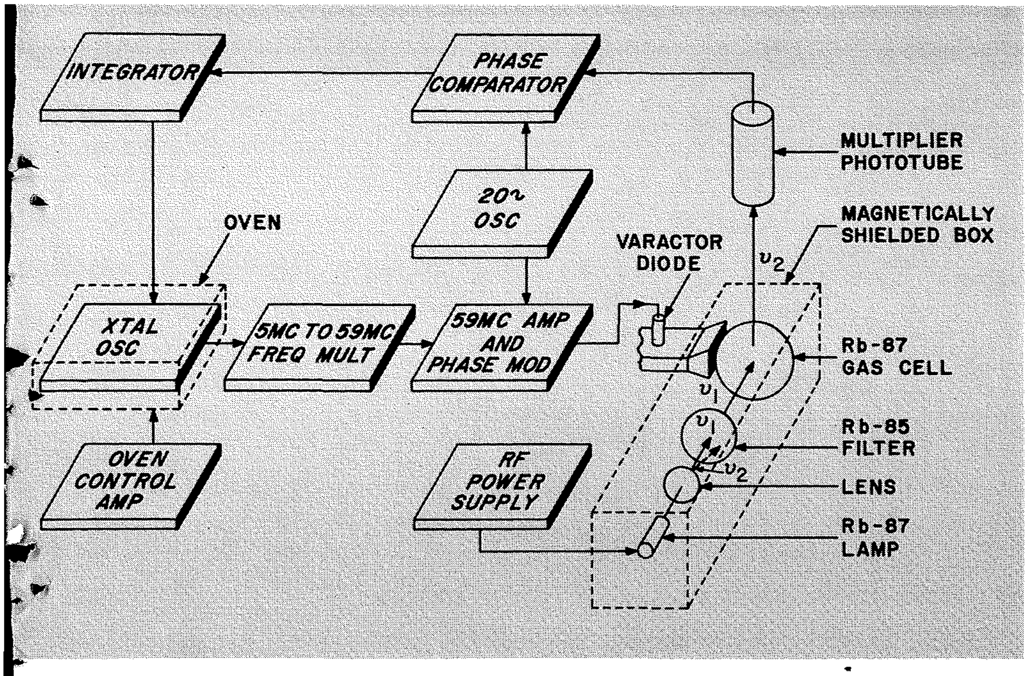


Fig. 2—Laboratory setup of atomic frequency standard.

Fig. 3—Schematic of atomic frequency standard.

However, the physical realization of a cesium-beam atomic clock is necessarily a large and cumbersome affair such as to preclude its use in missiles and space vehicles, and even in some ground based installations, regardless of its stability.

This article shows how DEP Applied Research has made practical use of basic research[4–10] to produce an atomic frequency standard having stability comparable to that of beam standards but requiring an order of magnitude less space, power, and weight, and being quite insensitive to environments.

TYPES OF STANDARDS

Precise standards of frequency (and time) may be divided into two categories[11]: 1) those which rely on the dynamical behavior of aggregations of matter and 2) those which rely on the absorptive properties of molecules, atoms, or nuclei.

The frequency of a standard in the first category, for example, a pendulum or a quartz crystal, is subject to dimensional changes in the controlling elements; hence, its environment must be closely controlled. Even then, the best of these (a quartz crystal oscillator) will have long-term drift in frequency which is attributed to "aging" of the crystal.

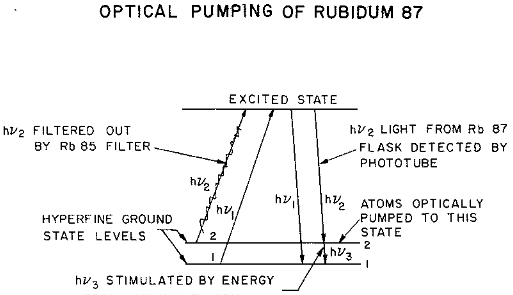


Fig. 4—Optical pumping of Rb^{87}.

In the second category, the transition frequencies at which radiation or absorption processes occur will not change with time. This is so within our present ability to measure. (Cosmologic considerations suggest that the universal gravitational constant and, hence, the fine-structure constant are changing.[12]) The extent to which these standards change with time will be determined by noise and by changes in associated parts. In active standards, i.e., atomic oscillators, the changes will be those in the microwave part of the oscillator circuit. In passive standards, i.e., comparison type standards, the changes will be those occurring in the servo loop. Noise will principally affect instantaneous stability while changes in allied parts of the system will affect long-term stability.

The rubidium-vapor atomic frequency standard to be described is a passive system. In a passive molecular or atomic frequency standard the frequency of a standard crystal oscillator is compared with a selected resonant transition frequency in the reference atom. An error signal resulting from this comparison is used to correct the crystal oscillator so that the two are essentially the same. The selected resonant transition has very low dependence on its environment and does not change with time; hence the long-term frequency drift normally inherent in the crystal oscillator is, for practical purposes, eliminated.

The stability of a molecular or atomic frequency standard as a function of time is illustrated in Fig. 1. For comparison, the drift characteristics have also been plotted for the very best obtainable crystal oscillator. During the period immediately following turn-on, and before the atomic frequency standard locks to the atomic resonance line, the two standards will be equivalent. After lock-on, which will occur well within the first half-hour of operation, the long-term stability of the atomic frequency standard will be maintained within the shaded region. The actual stability level obtained will be largely determined by the gas resonance characteristics, the manner in which they vary with temperature, and the effectiveness of the associated servo system.[11] The short-term stability of the molecular frequency standard will not exceed that of the quartz crystal oscillator, because the sampling rate cannot be made high enough to enable the servo system to correct for short-term variations.

SYSTEM DESCRIPTION

Fig. 2 shows the laboratory setup of Applied Research's rubidium-vapor molecular frequency standard. The operation can be followed in the block diagram of the system shown in Fig. 3. Light from the rubidium lamp optically pumps the Rb^{87} atoms in the gas cell to a higher energy state, from which they fall into a microwave energy level in the emissive state. The cell is irradiated with microwave energy whose frequency is crystal controlled to correspond closely to that of the rubidium microwave transition. The microwave signal of 6834 megacycles, close to the resonant frequency of Rb^{87}, is obtained by frequency-multiplying the output of the crystal oscillator from 4.996115 mc to 59 mc, then amplifying the 59-mc signal. Multiplication from 59 mc to 6834 mc is performed by a varactor diode mounted in a conventional crystal-detector mount. When the frequency of the applied microwave field closely matches the microwave resonant frequency of Rb^{87}, stimulated microwave emission takes place.

OPTICAL PUMPING AND DETECTION

The energy level diagram (Fig. 4) qualitatively illustrates the action which occurs within the Rb^{87} gas cell. This diagram is an oversimplification and does not show all the transitions taking place in the cell. The microwave transition of interest is that with frequency ν_3. The number of these transitions that occur when the microwave energy is on resonance depends on the population difference between the two ground-state hyperfine levels. The population difference between these levels is increased by "optical pumping." In this process an Rb^{85} filter is used to absorb the ν_2 spectral components of the rubidium lamp light, so that only the ν_1 component is incident on the absorption cell. This effectively leaves the atoms in state 2 (Fig. 4) undisturbed, while the atoms in state 1 are "pumped" to an excited state, from which they descend by emitting energy $h\nu_1$ or $h\nu_2$ (where h is Planck's constant) with equal probability to either of the two ground states.

Since atoms are being pumped out of only the lower ground-state, and since the natural relaxation time across the ground-state hyperfine levels is much longer than that for the optical transitions, an excess of atoms is accumulated in the upper ground-state. As the microwave frequency approaches the Rb^{87} resonant frequency (ν_3) from either direction (high or low), the number of atoms falling from the upper ground-state to the lower ground-state by stimulated emission gradually increases until at resonance a maximum number of transitions is reached. The atoms that fall into the lower ground-state are thereby in the condition where they can begin the "optical pumping" cycle again. Since all the absorption and emission processes described above occur in series, the number of emissive transitions at ν_2 will be proportional to the number of transitions at ν_3. The re-radiated light at ν_2 is given off in all directions, so that a photo-pickup at 90° to the incident beam will detect the re-radiated energy and, hence, can serve as a resonance detector.

The manner in which the number of transitions resulting from stimulated microwave emission varies with the frequency of the incident microwave energy is known as the Lorentzian line shape. A trace of such a line taken with the laboratory model is shown in Fig. 5. At the peak of the Lorentzian line, the frequency of the incident microwave energy matches the resonant frequency of Rb^{87}. The analytical expression describing the Lorentzian line shape has the same form as that for a parallel-tuned circuit. A measure of the accuracy to which one can determine the resonant frequency of Rb^{87} can be obtained by comparing the Q of the equivalent parallel-tuned circuit with the Q for a high-precision crystal. For the laboratory setup, the half-power points are 60 cycles apart, indicating an equivalent Q of 10^8, as contrasted to a value of 10^6 for a good crystal. Thus, the change in frequency from on-resonance to a half-power point is 5 parts in 10^9.

The near symmetry[13] of this line offers an excellent means of error detection. The microwave frequency can be modulated a small amount and the phase of the resultant light modulation can be compared with the modulation signal (Fig. 6). Comparison by means of a phase detector develops an error signal which is used to correct the source of the microwave frequency. Close scrutiny of Fig. 6 will show that phase does not change continuously, but changes through resonance region by 180°. On either side of resonance phase does not change appreciably.

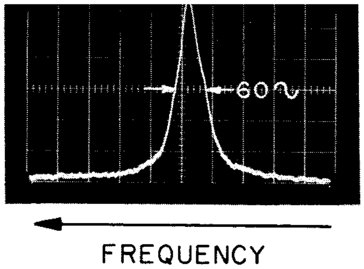


Fig. 5—Lorentzian line shape for atomic frequency standard.

DETECTION LIMITATIONS

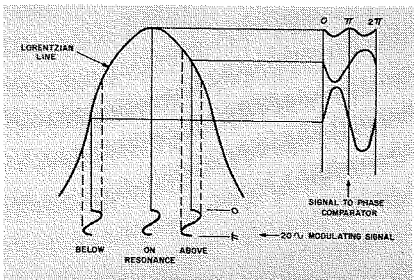
The ability to control the frequency of the crystal oscillator with reference to the resonant frequency of the rubidium gas cell is limited by the noise on the output signal. It can be seen from Fig. 5 that the noise is about 1/100 of the half-power signal. Hence, the stability limit of the laboratory set-up that may be expected is 1/100 of 5 parts in 10^9—or, conservatively, 1 part in 10^{10}.

To achieve the maximum stability available from the gas cell, great care must be exercised in the design of the associated electronic parts of the system. The phase jitter accumulated in the frequency multiplier must be lower than can be obtained with conventional harmonic generation schemes. The servo system should reference the crystal oscillator to the *center* of the rubidium resonance line in such a manner that no offset arises from drift of the loop-gain characteristics, or from nonsymmetry of the rubidium resonance line. Recent measurements indicate that the line symmetry can be affected by operating conditions.[14] Both the optical and microwave input power must be held to very low values for minimum effect on the symmetry of the line.

ADVANTAGES

The major advantage of an atomic frequency standard is that it automatically adjusts the frequency of a crystal oscillator to a predetermined value and maintains it at that value indefinitely within the instantaneous stability limits. This feature is important in many applications where it is neither desirable nor possible to continually adjust a crystal oscillator for drift. A possible disadvantage lies in the fact that with a simple system, the adjusted frequency of the crystal oscillator is not a whole number, and a frequency translator or synthesizer circuit must be used when a whole number is required.

Fig. 6—Modulation of microwave frequency to obtain an error correcting signal.



The atomic frequency standard developed by Applied Research has several further advantages. With automatic search and lock-on, the final value of frequency is reached within 30 minutes after turn-on. Through the use of a gas cell and optical detection the size and weight requirements are greatly reduced. Present studies indicate that with transistor circuitry all of the system components of Fig. 2 can be placed within one cubic foot of space and weigh less than thirty pounds. The box shown in Fig. 7, a first step in this direction, will contain the complete system now under development.

APPLICATIONS

The extremely high stability now made available in a device requiring very little space and power extends the use of frequency and time standards to many new applications. Sophisticated communications systems which required highly stable local oscillators will now be possible. This application should improve the security of military communications and reduce the error rate of data processing systems.

Primary Frequency Reference

The zero-drift characteristic of atomic frequency standards makes them ideal primary frequency references for laboratory work. Their use would eliminate many uncertainties and difficulties associated with crystal standards. At present, crystal standards must be operated continuously to attain maximum stability. Even then, because of the long-term drift inherent in crystals, the frequency must be periodically checked and corrected against WWV transmissions. Lengthy observations are required to make these comparisons so as to eliminate propagation effects. Final correction must take into account departures of WWV transmission frequency from the United States Frequency Standard.[16] However, with an atomic frequency standard in the laboratory, these corrections to WWV transmissions would not be required. Full stability is obtained 30 minutes after the standard is turned on, since it is then locked to the atomic transition selected. Final determination of frequency in the laboratory could be made by direct comparison of the local source to the laboratory atomic frequency standard. The simplicity of the *gas cell* atomic frequency standard developed by Applied Research naturally leads to high reliability and relatively low cost, making the above advantages easily available to small laboratories.

Time Standard

The stability data of Fig. 1 indicates that the atomic frequency standard should make an excellent time standard. It is interesting that if the frequency of the standard is known, at least 300 years of operation would be required to accumulate a time error of 1 second if the stability were 1 part in 10^{10}. However, exact values of time or frequency have not been determined to better than 2 parts in 10^9. In fact, the time we live by, as determined by the rotation of the earth, is not uniform—that is, not all seconds have the same length. A number of difficulties arise because of the complex relations involved. For example, an atomic clock whose seconds were exactly the same length as earth-time seconds in 1900 would now be 32.5 seconds fast by earth time.[15] However, wherever a highly precise, uniform time system (all seconds the same length) is required or where during the measuring period the difference accumulated is negligible, an atomic time standard will find applications. Because of its small size, the *gas cell* "atomic clock" should be useful in missile and space navigation systems and in range instrumentation systems such as those at Cape Canaveral.

ACKNOWLEDGEMENTS

The authors wish to express their appreciation for the assistance and counselling of many people: Dr. P. L. Bender of National Bureau of Standards, and Dr. J. P. Wittke and R. R. Goodrich of RCA Laboratories for gas-cell work, and M. E. Malchow, J. E. Saultz, and W. E. Arrowood of DEP Applied Research for transistor circuitry.

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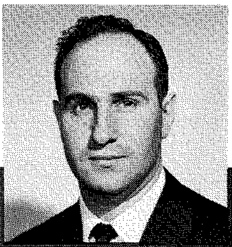
J. R. PARKER received a B.S.E.E. at University of Nebraska in 1943 and an M.S.E.E. at the University of Pennsylvania in 1952. He joined RCA in 1943. Following special studies at the Oak Ridge Institute of Nuclear Studies in 1948, he has been principally involved in nuclear instrumentation and effects. Other activity includes stabilization of high voltage supplies for the electron microscope, development of an X-ray microscope, a recording optical spectrophotometer, and a two million volt electron-beam generator for food sterilization. In mid-1959 he became project engineer on the atomic frequency standard. He is a Professional Engineer in the state of New Jersey, a member of the IRE and several of its professional groups, Sigma Tau, and Pi Mu Epsilon.

R. G. STRAUCH received a B.E.E. degree from the University of Florida in 1959. He is presently doing graduate work at the University of Pennsylvania under the Graduate Study Program. Since joining RCA in 1959, he has worked in Applied Research on the atomic frequency standard and on a microwave correlation study. His principle responsibility on the atomic frequency standard was the frequency generation, phase modulation, and optical detection circuitry.

L. J. NICASTRO received a B.A. in Physics from LaSalle College in 1953. Sponsored by an AEC Radiological Physics Fellowship, he received an M.A. in Radiation Biology from the University of Rochester in 1956. He is presently taking graduate work at Temple University. Following service as an instructor in chemistry and Physics at LaSalle College, Physicist in Ballistics at Frankford Arsenal, and Health Physicist at Brookhaven National Laboratories, Mr. Nicastro joined the Neutron Physics Section at the National Bureau of Standards in 1956. In early 1959 he joined RCA where he has conducted an experimental program exploring resonant transitions in Rb^{87} vapor.

SAM AZEEZ received his B.A. degree in Physics from Temple University in 1955. His early work at RCA was concerned with the design of capstan speed servos and tape transport systems for video recorders, and an error analysis of an analog firing control computer. Later, he served as project engineer on the design and construction of a noise figure monitor for the BMEWS program. During the past year he participated in programming a special purpose digital computer, and is presently engaged in development work on the servo system for the atomic clock. Mr. Azeez is a member of the IRE and Sigma Pi Sigma.



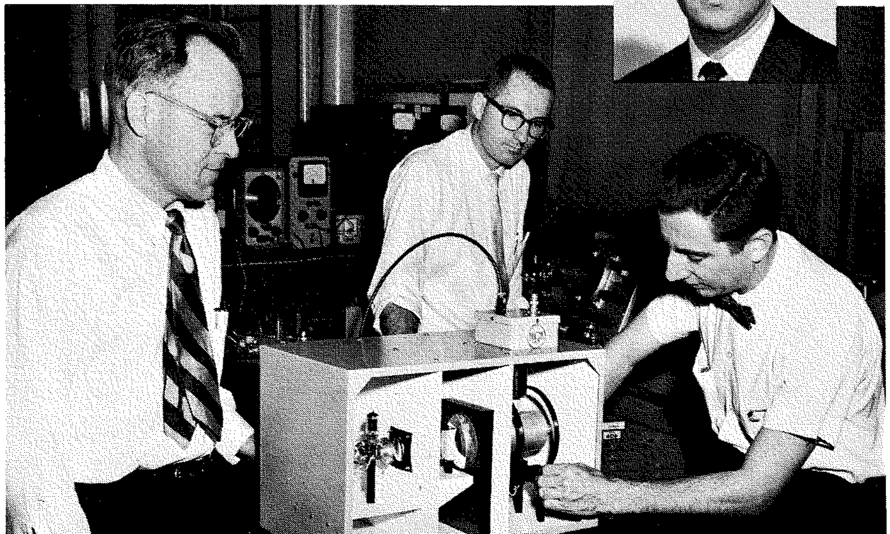
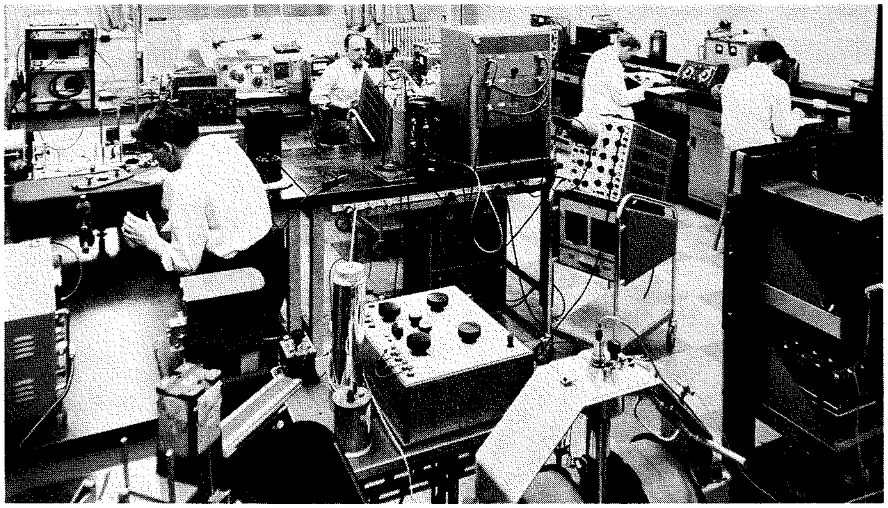
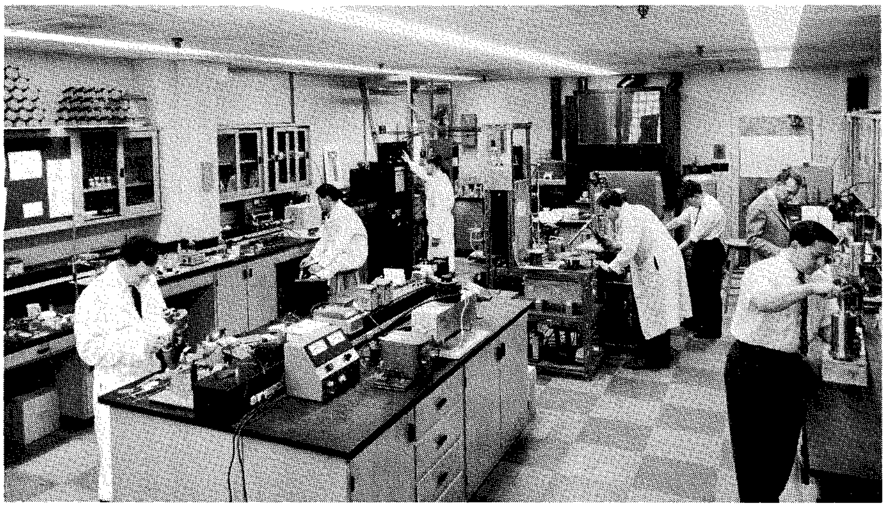


Fig. 7—Co-authors (left to right) J. R. Parker, R. E. Strauch and L. J. Nicastro inspecting new model of the atomic frequency standard. Inset is co-author S. Azeez. Microwave energy is cavity-coupled to the gas cell, eliminating the microwave horn shown in Fig. 3 (between the varactor diode and the Rb^{87} gas cell).



RCA RESEARCH IN MONTREAL

by **DR. J. R. WHITEHEAD, Director**
Research Laboratories
RCA Victor Company, Ltd.
Montreal, Canada



Two of the laboratory facilities at RCA Victor Ltd. Research in Montreal. Top: Device Physics. Bottom: Semiconductor Materials.

It may not be widely known within RCA that the RCA Victor Company, Ltd., Montreal, Canada, operates flourishing research laboratories which are increasingly attracting international attention. These laboratories were started in 1955 at the instigation of the late F. R. Deakins, former President of RCA Victor, Ltd. The author, together with two colleagues, left the physics department staff of McGill University in that year to create something unique in the Canadian Electronics Industry—laboratories engaged in scientific research.

ORGANIZATION AND STAFF

The success of research laboratories, as of most activities, depends heavily upon the quality of the men engaged. For this reason, great care has been taken in the selection of the staff, and a high average standard has been set. This has been possible partly because of the lack of opportunities for research in Canada, other than in government or university Laboratories, and partly because of the growing reputation of the RCA Victor Research Laboratories in the Canadian Universities.

Of the present staff of forty-seven, including six students, forty are directly engaged in scientific or technical activities and the remainder in supporting services. This apparently high ratio of technical staff to others results primarily from the use of central accounting, purchasing, model-shop, and contract-administration services that serve the Canadian Company as a whole. [The Manager of Research Administration is H. J. Russell, recently appointed as RCA Victor Company, Ltd. Editorial Representative for the RCA Engineer; see Vol. 6 No. 1, page 56.]

The Laboratories occupy about 10,000 sq. ft. of the second and third floors of the Montreal plant. Library facilities include most of the scientific and engineering journals of Canada, the United Kingdom, the United States, and the USSR.

The Laboratory research program is divided into three main departments, as shown in Fig. 1: *Semiconductor,* under Dr. R. W. Jackson; *Microwave,* under Dr. M. P. Bachynski; and *Electronics,* under Dr. F. G. Ross Warren.

SEMICONDUCTOR RESEARCH

The Semiconductor Research groups occupy three main laboratory facilities which can be classed broadly as materials, devices, and circuits.

The materials laboratory is equipped for the vertical and horizontal growth of single crystals of silicon, germanium, and compound semiconductors, and for the various other processes associated with semiconductor research.

In the devices laboratory, apparatus is available for X-ray diffraction, Hall measurements, and infrared spectrometry. The laboratory also houses apparatus and radioactive sources for research on alpha-particle detection and energy resolution, and equipment for studying noise in semiconductor devices, infrared photoconductive cells, and avalanche breakdown in semiconductor p-n junctions.

The circuits laboratory is specially equipped for the analysis of the circuit behavior of semiconductor devices. Here, the equipment is mainly electronic for study of tunnel diodes, thyristors, transistors, and other semiconductor devices.

Materials Research

There are problems in growing certain crystals to the very high degree of perfection required for some investigations of bulk properties and for the construction of some new experimental devices. Of particular interest in this laboratory are the photoconductive properties of germanium doped with some of the more exotic elements, such as gold, which contribute two or more ionization levels to the lattice and result in excitation thresholds corresponding to radiation quanta in the infrared.

Some of the semiconducting compounds, formed from elements in the third and fifth, second and sixth, or other combinations of columns in the periodic table, are also of particular interest for their behavior in the infrared. This is a field of research still relatively untouched, owing to the formidable difficulties which must be overcome before single crystals of these compounds can be grown to the necessary purity and perfection. Cadmium telluride is one currently under study. Work in these fields is partially supported by contracts from the Canadian Armament Research & Development Establishment (CARDE) and the Defense Research Board of Canada.

Infrared Detection

Infrared research has included the fabrication of detectors from one of the doped germanium materials. Several units have been supplied to CARDE for experimental purposes. These are relatively large-area detectors in all-metal, demountable, vacuum housings capable of operating for hours on a single filling of liquid-nitrogen coolant.

One of these detectors is shown in Fig. 2. The doped germanium element is mounted on the end of the inner vessel of the dewar in a block of gold-plated copper. The inner vessel is filled with liquid nitrogen which cools the element via a conducting rod and also cools a charcoal "getter" which mops up residual gases from the evacuated space. Great care has been taken in the selection of metals for the dewar to minimize conductive heat loss. The lower part of the outer vessel may be removed for access to the detector.

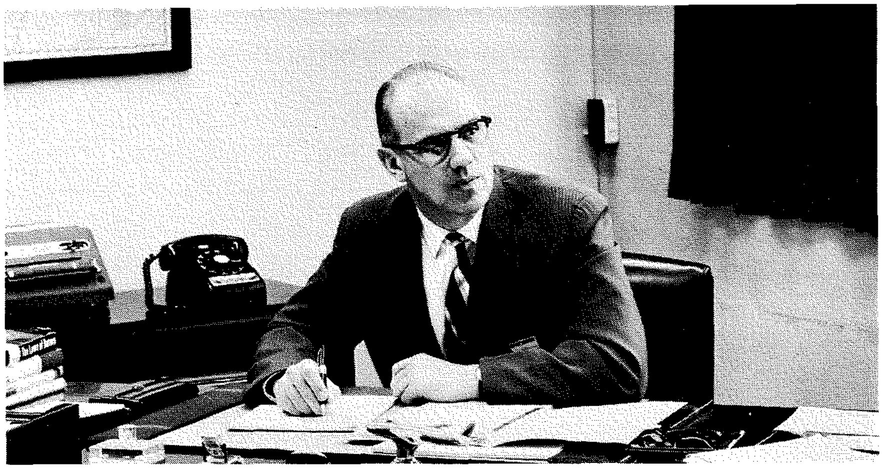
Breakdown Process in Junctions

A further subject of research in the Semiconductor Laboratories is the mechanism of electrical breakdown in a p-n junction. Breakdown can be of the Zener type, for very abrupt junctions, or of the avalanche type. Avalanche breakdown occurs when a carrier being accelerated across the depletion layer creates, on the average, more than one hole-electron pair through ionization of the lattice atoms.

At its onset, breakdown is sporadic, and the current is conducted in a series of pulses of uniform height but random duration. As the voltage increases, the pulses become more frequent and longer until finally the current is continuous. At slightly higher voltages, another set of pulses begins which follow the same cycle.

Many of these sets of pulses have been observed in sequence on a single diode. Other work has shown that each of these sets of pulses corresponds to a breakdown in an extremely small region of the junction, perhaps about 500 Angstroms in length and 500 Angstroms in diameter, and that the breakdown regions, or microplasmas, occur preferentially where dislocation lines in the crystal intersect the junction.

The physical processes governing the behavior of the microplasma, at room temperature and at low temperatures, and the role of the dislocations are



DR. J. RENNIE WHITEHEAD graduated in Physics from Manchester University, England, in 1939. He entered the British Radar Research Establishment, later to become TRE, in 1939 and worked on radar throughout the war, designing the Mark III IFF airborne transponder, heading the IFF group, and later spending more than a year in Washington, D. C., on scientific liaison. After the war, Dr. Whitehead headed a research group on pulsed light and millimeter waves at TRE. This group made in 1946 the first experimental operating radar on a wavelength below 1 cm. In 1946 he went on loan to the University of Cambridge as a consultant in electronics. There he designed electronic instrumentation for research on friction and metallic surface phenomena and carried out his own research on friction at light loads, for which he was awarded the degree of Ph.D. in 1949. At the same time he wrote the book *Superregenerative Receivers*. On his return to TRE in 1949, Dr. Whitehead headed the Research Division on Physical Electronics, which included research on noise in photoconductors and on parallel-filter doppler radar systems. In 1951 he emigrated to Canada, where he joined the Eaton Electronics Research Laboratory of McGill University. While Associate Professor of Physics, he was also responsible for the Defence Research experimental work, technical trials, and the development of doppler equipment for the Mid-Canada Line. In September 1955 he joined RCA Victor Company, Ltd., as Director of Research. Dr. Whitehead is a Fellow of the Institute of Physics, a Senior Member of the IRE, and a Member of the Institution of Electrical Engineers, Sigma Xi, the Canadian Association of Physicists, and the American Physical Society.

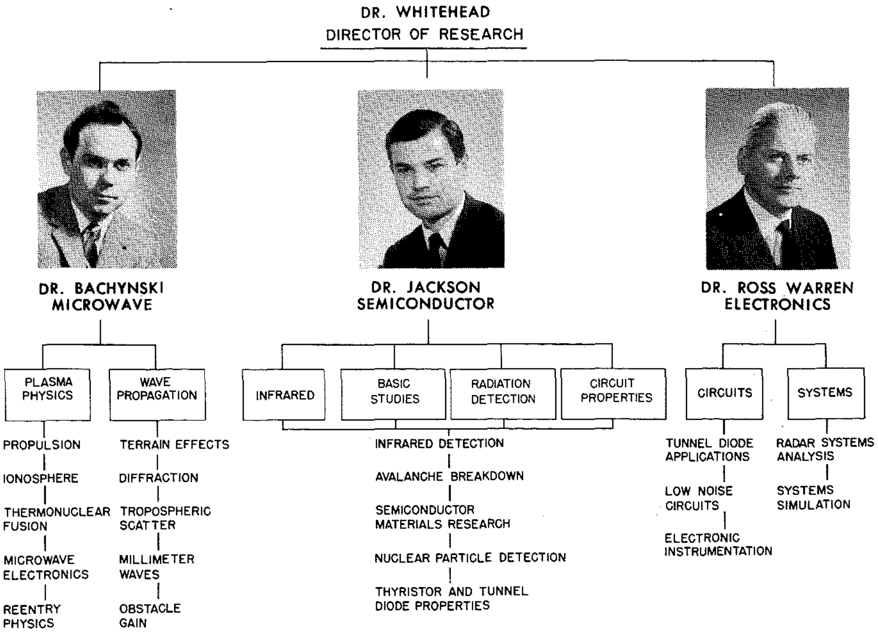


Fig. 1—Organization. Pictured are Dr. M. P. Bachynski, Head of Microwave Research; Dr. R. W. Jackson, Head of Semiconductor Research; and Dr. F. G. Ross Warren, Head of Electronics Research.

Dr. Morrel P. Bachynski graduated in 1952 from the University of Saskatchewan with the B.E. in Engineering Physics, with the highest scholastic standing in his graduating class. He then obtained his M.Sc. in Physics at the University of Saskatchewan. At McGill University he was awarded a Ph.D. in 1955. He then joined the RCA Victor Company, Ltd., where he has conducted research on wave propagation, diffraction, reflection, obstacle gain, radome design, antennas, microwave techniques, shock front structures, and plasma physics.

Dr. Ray W. Jackson graduated in 1944 from the University of Toronto with a B.A.Sc. in Engineering Physics. At McGill University, he received his Ph.D. in Nuclear Physics in 1950. From 1951 to 1952 he held a fellowship at Yale University from the American Council of Learned Societies for study in the philosophy of science. He remained there, working on undersea detection, until 1954, when he joined Sprague Electric Co. in semiconductor materials research. In 1956, he joined the RCA Montreal laboratories. His experience includes accelerator physics (particularly the synchrocyclotron), r-f induction heating, rectifying junctions, minority-carrier lifetime, and semiconductor applications.

Dr. F. G. Ross Warren graduated from the University of Manitoba in 1941 with a B.Sc. in the Honours Course, specializing in Physics and Chemistry. He entered McGill University in 1945 and obtained his Ph.D. in nuclear physics in 1948, receiving a National Research Council Fellowship in 1947. He joined RCA Victor Company, Ltd., in 1949. From 1954 to 1956 he was loaned to the Department of National Defence, for radar systems engineering work on the Mid-Canada Line. On his return, he was appointed to the ASTRA project as manager of systems engineering. He has specialized in microwave optics, radar and aerial navigation systems analysis, and detection of small signals in noise, and holds scanning-antenna patents.

being studied in detail for silicon junctions. This work is being supported by the Defense Research Board of Canada.

Nuclear-Particle Detection

In the course of investigations of radiation effects in semiconductors, it was found that when a high-energy alpha-particle, or other highly ionizing nuclear particle, passes through the depletion layer of a reverse-biased semiconductor junction, the ionization products are swept out by the electric field across the depletion layer and register a pulse of current in the external circuit. If the junction can be formed close enough to the surface that little energy is lost by the particle in the "dead" layer before it penetrates the sensitive depletion layer, the junction makes a highly efficient detector of alpha-particles.

Furthermore, the depletion layer can, by the appropriate choice of base material and bias voltage, be made deep enough to stop 10- or 15-mev alpha particles. This results in an accurate proportional counter for measuring the energies of incident alpha particles. Energy resolution better than $\frac{1}{2}$ percent has been obtained in units of 2-mm^2 detecting area. Fig. 3 shows two demonstration models of complete alpha-particle monitors using silicon-junction detectors.

Since the first announcement of this type of detector in early 1960, inquiries or orders for sample quantities have been received from Canada, U. S., U. K., Norway, Holland, France, Belgium, Italy, Germany, Israel, Egypt, Yugoslavia, and Japan. Inquiries have come from more than 300 nuclear establishments in all.

The Research Laboratories have fabricated all the samples to date, but the process of handing over production to the Semiconductor Engineering and Production Department of the Montreal Tube Division is under way.

Semiconductor Circuits

This program involves the study of the physical processes which are the basis of the electrical-circuit properties of a given device. Thus, in the case of the drift transistor, the equations for the transport of carriers through the base region are the starting point for the derivation of the four-terminal admittance functions of the device, their approximate representation by equivalent electrical networks, and the prediction of their parameters as functions of frequency. The inclusion of noise sources in the equivalent circuit, based on the physical sources of noise at the semiconductor junction, permits the prediction of the noise figure which corresponds to any conditions of operating point, circuit configurations, and terminating impedances.

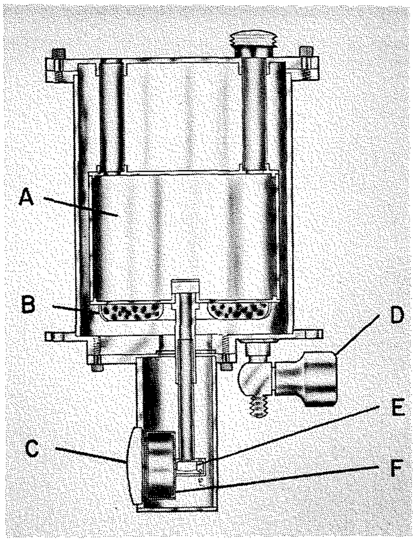


Fig. 2—Gold-doped germanium infrared detector. A—coolant chamber; B—charcoal getter; C—germanium lens; D—pumping valve; E—detecting element; F—radiation shield.

The theory and equations by which this can be done have been worked out, with particular attention to shot- and thermal-noise sources in the drift transistor and on the noise figures obtainable at high frequencies. Extensive measurements have been carried out which show good agreement with theory. The conditions for optimum performance have been studied and it has been demonstrated, for example, that amplifier noise figures of less than 1 db can be obtained at frequencies up to the beta cutoff frequency of some contemporary high-frequency transistors.

Interest extends to the tunnel diode and thyristor. In particular, the processes involved in fast switching in the latter device have been under investigation for some time.

A good deal of this semiconductor circuit work is done in close association with the Princeton Laboratories.

MICROWAVE RESEARCH

Two main lines of research involving microwaves are followed: microwave propagation and plasma physics. The microwave propagation laboratory is equipped for phase and amplitude measurements at 3 cm, 1.25 cm and 8.5 mm. The plasma physics laboratory is at present building up apparatus for confining and measuring plasmas.

Propagation—Obstacle Gain

Long-range propagation experiments conducted over the last few years have shown the presence of relatively large fields beyond the horizon as well as behind local natural obstacles such as mountains. The effect of such natural obstructions has stimulated interest in *obstacle gain;* that is, the difference in signal observed in the presence of an obstacle relative to the field which would be observed in the absence of the obstacle. In many instances, the received signal can be increased by the presence of the obstruction. Hence, obstacle gain is achieved.

Full-scale obstacle-gain experiments are difficult. It is, of course, virtually impossible to vary the most important parameters, such as the size, shape, and location of the obstacle. The only variable which can be changed systematically with relative ease is the height of the antennas. In addition, the establishment of suitable transmitter-receiver stations is extremely costly. Finally, random features of the terrain and atmosphere may contribute effects difficult to evaluate.

Scale-model experiments have been conducted within the laboratory in attempts to formulate better theories of the propagation mechanism involved in obstacle gain. The great advantage of model measurements is the ease with which the important parameters may be controlled. Scale models of idealized obstacles are initially being investigated, and as their effects become understood, progress is made towards more-complex models which approximate more closely the actual terrain.

Terrain Effects

The effect of small undulations of the earth's surface on propagation of electromagnetic waves is of vital concern. It is the energy reflected from the earth's surface which causes destructive interference, fading for line-of-sight transmission, and clutter in search radar. Because of random variations from one point to another, these effects are extremely difficult to predict, and actual measurement in the field are subject to so many uncontrolled variables that a clear understanding of the propagation phenomenon is impossible. Model experiments, coupled with theoretical study, seem to be especially adaptable for a systematic study of such surface effects.

Diffraction by Absorbing Disks and Screens

Experimental and theoretical investigations on back-scattering are usually confined to perfect conductors. Because the earth is not a perfect conductor, it is of practical interest to investigate scattering and diffraction by absorbing bodies.

Theoretical scattering and diffraction by absorbing disks and screens has been obtained in the form of fairly simple relationships. One result of this investigation is that the absorbing disk is invisible to a conventional radar, while it may be seen when the transmitter and receiver are separate. When the disk is not perfectly absorbing, as in all practical cases, it is seen by the radar at a reduced intensity which may be calculated from the reflection coefficient of the material.

Millimeter Wave Studies

A survey of the electromagnetic spectrum above 10 kmc has recently been made. The results include methods of generation and amplification of short-wavelength radio energy, the progress being made in millimeter-wave components and the effect of the atmosphere, rainfall, and natural obstacles on the propagation of energy at these high frequencies.

Plasma Physics

Research in this field originated from an interest in earth satellites and ballistic missiles, rather than thermonuclear effects. Of interest to communications are the problems of the interaction of electromagnetic waves with sheaths of electrons and ions formed as a high-speed projectile traverses the atmosphere, the behavior of antennas in such an environment, and methods of diagnosing plasmas which are set up in the laboratory to stimulate actual conditions. Many of the results, however, prove equally useful in the control and confinement of plasmas in thermonuclear fusion.

The microwave laboratory is carrying out a program concerned with the fundamental investigation of interaction between electromagnetic waves and plasmas. The aim is to contribute to the knowledge of basic plasma physics, to apply microwave techniques to shock-front diagnostics, to investigate problems associated with satellite and outer-space communication and long-range missile guidance and detection, and to keep abreast of developments in the field of thermonuclear fusion. Investigations currently in progress include:

1) *Plasma kinetics* — collision frequency and scattering cross-sections of plasma constituents; relaxation effects in plasmas created by a shock wave (such as dissociation, relaxation and diffusion rates).

2) *Passive radiation from plasmas* — emission from plasmas in the microwave range of the spectrum.

3) *Electromagnetic propagation in plasmas* — propagation in nonlinear media, effects of plasma geometry, polarization phenomena.

4) *Effect of ionized media on antenna properties.*

5) *Diagnostic techniques* — with improved spatial and time resolution, particularly the use of modulated electron beams as plasma probes.

Plasma and Ion Propulsion

In space exploration, a conventional rocket can be used to launch a vehicle into orbits of negligible gravity and drag. Once there, only minute amounts of thrusts are needed to propel the vehicle for months or even years. It appears that such a rocket motor might be achieved using electrical or electromagnetic techniques for propelling plasmas and/or ions. Studies underway on such methods are aimed at the important parameters of possible propulsion systems, their limitations and possibilities.

ELECTRONICS RESEARCH

This laboratory includes a transistorized simulator to reproduce the signal and noise conditions of complex radar systems in a variety of environments.

The determination of an absolute criterion by which to judge the various means of radar target-detection is a problem which has only partially been solved. A radar systems research program has concentrated on this problem. The process of applying it to specific operational situations with the aim of determining the optimum systems configuration for a given environment is now actively in progress.

The theoretical approach to detecting targets in a variety of environments is paralleled by use of the systems simulator. A large part of the work of this laboratory is supported by the Defense Research Board of Canada. The extension of such work to application recommendations and feasibility tests on a complete or partial system will be the responsibility of this group. This not only includes radio communications and radar, but also infrared.

An extension of the problem outlined above suggests a solution in the form of a system sufficiently flexible to adapt to its own environment, a valuable concept where the nature of the target environment is difficult or impossible to determine accurately in advance. The studies under way and proposed involve the use of sophisticated control systems. This principle of adaptive systems also has potential applications to industrial problems.

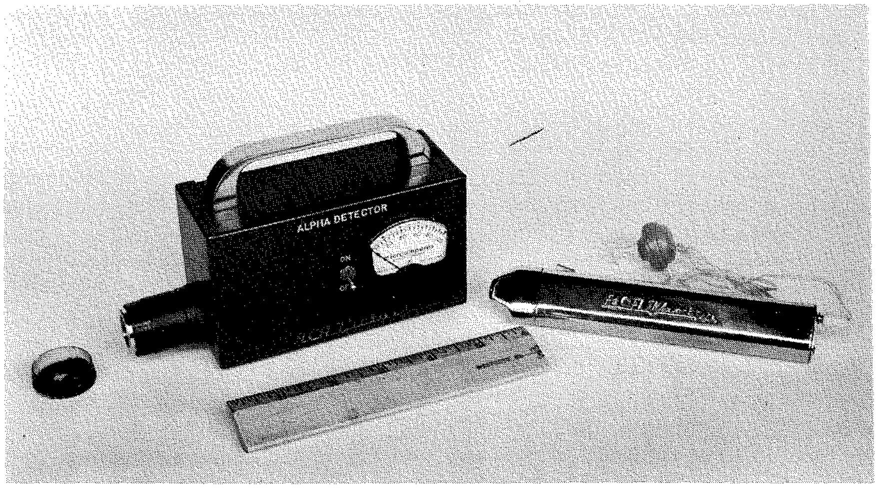
A research group in this laboratory is to be engaged in research on electronic circuits, to complement the semiconductor circuits group, which is primarily preoccupied with the circuit properties. Also, in the course of research program in semiconductors and microwaves, many devices and circuits are suggested and instruments designed to facilitate the immediate solution of research problems. It is the function of this particular group to pursue the development and wider application of any such devices, circuits, and instruments.

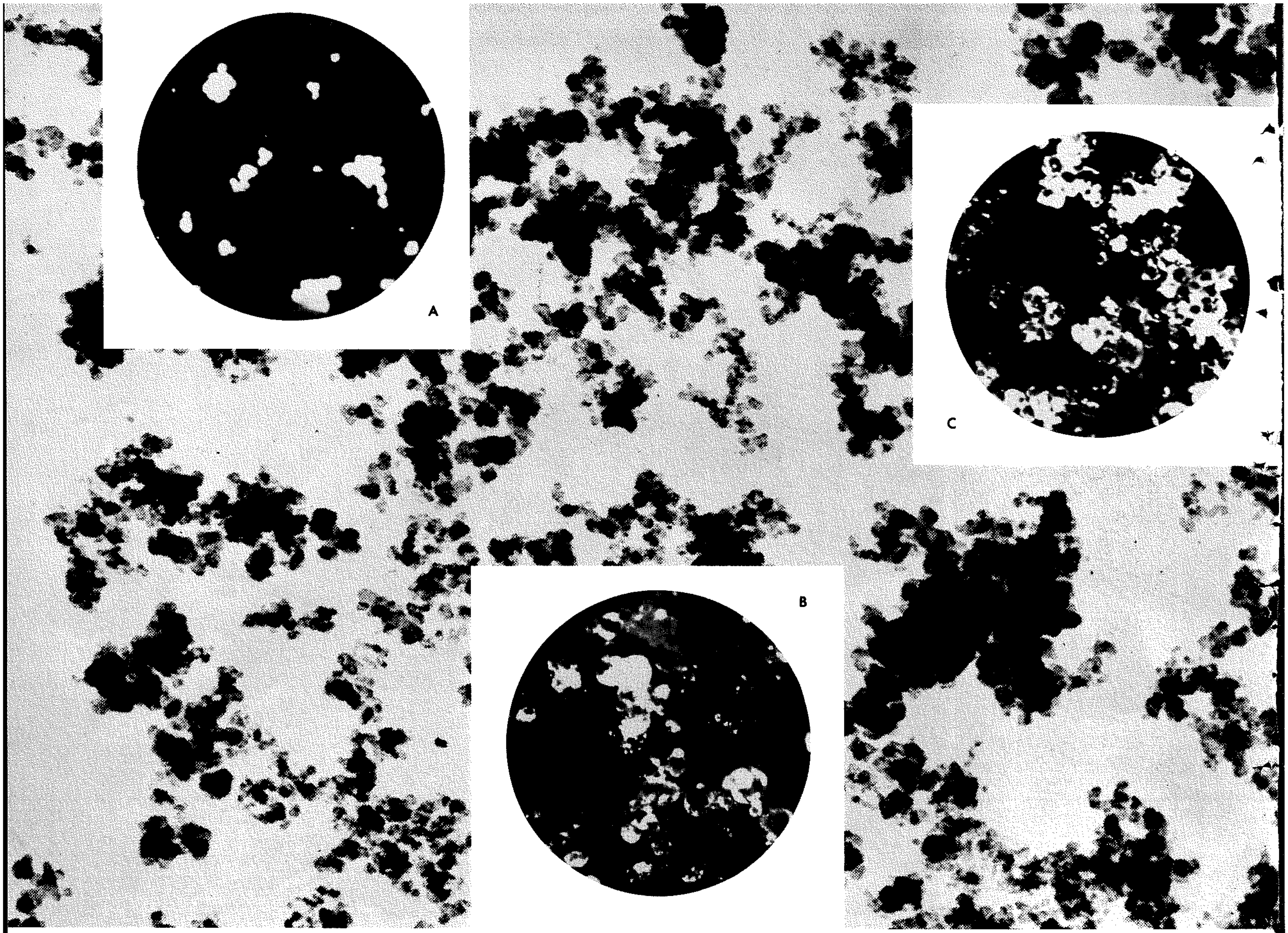
SUMMARY

The research activities of the RCA Victor Research Laboratories parallel, but do not duplicate, those of the David Sarnoff Research Center at Princeton. The research program has been chosen with due regard to the interests of the Canadian Company and to the programs not only of the Princeton Laboratories but also of other major laboratories in North America. Access to this work has been greatly assisted by association with Princeton, with whom communication has always been good.

While 80 to 90 percent of the research program is supported by outside contract, an active effort is continually made to direct the research in the best interests of the Canadian Company. In particular, every opportunity is taken to follow up new ideas that may result in new engineering data or new products which will improve the Company's competitive position in Canada.

Fig. 3—Miniature experimental alpha-particle monitors.





ANTI-STATIC PHONOGRAPH RECORDS

by **G. P. HUMFELD, Mgr.,**
Record Compound Development Group
RCA Victor Record Division
Indianapolis, Ind.

Since the advent of 45's and L.P.'s, record users have become acquainted with static electricity on disk surfaces causing accumulations of dust and lint in star-like patterns and swirls. Attempts to remove the dirt usually result in a scratched surface of inferior playing quality.

Static electricity has been blamed unjustifiably for some record troubles. Reference is sometimes made to ticks and pops in the sound grooves as being due to the discharge of static electricity from the plastic surface to the cartridge or tone arm. It is doubtful if this is true. Usually these sounds are caused by surface imperfections resulting from poor molding in the factory or mishandling and scratching during use by the customer.

The plastic materials normally selected for use in the manufacture of records are notorious in their ability to pick up and hold for a long period of time a high static charge. Usually, the higher the record quality the purer the composition, and therefore the greater the static charge. This has been unfortunate as far as the customer is concerned.

The first strong charge is created on a record at the time of its manufacture. It develops at the moment when the record is separated from the surfaces of the cavity in which it is molded. In the hands of the customer, additional charges can be built up by pulling the record out of its jacket. Therefore, without some permanently effective method of reducing the disk's static charge the customer is continually confronted with it as a problem.

ANTI-STATIC METHODS

Over the years, many gimmicks have been placed on the market to minimize or eliminate the tendency of a record to pick up and carry a static charge.

First in this category is the large group of wetting agents or detergents. These can be mixed in minute quantities with tap water (about a 1-percent solution, or a teaspoon to one quart of water) to make up a wiping solution. A lint-free cloth moistened with this solution will effectively clean disk surfaces and impart some anti-static effect. Its effectiveness is limited to relative humidity values above 35 percent. It has no lasting value, because a cloth dampened with water alone will wipe off most of the coating.

Other devices depend upon air ioniza-

Fig. 1—(Background photo) Electron microscope view of conductive carbon black.

Fig. 2—(Insets in Fig. 1) Vinyl particles, showing difference in particle shape between suppliers A, B, and C.

tion to reduce the static charge on a record. They employ materials like polonium in combination with a brush which removes the dirt as the record surface and particles are freed of their charge.

Work on anti-static records started almost as soon as L.P.'s and 45's appeared on the market. Three general methods of attack were employed: 1) Coat records with films which would improve surface conductivity to the point where the records would not hold a charge. 2) Mix into the record plastic a conductive carbon black following the principles used in making molded rubber articles conductive. 3) Mix into the record compound a material which possessed only limited compatibility with the ingredients in the mix; by careful control of the quantity added to the mix, a controlled bleed-out might reduce surface resistivity to the point where anti-static properties could be obtained.

THIN-FILM COATINGS

Considerable time was spent on method one. Records were coated with thin films of such materials as titanium tetrachloride, platinum chloride, and tin chloride. None of these produced films that were effective in reducing surface conductivity.

An attempt was made to sulfonate a vinyl record surface in a manner similar to that performed on polystyrene records, as described in U.S. Patent 7,727,831. Sulfonation did not occur under short exposures. Time intervals in the order of 20 minutes at temperatures of 120° to 140°F reduced surface resistivity, indicating that sulfonation might have occurred. The vinyls, however, decomposed under this severe treatment in concentrated H_2SO_4 and then in 20-percent NaOH. It may have been the resulting decomposition products which reduced the resistivity values.

A number of surface active agents were evaluated (see Table I). Records were treated by dipping them in 0.1-, 1-, or 10-percent solutions of the various materials. This was followed by a dry spinning step. Surface resistance was measured using the method described in ASTM designation D-257-52T.

The surface resistance at which a coating is effectively anti-static at a particular humidity is not specifically known. The literature contains many references ranging from very low values for surface resistance to fairly high values at which a surface may be considered anti-static. Therefore, we have assumed the arbitrary range of values of 10^9 to 10^{11} ohms as being low enough to produce desirable anti-static properties for phonograph records. Using this range of values as a tentative standard, none of the materials listed in Table I were effective in 0.1-percent solutions at low humidity. Coatings of Zelec NK (E. I. du Pont Co.) from 1-percent solutions were effectively anti-static, but were badly stained and were wiped off readily with a damp cloth. From this work it was felt that a coated record would not give the high quality anti-static disk desired.

TABLE I SURFACE RESISTIVITY, OHMS

Product	*Relative Humidity, %*	*Surface Resistivity, ohms, at Various Concentrations in Water*		
		0.1%	1%	10%
Niatex AG-2	10	6×10^{13}	3×10^{10}	6×10^{8}
	52	3×10^{13}	5×10^{11}	2×10^{9}
Tergitol Nonionic TMN	10	7×10^{15}	3×10^{15}	8×10^{12}
	52	7×10^{14}	3×10^{14}	8×10^{12}
Tergitol Nonionic NPX	10	8×10^{15}	4×10^{14}	6×10^{12}
	52	6×10^{15}	8×10^{14}	7×10^{11}
Tergitol Nonionic NP-27	10	1×10^{16}	5×10^{15}	2×10^{13}
	52	1×10^{16}	6×10^{14}	3×10^{12}
Carbowax 200	10	1×10^{16}	1×10^{16}	1×10^{13}
	52	1×10^{16}	8×10^{14}	1×10^{13}
Propylene Glycol	10	1×10^{16}	1×10^{16}	1×10^{16}
	52	1×10^{16}	1×10^{16}	1×10^{16}
Ucon Lubricant 50-HB-3520	10	1×10^{16}	3×10^{14}	2×10^{13}
	52	8×10^{15}	1×10^{14}	3×10^{12}
Ucon Lubricant 50-HB-55	10	1×10^{16}	1×10^{16}	8×10^{14}
	52	1×10^{16}	1×10^{16}	8×10^{14}
Zelec DP	10	1×10^{16}	1×10^{13}	4×10^{10}
	52	8×10^{15}	6×10^{10}	1×10^{9}
Zelec DK	10	4×10^{15}	3×10^{12}	5×10^{10}
	52	1×10^{14}	2×10^{11}	9×10^{8}
Zelec NE	10	6×10^{15}	2×10^{17}	3×10^{9}
	52	3×10^{15}	6×10^{11}	8×10^{8}
Zelec NK	10	1×10^{16}	7×10^{10}	4×10^{9}
	52	5×10^{14}	6×10^{12}	9×10^{9}

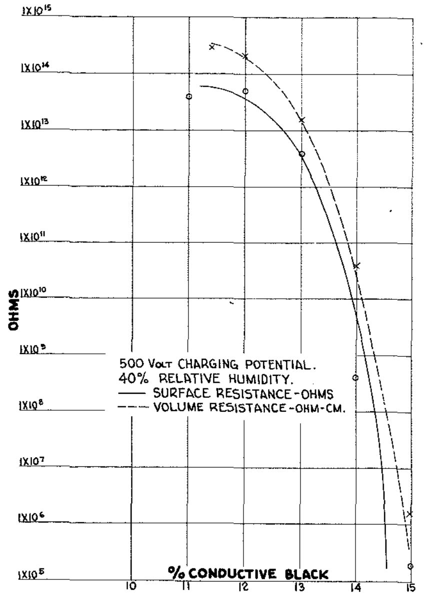


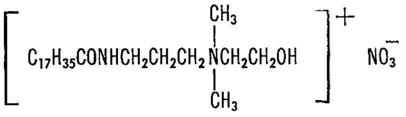
Fig. 3—Resistance of record compound with 11 to 15 percent of conductive carbon black.

CARBON-BLACK MIX

Method two, employing the use of a conductive carbon black, was investigated quite thoroughly. The so called acetylene blacks and high-structure furnace blacks were employed in this study. An electron microscope view of this type of carbon black is shown in Fig. 1. Experience showed there is a threshold loading that must be reached before any conductivity can be obtained. This value appears to be around 13-percent (by weight) loading of these special blacks in the plastic material. From this value, further loading improves conductivity, as shown in Fig. 3. Unfortunately, this type of formulation presents many difficulties: 1) it is extremely slow to fuse in a banbury mixer; 2) the presence of the carbon black reduces the strength and flexibility of the plastic composition below the normally accepted safe values; 3) the audio properties of disks made from such a mix are poor because of a steady hiss caused by the carbon black in the plastic and 4) it is extremely difficult to mold into perfect L.P. records. Anti-static properties were very good. Surface resistivity values of around 9 × 10^6 were measured. In spite of the good anti-static properties, this method was rejected as not being commercially feasible.

CATIONIC MATERIALS

Method three was the only alternative left that showed any possibility of success. More than 100 different materials have been tested over the last ten years as possible ingredients for milling into a vinyl record mix to reduce surface resistivity to a satisfactory value. Greatest success was obtained from a family of cationic materials supplied by the American Cyanamid Company. It was established rather early in the work that a quaternary ammonium salt gave the best compromise between compatibility and limited bleed-out to the disc surface necessary to produce this anti-static effect. Catanac SN was selected as being the most effective member of this family of compounds. American Cyanamid indicates its structure is as follows:



$$\left[C_{17}H_{35}CONHCH_2CH_2CH_2\overset{CH_3}{\underset{CH_3}{N}}CH_2CH_2OH \right]^{+} NO_3^{-}$$

stearamidopropyldimethyl-β-hydroxyethylammonium nitrate

A concentration of about 1.3 percent by weight mixed into the resin seemed to give optimum results. Tests in the factory however, showed it could not be added directly in the banburys to get a sufficiently uniform mix to produce good records. Stains were encountered on the record surface and very spotty noise in certain portions of the record indicated that a better mixing procedure was needed. The leading vinyl suppliers were called in and shown the problem. The request was made that they attempt to coat their resin with the agent during manufacturing to get a uniform coating on each particle of material. Each one achieved some degree of success in this work. However, particle shape plays a very important part in this process. Fig. 2 shows the difference in particle shape between suppliers A, B, and C. Experience has shown that coated materials like B and C tend to cake or block during storage. This causes handling difficulties in the compound plant. On the other hand, supplier A has produced a dry, free-flowing powder that processes without difficulty. More recently, work on the part of other vinyl manufacturers has shown that several of them have been able to modify the particle size distribution and shape of their resins to such an extent that they can supply a coated resin which is dry and free flowing.

COATED-RESIN PRODUCTION

The first production lots of coated resin were made available for test in early 1959. Results were promising, but refinements were needed to put the product on a commercial basis. An unofficial committee consisting of Steve Ransburg of our own engineering staff (now Manager of Manufacturing in the new Magnetic Tape Plant of the Record Division), Steve Crum of Union Carbide Plastics Company, and Frank Miner of American Cyanamide set up a crash program using the full support and know-how from each organization to solve the remaining problems and carry out the refinements necessary to make a fully commercial product. A series of runs were made to determine the upper and lower control limits of the Catanac SN content. Banbury cycles and processing temperatures were studied to determine their effect upon the anti-static properties. Formulation modifications were made to determine the effect of different types and concentrations of carbon black and heat stabilizer upon the anti-static properties.

In a three-month period extending from April through June, most of these points were evaluated and a satisfactory product was developed so that production could get underway by July 1, 1959.

Recognition should be given to Amel Vitalis and others of the American Cyanamid staff who developed analytical procedures for measuring the catanac content of the resin and who aided in the evaluation of surface molding imperfections caused by the presence of the Catanac SN. Recognition also goes to George Graeber of Union Carbide Plastics and his staff at Texas City for their efforts in learning how to produce a uniformly coated resin of high quality. In our own organization, recognition should be given to all people connected with R. O. Price's organization, who worked so diligently to make this crash program come to a successful ending.

SUMMARY

To the customer, for whom we all really work, we have given the following:

1) A record, labelled *Miracle Surface*, which is free of static charge;
2) A record which will not attract and hold lint and dust to its surface;
3) A record capable of being easily cleaned of lint and dust which may settle out on it when left lying out unprotected;
4) A record that will have better sound qualities over a longer period of time in the hands of the customer because of the freedom from lint and dust; and
5) Another "first" to the consumer under the name of RCA.

GEORGE P. HUMFELD graduated from Purdue University in 1937 with a B.S. degree in Chemical Engineering. He worked as a chemist in a nonferrous foundry for five years after graduation and then joined U.S. Rubber Company as a rubber compounder during the war years. He joined RCA in 1946 as an engineer in the Record Compound group and in 1947 was appointed group leader. In 1956 he was appointed Manager of this group. He is a member of the American Chemical Society and the Society of Plastics Engineers.

TUBES FOR HIGH-FIDELITY
Part II. Power-Output Types

by **M. Y. EPSTEIN***
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Part I of this paper in Vol. 5, No. 2 described new RCA tube types intended for use in the input circuits of high-fidelity audio equipment. This part discusses audio power-output tubes recently added to the RCA line, including the 6973, 6L6-GC, and 7027-A beam power tubes, and the 6BQ5 and EH5-family pentodes. Although the pentode types, in particular the EH5 series, are not normally considered high-fidelity tubes, their high power sensitivity and lower cost make them desirable for certain applications.

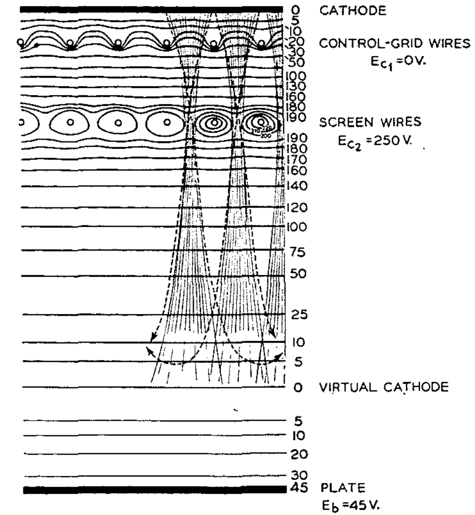

Fig. 3 — Alignment of grid lateral wires and focusing of electron stream in a beam power tube.

THE MAJOR REQUIREMENTS for an audio power tube are high efficiency, good power sensitivity, low distortion, and low internal tube impedance. The tube impedance shunts the plate load, and a low impedance is effective in damping out undesirable output peaks caused by the large resonant response of the loudspeaker at certain frequencies. This feature suggests the use of a triode rather than a pentode as an output tube. However, the plate potential of a triode is at the lowest value of its voltage swing just when the greatest cathode current is required, as shown in Fig. 1-a. A pentode, on the other hand, always has a large, fixed value of screen-grid voltage available to draw current from the cathode regardless of how the plate voltage varies, as shown in Fig. 1-b. Consequently, the cathode size (and hence the heater power) of a triode must be significantly greater than that of a pentode supplying equivalent current.

Because the cost of a power tube is almost directly proportional to its cathode size, the more efficient pentode or beam power tube is almost invariably used in modern-day audio systems in preference to the triode. The advantage of the triode's low internal impedance is thus sacrificed, but loudspeaker damping for the high-internal-impedance pentodes is easily obtained by feedback networks and by external resistance-capacitance shunting of the loudspeaker load.

POWER OUTPUT AND EFFICIENCY

Fig. 2 shows plate characteristics for a theoretically perfect pentode and a practical pentode. Power output is readily calculated from these curves as follows: $P.O. = (E_{max}-E_{min})\,(I_{max}-I_{min})/8$. For increased power output and efficiency of the practical tube, it would be necessary both to lower the knee voltage and to reduce the current that is lost to the screen grid. The knee voltage has a finite value because the negative charge of the electrons passing through the screen grid produces a potential dip in front of the plate. At low plate potentials, the attractive force of the plate is not strong enough to pull all the electrons through this space-charge barrier, and many return to be picked up by the screen grid. At plate potentials higher than the knee voltage (the voltage at which the plate overcomes the space-charge dip), all electrons passing through the screen-grid wires reach the plate. Screen-grid current exists even at high plate potentials, however, due to the cathode current that flows directly into the screen-grid wires.

Beam power tubes operate at higher efficiencies than pentodes because the alignment of the control grid and screen grid greatly reduces both the direct interception of current by the screen grid and the tendency of the electrons to return to the screen grid at low plate potentials[1], as shown in Fig. 3. The electron lens formed by the aligned grids in a beam power tube is designed so that the electrons emitted from the cathode are formed into beams that come to a relatively sharp focal point in the plane of the screen grid between the screen-grid wires. Furthermore, the shape of the electron beams causes the electrons to pass into the region beyond the screen grid along well-directed paths so that there is little tendency for the electrons to turn around and return to the screen grid. This feature increases the effectiveness of the plate potential in assisting the electrons in their forward direction, and thus lowers the knee voltage. The many electron beams combine uniformly in front of the plate to form a space-charge-potential minimum that prevents the flow of secondary-emission electrons from the plate to the screen grid.

In conventional pentodes, little effort is made to direct individual electrons and, consequently, many electrons flow directly into the screen-grid wires or follow curved paths that cause the electrons to return to the screen grid even after they have passed through it. The randomly directed electrons combine nonuniformly in front of the plate so that a special suppressor grid is required to prevent the flow of secondary electrons from the plate to the screen grid.

Many studies have shown a strong inverse relationship between tube life and dependability and tube tempera-

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* Now with RCA Laboratories.

Fig. 1 — Comparison between triode and pentode power-output tubes.

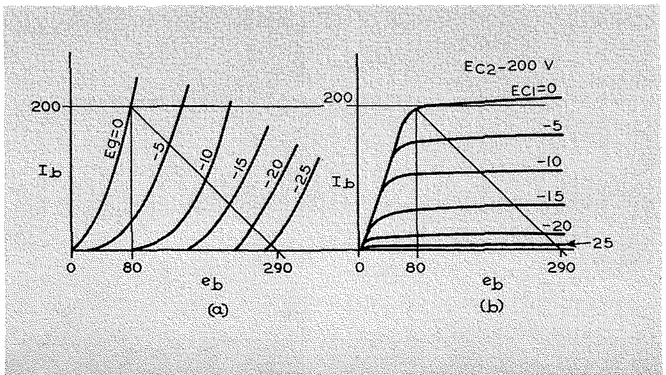
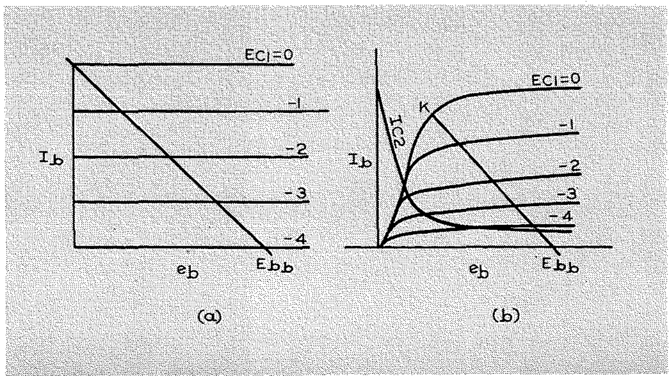


Fig. 2 — Comparison between a perfect pentode and a practical pentode.



ture. The higher the tube temperature, the greater is the danger of tube failure from grid emission, insulation breakdown of the glass between the electrode lead-in wires, and cathode poisoning from gases evolved from the hot electrodes.

Within the lower power-output ranges, heat removal from the tubes is generally no problem, and small power pentodes enjoy a cost advantage over beam power tubes because the alignment of the grids in beam power tubes requires extra care and effort. Within the higher power ranges, however, heat removal is a problem, and the cost of providing means for such removal becomes a major factor in over-all tube cost. Consequently, in spite of the relatively costly grid-alignment process, the efficient beam power tubes are less expensive to fabricate than are the less efficient pentodes.

The 6L6-GC and 7027-A beam tubes are specially designed to produce high power output with long life and dependability at low cost. High voltage ratings are achieved by the use of special high-resistance glass and careful spacing and insulation of the electrodes. Large quantities of heat are drained from the tubes by radiation from large fins and from the black-body plate, and by conduction through low-thermal-resistance electrodes and connecting leads.

Both the 6L6-GC and the 7027-A plates use 11-mil, carburized nickel-clad steel instead of the 6- or 7-mil material normally used in RCA receiving power tubes. Fig. 4 shows a temperature comparison between plates using 7-mil carburized-nickel-clad steel and 7-mil copper-cored steel.[2] The plate material used in the 6L6-GC and 7027-A gives results comparable to those obtained with copper-cored steel, but is less expensive. Because the electron stream impinges on the plate only over a small portion of its area, hot spots tend to form on the plate that give off cathode-poisoning gases. The thicker material used in the 6L6-GC and 7027-A rapidly dissipates the heat and prevents hot-spot formation. Use of 11-mil plate material on the 6L6-GC increased its possible plate dissipation by 40 percent as compared to that of the 6L6-GB.

The control-grid lateral wires of both the 6L6-GC and the 7027-A are made of high-work-function and low-thermal-resistance gold-plated molybdenum to lower the temperature of the grid and to prevent grid emission.

Fig. 4 — Temperature curves for plates using carburized-nickel-clad steel (A) and copper-cored steel (B). All parts 0.007 inch thick.

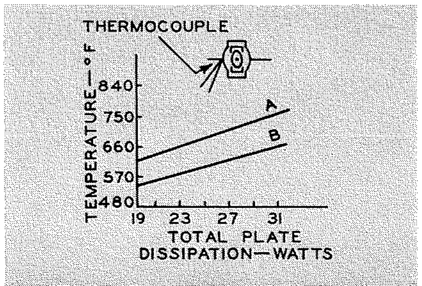
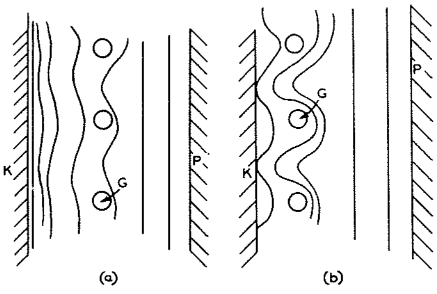


Fig. 5 — Illustration of inselbildung effect.



POWER SENSITIVITY

For a given power output, the necessary grid-driving voltage and the required voltage amplification of the input signal are largely determined by the power sensitivity ($P.S. = P.O./E_g^2$) of the output tube. In low-cost systems where each stage of the complete system is pushed to its maximum output, the available driving voltage is often limited and high-power-sensitivity output tubes are essential. In higher-priced systems, however, power sensitivity usually plays a secondary role to tube efficiency and distortion.

Part I of this article discussed the *inselbildung* effect in reference to microphonics. Actually, this phenomenon plays a major role in many aspects of tube design, and is especially pertinent to a discussion on power sensitivity.

When the ratio of control-grid-to-cathode spacing (D_{g1k}) to control-grid-turns pitch ($1/TPI$) becomes less than unity, the electrostatic fields at the surface of the cathode lose their uniformity and "islands" of potential are formed, as shown in Fig. 5. Consequently, electrons emitted from different sections of the cathode are exposed to different electrostatic fields and, in effect, are controlled to varying degrees by the instantaneous potentials on the control grid. Measured tube characteristics, therefore, are actually the summation of many tiny tube sections in parallel.

The family of curves in Fig. 6 shows the variation of amplification factor (μ) over the length of the cathode. These curves are normalized with respect to the composite calculated tube amplification factor. As would be expected, the cathode sections furthest from the grid turns are the least controlled by the grid, i.e., have the lowest values of amplification factor (μ). As the control grid becomes more negative, therefore, the electron emission of the high-μ sections of the cathode is cut off quickly, and the tube characteristics are established by the sections which are more difficult to control. Thus, for close-spaced tubes, μ is hardly a constant, but varies in some inverse manner with grid bias. The effects of this variation on power sensitivity can be explained as follows:

Plate current and grid voltage are related primarily by the following expression:

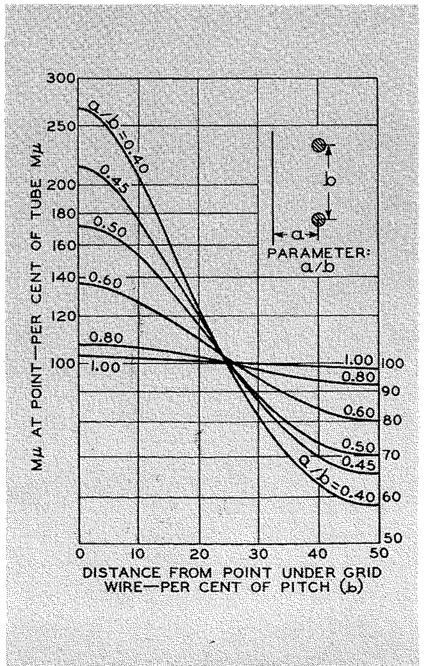
$$I_b = f\frac{\left(-E_g + \frac{E_{c2}}{\mu}\right)^{3/2}}{(D_{g1k})^2}$$

Where, I_b is the plate current, E_g is the control-grid voltage, E_{c2} is the screen-grid voltage, μ is the triode amplification factor, and D_{g1k} is the control-grid-to-cathode spacing.

At maximum power output, the amount of power output depends on plate-current swing, or maximum current at zero bias. (It is assumed that the tube is cut off at the other end of its grid-voltage swing.) Power sensitivity is determined both by the power output and by the grid-signal voltage. Thus, to raise power sensitivity (with a given cathode and heater power) it is necessary to raise the power output or to lower the signal voltage required to drive the tube from zero bias to cut-off (for maximum output). Thus, E_g may be considered as the voltage required to cut off the tube; from the above equation, $E_g = E_{c2}/\mu$.

Raising the cutoff value of μ to lower E_g unfortunately also tends to lower I_b and $P.O.$ A decrease in D_{g1k} would increase I_b and $P.O.$, but because of the inselbildung effects noted above, would tend to lower the cut-off μ and thus require an increase in E_g again. There are two different μ values of concern here. One is the value of μ at cutoff, which affects E_g; the other is the value

Fig. 6 — Variation of amplification factor along length of cathode.



of μ at zero bias, which controls I_b and $P.O.$ The two are related by means of the geometry of the tube (Fig. 2).

Thus, a decrease in D_{g1k} tends to lower the cutoff μ and requires an increase of the grid turns per inch (TPI) to maintain the a/b ratio parameter of Fig. 6. Higher TPI, of course, improves the shielding effects of the grid and undesirably raises the zero-bias μ. This effect may then be countered by the use of fine grid lateral wire. The net result is that, in order to raise power sensitivity, it is necessary to reduce the electrode spacings and to use high TPI and fine-wire grids. Limitations, then, on possible power sensitivities occur mostly from the mechanical problems of making the various parts and of combining them into a structurally sound tube.

Beam power tubes are far more sensitive to these restrictions than pentodes because of their need for proper alignment of the lateral wires of the control and screen grids. The limitations imposed by present grid-making and tube-assembly techniques are so severe that the TPI of beam-tube grids can be only about half that of grids available for pentodes.

With present techniques, the tube designer has just about reached the mechanical limits in his attempts to improve power sensitivity. New techniques are required and are being developed. The most spectacular new development, of course, is the nuvistor. As a power tube, the nuvistor will be a beam power tetrode or pentode whose unique construction will permit the use of automatically aligned grids with relatively small electrode spacings, small grid pitch, and fine-wire grids. For conventional structures, new grid forms, such as the frame grid, are being developed which will also permit automatic alignment with higher-TPI grids, and higher power sensitivity.

DISTORTION

The most significant aspect of the high-fidelity audio system and hence the high-fidelity tube is, of course, its distortion level. Distortion is generally described in terms of percentage of total output, i.e., total distorted output divided by total output. However, total distortion consists of many component parts, some more objectionable than others. For example, the normal push-pull type of output circuit tends to cancel even-order harmonic distortion present in the tube outputs. Furthermore, high levels of even-order harmonic distortion are not especially objectionable, whereas even small amounts of odd order harmonic distortion are objectionable.

Vacuum tubes are inherently nonlinear devices because the tube currents vary with the electrode voltages to powers other than one. However, the tube designer can control the power to which plate current varies with control-grid voltage to some extent by proper grid-geometry design. In addition, under dynamic conditions, the choice of load line will determine the amplitude relations between the control-grid voltage and the plate voltage. Together, these two factors may be used to shape the dynamic transfer characteristic of the tube and hence to determine the nature of distortion that the tube will generate.

Again, the inselbildung effect is significant. Severe changes in curvature of the tail of the tube transfer characteristic are caused by the variation in amplification factor as the high-μ sections of the cathode are suddenly and completely cut off with increasing negative grid voltage, as described above. Because operation of the tube in this region of the transfer curve produces extra distortion of high harmonic order, the tube designer must compromise between high power output at low distortion (obtained by high a/b ratios and cutoff μ's) and high-power-sensitivity tubes with high-μ, high-TPI grids operating in the inselbildung regions.

The 6L6 beam power tube was originally designed to produce a square-law dynamic characteristic when operated at its maximum power-output point (i.e., with its load line intersecting the knee of the e_b-i_b family of curves), and its harmonic content is composed almost exclusively of the second harmonic. The 6L6-GC, 7027-A, and 6973 are similar in this respect to the original 6L6 and, therefore, provide excellent low-distortion power output when operated in push-pull. At maximum levels of output, these tubes can be operated with less than 2-percent total distortion.

In pentodes, unfortunately, the grid geometries necessary to provide high power sensitivity tend to produce odd-order harmonic distortion when the load lines are chosen to produce maximum power output. When sufficient negative feedback voltage to reduce distortion is used, however, high-sensitivity pentodes such as the EH5 and 6BQ5 tubes provide satisfactory performance in low-cost, good-quality audio systems.

The difference between pentode and beam-power-tube performance is shown by a comparison between the 6973 and the 6BQ5. The 6973 beam power tube is designed for high-efficiency, high-quality, medium-power systems. Although the 6BQ5 pentode, which operates in the same power range, has four times the power sensitivity of the 6973, the 6973 has lower distortion, higher tube efficiency, and lower heater power than the 6BQ5. At the relatively low power levels at which these tubes operate, however, tube cost and over-all system cost are largely determined by the power sensitivity, with tube efficiency playing somewhat of a secondary role. As a result, the 6BQ5 has gained wide popularity along with the more expensive 6973.

STEREOPHONIC REPRODUCTION

Stereophonic reproduction is still too new to evaluate its effects on tube requirements. Although present tubes are being used satisfactorily, it is likely that more multiple-unit tubes will be designed, and that some special-purpose tubes will be required for the various new signal-mixing systems presently being contemplated.

Recently, RCA engineers demonstrated a low-cost stereo system designed around a new high-perveance beam power tube of the glass-octal type, specifically designed by the Electron Tube Division for use in the audio-output stage. This high-perveance tube—the RCA-50FE5—features high power sensitivity at low supply voltages. With a plate voltage of 130 volts, it is capable of delivering 3.5 watts at 10-percent distortion in single-ended audio-amplifier service. This amount of power was formerly obtained at low supply voltages by the use of two power-output tubes in push-pull service. Therefore, the RCA-50FE5 makes possible the design of compact, low-cost, three-tube stereo systems having relatively high power output. It is anticipated that this approach will become quite popular.

ACKNOWLEDGMENT

The author wishes to thank T. Boyer for his helpful discussions and assistance.

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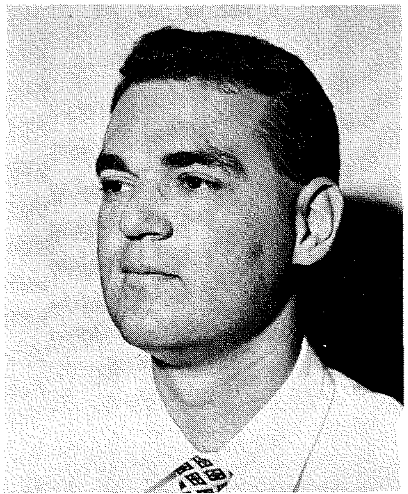


MULTIPLE-SUBCARRIER FM MULTIPLEX SYSTEMS

by **R. C. MULLICK and H. K. SCHLEGELMILCH**
Advanced Development
RCA Victor Home Instruments
Cherry Hill, N. J.

THE PRESENT practice of multiplexing by FM broadcast stations provides additional nonbroadcast services by impressing information on the subcarriers. This type of subcarrier operation (referred to as SCA) is accomplished without significantly degrading the main channel transmission. Operation to date has been limited to a 3-db audio signal-to-noise reduction of the main channel, but a 6-db reduction may be allowable.

With 50-percent modulation available, subcarriers can be suitably placed in such a manner as to provide two SCA services and a third for stereo broadcast service, each performing as well or better than existing multiplex transmissions.

ENGINEERING MEASUREMENTS

Practical evaluation of any multiplex subcarrier system requires performance data on signal-to-noise (S:N) ratios at the audio output, crosstalk, and distortion. The engineering laboratory setup of Fig. 1 employed two RCA BTX-1A subcarrier generators to obtain measurements on systems requiring modulated subcarriers for the SCA and stereo channels.

Audio modulation was supplied by Hewlett-Packard Model 200CD wide-range oscillators for the subcarrier and main channels; these same oscillators were utilized as unmodulated subcarrier sources. Necessary filtering at the outputs of the BTX-1A generators was added before feeding signals to the mixer. For isolation, the mixer contained a separate cathode follower for each input, and the outputs were resistively mixed and impressed on a Boonton Radio 202E FM-AM signal generator.

The test receiver side consisted of a Sherwood S-3000 FM tuner, modified with a cathode-follower output stage and followed by suitable preselector filters for the measurements. A circuit responsive only to frequency was utilized for the subcarrier FM detectors. These were followed by audio filters, at which point (D in Fig. 1) double-FM S:N measurements were made. Measurements that included 75-μsec de-emphasis were made at point E. First-FM S:N measurements were made at point C. Ballantine Laboratories Model 310A and Model 314 electronic voltmeters were used to measure S:N ratios.

SIGNAL-TO-NOISE RATIO INVESTIGATION

A general investigation of S:N ratios for single and double FM was made.

Single FM

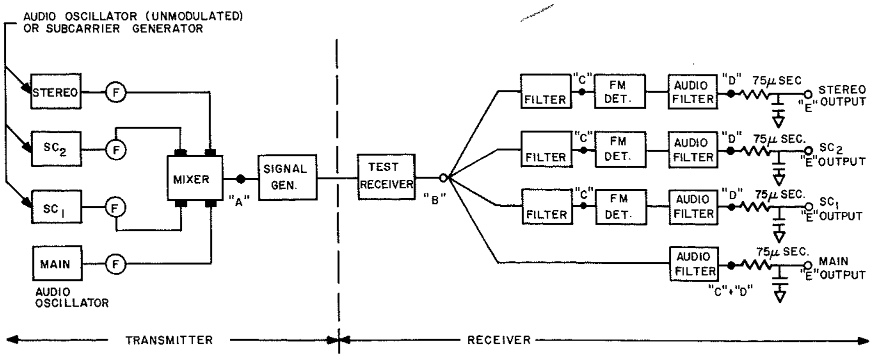
For single FM, the S:N of the final audio ($S{:}N_a$) for sinusoidal-signal and thermal-noise components is:

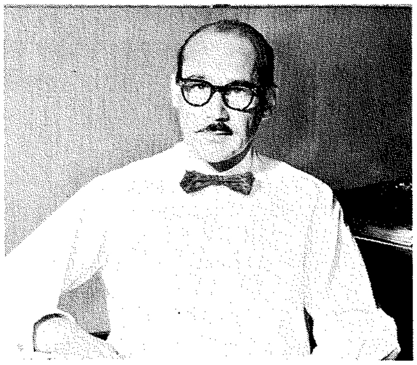
$$S{:}N_a = \sqrt{3}\left(\frac{F_{a_1}}{\sqrt{f_2^3 - f_1^3}}\right)\frac{1}{N.F.}\quad (C{:}N) \qquad (1)$$

Where: F_{a_1} = peak deviation of carrier, in kc; f_2 = upper cutoff frequency, in kc, of the receiver audio output band-pass filter; f_1 = lower cutoff frequency, in kc, of the receiver audio output band-pass filter; $N.F.$ = noise factor of the receiver (50-ohms input impedance); and $C{:}N = C/\sqrt{4KTR(2\times10^3)}$, where C = rms open-circuit signal voltage from the source, R = source resistance (50 ohms), K = Boltzman's constant, and T = absolute temperature (295°K).

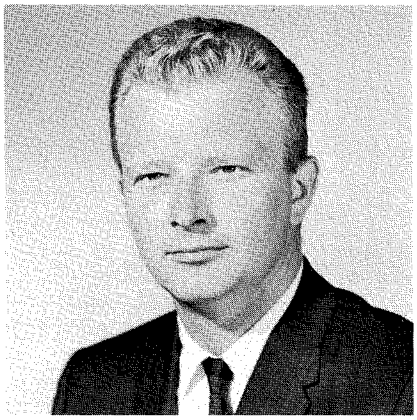
Table I indicates the measured and calculated S:N values for first-FM using

Fig. 1—Engineering laboratory setup for evaluation of multiplex subcarrier systems.





R. C. MULLICK received the B.Sc. degree in EE and Honors Diploma in General Engineering from London University in 1934. Following graduation, Mr. Mullick was with The Gramophone Co., Ltd. in England as a development engineer on domestic radio. Later at Burndept, Ltd. he became Chief Physicist on electronic apparatus for the service. While with Philips for eight years as Mgr. of Components Laboratories, he was engaged in industry and Ministry of Supply work and later concerned with domestic radio and TV advanced development. After three years at Cottage Laboratories working on underwater-detection projects and electronic displays for the Admiralty, Mr. Mullick joined RCA Victor Company, Ltd., Montreal, Canada, on an RCAF Contract. In 1956, he transferred to RCA Home Instruments at Cherry Hill, N. J. where he is currently associated with Advanced Development.



HARRY K. SCHLEGELMILCH became a member of the Specialized Trainee Program at RCA upon receiving a BEE degree from New York University in 1952. That year he also entered the Signal Corps and was assigned at the OIC Electronic Maintenance Branch of the Army Aviation Center at Ft. Monmouth, N. J. After discharge in 1954, he rejoined RCA in TV Advanced Development, working on TV antenna multiplex systems, application of transistors to black-and-white and color-TV receivers, parametric devices, and FM multiplex systems. He is currently working on communications systems in the Microwave and RF group of the Airborne Systems Division, DEP. Mr. Schlegelmilch is a member of the IRE.

TABLE I. FIRST-FM S:N RATIOS FOR VARYING TUNER NOISE FACTORS

F_d = 37.5 kc; f_a = 15 kc (LP filter); 75-μsec de-emphasis; 10-μv signal (50 ohms).

Noise Factor, db	*S:N Ratio, db*	
	Calculated	*Measured*
4.5	57.5	57
6	56	55.4
11.5	50.5	50
29	33.0	32.2*

*Measured with no de-emphasis and at 100 μv, then corrected for above conditions.

TABLE II. S:N RATIOS FOR THREE-SUBCARRIER SYSTEM "A"

Rcvr. N.F. = 6 db; Antenna Input = 10 μv

*Channel:**	*Main*		*SC_1*		*SC_2*		*Stereo*	
De-emphasis:	*None*	*75-μsec*	*None*	*75-μsec*	*None*	*75-μsec*	*None*	*75-μsec*
Audio BW (Actual)	f_a = 15 kc		f_α = 3.5 kc		f_α = 4.7 kc		f_α = 8 kc	
Preselector Filter	—		B.P.F. = 20–28 kc		B.P.F. = 34–38 kc		Single-Tuned F. = 54–80 kc	
S:N, db—Meas.	42.2	55.4	30.5	34.2	26.8	33.4	25.0	34.4
—Calc.	42.8	56.0	28.7	32.4	24.6	30.0	23.5	32.9
Audio BW (System)								
S:N, db—Meas. (corr.)	42.2	55.4	30.5	34.2	26.0	31.7	22.1	32.5
—Calc.	42.8	56.0	28.7	32.4	23.8	29.5	20.6	31.0
Degradation of System from 100-pct								
Main, db—Meas.	−6	−6	−17.7	−27.2	−22.2	−29.3	−26.1	−28.9
—Calc.	−6	−6	−20.1	−29.6	−25.0	−32.5	−28.2	−31.0

*Main: F_d = 37.5 kc; f_a (max) = 15 kc
SC_1: f_c = 24 kc; F_{d_1} = 9.375 kc; F_{d_2} = 3 kc; f_α (max) = 3.5 kc
SC_2: f_c = 41 kc; F_{d_1} = 9.375 kc; F_{d_2} = 5 kc; f_α (max) = 5 kc
Stereo: f_c = 67 kc; F_{d_1} = 18.750 kc; F_{d_2} = 8 kc; f_α (max) = 10 kc

TABLE III. CROSSTALK, THREE-SUBCARRIER SYSTEM "A"

Rcvr. N.F. = 6 db; Antenna Input = 1 μv.

Interfering Channel	*Modulation Freq., kc*	*Side-band* **	*Crosstalk, db*		*Calc. Atten. Req'd, db*
			Calc.	*Meas.*	
INTO MAIN:					
SC_1	3.5	2	—58.2	—54.5*	none
	3.5	3	—68	——	none
SC_2	max.	—	——	negl.*	
Stereo	max.	—	——	negl.*	
$SC_1 + SC_2$ + Stereo	Carriers	—	——	—52.5	
$SC_1 + SC_2$ + Stereo	3.5 (SC_1)	—	——	—50.5	
INTO SC_1:					
SC_2	5.	3	—40.2	—41*	9.8 xmtr.
	4.8	—	——	—39*	
	4.67	3	—37.5	——	12.5 xmtr.
	4.33	3	—39.7	——	10.3 xmtr.
	4	3	—47.7	—50*	2.3 xmtr.
SC_2 (with HP xmtr. filter, 34-kc cutoff)				<—50	
Main	15	1	—14	—48.5*	36 rcvr.
	12	1	—21	——	29 rcvr.
	5.25	2	—50	——	none
INTO SC_2:					
Main	12.67	3	—50	——	——
	1	—	——	—46.2*	
	2	—	——	—45.2*	
SC_1 (Carrier only; 2nd harmonic of 24 kc gives 7-kc beat)				—45.7*	
SC_1	0.4	—	——	—39.7*	
	3	3	—48.8	—35.7*	1.2 rcvr.
	3.5	3.5	—54	——	none
SC_1 (with LP xmtr. filter, 30-kc cutoff)				<—58	
Stereo	7.33	3	—36	—35.7*	14 xmtr.
	8.5	—	——	—46.7*	
	9	2	—38	—41.7*	15.6 xmtr.
	10	2	—34.4	—33.7*	12 xmtr.
Stereo (with HP xmtr. filter, 56-kc cutoff)				<—50	
INTO STEREO:					
SC_2	0.4	—	——	—59.3*	
	5	3	—57.2	—57.8*	none
Main + $SC_1 + SC_2$	0.4 (SC_2)	—	——	—56.3*	
	5 (SC_2)	—	——	—54.3*	

*No xmtr filters
**pertains to "calculated" crosstable values

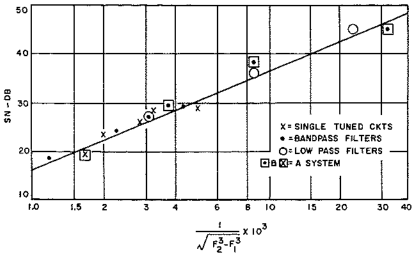


Fig. 2—Single-FM S:N at 10-μv input. Points are measurements using various filters. Solid line is S:N calculated from Equation 1 with N.F. = 4.5 db, F_{d_1} = 25 kc, and $f_2 - f_1$ = noise bandwidth of filter.

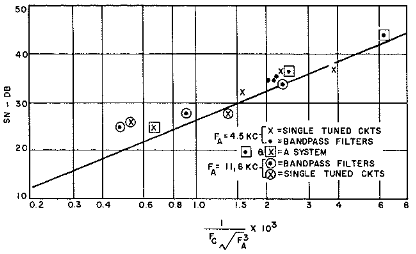


Fig. 3—S:N after second FM for 10-μv input. Points are measurements using various filters. Solid line is S:N calculated from Equation 2, with F_{d_1} = 25 kc, F_{d_2} = 4.5 kc, and N.F. = 4.5 db.

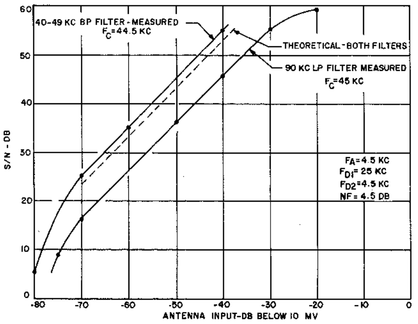


Fig. 4—Double-FM S:N with narrow- and wide-band preselection filters.

receivers exhibiting different tuner noise-factors. The calculated results using Equation 1 and a receiver noise-factor measurement show good agreement with the measured S:N. Additional measurements with varying conditions of audio cutoff, or bandpass selectivity after first FM, were made to observe the correlation of measured results with theory.

First-FM S:N measurements were taken using various filters (single-tuned circuits, bandpass, low-pass). These measurements are plotted as points in Fig. 2 against the remaining variable in Equation 1, the audio cutoff, or bandpass, condition, $(1/\sqrt{f_2^3 - f_1^3}) \times 10^3$. The solid line shows the *theoretical* S:N according to Equation 1. For single FM, the theory predicts to a good degree of accuracy the S:N for any audio cutoff (bandpass) and deviations imposed.

Double FM

The S:N ratio for double FM ($S = N_{f\alpha}$) is considered to be:

$$S{:}N_{f\alpha} = \sqrt{\frac{3}{2}}\;\frac{F_{d_1}}{f_c}\;\frac{F_{d_2}}{\sqrt{f_\alpha^3}}\;\frac{1}{N.F.}\,(C{:}N) \qquad (2)$$

Where: f_c = subcarrier frequency in kc; f_α = cutoff frequency, in kc, of the receiver audio output; F_{d_2} = peak audio deviation of the subcarrier, in kc; and F_{d_1}, *N.F.*, and *C:N* are defined as in Equation 1.

The measurements taken for double FM are plotted as points in Fig. 3. In this case, then, the abscissa becomes $(1/f_c\sqrt{f_\alpha^3}) \times 10^3$. The points plotted in Fig. 3 are for narrowband preselector filters (i.e., filter half-bandwidth $< 3\,f_\alpha$). The solid curve was plotted from Equation 2. In most cases, the measured points gave a better S:N ratio than

TABLE IV. CALCULATED CROSSTALK INTO SC$_1$; TWO-SUBCARRIER SYSTEM

SC$_1$ crosstalk into MAIN and STEREO <-50 db.

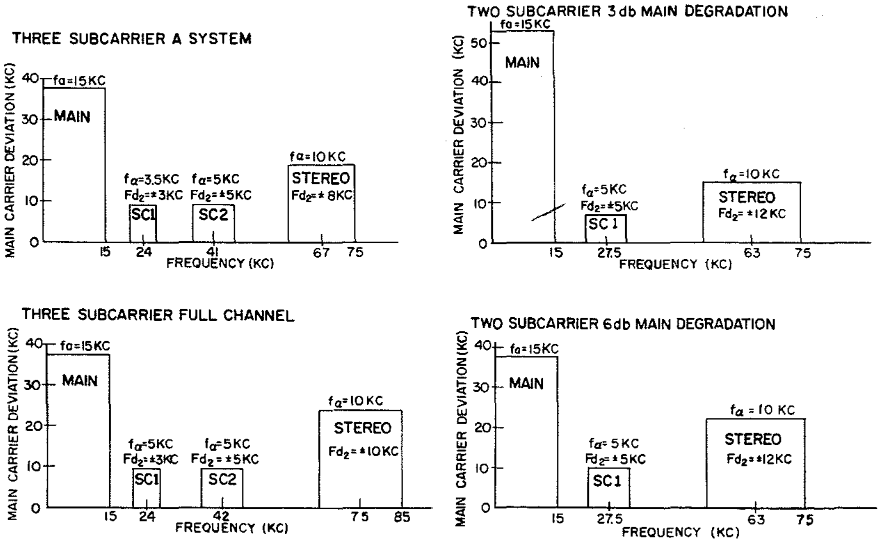
Interfering Channel	*Modulation Freq., kc*	*Side-band*	*Crosstalk into SC$_1$, db*	*Atten. Req'd, db*
		6-db Main-Channel Degradation*		
STEREO ($f_c = 63$ kc, $F_{d_1} = 27.5$ kc, $F_{d_2} = 12$ kc, $f_\alpha = 10$ kc)	10	4	−48.5	15.5 xmtr.
	10	3	−34.8	
	9	4	−53.7	3.6 rcvr.
	9	3	−47.2	
	8	4	−38.1	11.9 xmtr.
	8	3	−52.3	——
MAIN ($F_{d_1} = 37.5$ kc, $f_a = 15$ kc	15	1	28.5	21.5 rcvr.
		3-db Main-Channel Degradation**		
STEREO ($F_{d_1} = 15$ kc)	10	4	−50.7	13 xmtr.
	10	3	−37	
	9	4	−55.9	1.4 rcvr.
	9	3	−49.4	
	8	4	−40.3	9.7 xmtr.
	8	3	−54.3	——
MAIN ($F_{d_1} = 53$ kc, $f_a = 15$ kc)	15	1	22.4	27.6 rcvr.

*SC$_1$: $f_c = 27.5$ kc, $F_{d_1} = 10$ kc, $F_{d_2} = 5$ kc, $f_\alpha = 5$ kc
**SC$_1$: $F_{d_1} = 7$ kc

Equation 2 predicts. One source of error is that in the calculation, the smallest bandwidth was used for f_α. If the preselector and audio bandwidths are on the same order, a more accurate calculation should include the overall bandpass characteristics of all filters that limit the final audio, which may result in a still-narrower bandwidth.

Fig. 4 indicates, however, that for practical purposes the relative double-FM performance for a given receiver follows closely the theoretical curve from Equation 2 for narrow-band preselection filters. For the case of wide-band preselector filters, however, some discrepancies exist between the theory and measurements. Equation 2 shows that the double-FM S:N is independent of preselector bandwidth. Measurements have indicated more dependence than might ordinarily be expected by increasing preselector bandwidth from the order of the audio bandwidth to, as Fig. 4 indicates, ten times the audio bandwidth. The audio S:N ratio as shown in Fig. 4 is on the order of 7 db noisier than the theory predicts. At present, there is no justifiable explanation for this occurrence.

Fig. 5—Spectrum positions and deviations for the systems discussed.



Dividing Equation 1 by Equation 2, the reduction in S:N of any multiplex subcarrier with respect to 100-percent main modulation (75 kc) and top audio cut-off, f_a, of 15 kc, can be computed. The result before de-emphasis is:

$$\text{Reduction (db)} = 3 + 20 \log \left(\frac{f_c}{F_{d_1}} \frac{75}{F_{d_2}} \sqrt{\frac{f_\alpha^3}{f_a^3}} \right) \qquad (3)$$

THREE-SUBCARRIER SYSTEM "A"

System A, utilizing three subcarriers in addition to the main, was set up for evaluation. Fig. 5 shows the spectrum position and deviation for the system and indicates the audio-cutoff frequencies for each channel. Allocation of the highest subcarrier frequency for stereo substantially eases the filtering requirement, which can result in a relatively inexpensive stereo receiver.

Other facts also entered into the choice of the highest frequency for stereo. The crosstalk possibility between two strong, adjacent channels could necessitate a substantial guard band, thereby unnecessarily wasting spectrum space. The tack, therefore, was to place the subcarriers to make maximum utilization of the spectrum for the information transmitted.

Signal-to-Noise Ratio

The S:N measurements are summarized in Table II. The system as it actually measured is shown. The bandwidths mentioned were not exactly reproduced, therefore, the measured S:N ratios were corrected for the differences in bandwidth. These corrections were made before de-emphasis, using Equation 2. The improvement due to the 75-μsec de-emphasis for the system bandwidths is applied to the corrected figures.

An important factor to consider for any system is the degradation in S:N ratio that might be expected for each channel with respect to the main. These degradations have been computed for the system using Equation 3. The measured and calculated results are also shown in Table II.

Distortion

Harmonic-distortion measurements indicated less than 2-percent distortion for the 41-kc and 67-kc channels. A maximum of 2.3 percent was measured for the 24-kc channel. These maximum distortions occurred at a frequency approximately equal to half the cutoff frequency after de-emphasis. The figures quoted are for the most part due to phase distortion in the filters used and could be considerably reduced with the use of linear phase filters.

TABLE V. ESTIMATED ENERGY BEYOND 100 KC

Channel	*nf, kc*	*n*	*f_a, kc*	*Power, db*
STD. FM ($F_{d_1} = 75$ kc, $f_a = 15$ kc)	100	7 - 9	14.25	—22.6
	100	8 - 10	12.5	—24.4
	100	10 - 12	10	—27.6
	100	20 - 22	5	—42.3
STEREO ($F_{d_1} = 18.75$ kc, $F_{d_2} = 10$ kc, $f_\alpha = 10$ kc)	100	3 - 4	10	—45.2
	100	3 - 4	8.3	—41.3
	100	5 - 6	5	—51.0

TABLE VI. CALCULATED CROSSTALK: THREE-SUBCARRIER SYSTEM, FULL CHANNEL WIDTH

*Interfering Channel**	*Modulation Frequency, kc*	*Side-band*	*Crosstalk, db*	*Attenuation Req'd, db*
INTO MAIN:				
SC_1	4	2	—57	—
	3	2	—55.8	—
	5	1	—49.3	—
INTO SC_1:				
Main	15	1	—14	36 rcvr.
	14	1	—17	33 rcvr.
	5.25	2	—50	—
SC_2	4	4	—50.6	—
	5	3	—39.2	10.8 xmtr.
	4.33	3	—37.7	12.3 xmtr.
	4	3	—41.7	8.3 xmtr.
	3.67	3	—44.6	5.4 rcvr.
INTO SC_2:				
Main	4.33	3	—50	—
	5	3	—54	—
SC_1	4	3	—47.8	2.2 xmtr.
	5	2	—53.7	—
Stereo	8	4	—53.1	—
	10	3	—37.2	12.8 xmtr.
	9.33	3	—38	12 xmtr.
	8.67	3	—46.2	3.8 rcvr.
INTO STEREO:				
SC_2	5	4	—81	—
	4.5	4	—82	—

*Main: $F_d = 37.5$ kc, $f_a = 15$ kc
SC_1: $f_c = 24$ kc, $F_{d_1} = 9.375$ kc, $F_{d_2} = 3$ kc, $f_\alpha = 5$ kc
SC_2: $f_c = 42$ kc, $F_{d_1} = 9.375$ kc, $F_{d_2} = 5$ kc, $f_\alpha = 5$ kc
Stereo: $f_c = 75$ kc, $F_{d_1} = 18.75$ kc, $F_{d_2} = 10$ kc, $f_\alpha = 10$ kc

Crosstalk

Table III summarizes the calculated and measured crosstalk for System A. In the evaluation of the system for crosstalk, a figure of —50 db or less was considered to be adequate.

The crosstalk in the main channel with the subcarriers present is essentially negligible. The most serious is that due to the SC_1 channel when modulated with a 3.5-kc note. The calculation shows —58.2 db, compared to a measured figure of —54.5 db for the given system. A point worth noting that shows up in the measurements, occurs with the three unmodulated subcarriers on. A crosstalk figure of —52.5 db was measured, and the interfering signal was at a frequency of 2 kc. This occurs when $\pm f_{sc_1} \pm f_{sc_2} \mp f_{stereo} = f_i$. The interesting point here is that this could be eliminated by the proper choice of subcarrier frequencies; i.e., when $f_i = 0$.

From the crosstalk standpoint, the SC_1 and SC_2 channels have the most serious problem, each having a strong adjacent channel. A need for filtering at the transmitter is seen in the *Attenuation Required* column. The crosstalk from the third harmonic of a 5-kc modulation frequency on SC_2 indicates an interference signal of —40.2 db at 26 kc in SC_1. This is directly in the bandpass of SC_1 and, therefore, cannot be filtered out at the receiver. At the transmitter, however, a filter with an attenuation of 9.8 db at 26 kc can be inserted in the SC_2 channel, and the crosstalk should be —50 db. Utilizing filters as shown in Table III resulted in crosstalk figures of less than —50 db for both SC_1 and SC_2. As Table III indicates, the crosstalk measured in the stereo channel was less than —50 db.

TABLE VII. THEORETICAL S:N DEGRADATIONS

From 100-percent-modulated main-channel audio S:N ratio

System	*Channel S:N Degradation, db*			
	Main	*SC_1*	*SC_2*	*Stereo*
3—Subcarrier (A)	—6	—29.6	—32.5	—31
2—Subcarrier	—6	—28.5	—	—23.2
	—3	—31.6	—	—28.5
3—Subcarrier (Full-Channel)	—6	—32.3	—32.8	—30.1

TWO-SUBCARRIER SYSTEMS

Table IV indicates the calculated crosstalk from the stereo and main audio channels into the SC_1 channel for 6-db and 3-db degradation of the main audio. The crosstalk due to SC_1 into the other channels is less than —50 db.

THREE-SUBCARRIER SYSTEM UTILIZING FULL CHANNEL WIDTH

Table V indicates the estimated total transmitted energy outside the allocated half-channel width of 100 kc for 75-kc deviation at various audio frequencies. This varies between —42 db at 5 kc to —22.6 db at 15 kc. Using this as a criterion, similar figures have been computed for a subcarrier center frequency of 75 kc, when modulating the main carrier 18.75 kc. Under these conditions, maximum audio deviation of this subcarrier (when limited to 14 kc) will result in similar interference outside the band, when $f_\alpha = 5$ kc, and is somewhat less at the highest audio frequency.

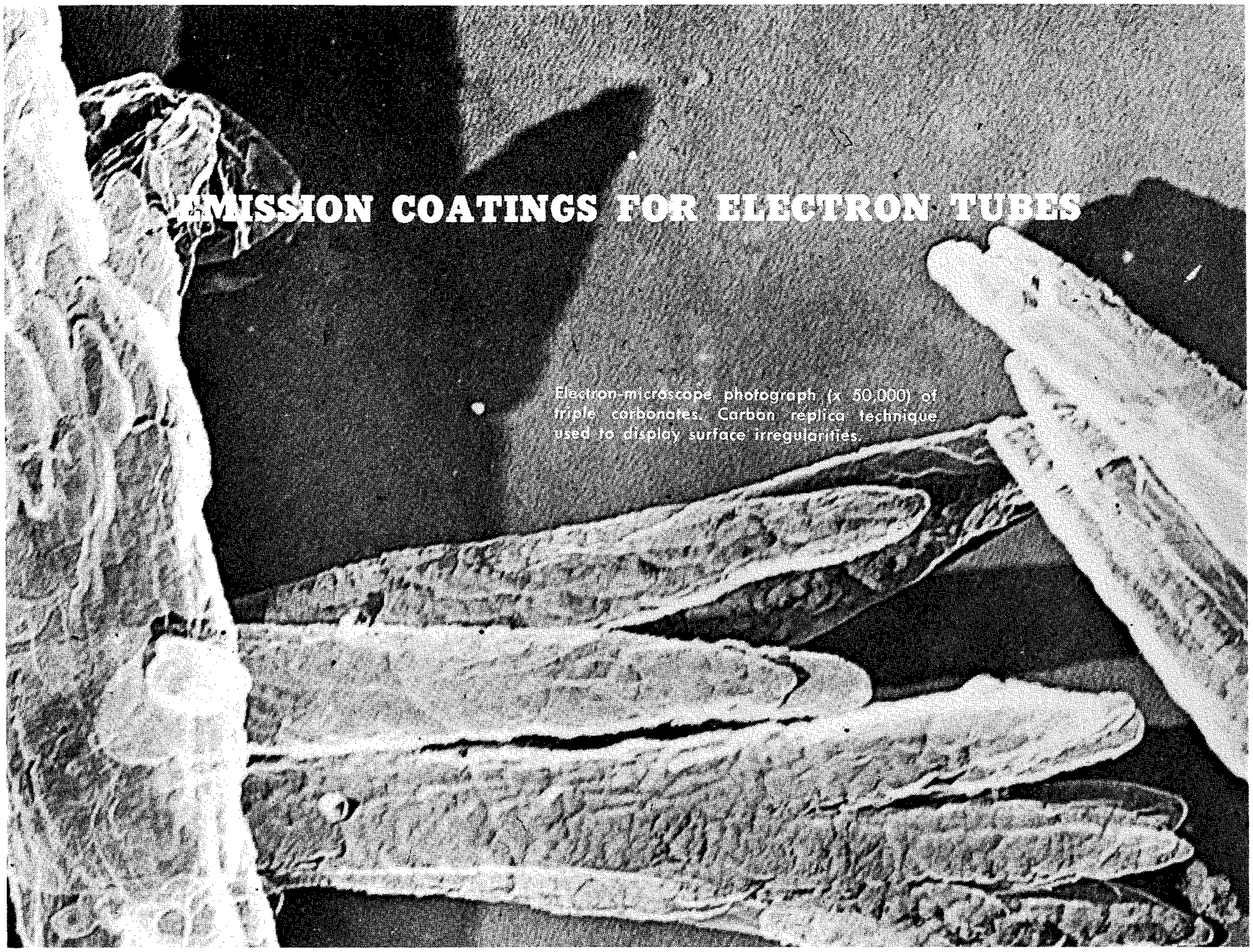
However, in order to meet crosstalk requirements, shown in Table VI, the maximum audio deviation has been limited to 10 kc, resulting in the figures shown.

The spectrum position with respect to deviations for all systems discussed are indicated in Fig. 5. The theoretical S:N degradations from a 100-percent-modulated main-channel audio S:N ratio for all systems discussed is shown in Table VII.

CONCLUSIONS

Experimental results have shown that in addition to a multiplex channel for stereo (with 10-kc fidelity), two multiplex channels for SCA can be provided. The performance characteristics for all channels are equal to or better than present commercial SCA broadcasts, if the main-channel audio S:N is reduced 6 db.

EMISSION COATINGS FOR ELECTRON TUBES



Electron-microscope photograph (x 50,000) of triple carbonates. Carbon replica technique used to display surface irregularities.

by **C. H. MELTZER**
Chemical and Physical Laboratory
Electron Tube Division
Harrison, New Jersey

The oxide-coated cathode is a system for producing efficient emission of electrons by the application of thermal energy to a material having a low work function. The system uses a nickel alloy for the cathode substrate metal, upon which is formed the oxide coating derived from alkaline-earth carbonates. The presence of an activated oxide coating lowers the work function of the substrate nickel core metal. The low work function of the system permits operation at the relatively low temperature of 1025°K and copious electron emission at low wattage input. Basic factors that influence electron emission include the effects of this low work function as well as the electron-transfer efficiency involved in the porous nature of the emission-oxide matrix.

BASIC CONSIDERATIONS FOR ELECTRON EMISSION

The work function, $\emptyset$, or the total amount of work necessary to free an electron from a solid, is measured in electron-volts (ev) and is temperature-dependent. Such temperature dependence may be produced either by the work function of the basic metal, or by adsorbed layers of atomic films. As shown in Fig. 1, the work function increases with the decrease in atomic volume or lattice spacing of the metal. When atoms of a lower work function are adsorbed onto the surface of a higher-work-function metal, the work function of the substrate metal is reduced by the lowering of the potential barrier at the surface of the metal.[1] For example, when a monolayer of barium ($\emptyset = 2.52$ ev) is vaporized onto the surface of nickel ($\emptyset = 4.96$ ev), the resultant adsorption layer, barium-oxygen-nickel, has a work function, $\emptyset$, of 0.9 ev.

Although large lattice spacings in a solid contribute to a low work function (i.e., the nuclear forces of attraction for electrons decrease with the increase in atomic volume), they are also associated with low melting-point and low boiling-point characteristics. Therefore, the usefulness of materials having large lattice spacings is limited by their high rate of evaporation, which tends to shorten the life of a system under vacuum-tube conditions. A balance of the two factors—work function and rate of evaporation—is the desired feature to be incorporated in an oxide-cathode system. In terms of these conditions, the barium–barium-oxide system meets the requirements of having the lowest *usable* work function consistent with minimum rate of evaporation and long life at the operating temperature of the tube. Fig. 2 illustrates the relative emission capability of the oxide, tungsten, and thoriated-tungsten systems.

Normally, pure barium oxide has a resistivity of 10^{12} ohms, i.e., it is an insulator. By an activating process, the oxide is made to act as a semiconductor by a process of physical-chemical reactions which lead to the formation of barium and associated

CARL H. MELTZER received the B.S. in Chemistry from the College of the City of New York in 1936. He received the M.S. degree in Physical Organic Chemistry from New York University in 1953. From 1938 to 1941, he was employed by the Lawyers Title Corp. of New York as engineer in charge of chemical plant appraisals for design and installation. From 1941 to 1946, he served in the U.S. Air Force as a specialist in airborne radio and radar search-bombing equipment. From 1946 to 1952, he was employed as a development engineer by the Nepara division of Warner-Chilcott Company and U.S. Organic Laboratories in the fields of carbonium ion reactions, heterocyclic nitrogen compounds, and alkaline-earth peroxides. Since 1952, he has been in the Receiving-Tube Chemical and Physical Laboratory of the RCA Electron Tube Division in Harrison, N. J., working in the fields of emission coatings, cathode metal alloys, and oxide-cathode phenomena related to electron-tube systems under exhaust, stabilizing, and life conditions. Mr. Meltzer is a member of Sigma Xi, American Radio Relay League, and the American Chemical Society. He has certificates of study in electronics at RCA Institutes, Air Force Communications, and Harvard-MIT, and has held FCC amateur and commercial radio licenses.

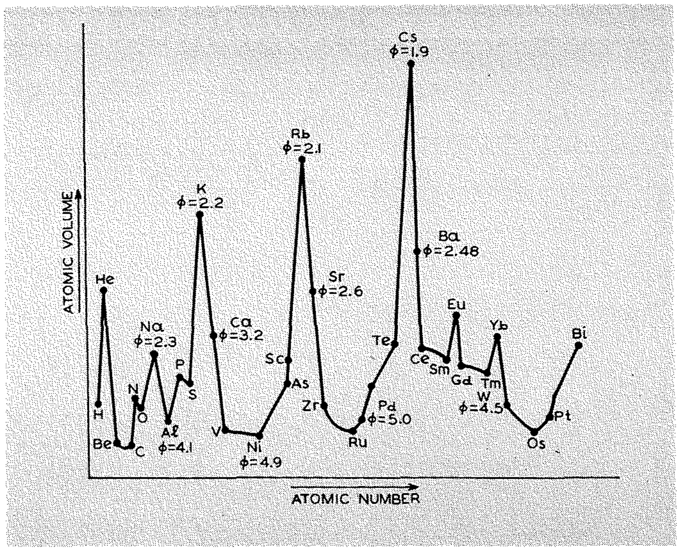


Fig. 1—Decrease in work function with increasing atomic volume.

donor sites in the oxide lattice.[2] In addition to having a low work function and a basic semiconductor method of electron transfer at the temperatures below 575°K, a relatively thick oxide coating of 0.5-mil to 3.0-mil thickness introduces a factor of coating porosity.[3] There exists a phenomenon of electron transfer through an *electron pore gas* in the interstices between macroscopic crystal particles of the oxide matrix at temperatures above 575°K. Although the electron gas, i.e., a cloud of electrons which is considered in terms of kinetic gas theory, does not reduce the work function of the system, it does increase the efficiency of emission by increasing the conductivity of the system, as shown in Fig. 3. A higher level of emission performance at the operating temperature of 1025°K is possible because there is a greater net voltage applied between cathode and anode as a result of the lower voltage drop across the oxide coating.

Barium and associated donor centers are produced by chemical reduction of the barium oxide by reducing agents of carbon, magnesium, silicon, and tungsten in the cathode nickel alloy base metal. Thus, barium oxide plus reducing metal yields the metal oxide plus barium ($BaO + M = MO + Ba$). Thermal decomposition of barium oxide to barium and oxygen cannot be achieved within the temperature limitations of the vacuum tube (the temperature required to decompose barium oxide would be close to 3000°K at a vacuum pressure of 10^{-5} millimeter), and electrolytic dissociation of barium oxide occurs only to a small extent to yield about two percent of the available barium donor centers.

The role of the reducing-element content (carbon, magnesium, silicon, etc.) of the cathode nickel base metal in terms of effective concentration, rate of diffusion through the metal, and rate of reaction with the oxide at the interface region is to create and replenish the supply of barium centers which maintain the low-work-function system. The operating characteristics of the cathode system with respect to other tube electrodes are determined by the preparation of the emission carbonates in terms of composition, purity, and particle size; the techniques for applying the carbonate coating to the cathode metal; the conversion of the carbonates to the oxide-matrix crystal structure; the rate of thermal diffusion of barium through the coating; the rate of electrolytic transport of barium ions; the rate of evaporation of barium–barium-oxide; and the concurrent formation of surface films on adjoining tube elements. Thus, the oxide-cathode system operates as a dynamic equilibrium system involving solid, ion, and gas phase-changes across several boundary surfaces of the electrodes in the tube.

THE OXIDE FORM

Numerous methods are used for the application of the alkaline-earth compounds to the cathode base-metal. The emission coating cannot be applied directly in the form of the oxide during the manufacturing operation because it reacts with water vapor and carbon dioxide in the air to form the hydroxide and carbonate compounds, respectively. Therefore, some prior form that is stable to atmospheric conditions, but easily convertible to the oxide form under vacuum conditions, is required for the cathode base-metal coating. The alkaline-earth carbonates have this required stability, purity, and ease of conversion.

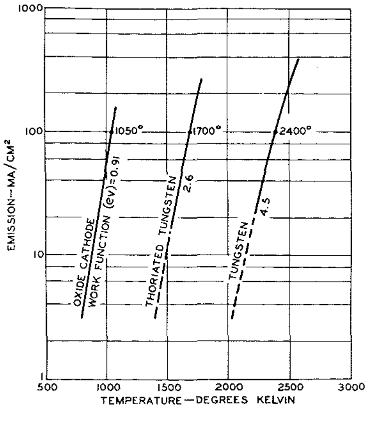
Although the system barium–barium-oxide has the lowest usable work function of the family group (barium, strontium, calcium) at the operating temperature, the barium carbonate-to-oxide system is not useful as an emission coating when used alone because, as shown in Fig. 4, it inherently passes through a comparatively low-melting eutectic phase while being decomposed from barium carbonate to the barium oxide.[4] However, the strontium and calcium systems do not pass through such a eutectic phase from carbonate to oxide at these temperatures.

$$BaCO_3 \rightleftarrows 2BaCO_3{:}1BaO+CO_2 \rightleftarrows BaO+CO_2\uparrow$$

$$SrCO_3 \xrightleftharpoons{\hspace{6em}} SrO+CO_2\uparrow$$

$$CaCO_3 \xrightleftharpoons{\hspace{6em}} CaO+CO_2\uparrow$$

Fig. 2—Degree of emission as a function of temperature for various cathode types.



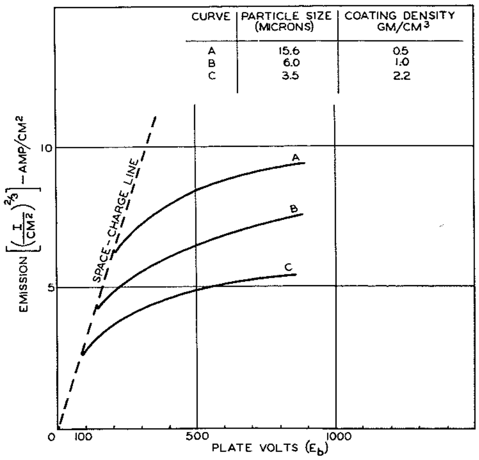


Fig. 3—Pulsed emission for emission carbonates having various densities.

The melt condition of the eutectic phase of barium-carbonate–barium-oxide, $2BaCO_3{:}1BaO$, (melting point 1300°K) compared to that of barium oxide, BaO, (melting point 2170°K) causes the emission coating that is formed from barium carbonate alone to sinter to a great degree under certain conditions of temperature and carbon dioxide gas equilibrium pressure. The level of emission is reduced in a sintered oxide coating because of the decrease of porosity and the increase in the size of the crystallite lattice. The conductivity of such a sintered coating is decreased as the effect of the electron-pore-gas type of electron transfer is diminished. Consequently, the co-precipitated double carbonate of barium-strontium (50/50 mole percent) composition was used because it minimized the eutectic melt formation of the barium carbonate component as a result of the diluent effect exerted by the strontium carbonate at the temperature of processing and operation. In addition, the co-precipitated double carbonate, $(BaSr)CO_3$, yields larger crystals than the single barium or strontium carbonate under the same conditions of precipitation. The increased size of the precipitated particles, as carbonates, decreases the packing density of the emission oxide coating.

Similarly, use of the co-precipitated triple carbonate of barium, strontium, and calcium, $(BaSrCa)CO_3$, of 57/39/4 weight percent, permits still-larger particle-size formation under the same conditions of precipitation. The photomicrograph presented on page 28 shows the large-size needle form of crystal structure obtained for the triple carbonate. The conductivity of the oxide coating derived from such carbonates is maintained at a higher level by virtue of the increased mean free path of the electron pore gas associated with increased porosity. Although the larger carbonate crystal size of the three-component system ensures a higher degree of porosity in the oxide matrix, more uniform decomposition characteristics, and single-phase, small internal crystallite size in the oxide system (factors that contribute toward a higher level of emission performance), high-level emission capability by virtue of an increased porosity factor involves a greater sensitivity to the vapor phase reactions within the tube environment. Hence, the final choice of the carbonate particle size and ultimate packing density of the oxide form for production purposes depends not only on emission considerations, but also on the stability of the cathode system to certain side reactions which are encountered in normal tube operation.

THE CARBONATE FORM

The preparation of the alkaline-earth carbonates for use as emission coatings is a critical function in terms of composition, particle size, purity, and uniformity. The carbonates are formed by the normal wet-chemical method of precipitation in which a solution of sodium and/or ammonium carbonates is added to a solution of alkaline-earth nitrates. The solutions are made under controlled conditions using distilled water and are filtered before being mixed together in the reaction. The reaction is the double decomposition type in which the equilibrium is shifted in the forward direction because of the insolubility of the alkaline-earth carbonate which precipitates out of solution.

$$\underset{\substack{\text{3-component}\\ \text{alkaline-earth}\\ \text{nitrate}}}{2(BaSrCa)(NO_3)_2} + \underset{\substack{\text{sodium}\\ \text{carbonate}}}{Na_2CO_3} + \underset{\substack{\text{ammonium}\\ \text{carbonate}}}{(NH_4)_2CO_3}$$

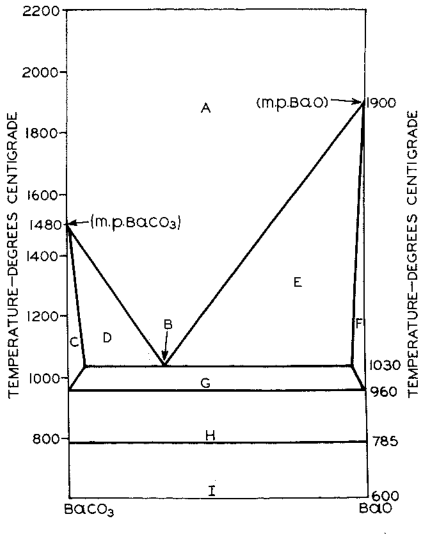
$$\rightleftarrows \underset{\substack{\text{3-component}\\ \text{alkaline-earth}\\ \text{carbonate}}}{2(BaSrCa)CO_3\downarrow} + \underset{\substack{\text{sodium}\\ \text{nitrate}}}{2NaNO_3} + \underset{\substack{\text{ammonium}\\ \text{nitrate}}}{2NH_4NO_3}$$

The precipitation is controlled with respect to temperature, concentration of the reacting solutions, rate of addition, pH of the reaction media, and rate of mixing to obtain uniform particle-size range and distribution. The carbonates are made either as the needle form or round spherulite form, depending upon the temperature and concentration of the reagent solutions. Because the purity of the product is essential to emission performance, the effects of adsorption and entrapment of foreign ions are minimized by the use of proper sequences of precipitation and washing operations. These methods ensure the production of a chemically pure product with a minimum amount of contamination from the alkali ions and salts.

PARTICLE SIZE AND SHAPE OF THE CARBONATES

The factors of temperature, concentration, pH of the reacting media, and rate of mixing of the reagent solutions are major determinants of the shape and size of the precipitated carbonate crystals. The crystals are produced as relatively large needles in the temperature range above 80°C. A mixture of crystal forms, varying from spatulate clusters of needles to spherulite forms, are obtained in the mid-temperature range from 50° to 75°C. Spherulite formation occurs predominantly at temperatures below 50°C. All crystal forms within the composition ranges in use are of the ortho-rhombic type of lattice formation.[5,6] Particle size varies directly with temperature and inversely with concentration of the reacting solutions. When the pH of the reacting media is below 7, the precipitated carbonate crystals are larger than those precipitated from a reaction media above pH 7. The rate of addition of

Fig. 4—Phase diagram for $BaCO_3$ and BaO; (A) one phase—liquid solution of $BaCo_3$ and BaO; (B) eutectic phase—33 percent BaO, 67 percent $BaCO_3$; (C) one phase—solid solution of BaO in $BaCO_3$; (D) two phases—solid solution of BaO in $BaCO_3$ and liquid solution of $BaCo_3$ and BaO; (E) two phases—solid solution of $BaCO_3$ in BaO and liquid solution of $BaCO_3$ and BaO; (F) one phase—solid solution of $BaCO_3$ in BaO; (G) two phases—mixture of two solid solutions; BaO in $BaCO_3$ and $BaCO_3$ in BaO; (H) mixture of two solids: hexagonal $BaCO_3$ and cubic BaO; (I) mixture of two solids: orthorhombic $BaCO_3$ and cubic BaO.



the reagent solutions to each other influences the particle size; rapid addition causes small particle-size formation, whereas slow addition causes large particle-size formation. The rate of mixing, the shape of the impeller blade, and the turbulent currents produced in the reactor vessel influence the crystal habit of nucleation and growth. Manufacturing practice has resulted in the standardization of processes designed to control all these factors to the high degree necessary for the production of uniform, chemically pure, ultra-fine quality carbonates.

The relationship between the size and shape of the emission carbonate particle as precipitated and the emission performance of an oxide coating is complex. In general, carbonate particle sizes within the limits of 2 to 18 microns in length and 2 microns in diameter (as observed at 1000-power magnification under an optical microscope) yield an oxide coating capable of a higher level of emission than can be obtained from carbonates which are originally precipitated larger than 25 microns long or smaller than 2 microns long. A balance of factors involving particle size and ultimate porosity of the coating, decomposition characteristics, resistance to poisoning-retarding actions, and level of emission performances determines the final selection of the type of carbonate material to be used. Manufacturing problems associated with particle size and extra washing operations must also be considered. Coarsely crystalline material, for example, can be heavily contaminated by entrapment of foreign ion impurities, whereas smaller particles can be heavily contaminated by adsorption effects of greater surface areas. Moreover, when emission-coating mixtures of too large a particle size carbonate crystal are finely ground to produce a smooth, dense coating, a build-up of silicate clay (abrasive losses from the ball mill and pebbles) increases the electrical resistance of the oxide-coating matrix.

Although the more-rapid decomposition characteristics of coatings made from larger carbonate crystals permit faster exhaust operations and shorter aging schedules, the resultant porous type of oxide coating is affected more quickly by environmental gases. Conversely, coatings made from dense, small-particle carbonates possess a minimum porosity so that the decomposition of the coating is slower and the aging schedule is longer. Fig. 5 shows that the level of emission performance for the less porous type of coating is definitely lower because of the decreased conductivity of the coating. However, the denser type of coating is more resistant to *poisoning actions*, i.e., physical-chemical reactions from the environmental gas and vapor phases in the tube, that tend to decrease the amount of active barium donor centers of the oxide matrix as well as to decrease the conductivity of the coating. The denser type of oxide coating offers more dimensional stability with respect to grid-to-cathode spacing and, because of the decrease of internal surface areas within the bulk of the oxide matrix, also contributes a smaller quantity-rate of evaporation of barium–barium-oxide onto adjoining tube electrodes.

APPLICATION OF THE COATING TO THE CATHODE

In addition to the effects of the particle size of the precipitated carbonate crystals and the type and duration of the ball-milling action, the emission performance of the oxide coating is influenced by the methods used to deposit the carbonate coating onto the cathode base metal. The physical properties of texture and porosity of the carbonate coating are transferred to the oxide form despite the conversion from the ortho-rhombic lattice of the carbonate to the cubic lattice of the oxide crystals, i.e., a porous carbonate coating becomes a porous oxide coating; a dense carbonate coating becomes a dense oxide coating.

The type of solvents used in the carbonate-spray formulation influences the relative bulk density (porosity) of the emission coating as it is applied to the base metal. Solvents having a high vapor pressure (low boiling point) evaporate rapidly and produce a porous, fluffy coating. Solvents having a low vapor pressure (high boiling point) evaporate slowly to leave a smooth, dense coating.

The spray-gun aperture settings control the amount of material deposited per application, whereas spray-gun air pressure and distance from the cathode control the degree of porosity of the applied coating. High air pressures tend to deposit dry, fluffy coatings; low air pressures tend to deposit wetter, more dense coatings. A porous coating is deposited onto the cathode metal when the cathode is farther away from the gun nozzle; a denser deposit of coating material is obtained when the cathode metal is closer to the gun nozzle. The ratio of solids to solvents in the emission mixture influences the adjustments of the gun settings and the distances from the cathode. As a result, the emission formulations are made to close limits of specific gravity and viscosity to ensure uniform spray application.

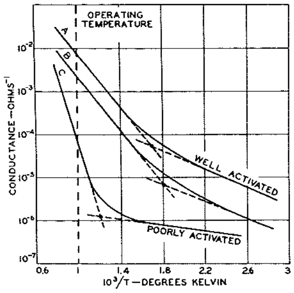


Fig. 5—Variations in conductance for three degrees of porosity of emission coating aged under identical conditions: (A) most porous; (B) intermediate porosity; (C) least porous.

Atmospheric conditions of low humidity and high temperature increase the rate of evaporation of the solvents and produce a more porous coating. High humidity conditions cause the nitrocellulose binder to set in a brittle fashion and thus contribute to imperfect adherence of the coating to the cathode base metal. Therefore, the emission coating is applied in an air-conditioned environment of 50-percent relative humidity and at a temperature of 72°F to insure reproducible uniform coating application. The dewpoint of the water vapor in the compressed air is maintained at —40°F to ensure further the conditions for good spray techniques. The rate of air flow through the spray booth is maintained at a constant value so that a constant rate of evaporation of the selected solvents used in the spray formulations is maintained for uniform coating deposition. Thus, in tube-manufacturing practice, a balanced condition in terms of base-metal reducing activity and the coating parameters of weight, density, and thickness are controlled in order to establish and maintain a temperature-time-pressure equilibrium during the decomposition of the coating.

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PHASE EQUALIZATION OF TV BROADCAST SYSTEMS

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THE ELEMENTS OF a complete TV system (from studio through transmitters through receivers) are numerous—sometimes complex and widely separated. The specifications of one system element are important only insofar as they assure successful operation of the complete system. Also, elements should have characteristics similar to each other and to the characteristics of the complete system, to enable system enlargement or reduction with minimum complication. Consider standard broadcasting, where the desired equivalent audio response of the entire system is flat; therefore, most audio-amplifier response curves are flat. The circulating audio signal is standard almost everywhere, allowing flexible program switching and routing.

ECONOMY AND STANDARDS

In many large systems, however, economic or technical reasons justify some elements with "nonstandard" response, e.g., a long transmission line and its associated equalizers. Though usually economically preferable, it will not provide the flat response curve obtained in a transmission line alone (with enough copper). Another example is in FM broadcasting, where pre-emphasis is given to high-frequency audio at the transmitter, and an inverse de-emphasis is performed at the receiver. This departure from flatness is not inherited, as in the transmission-line example, but is deliberately introduced because it accomplishes a technical improvement and a reduction in receiver cost.

The visual part of a TV system, excluding the camera chain and kinescope, can be considered a huge video amplifier that should be linear, have a flat frequency response (from 0 to 4 mc in the U.S.), and have a linear phase characteristic, i.e., a constant time delay within the pass band. These characteristics are imposed on most elements of the system.

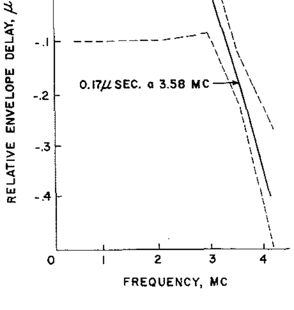


Fig. 1—FCC specifications on the radiated-signal-time-delay characteristic (dashed lines are the tolerance limits).

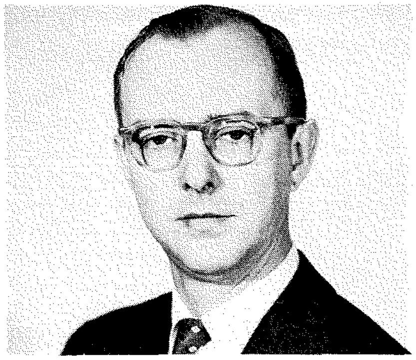
Exceptions to be discussed herein consist of paired "deficient" elements and equalizers, the combination removing the deficiency from the system. Specifically, phase or time-delay (the slope of the phase characteristic; also called envelope, or group delay) distortions are introduced in the TV system for the compelling economic reasons previously mentioned. These so-called "deficient" elements have long been acceptable unequalized monochrome components. In a sense, these deficiencies result from color-TV standards that are considerably tighter in some areas than the monochrome standards.

RECEIVER EQUALIZER

That the time-delay characteristics for color transmission systems are of greater importance than those for monochrome is reflected by the FCC. While no time-delay specifications existed for monochrome TV, they do for color (Fig. 1). The roll-off of the time delay at the upper end of the band is a precompensation for the sharp high-frequency cut-off in color receivers.

The color-receiver requirements are rather stringent. First, the amplitude response must be substantially flat from d-c to over 4 mc to maintain proper chrominance and luminance balance. Secondly, the attenuation must be large at the sound carrier, 4.5 mc, in order to prevent sound beats in the picture. This sort of sharp cut-off response, if realized with simple networks (e.g., minimum phase), is characterized by time-delay distortions. The components of the signal in the upper half of the band are delayed more than those in the lower half; a misregistration of color pictures with poor edges results. If the radiated signal had a time delay uniform over the band, it would require complex receiver bandpass circuits. This is avoided by equalizing, at the transmitter, the time-delay errors of simple receiver circuits that achieve the desired amplitude response. Hence, the nonuniform time-delay characteristic specified for the radiated signal is as shown in Fig. 1.

The transmitter precompensation for the receiver high-frequency cut-off is performed by a passive all-pass equalizer placed in the video line to the transmitter input. The characteristics of this *high-frequency receiver equalizer* are essentially the same as those in Fig. 1, except that the corners are rounded and the tolerances (±0.015 μsec) are tighter.



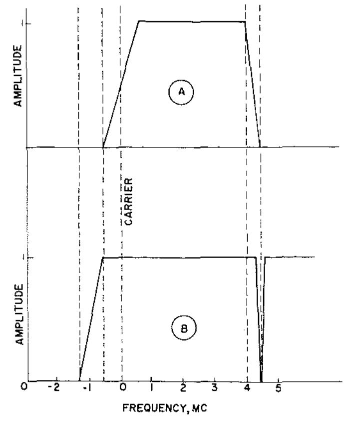
GEORGE A. OLIVE received the BSEE from the University of Nebraska in 1949, whereupon he joined RCA as a Member of the Technical Staff at the RCA Laboratories. In 1959, Mr. Olive was appointed a Staff Engineer, Engineering Plans and Services, IEP. In this new position, he has participated in the analysis of data and the formation of policies to assure high-quality engineering throughout the field of RCA Industrial Electronic Products. As an active member of the IRE and the AIEE, he has been the author of articles on technical subjects ranging from experimental TV transmitters to single-sideband systems.

FILTERPLEXER

Since the high-frequency receiver equalizer has precisely the time-delay characteristic specified for the radiated signal, the over-all time-delay characteristic of the rest of the transmitter equipment should be constant. This leads to the *vestigial-sideband filter* and *notch diplexer*. The latter combines the visual and aural transmitters into a single antenna feed-line, putting a sharp null in the equivalent video response at 4.5 mc. A *filterplexer* combines these functions in an integrated unit.

The r-f amplitude response of an idealized receiver and an idealized filterplexer is shown in Figs. 2a and 2b. On the lower side of the carrier, the response at the transmitter is maintained at 100 percent until the response of the receiver is essentially zero. The intention here is to make the receiver unaware, to a first approximation, that the radiated

Fig. 2—R-F response: A) idealized receiver; B) idealized filterplexer.



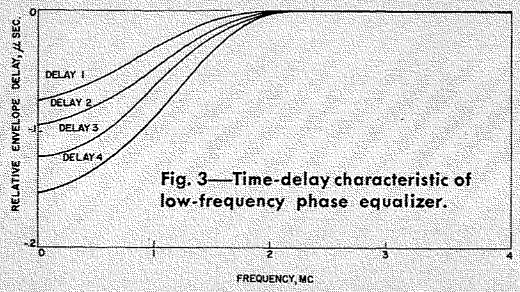


Fig. 3—Time-delay characteristic of low-frequency phase equalizer.

Fig. 4—Time-delay characteristic of high-frequency notch equalizer.

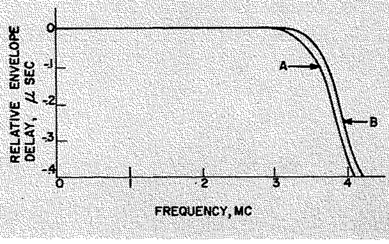
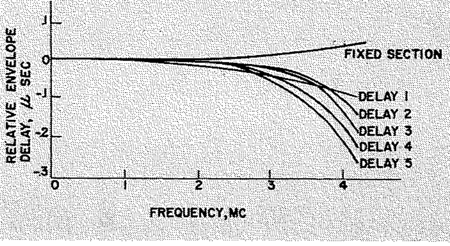


Fig. 5—Time-delay characteristic of high-frequency variable equalizer.



signal has been filtered. This bit of sleight-of-hand is designed to make the system performance indifferent to channel switching in the receiver.

That the lower sideband is missing is only partially concealed from the receiver, however. The sharp cut-off in the sideband filter is accompanied by a disturbance of the phase characteristic extending well into the pass band. Although the equivalent video amplitude characteristic is not unduly disturbed, the equivalent video phase characteristic has a pronounced departure from linearity in the lower half of the band. The low video frequencies are delayed more than the high video frequencies. With monochrome signals, the resulting waveform distortion is noticeable, although tolerable; in fact, it was almost universal practice to neglect this system deficiency until the introduction of the NTSC color system.

LOW-FREQUENCY PHASE EQUALIZER

To provide proper chrominance and luminance registration, the low-frequency time-delay distortion introduced by the vestigial-sideband filter must be corrected. To do so at the source of trouble involves additional massive, high-Q, high-power circuit elements. The commercial practice, less expensive and entirely satisfactory, is to precompensate for the sideband filter distortion in the video line to the transmitter. Thus, a second, passive all-pass equalizer is included at the transmitter, the *low-frequency phase equalizer* (Fig. 3). The choice of delay characteristics allows almost any vestigial-sideband filter to be matched by this equalizer.

NOTCH EQUALIZER

The notch in the filterplexer response causes a delay distortion of the same type caused by the receiver high-frequency cutoff, i.e., the high video frequencies are delayed more than the lows. This notch is phase-equalized in the video line to the transmitter input by the *high-frequency notch equalizer* (Fig. 4), also to avoid the use of additional high-power elements in the filterplexer. Two positions are available to enable the equalizer to accommodate to various-width notches.

VARIABLE EQUALIZER

A *high-frequency variable equalizer* (Fig. 5), is also generally inserted in the transmitter video input to compensate phase errors due to roll-off in the transmitter tuned circuits. Each of the five delays may be selected with the fixed section in or out, for a total of ten combinations. This equalizer is sometimes called the "mop-up" because the general practice is to peak-up the system with this one after the other equalizers have been set.

WAVEFORMS

The waveforms shown in Fig. 6 are the demodulated output of a TV transmitter and include neither the filterplexer nor a receiver. The input video signal is a step function (the trailing edge of sync) with no overshoot or ringing. In Fig. 6a (no equalization), the overshoot and ringing is caused by the cutoff of the transmitter output circuit. In Fig. 6b (variable equalizer in to correct for the transmitter output circuit), the ringing following the step is greatly reduced in amplitude, and the step is now preceded by a small amplitude ringing. A symmetrical response to a step function such as this is typical of constant time delay low-pass filters. Fig. 6f (all equalizers in) is typical of the transmitter input waveform required to produce a waveform similar to Fig. 6b at the grid of the kinescope.

Fig. 7 shows the transmitter response to a more complex waveform, a portion of a line from the familiar monoscope Indian Head. Fig. 8 shows the receiver output (at the kinescope grid) where the input to the transmitter is a 1-μsec flat-top pulse. A filterplexer is included.

SUMMARY

The waveforms were taken on a system equipped with stock commercial equalizers designed by the Broadcast and Television Equipment Division of IEP as part of their complete line of broadcast equipment. These equalizers have been proving their value since the early days of color TV. Although this refinement came about through color telecasting, the benefits are also applicable to monochrome TV.

Fig. 6—Transmitter response to step function: A) no equalization; B) variable equalizer in; C) variable equalizer and receiver equalizer in; D) variable equalizer and notch equalizer in; E) variable equalizer and low-frequency equalizer in; F) all equalizers in.

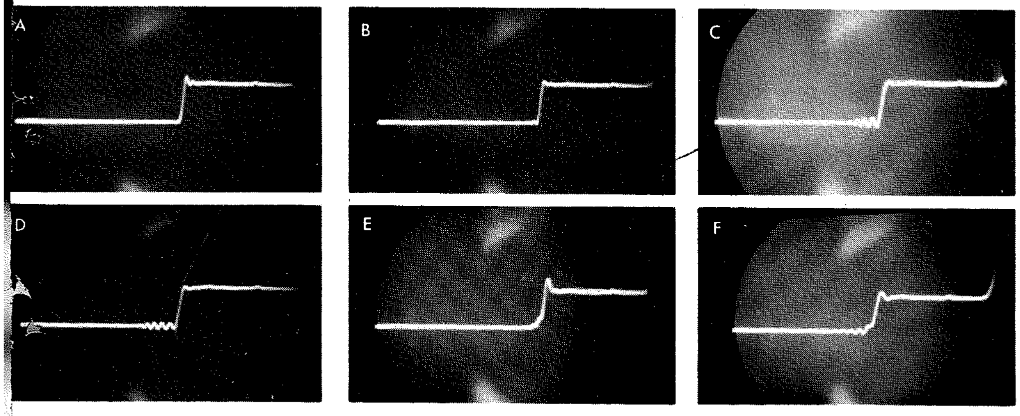


Fig. 7—Transmitter response to complex waveform, wide pulse about 1 μsec: A) video input; B) transmitter output, no equalization; C) transmitter output, variable equalizer in.

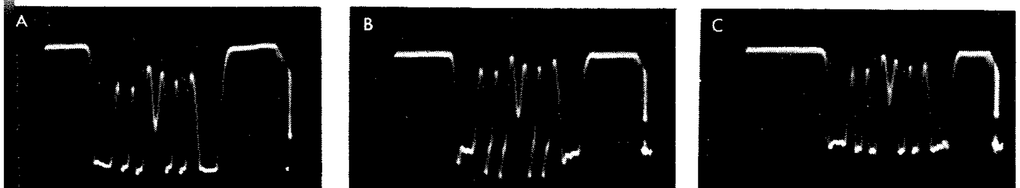
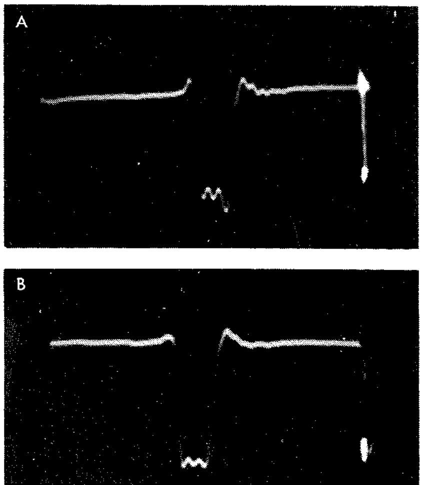


Fig. 8—Receiver response to a pulse: A) no equalization; B) all equalizers in.



DEE . . . Digital Evaluation Equipment . . . FOR MULTI-MISSILE CHECKOUT

by **F. EVERHARD**
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The RCA Digital Evaluation Equipment (DEE) is an integrated, automatic, test-and-checkout system for the Nike Ajax, Nike Hercules, Hawk, Lacrosse, and Corporal missile systems of the U.S. Army. For these five weapon-system families, DEE (Fig. 1) performs calibrations, fault-isolation tasks, and go, no-go tests, starting with the over-all systems and ending at the chassis level. Choice of modular building-block design for the DEE makes it possible to accommodate future growth to serve new prime systems. The Airborne Systems Division was responsible for the over-all development program, with the Surface Communications Division and the RCA Service Co. participating in the program comparator and stimulus development.

FOUR YEAR SERVICE COMPANY STUDY

DEE is based on a four-year RCA Service Co. investigation of U. S. Army Ordnance test-equipment problems. This study showed the existence of a vast number of peculiar test equipments, each requiring a tailored training program and separate supply channels. Large missile systems needed such complex test devices that personnel trained in the operation and maintenance of a particular system could not operate any other system without undergoing an extensive retraining course. When such weapon systems became obsolete and were subject to major modification, the test devices were invariably scrapped, with a resultant loss of millions of dollars in equipment and engineering and production hours.

Army Ordnance experience in the early missile programs for the Corporal I, Corporal II, Nike-Ajax, and Lacrosse stimulated a revision in the Army's field support concept. This revised thinking sought to prevent compounding of maintenance problems at a time when the Nike-Hercules, Hawk, Sergeant, Pershing, Mauler, Red Eye, Lobber, Nike-Zeus, and Missile "A" Systems were to be added. Based on its proposal to study this problem, RCA Service Co. was directed by U. S. Army Ordnance in 1955 to investigate the feasibility of standardizing test equipment for all Army missile programs.

The early phases of the RCA Service Co. study confirmed that test equipment could be standardized with the maintenance of flexibility. The key was modularization by test function and the establishment of the electromechanical compatibility standards. This led to the development and production of building-block test equipment for Raytheon's Hawk missile system by the RCA Service Co.'s Alexandria facility and the Airborne Systems Division. The study had recommended the automation of testing to reduce the operator skill requirements. Engineering models of automatic testers which verified these principles were constructed. Following successful demonstrations of these, Ordnance requested that a feasibility model for a test system be developed embodying the principles of functional modularization, automation, and "universal," or multi-application, test capability for all Army missile systems, past, present and future. This task was completed in December 1959 when the DEE feasibility model was successfully demonstrated.

The DEE demonstrated, in addition to substantiating the building-block concepts, that operator skills could be conserved during the performance of acceptance, calibration, and fault-isolation tests on a number of representative subassemblies of the Nike-Ajax, Nike-Hercules, Lacrosse, Hawk, and Corporal missile systems. The DEE exceeded all estimates for testing rates. A typical unit-under-test (uut) that formerly had a 4-hour test was checked in 7 minutes. DEE physical volume is small when compared to the volume of equipment of equal capability replaced by it, requiring one third of the volume previously required by the specialized test equipment for a typical missile system. Part of this reduction is due to the almost-100-percent solid-state design and the accompanying high packaging density, while the remainder is attributable to the functional building-block principle together with an integrated system design.

SYSTEM DESIGN

In order that the requirements for complex switching, control, high precision, speed, and flexibility could be met,

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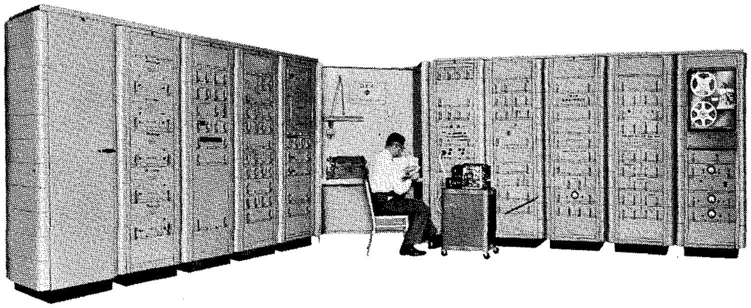

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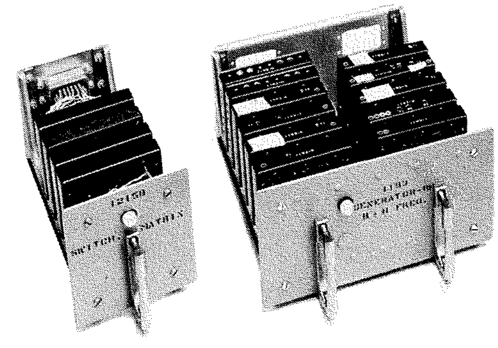

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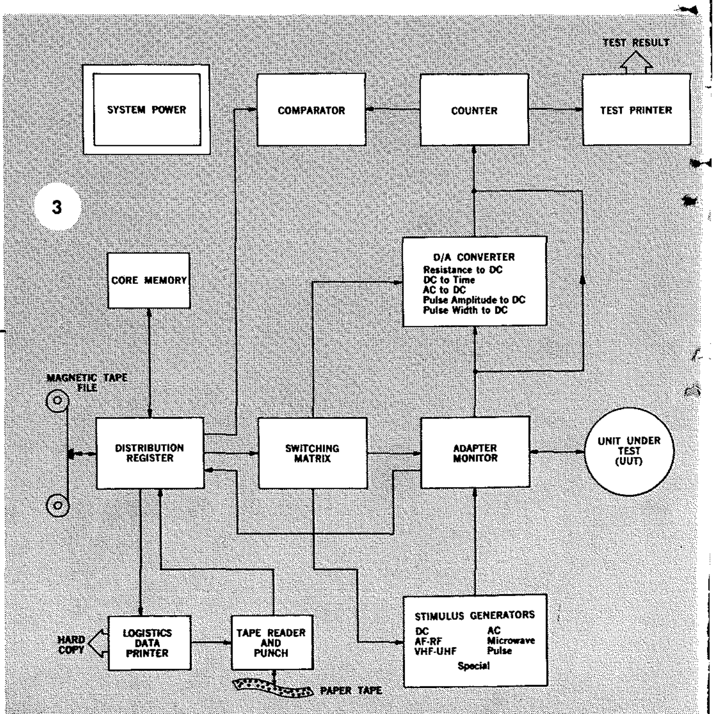


FREDRIC U. EVERHARD (right) majored in matematics and physics at the University of Wisconsin and Ripon College, Wisconsin. He joined the RCA Service Company in 1950 and transferred to the ASD, System Support Engineering, in 1959. He has been responsible for the design of a complete Naval communication complex for the Far East and has served as staff technical advisor for the Army Ordnance Guided Missile School for all active and proposed missile systems. At the Service Co.'s Alexandria Engineering Facility he was the design leader for modularized, automatic checkout equipment for the Lacrosse and Nike missiles. With ASD, Mr. Everhard is responsible for the system design of the Digital Evaluation Equipment. At present he is the Project Engineer assigned the responsibility for expanding the DEE capability and application to other areas of military checkout.

computer techniques were selected for data handling and programming control of the DEE.

Magnetic tape was selected for the basic data-storage medium as it provided high-density storage of information. To ensure compatibility between the programming system and the measurement section, analog-to-digital conversion was utilized in the measurement section. Control for the stimulus generator-signal generation equipment, input-output devices, and variable loads were included to permit unlimited growth as new test requirements occurred. The DEE was to provide: 1) automatic programming, 2) go, no-go test indications, 3) piece-part fault-isolation capabilities, 4) self-testing and self-checking, 5) printed and punched logistics data outputs, 6) printed read-outs of all measurements, 7) high speed and accuracy of testing, 8) minimum operator participation, and 9) operation and maintenance by low-skill-level personnel.

These design goals were established by analyzing hundreds of electronic subassemblies (uut's) from five missile-system families. The uut checkout and maintenance data was then utilized to establish the DEE system parameters. Functional building blocks, or modules, were then developed to provide the necessary test capability. The modules were designed using the principle that each test function was to be accomplished by one or more modules that could be replaced, removed, or added as test requirements changed. As most test requirements are common to all missile systems, the standardized modules made DEE test capability applicable to many missile systems. Any peculiar test requirements are supplied as special modules, providing the desired standardization with simplicity and restriction of obsolescence to modules rather than to the system.

Automatic operation was used to accelerate the testing process, lower the skill requirements for operating and maintenance personnel, and to obviate human errors. High-speed and high-storage-density magnetic tape was selected for the storage of test routines, repair instructions, and logistic data. The present reel of tape (2500 feet) stores information capable of performing 100 tests on each of 100 uut's.

MECHANICAL DESIGN

Physically, the module consists of front and back panels with die-cast aluminum side frames (Fig. 2) with integral guides for quick and easy installation. All connectors are mounted in the back panels.

The basic assembly is 10 inches deep, 4.68 inches wide and 5.22 inches high. Four modules may be fitted in the 19-inch standard rack width. For larger modules, dimensions increase in unit increments providing a variable packaging scheme to meet the need for a variety of sizes. The modules utilize plug-in subassemblies (printed circuit boards) and chassis-mounted components. The subassemblies are either glass-epoxy–printed circuit boards, or boards with point-to-point wiring. In addition, solid-state components are encapsulated into mini-module logic units.

The present model of the DEE could be used at a fixed-installation; the field version will be fully militarized and installed in a 2½-ton shop truck.

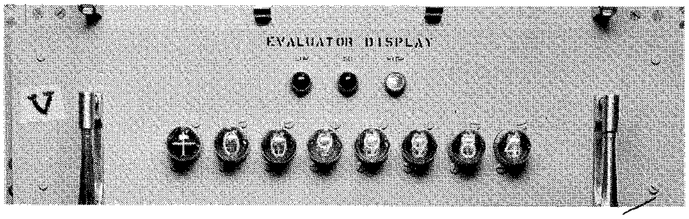
DEE OPERATION

The uut is connected to DEE through the adapter monitor (Fig. 3). The cable connector at the adapter monitor contains the uut code number. This is routed to the distribution register for comparison with test address information that is transferred from the magnetic tape through the buffer memory to the distribution register. When the address of the connector and the test address are identical, the test cycle begins.

Switching information is then transferred from the memory through the distribution register to the switching matrix. This matrix, in turn, connects the proper stimulus generator to the uut and the proper uut outputs to the digital-to-analog converter.

All analog signals are converted to time-equivalent digital signals in the converter and are then routed to the counter. Measurements involving time are received directly by the counter.

The uut outputs are counted (or measured) in the counter and are then



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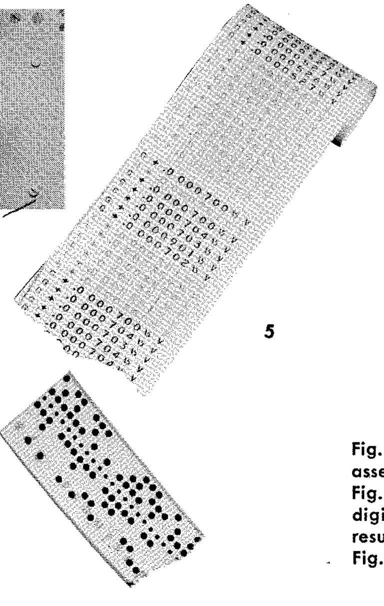

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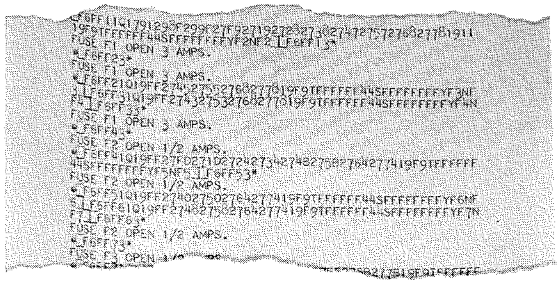

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Fig. 1—DEE system. Fig. 2—Two DEE modules; basic assembly at left. Fig. 3—Block diagram of DEE system. Fig. 4—Visual display showing test results in seven digits plus sign. *High*, *Go*, and *Low* lights indicate result of test comparison. Fig. 5—Tape printer record. Fig. 6—Catalog printout.

compared, in the comparator, with the upper and lower limits obtained from the magnetic tape via the distribution register and the memory. The test results are then recorded by the data printer. If a no-go test results, any logistic data for that uut test is printed out by the printer.

PROGRAMMING

Programming of the DEE for a particular uut begins with the preparation of a uut test procedure. This procedure is a test plan to determine if the uut will operate correctly, and providing fault isolation to the replaceable subassembly, circuit, or component level. Automatic fault isolation to the component level depends on the design of the uut and the available test points.

In the preparation of a test procedure, a logical sequence of static and dynamic tests are established that will exercise both the individual circuits and circuit combinations of the uut through their range of normal operation. For abnormal operation, the test logic must provide a series of tests to further isolate the fault. This includes print-out provisions for every possible fault. The test procedure is a logical sequence of tests which ensures that 1) the uut is properly connected and exhibits no faults that could affect the uut or DEE detrimentally upon application of power, 2) all the uut circuits perform satisfactorily through their normal range of operation, 3) the circuits operate in combination to perform the intended function of the uut, and 4) any fault in the unit is isolated as close to the piece-part level as possible.

The programming information is inserted in binary-coded decimal form, in blocks. Since some tests require more characters than can be accommodated in one block, DEE has been designed to accept up to nine blocks per test. Of these nine, two contain test instructions and seven contain logistic information. This means that for any one test, up to 512 instructions can be used for test and evaluation control, and up to 1,792 instructions for logistic information.

Programs are constructed on the basis of the number of tests required and the steps in which they must be performed. Each test is given a test number which yields a go address, if the test is successful. The go address is also the test number for the next test to be performed, as defined by the unit test procedure. A malfunction results in a no-go address which is the test number for a test routine that determines the faulty area within a uut.

The number and types of tests required for any particular uut vary. A simple test might consist of determining impedances between connector pins, while more complicated tests require the application of stimuli to the uut and the evaluation of its output.

OUTPUT MEDIA

Printed copy and visual displays are the DEE output media. Visual displays consist of eight Nixie tubes, which display test results in seven digits plus sign (Fig. 4). In addition, high, go and low lights indicate the result of the test comparison.

The printer provides a continuous record of tests performed by DEE (Fig. 5) and can print 11 characters at a maximum speed of four lines per second on continuous rolls of paper tape. The print-out for all tests consists of 1) uut number, 2) test number, and 3) measured value. The print-out for the measured value consists of 1) condition of the test valve (go, high, or low), 2) function of the measurement (frequency, positive d-c voltage, phase, etc.), 3) test value (7 digits plus sign), 4) decimal-point placement, and 5) units of measurement (volts, microseconds, etc.).

In addition to these, the logistic data printer supplies the operator with detailed catalog information (Fig. 6) consisting of the description of the trouble, the responsible circuit or component, repair instructions, and replacement part information. Instructions to the operator, such as manual adjustments necessary, or precautions to be taken can be printed during a testing cycle.

SELF-CHECKING

In any automatic test system, all possible precautions must be taken to assure proper equipment operation and to prevent any damage to a uut by improperly processed test information or by faulty switching of signals. Such self-checking features are provided in DEE.

A parity checking circuit assures proper transfer of correct information from one point to another in the system. Parity is continuously checked when information is being transferred from tape to memory, from memory to tape, and from memory to switching.

Whenever incorrect parity occurs the equipment is stopped to prevent improper testing or damage to the uut or DEE.

The distribution register is the point from which all switching functions are energized. Every step of a switching operation is verified before the equipment proceeds to the next step. Every switching character that actuates a relay or relay tree is encoded on return lines from contacts that have been actuated. This encoded character is routed to the switching comparator, where it is compared against the original character. Such a check assures that the proper relays have been actuated before the equipment proceeds to the next switching operation.

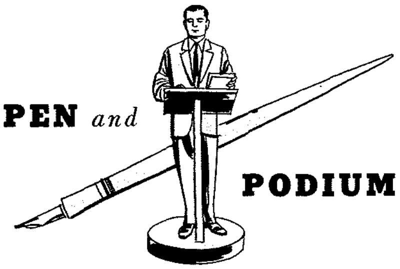
Additional verification of switching operations is performed in the monitor switch, the central switching point for the inputs and outputs of the uut. Switching verification is made after the last switching function has been completed to ascertain that the relay trees have been properly selected and connected.

The system and subsystem self-check is based upon a check against internal evaluator standards. At any time during equipment operation, the evaluator may be compared to the built-in standards by the operation of manual selector switches. The values of the standards are known by the operator, and he can observe that the visual display on the evaluator corresponds to the value of the internal standard.

The DEE system may be programmed to route the outputs of the stimulus generators back to the input of the evaluator. The evaluator then checks the stimulus generators, and if one is faulty, the logistic information for the malfunctioning stimulus generator is typed out by the data printer. A complete program for checking all stimulus generators can be employed to permit a check of the entire system at any given time, or the programs can be written to check each stimulus as it is applied to the uut.

OTHER APPLICATIONS

Although the DEE was designed as a test system for the evaluation of electrical and electronic portions of U.S. Army missile systems, its versatility, expansibility, speed and ease of operation and maintenance is being extended to other fields. A recent U.S. Army Signal Corps contract, for instance, directed ASD to build a DEE for the Tobyhanna Signal Depot for use with communications equipment. In addition, industrial application of the DEE is being actively investigated by ASD for use as a production-line testing device. Applications for automatic testing of printed boards, potted modules, automatic waveform analysis, and automated training devices are also to be investigated. Studies of the future space maintenance requirements are also underway.



PEN *and* PODIUM

BASED ON REPORTS RECEIVED OVER A PERIOD OF ABOUT TWO MONTHS

INDUSTRIAL ELECTRONIC PRODUCTS

Remote Control of TV Microwave Equipment
J. B. Bullock: IRE Internat'l Convention, New York City, March 21-24, 1960.

TV Station Automation
R. D. Houck: IRE, Professional Group on Broadcasting, Philadelphia Chapter, April 14, 1960.

Tunnel Diode Computer Logic Circuits
R. K. Lockhart: IRE, PG on Electronic Computers, Washington, D. C., April 21, 1960.

A Transistorized Portable Magnetic Recording Channel for Film
C. E. Hittle, M. Rettinger and K. Singer: SMPTE Convention, Los Angeles, May 1-7, 1960.

An Automatic Store and Forward Message Switching System
T. L. Gennetta, H. P. Guerber, and A. S. Rettig: Western Joint Computer Conference, San Francisco, Calif., May 3-5, 1960.

ELECTRON TUBE DIVISION

Analysis of Noise in the Image Orthicon
B. H. Vine: SMPTE Convention, Los Angeles, Calif., May 1-7, 1960.

Powder and Transparent Phosphor Screens Under High Ambient Illumination
A. E. Hardy: Electrochemical Society Mtg., Chicago, Illinois, May 3, 1960.

Luminescence vs. Composition Studies of Complex Zinc and Cadmium
A. L. Smith: Electrochemical Society Mtg., Chicago, Illinois, May 2, 1960.

Radiation Safety in the Laboratory
H. A. Stern: Safety Mtg., Lancaster Bell Telephone Engineers, Lancaster, Pa., May 13, 1960.

A High-Vacuum Modulator Tube for High-Power Millisecond-Pulse Switching
W. E. Harbaugh and A. C. Tunis: Sixth Symposium on Hydrogen Thyratrons and Modulators, Fort Monmouth, N. J., May 17-19, 1960.

A Four-Terminal Low-Noise Parametric Microwave Amplifier
F. Sterzer and W. Eckhardt: IRE Nat'l Symposium, Microwave Theory and Techniques, San Diego, Calif., May 9-11, 1960.

Some Aspects of X-Ray Technics in the Electron Tube Industry
E. P. Bertin: Clark Memorial Symposium, Univ. of Illinois, May 27, 1960.

An Electrostatically Focused Traveling Wave Tube for Wide-Band Amplification In L- and S-Band
C. L. Cuccia and W. C. Johnson: *Proceedings* of 1959 Nat'l Electronics Conf., May 1960.

Simplified Determination of Plate Dissipation in Horizontal-Deflection-Amplifier and Damper Tubes
K. W. Angel: *Electronic Design*, May 25, 1960.

Advances in Estiatrons, Traveling-Wave Tubes and Magnetrons
M. Nowogrodzki: RCA Microwave-Radar Symposium, Moorestown, N. J.

Power-Output Nomograms
L. J. Striednig: *Electronic Design*, June 22, 1960.

Automatic Polishing Techniques for Electronic-Industry Ceramics
T. F. Berry: American Society for Testing Materials, Atlantic City, N. J., June 28, 1960.

A New Miniature Beam-Deflection Tube
M. B. Knight: *RCA Review*, June 1960.

Parametric Amplification, Power Control, and Frequency Multiplication at Microwave Frequencies Using Cyclotron-Frequency Devices
C. L. Cuccia: *RCA Review*, June 1960.

How to Edit Your Own Papers
E. M. McElwee: 1960 IRE Convention Record, July 1960.

Sintered Cadmium Sulfide Photoconductive Cells
C. P. Hadley and E. Fischer: *Proceedings* of 1959 National Electronics Conference, May 1960.

Electroluminescence
S. A. Harper: Optimists' Club, Lancaster, Pa., June 1, 1960.

Absolute Spectral-Response Characteristics of Photosensitive Devices
R. W. Engstrom: *RCA Review*, June 1960.

The Effectiveness of Ultrasonic Degreasing as Measured by Radiotracer Techniques
H. A. Stern and E. L. Romero: 1960 IRE Convention Record, July 1960.

An Electrostatically Focused High-Power Traveling-Wave Tube
E. F. Belohoubek, W. W. Siekanowicz, and F. E. Vaccaro: RCA Microwave-Radar Symposium, Moorestown, N. J., June 8, 1960.

Tunnel Diode Microwave Oscillators and Amplifiers
D. E. Nelson and F. Sterzer: Electron Tube Research Conf., Seattle, Washington, June 30, 1960.

A Parametric Subharmonic Oscillator Pumped at 34.3 KMC
A. H. Solomon and F. Sterzer: *Proceedings of the IRE*, July 1960.

SEMICONDUCTOR AND MATERIALS DIVISION

An Investigation of the Discharge-Characteristics of Groups VI-VIII Oxides In An Alkaline Electrolyte
C. K. Morehouse and R. Glicksman: *Journal of the Electrochemical Society*, May 1960.

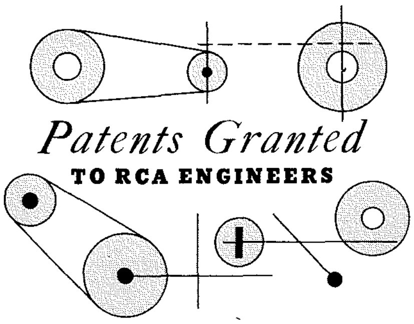
Gallium Arsenide Tunnel Diodes
A. J. Wheeler: Solid-State Device Research Conf., Pittsburgh, Pa., June 13, 1960.

An Experimental Gallium Arsenide Transistor
N. Almeleh, L. D. Armstrong, and J. Mydosh: Solid-State Device Research Conf., Pittsburgh, Pa., June 13, 1960.

Transistorized Automobile Receivers Employing Drift Transistors
R. A. Santilli and C. F. Wheatley: *Semiconductor Products*, June 1960.

Ultra-High-Vacuum Pumping by Vibrating Membrane
H. Schwarz: *Transactions* of 1959 American Vacuum Society Symposium, July 1960.

A Portable AM/FM Receiver Using RCA Drift-Field Transistors
R. A. Santilli and H. Thanos: *Electronics*, July 8, 1960.



Patents Granted
TO RCA ENGINEERS

BASED ON SUMMARIES RECEIVED OVER A PERIOD OF ABOUT TWO MONTHS

INDUSTRIAL ELECTRONIC PRODUCTS

Sideband Transmitter With Phase and Amplitude Modulation Components Amplified Over Separate Paths
2,944,228—July 5, 1960; G. A. Olive.

Convertible Self-Biasing or Amplifying Circuit For Magnetic Recording or Reproducing
2,946,858—July 26, 1960; M. C. Kidd.

ELECTRON TUBE DIVISION

Image Tube
2,946,895—July 26, 1960; R. G. Stoudenheimer and J. C. Moor.

DEFENSE ELECTRONIC PRODUCTS

Electrostatic Printing
2,946,682—July 26, 1960; J. P. Lauriello.

Headset
2,946,860—July 26, 1960; R. E. Jansen and R. E. Ulrich.

Radar System and Display
2,944,253—July 5, 1960; F. D. Covely 3rd and L. E. Haining.

DEFENSE ELECTRONIC PRODUCTS

Foamed-In-Place Structures for Space Vehicles and Stations
C. C. Osgood: A.A.S. Conference, Aug. 8 '60.

A Multi-Level File Structure for Information Processing
L. Miller, J. Minker, W. G. Reed and W. E. Shindle: Western Joint Computer Conference, San Francisco, California, April 1960.

The Design and Simulation of an Information Processing System
Dr. H. M. Gurk and Dr. J. Minker: FIELDATA Applications Systems & Techniques Conference, Disneyland, California, March 1960.

Transient Ablation and Heat Conduction Phenomena at a Vaporizing Surface
R. Fleddermann: Internat'l Congress of Chemical Engineering, Mexico City, June 21, 1960.

Statistical Pitfalls for the Reliability Engineer
G. H. Beckhart: 4th National Convention of Military Electronics, June 27-29, 1960.

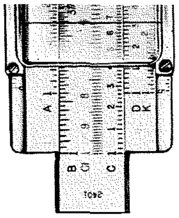
Outline-Plasma Acceleration in an R-F Field Gradient-Theoretical
G. D. Gordon: APS Toronto Meeting, June 1960.

Outline-Plasma Acceleration in an R-F Field Gradient-Experimental
G. A. Swartz, H. W. Lorber and T. T. Reboul: APS Toronto Meeting, June 1960.

Automatic Test Equipment Checks Missile Systems
D. B. Dobson: *Electronics*, July 15, 1960.

Normalized Admittance of Parameters of the Tunnel Diode
E. P. McGrogan: Masters Thesis, University of Pennsylvania, June 1960.

Engineering NEWS and HIGHLIGHTS



IEP EFFECTS MAJOR REORGANIZATION

With the growing complexity of industry, finance, and commerce, electronics has become an increasingly significant aid to efficiency through the three C's—*computers, controls*, and *communications.* To increase its potential for the development and production of advanced systems in these fields, a rapidly growing part of RCA's business, Industrial Electronic Products recently reorganized its operating divisions.

This reorganization, as announced by **T. A. Smith,** Executive Vice President, IEP, resulted in establishment of the new Communications and Controls Division, in addition to the other four—the Electronic Data Processing Division, the Broadcast and Television Equipment Division, the Aviation Division, and RCA Communications, Inc.

The chart on this page indicates the engineering activities under this new organization. [In addition, see *Engineers in New Posts,* this issue, for a number of the assignments within these engineering activities.]

J. J. Graham, who has had executive responsibilities in IEP since its inception in 1957, will guide the efforts of both phases of his division (Communications Products and Industrial Controls), as well as those of various IEP Staff activities, including **W. C. Morrison's** Engineering Plans and Services.

Engineering within the Electronic Data Processing Division now operates in four integrated activities—Commercial Systems, Data Communications and Custom Projects, Industrial Computer Systems, and Advanced Systems Engineering. The Commercial Systems Dept., under **G. W. Dick,** will handle the RCA 301, 501, and 601 product-line data-processing systems. Mr. Dick, who joined RCA this year, formerly was Vice President of marketing for the American Mutual Liability Insurance Co. Prior to that he spent 17 years with IBM.

The Data Communications and Custom Projects Dept., headed by **J. W. Leas,** who was EDP Chief Engineer in the former organization, will devote its efforts to ComLogNet, AutoData, and other specialized digital equipments. The Industrial Computer Systems Dept. was recently established at Natick, Mass. under **C. M. Lewis.** Advanced EDP systems-engineering activities will be headed up by **J. N. Marshall.**

C. H. Colledge, for many years with NBC and since 1958 General Manager of the Broadcast and Television Equipment Division, continues to direct that activity as Division Vice President and General Manager. No changes were made in RCA Communications, Inc., whose world-wide communications-network activities are headquartered in New York. **H. J. Chase** heads up the activities of the new Aviation Division as its Division Vice President and General Manager, under **E. D. Foster,** Division Vice President, Plans and Programs.

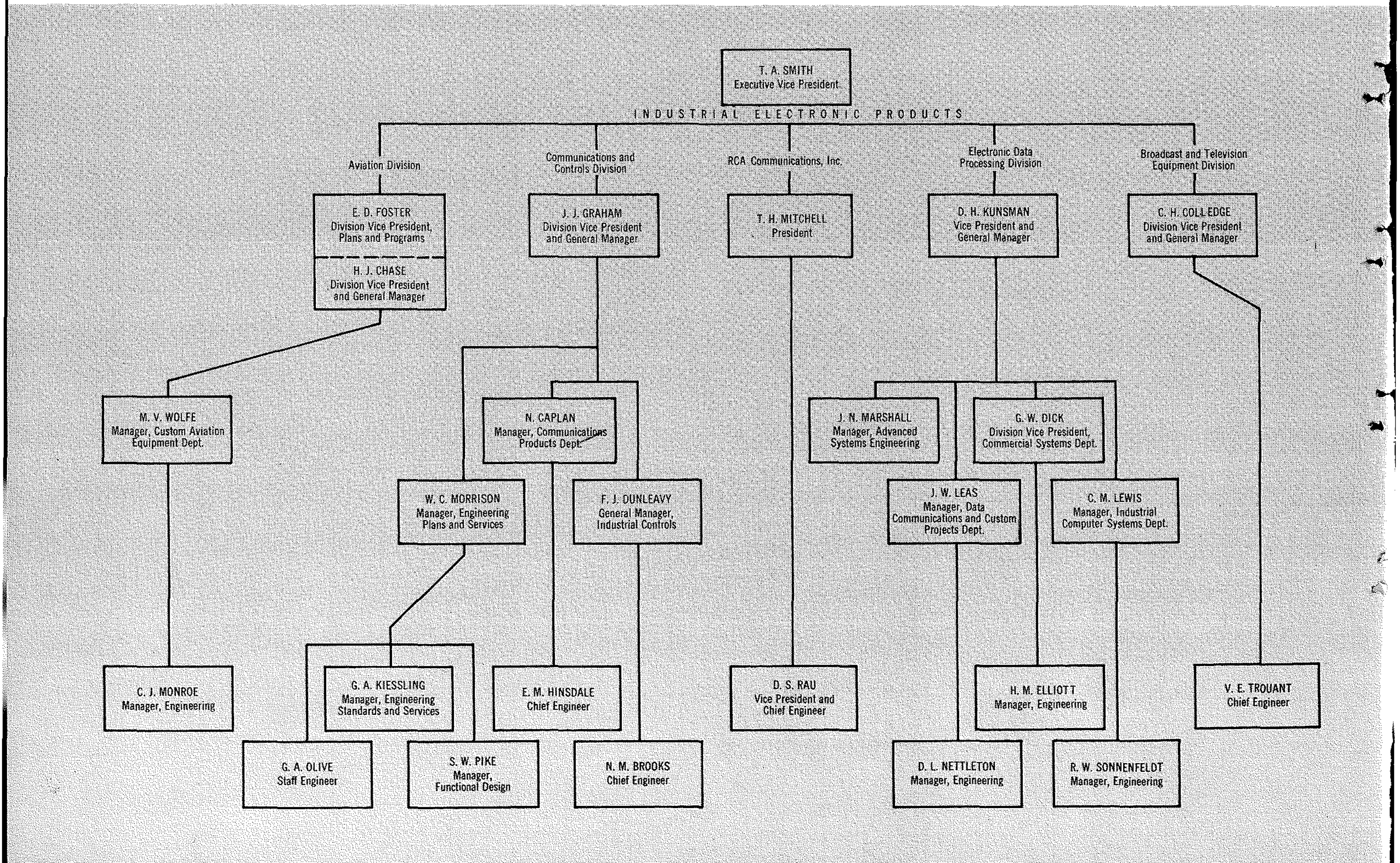
EDP EXPANDS TO FLORIDA AND CHERRY HILL; HOME INSTRUMENTS TO RELOCATE AT INDIANAPOLIS

Ground was broken on August 15, 1960 for a new RCA electronic data processing equipment manufacturing plant at Palm Beach Gardens, a new city being created five miles north of Palm Beach, Fla.

The new $4 million plant, located on a 100-acre plot, is planned to be in operation by January 1961. It will supplement office, engineering, and manufacturing facilities of EDP in Camden. The new facility will be a complex of one-story buildings occupying 180,000 sq. ft. It is anticipated that several hundred persons will be employed there in manufacture of the RCA 301 computer system. Demand for the 301, introduced in April 1960 and suited for moderate-size business applications, has exceeded expectations.

Other EDP groups will move to Cherry Hill, N. J., as the Home Instruments Division and RCA Sales Corporation relocate in Indianapolis, Indiana. The Cherry Hill facility is now a center of major training and methods activities of the EDP Division, as well as the site of one of the RCA-501 electronic data processing centers. Cherry Hill is also the headquarters of the RCA Service Co.'s Electronic Data Processing Service Dept.

Organization of Engineering activities in IEP.



I. K. Kessler (left), Division Vice President and General Manager, Airborne Systems Division, DP, accepts the 1960 GSE award from E. Bergaust.

RCA RECEIVES AWARD FOR "DEE" ENGINEERING

RCA has been honored for development of the DEE (Digital Evaluation Equipment) multi-missile checkout system through a 1960 GSE Award from *Ground Support Equipment* magazine. The award, a bronze plaque with the inscription ". . . *For outstanding engineering achievement in the development of the DEE Missile Checkout Equipment* . . ." was presented to **I. K. Kessler,** Division Vice President and General Manager, Airborne Systems Division, DEP, at the 1960 GSE Symposium dinner at the Shoreham Hotel, Washington, D.C., on September 8, 1960 by E. Bergaust, President of the Sheffield Publishing Co. (See photo.)

Development of the DEE equipment stands as an important advance in the area of support engineering, since it provides, in one equipment, checkout capability for a number of different missile systems. It is described in this issue by **F. Everhard** in "DEE . . . Digital Evaluation Equipment . . . for Multi-Missile Checkout."

ENGINEERS IN NEW POSTS

In the RCA Service Co., **E. A. Speakman** has been named to the new position of Division Vice President, Missile Range Programs by **S. D. Heller,** Division Vice President, Government Services. Under Mr. Speakman is **G. D. Clark,** Mgr., Missile Test Project.

In the RCA International Division, **M. E. Karns** has been appointed Division Vice President, License Operations, under **D. C. Lynch,** Vice President and Managing Director.

In RCA Victor Home Instruments Division, **D. L. Mills** has been named Division Vice President and General Manager. His staff includes: **W. E. Albright,** Mgr., Manufacturing Development; **E. I. Anderson,** Chief Engineer; and **J. D. Walter,** Mgr., Materials.

In the Semiconductor and Materials Division, **W. H. Painter** has been named Division Vice President, Operations Planning, under **A. M. Glover,** Vice President and General Manager. **R. E. Rist** has been appointed Mgr., Computer Transistor Manufacturing. **R. J. Hall** has succeeded **J. M. Spooner** as Plant Manager, Findlay, Ohio, plant. Mr. Spooner assumes a position with a new management group being organized by RCA International, Ltd., for activities in Rome, Italy. Mr. Hall's staff includes **R. H. Kramer,** Mgr., Manufacturing Standards; **K. D. Lawson,** Mgr., Plant Engineering; **J. W. Ritcey,** Mgr., Manufacturing and Production Engineering; and **H. A. Uhl,** Mgr., Plant Quality Control.

In the RCA Electron Tube Division, **D. Y. Smith,** Vice President and General Manager, announces his staff to include: **H. F. Bersche,** Mgr., Distributor Products Dept.; **C. E. Burnett,** Division Vice President, Industrial Tube Products Dept.; **L. R. Day,** Mgr., New Business Development; **J. B. Farese,** Division Vice President, Entertainment Tube Products Dept.; and **G. R. Shaw,** Chief Engineer. At Harrison, **F. J. Lautenschlaeger,** Plant Manager, announces his staff to include: **C. A. Dickinson,** Mgr., Tube Manufacturing; **J. P. Gunther-Mohr,** Mgr., Manufacturing Standard; **R. A. Jacobus,** Mgr., Quality Control; and **C. G. Schwartz,** Mgr., Plant Engineering. At Woodbridge, **W. B. Brown,** Plant Manager, announces his staff to include: **A. H. Bishof,** Mgr., Plant Engineering; **R. H. Handler,** Mgr., Tube Manufacturing; **M. O. Juvrud,** Mgr., Plant Quality Control; and **H. H. Wheaton,** Mgr., Manufacturing Standards. At Harrison, Mr. Dickinson's staff includes: **W. R. Andrews** as Mgr., Tube Production Engineering, whose group in turn consists of **J. Florek,** Mgr., Computer-Premium Tube Production Engineering; **S. W. Lefcourt,** Mgr., Miniature Tube Production Engineering; **C. J. Lee,** Mgr., Metal Tube Production Engineering; and **R. C. Schoellkopf,** Mgr., Parts Preparation Production Engineering. **E. Rudolph,** Mgr., Equipment Design and Development, Receiving Tube Operations, announces his staff to include: **M. M. Bell,** Mgr., Nuvistor Equipment Development Design; **J. G. Woehling,** Mgr., Receiving Tube Equipment Development Design; **P. L. Farina,** Mgr., Technical Services; and **H. Hermanny,** Mgr., Equipment Development Design Resident Engineering. Mr. Bell's group includes: **W. T. Ackermann** and **W. T. Engel,** both Mgr's., Mechanical Equipment Development Design, and **S. N. Nasto,** Mgr., Electrical Equipment Development Design. Mr. Woehling's group includes: **H. C. Fioretti, T. E. Swander,** and **H. F. Welsh** as Mgr's., Mechanical Equipment Development Design; and **F. J. Yanotti** as Mgr., Electrical Equipment Development Design. In Conversion Tube Operations, **W. E. Rohland, Jr.,** Mgr., Camera, Oscillograph and Storage Tube Manufacturing, announces his staff to include **G. D. Cartwright,** Mgr., Production Engineering, Oscillograph and Storage Tubes; and **W. S. Lynch,** Mgr., Production Engineering, Camera Tubes.

In DEP, **W. G. Bain,** Vice President and General Manager, Communications and Aerospace, announces the appointment of **S. W. Cochran** as Division Vice President and General Manager, Surface Communications Division, and **I. K. Kessler** as Division Vice President and General Manager, Airborne Systems Division. In the Missile Electronics and Controls Division, **W. B. Kirkpatrick,** General Manager, announces the appointment of **Dr. S. L. Simon** as Chief Engineer. Dr. Simon succeeds **Dr. R. C. Seamans, Jr.,** who has accepted a post with the NASA. Three new BMEWS appointments in the Missile and Surface Radar Division include: **W. W. Pleasants** as Mgr. of the BMEWS installation at Clear, Alaska; **J. L. Sarafian** as Mgr., BMEWS Central Computer and Tactical Display facility at NORAD Headquarters in Colorado Springs; and **J. J. Guidi** as Mgr., BMEWS Field Support Activities.

Within the new IEP Communications and Controls Division, **F. J. Dunleavy,** General Manager, Industrial Controls, announces his staff to include: **N. M. Brooks,** Chief Engineer, **T. L. Dmochowski,** Mgr., Fleet Marine Equipment Dept., **E. J. Hart,** Mgr., Microwave Dept., **S. K. Magee,** Mgr., Controls and Scientific Instruments Dept., **I. C. Maust,** Mgr., Detroit Industrial and Machine Tool Dept., and **H. R. Swartz,** Mgr., Production Dept. Under Mr. Hart, **N. E. Edwards** is Mgr., Engineering and **H. S. Wilson** is Mgr., Custom Microwave Project. Under Mr. Maust, **M. A. Scherrens** is Plant Manager, Detroit Plant; and **A. J. Pardikes** is Mgr., Equipment Installation. **N. Caplan,** Mgr., Communications Products Dept., announces his staff to include **E. M. Hinsdale,** Chief Engineer; and **R. E. Wilson,** Plant Manager, Canonsburg Plant. Mr. Wilson's staff includes: **C. T. Burgett,** Mgr., Quality Control; **J. W. Chambers,** Mgr., Manufacturing; **D. H. Mercer,** Mgr., Manufacturing Engineering; and **D. E. Bailey,** Mgr., Plant Engineering. Mr. Hinsdale's staff includes: **L. J. Anderson,** Mgr., Audio Products Engineering; **N. C. Colby,** Mgr., Systems Engineering; **K. L. Neumann,** Mgr., Two-Way Radio Engineering; **W. D. Rhoads,** Mgr., Sustaining Engineering; and **G. F. Rodgers,** Mgr., Advanced Development.

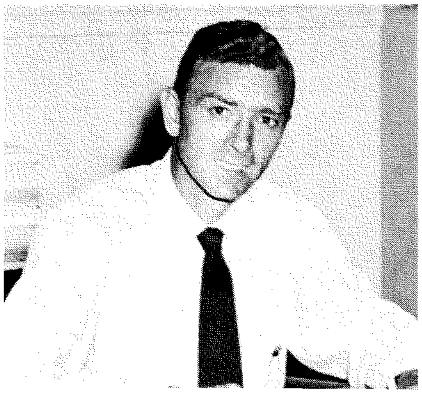
REGISTERED PROFESSIONAL ENGINEERS

Mark E. Meer, SurfCom, DEP, Camden..................Prof. Eng., 36986, N.Y.

◀ A Tribute to a Good Friend . . . Bill Bohlke

Because of the press of duties in a new assignment in the RCA Service Company, Bill Bohlke, loyal friend, supporter, and active Editorial Representative ever since the RCA ENGINEER's inception, has stepped out from the ranks of Ed. Reps. Bill's 32-year distinguished career with RCA and his 5 years of outstanding work as an Editorial Representative are deserving of only our highest praise. So long as we can count men of Bill's caliber among our Editorial Representatives, the RCA ENGINEER cannot help but thrive.

. . . The Editors



J. H. Lipscombe

MORE U. S. DEFENSE BUSINESS FOR RCA VICTOR, LTD. IN MONTREAL

In an address at the annual banquet of the Canadian International Air Show in Toronto on Sept. 9, **John L. Burns,** President of RCA, stated ". . . As defense and space electronics has become more and more important, and as our U.S. Defense business had grown, we have increasingly drawn our Canadian facilities into both the development and production phases of this work.

". . . RCA, in cooperation with the Canadian Dept. of Defense Production, has placed with the RCA Victor Company, Ltd., [Montreal], a $2 million defense order for equipment for an electronic detection and control system which is part of the North American aerial defense. This system involved the automatic transmission of information to interceptor planes and Bomarc missiles . . ."

ROSS-WARREN, RCA MONTREAL, TO CHAIR RADAR SYMPOSIUM SESSION

Dr. F. G. Ross-Warren, Director of the Electronics Laboratory, RCA Victor Research Laboratories, Montreal, will act as Chairman of Session I at the International Symposium on the Application of Low-Noise Receivers to Radar and Allied Equipment, to be held at the Lincoln Laboratories, MIT, Oct. 24-28, 1960. under the auspices of the Tripartite Technical Cooperation Program Subgroup K, sponsored by the United States, United Kingdom, and Canada.

—*H. J. Russell*

TEN RCA ENGINEERS ACTIVE AT WESCON

Ten RCA engineers took part in the 1960 WESCON in Los Angeles, held Aug. 23-28. **W. R. Isom,** DEP Applied Research, chaired a session on "Magnetic Data Recording"; **D. Mackey,** SC&M, Somerville, took part in a panel on "Microminiaturization"; and **E. A. Speakman,** took part in a panel on "Management of Man-Machine Systems." Papers were delivered by **D. E. Nelson** and **F. Sterzer,** RCA Laboratories, "Tunnel Diode Microwave Oscillators with Milliwatt Power Outputs"; by **D. T. Levy,** SC&M, Somerville, on "A Packaged Micromodule Laboratory for Industry" (planned for an early issue of the RCA ENGINEER); by **A. Bogush,** DEP Moorestown, "Fresnel Region Boresight Methods"; by **R. E. Davis,** DEP-ASD, Camden, "Automation in Air Traffic Control" (see Vol. 5, No. 3, RCA ENGINEER); and by **E. L. Danheiser** and **M. Korsen,** DEP Moorestown, "The BMEWS Automatic Monitoring System."

COMMITTEES

In IEP, **G. Zappasodi,** Mgr., IEP Packing Design, was recently elected Program Chairman of the Philadelphia Chapter of the Society of Packaging and Handling Engineers. **D. Bowen,** IEP Standards Engineering, has assumed the Chairmanship of the IRE Philadelphia Section Symposia Committee for 1960-61. —*S. F. Dierk.*

LIPSCOMBE NEW ED REP AT MARION; COOK NEW SERVICE CO. ED REP

For Black and White Kinescopes engineering, Marion, Ind., (Electron Tube Division), **John H. Lipscombe** has replaced **Jan DeGraad** (who has left RCA) as Editorial Representative. John will serve on **J. F. Hirlinger's** Editorial Board.

In the Consumer Products Service Dept. of the RCA Service Co., **W. W. Cook** has succeeded **Bill Bohlke** as Editorial Representative. (Mr. Cook's biography will be presented in a subsequent issue.)

John H. Lipscombe, an engineer in the Chemical and Physical Laboratory of the Marion plant, was born and educated in Great Britain, receiving his engineering degree from Acton Technical College. He joined RCA in 1958, after working for other firms in England and Canada in the production and development of fluorescent material, electron tubes, germanium diodes, and vacuum equipment. He has made a number of noteworthy contributions both to RCA and to civic activities since coming here, and is in frequen tdemand as a speaker for service clubs and school groups.

DEGREES GRANTED

In DEP, **C. N. Hill,** Product Design Assurance, Airborne Systems Division, received the BSEE from Drexel. —*J. Biewener*

In SurfCom, **J. Liebermann** received the MSEE from the University of Pennsylvania.

ENGINEERING MEETINGS AND CONVENTIONS

Nov. 4-5
Communications Symposium (IRE), Queen Elizabeth Hotel, Montreal, Canada.

Nov. 14-16
Mid-America Electronic Convention (MAECON), Hotel Muehlebach, Kansas City, Mo.

Nov. 15-16
PG on Production Tech. 4th Annual Conference (PGPT & NEREM), Boston, Mass.

Nov. 14-17
Conf. on Magnetism & Magnetic Materials (AIEE:AIP:ONR:IRE: AIME:PGMT&T), New Yorker Hotel, New York, N.Y.

Nov. 27-Dec. 2
ASME Winter Annual Meeting, Statler Hilton Hotel, New York.

Dec. 1-2
PGVC (Vehicular Communications), Annual Meeting, Sheraton Hotel, Philadelphia, Pa.

Dec. 13-15
Eastern Joint Computer Conference (PGEC:AIEE:ACM), New Yorker Hotel and Manhattan Center, New York.

Jan. 9-11, 1961
7th Natl. Symp. on Reliability & Quality Control in Electronics (PGRQC : ASQC : AIEE : EIA), Bellevue-Stratford Hotel, Philadelphia, Pa.

Jan. 1961
Symposium on Space Instrumentation (PGSET), Washington, D.C.

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