OUR COVER

. . . uses as a background an enlarged photomicrograph of the phosphor dots on an RCA color picture tube as they are being illuminated by the electron beam. In the center photo, Billie Haas (left) and Robert Carter, of the Applications Dept., Color TV Product Engineering, TV Picture Tube Div., ECD, Lancaster, Pa., are shown with a color receiver mounted in a test frame. The microscope seen at the left of the NTSC test picture on the tube is used to examine the illuminated phosphor dot pattern on the picture tube. (Cover art direction, J. Parvin. Photo, R. Allen.)

Color—From Drought to Boom

Color television is now synonymous with thriving enterprise. Credit for this achieve- ment goes in no small measure to the RCA engineers whose perseverance anc ingenuity overcame numerous anxieties as color TV grew slowly at first in consume acceptance—then skyrocketed to an overwhelming, ever-increasing demand.

This demand, resulting in to-day's temporary short supply of color picture tubes prompted RCA's decision, announced June 16, 1965, to spend an additional $36.4 million on new facilities at our Marion, Ind., and Lancaster, Pa., color picture tube plants. When completed, RCA will have spent more than $65 million for colo tube expansion since 1962.

As the world's largest manufacturer and supplier of color picture tubes to th TV industry, our present annual output is more than 1,350,000 units. The lates expansion program will enable us to increase our annual color tube production t over 2,000,000 units in 1966, to more than 2,500,000 in 1967.

Compare these figures with those for just five short years ago—when the industr demand in 1960 was for only 100,000 color picture tubes—and our annual produc- tion capacity was 360,000. Indeed, the present-day manufacturing climate for RCA color picture tubes certainly is quite a contrast from the drought period *befor* color "took off" in the latter part of 1961 and emerged as a significant contributo to the Corporation's sales and profits.

It was during this discouraging drought period that the engineer had to disregar his frustration in the slow consumer acceptance of color and take every advantag to improve his technical capabilities. He was equal to the challenge. He responde not only with patience, but with an uncompromising determination to maintai our picture tubes' high quality standards. We believe this high quality to b largely responsible for the changed attitude in public acceptance of color—and a main factor in the color boom.

Truly, color has arrived. But the RCA engineer's responsibility in man respects has only just begun. In upholding our position of leadership, he mus now be alert to competition and market demands for innovations as well as nev system approaches. This is his tradition and heritage.

J. B. Fares
Division Vice Presiden
Electronic Components and Device
Radio Corporation of Americ

RCA ENGINEER

VOL. 11, NO. 2
AUG.-SEPT. 1965

CONTENTS

PAPERS

NOTES

DEPARTMENTS

A TECHNICAL JOURNAL PUBLISHED BY **RADIO CORPORATION OF AMERICA,** PRODUCT ENGINEERING 2-8, CAMDEN, N. J.

• 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 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.

An index to RCA ENGINEER articles appears annually in the April-May issue.

Editors Note: Engineers often think of the technical article, a professional paper, or a report as the only media for recording their general or specialized knowledge. But, the important medium of the **technical book** must not be overlooked. This paper emphasizes the opportunities and the rewards of recording and publishing in the more comprehensive form—the technical professional book.

The Engineer and the Corporation

BOOKS LOOKING FOR AUTHORS

C. W. FIELDS
Engineering Editor
Communications Systems Division
DEP, Camden, N. J.

THIS article begins with a truism: *there is an important market for authoritative books by engineers and scientists.* Research, development, and design activities generate voluminous data and know-how on everything from material research involving new crystalline structuring to ingenious ways of designing and packaging circuitry. Technical publishing houses are aggressively seeking the creators of these new data and techniques to turn the originators into authors of books being sought by other engineers and scientists.

The potential purchasers of technical books fall into two main categories: 1) practicing engineers, scientists, and technicians; and 2) educators and students. If the book catches fire with either of these two groups, the author is handsomely rewarded by royalties. Many books just keep modest but persistent royalties coming in.

HOW THE TPA CAN HELP

The engineer already caught with the inspiration needs to be brought together with the particular publisher interested in his category. At RCA, where engineers and scientists are warmly encouraged to write books, Technical Publications Administrators and Editorial Representatives are available for guidance in evaluating the idea, selecting a publisher, and getting Corporate approvals[1].

We contacted some of the major technical book houses with the query: *What particular category of authorship are you looking for currently?* All responded, resulting in the listings here; several didn't want to reveal the information, but sent catalogs of recent publications.

TYPICAL "WANTED" BOOKS

PRENTICE-HALL, INC., say they have a list of wanted titles of over a hundred just in the communications area. These cover electrical engineering, applied mathematics, automatic computation, physics, pure mathematics, etc., and run the gamut from technician-level education to university graduate levels. Specifically they would be interested in hearing from prospective authors on the following topics:

1) *communications systems*—undergraduate level course on principles, textbook overview of the field for one semester.
2) *coding and modulation*—senior-graduate-level text.
3) *transistor circuits or electronics*—assumes a minimum of one course in electronics.
4) *digital data communications* — Engineering-oriented rather than mathematical-theoretical: modes of techniques, characterizing the channel, coding, high-speed systems, microwave links, strong emphasis on pulse code modulation.
5) *switching circuits*—general text.
6) *pulse code modulation*—senior-graduate level.
7) *teleprocessing.*
8) *integrated circuits*—the need is for a tutorial work which emphasizes applications rather than fabrication techniques.

D. VAN NOSTRAND COMPANY, INC. proudly cited the books: *Microwave Solid-State Engineering*, edited by Drs. Nergaard and Glicksman; *Photoelectronic Materials and Devices*, edited by Dr. S. Larach (in preparation); *Acoustical Engineering* and *Dynamical Analogies* both by Dr. Olson—the two latter having become standard reference works in the field. All the authors mentioned are with the RCA Laboratories, Princeton. (See also some current RCA authors and book titles, this issue).

Van Nostrand says, "Our range of publishing extends quite widely over the fields of science, engineering, and mathematics. Specifically, we are actively seeking more up-to-date books on computers and data processing. While we have quite a few titles in this field, we are naturally interested in obtaining those representing the newer developments. We also believe that the field of lasers represents a most promising one in which to publish."

HAYDEN BOOK COMPANIES spoke a publishing business truism: "Hayden Book Division of the Hayden Publishing Company, Inc., is interested in publishing scientific books aimed at practicing engineers as well as engineering undergraduate and graduate students. Topics in all branches of science and engineering are desired." Their John F. Rider division is looking for books aimed primarily at the technician, and serviceman, and junior college and technical institute students. Hayden also supplied the typical proposal outline shown in Table I.

Table II shows a list of technical book publishers with an indication of their interests in engineering and scientific books.

Your idea for a book may come from this article, from missionary work by a publisher, as a result of discovering a gap in the literature during personal research, or from other stimuli. However or whenever the idea comes, *there is probably a book on that idea looking for an author.*

BIBLIOGRAPHY

1. M. P. Rosenthal (RCA-CSD, New York) "How to Write a Technical Book and Get It Published," *IEEE Trans. on EWS*, 7-2, Sept. 1964 (includes list of 60 technical-book publishers and their requirements); also appeared (excluding publisher list) in RCA ENGINEER, *10*-2, Aug.-Sept. 1964.
2. J. C. Hogan and S. Cohen, *Scholarly Publishing and the Law*, Prentice-Hall, Inc., Englewood Cliffs, N. J.
3. *The McGraw-Hill Author's Book;* McGraw-Hill Book Company.
4. *Writer's Market*, Writer's Digest, Cincinnati 10, Ohio.

Final manuscript received May 25, 1965

C. W. FIELDS received the BS in Journalism from Temple University in 1955 and has since taken courses in electronics and technical writing. After work on local industrial periodicals, he joined RCA in 1956 as technical writer, later advancing to engineering editor, concerned with writing and editing a variety of engineering publications in DEP Communications Systems Division. In 1963, he was named Chief Editor, CSD Documentation and Engineering Publications. He currently heads a CSD function responsible for soliciting, editing, and placing technical papers; creating and running technical communications and information projects; and editing and processing R&D reports. He created and helped coordinate the continuing "engineering lecture" series in Camden. He has served as an RCA ENGINEER Editorial Representative and as a member of the DEP Editorial Board for several years. Mr. Fields has published several papers in RCA and outside magazines and journals. He is a member of the IEEE Group on Engineering Writing and Speech, Editor of the G-EWS "Newsletter", Associate Editor of the "Transactions on EWS" and a member of the editorial board of the IEEE Philadelphia Section "Almanack." He is 1965-66 Chairman of the Philadelphia Chapter of G-EWS.

TABLE I—Outline for Book Proposal

1. Title of book (even if tentative).
2. Author's name, affiliation, and a word or two on his qualifications for writing on this subject.
3. A brief general summary of the book idea including the significance and uniqueness of the author's approach to the subject—a kind of preface to the work.
4. For whom is the book intended—what are the potential audiences, at what level is the book written?
5. What is the approximate length of the proposed book?
6. Approximately when is the manuscript expected to be completed?
7. Are there competitive or similar books in print? If so, how does the proposed work differ from those already in print?
8. A detailed chapter outline of the proposed book.
9. A sample chapter or two of the proposed book to give us some idea of the author's treatment of the subject matter.
10. Pertinent information on illustrations: approximate number; are they line drawings, or will some be photographs; any four-color illustrations; et cetera.

TABLE II—Sample List of Technical Book Publishers
(extracted from *Writers Market*[4])

Academic Press, Inc., 111 Fifth Ave., New York 3, N.Y. Kurt Jacoby, Editor. Specializes in scientific works.

Addison-Wesley Publishing, Inc., Reading, Mass. Publishes technical books on the college and graduate level only. Payment is on royalty basis.

American Book Company, 55 Fifth Ave., New York 3, N.Y. Dr. James U. Rundle, Manager, College Publications; Leroy L. Burggeman, Manager, International Publications. Publishes classroom textbooks for all widely taught subjects at college and university levels. Manuscripts are usually written and submitted after preliminary agreement. Royalty payment to authors; outright payment to illustrators.

Barnes & Noble, Inc., 105 Fifth Ave., New York 3, N.Y. Samuel Smith, Editor. Publishes educational books and scholarly works, as well as nonfiction how-to-do-it books. College Outline Series, Everyday Handbooks, University Paperbacks American Authors and Critics Series, U Books, Barnes & Noble Art Series.

Barron's Educational Series, Inc., 343 Great Neck Road, Great Neck, N.Y. Dr. Vincent F. Hopper, General Editor. Publishes high school and college educational science books. Prefers outlines and sample chapters before finished manuscript is submitted. Royalty schedule is subject to the manuscript.

Chelsea Publishing Company, 50 East Fordham Rd., New York 68, N.Y. Aaron Galuten, Editor. Publishes books on science and mathematics.

Hayden Book Companies, 116 West 14th St., New York 11, N.Y. Edward E. Grazda, Director Scientific and Engineering Projects.

Iowa State University Press, Press Building, Ames, Iowa. Marshall Townsend, Manager. Publishes books of science and engineering—authoritative professional and textbooks of modern appeal, mostly college level. Prefer outline or full table of contents with query letter. Reports in 30 to 60 days. Payment is on royalty basis.

McGraw-Hill Book Company, Inc. (Trade Division), 330 West 42nd St., New York 36, N.Y. Edward Kuhn, Jr., Robert Cousins, John Starr, Robert Gutwillig, Barbara L. Collins, Leon Wilson, and David Scott, Department Editors. Publishes science, engineering, and how-to books. Prefers length to be 50,000 to 125,000 words. Royalty schedule is 10% to 5,000, 12½% to 10,000, 15% thereafter.

Open Court Publishing Company, 1307 Seventh St., La Salle, Illinois. Editorial Office: Box 268, Wilmette, Illinois. Dr. Eugene Freeman, Editor-in-Chief. Publishes scholarly books in the fields of philosophy, mathematics, science and education, of 75,000 to 150,000 words. Queries are not necessary. The royalty schedule is 10% of net.

Prentice-Hall, Inc., Englewood Cliffs, N.J. and 70 Fifth Ave., New York 11, N.Y. Stuart L. Daniels, Editor-in-Chief, Trade Book Division. Publishes nonfiction of all types and a limited amount of fiction. Wants practical self-help, inspirational, topical, historical, and biographical. Payment is on royalty basis.

G. P. Putnam's Sons, 200 Madison Ave., New York 16, N.Y. Howard Cady, President and Editor. 60,000 words and up, of all types. Non-fiction in travel, science, biography, etc. College textbooks. Well-known authors may submit outline and a sample chapter. Lesser known authors should submit at least half the book for inspection. Payment is on royalty basis. Edmund L. Epstein is Editor of the Capricorn Books Dept.

Reinhold Publishing Corp., 430 Park Ave., New York 22, N.Y. G. G. Hawley, Executive Editor; Art and Architectural Editor, John Koefoed. Publishes technical and scientific books in chemical and allied fields; college textbooks (Editor, J. B. Ross). Contracts are offered on the basis of an outline and a sample chapter. Payment is by royalty.

Howard W. Sams and Co., Inc., 2201 E. 46th St., Indianapolis 6, Ind. Verne M. Ray, Editor-in-Chief. Publishes technical books for the electronics industry. Their audience is comprised of students, technicians, engineers, hobbyists, experimenters. Prefers queries, outlines, and sample chapters, in this order. Royalty depends on author, subject, etc. Usually reports within 30 days.

D. Van Nostrand Company, Inc., 120 Alexander St., Princeton, N.J. Edward M. Crane, President. Publishes scientific, educational, reference, and trade books. No fiction. Theodore Saros, Executive Editor, College Department; Williams R. Minrath, Vice President; Norman Hood, Senior Trade Editor. Publish Anvil Books, Insight Books, Searchlight Books.

Verlan Books, Inc., 915 Broadway, New York 10, N.Y. Lester Kaplan, Editor. Publishes technical books on electronics, radio, hi-fi and tape recording, electrical repairs, computers. Books in soft and hard cover for hobbyist, amateur and scholarly fields. Should run about 25,000 words, plus illustration, sketches or photos. Query first, sending outlines and sample chapters. Royalty schedule negotiated with prospective author. Reports within 30 days.

John Wiley & Sons, Inc., 440 Park Ave., South, New York 16, N.Y. Publishes technical, scientific and business books. Also college textbooks.

REVIEWS OF RECENT TECHNICAL BOOKS BY RCA AUTHORS

"TABLES OF LAPLACE TRANSFORMS"

G. E. Roberts and H. Kaufman
RCA Victor Co., Ltd.
Montreal, Canada

This is a comprehensive collection of Laplace transforms. It contains both direct and inverse transforms with statements on the validity conditions on the parameters and features an effective key for locating individual entries. (*To be published in late 1965 by W. B. Saunders, W. Washington Sq., Philadelphia, Pa. Price not yet known.*)

GEORGE E. ROBERTS graduated in 1945 from Portsmouth Naval College and was also granted Associate Membership in the Institute of Engineering Technology in 1944 in Radio and Television theory. Mr. Roberts was with the British Admiralty where he gained nine years experience in radar and communications equipment and in mathematical statistics and probability theory. In 1951 he joined RCA Victor Company, Ltd., to do mechanical design and development work on the AN/TPS-503 Height Finder Radar and communication antenna design; he has also engaged in systems studies, theoretical analysis of the effects of nonlinear devices on complex waveforms, antenna design studies, and in systems reliability studies on spacecraft. He has published numerous papers in his field.

HYMAN KAUFMAN graduated in 1941 from McGill University with the Anne Molson Gold Medal and First Class Honors in Mathematics and Physics. He received his Master's degree in 1945, and his Ph.D. degree in 1948. He has been an Associate Professor and Professor in the Mathematics Department at McGill University since 1952. He has also been mathematical consultant to Adalia Computations Ltd., Montreal, and to Electronic Systems, Inc., Boston. He has published numerous papers in his field of geophysics. He is listed in American Men of Science and is a member of the IEEE, American Mathematical Society, Mathematical Association of America, Society of Exploration Geophysicists, American Association for the Advancement of Science, Society of Sigma Xi, Operations Research Society of America, Association of Computing Machinery, and Society of Industrial and Applied Mathematics.

"FIELD-EFFECT TRANSISTORS"

Edited by J. T. Wallmark and Harwick Johnson
Contributing RCA Engineers:
A. Rose, J. T. Wallmark, K. H. Zaininger, D. Meyerhofer, A. G. Revesz, S. R. Hofstein, H. Johnson, S. M. Christian, F. P. Heiman, P. K. Weimer, D. Griswold, P. E. Kolk, A. K. Rapp and L. Greenspan
(See below for division and location)

It is the purpose of this book to assist physicists, device engineers and applications engineers interested in field-effect transistors by presenting all essential information on the field-effect transistor in one place and in easily accessible form. This broad coverage is particularly desirable since the building of integrated circuits, in which field-effect transistors appear destined to play an important role, requires the collaboration of many different groups of specialists, each with a need to understand the problems of the others.

The chapters, titles, and names of RCA contributors are as follows: Foreword by A. Rose, RCA Laboratories, Princeton, N. J., 1) Introduction (to Field-Effect Transistors) by J. T. Wallmark, RCA Labs., Princeton, N. J., 2) Semiconductor Surface Physics by K. H. Zaininger, RCA Labs., Princeton, N. J., 3) Conduction Through Insulating Layers by D. Meyerhofer, RCA Labs., Princeton, N. J., 4) Growth and Properties of Thin SiO_2 Films by A. G. Revesz, RCA Labs., Princeton, N. J., 5) Field-Effect Transistor Theory by S. R. Hofstein, RCA Labs., Princeton, N. J., 6) Noise in Field-Effect Transistors by Harwick Johnson, RCA Labs., Princeton, N. J., 7) Radiation Tolerance of Field-Effect Transistors by S. M. Christian, RCA Labs., Princeton, N. J., 8) MOS Field-Effect Transistors by F. P. Heiman, RCA Labs., Princeton, N. J., 9) Thin-Film Transistors by P. K. Weimer, RCA Labs., Princeton, N. J., 10) Applications of Field-Effect Transistors in Linear-Amplifier or Attenuator Circuits by D. Griswold, Electronic Components and Devices, Somerville, N. J., 11) The Field-Effect Transistor in High-Frequency Linear Circuits by H. Johnson, RCA Labs., Princeton, N. J., and P. E. Kolk, Electronic Components and Devices, Somerville, N. J., 12) Applications of Field-Effect Transistors in Digital Circuits by A. K. Rapp, RCA Labs., Princeton, N. J., and 13) Field-Effect Transistor Bibliography by J. T. Wallmark and L. Greenspan, RCA Labs., Princeton, N. J. (*The book publisher is Prentice-Hall; publication approximately end of 1965; no price given as yet.*)

Editor's Note: Because of the great number of contributors, biographies and author photos were of necessity omitted, with the exception of the book editors.

J. TORKEL WALLMARK received the degrees of Civilingenjor in electrical engineering in 1944, Teknologie Licentiat in 1947, and Teknologie Doktor in 1953, from the Royal Institute of Technology, Stockholm, Sweden. From 1944 to 1945 he was a vacuum-tube Designer for the A. B. Standard Radiofabrik, Stockholm. He was with the Royal Institute of Technology as a Research Assistant on vacuum-tube problems from 1945 to 1953. At the same time he spent periods at the RCA Laboratories in Princeton, N. J., and at Elektrovarmeinstitutet and Tekniska Forskningsradet, both in Stockholm, engaged in work on secondary emission tubes, semiconductors, and research administration. In 1953 he joined RCA Laboratories, Princeton, N. J., where he has been engaged in research on magnetrons, color television, semiconductor devices, and intergrated electronics. He is now on leave of absence as a professor at Chalmer University, Gothenburg, Sweden.

HARWICK JOHNSON received the BSEE in 1934 from the Michigan College of Mining and Technology; the MSEE in 1940 and the Ph.DEE in 1944 from the University of Wisconsin. He joined RCA Laboratories in 1942, and has worked in several areas of electronics, including microwave tubes, gas discharge noise sources, and semiconductor devices. Dr. Johnson is the author of four technical papers and holds several U.S. Patents. At present, he is Associate Director of the Electronic Research Laboratory and Head of the Semiconductor Electronics Section.

"ELECTRICAL INTERFERENCE"

R. Ficcki
DEP Communications Systems Division
Camden, N. J.

Mr. Ficcki's book, "Electrical Interference" published by Hayden Book Company, N. Y., 1964, has been published in a British Edition of ILIFFE, Ltd., London. This is for distribution in the Commonwealth nations and represents a broadening of the marketing possibilities. A second printing of the American Edition is being prepared.

This book was covered in the Aug.-Sept. RCA Engineer, 1964.

"SPACECRAFT STRUCTURES"

C. C. Osgood
Astro-Electronics Division
DEF, Princeton, N. J.

All the factors of importance in the design of spacecraft structures are surveyed and much information and data is given for the convenience of the designer or analyst. Six sections are included: 1) Mission Analysis, 2) Design Approaches and Criteria, 3) Analytical Techniques, 4) Structural Types and Materials, 5) Design Examples, and 6) Future Techniques. Explanations are given for the designer on how the structural requirements arise from the mission; successful methods of satisfying these requirements are illustrated. The topics were treated by surveying the present state of the art as revealed by recent books, research literature and analyses obtained directly from design organizations within the aerospace industry. (*Published by Prentice-Hall, 1965; approximate price $12.00 - $14.00.*)

CARL C. OSGOOD received the MSME in 1943 from the University of Maine, the MS in Metallurgy from the University of Pennsylvania in 1951 and has completed course requirements for the Ph.D. He is a Member, Technical Staff, RCA Astro-Electronics Division where he specializes in mechanical and metallurgical engineering. He taught these disciplines for 11 years at several universities. At AED he has been responsible for the mechanical design, construction, and testing of two observation satellites, and was Design Manager for the TIROS and Relay satellites. Mr. Osgood is Chairman of Design Reviews for TIROS, Apollo Cameras and classified projects; and he is a consultant in Mechanical and Materials Engineering for Spacecraft Design. Mr. Osgood is a member of the New York Academy of Sciences, the American Society of Metals, the Review Board for "Applied Mechanics Review," and is a Professional Engineer in Maine and New Jersey. He has published numerous technical papers and, in 1965, a book on "Spacecraft Structures."

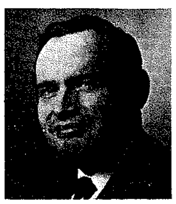
"HIGH-FIDELITY AND STEREO"

M. P. Rosenthal
Communications Systems Div.
DEP, New York City

The basic principles of High-Fidelity and Stereo for the semi-technical layman who either owns or contemplates owning a Hi-Fi setup. Ten chapters include a brief history of Hi-Fi and an extensive glossary of Hi-Fi terms; fundamentals of stereo sound; sound transmission and reception (microphones, transmitters, antennas, tuners, and receivers); disk recording and record players; tape recording and recorders; preamplifiers and amplifiers; loudspeakers; enclosures; acoustics and the listening area; and guidelines for and hints on troubleshooting in the home. (*Published by John F. Rider Publisher, Co., Div. Hayden Books Co., N.Y., 1965; price approximately $6.00.*)

MURRAY P. ROSENTHAL received his BS in Physics from Brooklyn College in 1959, and is now taking graduate work. He has been involved with electronics since 1944, when he served as a radio-radar technician with the USAF. He has been concerned with technical writing since 1953, in various capacities. In 1960, he joined RCA in the DEP-CSD Systems Laboratory in New York, where he is a Senior Member Technical Staff, now supervising the Engineering Publications Department. He has written two previous books, *Basics of Fractional Horsepower Motors* and *Fundamentals of Radio*, and a chapter for the EIA Advanced Servicing Techniques Manual for Technicians, Tape Recorder Servicing Techniques (J. F. Rider, 1962, 1965, and 1964, respectively).

"PHOTOELECTRONIC MATERIALS AND DEVICES"



Edited by S. Larach

Contributing RCA Engineers:
A. G. Fischer, R. E. Shrader, S. Larach, R. H. Bube, M. L. Schultz, G. A. Morton, A. H. Sommer, W. E. Spicer, A. Rose, P. Rappaport, J. J. Wysocki, E. E. Loebner, F. H. Nicoll, and J. A. Amick
(See below for division and location)

Here is a coherent exposition of the physics, chemistry, and device applications of photoelectronic materials, presented by recognized experts in these fields. This book covers in full the many types of conversion of light and electricity, the photoconductive effect, the photoemissive effect and the photovoltic effect. New developments are included such as the germanium and germanium-silicon photoconductors. Up-to-date information is given on the solid-state image intensifiers and the new Electrofax copying systems.

The chapters, titles, and names of RCA contributors are as follows: 1) Luminescence of Solids by A. G. Fischer, R. E. Shrader, and S. Larach, RCA Laboratories, Princeton, N. J., 2) Photoconductors by R. H. Bube, formerly with RCA Labs., Pr., 3) Infrared-Sensitive Extrinsic Germanium and Germanium-Silicon Alloy Photoconductors by M. L. Schultz and G. A. Morton, RCA Electronic Components and Devices (presently at RCA Labs., Princeton, N. J.), 4) Photoelectric Emission by A. H. Sommer, RCA Labs., Princeton, N. J., and W. E. Spicer, formerly with RCA Labs., Princeton, N. J., 5) Noise Currents by A. Rose, RCA Labs., Princeton, N. J., 6) The Photovoltaic Effect by P. Rappaport and J. J. Wysocki, RCA Labs., Princeton, N. J., 7) Solid-State Optoelectronics by E. E. Loebner, formerly with RCA Labs., Princeton, N. J., 8) Solid-State Image Intensifiers by F. H. Nicoll, RCA Labs., Princeton, N. J., and 9) A Review of Electrofax Behavior by J. A. Amick, RCA Labs., Princeton, N. J. (*The book publisher is D. Van Nostrand Co., Inc.; price is approximately $12.00.*)

Editor's Note: Because of the great number of contributors, biographies and author photos were of necessity omitted, with the exception of the book editor.

DR. SIMON LARACH served as electronics officer in the U.S. Air Force from 1943 to 1946 and was associated with Cruft Laboratory of Harvard University and with the Radar School of the Massachusetts Institute of Technology. He later joined New York University's College of Medicine Research Service and became a research chemist with RCA Laboratories in 1946. Dr. Larach received a citation from the Committee on Medical Research of the Office of Scientific Research and Development in 1946 and RCA Achievement Awards in 1952, 1954, 1957, and 1964. He is a member of the American Chemical Society, the American Physical Society, the Electrochemical Society and Sigma Xi. He has published more than 25 papers in various journals and has approximately 15 issued patents.

"PRINCIPLES OF APPLIED ELECTRONICS"

B. Zeines
RCA Institutes, Inc.
New York City, New York

This basic text in electronics gives the modern technical student an understanding of the basic tube and transistor electronics carefully explaining all theories and concepts as they are introduced. After discussing the physics of vacuum tubes and semiconductors, the author considers the graphical and analytical methods generally employed in electronic and semiconductor circuits. Special emphasis has been placed on the operations that can be performed with the basic electronic circuits. The author has relied throughout the text on problems taken from actual practices. (*Published by McGraw-Hill Book Co., N.Y. City, 1964; approximate price $6.95.*)

BEN ZEINES received a BEE from New York University and an MEE from Brooklyn Polytechnic Institute. He has served on the faculty of RCA Institutes for the past 17 years. He has also served as an Adjunct Assistant Prof. at Hofstra University for the past 12 years. A senior member of the IEEE, Mr. Zeines has also had published "Servomechanism Fundamentals" by McGraw-Hill Book Co., 1959.

"THE PARTICLE KINETICS OF PLASMAS"


I. P. Shkarofsky


T. W. Johnston


M. P. Bachynski

I. P. Shkarofsky,
T. W. Johnston
and M. P. Bachynski
RCA Victor Ltd.
Montreal, Canada

This book sets out the fundamental ideas of the particle kinetics which describe a gaseous plasma and apply these theories to the development of basic equations describing a plasma under various conditions. Although only gaseous plasma behavior is discussed explicitly, some of the concepts are equally applicable to plasmas in the liquid or solid state. A companion volume, to be published as a sequel, will deal with wave analysis and the interactions between electromagnetic fields and quiescent plasmas. (*To be published by Addison-Wesley Publishing Company, Inc., Reading, Mass., U.S.A. in the fall of 1965; price not yet known.*)

ISSIE P. SHKAROFSKY graduated in 1952 from McGill University with a B.Sc. degree and first class honors in physics and mathematics and obtained his M.Sc. degree in 1953 in the fields of microwave optics and antennas. He then joined the microwave tube and noise group at the Eaton Electronics Research Laboratory and received his Ph.D. degree in 1957 with a thesis on modulated electron beams in space-charge-wave tubes and klystrons. After graduation, he joined the RCA Victor Co., Ltd., Microwave Research Laboratory. His particular interest in plasma studies has been in the following topics: plasma transport coefficients, collisional effects in plasma, Boltzmann and Fokker-Planck theory, magnetohydrodynamics, and re-entry plasma physics. Dr. Shkarofsky is an associate member of the Canadian Association of Physicists and a member of IEEE, of the American Physical Society and of the American Geophysical Union.

TUDOR W. JOHNSTON graduated in 1953 with a B.Eng. degree in Engineering Physics from McGill University. He then entered Trinity College, Cambridge, where he received his Ph.D. degree in 1958 with a thesis on the dynamics of magnetically-focussed electron beams and phenomena related to the presence of ions in such beams. At the RCA Victor Laboratories, Dr. Johnston has carried out theoretical investigations on many aspects of plasma physics. Dr. Johnston is a member of the Institute of Electrical and Electronics Engineers and the American Physical Society.

MORREL P. BACHYNSKI graduated in 1952 from the University of Saskatchewan with the degree of B.Eng. in Engineering Physics. He was awarded the Professional Engineers of Saskatchewan prize for the highest scholastic standing amongst the graduating class. In the following year he obtained his M.Sc. degree in physics at the University of Saskatchewan and his Ph.D. degree in 1955 from McGill University. Dr. Bachynski remained at the McGill Eaton Laboratory carrying out research on the imaging properties of non-uniformly illuminated microwave lenses. In 1955, he joined RCA Victor Company, Ltd., Research Labs., and became Director of the Microwave and Plasma Physics Laboratories in 1958. In 1965, Dr. Bachynski was appointed Director of Research in succession to Dr. J. R. Whitehead. Dr. Bachynski is a senior member of IEEE, a member of the professional groups on Antennas and Propagation and Microwave Theory and Techniques, a member of the American Physical Society and of the Canadian Aeronautics and Space Institute. In 1963 he was awarded the David Sarnoff Award for Outstanding Individual Achievement in Engineering.

"STANDARD ELECTRONICS QUESTIONS AND ANSWERS. VOL. I: BASIC ELECTRONICS; VOL. II: INDUSTRIAL APPLICATIONS"

J. L. Bernstein, Assoc. Dean
RCA Institutes, Inc., N.Y.C.
and
S. M. Elonka,
Senior Assoc. Editor
Power Magazine

"Standard Electronics Questions and Answers" provides a comprehensive and dependable coverage of basic and practical electronics. Vol. I explains simply the basic principles of electronics. Individual chapter headings are: Direct Current; Magnetism, Inductance, and Capacitance; Alternating Current; Vacuum Tubes; Semiconductors and Transistors; Voltage Amplifiers; Power Supplies. Vol. II (Industrial Applications) gives the many basic industrial circuits in their simplest form and explains exactly what happens inside each circuit and device to make it function. Chapter headings are: Oscillators; Special Circuits; Transducers and Sensors; Control Systems; Closed-Circuit and Color TV; Industrial Processes and Devices; Test Equipment. (*Vol. I: 232 pages plus index; price $8.50. Vol. II: 452 pages plus index; price $8.50. Published by McGraw-Hill. $15.95 a set; publication date: June 1964.*)

JULIAN L. BERNSTEIN is Associate Dean of the Day School at RCA Institutes, Inc., and has been associated with the school for 11 years, serving as instructor and department head before accepting his present assignment. He has had wide experience in electronics quality control and production engineering, is the author of a previous book, "Video Tape Recording," and has written a number of magazine articles on audio- and radio-electronics. Mr. Bernstein is a member of both IEEE and SMPTE and is chairman of an education committee of the latter organization. He holds a BS in physics and mathematics together with an MS in Education.

"COMMUNICATION SYSTEMS ENGINEERING HANDBOOK"

Contributing RCA Engineers:
R. K. Andres, W. F. Meeker, E. Furth, P. Schneider, J. H. Wolff, E. D. Becken, P. F. Siling, and R. Guenther
(See below for division and locations)

This 600-page basic reference work (edited by D. H. Hamsher, U.S. Army Electronic Res. and Dev. Lab.) represents a concerted effort to present the fundamental data and essential criteria needed by all communications engineers. The application of the systems approach to communications has given the handbook special validity for the solution of design problems that are novel or lack precedent; yet the book is also a digest of good practice. Experts in every aspect of the field, from the analysis of system requirements to the installation of wires and cables, have contributed material, and the result is a practical and thorough guide. The book covers all methods of communicating.

RCA engineers have contributed 8 of the 25 chapters as follows: 1) System Design Requirements by R. K. Andres, RCA Communications, Inc., N. Y., 2) Acoustic Effects by Willard F. Meeker, DEP-CSD, Camden, N. J., 3) Communication System Modeling by E. Furth, DEP-CSD, N. Y., 4) Switching Engineering of Switched Systems by Philip Schneider, DEP-CSD, N. Y., 5) Wire and Cable Transmission Characteristics by J. H. Wolff, DEP-CSD, N. Y., 6) High-Frequency Communication Circuits by E. D. Becken, RCA Communications, Inc., N. Y., 7) Radio Relay Communication Circuits by Dr. R. Guenther, DEP-CSD, Camden, N. J., and 8) Radio Frequency Allocation and Assignment by P. F. Siling, RCA Frequency Bureau, Wash. 4, D. C. (*To be published by McGraw-Hill Book Co., N. Y., in the fall of 1965; price $25.00.*)

Editor's Note: Because of the great number of contributors, biographies and author photos were of necessity omitted.

"BASIC PULSE CIRCUITS"

R. Blitzer
RCA Institutes, Inc.
New York City

The most extensively used pulse circuits of computers, missiles and radars are described in this book adopted by many technical institutes and colleges. Each circuit is given a dual explanation, using first the vacuum tube, and then the transistorized version. Numerous, fully worked-out examples, along with many problems and their answers are also included in each of the eleven chapters. Among the subjects, discussed at an advanced technician level, are: Binary and Octal number systems; Electronic Counters; Linear Wave Shaping of square and ramp-shaped voltages in R-C and L-R circuits; Non-Linear Wave Shaping using Limiters, Clippers, and Clampers; Gates, Astable, Monostable, and Bistable Multivibrators; Blocking Oscillators; Miller Integrator; Phantastron; Schmitt Trigger, Digital Multiplier, Shift Register; Digital Voltmeter; Reactance Tubes; TV Sync Pulse Generator; Phase Comparators; Step Counter; Transient Analysis of R-C, L-R, and Multivibrator circuits; Networks; Pulse Amplifiers. (*Published by McGraw-Hill Book Co., price $8.00.*)

RICHARD BLITZER attended City College of N. Y. and St. Louis University. He taught radar for the Air Force, and was later employed as radar engineer by Emerson Radio Corp. He joined the Faculty at RCA Institutes in 1945, teaching in the Electronics Circuits and Systems Program, and has authored many articles which have appeared in technical periodicals. He has also served as technical writer on guided missile, radar, and computer projects.

COLOR-PICTURE-TUBE ENGINEERING

Organization and Charter

C. W. THIERFELDER, Mgr.
Television Picture Tube Product Engineering
Television Picture Tube Division
Electronic Components and Devices
Lancaster, Pa.

THE RCA $130-million investment to pioneer and create the color-television industry in now paying well-earned dividends. Color television is today the most prosperous and fastest growing business in the consumer sector of the economy. The cornerstone of the color-television business is the shadow-mask color picture tube, the most complex "chemelectromechanical" device ever to be mass-produced for the consumer market. RCA's success and profit position in the color-picture-tube business depends largely upon our unique engineering and manufacturing know-how. The overall objective of the color-picture-tube engineering organization is to assure RCA's continued product leadership and to further enhance its business position.

TV PICTURE TUBE ENGINEERING

The engineering department of the EC&D Television Picture Tube Division is organized to handle the complete engineering requirements for display devices, including applied research, advanced development, design development, engineering production development run, and direct manufacturing support engineering. The engineering department requires a diversity of technically trained people and includes specialists such as chemists, chemical engineers, electrical engineers, ceramics and glass technologists, mechanical engineers, electronics engineers, mathematicians, metallurgists, physicists, solid-state physical chemists, and industrial engineers. The engineering department is organized into three separate activities located at Princeton, N.J., Lancaster, Pa., and Marion, Ind.

The *Material and Display Devices Laboratory*, affiliated with the Princeton Laboratories, is responsible for the research, applied research, and advanced development of picture-tube devices including color and monochrome picture tubes, solid-state, and other display techniques.

The *Marion Picture Tube Engineering Organization* is responsible for the advanced development, design development, and direct manufacturing support engineering of black-and-white picture tubes and of color picture tubes manufactured at the Marion plant.

The *Lancaster Picture Tube Engineering Activity* is responsible for the advanced development, design development, engineering production development run and direct manufacturing support engineering of color picture tubes.

ENGINEERING PHILOSOPHY

The guiding engineering philosophy for the development of new color picture tubes is to achieve the ultimate design potential for performance, quality, and reliability, and then wherever possible to enhance the potential for economy of manufacture. To engineer a unique color picture tube for mass-production that will meet sophisticated commercial and highly competitive quality standards, one must have an intimate and thorough understanding of very complex technical phenomena, and then use this knowledge to establish process controls for every basic manufacturing operation. One must work toward a zero defects goal for every operation in every manufacturing process center. The shadow-mask color-tube construction involves a very large number of independent and interrelated parameters that lead to a "learning curve" phenomenon when the color-picture-tube design is married with the production processes and the automated production equipment in the factory environment with production operators. This "learning" phenomenon inherently limits the rate of advance in the design and manufacture of color picture tubes. It also adds an additional development phase i.e., the engineering production development run, to the color-tube engineering cycle. Such a development run for the 19-inch 90° rectangular color-tube has just been completed. The 19EXP22 and the 19EYP22 are the fifteenth and sixteenth in the series of commercial color picture tubes to be marketed by RCA.

THE CHALLENGE AHEAD

The industry now stands at the golden threshold of the color-television era. Despite the great progress already made, unique and challenging engineering opportunities abound. The product demand continues to increase more rapidly than the industry can expand. Consequently, there are more challenging engineering problems to be solved and gainful engineering developments to be undertaken than the industry can find experience, talent, and time to handle. We are confident, however, that the EC&D picture tube engineering and manufacturing organizations will use their hard-earned experience and resources wisely and efficiently to maintain RCA's leadership in this highly competitive business.

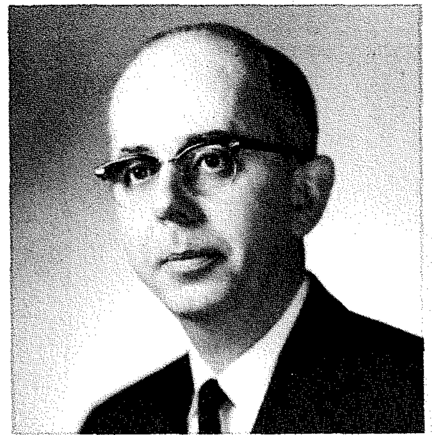
C. W. THIERFELDER received his BSEE from the University of Oklahoma in 1946 and was awarded his MS in Physics from Franklin and Marshall College in 1951. He was employed by RCA in 1946 as a Product Development Engineer at the Lancaster Plant, working on cathode ray devices of various types and applications. In 1954 Mr. Thierfelder was made Manager, Design and Standardizing, for the black and white kinescope product line. In 1956, he was promoted to Manager, Black and White Kinescope Engineering, with responsibility of all engineering on that product line. During this period, he became a recognized authority on black and white kinescopes. He has been Manager, Television Picture Tube Product Engineering, since February 1961. In this capacity, he is responsible for product development engineering for both black and white and color picture tubes at the Lancaster, Pa., and Marion, Ind., facilities, and the Materials and Display Device Affiliate Laboratory at Princeton, N. J. He is a member of the American Association for the Advancement of Science, Sigma Pi Sigma, Tau Beta Pi, Sigma Tau, Eta Kappa Nu and is holder of several patents.

Final manuscript received June 25, 1965

DEVELOPMENT OF THE NEW RCA 90° RECTANGULAR COLOR PICTURE TUBES

The new RCA rectangular 90° shadow-mask color picture tubes represent basic advancements in the art of picture-tube development. This family of tubes includes the 25-inch 25AP22A and 25BP22A, plus the recently announced 19-inch 19EYP22 and 19EXP22, with other smaller sizes to follow. The result of an extensive developmental program, this new family of color picture tubes features shorter overall length and all the performance potential and reliability features established by the earlier RCA 21-inch 70° color tubes.

A. M. MORRELL, Ldr.
Color Picture Tube Product Design
Television Picture Tube Division
ECD, Lancaster, Pa.



A. M. MORRELL received the BSEE from Iowa State University in 1950, and has since done graduate work at Franklin and Marshall College. He joined the Electron Tube Division of RCA at Lancaster in 1950 as a design engineer. He has specialized in tube design and worked on many phases of the color picture tube. In 1956 he became Engineering Leader in charge of Product Design of Color Picture Tubes. Mr. Morrell has numerous patents on various phases of color tube design. He has published and presented a number of technical papers related to color tube developments. He is a member of Phi Kappa Phi, Eta Kappa Nu, and the IEEE. In 1964 he was named as a recipient of the "David Sarnoff Team Award for Engineering" for development of color picture tubes.

The screen shape (rectangular) and the increased deflection angle (from 70° to 90°) of the new types of color picture tubes introduced many new engineering and production problems. Their rectangular shape required not only new bulb designs, but also the development of new frames, mask-support systems, and mask-forming techniques. Furthermore, the screen tolerance required with the increased deflection angle introduced problems in the electron optics and design geometry. It also required development of new deflection-yoke systems and raster-correction techniques, as well as dynamic convergence circuits. In addition, the rectangular-tube family required a gun design which was compatible with the smaller neck size required for both economy of deflection power and shorter tube length.

As shown in Table I, the overall length of the 25-inch 25AP22A is just under 21 inches, which represents a reduction of 4⅓ inches as compared to the earlier 21-inch 70° tube. A screen area of 295 in² is obtained, as compared to 267 in² for the 21-inch round tube. The 19-inch 19EYP22 has a screen area of 180 in² with a length of about 18 inches. The curvature of the faceplate is flatter on the rectangular tubes than on the 70° round types. Faceplate radius on the newer tubes has been selected to optimize the conflicting requirements of convergence, register, and correction of raster shape.

BULB DESIGN

The two-piece glass bulb developed for the rectangular tube types features many characteristics found in the glass bulb used for the round 70° type. These characteristics include a harder glass to minimize deformation during thermal processing, proper glass absorption to reduce radiation, an alignment system for proper positioning of the cap and funnel assembly, accurate control of the inner contour of the faceplate, and precise alignment of the neck with respect to the referencing system of the bulb. These features, which were first established in the RCA type 21CYP22, are considered essential throughout the industry for a high-quality color tube.

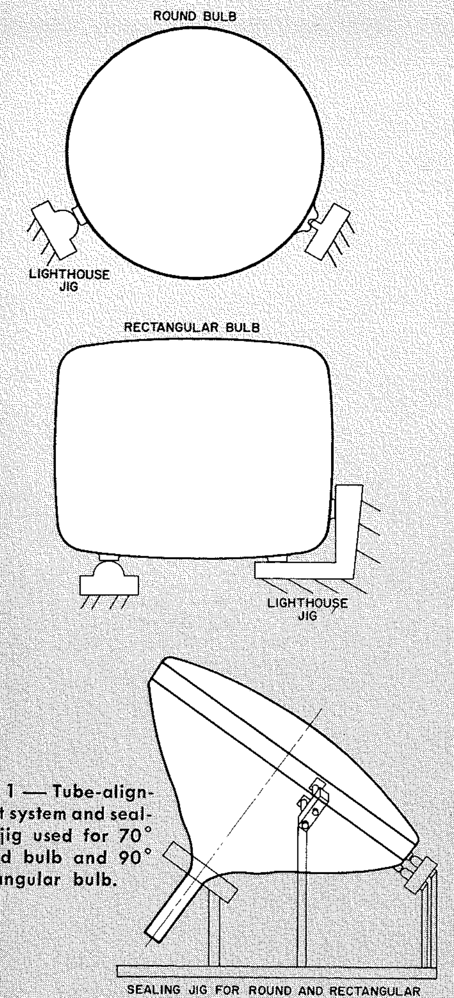
Because of the rectangular screen shape on these new types, a number of design innovations have been introduced. In the 70° tubes, the funnel-seal edge to which the panel is frit sealed after screening is relatively wide, and the positioning of the panel on the funnel is not overly critical for a satisfactory seal. With the rectangular types, however, rotational orientation must be maintained. In addition, because of the shape factor the seal edges tend to deviate more than with the round bulb. Because of these differences, a satisfactory frit seal for rectangular bulbs requires a more precise adjustment between the seal edges of the panel and the funnel. This consideration, therefore, governs the method of overall tube alignment.

TABLE I — Physical Characteristics of 21FJP22A, 25AP22A, and 19EYP22

Dimension	21FJP22A	25AP22A	19EYP22
overall length, inches	25.218	20.924	18.048
neck length, inches	9.625	6.693	6.693
min. screen area in.²	267	295	180
screen height, inches	16.0	15.575	12.185
screen width, inches	19.250	19.875	15.585
aspect ratio	3.32:4	3.14:4	3.14:4
deflection angles, degrees:			
diagonal	70	89	89
vertical	55	63	63
horizontal	70	78	78
neck diameter, inches	2	1.438	1.438

In the tube-alignment system used for the 70° round type, a vee-groove and a pad are used on the panel (Fig. 1). These pads are molded into the part, and are not ground or further modified in bulb fabrication. The funnel has two pads which are ground during bulb fabrication so that the neck is concentric

Final manuscript received May 14, 1965.



1 — Tube-align-
t system and seal-
jig used for 70°
d bulb and 90°
ngular bulb.

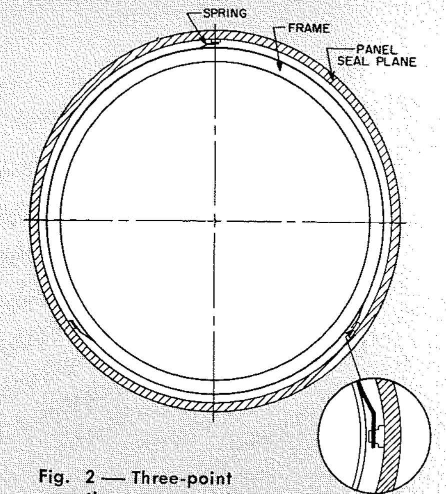


Fig. 2 — Three-point mounting system used in round tube.

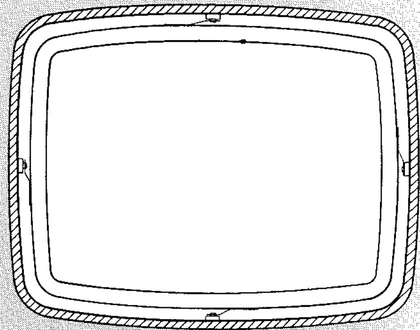


Fig. 3—Four-point mounting system used in rectangular tube.

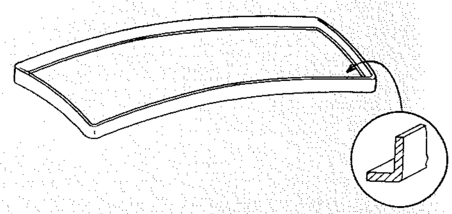


Fig. 4—Rectangular frame.

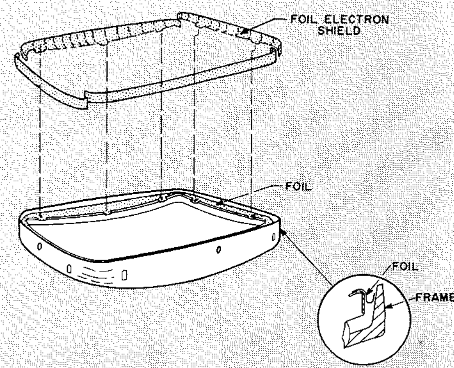


Fig. 5—Foil electron shield.

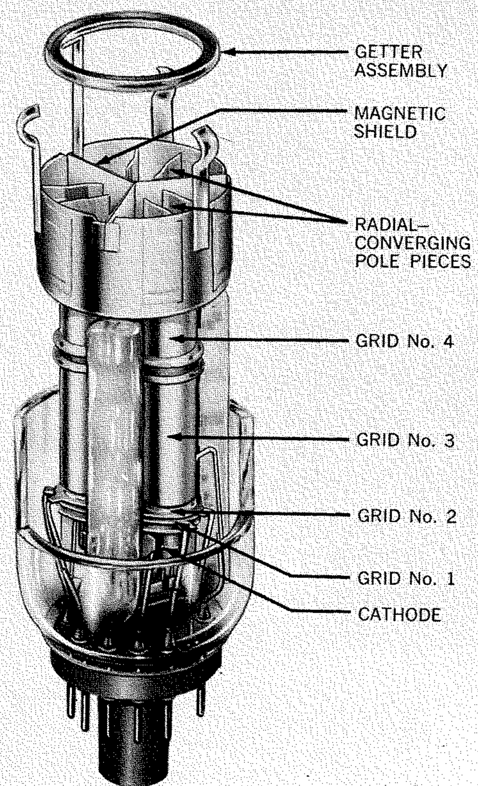


Fig. 6—Electron gun design.

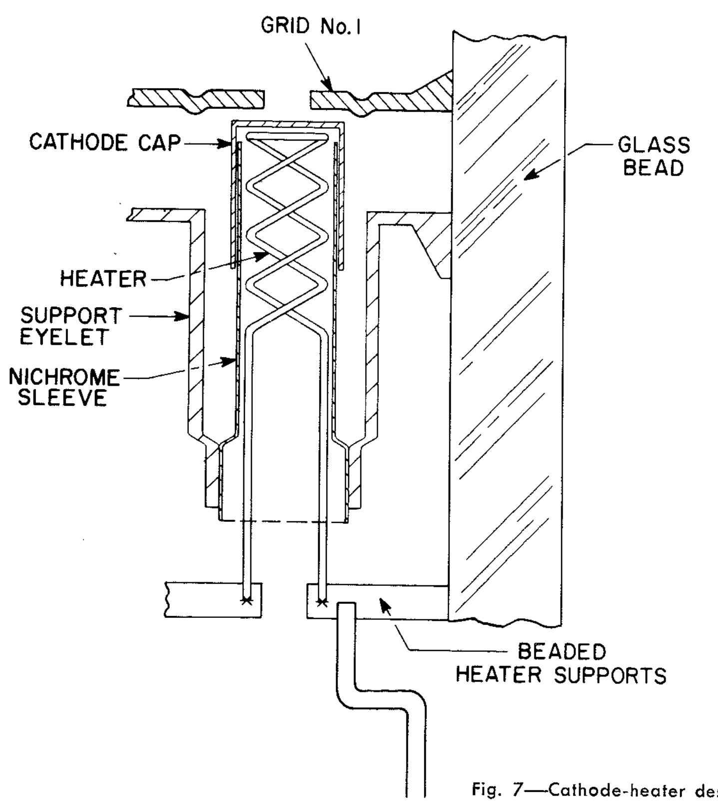


Fig. 7—Cathode-heater design.

with and perpendicular to the plane through a seal edge, and referenced to and spaced from the two pads. In the exposure of the screen on the "lighthouse", the panel is referenced to its two molded protrusions. The panel and funnel are then sealed in a jig (Fig. 1) that has the same bogie dimensions to the panel pads as those used on the lighthouse. These pads in turn are referenced to the ground pads on the funnel; this technique assures that the center of the neck in the final tube is aligned within close tolerances to the center of the lighthouse system used during the exposure of the tube.

The rectangular bulb requires both the above procedure and measures to insure accuracy of the frit-seal alignment. In the 25-inch bulb, the glass protrusions on the panels were originally ground until their centers were concentric with the geometric center of the glass part. With experience, bulb suppliers have developed techniques which allow them to assure accuracy of alignment without the necessity for grinding the pads on the panel. Therefore, the 19-inch bulb is made without pads (however, reference is made to the wall of the panel in the same relative positions where the pads are located on the 25-inch type).

As shown in Fig. 1, the system used on the rectangular bulb employs three pads on the funnel and three pads or three reference points on the panel. Two of them are relatively close to each other on one corner of the panel and funnel; the third is some distance away. The two pads close to each other form the points on a "*v*", which would engage a referencing or jigging system, as with a large vee- groove. The remaining isolated point provides a third point of contact which establishes unique positioning of the panel and funnel.

The sealing jig (Fig. 1) is basically the same proven system pioneered by RCA for the round 21CYP22. This jig employs gravity loading and is relatively insensitive to changes caused by heat or wear other than the relative alignment of the two closely spaced sets of points that contact the panel and the funnel. In this type of jigging, careful control of the jig-to-glass thermal expansion match is not required because this relative motion can cause only a slight tilting in the angle of the bulb with the jig. This change is of little consequence in the actual alignment of the parts.

Thermal processing of a rectangular bulb is in general more difficult than that of a round bulb because of the shape factor. In rectangular bulbs, for example, thermal expansion of parts does not have the same degree of symmetry found in a round bulb. Accordingly, the requirements for proper temperature gradients in processing, and the need for a strong frit seal, are even more important in this type than in a round bulb. The use of improved frits has proved to be an important factor in overcoming this inherent difficulty. Another important factor in the processing of the rectangular 25-inch bulb has been the development of fabrication means by the bulb supplier to produce a wider funnel seal edge.

MASK SUPPORT

The requirements for the mask-support system in a rectangular bulb parallel those for the round bulb. The support system must have the inherent performance characteristic found in the round tube plus those features dictated by the rectangular shape.

Fig. 2 shows the mounting system used in the 70° tubes. This system employs three studs sealed into the glass and three corresponding springs welded to the *L*-frame which engage the studs and provide unique positioning, together with mechanical rigidity. This system was developed by RCA for the round tube and has been adopted as standard by the entire industry as a result of ten years of successful use. However, this system, designed for the round tube, is not as effective with the rectangular tube because of a number of factors associated with the lack of symmetry of the rectangular bulb. For example, because of the complete symmetry of the round bulb, this type is inherently stronger and does not have any weak axis. In addition, the round frame employed in the 21-inch tube is somewhat smaller and, accordingly, has a relatively short span between support points; it also has angular symmetry between support points. If the three-point system were used on the rectangular frames, however, the span around one of the corners would tend to be rather long and would require a strong and more expensive frame to achieve the precision required for a high-quality reliable product.

In view of these and other considerations, the RCA rectangular tubes employ a four-point system (Fig. 3) which provides symmetry to the support of the frame and reduces the span between support points. Because three points establish a unique position of the mask assembly within the panel, adjustment means have been provided so that the fourth spring is properly aligned in respect to the other three. Although this system requires that the particular mask-frame assembly be mated with a particular panel by spring-stud orientation, this same restriction is placed on any assembly as soon as first exposure is made.

The rectangular frame design (Fig. 4) is basically similar to that of the round frame. In essence, it is a wrapped and welded cold-rolled steel frame having an *L*-shaped cross-section. The obvious difference from the round mask is that the vertical height of the rectangular mask varies as a function of the periphery of the panel. This height is greatest at the ends of the minor axis and smallest at the diagonal. If the frame were maintained as a flat section, either the skirt of the mask would have a variable height or the vertical section of the frame would have a height variation around the periphery. Because neither of these conditions is optimum, the RCA design uses a frame having a generally spherical surface. With this design, the height between the bottom section of the frame and the edge of the aperture mask is constant around the tube. As a result, a uniform cross-section of frame material, as well as a simple wrap and weld technique from a continuous strip of metal, can be employed. In addition to the resulting savings in cost and fabrication, this technique also improves performance because the closeness of the frame to the useful portion of the mask minimizes the amount of frame or mask area exposed to overscan of the electron beam. This feature minimizes heating of the assembly, as well as reflection of electrons off the vertical surfaces. Such reflection causes a scattering of electrons and leads to unwanted dilution of color purity.

The mask-frame assembly also features a unique electron shield (Fig. 5). As is known from the 70° tube, the small space between the frame and the sidewall panel, if not filled, allows electrons from the over-scan of the raster to ricochet through the space and land in a random fashion on the phosphor screen near the periphery of the tube. These electrons result in undesirable bands of impurity and higher brightness near the edge of the tube. To prevent such scattering, the 70° RCA tubes use a system of electron shields which are essentially flat, thin-sheet iron strips welded to the bottom surface of the frame.

In the case of rectangular tubes with increased deflection angle, the problem of electron scatter is more serious and a more sophisticated electron shielding approach is needed. The rectangular tubes use a thin aluminum-foil shield which generally conforms with the curvature of the frame and glass and fills the gap completely. Because the foil is light in weight, the minor gap variations from tube to tube are easily accommodated by merely forcing the foil into contact with the glass. Furthermore, any variations in the glass-to-frame gap caused by expansion of the parts during tube processing are accommodated by slight springing of the foil. Therefore, the design achieves a relatively tight seal between the glass and the frame, and completely eliminates this source of stray electrons.

GUN DESIGN

The electron gun used for the rectangular tube types is similar to the type developed by RCA in 1962 for the round 90° tube. The new gun is similar to its 70° counterpart (Fig. 6) except that it has been reduced in size to fit into a 1⁷⁄₁₆-inch-diameter neck (as opposed to the 2-inch-diameter neck used for the 70° type). This reduced gun size permits the use of a smaller-diameter yoke which, in turn, increases the efficiency of scanning needed for the larger deflection angle. The smaller size also reduces beam separation in the deflection yoke, so that problems of convergence are minimized.

Further improvements have been made throughout the gun. For example, the cage assembly, which holds the radial-converging pole pieces and the magnetic shields between them is designed as a precision deep-drawn cup; in the 70° type these parts were mounted between a pair of discs. The cup design provides increased rigidity of the parts which, because of the larger deflection angle of the rectangular types, is essential for uniformity of convergence sensitivity and for direction of convergence. The focusing lens between grid No. 3 and grid No. 4, plus the electron optics that follow, are generally similar to those of the 70° type. The construction of grids No. 1 and No. 2 of the 90° type is unique; each grid is formed from a single piece of metal and, therefore, the bead straps are an integral part of the grids. Grids No. 1 and No. 2 are complementary parts having essentially the same design with the beading straps reversed in direction. The same three-bead support system used in the 70° types is employed in the 90° tube.

In the cathode and heater design, a nonceramic cathode structure is used in which the cathode is insulated from the grids by glass support beads, as shown in Fig. 7. This nonceramic design eliminates variations previously found in thermal conductance of the ceramic and ceramic-to-metal joints, and also provides complete mechanical rigidity of the parts, thus eliminating any possibility of microphonics. The heaters are connected in series and are supported by metal tabs beaded into the glass support rods. The thermal efficiency of the cathode has been improved by about 40% by the use of a small nichrome sleeve which thermally isolates the active portion of the cathode from the support mechanism. The resulting reduction in input power allows the stem to run cooler and also transmits less heat to the adjacent gun parts. As a result, movement of parts because of thermal expansion is reduced and, therefore, convergence drift is minimized.

The rectangular tube types use a rigid-lead stem and wafer, as opposed to the base and flexible-lead stem used in the 70° type. This approach results in a shorter base and minimizes any reliability problems resulting from poorly soldered connections in the base or from loose bases. This basing arrangement, originally introduced by RCA in 1962, is now the recognized standard basing for 90° color tubes.

PERFORMANCE

The performance of rectangular tubes has been the guiding motive in their design. The performance design potential of rectangular tubes is comparable to that of 70° types in brightness, purity, and uniformity. The rectangular types have a design maximum anode voltage rating of 27.5 kv, which is the same as that of the 70° types. Other voltages for 70° types and the corresponding voltages for rectangular tubes are shown in Table II. The grid No. 1 and grid No. 2 voltage cutoffs are similar, as are the drive characteristics of the two guns.

The rectangular tubes employ a rare-earth red phosphor for improved efficiency and light output. In any consideration of light output, the limiting factors of highlight brightness must be considered. This factor is usually limited by the beam spot size. In the rectangular-tube design, optimum focus characteristics of the gun have been maintained. Several factors were considered in determining this optimum focus. First, the resolution with a somewhat smaller-diameter gun is, of course, more difficult because of higher lens aberrations. Some slight gain is obtained because of the reduced "throw" distance from the gun to the screen; however, good alignment of gun parts, plus close parts tolerance, must be maintained.

Other factors affecting resolution are quite remote from the gun itself. The corrections that must be applied to obtain color purity and convergence are perhaps the principal items of concern in resolution. These corrections include the magnetic fields required for blue-lateral and radial-convergence as well as purity adjustment. Because rectangular tubes require a minimum amount of corrections, the beam distortion caused by them is held to very low level.

The rectangular types use a novel lateral-converging device. This device and the neck purity device can be positioned and operated on the neck of the tube with insignificant mutual interaction during the tube "setup".

Contrast of rectangular tubes has been held at a high level by optimum tapering of the aperture mask holes and by means of the aluminum-foil electron shield discussed previously. The gray filter glass used in the panel and safety windows enhances the contrast under conditions of high ambient illumination.

Both the 25-inch and the 19-inch tube types have approximately the same number of apertures in the mask; in the 25-inch tube, center-to-center spacing of apertures is 0.028 inch; it is 0.022 inch in the 19-inch tube. The spacing was scaled down on the 19-inch type to minimize moire patterns—caused by the beat interference between the rows of apertures and the raster scan lines.

In addition to the mechanical innovations of the rectangular tubes, radically new lighthouse systems of lensing have been developed. These developments have been geared to the corresponding development of deflection yokes for these types, and are designed to permit close "tracking" of the beam and dot trios and thus permit optimum register and tolerance for tube setup.

CONCLUSION

The development of these new tube types represents a basic advancement in the art of picture tube design and is the result of a joint team effort of many development, design, and production engineers, who successfully solved many unique problems.

TABLE II — Electrical Ratings for 21FJP22A, 25AP22A and 19EYP22

Rating	21FJP22A	25AP22A	19EYP22
anode voltage, V:			
maximum	27,500	27,500	27,500
minimum	—	20,000	20,000
total anode current (long term average), max. μA	1,000	1,000	750
grid No. 3 (focusing electrode) voltage, max., V:	6,000	6,000	6,000
peak grid No. 2 voltage, max., V:	1,000	1,000	1,000
grid No. 1 voltage:			
negative bias value, max., V	400	400	400
negative operating cutoff value, max., V	200	200	200
heater voltage (AC or DC), V:			
maximum	6.9	6.9	6.9
minimum	5.7	5.7	5.7
heater current (at 6.3 V), A	1.80	0.80	0.80

COLORIMETRY AND PERFORMANCE OF COLOR-TV PHOSPHOR SCREENS

A Survey of Improvements

Color television is now increasingly in demand by the consumer public, and is one of the most vigorous manufacturing and engineering activities within RCA. Since its inception, color television has undergone a steady and continuous evolution of improvement in quality and performance on all fronts: camera tubes, receiver circuits, picture-tube design, and phosphor screens. This paper describes the improvements that have been made in phosphor screens.

A. E. HARDY, Ldr.
Chemical and Physical Laboratory
Television Picture Tube Division
ECD, Lancaster, Pa.

THE phosphors for cathode-ray tubes are inorganic crystalline compounds which efficiently emit light when they are struck by fast-moving electrons.[1] Fortunately for color television, there are phosphors that emit red, blue, and green light. In fact, there are several phosphors available for each of the primary colors. Some of these phosphors have been used for color television for several years. Others have been known for a long time but have been refined just recently and are now being used. All combinations of three phosphors for color-television screens are designated by one phosphor identification, P22.

The earliest phosphors used for color television by RCA were blue calcium magnesium silicate, green zinc silicate, and orange-red cadmium borate. In 1951, a new red phosphor, zinc phosphate, was discovered by Dr. A. L. Smith of the Lancaster plant.[2] This red zinc phosphate was more efficient than cadmium borate, and produced a deeper shade of red light. At about the same time a suitable blue zinc sulfide was also developed. The combination of sulfide-silicate-phosphate, which was used in the 21AXP22 and 21CYP22 color picture tubes, has a basic white-light efficiency of 1.0 to 1.4 lumens per watt (lm/W).

In 1961 RCA introduced a basically new phosphor screen[3] consisting of a green-emitting zinc cadmium sulfide and a red-emitting zinc cadmium sulfide. These two new phosphors were used in combination with the blue-emitting zinc sulfide previously developed to provide an "all-sulfide" screen. This combination of phosphors raised the white-light screen brightness about 50% to a level of 2 lm/W. The all-sulfide screen was later optimized for light output and a level in excess of 2.6 lm/W was achieved.

Within the last few months another family of phosphors, the rare-earth compounds,[4] has been developed commercially, and some red-emitting materials are now being used in combination with the blue sulfide and green zinc cadmium sulfide already in use. Rare-earth red phosphors such as europium-activated yttrium vanadate offer an improvement in white screen brightness of about 10% as compared with the optimized all-sulfide screen, and provide an efficiency of almost 2.9 lm/W.

PHOSPHOR CHARACTERISTICS

In color-television picture tubes, the laws of additive colorimetry prevail.[5] The sensations of color and brightness perceived by the eye are the simple summation of the light emitted by the individual primary color phosphors.

The potential color gamut and picture brightness are determined chiefly by the absolute emission efficiency and the distribution of the radiant energy. These characteristics can be expressed in various ways. For example, spectral energy distribution is usually shown in the form of a curve of relative emission intensity as a function of wavelength. Figs. 1 to 4 show curves for the following phosphors: 1) silver-activated blue zinc sulfide; 2) silver-activated green zinc cadmium sulfide; 3) silver-activated red zinc cadmium sulfide; and 4) europium-activated yttrium vanadate.

It is usual practice on such curves to normalize the wavelength of maximum emission to 100%. For in-plant control of phosphor efficiency, this parameter is called peak efficiency. The sulfide phosphors shown in Figs. 1 to 3 are typical broad-band emitters. The shape of these curves is fairly insensitive to the resolution of the spectroradiometer that is used to measure the curves. In the case of the rare-earth phosphor, however, the widths of the narrow emission bands are determined directly by the spectroradiometer entrance slit width. The curve shown in Fig. 4 was measured with a new spectroradiometer that has a slit width of 0.025 millimeters which corresponds to a resolution of 0.80 nanometers.

Although spectral-energy-distribution curves are particularly useful as a control parameter for production lots of standard materials, they cannot be used directly for colorimetric calculations. For this purpose, curves must be reduced to x—y coordinates in the CIE color specification system. Basically this system specifies the *relative* amounts of three theoretical color primaries which, when mixed, would color-match the emission of a given sample. The x—y values are plotted on a mixture diagram such as that shown in Fig. 5. The points on this diagram are unique; i.e., any phosphors, light sources, or colored surfaces having the same coordinates will produce the same sensation of color when viewed by the standard observer.

The color of phosphor emission is fully described by the x—y coordinates. Another useful color specification system utilizes the parameters of dominant wavelength and saturation. The boundary or periphery of a mixture diagram such as that shown in Fig. 5 is the locus of the pure spectrum colors. White on such a diagram is an ill-defined area near the center. The white for color-television picture tubes has been selected as a brightness temperature of 9,300°K with coordinates of $x = 0.281$, $y = 0.311$. Dominant wavelength for a particular phosphor can be determined as follows: A straight line is drawn from the white point on the mixture diagram through the phosphor point, and the line is extended until it intersects the spectrum locus. The point of intersection on the locus is the dominant wavelength for the phosphor. The length of the line from the white point to the spectrum locus represents 100% saturation, and the linear distance from the white point to the phosphor point is then proportional to the per-cent sat-

Final manuscript received May 27, 1965.

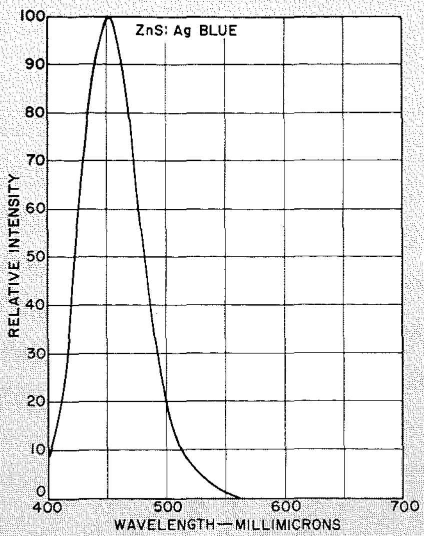


Fig. 1—Spectral-energy distribution curve for blue zinc sulfide phosphor.

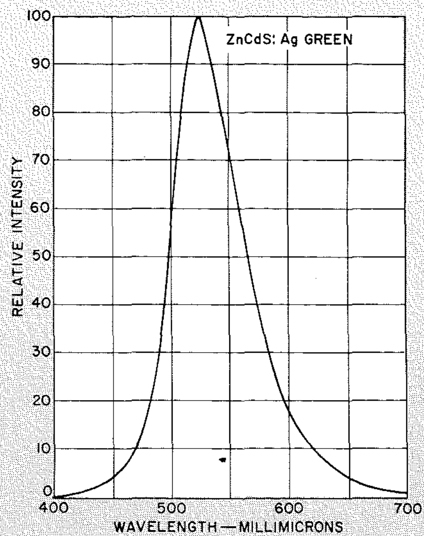


Fig. 2—Spectral-energy distribution curve for green zinc cadmium sulfide phosphor.

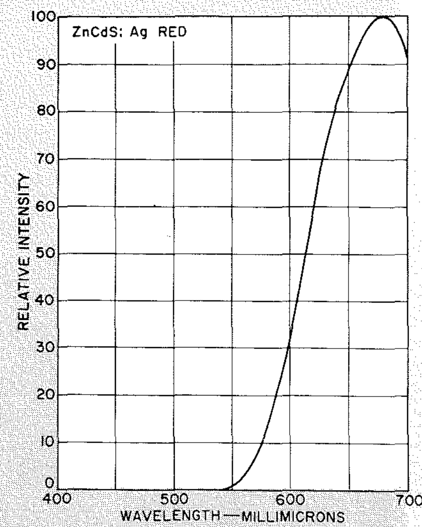


Fig. 3—Spectral-energy distribution curve for red zinc cadmium sulfide phosphor.

uration. In this concept, all colors are considered to be a mixture of monochromatic radiation and white. Obviously, the dominant wavelength is dependent on the white point chosen for reference. Also, there is only a very rough correlation between dominant wavelength and the peak wavelength of emission described earlier. Table I summarizes these characteristics.

The fundamental expression of phosphor efficiency is in terms of watts of emitted radiation per watts of electrical energy in the bombarding electron beam; typical values range from 5 to 15%. A more useful concept for colorimetric calculations, however, is luminous efficiency, which is usually expressed in lumens per watt of electron beam energy. The most useful concept is the so-called colorimetric weight, which is denoted in this paper by the term *stimulability*, S. Stimulability or colorimetric weight is also derived from the CIE color specification system; it is the sum of the absolute amounts of the CIE primaries required to match the sample in color and *intensity*. Color is defined by the lower-case letters x, y, and z, but $z = l - x + y$. Simulability is defined by the summation of the tristimulus values which are the capital letters X, Y, and Z. Because Y in the CIE system is chosen to match the eye-response function, luminosity measurements with eye-corrected photocells provide a large Y value directly in units of lumens per watt. The summation $\Sigma = X+Y+Z$ may be obtained as the ratio Y/y because, by definition, $y = (Y)/(X+Y+Z)$.

The quantities s, y, and S are fundamental numbers required to calculate the potential color gamut and brightness capabilities of phosphors for color-television picture tubes. In some cases another factor, luminous equivalent, is given. This factor simply expresses the number of lumens emitted per watt of radiation from a source with a stated spectral distribution. For example, 1 watt of monochromatic radiation at the wavelength of maximum eye sensitivity (555 nanometers) is equivalent to 681 lumens. This value is called the mechanical equivalent of light. Radiation of 1 watt at any other wavelength emits less than 681 lumens; the actual value

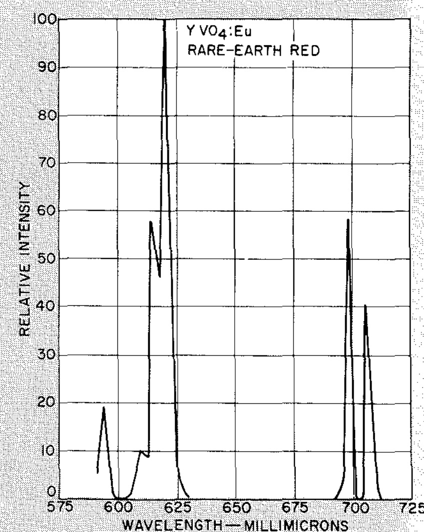


Fig. 4—Spectral-energy distribution curve for red yttrium vanadate: europium phosphor.

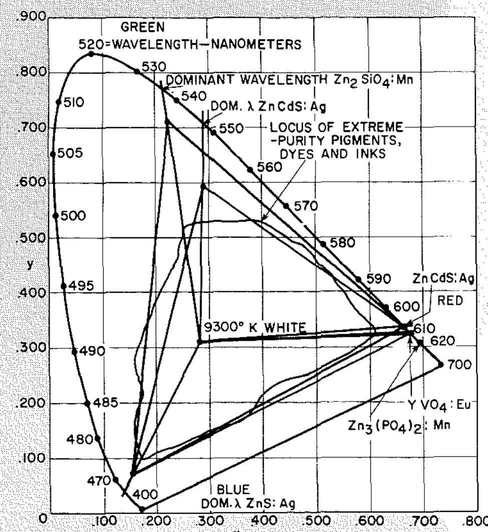


Fig. 5—C.I.E. mixture diagram with phosphor coordinates and white.

TABLE I — Some Important Characteristics of Phosphors

Phosphor	Color	x	y	Luminous Efficiency lm/W	S	Luminous Equivalent	Power Efficiency	Dominant Wavelength	Per-Cent Saturation
$Zn_3(PO_4)_2$:Mn	red	0.674	0.326	7.0	21.5	162	0.05	613	100
Zn_2S:O_4:Mn	green	0.218	0.712	31.1	43.7	520	0.06	537	87
ZnS:Ag	blue	0.154	0.068	7.5	110	57	0.15	464	87
ZnCdS:Ag	red	0.663	0.337	8.6	25.5	119	0.12	609	100
ZnCdS:Ag	green	0.285	0.595	46.0	77.3	434	0.14	548	72
YVO_4:Eu	red	0.675	0.325	9.5	29.3	135	0.06	613	100

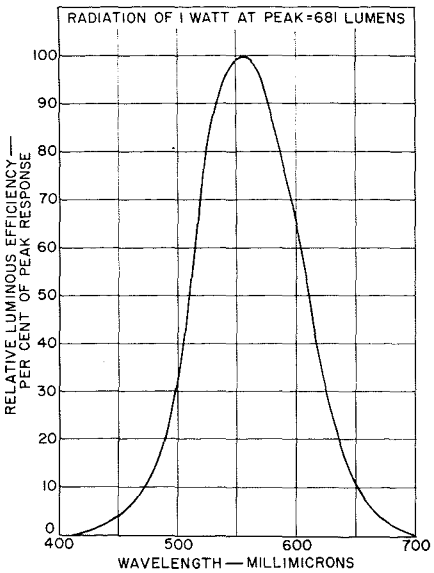


Fig. 6—International standard luminosity curve.

can be determined from the eye-response curve or luminosity function shown in Fig. 6. For example, 1 watt of blue monochromatic radiant energy at 450 nanometers emits about 41 lumens (6% of 681); and 1 watt of red monochromatic radiant energy at 620 nanometers emits 259 lumens (38% of 681).

Although most phosphors do not approach monochromatic emission (the rare-earth phosphors come very close), the luminous equivalent concept may still be applied. This concept is expressed as follows:

radiated (*lumens per watt*)

$$= 681 \sqrt{\frac{y\,w\,d\lambda}{w\,d\lambda}}$$

where y is the luminosity function and w is the relative emission intensity of the phosphor over the interval $d\lambda$. This expression indicates that luminous equivalent is independent of the basic efficiency of the phosphor and is related only to the relative spectral energy distribution of the emission from the phosphor.

The potential color gamut of a three-primary phosphor system is the area on the CIE mixture diagram encompassed by the straight lines joining the x—y coordinates of the three phosphors. Fig. 5 shows this gamut for the three-phosphor combinations mentioned previously. The expression *potential color gamut* is used to indicate that system restrictions reduce the color gamut established by the phosphors. This system limitations include camera response,[6] scene color temperature, and several picture-tube characteristics such as phosphor cross-contamination and stray electron excitation (these last two items are generally secondary effects).

At first glance, it appears that major consideration should be given to obtaining the largest possible color gamut, i.e., that the phosphor primaries should be as saturated as possible and located deep within the primary color area. However, the limitations of color photography, printing inks, and dyes and colors in nature make it unnecessary to use extremes in saturation and hue. The limiting locus[7] of pigments, dyes, and printing inks is shown in Fig. 5.

Fig. 7 shows several areas that define familiar colors in nature.[8] Although some reduction in gamut occurred when the green-emitting silicate phosphor was replaced by the green sulfide phosphor, the gamut of the all-sulfide screen still compares very favorably with other color-reproduction systems.

Early color tubes were somewhat marginal for screen brightness or light output, particularly with respect to black-and-white picture tubes. As a result, there were some difficulties in daylight viewing in the home, and some unfavorable comparisons with black-and-white sets on the dealer's floor. Although color-tube light output is no longer marginal, some compromise in color gamut might still be considered if such a compromise could produce a substantial increase in light output. The device efficiency of the shadow-mask color tube is inherently low. In addition, it is less efficient to produce white light from a three-component phosphor system than from a two-component system. For example, black-and-white tubes have a device efficiency of 36 lm/W, while the best color tubes have been able to reach only about 3 lm/W. However, this factor of 12:1 is effectively reduced to 4:1 because three guns are used in the shadow-mask tube. In addition, in the color tube both the beam-accelerating voltage and the average gun beam current are higher; as a result, the operating brightness level of color-television receivers is not too different from that used in black-and-white sets. In color pictures, the effect of color contrast also reduces somewhat the brightness level needed for satisfactory viewing.

It is of interest to calculate the theoretical brightness potential for several of the three-phosphor combinations that have been used or are being used for color picture tubes. The most meaningful way to make this comparison is to calculate the current in microamperes needed from each gun to produce a

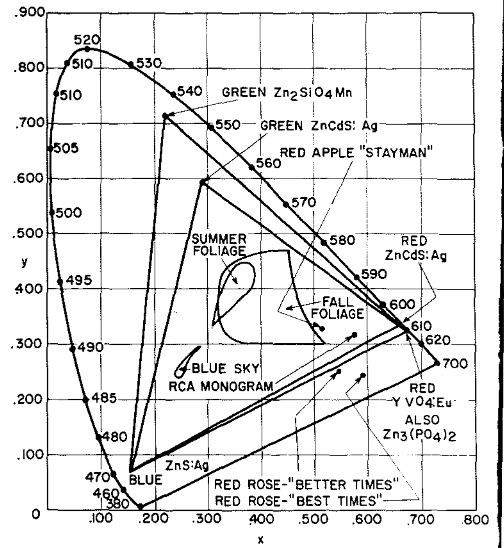


Fig. 7—C.I.E. mixture diagram with identification of several familiar color areas.

TABLE II — C.I.E. Coordinates of Phosphate/Silicate/Sulfide Phosphors

Phosphor	*x*	*y*	*z*	*X*	*Y*	*Z*
Red Zinc Phosphate	0.674	0.326	—	14.5	7.0	—
Green Zinc Silicate	0.218	0.712	0.070	9.5	31.1	3.1
Blue Zinc Sulfide	0.154	0.068	0.778	16.9	7.5	85.5
9300°K White	0.281	0.311	0.408			

TABLE III — C.I.E. Coordinates of All-Sulfide Phosphors

Phosphor	*x*	*y*	*z*	*X*	*Y*	*Z*
Red Zinc Cadmium Sulfide	0.663	0.337	—	16.9	8.6	—
Green Zinc Cadmium Sulfide	0.285	0.595	0.110	22.0	46.0	8.5
Blue Zinc Sulfide	0.154	0.068	0.778	16.9	7.5	85.5

TABLE IV — C.I.E. Coordinates of Rare-Earth Phosphors

Phosphor	*x*	*y*	*z*	*X*	*Y*	*Z*
Red Yttrium Vanadate	0.675	0.325	—	19.8	9.5	—
Green Zinc Cadmium Sulfide	0.285	0.595	0.110	22.0	46.0	8.5
Blue Zinc Sulfide	0.154	0.068	0.778	16.9	7.5	85.5

TABLE V — Gun Currents for Three-Phosphor Combinations

P22 Screen Type	*Gun Currents for White Brightness Level of 8 FtL*			
	Red	*Green*	*Blue*	*White*
Phosphate-Silicate-Sulfide	165	114	77	356
All-Sulfide	100	84	72	256
Rare-Earth	84	86	71	241

white brightness level of 8 footlamberts (ftL). The shade of white is defined by the brightness temperature of 9,300°K. The relative and absolute currents required from each gun to produce any color point within the color triangle may be calculated by means of Grossman's equations. Basically, these equations state that the X, Y, and Z tristimulus values of a mixture are equal to the sum of the X, Y, and Z values of the component colors:

$$X_{9300} = I_R X_R + I_B X_B + I_G X_G$$
$$Y_{9300} = I_R Y_R + I_B Y_B + I_G Y_G$$
$$Z_{9300} = I_R Z_R + I_B Z_B + I_G Z_G$$

where I_R, I_B, I_G are the currents of the red, blue, and green guns and X_R, Y_R, Z_R, and so on are the CIE tristimulus values of the red, blue, and green phosphors, respectively.

These values are given in Tables II, III, and IV for the various P22 phosphor groups. When the data shown in Table II are substituted in Grossman's equations, the following expressions are obtained:

$$x_{9300} = 0.281 = \frac{14.5\, I_R + 9.51\, I_G + 16.9\, I_B}{21.5\, I_R + 43.7\, I_G + 110\, I_B}$$

$$y_{9300} = 0.311 = \frac{7.0\, I_R + 31.1\, I_G + 7.5\, I_B}{21.5\, I_R + 43.7\, I_G + 110\, I_B}$$

$$z \quad = 0.408 = \frac{0 + 3.1\, I_G + 85.5\, I_B}{21.5\, I_R + 43.7\, I_G + 110\, I_B}$$

Solution of these equations provides values of $I_G = 0.32$, $I_B = 0.21$, and $I_R = 0.47$, and $Y_{9300} = 14.9$ lm/W (phosphate-silicate-sulfide) where I_G etc., are the relative gun currents.

For the calculation of absolute currents, the following conditions are assumed:

screen brightness	8 ftL
scanned area	308 in^2
total luminous emission	17.1 L
mask transmission	18%
faceplate transmission	72%
anode voltage	25,000 V
Y_{9300} (*for phosphate-silicate-sulfide phosphor*)	14.9 lm/W

The beam power is then calculated from the following relation:

$$\textit{beam watts} = \frac{\textit{luminous emission (lm)}}{Y_{9300}\ \text{(lm/W)} \times \textit{mask transmission (\%)} \times \textit{faceplate transmission (\%)}}$$
$$= \frac{17.1}{14.9 \times 0.18 \times 0.72} = 8.9 \text{ watts}$$

The beam current is then given by:

$$\textit{Total current} = \frac{8.9\ \text{(W)}}{25000\ \text{(V)}} = 356\ \mu\text{A}$$

Therefore, $I_R = 165\ \mu A$, $I_G = 144\ \mu A$, $I_B = 77\ \mu A$

When calculations are repeated with data from Tables III and IV, the values summarized in Table V are obtained. The calculated currents shown in this table indicate the theoretical potential brightness of the various P22 screen types. However, there are practical difficulties in achieving these brightness levels under high-volume production conditions. For example, the phosphate-silicate-sulfide phosphor combination required a total beam current of 440 μA in production, as compared with the calculated value of 356 μA. The optimized all-sulfide phosphor required 260 to 265 μA, as compared with the calculated value of 256 μA. The calculated values for the rare-earth combination indicate a red-gun current slightly less than the green-gun current; this situation has not been achieved even under laboratory conditions.

CONCLUSION

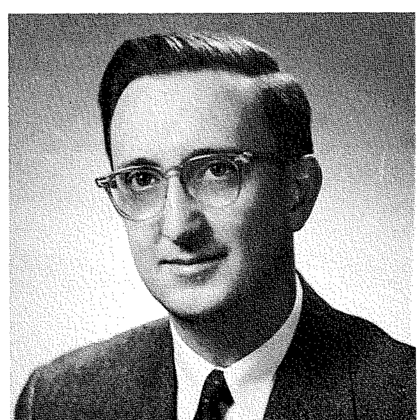
It is predicted that the future will see additional improvements in phosphor efficiency, although probably only of the order of 15 to 20%. As mentioned earlier, some compromise in hue and saturation might be acceptable if brightness gains of 20 to 30% could be realized. In the long run, however, the trend will be to increase saturation and hue while maintaining brightness.

It should be pointed out that the greatest potential for increased brightness is to deliver more power (either current or voltage, or both) to the phosphor screen. The maximum current that a gun can deliver to the screen in the shadow-mask tube results in a phosphor current-saturation effect of only about 10%, i.e., a departure from linearity of only 10% in the *light-output/beam-current* characteristic. Clearly the screen would emit more light if more current could be delivered to it. Similarly, more light could be obtained if the anode voltage could be increased from the present value of 25 kV. However, the use of higher voltages would create various other problems and is not envisioned at this time. It is hoped that future work will solve the existing problems in a practical and economic way and make possible brightness levels of three to four times those currently being achieved.

BIBLIOGRAPHY

1. H. W. Leverenz, *An Introduction to the Luminescence of Solids,* John Wiley & Sons Inc., 1950.
2. A. L. Smith, *J. Electrochemical Society, 98,* 1951.
3. *U. S. Patent No. 2,991,383,* July 4, 1961 (A. E. Hardy).
4. A. K. Levine & F. C. Palilla, *Applied Physics Letter,* Vol. *5,* No. 6 (September, 1964).
5. D. B. Judd, *Color in Business, Science and Industry,* John Wiley & Sons Inc., 1952.
6. D. W. Epstein, *RCA Rev. 14,* 1953.
7. D. L. Macadam, *J.O.S.A.,* Vol. *35,* pp. 293-296, April, 1945.
8. W. T. Wintringham, *Proc. IRE,* Vol. *39,* p. 1161, October, 1951.

AUSTIN E. HARDY received the BS in chemistry from the University of New Hampshire in 1943. He has done graduate work in physics at Franklin and Marshall College. He joined the Chemical and Physical Laboratory at RCA, Lancaster in May 1943 as a phosphor chemist on the development of zinc sulfide and zinc cadmium sulfide phosphors for radar display tubes. He designed and constructed a recording spectroradiometer and other colorimetric and photometric equipment. Technical papers on these subjects presented before the Electrochemical Society earned him the "Young Author's Prize" and the "Turner Book Prize." Later he became active in phosphor screening and was intimately involved in the development of black-and-white television tubes. Since 1949 he has been a group leader in the Chemical and Physical Laboratory. His current responsibilities include color-television phosphor-screen deposition and colorimetry. Mr. Hardy is the current chairman of the Electronics Division of the Electrochemical Society and chairman of the JTC 6.3 sub-committee on phosphor-screen characteristics. He is the author of a number of technical papers and holds several patents. He was one of the recipients of the "1963 David Sarnoff Team Award in Engineering."



INDUSTRY'S FIRST LARGE-SCALE LAMINAR-FLOW CLEAN ROOMS

Part of the New Lancaster Conversion Tube Facility

Successful development and production of conversion tubes for government and commercial applications requires precise environmental control to meet the stringent performance and quality requirements of the nuclear and space age. The Electronic Components and Devices capability in the very competitive industrial-tube market has recently been improved by completion of a new conversion-tube facility at the Lancaster plant. This new facility, one of the most advanced in the electronics industry, provides contamination-control features far superior to those normally found in conventional electronics engineering and manufacturing plants.

F. C. WEISBACH, Mgr.
Facility Planning
Electronic Components and Devices
Harrison, N. J.

The new EC&D 157,000-ft^2 Engineering and Manufacturing Center at Lancaster, Pa., is one of the most complex engineering and manufacturing buildings within the electronics industry (Figs. 1, 2). The complexity of this facility stems from the varied nature of the occupants who must use it (scientists, chemists, engineers, and technicians) and the precisely controlled environment needed to produce very complex electron devices which must have unprecedented performance and quality levels. This new facility includes the world's first large-scale vertical-laminar-flow clean rooms—occupying over 20,000-ft^2 that have literally advanced the state-of-the-art in industrial environmental control. In addition, the remainder of the 157,000-ft^2 facility features a controlled cleanliness that is very close to that found in many conventional industrial "clean rooms."

Among the products that require this close environmental control are the various types of RCA conversion tubes (devices which convert heat or light to electrical energy, or vice versa). These electron tubes perform counting, sorting, display, and control functions in

Final manuscript received June 25, 1965.

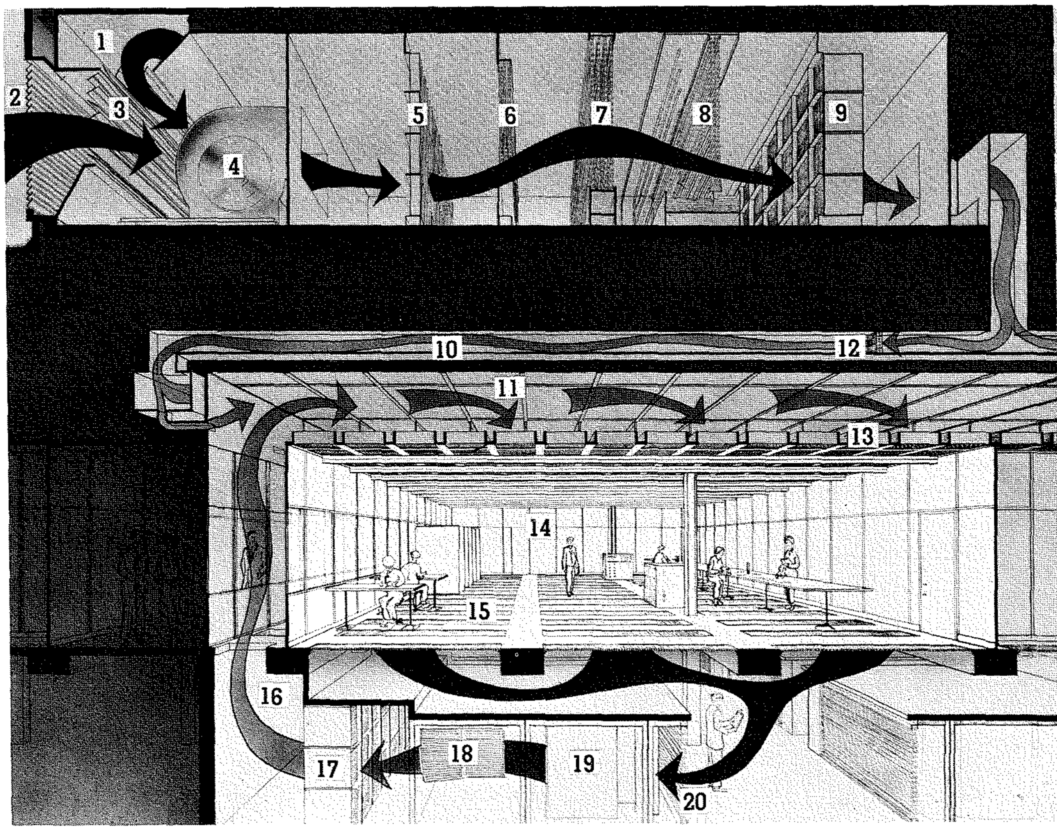


Fig. 1 — Cross-sectional view of 9,000-ft^2 laminar-flow clean room.

KEY:
1) return air duct
2) outside air intake
3) mixing dampers
4) fan
5) pre-filter
6) pre-heat coil
7) pre-cooling coil
8) dehumidifier
9) filter
10) primary supply duct
11) plenum ceiling
12) reheat coil
13) final filter (absolute)
14) clean area
15) floor grating
16) recirculated air
17) filter
18) recirculating fans
19) sound attenuators
20) cooling coils

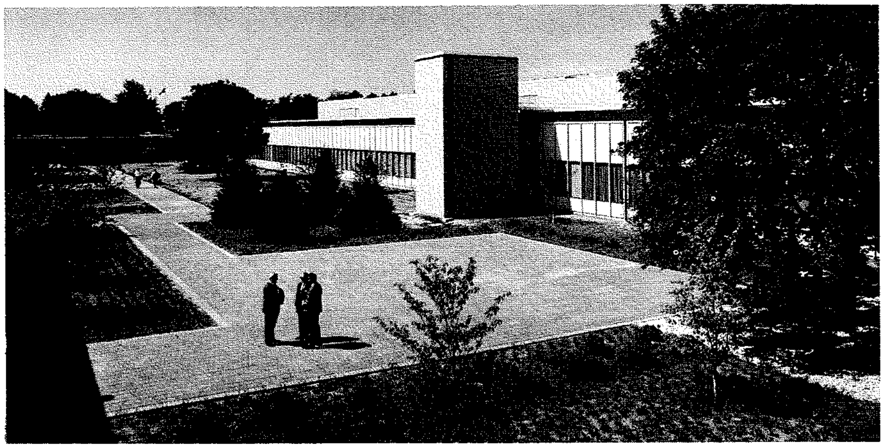


Fig. 2—Exterior and surrounding mall of Engineering and Manufacturing Center.

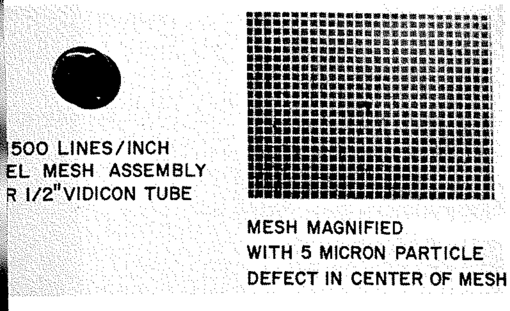
such diverse applications as radar-TV scan-conversion links, astronomical image intensifiers, ultraviolet and infrared radiation detectors, nuclear scintillation counters, military night surveillance and guidance equipment, star-tracking systems, space exploration, and, of course, television.

Two of the more spectacular accomplishments of conversion tubes are those used in TIROS and RANGER. The TIROS meteorological satellites employ two miniature vidicons of advanced design which have provided literally thousands of photographs of the earth for use in studying weather and atmosphere. The RANGER lunar probes use six vidicons to obtain photographs of the moon. Development of these and similar tubes required the highest degree of skill from EC&D engineering and production staffs working in the then-existing facilities. The problems associated with the critical environmental requirements emphasized the need for a more closely controlled environment to meet the performance and quality demands of both government and commercial customers.

NEED FOR ENVIRONMENTAL CONTROL

As more advanced technical performance is continually required from conversion tubes and devices, improved processing techniques such as spot-free photoconductive surfaces and precision

Fig. 3—Fine wire mesh used in advanced RCA vidicon camera tubes.

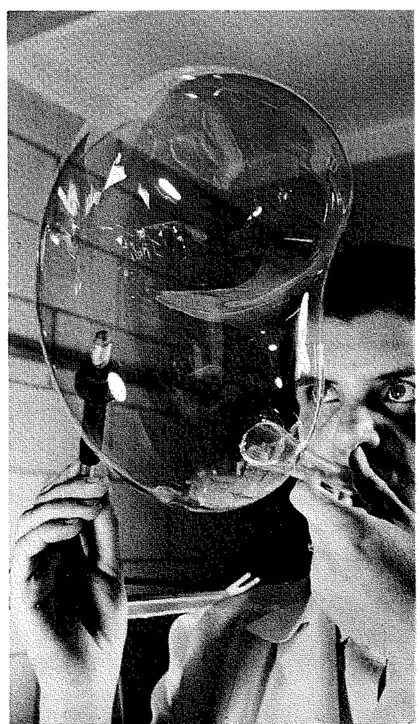


deposition of multilayer thin-film surfaces on optically perfect faceplates must be developed. Fig. 3 shows the much finer wire mesh and Fig. 4 the improved target assemblies developed to provide superior performance in vidicon camera tubes. However, successful production of such intricate assemblies as screens for image tubes, fine mesh for camera tubes, and semiconductor surfaces for phototubes requires the elimination of dust, excessive humidity, large variations in temperature, impure water and contaminated atmosphere. Some precise mesh assemblies have as many as 2,000 lines per inch. Target assemblies are made from a very thin glass membrane which is subject to very rapid weathering when the relative humidity varies from a specified amount. Fine dust particles are a particular source of contamination, especially on multilayers of thin-film materials used for delicate photosensitive surfaces. In the development and production of photomultiplier tubes, excessive variations in humidity result in high dark current and an increase in the number of background pulses. Recent developments of photomultipliers for pulse counting and liquid scintillators demand an exceedingly low number of background pulses for practical application to nuclear, medical, and biological sciences.

Although much of the attention in the electronics industry has been directed to dust control, a tube plant making a diverse line of products has other unique contamination-control problems. Many gases such as hydrogen sulphide and chlorine are used for processing purposes, as well as acids such as hydrofluoric, nitric, hydrochloric, and sulphuric. Years of experience and hundreds of thousands of dollars in scrap losses caused by gaseous and particle contamination have demonstrated the necessity for scrubbing the air coming

FREDERICK C. WEISBACH is a graduate of Thaddeus Stevens Trade School where he majored in the electrical trades and mechanical drafting. He later attended both the University of Pennsylvania and Penn State College where he pursued the Business Administration curriculum. He joined RCA in 1943 after serving in the capacity of Division Service Representative for the Pennsylvania Power and Light Company. His initial responsibilities with RCA concerned administrative and equipment problems associated with establishing the Lancaster plant, including installation planning, facilities and cost estimating. In 1948, he became Supervisor of Capital Budgets and Appropriations, and two years later was promoted to Manager of the Facilities and Planning Group for the Lancaster plant. In 1952, Mr. Weisbach was transferred to the Company's Divisional office in Harrison, N. J., and simultaneously promoted to the position of Administrator, Facilities. In this capacity he was responsible for the overall planning and coordination of major facility expansion plans for the Electron Tube Division. In 1954, he became Administrator, Tube Parts and Facility Planning for the Cathode Ray and Power Tube operations at the Company's Marion, Harrison, and Lancaster locations. In 1957 he was named Administrator, Planning, for Industrial Tube Products and in 1958 was promoted to Manager, Planning, Nike-Zeus Project. From 1959 to 1962 he served in the capacity of Administrator, Advanced Market Planning, Systems and Components. In June, 1963, he was named Project Manager of the Conversion Tube Expansion Project at Lancaster, and in August of 1963 was promoted to Manager, Facility Planning, Electronic Components and Devices.

Fig. 4—Manufacture of glass targets for vidicon camera tubes.



from the industrial exhaust systems before it is discharged into the atmosphere where it may be picked up by the fresh-air intakes of the air-conditioning system. Chemicals must also be treated before they are discharged into sewers and streams to minimize toxic or contaminating effects. These contamination-control requirements not only add to the complexity of a tube plant, but also account for much of the capital investment required to produce a quality product successfully at a reasonable cost.

TYPE OF BUILDING SELECTED

In the electronic components and devices field, rapid changes in types of products to be engineered and manufactured are an inevitable part of the daily business life. Planning for the new plant had to anticipate such changes and provide a flexible facility which could be readily adapted and changed without excessive costs. In addition, the plant had to include the environment control which would provide EC&D operations with the necessary "clean-room" facilities to meet both EC&D requirements and governmental clean-room standards.

Original planning for the building considered many factors, including operating efficiency, capital costs, utility value, and flexibility for new products. One of the basic requirements set forth by the engineering staff was the elimination of any overhead piping and utilities which could generate dust over a critical working area. Complete flexibility was considered essential so that plant rearrangements could be made with a minimum of lost time, expense, and dirt generation. As in every engineering decision, both initial cost and operating cost were basic considerations in planning for the new facility. The architects and consulting engineers, in cooperation with EC&D engineers, made an analysis of three basic types of buildings and service-distribution systems, as follows:

1) A one-story building with a utility basement and a penthouse area. All engineering and manufacturing departments would be on the main floor, with utilities distributed in the basement. All service piping and electrical lines would pass through the floor slab to the equipment above.
2) A two-story building with a fan-room penthouse and a service area sandwiched between the first and second floors. The distribution of services would be in a utility area between the ceiling of the first floor and the slab of the second floor. Pipe lines would pass down through the ceiling to equipment on the first floor and up through the floor slab to equipment on the second floor. The air-distribution system would be accommodated by ductwork from the penthouse area.
3) A two-story building, contiguous to the existing plant buildings, in which the upper floor would be especially-clean-room space reserved for engineering and manufacturing of devices requiring close environmental controls. The first-floor area would be used for the service-distribution systems and comparatively "dirty" processing areas.

Analysis of the three basic proposals showed that EC&D could best meet its objectives at a minimum overall cost by erecting a one-story plant with a service basement below and penthouse areas above. The one-story approach permits installation of the service-distribution system and air-conditioning compressors in a basement area. Because most of these utilities are thus within easy reach of a maintenance man, economies can be achieved in maintenance and rearrangement expenses.

The one-story structure chosen includes four set-back mechanical penthouses that accommodate the main air-handling and dehumidification systems. All vents and exhaust ducts are contained, out of view, within the building's super-structure.

A "drop" ceiling below the penthouse area intercepts "fallout" from roof slabs, sprinkler piping, air-distribution ducts, and power conduits and helps to maintain a clean environment throughout the building.

The entire steel structure of the building is enclosed with buff brick masonry panels articulated to express the bearing columns, as shown in Fig. 2. A bank of windows on one wall overlooks a gently landscaped mall created as a natural and pleasant transition between the conversion devices center and the main RCA plant building.

LAMINAR-FLOW CLEAN ROOMS

The focal point of this modern EC&D plant is the special environmentally controlled clean rooms in which all sensitive parts are processed and assembled. The new facility contains the world's first large-scale vertical-laminar-flow clean rooms, a total of more than 20,000 ft^2 of floor space. These clean rooms house more than 200 RCA engineers and technicians in an environment where sensitive miniaturized components can be developed and assembled in quantity production with a degree of consistent dependability unparalleled in the industry. A complex of fans, air-conditioning equipment, and absolute filters provides within this half-acre of floor space an atmosphere so rigidly controlled and so pure that it has rarely been experienced before except in small experimental rooms or at individual laminar-flow work stations.

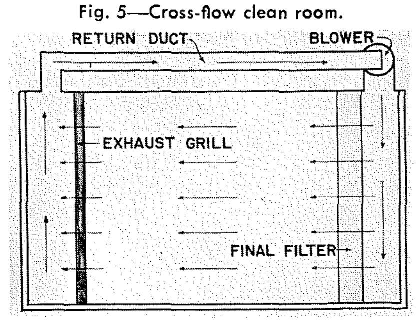
The entire clean-room "state of the art" has been advanced by RCA's Lancaster project. The new RCA clean rooms exceed the U.S. Government's Class 100 Specification, which specifies that each cubic foot of air shall contain no more than 100 particles of contamination, 0.5 micrometer or larger, and shall be maintained within specified limits of temperature and humidity. The magnitude of this cleaning operation can be understood in terms of the particle contamination in various open-air locations. In fairly open country, the average cubic foot of air contains up to 850,000 particles of contamination that are 0.5 micrometer or larger. In an urban area, the number may be as high as 5,000,000 particles; in smog areas, as high as 10,000,000. Three miles above the earth, in the stratosphere, there are some 200 particles/ft^3.

The presence of contaminants of this nature in a production area can play havoc with the photosensitive surfaces and miniature components so essential to electronic systems today. In the new RCA laminar-flow clean rooms, all but 2 or 3 of the millions of contaminating particles normally found in a cubic foot of ordinary air are removed. In addition, each remaining particle (which can be counted only by electronic instruments) is no larger than 1/80,000 inch, or 0.3 micrometer.

EVOLUTION

Achievement of this major advancement in clean-room technology was accomplished in one giant step. When EC&D broke ground for its new conversion-tube facility in September 1963, the dominant question in the industry seemed to be, *How clean is clean?* That year, the Air Force Standard 00-25-203 was updated to include specifications for a clean room that would operate with an atmosphere containing no more than 10,000 particles of half a micrometer or larger per cubic foot of air. At that time, this specification was considered "super clean."

Fig. 5—Cross-flow clean room.



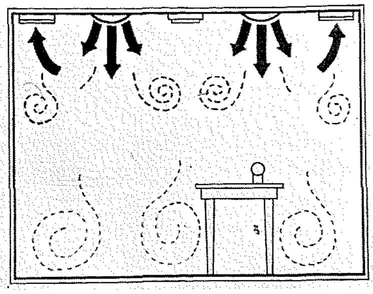


Fig. 6—Air turbulence patterns in conventional clean room.

Meanwhile, however, the Sandia Corporation of Albuquerque, New Mexico, a nonprofit corporation formed as an arm of the Atomic Energy Commission, had developed small portable rooms which utilized the *laminar-flow* principle. Laminar flow, and particularly vertical laminar flow, had succeeded in producing and maintaining new working levels of cleanliness in small, portable, easily constructed rooms. These new levels formed the basis for the "classification 100" standard.

Prior to the work of the Sandia Corporation, the principle of horizontal laminar flow had been applied to clean rooms up to 5,000 ft^2 in size, as shown in Fig. 5. These rooms had achieved overall levels of cleanliness of only 10,000 particles/ft^3. The major disadvantage of horizontal laminar flow is that critical work must be done close to the air supply because contamination increases "downstream." Because there is no "downstream" or "upstream" with vertical laminar flow, all areas are equally clean at the work station.

Investigations demonstrated very quickly that it would be virtually impossible to realize the government's new 100-particles/ft^3 classification in a conventional "clean room." In this type of room, as shown in Fig. 6, purified air enters through ceiling vents, is circulated through the room, and is exhausted through registers on the wall, near either the ceiling or the floor. Experiments showed that this indirect circulation sets up turbulent side currents which entrap particles in small eddies and either hold them in corners near the ceiling or pile them on the floor. In addition, some of the dirt picked up at one work station is simply carried around and dumped on other work areas. *Entrapment* and *entrainment* had become the scare words of conventional clean rooms.

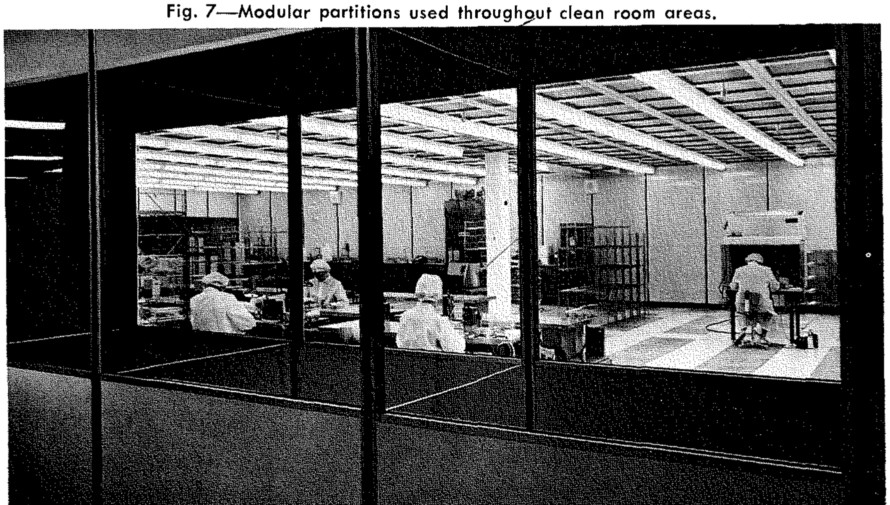
The vital question in designing the new Lancaster system, therefore, was whether to tackle the enormous problems and cost risk involved in projecting the vertical-laminar-flow concept to the necessary massive plant-production level. EC&D accepted the challenge of this task and engaged Vincent G. Kling & Associates, Architects, and Robert J. Sigel, Inc., Consulting Engineers, to work with RCA specialists in the design of large-scale vertical-laminar-flow clean rooms that would satisfy the government's new "100 Classification" specifications. These rooms, to be from 100 to 300 times cleaner than any rooms yet built approaching their size, would be of three sizes: a 5,000-ft^2 phototube assembly room, a 6,000-ft^2 camera-tube assembly room, and a 9,000-ft^2 room for research and development (Fig. 1).

DESIGN OF CLEAN ROOMS

In the Lancaster vertical-laminar-flow clean rooms, employees work under a gentle shower of pure air passing directly from banks of HEPA (high-efficiency particulate arresting) filters which cover more than 65% of the ceiling. Filtered air, conditioned to a temperature of 72°F and a relative humidity of 35% moves straight down and out of the rooms through grates which cover 40% of the floor. The air descends from the ceiling at the rate of 50 ft/min, or less than a mile an hour. There is no significant turbulence. Without drafts or discomfort to workers, the air is changed more than 300 times an hour.

The filtered air is drawn down and through the clean rooms by thirty-six 30,000-ft^3/min fans located in the basement area. It is then passed through rough filters and returned to the air conditioning system by way of wall plenums. The fans are covered with four-inch reinforced concrete hoods, and are baffled at the intake end to keep the noise level in the clean rooms down to the level normally present in an average business office. The wall and ceiling plenums are completely sealed to form a single-leak-proof envelope of great strength that covers all the clean-room areas.

Fig. 7—Modular partitions used throughout clean room areas.



An important hazard to maintaining a "100 classification" in a conventional clean room is the people who work in the room and the objects they carry into it. The most meticulously clean human being throws off an average of 1,500,000 particles of contamination every minute. Clothing disgorges additional dust. A clean-looking data-processing card can harbor from 1,000 to 1,700 particles from 5 to 10 micrometers in size on its surface. These invisible particles become entrapped and entrained in conventional clean rooms. In one so-called "super-clean operation," more suspended dirt was discovered inside the clean room than outside after the workers had entered.

The reason for this entrapment of dirt is that conventional systems lack another important function that vertical-laminar-flow rooms possess: immediate wash-down, on the spot, of all people and objects brought into the room. As a result, expensive coveralls, booties, hoods, caps, and gloves must be supplied to workers in conventional clean-room operations. Each worker must take one or more elaborate air showers before entering the rooms. Industry sources have estimated that the cost of trying to maintain even a 10,000-particle/ft^3 level in conventional clean-operations, averages more than $2,500 per year per worker for all the required gear and equipment, plus training, maintenance, and inefficiencies.

These costs are almost totally eliminated at the new RCA Lancaster facility. Head covers and simple smocks are the only employe equipment required with the system. Simple, coarse-fibered scrub rugs cover the floors near the only two doors where workers enter the building. Personnel may enter or leave the rooms frequently without fear of contamination. A positive air pressure is maintained in the rooms that is higher than that in the surrounding building. Air pressure within the non-clean-room or "gray" areas of the surrounding building is also higher than the outside atmosphere. When a door is opened, therefore, dirt goes out, not in. The resulting savings in personnel "preparation" time will produce major

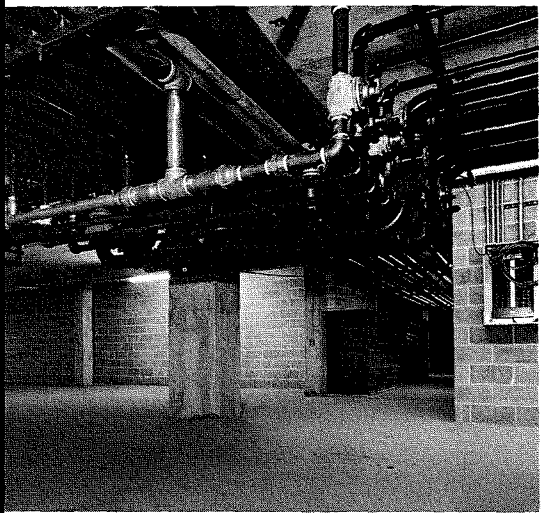


Fig. 8—Utility distribution system.

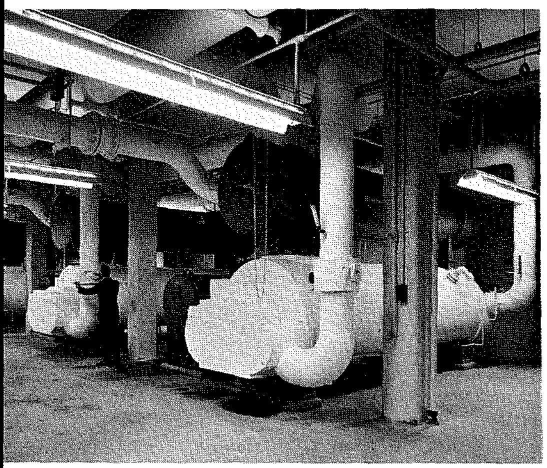
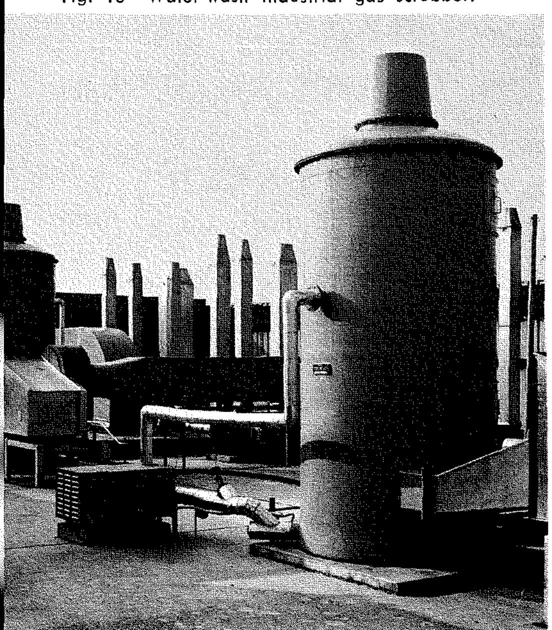


Fig. 9—Centrifugal refrigeration system: 2,400-ton total capacity.

Fig. 10—Water-wash industrial gas scrubber.



economies at the EC&D clean rooms.

Other economies are also achieved as a result of the new clean-room design. There is little or no money-wasting "down time" for repairs inside the clean rooms. Relatively "dirty" maintenance work can be performed while critical work continues at a nearby bench with little danger of cross contamination. Delicate assemblies can be made side by side with rougher or less clean work without contamination. The absolutely rigid control of particulate matter in the air also permits extreme accuracy and dependability of production and will result in fewer rejects in quality control. In addition, these clean rooms, unlike any other large clean rooms in existence, can be shut down when not in use. All 20,000 ft^2 clean up to the most rigid specifications within 20 or 30 seconds of going back "on stream" after an idle weekend. In the event that production requirements change in the future and a less severe environment is adequate, the recirculating fans can be shut down and the room can be operated as a conventional clean room or general factory area.

GENERAL PLANT AREA

All the clean-room areas, equally divided between engineering and production, are supported by an adjoining complex of highly flexible engineering development shops and production areas. These "gray" rooms and corridors, which cover 138,000 ft^2, were created on a concept of *coordinated modular flexibility*, with the module designed on a 4-foot grid between the 36-foot spans of supporting columns. The cleanliness level in these areas is very close to that found in many conventional clean rooms.

The modular partitions in the new facility, shown in Fig. 7, are surfaced with high-pressure laminate. The partitions can be set up or taken down easily and quickly without major structural surgery and without the creation of contaminating dust. Surfaces are resistant to abrasion and never require painting. All lights in the drop ceiling are flush mounted. Light levels are in excess of 75 footcandles in the general areas and 150 footcandles in the clean rooms. Special diffusers are used on the clean-room light fixtures to prevent the damaging effects of ultraviolet light on sensitive screen surfaces.

BASEMENT AREA FOR SERVICES

One of the major advantages of a basement service area is cleanliness. Other advantages include ease of maintenance and inspection, flexibility in making changes, low cost of installation and rearrangement of equipment (no scaffolding or step ladders required), and ready access to several hundred mechanical vacuum pumps used for exhausting tubes. A major piping network and electrical-bus distribution system is used to provide water, gas, electricity, and steam to any part of the basement. The piping network has take-off valves on 12-foot centers to make it convenient to install, expand, or rearrange equipment on the floor above.

The main distribution service system includes twelve basic services: hot process water, cold water for cooling, hot deionized water, cold deionized water, steam, city gas, nitrogen, oxygen, forming gas, high-pressure air, low-pressure air, and hydrogen. In addition, a basic network of process drains, chemical drains, and industrial exhaust ducts serves all areas on the floor above, as shown in Fig. 8. All special high-quality process gases are supplied from a central gas-generating plant owned and operated by RCA. Demineralized water, air, and steam are supplied from the central power house. Chemical waste is piped to an RCA-operated central waste-treatment plant for processing prior to discharging into a stream adjacent to RCA property.

Included in the basement is a special utility area for the air-conditioning compressors and associated pumping systems. Three 800-ton centrifugal refrigeration units are installed in this area, as shown in Fig. 9. These units supply 36°F brine (water and ethylene glycol) to the air-handling systems located in the penthouses on the building roof and to the 36 special fan rooms located below the clean rooms.

Another advantage of the service basement is that it provides space for a centralized vacuum-cleaning system that includes a piping network and a flexible system of convenient outlets throughout the building. In addition to its function as a dust and dirt remover, this system is also used as a "mop" in floor-washing operations and thus eliminates the need for brooms, mops, and other janitorial tools.

FUME DISPOSAL

Special provisions are included in this new facility for controlling contaminating gases. Between the penthouse areas on the building roof, five 25,000 ft^3/min scrubbing towers are installed for the control of toxic and corrosive exhaust, as shown in Fig. 10. Exhaust trunk lines are distributed throughout the building for ease of connection and flexibility.

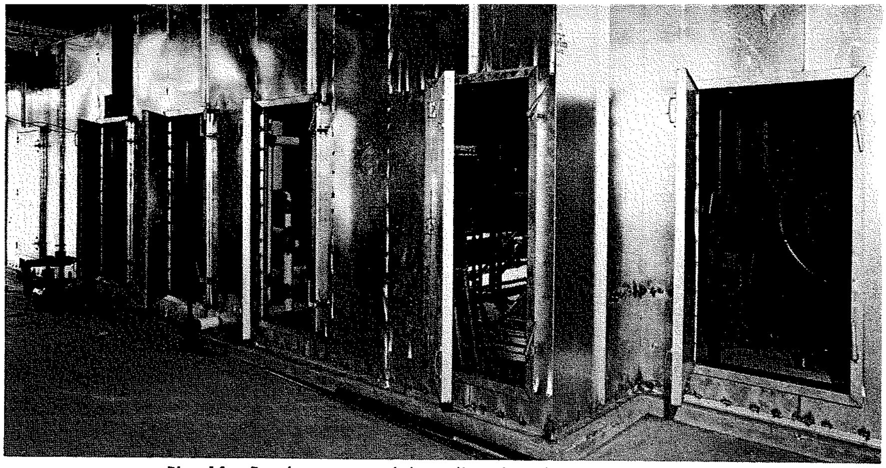


Fig. 11—Penthouse containing all major air-handling systems.

PENTHOUSES

Four 10,000-ft^2 penthouses are provided for heating, ventilating, and air-conditioning purposes, as shown in Fig. 11. One of the air-handling systems located in these penthouses supplies saturated air at approximately 41°F to provide industrial-exhaust make-up air and humidity control for the clean rooms. The remainder of the plant is served by four 60,000 ft^3/min air-handling systems, each supplying one quarter of the building.

Air conditioning is supplied to the areas through conventional ducts. Half of the return air passes between the hung ceiling and the roof to pick up heat from the roof and lights, and half is returned through the basement for special ventilation of utility area.

CENTRALIZED CONTROL SYSTEM

A major item in the cost of operating an air-conditioned plant and clean-room complex is the cost of personnel required to supervise, maintain, and inspect the equipment on an around-the-clock basis every day of the year. In a building as complex as EC&D's new facility, checking the performance of the environmental-control system and making adjustments can involve a great deal of time. There are 36 fan rooms in the clean-room complex and 5 major fan systems in the penthouses which must be monitored and controlled. In addition to these special rooms, there are zones directly controlled by local thermostats, temperatures in the primary air-handling systems, and basic heating and refrigeration systems which must be supervised by responsible technical personnel. These functions are normally performed by personnel patrolling, monitoring, and logging various conditions.

To overcome much of this expense, EC&D selected and installed a centralized control system, shown in Fig. 12, to monitor and record data in all critical areas. This system is designed to reduce the cost of operating the air-conditioning system and to improve its performance. It collects, at a central location, all the key data the operator needs to monitor the system. It also incorporates all the remote-control devices needed to supervise its operation. Without moving from the console, the operator performs the following functions:

1. Checks and logs key temperatures and humidities.
2. Adjusts temperatures, humidities, and dampers.
3. Starts and stops equipment, including all fans.
4. Supervises all alarm equipment.
5. Investigates and handles complaints.

Schematic layouts of all fan systems, floor plans, and zones can be selected and immediately displayed on the console by simple operation of a switch. This feature adds to the operator's own efficiency and helps him to train new personnel and to direct repairs by means of the built-in intercom system between the local control stations and the central control console. In brief, the central control system makes it possible for one man with one set of controls and at one convenient location to supervise the entire air-conditioning system and clean-room complex. Maintenance mechanics, relieved of system-monitoring duties, can more efficiently perform the very important preventative maintenance work on the mechanical equipment itself.

CONCLUSION

EC&D's experience with improved working environments indicates that a higher-quality product can be produced at profitable levels. Because of increasingly stringent technical requirements, this modern facility gives RCA engineers and production personnel the necessary tools to keep ahead of competition. Major operating-cost savings have already been predicted by both engineering and production staffs as a result of the use of the cleaner facility. The stimulating environment generated by the new plant facility should also improve creativity and productivity in the competitive days ahead.

ACKNOWLEDGMENT

The following people and firms made technical contributions and supplied services for the construction of this new plant facility:

V. G. Kling, F.A.I.A., & Associates, (*architectural design*); J. Naylor, Project Architect (*project co-ordination*).

R. J. Sigel, Inc., Consulting Engineer, (*mechanical and electrical engineering*); J. Henderson, Project Engineer; C. Curtis, Project Engineer.

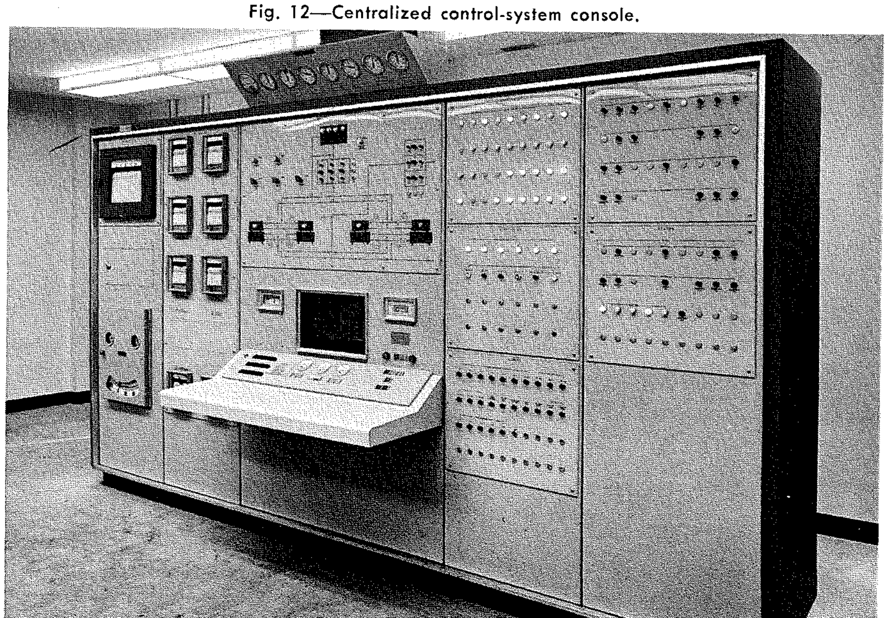
Sandia Corporation (*technical assistance*); G. J. King and W. J. Whitfield, (*advice and counsel on laminar flow concepts*).

Turner Construction Co. (*general contractor — project management and general construction*); J. Sweeney, Superintendent.

Corbit's Inc. (*mechanical contractor*); J. Falkenberg, Engineer.

H. F. Ortlip, Inc. (*electrical contractor*); P. Daniels, Superintendent.

Fig. 12—Centralized control-system console.



DEFLECTION YOKE FOR 19-INCH 90° COLOR TV PICTURE TUBES

At wide deflection angles (90°), it is not possible to optimize all performance characteristics of color TV yokes simultaneously. The color yoke for the new RCA 19-inch, 90° rectangular color picture tube has been designed for optimum convergence and beam-to-phosphor-dot register by analyzing the electromagnetic field flux distribution to obtain the proper astigmatism, coma, and location of deflection centers. A precise "fine tuning" of the flux distribution, without altering the shape of the coils, is obtained by a new method using series-connected strands in parts of the winding. Tight controls on the arbors and winding process and a 100% convergence check, as well as two mechanical adjustments to control the lateral position of the blue beam relative to the red and green, insure a converged color-pure picture equivalent or superior to anything previously on the market.

R. L. BARBIN

RCA Victor Home Instruments Div.
Indianapolis, Indiana

ROBERT L. BARBIN attended the University of Rochester from 1956 to 1960 where he graduated with a BS in Physics. Upon graduation he joined RCA and, after a short training program, joined the Electromagnetic Devices Development Department of the RCA Victor Home Instruments Division at Indianapolis where he has been working in applied research and, in particular, advanced color TV yoke design. He has been pursuing graduate work in mathematics at the Purdue University Extension in Indianapolis.

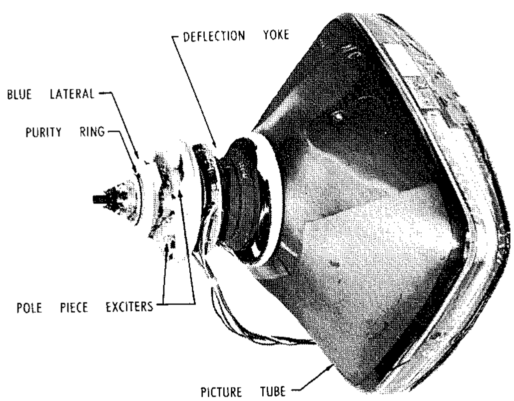


Fig. 1—RCA 19", 90° color picture tube, deflection yoke, and associated components.

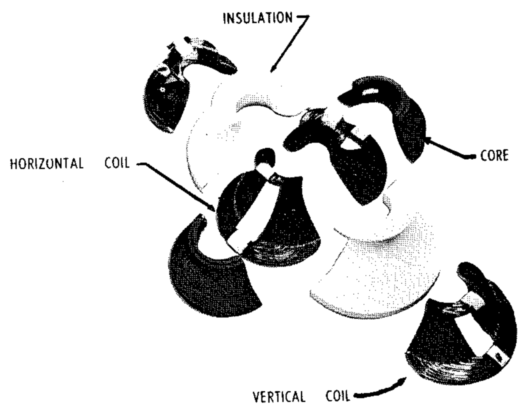


Fig. 2—Basic elements of RCA 19", 90° color deflection yoke.

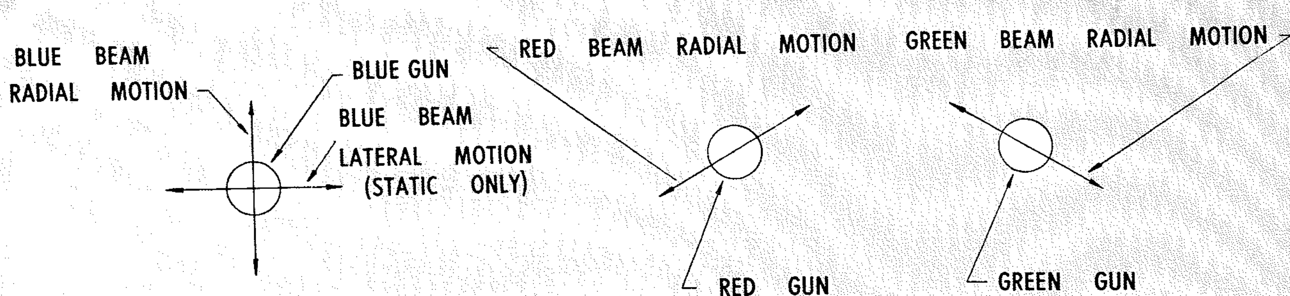


Fig. 3—Direction of motion of beams under deflection by convergence pole pieces.

THE continued increase in color TV receiver sales has been further augmented by the introduction of short, wide-angle, rectangular-shaped color picture tubes. An important addition is the 19-inch 90° rectangular color tube announced by RCA early in 1965, which promises bright, sharp color pictures in a smaller, less expensive receiver than ever before offered. Figs. 1 and 2 show a developmental RCA 19-inch tube and an RCA 90° color deflection yoke designed for this tube.

CONVERGENCE

To reproduce a black-and-white or color-TV picture on a shadow mask color picture tube, the three electron beams must be converged over the entire screen. Convergence along the axes of the screen is provided by the convergence pole-piece exciters which are driven by dynamic waveforms at both a horizontal and vertical scan rate, and deflect each of the three beams in a radial direction independently of the other two, prior to entering the yoke deflection field. A fourth convergence action, necessary to insure convergence in the center of the screen, is a static lateral or horizontal motion of the blue beam (Fig. 3). Since no provision is made for dynamic blue lateral, the yoke design must be such that the blue beam converges horizontally along the axes of the screen under the application of radial convergence only. To provide convergence over the entire raster, the yoke flux distribution must also be designed such that at any point on the screen the beams will converge under the combined application of the dynamic convergence waveforms required at the corresponding points on the adjacent horizontal and vertical axes.

ELECTRON BEAM LANDING

It is equally important that the beam from each gun excite only its respective primary-color phosphor dot. Each hole in the shadow mask allows three beams of electrons to strike the tube screen, one beam from each gun (Fig. 4). The shape of the triangle formed by these beams is an image of the beams entering the yoke field, and ideally forms an equilateral triangle and of equal size all over the screen, with the centers of the beams corresponding to the centers of tangent phosphor dots.

One factor which distorts the beam-trio landing pattern is the obliquity inherent in the geometry of the tube. A conical bundle of beams concentric with the tube axis will, under ideal deflection, remain circular in any plane perpendicular to the tube axis. However, if this beam bundle is cut by a sphere, such as the screen, which makes an angle ϕ with the perpendicular to the tube axis, the image on the sphere becomes an ellipse with the minor axis in a radial direction (Fig. 5). The ratio of the minor to major axes of the ellipse is a measure of the obliquity and is dependent on the angle ϕ and the deflection angle of the beam. On the 19-inch 90° system, this factor goes as low as 0.8 in the corners; since this foreshortening is alway radial, it causes the shape of the beam triangle to vary around the edge of the tube.

The other large factor in causing nonuniform beam spacing over the screen is the application of dynamic convergence. The dynamic convergence deflection is applied before the beams enter the yoke field, and alters the shape of the beam bundles in the yoke field. Dissimilar dynamic convergence required to converge the beams as they are deflected to different parts of the screen, causes the shape of the beam trios on the screen to vary accordingly.

The purity and white uniformity of the system are determined by the register of the beams to the corresponding phosphor dots. The phosphor dots are printed on the screen through the shadow mask by optical means and their locations can be controlled by the use of optical lenses. However, even where the phosphors are printed concentric with the beams, deviations from equilateral triangles give a poorer nesting of the phosphor dots with less of the screen covered with phosphor and a corresponding loss of light output.

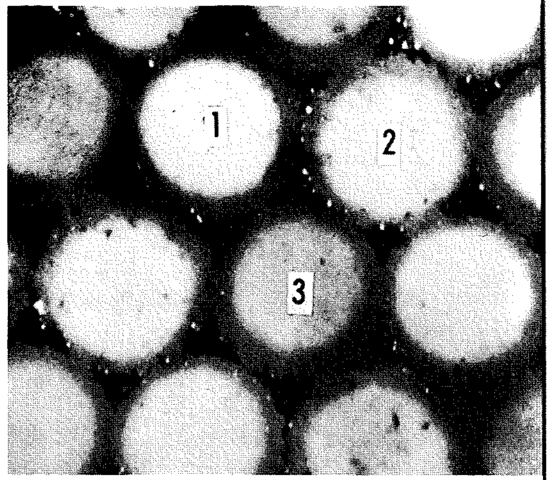
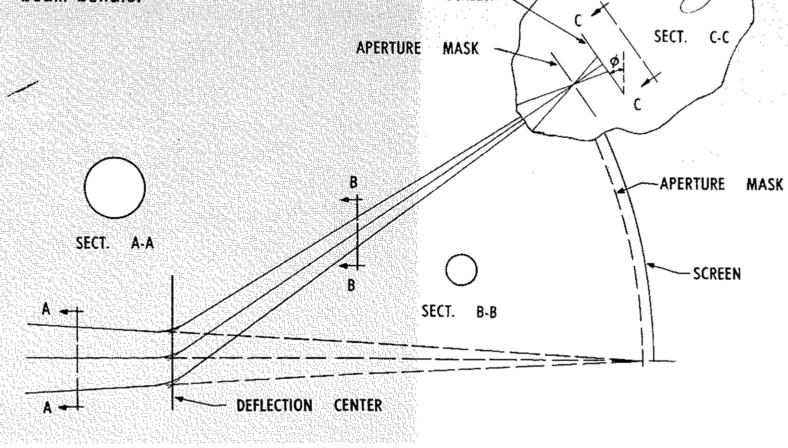


Fig. 4—Photomicrograph of phosphor dots in the center of an RCA developmental 19", 90° color picture tube. The landing of the electron beams on their respective phosphor dots is shown by the lighted circles. Numbers indicate: 1 green phosphor, 2 red, 3 blue.

PINCUSHION

The type of yoke flux distribution which gives best convergence and beam spacing, and the geometry of the tube, particularly for wide deflection angles, gives a raster which is pincushioned in shape. In black-and-white TV this is corrected by the use of localized permanent magnets mounted in front of the yoke to pull out the axes of the raster. These magnets locally distort the angle at which the beam strikes the screen, and in color TV cause unacceptable color purity and white uniformity. In the 19-inch 90° color yoke, we have chosen to design the flux distribution for opti-

Fig. 5—Obliquity; geometry of tubes causes radial shortening of a conical beam bundle.



Final manuscript received June 14, 1965.

mum convergence and register characteristics, and to correct the pincushion with time varying scan waveforms which have reduced amplitude when scanning to the corners.

ELECTROMAGNETIC FIELD CHARACTERISTICS

One of the most familiar TV deflection-yoke field characteristics is *astigmatism.* Analogous to lens optics, astigmatism is a relative stretching of the beam parallel or perpendicular to the direction of deflection (positive or negative astigmatism). Astigmatism of the deflection yoke can be considered as a combination of two types: *isotropic* astigmatism and *anisotropic* astigmatism. Isotropic astigmatism applies to each set of deflection coils independent of the other set, and its effect is carried linearly into the corners dependent upon the component of deflection from that set of coils. If a conical beam bundle is deflected horizontally by a set of coils having negative astigmatism, the beam bundle on the screen becomes elliptical with major axis vertical. This distortion of the beam bundle causes a dissimilar dynamic-convergence requirement for the three beams, distorting the beam spacing from equilateral. If the astigmatism is negative, this distortion is of the same polarity as the obliquity and increases the problem. Since isotropic astigmatism and dynamic convergence action add linearly into the corners, isotropic astigmatism does not present a convergence problem other than the dissimilar convergence waveforms required.

Anisotropic (corner) astigmatism on the other hand occurs only under simultaneous deflection by both pairs of deflection coils and is zero along the axes of the screen. This causes a distortion of a conical beam bundle in the corners only, and a resultant misconvergence which would require expensive corner-dynamic-convergence waveforms to correct. The 19-inch 90° color receiver and other commercially available color receivers are converged with on-axis dynamic waveforms only, which requires that the yoke field be such that the anisotropic astigmatism be negligible.

While astigmatism distorts a conical bundle of electron beams into a pattern which retains symmetry about axes parallel and perpendicular to the direction of deflection, another characteristic of the deflection field called *coma* distorts the beam bundle such that it no longer has symmetry about an axis perpendicular to the direction of deflection. Coma, which is generally a triangular distortion of a conical beam bundle, is *isotropic*—i.e. its effect in the corners is the linear combination of the effects on the adjacent axes. The orientation of the three guns relative to the direction of the deflection, causes coma to have a different effect along the horizontal and vertical axes. In the horizontal coils, coma results in a lateral displacement between the blue beam and the converged red and green beams, and therefore a wide or narrow blue raster dependent upon the polarity of the coma. The 19-inch 90° yoke flux distribution is designed so that there is no coma distortion in the horizontal coils and the raster converges without requiring dynamic blue lateral convergence. Coma in the vertical coils causes an unbalance in the dynamic convergence waveforms required top to bottom but does not alter the final overall convergence once the proper on-axis radial convergence waveforms are applied.

Each set of TV yoke coils has a deflection center defined as the intersection of the undeflected beam and the asymptote to the deflected beam (Fig. 5). In shadow mask color TV systems, it is necessary to position the yoke axially on the tube neck to align the deflection centers of the yoke with the tube color centers used in printing the phosphor dots. Misalignment of the yoke deflection centers and the tube color centers causes a misregister between the beams and the phosphor dots in a radial direction. The relative positions of the horizontal and vertical deflection centers may be adjusted by the physical placement of the coils, by frequency selective shunts (which differentiate between the horizontal and vertical deflection frequencies), or by the flux distribution of the coils. The relative location of the deflection centers should be coincident, or properly placed dependent on the printing of the tube phosphor dots, so that optimum purity along both the horizontal and vertical screen axes occurs for the same axial position of the yoke. In the 19-inch 90° color yoke, coincidence of horizontal and vertical deflection centers is achieved by the proper design of deflection field distribution.

FLUX FIELD MEASUREMENTS

In addition to the observation of the yoke performance on the picture tube, an analysis can be made of the yoke electromagnetic field distribution itself. The deflection fields of both sets of coils are symmetrical about both horizontal and vertical axes and can be defined to a third order approximation by two measurable functions.[1] These functions are the intensity of the main deflecting field along the axis of the yoke (H_1) and the component of the field perpendicular to this measured at some distance off both axes (H_2). Both of these are functions of the axial position along the yoke and can be measured using the equipment described in the above reference. The

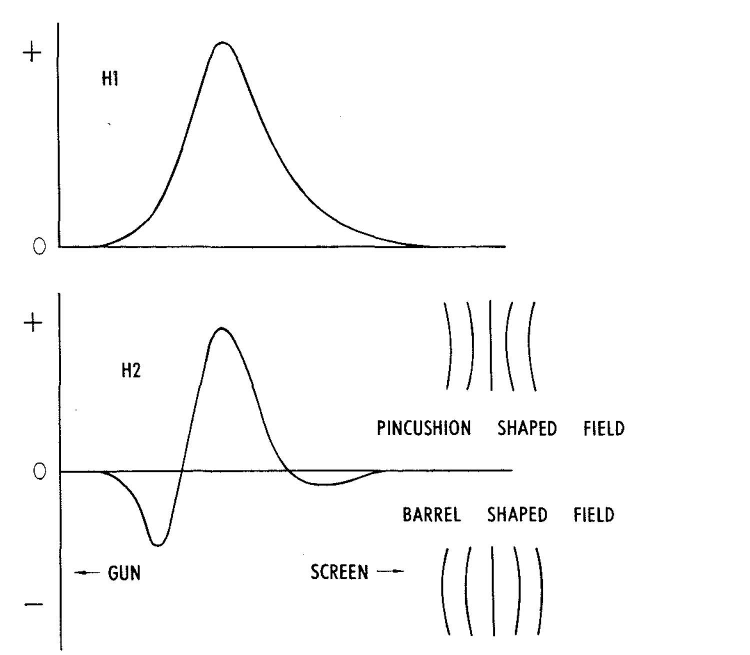


Fig. 6—Typical H_1 and H_2 flux plot of 19", 90° color coils.

H_2 function is basically a measure of the shape of the deflecting field with a field pincushion in shape giving a positive H_2 value and a barrel shaped field having a negative H_2 value (Fig. 6). A complete analysis of the flux plots which determine the numerical values of astigmatism, coma and other yoke characteristics requires the use of a digital computer. However, in general, a turns distribution change which makes the field more pincushioned in shape causes the following changes in yoke characteristics: the coma goes toward narrow blue raster, the isotropic astigmatism toward negative or a tangentially stretched spot shape, pattern distortion toward less pincushion, and the location of the deflection center moves forward.

CONTROL OF FLUX DISTRIBUTION

Saddle-type yoke coils are made with the conductor distribution, and thus the flux field determined by winding the wires into a form, or arbor, and bonding them together under heat and pressure. The shape of the arbor cavity is controlled to very close tolerances to give the proper flux distribution. The uniformity of arbor cavities, winding tension on the wire and the winding process is very critical since a constant turns density distribution from coil to coil must be maintained to get acceptable uniformity of product.

While the design of the arbor cavity which controls the mechanical locations of the wires is the primary control of the flux distribution, a new method has been devised to modify the electromagnetic field without changing the coil shape. This is done by winding the coil multifilar and pulling taps at specified points in the winding. In sections of the winding, where it is desired that their contributions to the flux pattern be increased, the strands are connected series aiding rather than in parallel. A schematic of a bifilar winding with a tap near the start of the winding is shown in Fig. 7. With the two wires in the start-to-tap section of the winding connected series aiding, the ampere turns from that section relative to the rest of the coil is twice what it would have been had these strands been connected in parallel. In the 19-inch 90° color yoke there is a series aiding section near the start of the horizontal windings and near the finish of the vertical windings. The location and magnitude of these sections were carefully chosen to optimize yoke performance on the 19-inch color picture tube.

CONVERGENCE TEST

All RCA color yokes are 100% tested for proper convergence. These tests are made on a crosshatch video pattern consisting of white horizontal and vertical bars on a black background. The misconvergence at a point is measured as the horizontal distance between the centers of the vertical bars of any two colors (vertical bar misconvergence) and the vertical distance between the centers of the horizontal bars of any two colors (horizontal bar misconvergence). The approximate spacing of the phosphor dots on an RCA developmental 19-inch color tube is shown in Fig. 8. The misconvergence between two colors is measured by counting the number of dots between the centers of the lines and multiplying by the appropriate spacing factor (Fig. 8). The convergence specifications on the 19-inch 90° color yoke require that, with the center of the screen and adjacent axes properly converged, the horizontal or vertical misconvergence between any two colors in the corners be no more than 0.055 inch on a calibrated RCA 19-inch picture tube.

BLUE LATERAL ADJUSTMENT

In addition to the static and dynamic convergence waveforms, which are similar to those used in the 70° color receivers, the 19-inch 90° color system has two additional adjustments for better control of the horizontal position of the blue raster relative to the red and green. A small rotation of the convergence pole piece assembly around the tube neck will move the blue raster horizontally in the direction that the top of the convergence assembly was moved. This action is zero in the center of the screen and increases with distance from the center in any direction. The proper rotation of this will either adjust the blue beam

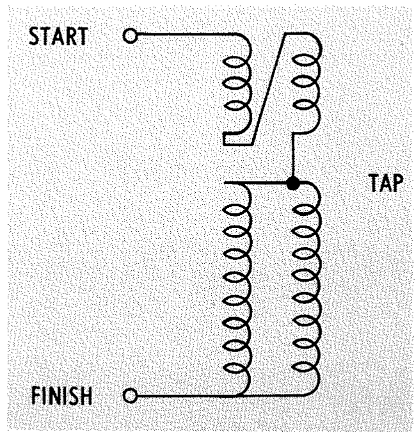


Fig. 7—Schematic of a horizontal coil for an RCA 19", 90° color yoke.

to converge with the red and green, or to be equally wide or narrow on each side. To control minor variations in the width of the blue raster, a screw adjustment is incorporated in the yoke mount which raises or lowers the back of the yoke with respect to the tube neck. If the back end of the yoke is raised, the width of blue raster gets narrower relative to the red and green. These additional adjustments will correct variations in the horizontal position of the blue beam due to normal production variations in the picture tube and yoke.

PURITY RING

The setup adjustments to obtain the best purity and white uniformity are the adjustment of the purity ring located in back of the blue lateral device and the axial position of the yoke on the tube neck. The method of setup is similar to that of the 70° color system.

BIBLIOGRAPHY

1. L. J. Bazin, "A Technique for Measuring Symmetrical Magnetic Fields," RCA Engineer, 6-5, Feb.-Mar. 1961.

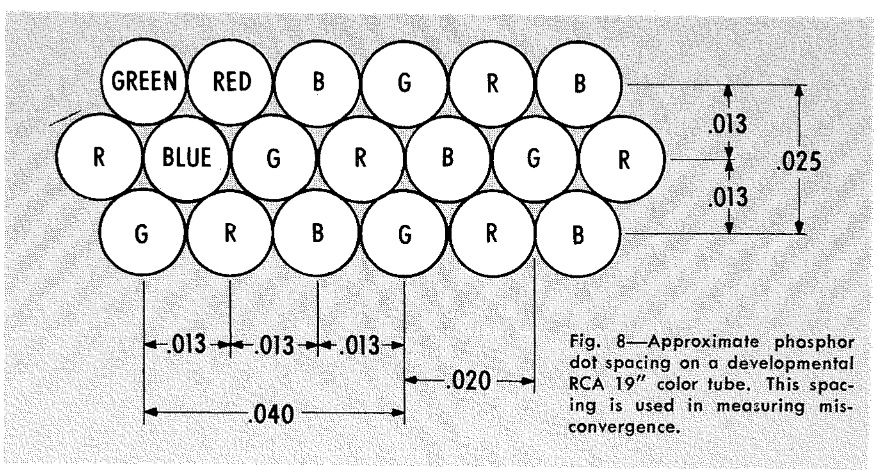


Fig. 8—Approximate phosphor dot spacing on a developmental RCA 19" color tube. This spacing is used in measuring misconvergence.

IMPROVED MANUFACTURING TECHNIQUES FOR RCA MONOCHROME PICTURE TUBES

The RCA reputation for quality in its monochrome television picture tubes results largely from continually refined and improved manufacturing. Such improvements, specifically in environmental control and ultrasonic cleaning techniques, have been incorporated in the manufacture of electron guns at the ECD Marion plant since August 1960, thus increasing high-voltage stability by about 6 kV, and greatly reduced arcing, stray emission, neck fluorescence, and interelectrode shorts and leakages. This paper describes the "total clean" concept, and its use in the manufacture of electron guns.

J. C. HALBROOK
Television Picture Tube Division
ECD, Marion, Indiana

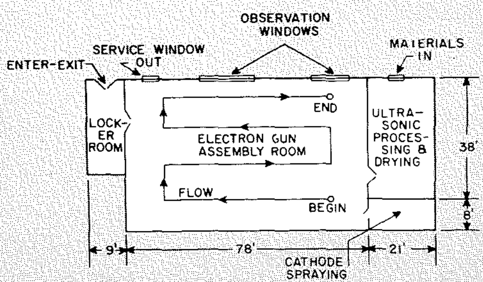


Fig. 1—Floor plan of environmentally controlled area.

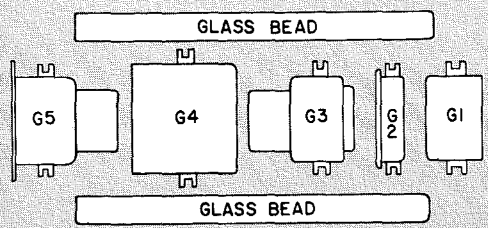


Fig. 2—Beaded assembly.

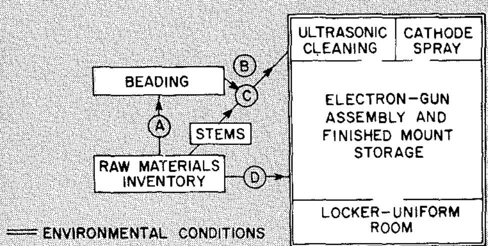


Fig. 3—Material flow routes.

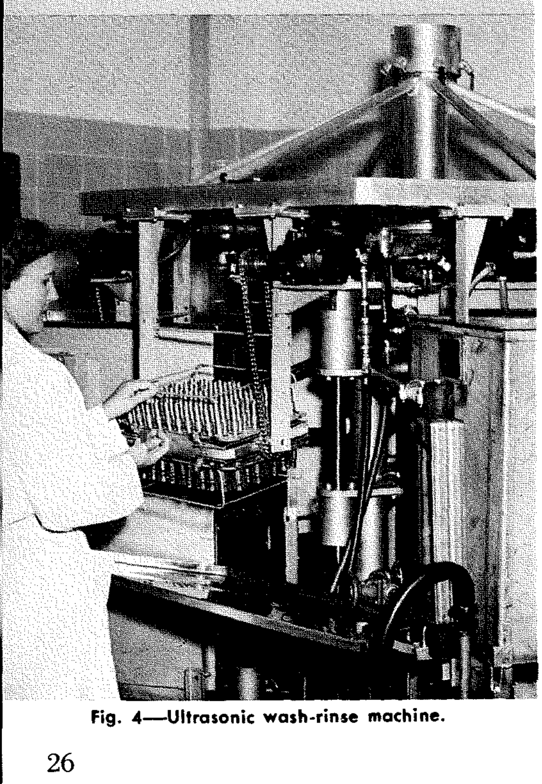


Fig. 4—Ultrasonic wash-rinse machine.

An electron gun, no matter how well designed, will not provide high-voltage stability, freedom from interelectrode leakage, nor required emission performance if the electrode surfaces are contaminated. Contaminants on the closely spaced electrodes used in modern precision electron guns can best be minimized by environmentally controlled manufacturing conditions. With this requirement in mind, detailed studies were made at the Marion plant of manufacturing physical and architectural factors, materials, and process flow; improvements desired in existing equipment; and anticipated new equipment and processes.

The result of these surveys indicated the need for a new addition adjacent to the existing facilities. As shown in Fig. 1, the floor space of the new addition which is totally enclosed and environmentally controlled is divided into areas for ultrasonic cleaning, drying and storage and facilities for spray-drying of emissive coatings, final gun-fabrication, uniform change, and storage.

The improvements achieved by this controlled, newly designed environment area have been augmented by the elimination of the exposure of raw materials, in-process components and assemblies, and sprayed cathodes and improvements in the handling and storage of finished quality-approved electron guns.

MATERIAL-FLOW CONCEPT

All possible preassembly operations (such as beading and stem making) are performed outside of the controlled area. Fig. 2 shows an exploded view of a beaded-cage assembly. During beading, all electrodes, except the cathode assembly, are assembled on the supporting glass beads; the grid-No. 1 cup is put in place for cathode insertion by a novel precision device described later.

Fig. 3 shows the material and processing flow routes. All incoming raw materials are received at a central supply point located outside the controlled area. Gun electrodes and beading glass are supplied directly to the beading operation *A*; other components, such as ceramics, bulb spacers, and grid-connector tabs, follow a route *C* directly to the ultrasonic room; the stems are formed, trimmed, and sublimation-shield eyelets are assembled in route. Getters, precleaned by vacuum immediately outside the controlled area, and filaments follow route *D*.

ULTRASONIC CLEANING PROCESSES

The advantage of the process to be described lies in the fact that the entire gun-grid structure, without the cathode, can be thoroughly ultrasonically cleaned and rinsed. Conventionally constructed electron guns cannot be cleaned by this process because the cathode (which is assembled in the grid No. 1 cup prior to beading) would be severely damaged by the microcleaning process.

The equipment for processing the assemblies through the ultrasonic wash and rinse cycles was designed at Marion. Fig. 4 shows an operator loading a rack of cage assemblies in the loading position. The control cabinet is at the left; the final water-rinse tank is on the right.

The ultrasonic washing machine has six heads which index in unison, horizontally, in a clockwise direction. The basic operating cycle of the ultrasonic washing machine which is shown in Fig. 5 include the following steps:

1) Operator loads and subsequently unloads machine at position *1*.

Final manuscript received February 16, 1965.

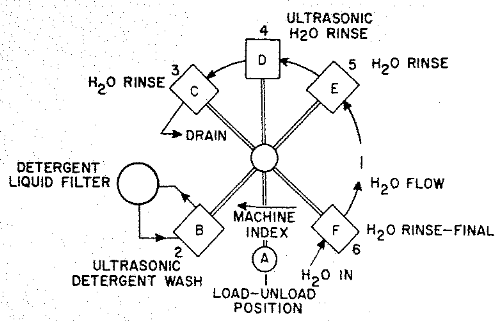


Fig. 5—Ultrasonic washing machine function.

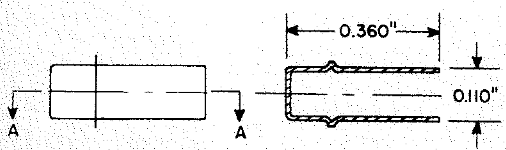


Fig. 6—Cathode sleeve.

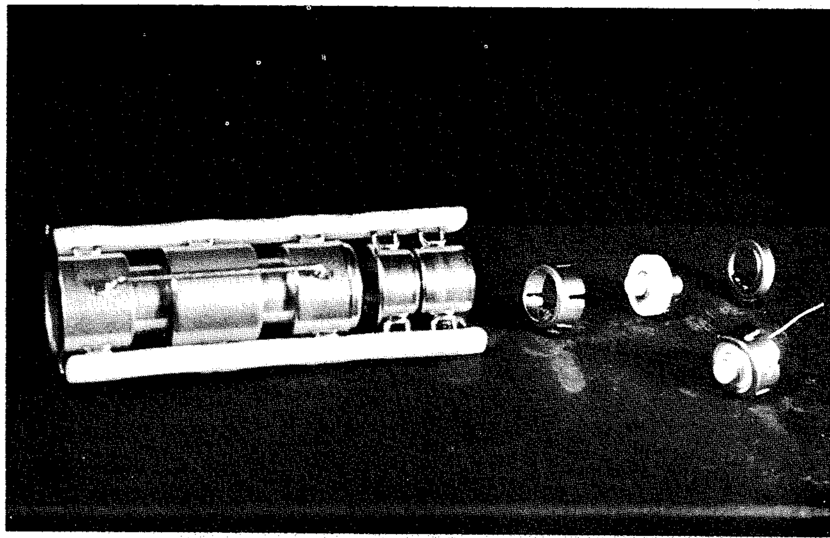


Fig. 7—Beaded cage assembly with annular ring.

2) Machine indexes clockwise horizontally, then lowers load into the ultrasonic detergent wash, position *2*. Each head (*B* through *F*) simultaneously is lowered into the respective tank. The loads revolve at 3 to 5 rotations per minute while submersed.
3) Upon completion of the ultrasonic detergent washing for the preset period, one minute for beaded-cage assemblies, the load is elevated and allowed to drain briefly while being rotated. It is then moved to position *3* for the first of four submersed rinsings in 60°C water.
4) Position *4* is an ultrasonic rinse position.
5) The load continues through positions *5* and *6* for final rinsings and then back to position *1* for unloading. It is then placed in drying ovens for 1½ hours at 160°C. Air flow through the ovens is 100 ft^3/min.

Components such as retaining rings and annular rings are also processed on the machine. In addition, all glass stems are cleaned ultrasonically in a 2.5-kW ultrasonic unit. Stems are loaded in stainless-steel baskets prior to delivery to the ultrasonic cleaning room. The grid construction of the basket provides each stem with a maximum exposure to ultrasonic cleaning, yet prevents stem-to-stem contact which would cause chipping and breakage. After drying, they are placed in covered racks and cooled to room temperature. Stems are stored in these racks inside the enclosures and delivered, as required, to the mount-assembly area in the racks.

The most difficult parts to cleanse and rinse effectively are the small nickel cathode sleeves of the type shown in Fig. 6.

This closed-end cylindrical sleeve is drawn from a 0.004-inch nickel-alloy strip. The shape and size of this part complicates the process requirements for thorough particle removal and adequate rinsing of the inside surfaces of the sleeve.

Formerly, the sleeve was processed through trichloroethylene degreasing, washed, and dried. Prior to spraying with the oxide cathode coating, the sleeves were air fired, followed by hydrogen firing, and then sprayed. This process did little to remove microscopic particles inside the sleeve.

An improved cathode-cleaning process, which uses an acid etch and ultrasonic cleaning operation, has been developed. The acid etching creates a desirable surface roughness on the cap surface of the cathode sleeve which enhances the emission-coating adherence and improves the emission capabilities of the oxide coating by removing contaminants tightly adhered to the metal-cap surface. It is important, that all traces of the acid be removed from the metal-sleeve surfaces.

For thorough particle removal and satisfactory rinsing of the residual acid from large batches (12,500) of sleeves, the following process has been developed:

1) Sleeves are etched with hot acid, the acid is drained off, and the part is rough rinsed with demineralized water.
2) Because of the closed-end shape of the sleeve, effective ultrasonic cleaning and thorough rinsing of the internal sleeve surfaces require the evacuation of air trapped inside the sleeves while the sleeves are submersed in demineralized water.
3) The sleeves are then transferred to a stainless-steel mesh basket and submersed in the ultrasonic transducer tank.
4) Upon completion of the ultrasonic processing, the sleeves are transferred to a stainless-steel drying basket and dried at 160°C for 8 hours. The dried sleeves are allowed to cool to room temperature while under cover and then are transferred into closed glass containers for delivery to the hydrogen-firing operation prior to the cathode-spray operation.

MOUNT ASSEMBLY

The gun assembly area receives the flow of beaded-cage assemblies and component parts directly from the cleaned-parts storage inventory. The sprayed cathode sleeves are delivered from the environmentally controlled spray room into the gun assembly area. The following sequence of operations is performed in the gun assembly area. The cathode sleeve is crimped into the ceramic; and the annular ring assembly consisting of the annular ring, crimped cathode-ceramic, and the retainer ring is prepared. Fig. 7 shows an "in-line" view of these parts.

Also shown is a beaded-cage assembly ready to have the annular ring-cathode subassembly inserted into the grid No. 1 cup. A novel precision grid No. 1 cathode spacing technique is used to determine initially and establish permanently the spacing between grid No. 1 and the cathode. This spacing is directly related to the cut-off voltage characteristics of the gun and, as such, is of vital importance in establishing proper modulation, light output, and transfer characteristics of the picture tube.

The assembly as originally developed consisted of four components: the unbeaded grid No. 1 cup, a spacer used to establish the spacing between the cathode cap and the grid-No. 1 aperture, the cathode-ceramic assembly, and a retaining ring used to hold the cathode ceramic tightly against the spacer. Fig. 8 shows these formerly used parts.

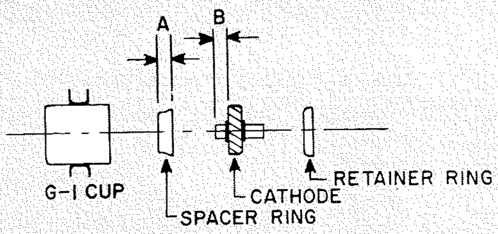


Fig. 8—Conventional grid-cathode construction.

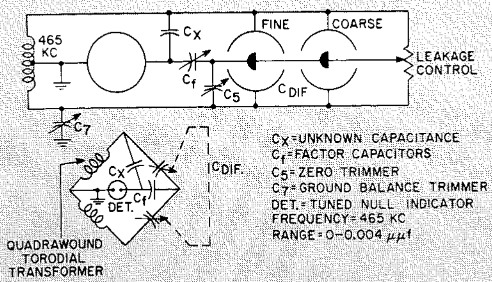


Fig. 9—Capacitance bridge circuit.

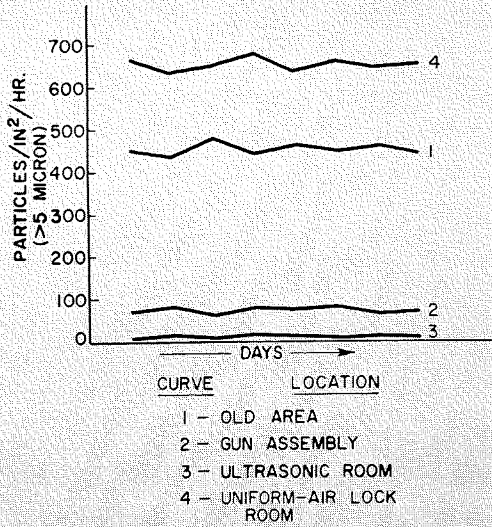


Fig. 10—Comparative level of particle contamination.

The accuracy of control for spacing between the cathode and grid No. 1 depended in large measure on the mechanical selection of spacer rings of the proper height (dimension *A*) and the matching of these rings with selected cathodes having compatible dimensions (dimension *B*). Once this assembly was fabricated, it had to be electrically checked to insure that the spacing was within specifications. The precision spacing technique now in use eliminates the uncertainty of the former process and has the following important advantages:

1) It eliminates time-consuming manual sizing and matching of spacers to cathode; the spacers are no longer required.
2) It eliminates the electrical-space checking operation as a separate operation.
3) It pemits the assembling of the entire beaded-gun structure including the grid No. 1 cup prior to inserting the cathode. This technique permits the use of ultrasonic cleaning.
4) It provides a much more reliable control in establishing and maintaining the desired spacing and cutoff-voltage specifications.

This technique uses a sensitive bridge circuit capable of measuring very small values of interelectrode capacitances. With this technique, the spacing between the cathode and grid No. 1 is determined as a function of the capacitance between the cathode and grid No. 2. The circuit is so designed that it measures the small direct capacitance by using larger commercially available capacitors. The circuit also eliminates the effects of lead-to-ground capacitance. The complete measuring apparatus consists of an oscillator power source, a bridge, and a detector. A simplified schematic of the bridge is shown in Fig. 9.

TABLE I—Product Improvement

Category	Per Cent Reduction
Gross rejects at finished-mount inspection	41.2
Gross leakage rejects at final tube testing	68.5
Gross emission rejects at final tube testing	46.3
Gross cathode to grid No. 1 cutoff rejects at final tube testing	59.5

PARTICULATE CONTAMINATION—CONTROLS

Fig. 10 shows a comparison of the dust levels of the former location and the present location.

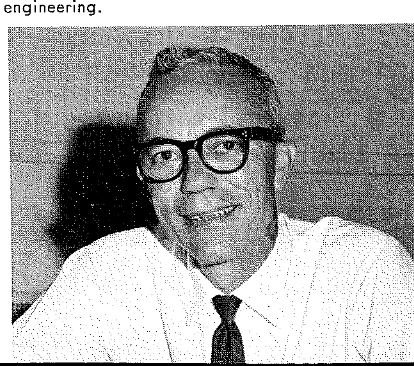
Particulate contamination levels are monitored by means of a Royco Counter. This counter provides a numerical readout on tapes for the various particle size ranges desired. Each monitoring readily indicates the out-of-control periods that may deviate from the desired normal operating level of the room ambient. The effective control of dust level requires constant supervision, trained personnel, effective sanitation services, a planned maintenance program for the air-conditioning system, and strict controls which permit only authorized personnel access to the areas.

CONCLUSIONS

Table I shows the present product improvement achieved by the program. As shown, ultrasonic cleaning, environmental control of manufacturing conditions, and a precision assembly technique for controlling the cutoff-voltage characteristic have resulted in electron guns and picture tubes of improved quality and reliability. These improvements are significant to both the television-equipment manufacturer and the consumer for the following reasons:

1) The increased threshold of high-voltage stability, which has been improved by about 6 kV, offers increased protection against circuit-component damage and filament burnout resulting from internal arcing of the picture-tube gun.
2) Reduction of leakage currents between the gun elements and improvement in control of cutoff and drive characteristics further assure operational circuit stability and impove the uniformity of focus, brightness, and contrast.
3) Elimination of particle contamination in the electron gun protects the sensitive emission coating on the cathode from the poisoning which results in decreased picture-tube emission life.

JACK C. HALBROOK received his BE in ChE from Vanderbilt University. He twice won the Wall Scholarship for scholastic achievement in the engineering school. From 1940 to 1945 he was employed by Jos. E. Seagram Corp. Ltd. in Production Administration. He developed and put into use what was, at that time, a new concept of programmed and coded equipment lubrication scheduling, with significant cost reductions. From 1945 to 1953, he was with Victor Chemical Works in research and plant management. Since 1953 he has been with RCA in Marion, Ind., where he has been a General Foreman, and a Process Engineer, Physics Group, C&P Laboratory. He has specialized in electron gun and component parts cleaning and processing, cathode cleaning and processing (sleeves), cathode temperature studies, and environmental control parameter studies. He developed the process and parameters described in this article and supervised introduction into the factory. He presented this article before the International IEEE Meeting in New York. He has taken several courses of study in electronics and holds an FCC 1st radio telephone license, and has experience in AM-FM-TV transmitter and studio engineering.



PARALLEL OPERATION OF A 50-KW TELEVISION TRANSMITTER

Described herein is the system of transmitter operation employing identical parallel circuitry in each leg. Design advantages and the design theory underlying the transmitter system are described; included are discussions of the exciter, transmitter, video line stretcher, diplexers, aural and visual power splitters, monitoring and phasing equipment. System performance features improved linearity.

R. E. WINN
Antenna Engineering
Broadcast and Communications Products Div.
Gibbsboro, N. J.

In 1964, television Station *WNAC*, located in Boston, Mass., became the first station in the United States to officially broadcast using parallel-operated transmitters. This system of transmitter operation, pioneered in the United States by RCA, represents a new concept in broadcast system design and operation.

ADVANTAGES OF PARALLEL SYSTEM

The basic advantage of the parallel system lies in the fact that if either transmitter fails, the remaining transmitter is unaffected, and because of the combining scheme used, a 6-dB fall-off in radiated power (half field strength) takes place. As a result, the viewer will probably notice no change in the aural reception. Close-in viewers will notice no change in picture quality, while distant viewers may lose some quality due to less contrast and resolution.

In a parallel system, employing identical units in each parallel leg, the mean time between failure for the system will be improved by a factor of 1.5 over the single system.[1] The *WNAC* System is comprised of a series-parallel combination. The series leg consists of the audio and video input equipment preceding the paralleled transmitters, and the filterplexer following the paralleled transmitters. The input equipment can be bypassed by patch lines in case of failure in this section and the transmitters driven directly from the studio cable. The filterplexer, although a critical item in the system, is a passive network and therefore is much less likely to fail than the transmitter. Thus, it is reasoned that the overall system reliability has been improved nearly 1.5 times.

Final manuscript received March 19, 1965.

With proper maintenance of the system, and with the 1.5 improvement factor, the off-air time should be negligible. This is evidenced by two similar parallel stations having a combined total of 30 seconds lost air time during 36 station months of operation.[2] The parallel system operating cost is lower than that of the main-and-standby system. Parallel operation eliminates having an idle transmitter used only during failures or during maintenance of the main transmitter. Inventory costs for spare tubes and components are lower since such parts are identical in both transmitters. Maintenance cost will be reduced, since this type of work can now take place during regular working hours by shutting down the transmitter half-section to be repaired.

DIFFERENCES OF THE PARALLEL SYSTEM

The system used at *WNAC* differs from previous schemes basically in two ways. Previous systems, as far as is known, phased the modulator pair at the time of installation for the best sine-squared-pulse combined output, and assumed very small phase error to occur in operation. In the *WNAC* system, continuous video phase monitoring and correction means are afforded by using a wideband differential oscilloscope as a phase detector and monitor, and a variable synthetic line-switching section for a correction device. This method allows the video phase to be monitored and corrected, as needed, during picture programs. This method has been very effective.

The second difference appears in the method of RF phase detection and correction circuits employed. This parallel transmitter system utilizes one constant-impedance line stretcher between exciter and transmitter in both the aural and visual parallel chains. By minimizing the combining diplexer reject-load power through varying the line stretcher length, the correct in-phase operation can be achieved easily.

DESIGN AND OPERATION

The design and layout of a parallel operated transmitter system can range greatly in the degree of complexity. Many variables influence the design of a good workable layout. Original cost, physical space limitations, what portions to make redundant, monitoring techniques, provisions for remote control, and automatic switching in case of failure are but a few considerations. Any one of the above factors can cause the system to grow without bounds. It is therefore up to the system designer to weigh each intricate portion on the economic scale to make certain that each additional invested dollar will be merited. Before the parallel transmitter system can be viewed as a workable system, each major part of the system should be studied and understood in order to fully comprehend the general scheme.

Exciter

Within the block marked *exciter* (Fig. 2) is contained a common aural and visual exciter with nominal outputs of five watts each. The aural chain is FM-modulated within this unit and an AFC circuit maintains the intercarrier separation of 4.5 Mc/s. Since the aural modulation takes place in the exciter, no audio phasing is necessary in this unit.

Note from Fig. 2 that no provision has been made in the exciter switching scheme to obtain visual drive from one exciter and aural drive from the other; this is because the aural-visual carrier separation is determined within the exciter. Although this separation could be maintained external to the individual exciter by additional circuitry to allow interswitching exciters, the possibility of a failure causing this mode of operation is considered very remote.

Transmitter

The *transmitter* blocks shown in Fig. 2 are made up of an aural amplifier chain and a visual amplifier and modulator chain. A simplified block diagram of the TT-25DH transmitter is shown in Fig. 3.

Video Line Stretcher

The video line stretcher used in this system is a synthetic lumped-constant line designed for a 30-Mc/s cut-off frequency. This video delay unit will produce up to 50 ns delay at 3.58 Mc/s in 10-ns steps.[3] Since most parallel transmitter systems employ two modulations with identical circuitry, equal overall video phase delays should be produced. Except for such variables as component tolerances which affect phase relationship, this assumption of equal video phase delays has been true in practice. Most previous parallel systems have corrected for video phase error by a "trial-and-error" cutting of the video feed lines to the modulators. The variable synthetic line used in the *WNAC* parallel system seems a small price to pay for the luxury of having uncomplicated initial adjustment and ease of compensating for any future video phase drift.

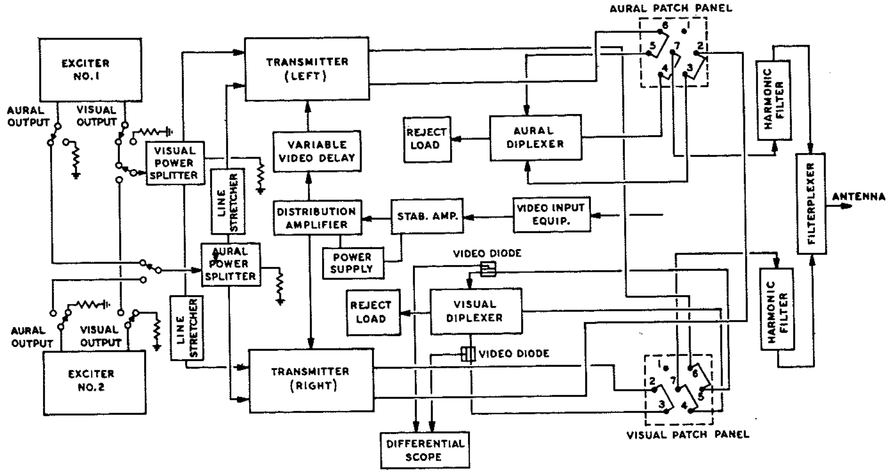


Fig. 2—Simplified block diagram of the WNAC-TV parallel transmitter system.

Diplexer

The diplexer equivalent circuit (Fig. 4) combines two like signals into a common load. Generators G_1 and G_2 correspond to the respective transmitter output signals to be combined. The inductive coupling sections shown are assumed for our purposes to be ideal networks containing no losses. The reject load corresponds to R_1 and the combined signal output appears across R_2. By writing a power flow equation we have:

$$P_{g1} = \frac{V_{g1}^2}{R_{total}} = \frac{2V_1^2}{R_{total}}$$

Or:

$$V_{g1} = V_1\sqrt{2} \qquad (1)$$

And, likewise:

$$P_{g2} = \frac{V_{g2}^2}{R_{total}} = \frac{2V_2^2}{R_{total}}$$

Or:

$$V_{g2} = V_2\sqrt{2} \qquad (2)$$

where: P_{g1} = power input at generator G_1, P_{g2} = power input at generator G_2, V_1 = induced voltage appearing in bridge from G_1, V_2 = induced voltage appearing in bridge from G_2, and R_{total} = resistance seen by generator.

The voltage V_{r1} appearing across R_1 is:

$$V_{r1} = V_1 - V_2\cos\theta - jV_2\sin\theta \quad (3)$$

And:

$$V_{r2} = V_1 + V_2\cos\theta + jV_2\sin\theta \quad (4)$$

And, the power into R_1 and R_2 can be found from Eqs. 3 and 4 to be:

$$P_{r1} = \frac{V_1^2 + V_2^2 - 2V_1V_2\cos\theta}{R_1} \quad (5)$$

And, likewise:

$$P_{r2} = \frac{V_1^2 + V_2^2 + 2V_1V_2\cos\theta}{R_2} \quad (6)$$

Since R_1 and R_2 are equal, we can drop the subscript and write the total power equation as:

$$P_{total} = P_{r1} + P_{r2}$$
$$= \frac{2}{R}(V_1^2 + V_2^2)$$
$$= \frac{2}{R}\,\frac{V_{G1} + V_{G2}^2}{4}$$
$$= P_{G1} + P_{G2}$$

The diplexer efficiency N is defined as the ratio of output power to total input power, or:

$$N = \frac{P_{r2}}{P_{total}} = \frac{\frac{1}{R}(V_1^2 + V_2^2 + 2V_1V_2\cos\theta)}{\frac{2}{R}(V_1^2 + V_2^2)}$$
$$= \frac{1}{2}\left(1 + \frac{2V_1V_2\cos\theta}{V_1^2 + V_2^2}\right) \quad (7)$$

If we now define a to be the amplitude ratio existing between V_2 and V_1, we get:

$$V_2 = aV_1$$

Or, consequently:

$$(P_2)^{1/2} = a\,(P_1)^{1/2} \quad (8)$$

Incorporating Eq. 8, Eq. 7 now reduces to,

$$N = \frac{P_{r2}}{P_{total}} = 1/2 + \left(\frac{a\cos\theta}{1 + a^2}\right) \quad (9)$$

This equation for diplexer efficiency contains terms representing the phase relationship present between the two input signals to be combined. Two curves showing diplexer efficiency can now be plotted: Fig. 5 shows efficiency as a function of input amplitude unbalance and Fig. 6 shows efficiency as a function of input phase relationship. The respective equations are:

For $\theta = 0°$:

$$N = 1/2\left(1 + \frac{2a}{1 + a^2}\right)$$

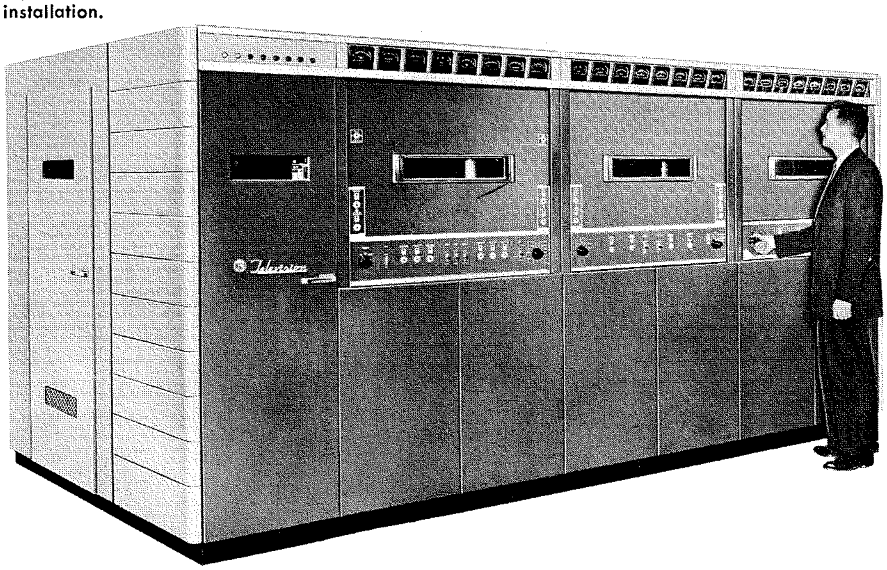
For $a = 1$:

$$N = 1/2\,(1 + \cos\theta) \quad (10)$$

Examining Fig. 5, it is found that the diplexer efficiency varies between 1.0 and 0.5 over a range of a from 0 to infinity, with the peak efficiency occurring at a = 1. Fig. 6 shows that the efficiency varies between 1.0 and zero as θ ranges from 0° to 180°, peak efficiency occurring at in-phase operation.

As stated in the introduction, the reject load at the combining diplexer holds the key to correct operation of a parallel transmitter system. The uniqueness of the reject power indica-

Fig. 1—RCA TT-25DH, 25-KW transmitter of the type used in the WNAC-TV parallel transmitter installation.



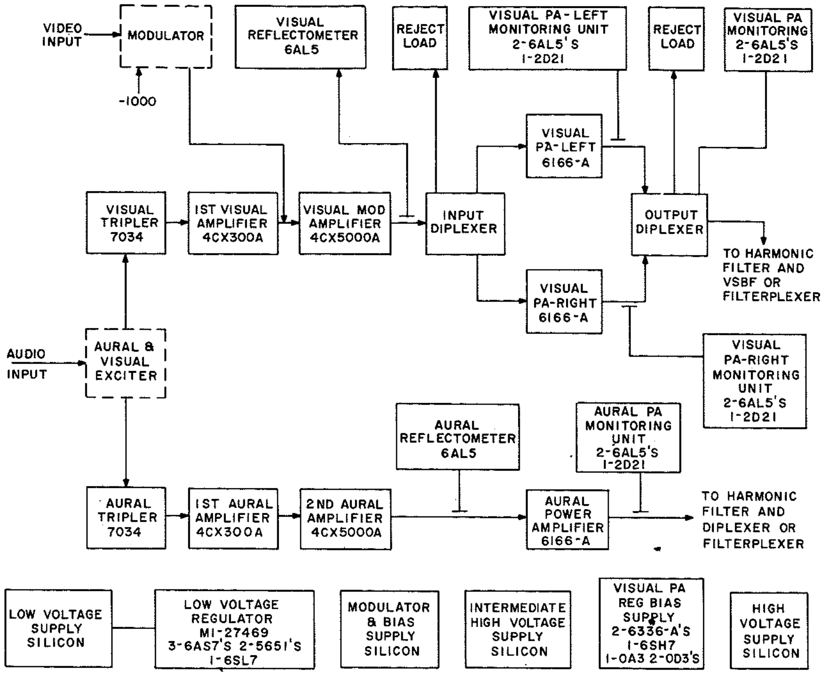


Fig. 3—Simplified block diagram of the TT-25DH 25KW transmitter.

tion can be shown from Eq. 9 by optimizing the diplexer efficiency to $N = 1$, or

$$N = 1 = 1/2 + \left(\frac{a \cos \theta}{1 + a^2}\right) \quad (11)$$

Solving for cos θ, we obtain:

$$\cos \theta = \frac{1 + a^2}{2a} \quad (12)$$

Since cos θ is bounded between ± 1, we can rewrite Eq. 12:

$$-1.0 \leq \frac{1 + a^2}{2a} \leq 1.0 \quad (13)$$

To solve Eq. 13, we will first solve the equalities and then solve for the bounds on a, therefore:

$$a^2 \pm 2a + 1 = 0 \quad (14)$$

for which $a = \pm 1$. Substituting these values of a into Eq. 11, the efficiency is unity when $a = -1$ and $\theta = 180°$, or when $a = +1$ and $\theta = 0°$. These are in effect both the same solution, hence only one set of bounds must be determined. This is done by finding the first quadrant solution where a is positive and θ lies between 0° and 90°. Thus, cos θ is positive and equal to or less than 1. Using this information in Eq. 12, and letting $a = 1 + p$, where p is any positive real quantity:

$$0 \leq \frac{1 + (1 + p)^2}{2 + 2p} \leq 1$$

$$(2 + 2p) \geq (2 + 2p + p^2) \quad (15)$$

Eq. 15 has only the solution $p = 0$. Therefore, the reject load power indication is unique in that the load receives zero power only when the two input signals are in phase and equal in amplitude. As was seen from above, either R_1 or R_2 can be used as the combined output arm of the diplexer depending upon the phase relationship of the two signals to be combined.

Aural and Visual Power Splitters

The power splitters used in this system are a coaxial ring hybrid.[4] Since the nominal power input to this circuit is only 5 watts, the physical size of the unit can be very small. This particular unit measures approximately 5 x 7 x 3 inches and contains, in total, some 120 inches of 75-ohm subminiature coaxial cable.

The schematic of the ring hybrid circuit is shown in Fig. 7. The input, port *1*, is 3/4 wavelength from port *4;* port *1* and *2*, *2* and *3*, and *3* and *4* are separated by 1/4 wavelength. The input signal first splits into two paths at port *1*. Both signals arrive at port *4* after traveling 3/4 wavelength in each path, therefore adding in phase. The signals arriving at port *3* are 1/2 wavelength apart and therefore cancel. At port *2*, the signals are again in phase and adding. Thus, if port *1* is used for the input, port *3* will be the reject load, and ports *2* and *4* will be the outputs—separated by 1/2 wavelength.

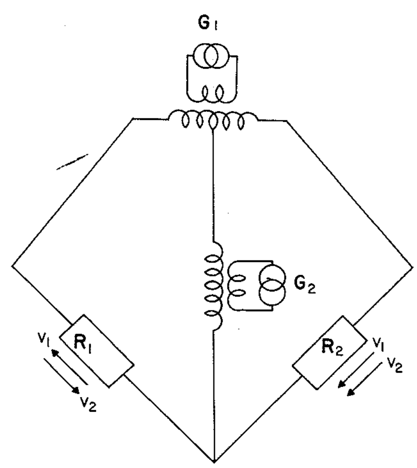


Fig. 4—Lumped circuit schematic of bridge diplexer.

As the design equation shows for the ring hybrid, the cable forming the ring should have a Z_o which is 1.41 times the external line Z_o.

Since 50-ohm cable was chosen as standard for input and output impedance, 70.5-ohm cable should be used to form the ring. However, since this cable is not readily available, 75-ohm cable was substituted with the results shown in Fig. 8.

Standing waves existing between the exciter and transmitter are usually of little consequence where broadband circuits are not involved and drive power is not at a premium. Considering this and observing Fig. 8, two ring hybrids could be built to cover the range of 40 to 90 Mc/s (RCA VHF exciter frequency range) with no worse than 1.3:1 VSWR; only two ring hybrid designs are needed to cover the entire VHF band.

Reject Load

The reject loads are used in conjunction with the combining diplexers to absorb the amplitude and phase mismatch power. Under normal circumstances the maximum fault power available at the load will be one-quarter of the normal diplexer output power; see Fig. 4. Therefore, the visual reject load for a 50-kW peak-of-sync antenna input must be rated for 12.5-kW peak or 7.45-kW average power.[5] Likewise, the aural reject load should be rated for 7.5 kW, considering a 60% sound/visual ratio.

Video Phase Monitoring

The video phase monitoring incorporated in this system is made up of two video detectors, premeasured video cable, and a two-channel differential oscilloscope. By reclaiming the video of each modulated visual transmitter an equal distance from the diplexer input, feeding these signals through like cables containing equal delay, and then into the differential oscilloscope, a continuous means of monitoring the video phase is available.

Correct video phasing can be readily detected using this method by feeding a standard video stair-step wave form containing 3.5-Mc/s burst on each step to the system input, and varying the video delay line switch for minimum

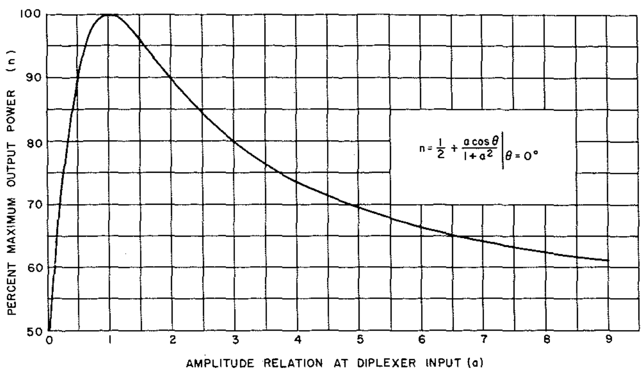


Fig. 5—Curve showing diplexer efficiency for various input voltage amplitude ratios.

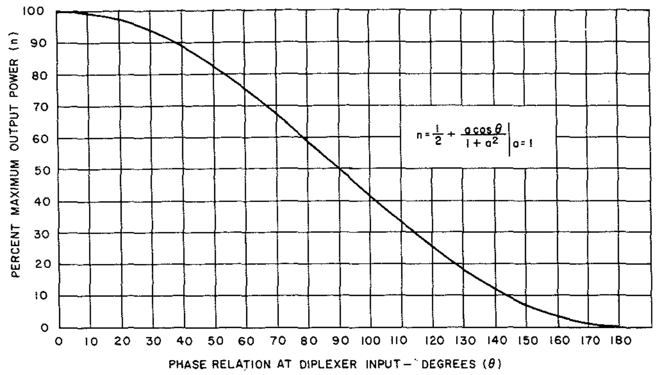


Fig. 6—Curve showing diplexer efficiency for various input voltage phase relationships.

vertical deflection as observed on the oscilloscope. Gain control adjustments on the oscilloscope are used to maintain equal inputs to both channels from the pick up diodes thus showing a true display of modulator combining phase.

RF Phasing and Amplitude Balance

To operate any paralleled transmitter system at its optimum, it is essential that the RF carriers of both transmitters to be combined are in phase and are equal in amplitude. If either phase or amplitude is unbalanced, power will be wasted in the diplexed reject load as discussed previously. To avoid this power waste, an RF phasing and amplitude control panel was designed and incorporated in the system. The panel is made up of two constant impedance line stretchers (one each for aural and visual RF chains), meters to indicate the amount of reject power, and amplitude controls to adjust power output of both aural and visual chains of each transmitter. The reject power is zero only when the transmitter outputs are in phase and equal in amplitude. By adjusting the amplitude and phasing control panels the reject power can be easily held below 150 watts.

FLOOR PLAN EXPLANATION

The floor plan, Fig. 9, shows a top view of the system, with the front of the transmitter at the bottom of the drawing.

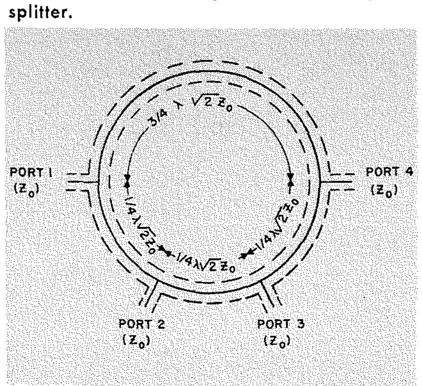
Each output from the transmitter is first fed into the manual patch panel section, where the signal can either be routed in its normal manner to the combining diplexer or, in case of failure, patched directly into the harmonic filter or test load. The patch panel section is mounted approximately 4 feet from the floor facilitating the patching operation.

The two diplexers, their reject loads and the filterplexer are all mounted near the back wall. The harmonic filters are mounted above the diplexers. At least four feet of aisle space should be left between the patch panels and transmitter to allow for test equipment entry and removal.

At the time of installation, coaxial line lengths are approximately equalized by makeup loops located between the patch panels and the lower input arm of the diplexers. To insure in-phase combining, the line lengths external to the two transmitter halves between diplexer input and power splitter output should be equal in length, the line stretcher making up slight differences in transmitter transfer phase and line cutting error.

Since the diplexer operation is independent of what has been done to the two separate signals prior to their arrival as long as they arrive in phase and equal in amplitude, the overall performance of the system can be greatly improved by taking into account the diplexer transfer characteristic. As previously shown in Fig. 6, when the input signals are in phase the signals will add at the combined output port R_2. When the input signals are 180° out of phase they will be added and transferred to the reject load. It is this feature that makes possible "ghost cancelling". This is done by driving the transmitters 90° out of phase and adding a 90° make up section in one transmitter output so that the input signals reach the diplexer in phase. Thus, the reflected wave returning down the antenna line will split at the diplexer, travel to the transmitter output stages, be reflected and return to the diplexer 180° out of phase as a result of passing the 90° makeup section twice. Consequently this energy will end up in the reject load, and no ghosting will occur. This "ghosting" advantage also can be incorporated in parallel amplifier systems using the same technique. Reports have been received on such installations where antenna icing has caused VSWR as high as 2:1 without noticeable ghosting on receivers.

Fig. 7—Schematic diagram of exciter power splitter.



CONSOLE FUNCTIONS

The transmitter console used in this system is essentially two modified RCA transmitter consoles, type TTC-5A.

The master monitor contains a picture monitor and wave form monitor used to view the video signal at various test points located in the transmitter system. These test points can be selected by pushbutton switches located on the two monitor control panels. The left-hand monitor control panel in addition to the selector buttons contains an input audio level meter, frequency monitor meter, and meters showing aural and visual power output of the left transmitter. The right-hand monitor control contains right transmitter aural and visual power output meters, and combined aural and visual power output meters, in addition to the selector buttons. Two master monitors are used so that the combined waveform can be viewed simultaneously with other system test points.

Transmitter indicator light panels are located above the monitor control panels. Lights indicating the status of each transmitter are displayed on these panels.

Below the monitor controls are the transmitter controls. These controls provide for complete operation of each transmitter from the console.

The TA-9 remote control panel controls the stabilizing amplifier and provides a common video gain control for the two modulators. The exciter control panel selects the wanted exciter and provides the common aural and visual excitation controls for the two transmitters.

The console is physically located in front of the transmitters and close

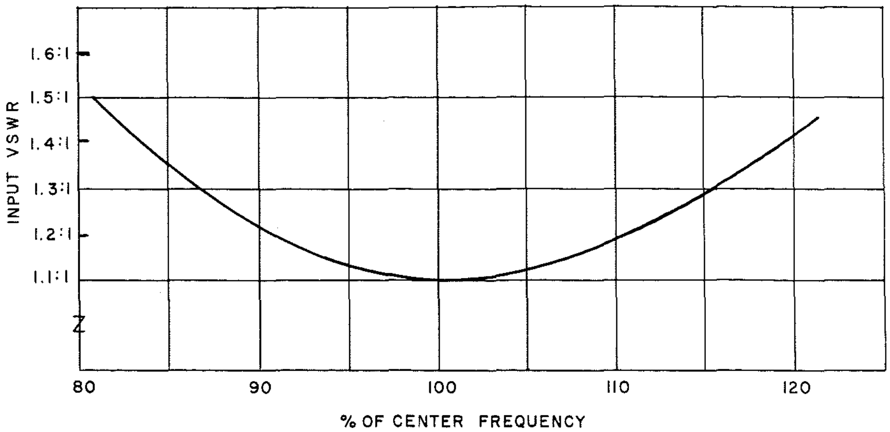


Fig. 8—Typical input VSWR values over a range of operating frequencies for the exciter power splitter.

enough so that all transmitter meters can be visually monitored from the console during operation.

PERFORMANCE

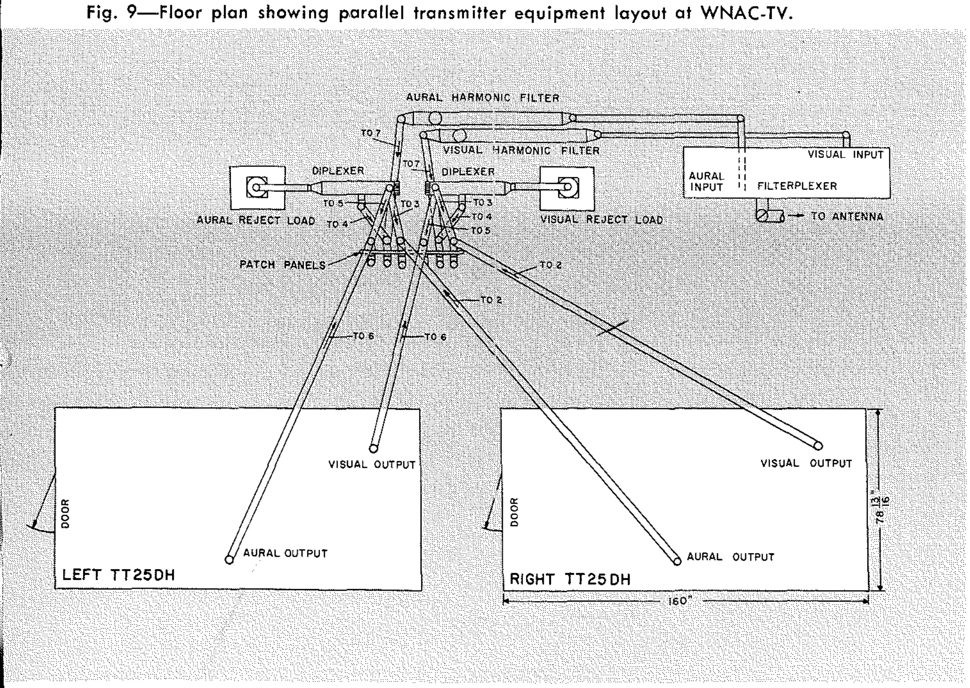
In the parallel system the amplitude response over the flat portion of the band is ± 0.25 dB as compared to approximately ± 0.3 dB for the single transmitter. Likewise the differential gain improvement is 0.4 dB compared to slightly greater than 0.4 dB for the single system.

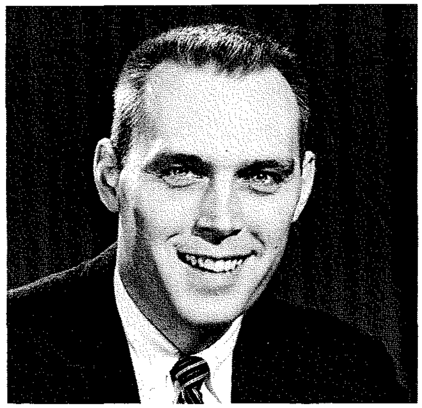
These two improvements suggest that the transfer characteristic obtained by paralleling is more linear than that of either individual transmitter. This is due to the supposition that irregularities occurring in one transmitter transfer characteristic do not occur at the same instant in the other; thus, an averaging of the two takes place.[2]

The amplitude and frequency response of this system was measured using a sideband response analyzer. This method, when used to compare system performance as was done here, has proved to be less conclusive than impulse test data. By comparing the recorded sine-squared pulse responses of the two systems, a more evident improvement is noted. Overshoots occurring during square wave modulation have also been shown to be reduced from ± 10% to 5%.[2]

The system has been installed and at the present time is being used to transmit Channel 7 programs to the Boston area. With the exception of the normal minor problems during installation the system has functioned well and the station personnel associated with the system are very pleased with the performance.

Fig. 9—Floor plan showing parallel transmitter equipment layout at WNAC-TV.





ROBERT E. WINN graduated from the University of Missouri with a BSEE degree in 1957 and that year joined the Broadcast Transmitter Engineering Group in Camden. Through the RCA Graduate Study Program he received an MSEE degree from the University of Pennsylvania in 1964. Design activities while he was with the Transmitter Group include work on FM, VHF and UHF television transmitters, UHF cavity design, and automatic switching systems. Since 1964 he has been with the Broadcast Transmitter-Antenna Systems Group located in Gibbsboro, New Jersey. Mr. Winn is a member of Eta Kappa Nu.

BIBLIOGRAPHY

1. G. D. Weinstock, "Matrix Analysis of Reliability for One Shot Redundant Systems," *Electro-Technology,* Vol. 70, No. 5.
2. M. W. S. Barlow, "Parallel Operation of TV Transmitters," *Broadcast Engineering,* Vol. 6, No. 3 (Mar. 1964) P24-26.
3. Millman & Taub, *Pulse & Digital Circuitry,* New York, McGraw-Hill, 1956, p. 292.
4. International Telephone & Telegraph Corporation, *Reference Data for Radio Engineers,* IV (Jan. 1957), p. 634.
5. *Television Equipment Theory and Operation,* RCA, Seventh Edition, (Dec. 1953) p. C-13.
6. M. W. S. Barlow, "The Operation or High-Power Television Transmitters in Parallel," *Journal of the Society of Motion Picture and Television Engineers,* Vol. 72, No. 1, Jan. 1963.
7. G. H. Brown, W. C. Morrison, et al., "Method of Multiple Operation of Transmitter Tubes Particularly Adapted for Television Transmission in the Ultra-High-Frequency Band," *RCA Review,* Vol. X, No. 2 (June 1949), p. 161.
8. V. J. Cooper and W. J. Morcom, "Band I Television-Transmitter Design with Particular Reference to the Transmitters at Crystal Palace," *Proc. IEE,* 103 Part B. No. 11, Sept. 1956.
9. C. Gillam, "The Diplexer," *Wireless World,* Mar. 1950.
10. F. C. McLeon, A. N. Thomas and R. A. Rowden, "The Crystal Palace Television Transmitting Station," *Proc. IEE,* 103, No. 2, Summer 1962.
11. W. J. Morcom, "Unattended Broadcasting Transmitters."
12. W. J. Morcom, "The Operation of Transmitters in Parallel," *Sound & Vision,* 2: No. 1, Spring 1961.
13. W. J. Morcom and D. F. Bowers, "The Design of High- and Low-Power Medium-Frequency Broadcasting Transmitters for Automatic and Semi-Attended Systems," *IEE Paper No. 2362R,* April 1957.
14. R. T. B. Wynn and F. A. Peachey, "The Remote and Automatic Control of Semi-Attended Broadcasting Transmitters," *Proc. IEE,* 104 Part B No. 18, Nov. 1957.

NEW TRANSISTORIZED AGC AND GAMMA CONTROL AMPLIFIERS FOR TV BROADCAST

Two experimental amplifier systems are described that when preceded by an automatic-black-level setting system, produce a form of automatic video control. (The complete video control system description is not within the scope of this paper.) The two amplifiers operate on noncomposite signals. Black picture information should approach a zero level with no setup, meaning that the raw camera signal should be clamped and clipped to black picture information before entering these amplifiers.

V. J. DUKE

National Broadcasting Company, Inc., New York, N.Y.

VERNON J. DUKE received a BSEE in 1928 from the University of Colorado. He entered the student engineering course of the General Electric Company where he was associated with some of the early television efforts using the lens disc and photo cell pickup equipment. In 1929 he joined NBC at radio station KOA in Denver. While at KOA he assisted in the installation and operation of one of the early 50-KW radio transmitters. In 1937 he transferred to the NBC Laboratory in New York for work on the then emerging electronic television system. During the war he was associated with several RCA projects involving radar and television. Since the war he has been with the NBC Laboratory, and has concentrated on color film for television both in recording and transmission. He has presented many patent disclosures, of which fifteen have resulted in granted patents.

In television broadcasting the AGC amplifier controls the peak level of a video signal within the framework of its built-in characteristics. In film and slide operation, sudden changes in average density occur without warning; thus, automatic control is inherently better than manual.

AGC AMPLIFIER

The input amplifier with its level control (Fig. 1) supplies a very low-impedance signal to an essentially resistive *L* pad with an automatically variable shunt element. The input to this pad has the variations inherent in the input signal while the output of the pad has practically no level variation.

The variable *L* pad shown in Fig. 2 consists essentially of a series element $(R + r)$ and a shunt element R_v. All of the input level variations Δe are at e; and no variations are assumed at e^1. The detector takes off at point e^{11} and around 4% of the input level variations exist at the point e^{11}. This method requires less gain and gives the detector control amplifier advantages over sampling only the output signal.

The control system causes the raysistor to vary over a range of about 40 to 1 and in so doing easily produces a control range of input signal of 6 to 1.

In this system, the value of R_v has been held to a range of 4,000 to 100 ohms. In general, most operation of R_v would be within 2,000 to 600 ohms.

Referring to Fig. 3, the control signal from the *L* pad is fed to transistor *5* where it is inverted and slightly high-peaked. Transistor *6* with no signal is well below cut-off. The DC restorer in the base of *6* allows about 20% of full level signals to go into the operating region. The detector system between transistors *6* and *7* supplies a peak to peak rectified signal to transistor *7*, which is DC-coupled to transistor *8*. The control filament of the raysistor is in the collector of transistor *8*. The resistor R_s places a minimum voltage of roughly 3.5 volts on the raysistor filament. As the signal level increases, transistor *8* comes into operation and the voltage on the control of the raysistor may go as high as 15 volts.

As can be deduced, a zero signal allows for 3.5 volts on the raysistor at which condition the signal electrode of the raysistor R_v raises to around 4,000 ohms. The raysistor remains at this value until sufficient signal arrives to operate the detector system.

Operating characteristics of the AGC amplifier are shown in Fig. 4; the dashed line shows what would happen if no automatic control existed. The solid line indicates the automatic control effect. In setting up the system a test pattern or other signal of representative input level is fed to the amplifier. Starting at a minimum position, the input level knob is raised until a threshold is reached at about 0.12 volt (peak-to-peak) at the test point. The meter just starts to rise from a minimum of 3.5 volts. The level is further increased perhaps to 0.25 volt (PP) with a meter reading of 6 volts. If the input control is left at this point the knee will be down 6 dB. If the input control is raised to around 0.37 volt (PP) the knee is then down 9 dB.

As in any system of this kind, it does not pay to control signals that are more than perhaps 9 dB down from normal as they may be close to noise and fade-outs become very abrupt. The amplifier holds down abnormally high signals.

The amplifier will, upon switching in a signal 6 dB above the knee, bring that signal to normal level within two television fields. Any faster control would probably result in some picture distortion. Normal title printing is sufficient to control the level. Only the finest glints go over level.

The control cycle of the amplifier at slow scan on the oscilloscope is shown in Fig. 5a; each division is one field. A step signal was used and the level was 6 dB above threshold and suddenly applied. As shown, the signal returned to normal output level in less than two fields with a slight undershoot. The control cycle with a window signal suddenly applied at around 9 dB above threshold is shown in Fig. 5b.

To use this AGC amplifier with modulated color signals, the detector should have a demodulator and nonadditive mixer between it and the signal source. The input level to this amplifier should be at least 0.3 volt (PP) noncomposite at 75 ohms.

The AGC amplifier output may be independently adjusted to a level of 0.5 to 1.0 volt (PP) at 75 ohms. The black level during the control cycle can be held flat either by a DC inserter or clamp circuit in the processing amplifier. The 117-volt AC power input is around 4 watts.

GAMMA AMPLIFIER

The gamma amplifier is used to control the transfer characteristic of the video signal. Prior to entering this amplifier, the black level and white level of the signal have been effectively controlled either by manual or automatic means.

The gamma amplifier has several features and methods not normally used in this type of system. One feature of this amplifier is a knee characteristic. Many amplifier systems use a white clipper to effectively chop off any signal above a fixed level. In this amplifier, the transfer slope is reduced by 4 to 1 above the knee. The knee characteristic may be used with vidicon cameras to attain somewhat the same effect as when operating an image orthicon above the

Final manuscript received June 4, 1965.

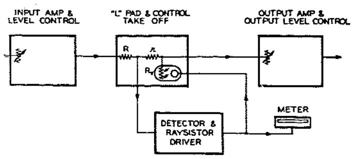


Fig. 1—AGC amplifier.

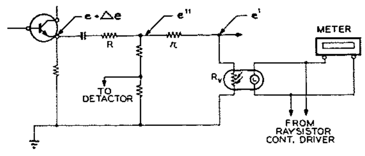


Fig. 2—Variable "L" pad.

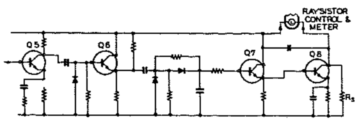


Fig. 3—AGC amplifier detector system showing raysistor control.

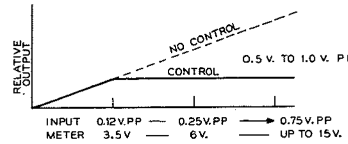


Fig. 4—AGC amplifier operating sketch showing "control" and "no control" conditions.

knee. When operating this amplifier following the AGC amplifier, it is well to operate just at the knee; then, glint spikes and sudden momentary overshoots will be suppressed.

The gamma section of this amplifier has several features: Video signals are generated, rather generally speaking, on a full bandwidth and standard rise-time characteristic that does not take into account various factors which have previously affected the general contrast range of the material. For instance, optical flare may dilute the black-end contrast, resulting in a compression of black material after the black-level setting; or, perhaps in film, the gamma and contrast of the original material needs to be processed to perhaps compress the white end.

In the case of stretching the black part to normal, the signal-to-noise may deteriorate; or, in compressing the white the detail seems to lose out rapidly. One reason these things happen is that the high-frequency components have been greatly affected during the stretching or compressing process. In this amplifier, the high-frequency components are not changed as rapidly as the general large-area signals.

As the black end is stretched in an ordinary gamma amplifier and the signal checked on an oscilloscope, the rate of rise in centimeters per microsecond becomes more steep. Inasmuch as the overall signal level has not increased, it must be presumed that the effect was an increase in the high-frequency response. At the same time, the effective fine-grain noise had increased in the black part of the signal—indicating a similar high-frequency gain which limits the effectiveness of black stretching.

The reverse situation exists when the white end of the signal is compressed in gamma lowering. How much of this compression may be used is partially controlled by a loss of detail. As gamma is lowered, the average brightness rises and detail which the ordinary gamma amplifier reduces is further obscured—resulting in a washed-out situation. This amplifier does not reduce the high-frequency signals as the gamma is lowered. If the upper part of the signal was almost completely flattened off, there would still be enough detail information for a useful picture.

To accomplish these objectives, a different approach was made to the gamma-control problem (Fig. 6). An unprocessed signal goes right past the gamma-control system and loads into rather low-value resistors R and R through series isolating resistors r. The r resistors are all different in value and are selected to maintain nearly equal peak-to-peak levels on the ends of the potentiometer as the white signal is stretched or compressed.

The gamma adder signals are positive and negative for white stretch and compress, and positive for black stretch—and have been rolled off in frequency response. There may be around 10% at 3.5 Mc/s.

When the r values are adjusted for, say, a stretch condition or compression condition of the top 40% to 50% of the signal, the peak level at the ends of the potentiometer are equal and the transfer characteristic may be swept from white compression to white stretch without changing the output level or differential frequency response at high frequencies. For black stretch, the signal goes to both ends of the potentiometer and consequently also leaves one free to swing the potentiometer without peak change or high-frequency change.

Figs. 7 and 8 show:

1) The separation of a portion of the low-frequency part of the waveform from the input signal, which in this case is modulated steps (Fig. 7). The a and b clipper levels are single-knob operated, and the $a + b$ signal is added back to a portion of the input signal to stretch the white end or subtracted to compress the white end. The stretch signal for the black end is handled in a similar fashion.
2) The signal as it is pushed up into the fixed knee of the amplifier (Fig. 8a).
3) Gamma-compressed white with the modulation unchanged (Fig. 8b).
4) White stretch condition (Fig. 8c). As in all the other Fig. 8 illustrations, the differential modulation is very little affected.
5) Black stretch with no increase in the modulation amplitude (Fig. 8d).
6) Both black and white stretch (Fig. 8c).
7) Black stretch and white compression (Fig. 8f).

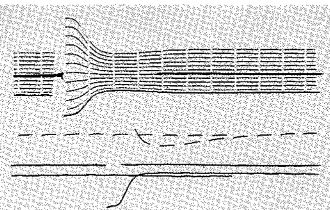


Fig. 5—AGC amplifier control cycle a) with slow scan on the oscilloscope and b) with a window signal suddenly applied.

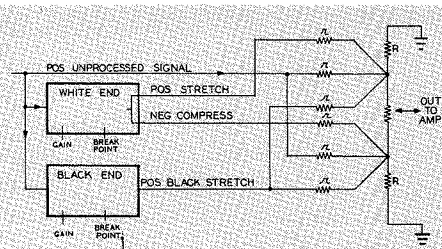


Fig. 6—Approach used to solve gamma control problem.

Fig. 7—General waveform operation of gamma amplifier.

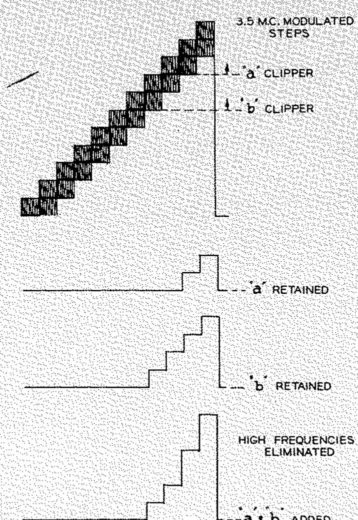
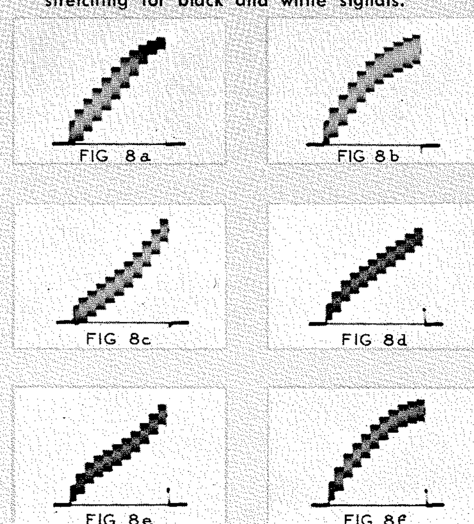


Fig. 8—Waveforms 8a through 8f show the signal in various stages of compression and stretching for black and white signals.



SPECTRAL RESPONSE OF RANGER TV CAMERAS—MEASUREMENT AND USE

All of the parameters of the RANGER TV cameras are fixed, and the electrical output of the cameras depends only on the luminance of the lunar scene. This output must be known in order to set the gain of the video amplifiers. However, a problem arises in that there is no usable source which approximates the Moon's spectral distribution and luminance; therefore, some other source must be used, and, based on its spectral distribution, its luminance will be set to provide the same output from the camera as would be provided if the lunar scene were observed. This paper describes the method for determining the luminance of this artificial source; also discussed are methods for measuring the spectral response of camera systems.

L. HERCZEG
Astro-Electronics Division
DEP, Princeton, N. J.

The cameras used in the RANGER TV Subsystem have fixed *f*-numbers and exposure times; the electrical parameters of the image sensor, the vidicon, are picked so that the cameras will operate most favorably with regard to parameters such as resolution, shading, erasure, and sensitivity. Once these are determined, the electrical output of the vidicon will depend *only* on the exposure of the sensitive surface. The output signal must then be amplified sufficiently to modulate the transmitters.

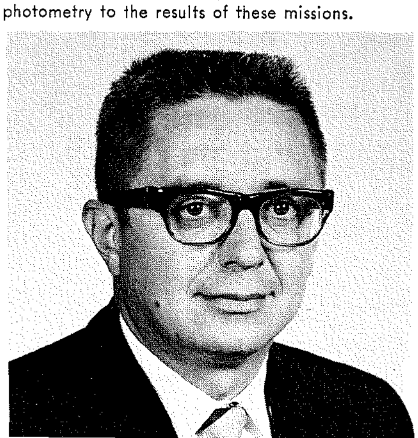
The ability to set the gain of the video amplifier correctly is very important. If it is set too low, the full range of modulation will not be obtained; if it is set too high, video information will be lost because of clipping by the circuits designed to prevent over-modulation of the transmitter. To correctly set the video gains, the electrical output of the vidicon, when exposed to the luminance of the lunar scene to be reproduced, must be known. If a source is available that has the spectral characteristics of the lunar scene, or a vidicon is available that has the spectral sensitivity of the eye, the problem of setting the video gain would be solved quickly.

Consider the light source: If it met the above specification, its radiance would be set to that of the lunar scene, and the gain of the camera could be adjusted accordingly. However, this required source is not available in a convenient size. The best approximation to the lunar scene is the light from a tungsten lamp of 2,878°K color temperature passing through a Corning 1-62 filter; but, because of the low transmissibility of the filter, this source could not be used with all cameras. Fig. 1 shows the spectral characteristics of this source, compared to the solar spectrum and to the source finally used to set the camera gains. As can be seen, this source does not meet the requirements for a simple solution to the gain-setting problem.

Final manuscript received June 9, 1965.

Consider the spectral characteristics of the vidicon: As previously mentioned, if these characteristics approximated those of the human eye, the vidicon could be used as a visual photometer. Under these conditions, it would respond only to the luminosity content of the source; hence, any source could be used as long as its luminance equaled that of the lunar scene to be reproduced. In general, the vidicon does not have the same spectral sensitivity as the eye, and as shown in Fig. 1, the source does not approximate the lunar scene. Therefore, the luminance of the calibration source must be set properly, and its value will not necessarily equal that of the lunar scene.

LOUIS HERCZEG received a BS in Engineering Physics from Lehigh University in 1949, and an MA degree in Physics from Temple University in 1956. After graduation in 1949, Mr. Herczeg was employed by the Franklin Institute Laboratories, where he worked on measurement of infrared radiation; design of an infrared absorption cell; feasibility studies for improved radar-room lighting; accurate calibration of thermistors; and experiments on the temperature distribution in reactor fuel elements. He redesigned a spectrometer to measure gun-flash radiation, which was later used in nuclear testing. He derived, theoretically, and verified, experimentally, the stellar magnitudes of objects of various shapes and reflectivities. Mr. Herczeg joined RCA in 1959. He then joined High Temperature Instrument Corporation in 1960 where he was responsible for the theoretical analysis and experimental evaluation of high-temperature strain gages and thermocouples. He joined RCA again in 1961. On RANGER, Mr. Herczeg was responsible for developing the focussing, spectral sensitivity determination, and vidicon sensitivity measurement techniques; he was a member of the scientific data analysis team for RANGER 7, 8, and 9 and applied earth-based lunar photometry to the results of these missions.



The luminance of the collimator is set correctly only if the video signals are identical when the camera views either the lunar scene or the collimator. The manner in which the luminance of the collimator is determined will be discussed in this paper; but first, the way in which a vidicon camera responds to light radiation must be understood.

SIMPLIFIED THEORY OF VIDICON-CAMERA RESPONSE

The response of a vidicon camera illuminated by a light source with a given spectral distribution is:

$$V_s = K_s\,(E_s)^{\gamma} \qquad (1)$$

where K_s is a constant which depends on the spectral sensitivity of the vidicon and the spectral distribution of the source; V_s is the video signal, in volts; E_s is the irradiance of the vidicon, in W/cm^2; and γ is a function of E_s. Experimentally, it can be shown that a region of E_s exists over which γ is constant. In the following discussion, E_s will be limited to the region of constant γ.

Eq. 1 can also be written as:

$$V_s = K_s \left[\int_{\lambda_1}^{\lambda_2} E(\lambda)\, d\lambda \right]^{\gamma} \qquad (2)$$

where $E(\lambda)$ is the spectral irradiance in W/cm^2 • μm on the vidicon.* Since the value of K_s, determined experimentally for one source, cannot be used to predict the video output for other sources, Eq. 2 is not very useful. However, a general equation which applies to any source can be developed in the following manner.

For narrow spectral regions, $E(\lambda)$ can be assumed constant equal to its average value over the interval of $\Delta\lambda$, and Eq. 2 can be written as:

* *Editor's Note:* The term *micrometer* (μm) is now preferred instead of the older term micron (often abbreviated μ); both refer to 10^{-6} meters.

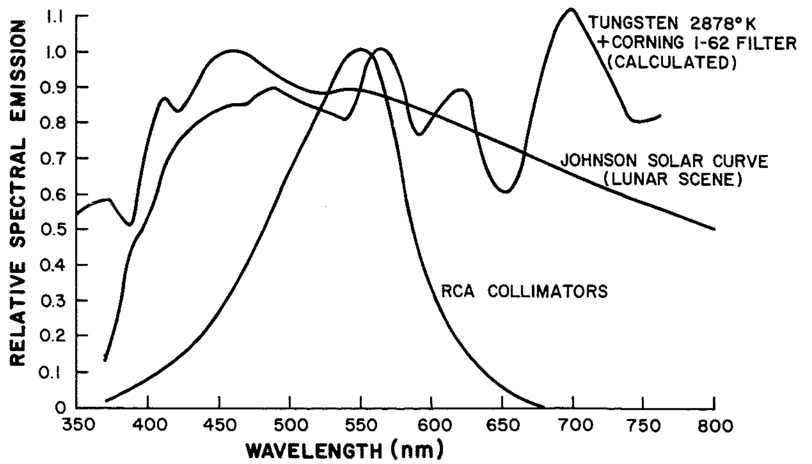


Fig. 1—Relative spectral emission of light sources considered for the Ranger cameras.

$$V(\lambda) = K_s' [E(\lambda) \Delta\lambda]^\gamma \quad (3)$$

where $V(\lambda)$ is the video signal due to radiation in the band $(\Delta\lambda)$ measured at wavelength λ. The value of K_s' is expressed as:

$$K_s' = \alpha K(\lambda) \quad (4)$$

where α is defined as a constant independent of λ, and $K(\lambda)$ expresses the wavelength dependency.

Substituting Eq. 4 into Eq. 3, the video signal $V(\lambda)$ becomes:

$$V(\lambda) = \alpha K(\lambda) [E(\lambda) \Delta\lambda]^\gamma \quad (5)$$

In order to develop Eq. 5 so that it can be applied to any source, consider the behavior when the vidicon is irradiated by n sources having identical spectral distribution, but different intensities. Individually, the video signals are:

$$V_n = \alpha K(\lambda_1) [A_n E(\lambda_1) \Delta\lambda]^\gamma \quad (6)$$

where A_n is proportional to the strength of the nth source. Since these sources have identical spectral characteristics, the video signal for the combined source is:

$$V_T = \alpha K(\lambda_1) \left[\sum_{n=0}^{n} A_n E(\lambda_1) \Delta\lambda \right]^\gamma \quad (7)$$

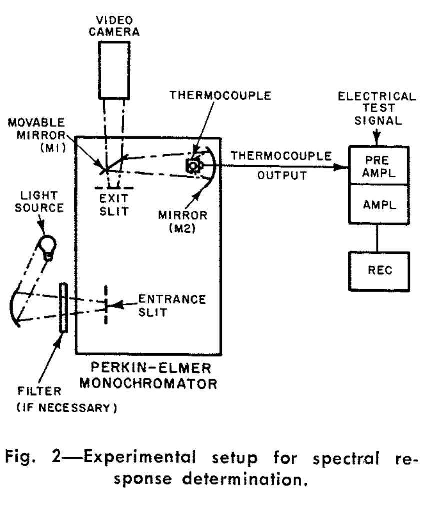


Fig. 2—Experimental setup for spectral response determination.

where V_T is the total video signal for all the sources. Eq. 7 can be used to determine the video signal for a combination of sources having different wavelength characteristics if, in the calculations, each source is replaced by a constant wavelength source that gives the same video signal. Consider a source made up of n components:

$$E_s = \sum_{n=0}^{n} E(\lambda_n) \Delta\lambda \quad (8)$$

The video signal for each individual source is given as:

$$V(\lambda_n) = \alpha K(\lambda_n) [E(\lambda_n) \Delta\lambda]^\gamma \quad (9)$$

The equivalent irradiance from the constant spectral source required to give the same video signal as the nth source is:

$$A_n E(\lambda_1) \Delta\lambda = \left[\frac{\alpha K(\lambda_n)}{\alpha K(\lambda_1)} \right]^{\frac{1}{\gamma}} E(\lambda_n) \Delta\lambda \quad (10)$$

Adding each of the equivalent sources:

$$\sum_{n=0}^{n} A_n E(\lambda_1) \Delta\lambda = \sum_{n=0}^{n} \left[\frac{K(\lambda_n)}{K(\lambda_1)} \right]^{\frac{1}{\gamma}} E(\lambda_n) \Delta\lambda \quad (11)$$

Substituting for the summation in Eq. 7, the video signal for the combined source becomes:

$$V_s = \alpha K(\lambda_1) \left\{ \sum_{n=0}^{n} \left[\frac{K(\lambda_n)}{K(\lambda_1)} \right]^{\frac{1}{\gamma}} \cdot E(\lambda_n) \Delta\lambda \right\}^\gamma \quad (12)$$

Eq. 12 can be written:

$$V_s = \alpha \left[\int_{\lambda_1}^{\lambda_2} K(\lambda)^{\frac{1}{\gamma}} E(\lambda) \, d\lambda \right]^\gamma \quad (13)$$

Eq. 13 is completely general and can be applied to any energy source once $K(\lambda)$, α, and γ are measured. Since Eq. 13 gives the response of the vidicon in its most useful form, the spectral response will be defined by the term $K(\lambda)^{\frac{1}{\gamma}}$; thus:

$$R(\lambda) = K(\lambda)^{\frac{1}{\gamma}}$$

Where $R(\lambda)$, the relative spectral response (unity at the point of maximum sensitivity), is the effectiveness of the radiant energy at wavelength λ to produce a video signal. Eq. 5 becomes:

$$V(\lambda) = \alpha [R(\lambda) E(\lambda) \Delta\lambda]^\gamma \quad (14)$$

And Eq. 13 becomes:

$$V_s = \alpha \left[\int_{\lambda_1}^{\lambda_2} R(\lambda) E(\lambda) \, d\lambda \right]^\gamma \quad (15)$$

For any source, Eqs. 15 and 2 give the same video signal. Equating these, the value of K_s is:

$$K_s = \frac{\alpha \left[\int_{\lambda_1}^{\lambda_2} R(\lambda) E(\lambda) \, d\lambda \right]^\gamma}{\left[\int_{\lambda_1}^{\lambda_2} E(\lambda) \, d\lambda \right]^\gamma} \quad (16)$$

EXPERIMENTAL METHOD FOR DETERMINING SPECTRAL RESPONSE

Using Eq. 14 and taking the ratio of $V(\lambda)$ to $V_p(\lambda)$ (video at peak sensitivity) the value of $R(\lambda)$ becomes:

$$R(\lambda) = \frac{\dfrac{a[V_p(x)]^{\frac{1}{\gamma}}}{E(\lambda) \Delta\lambda}}{\dfrac{a[V_p(x)]^{\frac{1}{\gamma}}}{E_p(\lambda) \Delta\lambda}} \quad (17)$$

TABLE I — Determination of the Illuminated Area on the Vidicon

Parameter	Wide-Angle Camera	Narrow-Angle Camera
Camera focal length, in.	1	3
Object distance, in.	15.1	15.3
Magnification	0.071	0.244
Distance to entrance pupil, in.	14.4	15
Radius of the entrance pupil, in.	0.53	0.725
tan φ	0.0368	0.0483
angle φ	2°6′	2°48′
sin $\varphi' = \sin \mu/m$	0.517	0.198
tan φ'	0.605	0.207
Image distance; focal length, in.	0.07	0.73
Radius of illuminated area, in.	0.04	0.147
Diameter of illuminated area	0.08	0.294
Size of resolution element	0.00055	0.00055

Note: The values in this table are only approximate, but they indicate that the illuminated area is considerably larger than the resolution element of the video system.

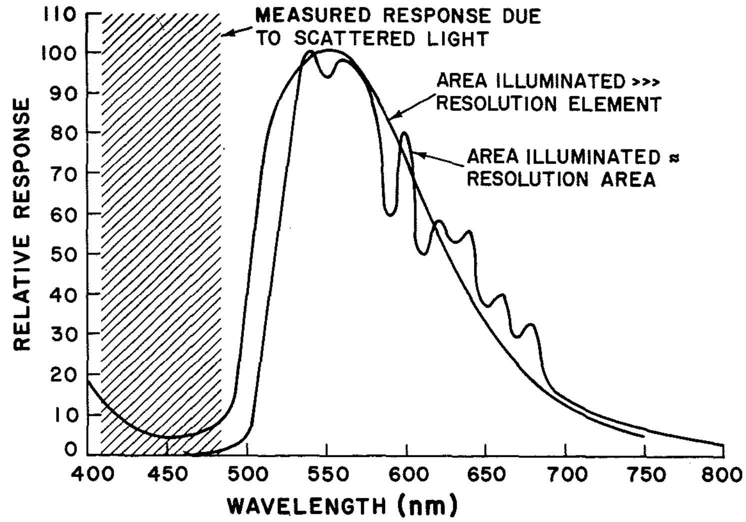


Fig. 3—Comparison of two methods for obtaining spectral response.

The parameters required to evaluate Eq. 17 are obtained from the experimental arrangement shown in Fig. 2.

Radiation in a narrow spectral region ($\Delta\lambda$) is obtained from a Perkin-Elmer Double-Pass Monochromator. The output of this monochromator is first allowed to fall on the camera under test; the monochromator slits and light-source intensity are adjusted until the desired video signal is observed. The radiation is then reflected to the thermocouple where the output is compared to a standard electrical test signal. Now, assuming that the thermocouple signal is proportional to spectrometer output and that the irradiance of the vidicon is proportional to the spectrometer output, a measure of $E(\lambda)\,\Delta\lambda$ is obtained. In terms of the thermocouple output and electrical calibration voltage, the following proportionality is obtained:

$$E(\lambda)\,\Delta\lambda \propto D_t(\lambda)\,\frac{C_v(\lambda)}{D_v(\lambda)} \qquad (18)$$

where $D_t(\lambda)$ is the recorder deflection for thermocouple output at wavelength λ; $D_v(\lambda)$ is the recorder deflection for the calibration voltage, $C_v(\lambda)$ measured at the same amplifier gain as $D_t(\lambda)$; and $C_v(\lambda)$ is the calibration voltage which gives $D_v(\lambda)$.

Substituting for $E(\lambda)\,\Delta\lambda$ in Eq. 17 from Eq. 18 and introducing a similar term for $E_p(\lambda)\,\Delta\lambda$ (the irradiance at the peak sensitivity of the vidicon) Eq. 17 becomes, in terms of measurable quantities: (19)

$$R(\lambda) = \left[\frac{V(\lambda)}{V_p(\lambda)}\right]\left[\frac{\frac{1}{\gamma}D_{tp}\,\dfrac{C_{vp}}{D_p(\lambda)}}{D_t(\lambda)\dfrac{C_v(\lambda)}{D_v(\lambda)}}\right]$$

where $D_p(\lambda)$, C_{vp}, and $D_p(\lambda)$ are terms obtained at the wavelength of peak sensitivity.

REQUIREMENTS FOR VALID SPECTRAL RESPONSE DATA

Before making the measurements for Eq. 19, the manner in which the camera is irradiated was studied. From this study, it was decided: *1*) to irradiate an area, on the sensitive surface of the vidicon, which is considerably larger than the scanning aperture of the electron beam; and *2*) to completely irradiate the entrance pupil of the camera system so that the lens contributions to

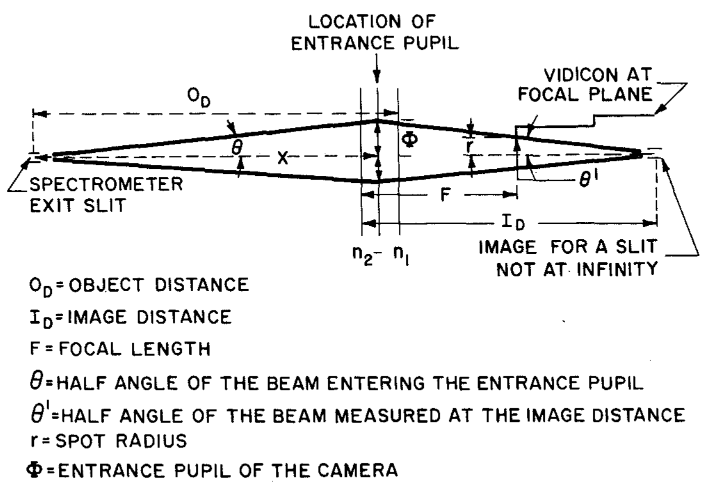


Fig. 4—Geometrical relationship between camera and spectrometer.

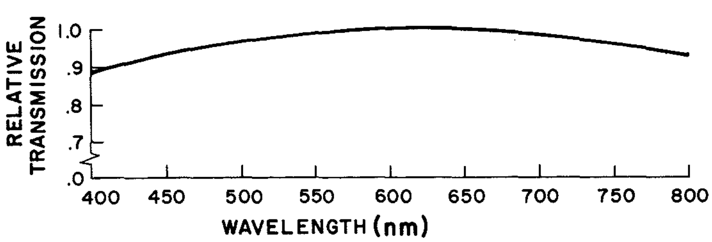


Fig. 5—Relative spectral transmission of light to the thermocouple.

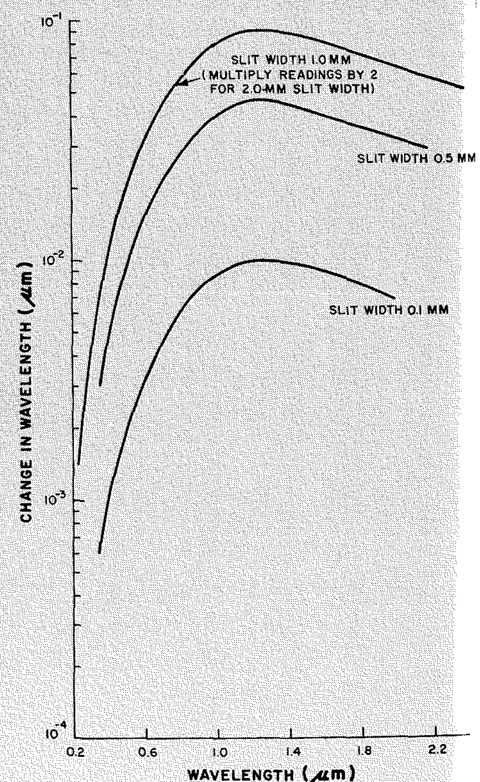


Fig. 6—Spectrometer bandpass.

the spectral response are properly included in the measurement.

The importance of the area illuminated is seen in Fig. 3 which shows the spectral responses obtained on a TIROS camera with different areas illuminated. From this comparison, a smooth curve is obtained when the area illuminated is large. As the area illuminated is reduced to the size of a resolution element, the aperture response and slight variation in the location of illumination on the sensitive area cause unpredictable fluctuations in the video signal—resulting in a spectral response curve with a large number of dips and peaks.

Fig. 4 shows the geometrical relationships between the camera and spectrometer. Using Fig. 4, the sizes of the illuminated areas are calculated and tabulated in Table I, where they are compared to the size of the resolution element.

Since it has been assumed that the irradiance of the camera is proportional to the radiation passing through the exit slit, the angular field of the emerging beam must be independent of wavelength. If this were not the case, the total flux passing through the slit would cover different areas for different wavelengths, and the irradiance at the camera would not be proportional to the value determined by the thermocouple. The width of the beam at the camera was measured at various wavelengths (by placing a screen in the light path) and was found to be independent of wavelength. Therefore, the assumption that $E(\lambda)\,\Delta\lambda$ is proportional to the light passing through the slit is valid.

As shown in Fig. 2, the light going to the thermocouple is reflected twice by front-surface mirrors, and it also passes through a window in the thermocouple housing. If the transmission of this light path is not constant with wavelength, corrections must be applied to the spectral response data.

The reflectivity squared of the movable mirror has been measured. This value was taken to be equal to the combined effect of the reflection from mirrors *M1* and *M2* (Fig. 2). Fig. 5 shows the effect of the two reflections combined with the transmission of the thermocouple window on a relative scale.

Since the spectrometer cannot give pure monochromatic radiation, it is felt that the wavelengths contained in the light falling on the camera at each wavelength setting should be included in the data.

Fig. 6 gives the bandwidth ($\Delta\lambda$) for various size spectrometer slits, as a function of wavelength.

Since the monochromaticity of the radiation passing through the exit slit of the spectrometer is being discussed, the effect of stray radiation should be considered. This stray radiation is inherent in all optical instruments and is due to scattering of light at all the optical interfaces of the spectrometer. Its effect, first noted when the spectral response of a TIROS camera was measured, is to contaminate the monochromatic radiation from the spectrometer. Fig. 3 shows response for the TIROS cameras below 0.48 μm; however, this response could not have existed, since TIROS cameras use filters having a sharp cut-off at 0.48μm. The experimental method used on TIROS was not corrected to eliminate the effect of scattered light and the region below 0.48 μm was neglected by extending the curve past the shaded area in Fig. 3.

The spectral characteristics of the scattered light depends on the radiation entering the spectrometer; to reduce the effects of this scattered light, the problem was approached in the following manner: considering the spectral response of TIROS cameras and remembering that the vidicons used in RANGER have identical sensitive surfaces, it can be assumed that scattered light, in that spectral region where the camera has its maximum spectral response, will have the greatest effect at short wavelength (where the camera sensitivity is low and the spectral output is weak); therefore, if the radiation from this wavelength region can be eliminated by the use of optical filters, the effects of scattered light on the measurements should be reduced. Fig. 7 shows the transmission of the filters that were used to eliminate scattered light during measurements at the short wavelength.

EXPERIMENTAL RESULTS

For the RANGER cameras, three different types of vidicons were used: those having serial numbers below 900, 900-series vidicons, and 3000-series vidicons. Fig. 8 shows response curves representing each type. Note that the response curves for the 900-series vidicons, which have post-laminate faceplates (that is, their faceplates are constructed from two pieces of glass which are cemented together) are quite different from the other two in the low-wavelength region. The 3000-series vidicons have their peak spectral responses shifted to longer wavelengths, with a corresponding increase in sensitivity in the red region of the spectrum. This type of vidicon utilizes the same sensitive target as the others, but the manufacturing process has been varied.

An interesting point concerning the 3000-series vidicons is the response below 450 nm (nanometers—10^{-9} meters) noticed first for these cameras, which have peak sensitivities about 600 nm. At the time of the measurements, it was felt that this behavior was due to scattered light. Even though filters are used to eliminate scattered light, considerable energy is still transmitted at long wavelengths (see Fig. 7). This energy and the increased long wave-length sensitivity was responsible for the apparent short-wavelength response shown.

At the time of the spectral response measurements, the experimental procedure could not be changed to completely eliminate the scattered-light effect from the data. Therefore, filters were obtained which did not eliminate scattered light, but which eliminated all but the scattered light. By using these filters, the effect of scattered light could be measured and the data corrected accordingly. This was done in the following manner:

1) With the spectrometer wavelength set at the desired point, the video signal was recorded.
2) A sharp cutoff filter which transmits at longer wavelength, but which does not transmit energy at the wavelength setting of the monochromator, is placed

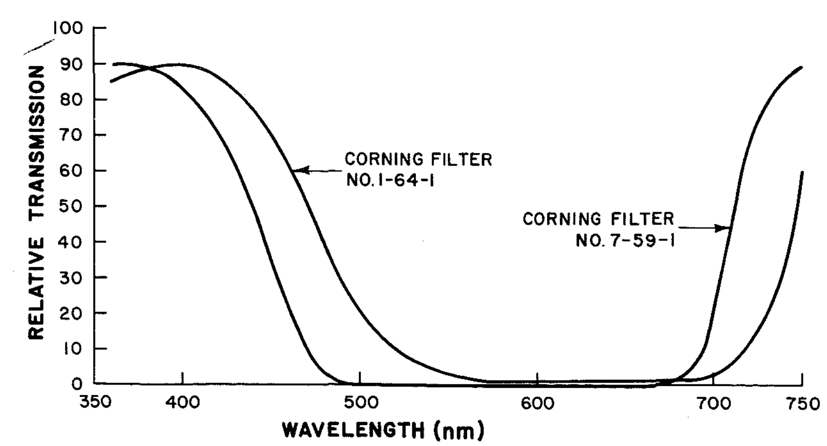


Fig. 7—Spectral characteristics of filters used to reduce the effects of scattered light.

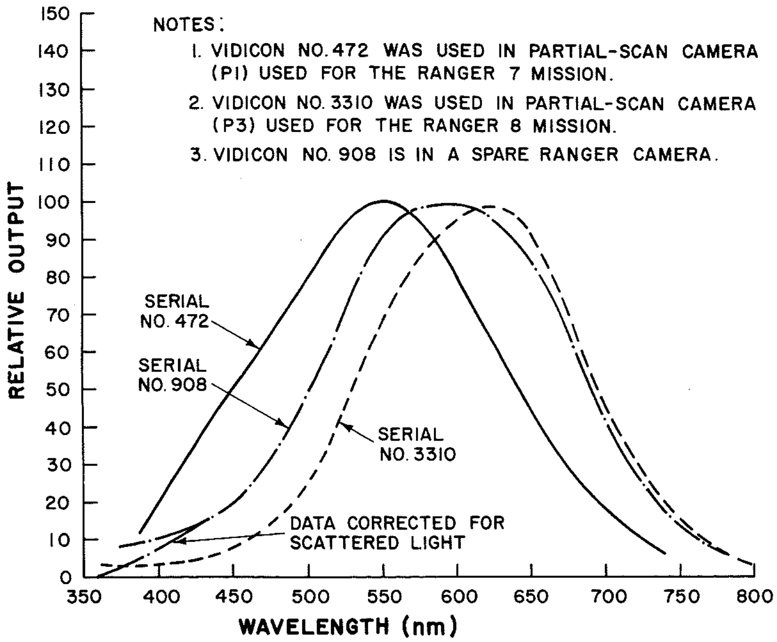


Fig. 8—Typical spectral response curves for Ranger cameras.

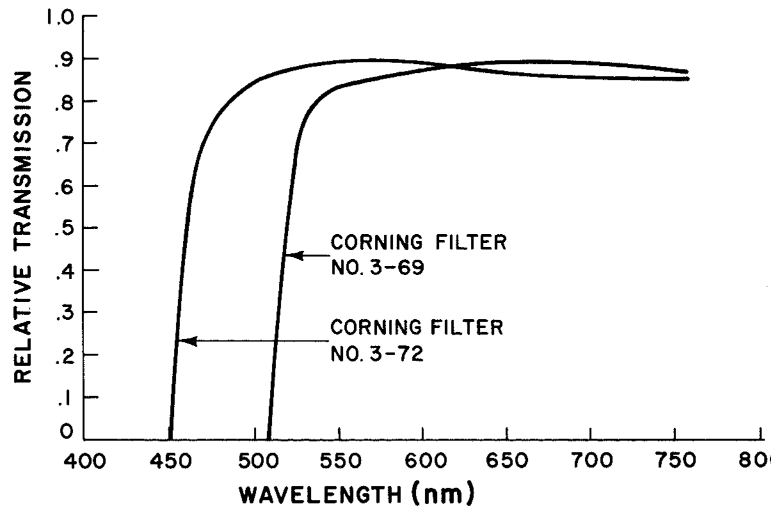


Fig. 9—Spectral response of filters used for determining the effects of scattered light.

in the light path, and the video signal is recorded. This signal is then due only to the scattered light.

3) Correcting this signal for the transmission of the filter, the signal due to scattered light in the original video reading is obtained.

Fig. 9 shows the response of the filters used in this evaluation. Correcting the spectral response data for the video signal due to scattering, the response shown in Fig. 8 for the serial No. 908 vidicon is obtained. This vidicon camera is the only one in which the effect of scattered light has been measured experimentally, and thus represents a basis for empirically correcting the spectral response data to calculate video signals for any light source.

APPLICATION OF SPECTRAL RESPONSE DATA

As stated previously, spectral response data is necessary in order to determine the spectral radiance required for the light source used to set the camera gain. Starting with the fact that the camera output for the test light source must be equal to the output when the camera views the lunar surface under the desired lighting conditions, the following development results:

$$V_c = V_M$$

$$\alpha_v [K_c \int_{\lambda_1}^{\lambda_2} R_v(\lambda)\, E_c(\lambda)\, d\lambda]^\gamma = \alpha_v [K_M \int_{\lambda_1}^{\lambda_2} R_v(\lambda)\, E_M(\lambda)\, d\lambda]^\gamma \quad (20)$$

where V_c is the video signal when the collimator is viewed by the camera; V_M is the video signal when Moon is viewed by the camera; α_v is the camera sensitivity; K_M is the scale factor for radiation reflected by the lunar surface *scale factors* are quantities which relate the relative values such as $E_c(\lambda)$ to absolute values]; K_c is the scale factor for the collimator light source; $R_v(\lambda)$ is the relative spectral response of the camera; $E_c(\lambda)$ is the relative spectral distribution of collimator light source; $E_M(\lambda)$ is the relative spectral distribution of radiation reflected by the Moon; and γ is the slope of the camera transfer curve. Solving Eq. 20 for K_c, the scale factor of the collimator light source:

$$K_c = K_M \frac{\int_{\lambda_1}^{\lambda_2} R_v(\lambda)\, E_M(\lambda)\, d\lambda}{\int_{\lambda_1}^{\lambda_2} R_v(\lambda)\, E_c(\lambda)\, d\lambda} \quad (21)$$

The value of K_M depends on the radiance of the lunar surface under the desired viewing and lighting conditions, and it is obtained as follows:

$$B_M = K_M \int_{\lambda_1}^{\lambda_2} E_M(\lambda)\, d\lambda \quad (22)$$

where B_M is the radiance of the lunar surface. Substituting in Eq. 21:

$$K_c = \frac{B_M \int_{\lambda_1}^{\lambda_2} R_v(\lambda) E_M(\lambda)\, d\lambda}{\int_{\lambda_1}^{\lambda_2} E_M(\lambda)\, d\lambda \int_{\lambda_1}^{\lambda_2} R_v(\lambda) E_c(\lambda)\, d\lambda} \quad (23)$$

Eq. 23 gives the desired scale factor. This scale factor can also be expressed in terms of the radiance of the collimator as measured by a radiometer. The equation for the radiance of the collimator is:

$$B_{cr} = K_r K_c \int_{\lambda_1}^{\lambda_2} E_c(\lambda) R_r(\lambda)\, d\lambda \quad (24)$$

where B_{cr} is the radiance of the collimator as determined by the radiometer; K_r is the scale factor of the radiometer; and $R_r(\lambda)$ is the relative spectral response of the radiometer. After substituting for K_c in Eq. 24, the required radiance of the collimator as determined by the radiometer becomes:

$$B_{cr} = \frac{B_M \int_{\lambda_1}^{\lambda_2} R_v(\lambda) E_M(\lambda)\, d\lambda K_r}{\int_{\lambda_1}^{\lambda_2} E_M(\lambda)\, d\lambda} \frac{\int_{\lambda_1}^{\lambda_2} E_c(\lambda) R_r(\lambda)\, d\lambda}{\int_{\lambda_1}^{\lambda_2} R_v(\lambda) E_c(\lambda)\, d\lambda} \quad (25)$$

Before Eq. 25 can be evaluated, the value of K_r (the scale factor of the radiometer) must be determined. This scale factor is obtained by calibrating the radiometer against a standard source whose radiance is known:

$$B_s = K_s K_r \int_{\lambda_1}^{\lambda_2} E_s(\lambda) R_r(\lambda)\, d\lambda = K_s \int_{\lambda_1}^{\lambda_2} E_s(\lambda)\, d\lambda \quad (26)$$

where B_s is the radiance as measured by radiometer (the actual radiance of the standard source); and $E_s(\lambda)$ is the relative spectral distribution of the standard source:

$$K_r = \frac{\int_{\lambda_1}^{\lambda_2} E_s(\lambda)\,d\lambda}{\int_{\lambda_1}^{\lambda_2} E_s(\lambda) R_r(\lambda)\,d\lambda} \qquad (27)$$

Now, substituting in Eq. 25 for K_r, Eq. 27 (the radiance of the collimator as determined by the radiometer) is:

$$B_{cr} = B_M \frac{\int_{\lambda_1}^{\lambda_2} R_v(\lambda) E_M(\lambda)\,d\lambda}{\int_{\lambda_1}^{\lambda_2} R_v(\lambda) E_c(\lambda)\,d\lambda} \cdot \frac{\int_{\lambda_1}^{\lambda_2} E_c(\lambda) R_r(\lambda)\,d\lambda}{\int_{\lambda_1}^{\lambda_2} E_s(\lambda) R_r(\lambda)\,d\lambda} \cdot \frac{\int_{\lambda_1}^{\lambda_2} E_s(\lambda)\,d\lambda}{\int_{\lambda_1}^{\lambda_2} E_M(\lambda)\,d\lambda} \qquad (28)$$

At this point it can be shown that the statement made about the source in the introduction is correct. If the spectral distributions of the Moon and the collimator are equal, that is, $E_M(\lambda) = E_c(\lambda)$, and if the spectral response of the radiometer $R_r(\lambda)$ is independent of wavelength, it can be seen that the required radiance of the collimator (or source) equals that of the lunar surfaces.

The radiance of the lunar surface B_M has been evaluated extensively by means of visual photometric techniques; therefore, in order to utilize these data, Eq. 28 should be transformed so that photometric quantities can be used in place of radiometric ones. This can be accomplished by using the luminosity function to express B_s (Eq. 26) and B_M (Eq. 22) in terms of luminance. Thus, Eq. 22 becomes:

$$B'_M = K_M K_e \int_{\lambda_1}^{\lambda_2} I(\lambda) E_M(\lambda)\,d\lambda \qquad (29)$$

And, Eq. 26 becomes:

$$B'_s = K_s K_r \int_{\lambda_1}^{\lambda_2} E_s(\lambda) R_r(\lambda)\,d\lambda = K_s K_e \int_{\lambda_1}^{\lambda_2} I(\lambda) E_s(\lambda)\,d\lambda \qquad (30)$$

where $I(\lambda)$ is the spectral sensitivity of the standard observer, K_e is the scale factor of the standard observer, and B'_M and B'_s represent photometric quantities. Using these terms in the above development and replacing the radiometer by a photometer, the brightness of the collimator as read by the photometer is:

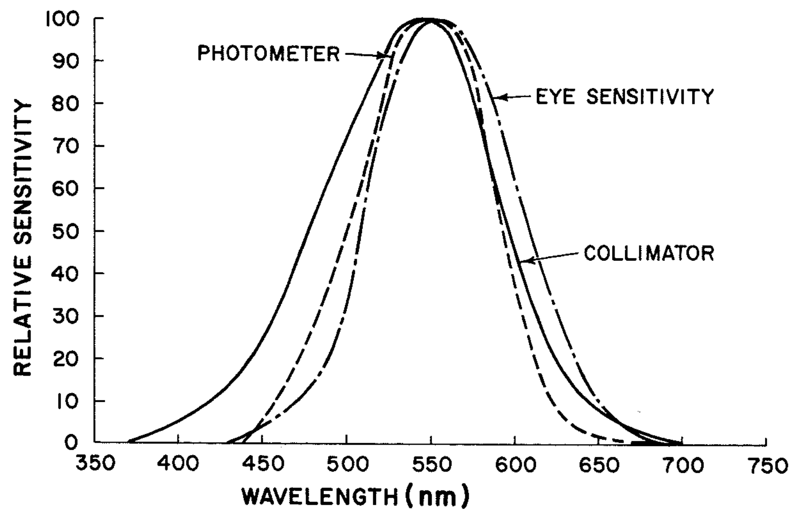


Fig. 10—Spectral response of Ranger collimators and photometer used to measure their luminance.

$$B'_{cr} = B'_M \left[\frac{\int_{\lambda_1}^{\lambda_2} R_v(\lambda) E_M(\lambda)\,d\lambda}{\int_{\lambda_1}^{\lambda_2} R_v(\lambda) E_c(\lambda)\,d\lambda} \cdot \frac{\int_{\lambda_1}^{\lambda_2} E_c(\lambda) R'_r(\lambda)\,d\lambda}{\int_{\lambda_1}^{\lambda_2} E_s(\lambda) R'_r(\lambda)\,d\lambda} \cdot \frac{\int_{\lambda_1}^{\lambda_2} I(\lambda) E_s(\lambda)\,d\lambda}{\int_{\lambda_1}^{\lambda_2} I(\lambda) E_M(\lambda)\,d\lambda} \right] \qquad (31)$$

As stated in the introduction, if the spectral response of the vidicon equals that the eye, that is $R'_v(\lambda) = I(\lambda)$, then B'_{cr} will approximate B'_M to a degree which depends on the spectral response of the photometer. If the photometer's spectral response equals that of the eye, the luminance values will be equal ($B'_{cr} = B'_M$) and independent of the spectral characteristics of the sources.[1]

Since the spectral emission of the source (collimator) does not approximate that of the lunar source and since the spectral response of the vidicon does not approximate that of the eye, Eq. 31 must be evaluated. To complete the evaluation of Eq. 31, the spectral emission $E_c(\lambda)$ of the collimator, the spectral sensitivity $R'_r(\lambda)$ of the photometer used to measure the luminance, and the spectral emittance of the standard source $E'_s(\lambda)$ must be known.

The spectral emission of the collimator is almost independent of voltage, and the filter used to modify the output of the tungsten lamp is the controlling factor in setting its spectral emission. Fig. 10 shows the spectral emission of the collimator, the spectral sensitivity $R'_r(\lambda)$ of the photometer, and the eye sensitivity curve $I(\lambda)$. The spectral emittance of the standard source $E'_s(\lambda)$ was assumed equal to that of a tungsten lamp operating at a color temperature of 2,854°K. The luminance value for the RCA collimators required to set the gain of the cameras is calculated from Eq. 31 and shown in Table II.

CONCLUSION

By using the spectral response data as shown in Eq. 31, light sources having spectral emission quite different from that of the lunar scene can be used to set the gains of the cameras. Since the spectral response curves show differences for the three types of vidicons and since the method gives similar characteristics for the vidicon of each type, it is felt that the method is accurace. Concerning the effects of scattered light, the last method used for correcting the data gives the best results.

BIBLIOGRAPHY

1. G. Smith and D. Willingham, *Ranger Photometric Calibration*, Ranger Block III, JPL Technical Memorandum, May 1964.

ACKNOWLEDGEMENT

This work was performed for the Jet Propulsion Laboratory, California Institute of Technology, sponsored by the National Aeronautics and Space Administration under Contract NAS 7-100.

TABLE II — Luminance Settings of RANGER 9 Collimators

Camera Serial No.	Lunar Luminance, B_M fL	Equivalent Collimator Luminance, B_c fL
15/15	1,500	3,093
39/33	1,500	3,544
43/43	650	1,128
49/49	650	1,301
44/44	650	956
14/14	1,500	2,406
17/17*	1,500	2,296

* spare camera

THE REVOLUTION IN ELECTRICAL ENERGY SOURCES

A State-of-the-Art Review

This paper reviews the state-of-the-art of direct-energy-conversion techniques, including solar cells, thermoelectrics, and thermionics. While the greatest impetus for new methods of power generation stems from military and space requirements, the resultant technology will eventually have significant impact on commercial and domestic power generation, especially in situations where conventional electrical power sources are either non-existent or inadequate.

P. RAPPAPORT
RCA Laboratories, Princeton, N.J.

SPACE TECHNOLOGY is providing much of the impetus for the development of new electrical power sources of many types, since power requirements range from tens of watts for communications, navigation, and weather satellites to millions of watts for electrical propulsion. To date, the solar cell has been the mainstay for space power below a few hundred watts. Radioisotopic thermoelectric generators have also been demonstrated as feasible for space. Many other systems are now under development, and are expected to become practical during the present decade.

Fig. 1 shows the various primary energy sources available and the energy conversion techniques that can be employed to convert them into electrical power. The three basic forms of this energy are the sun, fossil fuels, and nuclear reactors and isotopes. As time goes by and our fossil fuel reserves are consumed, the nuclear and solar sources will be the chief sources of electrical power, including that produced by central-station power plants which supply our conventional power lines.

ENERGY CONVERSION TECHNIQUES

Of the many methods of energy conversion, the most promising at the moment are those listed in Fig. 1.

In the battery, the electrodes take part in a chemical reaction which produces a flow of electrons and ions resulting in an external flow of electrons in a load. Primary batteries are useless after the chemicals have been consumed. However, secondary (storage) batteries are capable of being recharged or having the chemical process reversed by external power being applied.

A fuel cell is a form of battery in which the chemicals are constantly added and the by-products are constantly removed. The electrodes are also used up in different ways, but the life of the fuel cell is theoretically limited by the amount of fuel (chemicals) that can be supplied. Fuel cells have high efficiencies, ranging from 20% to 70% depending on the system. The major use for fuel cells in the near future will be for high power, short-duration space missions, where the expensive fuels—hydrogen and oxygen—are used to achieve high efficiency.

The solar cell converts light photons directly into electricity by the photovoltaic effect, giving an efficiency of 10% for a sunlight spectra of photons and considerably higher efficiency for a monoenergetic source of photons. If the source of photons is a heat source, the process is called the *thermal photovoltaic effect.*

The means for converting heat into electricity are manifold. One method, the conventional turbine-generator system, operates at efficiencies of about 40% in central-station power plants. Another method, known as *magnetohydrodynamics,* may someday compete with rotating turbine-generator systems for central station power. Magnetohydrodynamics is analogous to a rotating machine except that the electrical current, in the form of hot ionized gases or plasma, is forced through a magnetic field, thereby producing a potential difference between electrodes which are perpendicular to the magnetic field and the gas flow. Because of the high temperature (about 3,000°C) and the magnetic field required, plus the need for high-velocity gas flow, the higher-efficiency magnetohydrodynamics technique would be most applicable in a large installation. It could produce megawatts of power from heat produced by a reactor. The major problem to be solved is to find materials that won't corrode at the high temperatures involved, in the presence of a high velocity ionized gas.

Thermoelectric and thermionic devices convert heat into electricity quite simply. Efficiencies from a few percent to about 30% are possible with these Carnot-cycle-type heat engines.

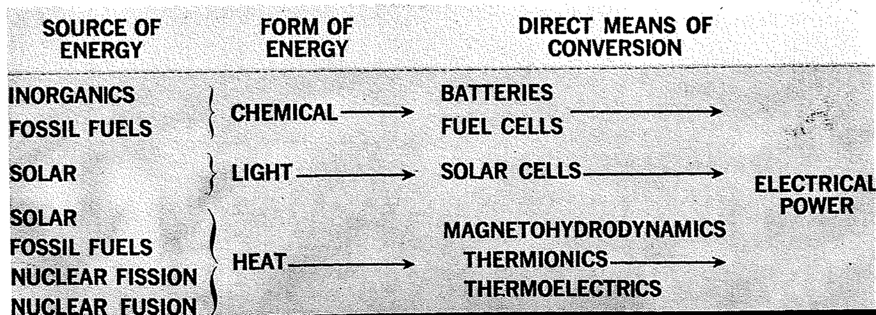
The conventional conversion technique of the dynamic or rotating turbine-generator unit is by no means completely out of the race as a compact, portable and efficient device useful in space. It may suffer from inherent reliability problems and operational difficulties because of the mechanical motion, but it is the reference against which other systems have to compete before their operational use is assured. This is especially true in the 30-to-300-kW power range. In a similar sense, the battery is the reference against which systems must compete at lower power levels.

The three specific energy-conversion techniques of particular interest to electronic engineers are *solar cells, thermoelectrics,* and *thermionics.* These techniques are truly static and are collectively called *direct-energy-conversion* devices. Fuel cells, magnetohydrodynamics, and dynamic machines all involve motion, and for this reason, their ultimate reliability may not be as good as the completely static systems.

The term *reliability* is worth emphasizing at this point for this is probably the most important single factor that

Final manuscript received June 9, 1965

Fig. 1—Direct-energy conversion technologies.



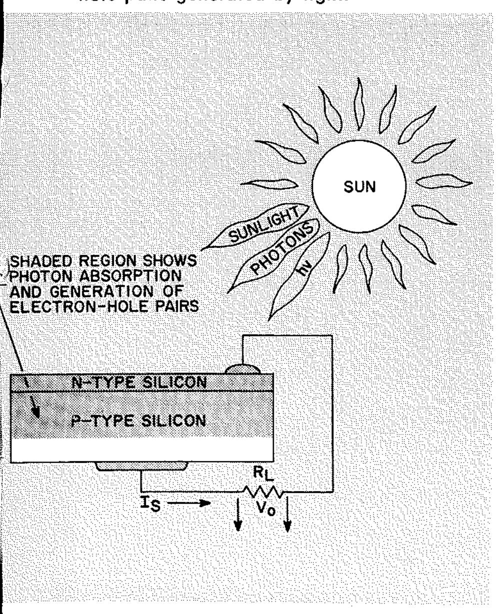
will ultimately determine which of the new electrical energy sources survives. Without high reliability, the newer techniques will not be able to compete with the more conventional and less costly techniques in use today.

An intriguing fact about energy conversion is that work in this field is based on many old ideas only now becoming practical because of improved materials and technologies.

SOLAR CELLS

The solar cell is the only *new* energy-conversion device being made in production quantities. It is essentially a p-n junction that has a large surface area. When this area is exposed to sunlight, the energy in the solar photons is converted into electricity by the p-n junction (Fig. 2). In Fig. 2, the shaded region is one of intense ionization due to electron-hole pairs generated by the light. The photons must have enough energy to break the silicon atom-to-atom bonds to produce this ionization. An energy of about 1 eV is required, and fortunately about two thirds of the solar photons have energy exceeding this value. The p-n junction is a potential barrier similar to the barrier formed when two dissimilar metals are brought together. Electrons flow from the p-type to the n-type silicon, and holes from the n-type to the p-type silicon, which constitutes a current flow as shown. Power can be delivered to a matched load with an overall efficiency of at least 10%. The p-n junction presents a nonlinear characteristic to the current-voltage load curve. Thus, it is possible to deliver over 75% of the power generated to the load.

Fig. 2—Basic action of solar cell. Shaded region has intense ionization due to electron-hole pairs generated by light.



Such cells are ideally suited to provide electrical power in space craft and will probably continue to be the mainstay for such use over the next 5 to 10 years. Well over 200 U.S. satellites have thus far used solar-cell power, ranging from the 5-watt VANGUARD to the 400-watt NIMBUS weather satellite. While development emphasis has been on space applications, the long range future for solar cells also includes terrestrial applications. A truly low-cost solar cell could have a profound effect on the economy of the emerging nations of the world.

When used for space power, the individual cells (a few square centimeters in area) are connected in series-parallel arrays. The cells are either attached to the surface of the satellite or they are attached to solar panels which project from the satellite (Fig. 3). On the NIMBUS satellite shown in Fig. 3, 10,944 cells (each 2 by 2 cm) are employed to yield about 400 watts. Each panel is about 24 ft^2 in area and is constantly oriented normal to the sun.

Many other solar energy conversion devices show promise of competing with solar cells for space power, but they have not yet been developed to the stage of: *1*) converting solar energy to electricity with 10% system efficiency, *2*) operating without special power conditioning equipment to produce high voltages, *3*) relative insensitivity to orientation effects, *4*) being relatively light and rugged, and *5*) requiring no special solar collector or heat radiator.

Solar cells also have limitations: *1*) sensitive to damage from radiation (important in many space applications); *2*) high in cost, important in terrestrial applications; *3*) useless during dark periods, thus requiring storage batteries; and *4*) limited to power levels up to a few kilowatts, although power in the 10-kW range may be more feasible for solar cells than for other systems now being contemplated where long life (1 year) is required.

Almost all of the several million solar cells produced in 1964 were made of single-crystal silicon. Other crystalline materials, such as gallium arsenide and cadmium sulfide, have been studied. Data on various semiconductors is given in Table I. The efficiencies shown are the best measured to date.

Solar cells currently in use require single-crystal material. Silicon and gallium arsenide are the most promising materials investigated to date.

PAUL RAPPAPORT received the BS and MS degree in Physics from the Carnegie Institute of Technology in 1948 and 1949, respectively, whereupon he joined the Technical Staff of RCA Laboratories. During the next two years, his work led to his invention of the Atomic Battery in 1953, which was the predecessor of the solar cell. In the following 12 years, he specialized in research on solar and radiation energy converters on radiation damage to semiconductors and on the physics of III-V compounds. In 1960 he was appointed Head of the Energy Conversion Research Group. He has had over 30 papers published, two book articles and has filed 15 patent applications. He is the recipient of two "RCA Achievement Awards" for outstanding work in research. Mr. Rappaport is a member of Pi Mu Epsilon, Sigma Xi, and the American Physical Society, and is listed in American Men of Science and Who's Who in Atoms. He is on the Editorial Board of the "Journal of Advanced Energy Conversion" and is serving on several government research advisory committees on electrical energy and space power systems. He has also served the AIAA, IEEE, and ASME technical society energy conversion committees. Mr. Rappaport was selected by NATO to present a discussion of space power systems at its meeting in Athens, Greece, July 8, 1963.

While the present results with gallium arsenide, as given in Table I, represent many years of effort applied to a difficult material, improvement in efficiency and reduction in cost are still necessary before the position of silicon for solar cells is challenged. However, for high-temperature operations (Venus or Mercury satellites), and when the solar cell is exposed to high radiation, gallium arsenide cells will be preferable to silicon cells. When n-on-p silicon solar cells are used with suitable cover glasses such as silica, the problems due to outer space radiation are minimized. Such cells can give reliable power for 5 to 10 years in almost all orbits.

Fig. 3—Satellite, utilizing solar cells on extended panels.

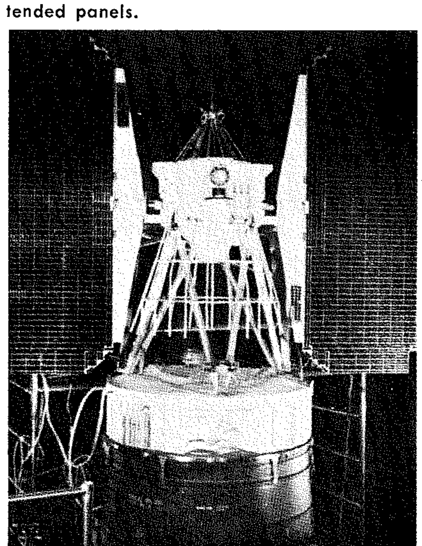


Table I—Solar Cell Materials

Material	Bandgap Energy (eV)	Efficiency (%) Theoretical	Efficiency (%) Measured
Silicon	1.11	20	14
Indium Phosphide	1.25	23	3
Gallium Arsenide	1.35	24	11
Cadmium Telluride	1.45	21	7
Gallium Phosphide	2.25	17	1
Cadmium Sulfide	2.4	16	7

Two of the most urgent requirements for future solar cells are lower cost and lighter weight: Presently, cells range from $100 to $500 per watt; as a result, their extensive use for terrestrial applications is not now economical. The major reason for this high cost is the need for single-crystal material in the cells. However, it has long been known that non-single-crystal films can be used for solar cells; for example, the selenium and copper oxide films which are used in the photoelectric exposure meter. More recently, the cadmium sulfide and the cadmium telluride film-type solar cells were developed. The exposure meter type devices have efficiencies less than 1%, while the cadmium sulfide cells have yielded efficiencies up to 7%.

Thin-film cells are basically light in weight and offer potential advantages for space applications. This lightness of weight stems from the fact that only very thin layers (microns) of most semiconductors are required for converting solar photons into electricity. Most of the 10 to 20 mils of silicon or gallium arsenide used in single-crystal devices serves as structural support. The thickness of semiconductor film required for solar cells is determined by their optical absorption.

Cadmium sulfide and cadmium telluride films are being studied by several different organizations, the state of development being about equal. Small-area 1- to 2-cm^2 films, made by evaporating the semiconductor and then forming a barrier layer with copper, yield efficiencies up to 7%. However, in large-area (100-cm^2) films, the efficiency drops to about 3% because of series resistance effects. Power-to-weight ratios of about 10 to 20 w/lb are claimed for flexible cadmium sulfide cells. This improvement, by a factor of three over silicon cells, is important for space applications, even though these cadmium sulfide cells are less efficient. Higher efficiencies and lighter-weight substrates should yield cells with power to weight ratios about 50 w/lb. It has been pointed out that such devices in very large area films (1,000 m^2) could supply power in the kilowatt range and may compete on a cost, weight, and time-available basis with a thermoelectric system such as SNAP 8. The large areas in such a solar-cell system would require some ingenious unfurling technique so that an area about a third the size of a football field need not be launched while open. Presumably, a flexible cell would permit such a solution.

THERMOELECTRIC ENERGY CONVERSION

The technology of thermoelectric energy conversion is developed to the point of demonstrated feasibility, yet actual devices are not in widespread use. Efficient thermoelectric generators utilize semiconductor p-n junctions similar to the solar cell. However, where the solar cell converts photons on a particle or quantum basis, thermoelectrics converts the heat produced by photons or other sources according to the thermodynamic principles of heat engines and limited by the Carnot cycle.

In this process, heat is applied to the p-n junction contact. The electron and hole concentration increases. In n-type material, this results in an excess of electrons, which sets up an electron gradient, forcing electrons along the n-type arm toward the cold end. A similar process occurs in the p-type arm, resulting in the motion of holes toward the cold end. This flow of charge in both arms results in a current through the load.

The thermoelectric figure of merit Z is generally regarded as the best single criterion in selecting a material's usefulness as an energy converter. It is defined as follows:

$$Z \cong S^2/K\rho$$

where S is the Seebeck coefficient (after the discoverer of this effect in 1821) or the voltage developed per degree centigrade temperature difference between the hot and cold end; K is the thermal conductivity of the material in watts per centimeter per degree centigrade, and ρ is the electrical resistivity in ohm-centimeters. The higher the figure of merit Z, the higher the efficiency of a thermoelectric converter, since (assuming $ZT << 1$):

$$Efficiency \cong 1/4\, Z \triangle T$$

where $\triangle T$ is the difference between the hot and cold temperature.

Highly doped semiconductor alloys or compounds are the best materials for achieving maximum Z. As yet, theory has not been able to predict the maximum limit of Z or the material which would best produce it. The $Z \triangle T$ of the materials used today are shown in Table II. A $Z \triangle T$ of 1 would be considered quite useful today. The cold temperature is assumed to be 150°C; however, in space applications where a higher radiator (cold) temperature is required, the best results are achieved by the higher temperature materials (e.g., silicon-germanium).

Besides a maximum in $Z \triangle T$ for efficiency, reliability is important, since the materials must operate at high temperature. Until 1962, the tellurides, especially lead telluride, were the most widely used materials for thermoelectric power generation in spite of some extreme difficulties, such as high volatilization, contacting problems, and poor material strength. With the discovery of the thermoelectric properties of germanium-silicon alloy at RCA Laboratories in 1962, the situation quickly changed, germanium-silicon can operate at considerably

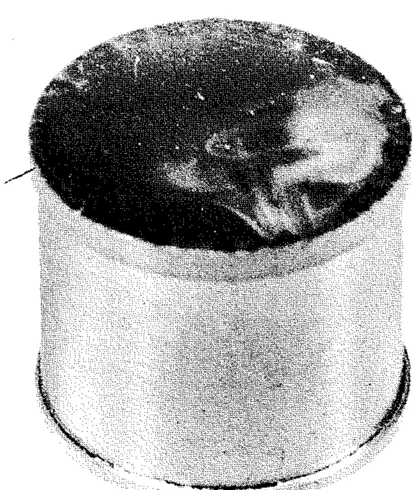


Fig. 4—Si-Ge thermoelement with tungsten contacts.

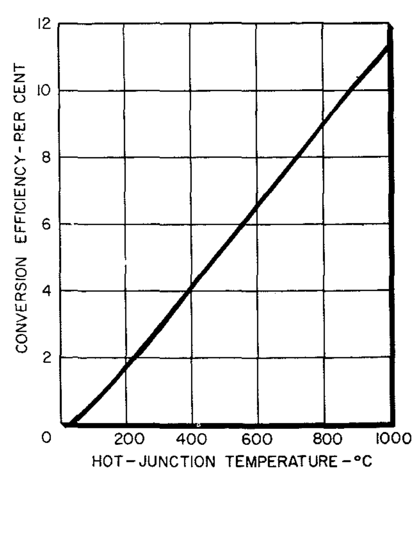


Fig. 5—Energy conversion efficiency of Si-Ge alloys.

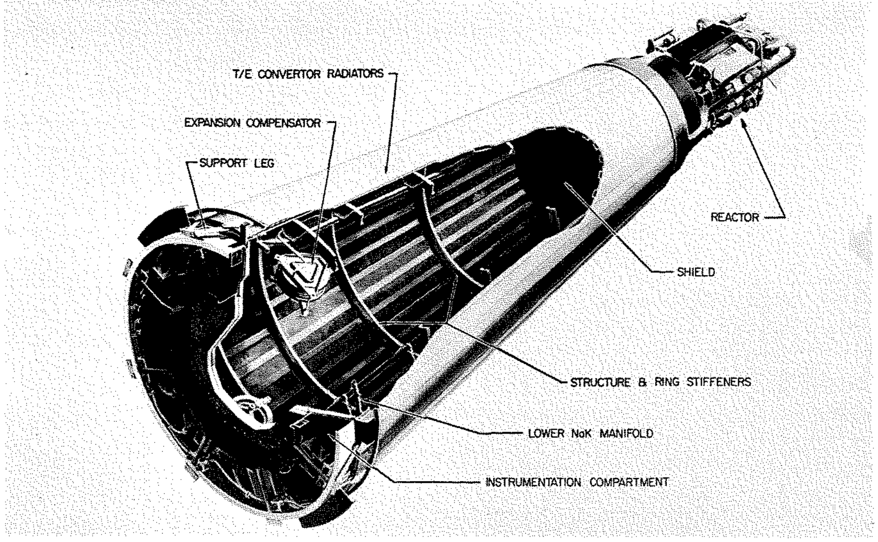


Fig. 6—SNAP-10-A atomic power unit.

higher temperatures has no volatile constituents, can be contacted permanently and has about five times the fracture strength of lead telluride.

Fig. 4 shows a photograph of a germanium-silicon element with permanent tungsten contacts—the geometry used for space applications. The curve in Fig. 5 shows the percent conversion efficiency as a function of temperature for a cold temperature of 25°C. The thermoelectric materials can be stacked together to take advantage of the fact that Z is greatest in different materials at different temperatures. Thus, a three-stage generator is possible using bismuth telluride, lead telluride, and germanium-silicon with transition temperatures at about 200°C and 500°C. Such a device could possibly provide efficiencies in the 15% to 17% range.

Thermoelectric generators are of interest for converting heat from fossil fuels, reactors, and isotope sources. Systems capability can range from milliwatts to kilowatts. Such systems can be portable and can be used in unattended operation for long periods under severe environmental conditions.

Thermoelectric generating systems that use fossil fuels, such as gasoline and propane, are operating today in a number of specialized terrestrial applications. Many new systems are being designed for both military and industrial applications, where the more conventional power generators are either unsatisfactory or unavailable. Radioisotope-thermoelectric power systems have been constructed for a variety of uses and a number of such systems

Table II—Thermoelectric Materials

Material	Max. Useful Temp. °C	Z (avg) $10^{-3}/°C$	$Z\Delta T$
BiTe	250	1.8	0.18
CeS	1,200	0.2	0.21
PbSnTe	550	1.0	0.40
PbTe	600	1.0	0.45
SiGe	1,000	0.6	0.51
AgSbTe	600	1.5	0.68

(SNAP-3 and 9A, developed by the Nuclear Division of the Martin Company for the AEC) have successfully operated in space environments. More advanced radioisotope-thermoelectric systems, using germanium-silicon for both space and terrestrial requirements, are now under development by RCA in the ECD Direct Energy Conversion Dept., Harrison, N.J.

The largest program to date to use thermoelectrics is SNAP-10A. This is a 500-watt system where the heat energy is generated by a compact reactor and the electrical energy by a large number of germanium-silicon thermoelectric elements. This system is being developed by the Atomics International Division of North American Aviation for the Atomic Energy Commission.

RCA's Direct Energy Conversion Dept. at Harrison developed and produced the germanium-silicon thermoelectric converter modules.[1] After extensive testing, the SNAP-10A was launched April 3, 1965, into a 700-nautical-mile circular orbit. The system functioned as planned with the generator developing about 570 watts. This has been a major space accomplishment, demonstrating the feasibility of reactor start-up in space and the feasibility of thermoelectrics for reactor energy conversion. The SNAP-10A operation ceased after 43 days in orbit because of reactor shut down. A cutaway drawing of the SNAP-10A reactor thermoelectric unit is shown in Fig. 6.

The use of thermoelectrics in radioisotope-thermoelectric systems appears to be promising for space and terrestrial applications. The power level of these devices is limited because of the large amount of isotope required. For example, a 100-watt generator would require about 500,000 curies of strontium-90 isotope, assuming a 5% conversion efficiency. Isotopes are also expensive; therefore, widespread use is not probable. Shielding requirements cause increase in weight; however, alpha emitters like plutonium-238, while very expensive, require much less shielding. A number of isotope systems are under development by the AEC (such as SNAP-9, 13, and 17A). For space applications, possible advantages of radioisotope-thermoelectrics over solar cells is that storage battery requirements are much less severe, and there would be little or no sensitivity to radiation belts. Deep space probes (away from the sun) would be more practical with radioisotope-thermoelectric systems.

For terrestrial use in military and special industrial requirements, fossil-fuel thermoelectric generators seem ideally suited. Such generators are most often considered where conventional power is not available and where portable sources of electric energy such as batteries and motor-generator sets prove unsuitable. Battery power systems have been beset by problems such as weight, shelf life, operating life, and poor resistance to adverse ambient environments. Although large motor-generator sets (2 to 10 kW) are capable of significantly better efficiencies than

Fig. 7—RCA fossil-fueled thermoelectric test generator.

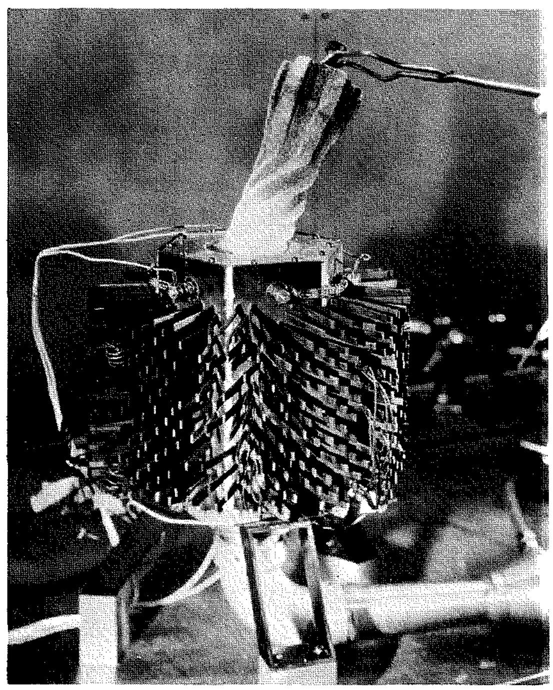
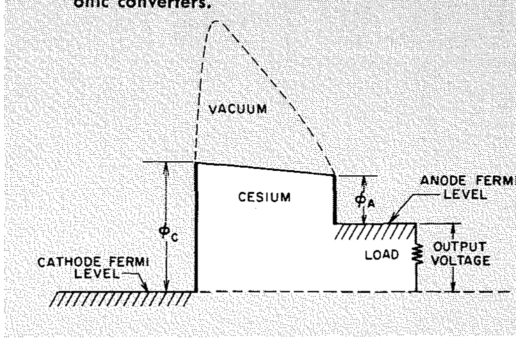


Fig. 8—Potential energy diagram for thermionic converters.



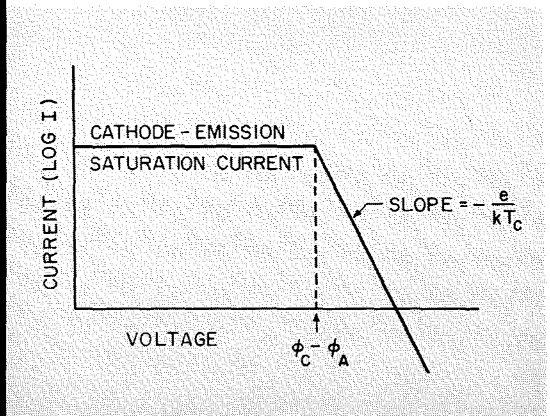


Fig. 9—Idealized V-A characteristic for thermionic converter.

present day thermoelectric generators, the efficiency of motor-generator sets decreases rapidly as the power ratings decrease. As a result, in the power range below 500 watts, the efficiency of thermoelectric generators becomes quite competitive. Also, thermoelectric generators, which have no moving parts, are capable of long periods of unattended silent operation.

An RCA-built 50-W fossil-fuel thermoelectric generator[2] made of special oxidation-resistant germanium-silicon AIRVAC modules is shown in Fig. 7. Such modules have shown excellent life-test results. Free convection cooling fins can be seen extending radially from the generator. The propane burner shown was developed specifically for this application.

THERMIONIC ENERGY CONVERSION

The thermionic energy converter is an electron tube capable of efficient conversion of heat into electrical energy, using solar, nuclear, or fossil fuel heat sources. It operates on the same principle as the thermoelectric converter; its higher efficiency results partially because it operates at temperatures up to 2,000°C or more, thus giving a higher Carnot efficiency.

When heat is applied to the diode cathode, electrons are emitted by thermionic emission, and are collected at the anode. The voltage developed depends on the difference in work function of the cathode and anode minus any arc drop that occurs between these electrodes.

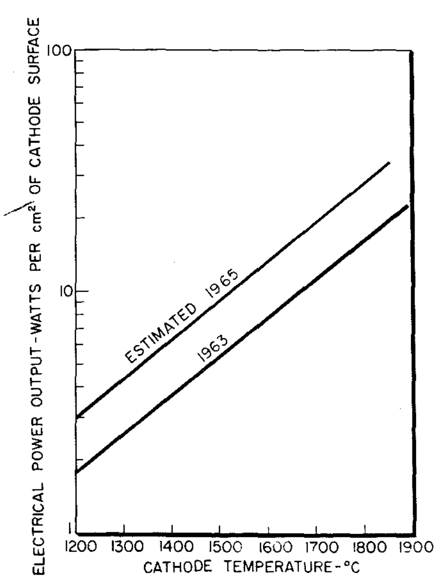
To avoid the problems of generating large currents in a diode, a plasma medium is used to neutralize the space charge. Cesium is used for this purpose since it has the lowest ionization potential of any suitable gaseous material. With the use of cesium, it is possible to draw currents as large as the cathode can stand, typically up to 20 amps/cm^2.

Fig. 8 shows the potential energy diagram of a thermionic converter. The dotted line shows the condition that would prevail if no cesium were added. To achieve efficient operation, the anode would have to be placed at or to the left of the maximum in the diagram, which corresponds to a few micrometers spacing—*not* a very practical solution. Under the conditions shown by the black line, where cesium is added, spacing usually is not critical.

Cesium performs another function in the converter in that it can set the surface work function of both cathode and anode. This is a function of the temperature of the converter. For example, an anode at 600°C would be completely covered by cesium and have a work function of 1.8 eV, while a cathode at 1,200°C would have a partial coverage of cesium (cesium pressure of 1 mmHg) and exhibit a work function of 2.3 eV or a difference of 0.5 volt. Since the cesium coating of the surfaces results from a dynamic equilibrium between the cesium in the gas and the surface, another advantage of cesium is obvious, namely that the surfaces have infinite life as long as the cesium is present. A possible disadvantage of cesium is its corrosive nature, especially at high temperatures. Much work has been done to find materials that are compatible with cesium, and indications are that this problem is solved.

Fig. 9 shows a current-voltage characteristic of a thermionic converter under idealized conditions. This characteristic is a good approximation to the high-temperature, low-cesium-pressure operating mode where the ionization takes place by surface contact ionization. This device requires a high-work-function cathode, and very little energy is used for generation of ions. However, when low temperature (1,350°C) operation is desired and the cesium pressure is increased so that the arc mode or ball-of-fire discharge is obtained, there is considerable arc drop and the *I-V* characteristic becomes distorted from that shown in the figure. Fig. 10 shows the state-of-the-art of power density versus temperature. At 1,600°C, power densities over 12 W/cm^2 have been achieved at an efficiency of about 20%. The efficiency of thermionic converters has been measured to be as high as 25%.

Fig. 10—State-of-the-art performance of thermionic converters.



A great potential advantage of a thermionic system in space is light weight. This results because of the high temperature anode and, hence, smaller radiator required. The anode upper temperature is limited by back electron emission. In practice, this temperature may be in the range of 500°C to 800°C. This high anode temperature may also be useful for cascading with other energy converters whose operating temperatures are in the range of the thermionic anode.

A nuclear reactor is one of the ideal heat sources for thermionic converters. Present-day power plants use coal or nuclear fuel to produce heat to boil water; the generated steam is then used to drive turbines which in turn activate generators to produce electricity. A large amount of auxiliary equipment in the form of boilers, pumps, heaters, preheaters, condensers, and turbines is required. In time, all this equipment may be replaced with a thermionic nuclear reactor which can utilize the heat the reactor is capable of generating at a very high energy level, and convert it directly into electricity without moving parts, noise, or auxiliary equipment and with a minimum of maintenance. The thermionic converters may be placed inside or outside the reactor. If they are inside, the fuel may either be used as the cathode itself or the cathode may be indirectly heated by the fuel. If they are outside the reactor, the converters may be arranged at the periphery of the reactor or they may be heated from liquid metal in an external loop similar to the SNAP-10A system. The specific method chosen will depend upon the final application.

Fig. 11 shows a converter designed for in-core operation. This RCA converter, designed at the ECD Special Electronic Components Division, Lan-

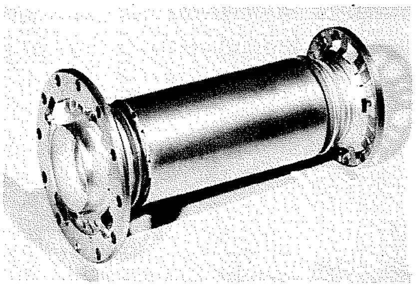


Fig. 11—Thermioni converter for operation in nuclear reactor.

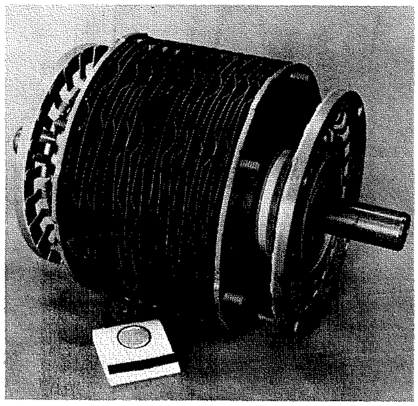


Fig. 12—Thermionic converter for operation in external loop.

caster, Pa., produces 150 W, and has run successfully for 310 hours in a reactor. Many of these converters connected together could be used in a nuclear reactor power system which could produce power of a megawatt or more.

Fig. 12 shows a converter heated by liquid metal in an external loop of a reactor system. This converter is designed to deliver 80 W, and has operated successfully on a liquid-lithium loop in a simulated space environment. Fig. 13 shows a systems concept of this type.

Because of the inherent low cost and high efficiency of thermionics, the concept of a fossil fuel converter is quite interesting. Several companies have developed fossil-fuel burners to work in air above 1,200°C with burning efficiencies over 50%. Fossil-fuel converters require a barrier around the metallic cathode to prevent unburned combustion products, such as hydrogen, from penetrating into the plasma region. Various ceramics have been successfully used for this purpose, with the added complication that the converter becomes more fragile and less able to withstand temperature cycling associated with start ups. This problem, however, seems soluble and should not limit the fossil fuel application. The RCA Lancaster group has recently completed a successful 1,000-hour life test on a converter using an aluminum oxide barrier.

The thermionic converter is a low-voltage, high-current device, and some form of power conditioning is required. Tunnel diodes can be used as high efficiency inverters for this purpose. Another solution to this problem is to construct converters that are integrally connected in series to fit one heat source. The cathode of one converter is connected to the anode of the next, and so forth. Fig. 14 shows a three-converter module. A special insulator technique had to be developed for this purpose. Using this same approach, the stacking of many converters in series would seem practical.

While the feasibility of the thermionic converter has been established for a large number of applications, the question of reliability still has to be proven. Converters have been operated by various organizations for 2,000 to 5,000 hours of life, and steady improvement is being achieved.

HOW CLOSE ARE PRACTICAL APPLICATIONS?

When can these devices be expected to come into real use? Three important factors are: *1*) the time it takes for the device to achieve operational reliability, *2*) how urgent is the need, and *3*) the cost.

Table III provides a very rough guess as to when a use will come into existence and what the price has to be for the use described. The cost level of $1 to $10 a watt is not far from reality at the present time. The cost of 10¢ a watt or less is a distance off. If the governmental need for very large-area solar cells is urgent enough to put several companies into the production business, a very low cost could result, since the film-type cells are definitely suited to a mass production technique. It is interesting to note the pattern; first governmental need and expenditure, then reduction in cost and improvement in reliability, and finally consumer use. It happens in other industries (especially aviation) and it can happen in electronics.

When will the various energy conversion systems become operational and when will widespread use be seen? Applying the crystal ball again, gives Table IV. The information is presented only for perspective. The fact that almost all are predicted for widespread use has to be somewhat tempered by the definition of *widespread.*

Table III—Factors Required for Utilization of Direct Energy Conversion

Customer	Application	Initial Equip. cost per watt*
Government	Space Military	$1000
Military and Industrial	Special Purpose	$10-100
Consumer	Auxiliary Power Boats Appliances	$1
Under-Developed Countries	Water Pumping Lighting Appliances	10c

* not including fuel costs

Table IV—Possible Time of Use for Energy Converters

	Operational	Widespread Use
1960–1970	Solar cells Thermoelectric Solar Dynamic Thermionic (fossil fuel)	Thermoelectric
1970–1980	Fuel cell (fossil fuel) Thermionic (reactor)	Solar cells (large area) Fuel cell (fossil)
1980–1990	Magnetohydro-dynamics	Thermionic (reactor)
1990–		Magnetohydro-dynamics

There is little doubt that we are at the beginning of a transformation in our electrical energy sources and that those who have the patience will see stand-by power sources in the homes that can afford them. This could be a thermoelectric, thermionic, or fuel-cell device. There will be homes that will be fed purely by fossil fuel, probably gas, with all the electricity coming from an energy-conversion device. The conventional central station power plant and automobile power plant still seem secure. However, with a technological breakthrough, no one can tell what role direct energy conversion will play in our future.

BIBLIOGRAPHY

1. L. J. Caprarola and W. J. Helwig, "Thermoelectrics for Space", in RCA reprint booklet *Direct Energy Conversion, PE-171,-172,-173,-174,* a collection of papers from RCA Engineer 9-3, Oct.-Nov. 1963.
2. W. F. Lawrence and Dr. A. G. F. Dingwall, "Fossil Fuel Thermoelectric Generators," *op. cit.*

Fig. 13—Reactor thermionic system using liquid lithium.

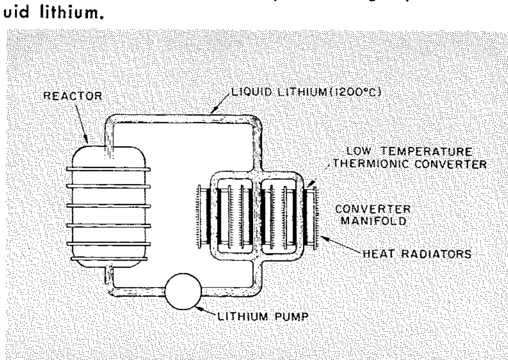
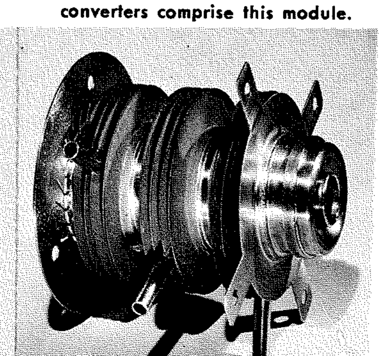


Fig. 14—Three series-connected converters comprise this module.



GRAPHIC AIDS FOR CONSOLE DESIGN

To provide maximum operating ease and efficiency, system operating and control consoles must be carefully designed with the operator's requirements in mind. Described herein is the application of anthropometric data to typical design problems; actual laboratory measurements are used to adjust existing Air Force data to provide a set of practical, easy-to-use design charts.

J. L. HANNA and DR. F. H. IRELAND, Mgr.

Human Factors Engineering

Systems Engineering, Evaluation and Research

DEP, Moorestown, N. J.

DESIGNERS frequently face the task of specifying exterior dimensions of control consoles based on operator requirements. Since such requirements depend upon the operator's tasks and the environmental conditions under which they are to be performed, a console designed for one application is often unsuitable for another.

Existing anthropometric (body measurement) tables and charts are of some help to the designer; but frequently, pertinent data are neither available nor in a form directly applicable to the design problem. This article presents relevant anthropometric data in a more usable form in order to simplify the console designer's task.

HYPOTHETICAL EXAMPLE

Consider a typical problem where the designer is told what types of control and display devices will be needed and approximately how many of each type. These devices are to be mounted on the console panel so that the operator seated at the console will be able to manipulate any control without standing up or moving his chair. Since the number of panel-mounted components is large, and because some extra space should always be left for future changes and additions, usable panel space must be maximized. Other requirements indicate that the panel should be tilted up from the horizontal, toward the operator, to improve his view of the displays; on the other hand, the console silhouette must be kept low enough to let the operator see a wall display located behind it. A narrow horizontal ledge on the front of the console is desirable as an elbow rest. Naturally, adequate knee clearance and leg room must be provided. The problem is to find the proper console dimensions that will satisfy these requirements and assure a good fit between the operator and his equipment.

Actually, the console should accommodate a rather large percentage (say 95%) of the particular population (e.g. Air Force personnel) from which operators are to be chosen. Its dimensions should therefore take into account the pertinent body measurements of these people. Such anthropometric data are available for various military as well as civilian groups. As will now be described, these data can be applied to operator equipment design.

Final manuscript received December 23, 1964

ANTHROPOMETRIC DATA

Table I lists some typical body measurements of Air Force personnel. The columns show 5th, 50th, and 95th percentile figures in inches. For example, 5% of the people sampled had a knee height of 20.1 inches or less; and for 50% and 95% of the population, the comparable dimensions were no greater than 21.7 and 23.3 inches, respectively.

Starting with the relatively simple problem of determining adequate vertical knee clearance for our console, here is how such information might be used: Since the 23.3-inch knee height for the corrected 95-percentile man does not take clothing dimensions into account, add perhaps 1.4 inches for heels. Thus, a vertical clearance of 24.7 (rounded to 25) inches will allow 95% of the population to get their legs beneath the console ledge without squirming. By applying appropriate corrections to the dimensions of the upper leg and the foot, and allowing for normal leg movement while sitting, one can similarly derive minimum acceptable values for the other leg-room dimensions.

CONSOLE HEIGHT

Another question for which the published data may be helpful is: *How tall can we make the console and still be sure that the operator can see the status board on the wall behind it?* Fig. 1 shows how to calculate the maximum allowable height of the upper console edge if one knows the vertical position of the board, the operator's height, and the distances from the operator's eyes to the wall display and to the upper console edge in question. To make sure that even a small (5th-percentile) operator can see the wall display, the 29.4-inch eye-height value is selected from Table I. To that, add the short operator's seat height (15.7 inches) corrected for heel height (approximately 1.4 inches), or approximately 17.1 inches. Eye level of a short operator, while sitting, will thus be about 46.5 inches above the floor. If the horizontal distance from the operator's eyes to the interfering upper console edge is known, the problem may

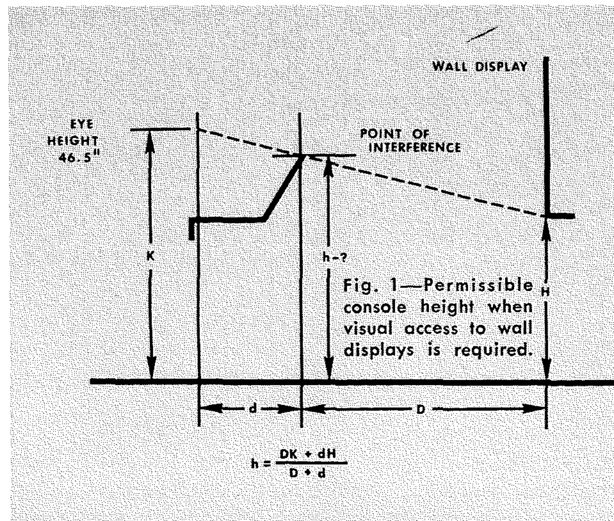


Fig. 1—Permissible console height when visual access to wall displays is required.

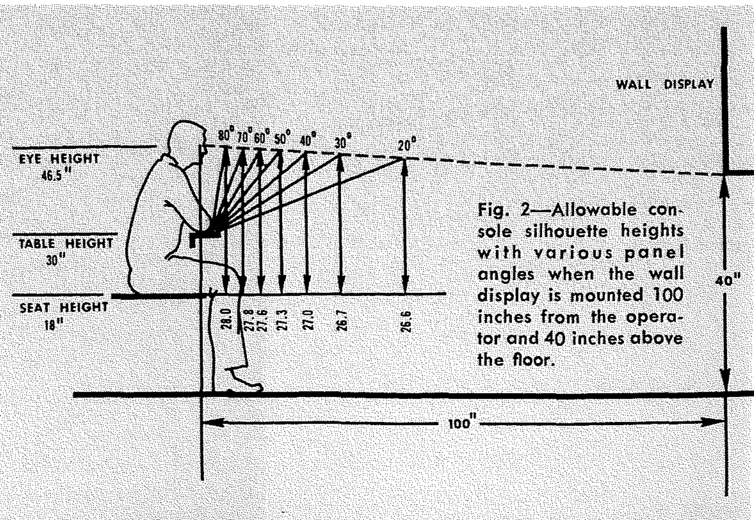


Fig. 2—Allowable console silhouette heights with various panel angles when the wall display is mounted 100 inches from the operator and 40 inches above the floor.

TABLE I—Typical Body Measurements of Air Force Personnel

	Measurement, inches		
	5th %	50th %	95th %
Height, sitting (seat to top of head)	33.8	36.0	38.0
Eye height, sitting (seat to eye level)	29.4	31.5	33.5
Shoulder height, sitting (seat to shoulder)	21.3	23.3	25.1
Elbow height, sitting (seat to elbow)	7.4	9.1	10.8
Buttock to knee length, sitting	21.9	23.6	25.4
Thigh height, sitting (seat to top of thigh)	4.8	5.6	6.5
Top of knee height, sitting	20.1	21.7	23.3
Popliteal height, sitting (i.e. floor to seat height)	15.7	17.0	18.2
Shoulder to elbow length	13.2	14.3	15.4
Forearm to hand length	17.6	18.9	20.2
Forward arm reach (shoulder to finger tip)	31.9	34.6	37.3
Shoulder breadth	16.5	17.9	19.4
Foot length	9.8	10.5	11.3
Waist depth (standing)	6.7	7.9	9.5

be solved as in Fig. 1. But if this distance is not established (and it usually isn't this early in the design) one can at least indicate a range of solutions for various panel angles as in the example of Fig. 2. For a specific solution, one must know the shelf depth, the vertical panel dimensions, and the panel slope. In other design problems where there it is no need to have the operator see behind the console, it might instead be necessary to determine how deep the shelf can be and still allow the operator to reach with ease all parts of a panel for which dimensions and inclination angle are given, or how far an operator can reach on panels tilted at 20°, 30°, or 45°. Finding the appropriate answers is an interesting problem and the principal reason for this article.

MAXIMIZING PANEL SPACE

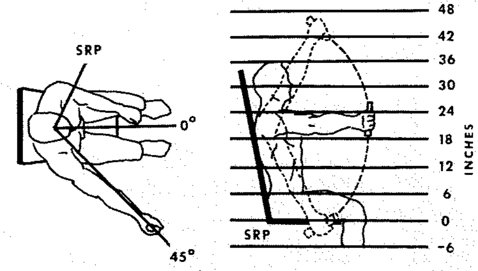
To get back to the hypothetical example, the objectives were to maximize the accessible component space on the panel, to maintain a low enough console silhouette for viewing the wall display, and to provide an elbow rest in the front. The emphasis here is on the word *accessible*, since a large, but *in*-accessible, panel would be useless to us.

First, assume fairly conventional values of 18 inches for seat height and 30 inches for the height of the console ledge (Fig. 2). Next, tentatively try a console ledge depth of 4 inches and draw the sloping visual cutoff line shown in Fig. 2. (Later, other values might be tested if either too little or too much panel space results.) With these parameters established, the next question is: *Which panel inclination angle will yield the greatest area of accessible panel space?* For this, information is needed on the reach capabilities, particularly of short operators.

Fig. 3 shows a sample of some of the more useful reach data for Air Force personnel.[1] The experimental conditions under which the measurements were obtained indicate that the information was intended primarily for cockpit designers. Subjects were seated in a standard Air Force aircraft seat with the backrest tilted 13° to the rear. They were asked to keep their shoulders against the backrest, extend the right arm as far as they comfortably could, and grasp a vertical control stick. Maximum reach was then measured horizontally from a vertical line through a seat reference point (SRP) located as shown in Fig. 3. Readings were taken at each of ten vertical locations for ten angles to the right of the vertical midplane. The sample data in Fig. 3 pertain to reach distances measured 45° to the side. Similar data are available for nine other angles including the 0°; or arm-straight-ahead case.

UTILIZING DATA

Though these are probably the best data available at the moment, they are *not* too useful without considerable extrapolation. A console operator generally is not rigidly constrained as were the subjects of the Air Force study; he can usually lean forward and to the sides as well as turn his shoulders to increase his reach. It would be helpful



Height Above SRP (in.)	Percentiles (in.) 5th	50th	95th
0	16.0	19.0	22.4
6	22.4	24.5	27.3
12	24.9	27.5	29.7
18	26.9	29.0	31.2
24	26.4	29.5	31.1
30	26.4	28.4	30.6
36	22.4	25.5	28.1
42	16.0	22.0	24.5
48		15.0	18.2

Fig. 3—Functional arm reach (sitting) 45 degrees from the midplane of the body.

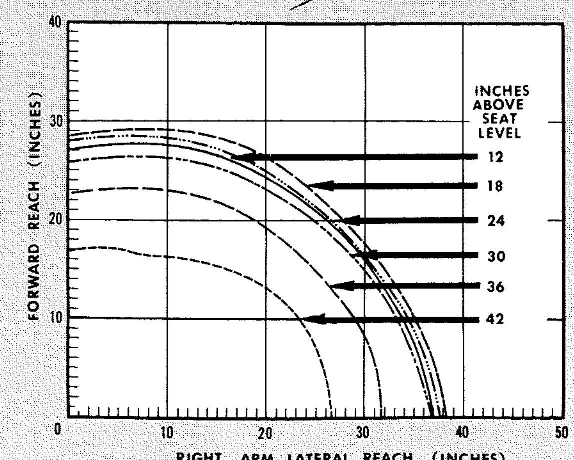
to have reach information for operators free to move in this way, but unfortunately, this does not seem to be available as yet—at least not for an adequate population sample nor for sufficient points in space to define the maximum reach envelope. Another problem with presenting data as in Fig. 3 is that a console designer cannot readily visualize operator reach profiles on panel planes that cut through the reach envelope at various angles and locations.

As will now be discussed, the cockpit design data can be made usable for console design by first cautiously extrapolating the information and then presenting the results in a more readily interpretable form.

PRACTICAL INTERPRETATION OF DATA

In place of the seating arrangement depicted in Fig. 3, consider one that is more appropriate for a console operator: instead of tilting the man 13° to the rear, *let him lean forward 13° toward his console*. In testing short (near-5th-percentile) subjects bent forward in this manner, their reach distances were found to approximate quite closely those obtained for the 5th-percentile Air Force personnel mentioned earlier, provided such measurements were taken from a vertical through the center of the subject's head instead of from one located above the rear edge of the seat as shown in Fig. 3. When a short operator sits close to his console and leans forward in the manner just described, the imaginary vertical through the center of his head will also be found to coincide approximately with the leading edge of the console shelf (see Fig. 2). This sim-

Fig. 4—Seated operator's unrestrained reach limits in horizontal planes located at 6-inch intervals between 12 and 42 inches above seat level.



plifies the subsequent determination of his reach profiles on console panels.

Letting the operator lean forward in this manner puts him in a somewhat more natural position for viewing the displays and manipulating the controls. But additional information is needed which defines the reach envelope of an operator free to increase his reach by moving his shoulders, and by stretching and flexing his torso. Individuals were therefore tested to determine the extent to which such freedom of body movement would increase their reach. It was found, for example, that in a horizontal plane 12 inches above the seat, a short (5th-percentile) operator could extend his forward reach by about 7 inches and his reach to the side by almost 9 inches. At 30 inches above seat level, his additional reach capabilities were 5.5 and 7.5 inches, respectively.

PRACTICAL REACH PROFILES

The values thus obtained were used to adjust the earlier data on Air Force Personnel whose body motions had been quite restricted. The resulting reach envelopes for console operators free to move the upper parts of their body in a natural manner were used to derive the reach profiles in various horizontal planes presented in Fig. 4. They also served as a basis for the reach profiles presented in Figs. 5 through 8, which are of greater interest to console designers. The latter curves define the different panel areas readily accessible to the operator as the depth of the console ledge is increased and the panel inclination angle is varied. The curves are for short (5th-percentile) operators and a console shelf, or lower panel edge, located 12 inches above seat level; a seat of 18 inches thus implies a shelf height of 30 inches above the floor.

HOW PROFILES WERE OBTAINED

The previously discussed Air Force anthropometric measurements pertained to operator reach profiles in planes through the vertical above the seat reference point and oriented 0°, 15°, 30°, 45°, 60°, 75°, and 90° relative to the vertical midplane of the subjects. As mentioned, Fig. 3 shows the 45° case. Data for the 5th-percentile subjects were used to construct reach profiles in horizontal planes located at regular 6-inch vertical intervals, starting 12 inches above the seat level. The latter profiles were then adjusted to reflect the additional reach capability of an operator free to twist and bend his torso while keeping his chair in place. Fig. 4 shows the curves obtained in this manner. The solid curve for a plane 12 inches above the seat level defines the maximum reach of a short operator on a horizontal table surface. Next, points were found at which these curves would be intersected by panels of different slopes and located at various shelf depths in front of the operator. These points were then replotted to form the graphs of Figs. 5 through 8 representing the console panel planes. Only the right halves of such planes are shown, since the left-hand reach profiles are assumed to mirror-image the right. Each graph shows the reach limits on the panels which, except for the 0° incline case of Fig. 4, are all tilted upward toward the operator. The different curves in each figure are labeled to show the console shelf, or ledge, depths to which they pertain. Scales along the left hand and lower margins of each graph reflect distances, in inches measured in the panel plane. The right-hand scale shows elevation, in inches, above seat level.

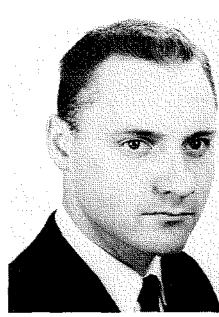
USE OF PROFILES

The graphs can be used to solve the hypothetical design problem presented earlier and some other typical ones. Recall that the hypothetical problem postulated a narrow console ledge, which we tentatively assumed to be 4 inches deep, and a console silhouette height that would allow a short operator to see a wall display mounted behind the console (Fig. 2). Assuming that the panel is rectangular and that all points on it must lie within easy reach of the operator, the objective is to find a panel angle that will result in the maximum usable panel area. Fig. 2 reveals that for a panel angle of 50°, the upper edge of the console should not be more than about 45.3 inches above the ground or 27.3 inches above the 18-inch seat level. In Fig. 6b (50° slope), a dotted horizontal line corresponds to this 27.3-inch height (right-hand scale in Fig. 6b). The intersection of this line with the 4-inch (console ledge depth) curve defines the upper right-hand corner of the panel; the dotted vertical to this point indicates the right-hand edge of the panel. The rectangular area thus defined on the graph contains approximately 580 square inches. Total panel area is twice this value, or 1,160 square inches, since the graph represents only the right-hand portion of the panels.

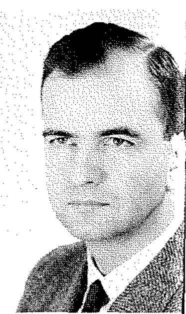
Applying the same procedure to other panel inclinations shows that the accessible panel space would be less (1,100 square inches for 40°, 1,145 square inches for 60°). Thus, a panel inclination near 50° should best meet the criteria. It should be noted that this example did *not* stipulate optimizing the viewing angle or eye-to-panel distance. It may be desirable to compromise the usable panel space somewhat by changing the panel angle or the shelf depth to achieve better viewing conditions.

As another example, assume that a 15-by-40-inch panel is to be mounted on a console at an angle of 30° from the horizontal. *What is the maximum shelf depth that will still allow an operator to reach every part of the panel?* Fig. 5b shows the answer to be a shelf depth of slightly more than 12 inches.

A console designer will find numerous other uses for these graphs in connection with his own problems.



J. L. HANNA



DR. F. H. IRELAND

JAMES L. HANNA received his BS in Industrial Design in 1960 from the Georgia Institute of Technology. He joined RCA in 1962 after serving two years in the Army as an Air Defense Artillery Officer. As a member of the Human Factors Engineering team of SEER, DEP's System Engineering, Evaluation and Research organization, he has worked on the BMEWS and AADS-70 projects and on several man-machine system studies and proposals. He specializes in the design of display and operator control equipment.

DR. FRED H. IRELAND received his BS (1948), MA (1949) and PhD (1955) in Experimental Psychology from Fordham University. From 1950 to 1952 he was Senior Research Associate with the human factors consulting firm of Dunlap and Associates where he worked on the Terrier Land Based Fire Control System, various mobile radar units and on a submarine fire control project. He then spent two years as a Research Psychologist with the N.Y. State Psychiatric Institute. In 1955 he joined RCA. As Manager of the Moorestown Human Factors Engineering activity he directed the human engineering efforts for TALOS, for the Atlas Launch Control and Checkout System and for BMEWS. He also held an appointment of human factors consultant with the HQ. USAF Directorate of Installations. For an eighteen month period, starting early in 1962, he held the position of Assistant Director for Information and Control Systems and Human Factors in NASA's Office of Manned Space Flight. Since rejoining RCA in 1963 he has been manager of Command Systems and Human Factors in DEP's Systems Engineering, Evaluation and Research (SEER) activity. He holds membership in IEEE, APA, and Sigma Xi.

BIBLIOGRAPHY

1. Morgan, Cook, Chapanis, and Lund, *Human Engineering Guide to Equipment Design.* McGraw-Hill Book Company, 1963 (Used by permission.)

Fig. 5—Reach profiles for 20° and 30° panel slopes.

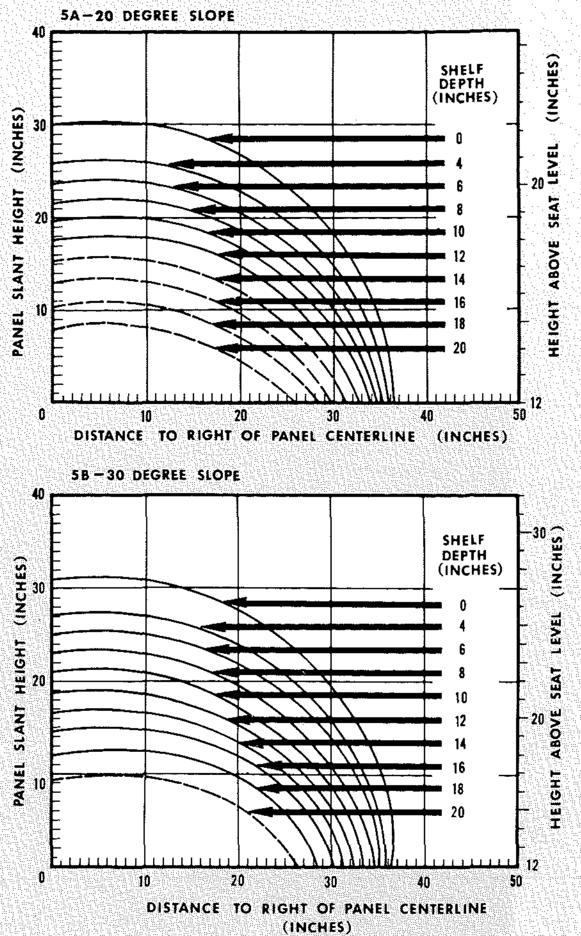
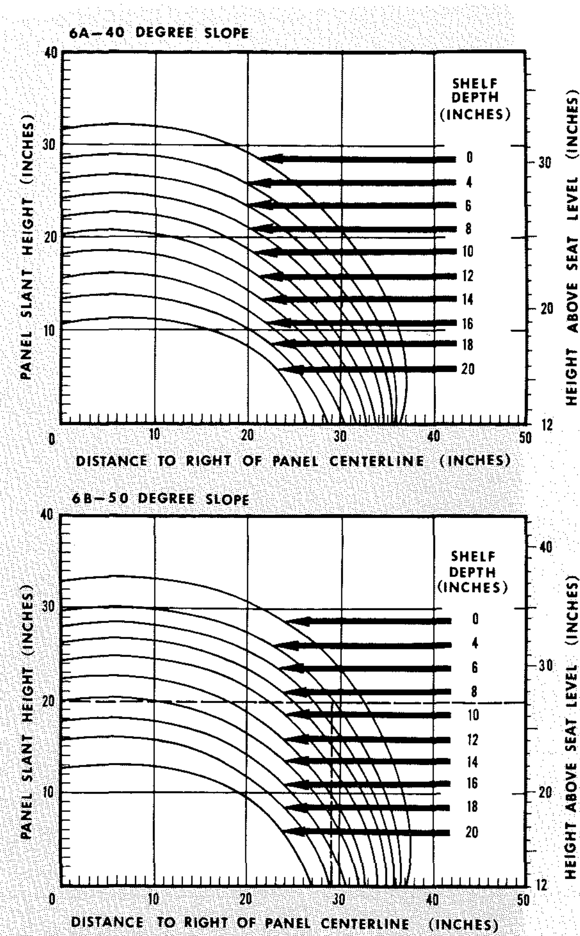


Fig. 6—Reach profiles for 40° and 50° panel slopes.



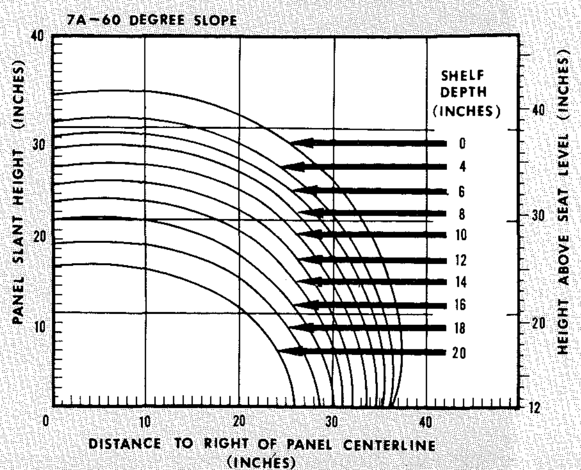


Fig. 7—Reach profiles for 60° and 70° panel slopes.

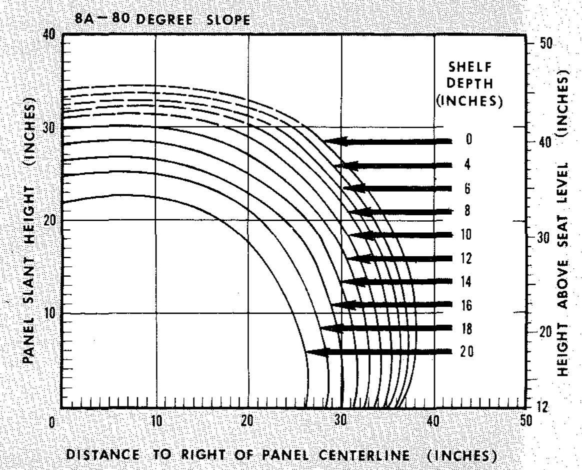
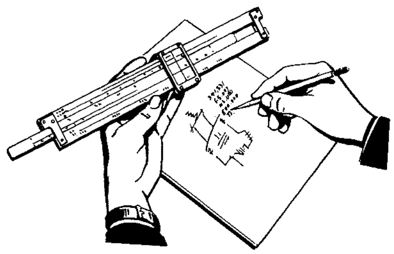


Fig. 8—Reach profiles for 80° and 90° panel slopes.

Engineering and Research NOTES

BRIEF TECHNICAL PAPERS OF CURRENT INTEREST



Bibliography of Papers Presented at the RCA "Symposium on Computer Applications in Engineering and Research"

H. Kihn
*Research and Engineering,
Princeton, N. J.*

Final manuscript received July 6, 1965

To emphasize the increasing importance of computers in the solution of engineering problems and to bring to the attention of potential users of methods and computer programs which have already been developed by RCA, a corporate-wide symposium was conducted recently on *"Computer Applications in Engineering and Research."* The considerable saving in time and reduction in cost of engineering projects by the use of computers is made evident in the papers presented at the symposium and listed below.

Because the limitation of a one-day session prevented the inclusion of many important areas dealing with the solution of problems in engineering and manufacturing by the use of computers, another similar symposium is being considered for late 1965. This could also provide opportunity for presentation of activities of which the symposium committee was not aware in planning this first meeting.

Symposium attendance consisted of RCA engineers and managers who it was felt could directly benefit from the program. But since this material is of great potential importance and interest, a *Symposium Proceedings* containing the complete papers is to be available in RCA Technical Libraries, for the general reference of the entire RCA technical staff. *(Note that the content of these papers is at this time restricted to the RCA technical staff only.)*

If the *Symposium Proceedings* is not available in your RCA Technical Library, contact RCA Staff Technical Publications, Bldg. 2-8, Camden, N.J., (PC-3396 or PC-4018).

The Chairman of the Symposium (Harry Kihn, Corporate Staff, Research and Engineering, Princeton, N.J.) may be contacted for further information on this symposium, or on future symposiums in this field.

The papers, presented in the four sessions noted, are:

Session I: Circuit Analysis and Synthesis

1. F. M. Brock (BCD, Camden), **Computers as Engineering Tools for Filter and Network Design**
2. R. L. Crane (RCA Labs., Pr.), **An RCA 601 Subroutine for Synthesis and Analysis of All-Pass Delay Equalizers**
3. R. E. Turkington (DEP-ASD, Burl.), **Circuit Analysis for Piece-Part Fault Isolation**
4. T. G. Marshall (DEP-AED, Pr.), **Ladder Network Synthesis by Matrix Transformation**
5. W. B. Schaming (DEP-AppRes., Camden), **Recursive Techniques in Transient Analysis**

Session II: Component Design

6. P. J. Musso (ECD, Hr.), **Receiving Tube Heater Drum Design**
7. G. P. Kirkpatrick (ECD, Hr), **Design of Solar Cells**
8. H. E. Kulsrud (RCA Labs., Pr.), **An Electron Optics Programming System**
9. H. R. Krall and J. F. Parker (ECD, Lanc.), **Multiplier Phototube Data and Crystal Matching**
10. I. Pessin (DEP-AED, Pr.), **Spacecraft Solar Power Supply Design**
11. F. Herzfeld (RCA Labs., Pr.), **Computer Solution of the Interface Between Design and Fabrication**

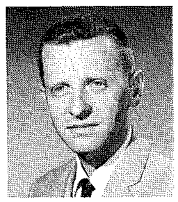
Session III: Simulation of Systems and Signal Processing

12. I. H. Sublette (RCA Labs., Pr.), **Automatic Classification of Patterns by Computer**
13. R. H. Goerss and J. R. Owens (DEP-AED, Pr.), **Computer Simulation of Thermal Behavior of Space Systems**
14. R. F. Pavley (DEP-MSR, Mrstn.), **Waveforms Synthesis and Analysis for Radar**
15. J. Oseas (DEP-MSR, Mrstn.), **A Space Track Program**
16. M. S. Corrington (DEP-AppRes., Camden), **Computer Simulation of Communications Systems**
17. J. A. Goodman (RCA Labs., Pr.), **PRETEND, A Program to Aid in System Simulation**

Session IV. Automated Design, Check-out and Automated Proposal Preparation

18. W. W. O'Neill and G. Smoliar (EDP, Camden), **Design Automation for Computer Printed Interconnections**
19. T. C. Hilinski (DEP-CSD, Camden), **Fact Retrieval and Processing for Computer Generation of Proposal Data**
20. J. Rankin (RCA Svc. Co., Cherry Hill), **Automatic Processor for Electronic Systems Testing**
21. N. A. MacInnes (DEP-ASD, Van Nuys), **RCA 110A Saturn Ground Computer Checkout**
22. O. I. Carver (DEP-ASD, Burl.), **Automatic Test Equipment Checkout (MTE & DIMATE)**
23. J. Oseas (DEP-MSR, Mrstn.), **Automatic Monitoring and System Checkout (BMEWS)**

Breadboard Technique for Integrated Circuits uses Universal Logic Board



W. Blackman, *Communications Systems Division,
Camden, N. J.*

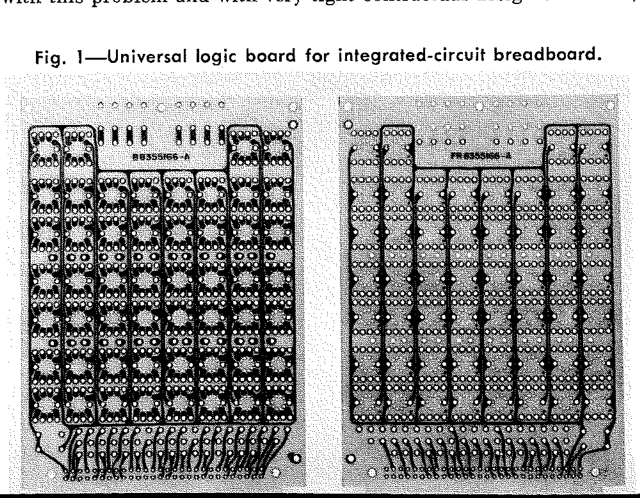
Final manuscript received May 26, 1965

To realize the advantages of integrated circuits in a given equipment design often requires a customized, unique packaging approach, in spite of attempts at standardization.

This *Note* describes how a degree of standardization can be achieved in the breadboard stage, with specific developmental cost savings on quick-reaction commercial or Mil-Spec equipment.

Two-sided boards provide printed voltage distribution lines in conjunction with wire-wrap termination pins for all logic interconnections. Figs. 1a and 1b show such a universal logic board which allows complete control plus rapid repairability of the basic board—to incorporate customer-directed changes and correct basic wiring errors. Using this technique in the breadboard stage can save money by delaying fabrication of final-type multilayer boards until the designs are firm. This approach is representative of the ultimate grouping and density of the integrated circuits, which allows realistic breadboards so that troubles can be corrected (noise, crosstalk, line loss, etc.) prior to final design. Confronted with this problem and with very tight contractual design schedules,

Fig. 1—Universal logic board for integrated-circuit breadboard.



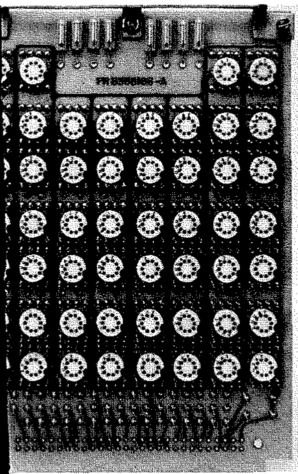


Fig. 2—Standard grid.

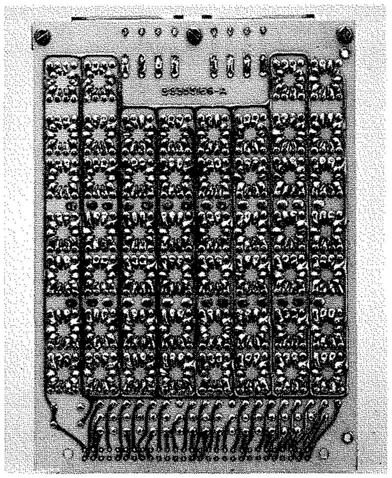


Fig. 3—Board preparation.

we developed the following technique. It is versatile, inexpensive and sufficiently flexible to accept almost any change required whether early in the design or even late in the debugging phase.

The initial pattern was established along the standard 0.025-inch RCA grid pattern for printed boards (Fig. 2). It is a 7 x 8 matrix, with four patterns eliminated at the top for 8 card test points. In the follow-up board pattern the individual test points were changed to test-point connectors (described later) and the maximum number of 56 units were now available for the functional board design. The front surface contains a printed ground distribution and voltage bus. The rear surface contains the second voltage bus and a second (redundant) ground bus tied via plated-through holes to the front surface ground. Since three leads at each device pattern are connected to these bus systems, only the seven remaining leads must be interwired on the breadboard. The interwiring is done on pins pressed into the front face of the printed board and interconnected to the far side via plated-through holes. The use of plated-through holes is not absolutely necessary, but does add reliability. The pins may be made round (as a screw-machine part) suitable for solder connections or square which lends itself to wire-wrapping techniques. Finally, the integrated circuit sockets and connector are assembled and the completed board dip-soldered (Fig. 3). The board is now ready for interconnection wiring and the pin pattern (Fig. 4) makes available tube-socket approach to wiring, plus providing a spare pin for each integrated circuit group. The use of 28-gauge solid wire for wrapping requires a minimum pin height of ⅜ inch above the board to insure the allowance for two wraps. The individual pins may be replaced up to five times in the same hole and still retain the minimum required retention force (this holding force is based upon the interference fit of the pins-to-holes and does not take into account the added strength of the solder dip added later in the assembly. Further, the use of integrated-circuit sockets is not mandatory and if cost is a factor, may easily be eliminated. As seen in Figs. 1 and 3, the rear board pattern has been designed to provide an offset mounting hole for the socket or integrated circuit, and the removal of either part is accomplished by lifting the leads with a small iron and merely pulling the unit out with a common tool or by hand. Fig. 4 illustrates the first board assembled to this design; note that of the 52 available integrated circuit locations, 50 were used, with the wire density negligible.

Board test points are made available by the use of two connectors, secured to the top of the board assembly and protected there by the handle. Two such connectors were used in the final design, making 16 test-probe connection points available for fault isolation (Fig. 5).

g. 4—"Tube-socket" approach.

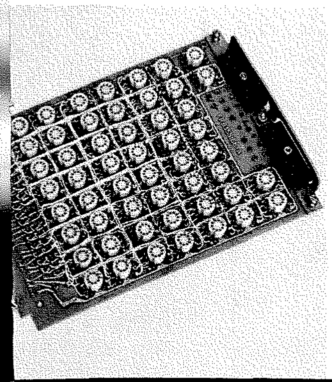
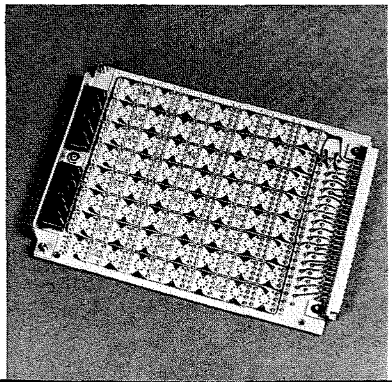


Fig. 5—The 16 test-probe points.



Cross-Pumped Cr^{3+}-Nd^{3+}: YAG Laser System[1]

Z. J. Kiss *and* R. C. Duncan,
RCA Laboratories,
Princeton, N. J.

Final manuscript received June 14, 1965

One severe limitation on the efficiency of optically pumped solid lasers has been the lack of suitable absorption bands associated with the active impurity ion, usually a rare earth, to match the spectral output of commercially available high power lamps. This difficulty could be overcome by the addition of a second impurity with more suitable absorption bands if the energy so absorbed were efficiently transferred to the impurity responsible for the laser action. We have observed such energy transfer and demonstrated both "cross-pumped" laser action and increased efficiency in the neodymium-doped yttrium aluminum garnet (Nd^{3+}: YAG) laser system[2] with chromium (C^{3+}) as the second impurity.[3]

The cross-pumping is illustrated in Fig. 1 where the Nd^{3+} excitation spectrum, i.e., the fluorescent intensity at 1.06 micrometers, the laser wavelength, as a function of the wavelength of the pumping light, is shown for Nd^{3+}-doped YAG (Fig. 1a) and doubly doped Cr^{3+}-Nd^{3+}: YAG (Fig. 1b). The absorption of YAG doped with Cr^{3+} alone is shown in Fig. 1c. The effectiveness of the Cr^{3+} in pumping the Nd^{3+} fluorescence is clear.

Observed laser thresholds of singly and doubly doped YAG lasers 3 cm long by ⅛ inches diameter are summarized in Table I. The laser testing configuration in which light from the pumping lamp is focused onto the crystal by two spherical mirrors is described elsewhere.[4]

The higher pulsed and tungsten-excited cw laser thresholds for the Cr^{3+}-Nd^{3+}: YAG are probably due to the relatively poor quality of these early doubly doped crystals. Neither the pulsed nor the tungsten-excited cw threshold should be strongly influenced by the double doping, the first because of a relatively slow transfer rate from Cr^{3+} to Nd^{3+}, and the second because tungsten lamp radiation is weak in the region of the Cr^{3+} obsorption bands.

The effectiveness of the cross-pumping is indicated by the ratio of the mercury-excited to tungsten-excited cw thresholds for the two systems. This ratio decreases by a factor of six in going from the Nd^{3+}: YAG where the strongest absorption is in the infrared (Fig. 1a) to the Cr^{3+}-Nd^{3+}: YAG where the mercury lamp pumps strongly in the Cr^{3+} bands (Fig. 1b). In absolute terms the cross-pumping reduced the mercury-excited threshold by a factor of four and the minimum overall cw threshold by a factor of two.

In conclusion a cross-pumped laser has been demonstrated in the doubly-doped Cr^{3+}-Nd^{3+}: YAG system and has resulted in improved efficiency of the already attractive cw room temperature Nd^{3+}: YAG laser. This improvement would be even greater for broad-band high temperature exciting sources, making this doubly doped system the best available for sun-pumped operations.

Acknowledgement: We acknowledge the contributions of H. R. Lewis in various phases of this work. The laser crystals were obtained from the Linde Company. The assistance of P. Accardi and W. A. Hickman with the experiments is appreciated.

Table I—Observed Laser Thresholds

Pumping Sources		Thresholds Nd^{3+}: YAG	Thresholds Cr^{3+}-Nd^{3+}: YAG
Pulsed: FX-33 Xenon	(joules)	0.6	1.3
CW: DWY Iodine-vapor tungsten	(watts)	510	700
CW: AH-6 mercury capillary	(watts)	1,050	250*

*This low cw threshold was obtained by reducing the effective pumping aperture by a factor of four and dividing the observed threshold by the same factor.

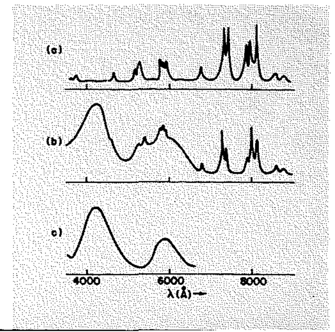


Fig. 1—Excitation spectra of the $^2F_{3/2} \rightarrow {}^4I_{11/2}$ fluorescent transition. a) 1.3% Nd-doped YAG. b) 1.3% Nd- and 1.% Cr-doped YAG. c) The absorption spectrum of 1% Cr^{3+}-doped YAG at 78°K.

1. The research reported here was sponsored by the Electronic Technology Division, Air Force Avionics Laboratory, Research and Technology Division, Air Force Systems Command, Wright-Patterson Air Force Base, Ohio under Contract No. AF33 (615)-1096 and RCA Laboratories, Princeton, New Jersey.
2. J. E. Geusic, H. M. Marcos and L. G. Van Uitert, *Appl. Phys. Letters 4*, 183 (1964).
3. Z. J. Kiss and R C. Duncan, *Appl. Phys. Letters 5*, 200 (1964).
4. R. C. Duncan and Z. J. Kiss, *Appl. Phys. Letters 3*, 23 (1963).

Short-Distance HF Sky-Wave Rapid-Fading Signal Statistics

S. KREVSKY, *Systems Laboratory, Communications Systems Division, DEP, New York, N.Y.*

Final manuscript received March 19, 1965

Fading statistics in the HF band have been made available by many investigators, the most notable being given by Laitinen and Haydon of the U. S. Army Radio Propagation Agency.[1] This information covers the day-to-day distribution of the hourly median field intensities (log normal), and the minute-to-minute distribution referred to the hourly medians (Rayleigh). In this *Note*, the second-to-second distribution referred to the minute median value is shown and compared to a calculated Rayleigh distribution. These fast fading distributions were obtained during a communications antenna test program[2] in the Canal Zone during November 1963.

A crude measure of the fading statistics was attempted, using the NF 105 Field Intensity Meter, which was calibrated with a Measurements Model 80 Standard Signal Generator. Because the meter readings of the NF 105 could be recorded by eye, several sets of microvolt readings were taken. Eleven 1-minute sets of data were taken by recording readings as fast as they could be observed and written—40 samples per minute. These have been reduced to standard probability terms; that is, the percent of time in 1 minute in which the observed signal ordinate is exceeded. This compared closely to a theoretical Rayleigh distribution about a median chosen at 35μV. Table I lists the reduced data and Fig. 1 gives the high, low, and average measured data and the calculated Rayleigh curve.

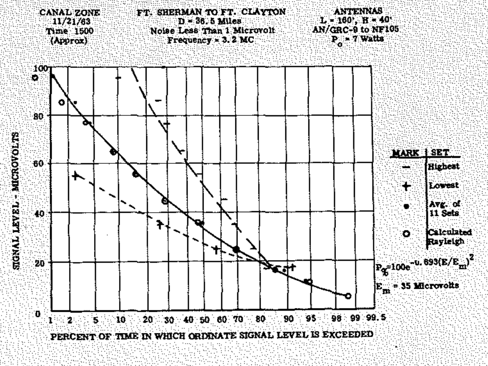
(The author is indebted to Messrs. L. H. Craig, M. Kaplan and L. Mueller of USAEL for their participation and contributions during this program.)

1. P. O. Laitinen and G. W. Haydon, *Analysis and Predictions of Sky Wave Field Intensities in the High Frequency Band.* Signal Corps Radio Propagation Agency, Fort Monmouth, New Jersey—07703. RPA-TR-No. 9.; August 1950. Pages 11, 15 and 111.
2. *Tactical Jungle Communications Study*—Interim and Final Reports, RCA, New York Systems Laboratory, DEP Communications Systems Division, New York City, N.Y., 3/21/63 and 12/20/63; Reports No. CR63-419-4 and 11. DA 36-039-AMC-00011(E); AD 445943 and AD 445944.

Table 1—Cumulative Distributions, %; Signal Level, μV

Set No.	Mark	15μV	25	35	45	55	65	75	85	95
1	—	83%	76	66	61	46	37	29	27	10
2		87	62	43	28	15	0	0	0	0
3		79	73	44	28	12	4.7	0	0	0
4		93	71	59	38	14	9.3	7.1	2.4	0
5		92	72	56	44	36	24	12	6	2
6		82	57	40	27	18	10	5	0	0
7		92	74	53	18	8	0	0	0	0
8		99	83	61	23	22	7.7	3.9	0	0
9		90	69	44	27	12	4.8	4.8	2.4	0
10	+	92	59	27	10	2.4	0	0	0	0
11		91	71	45	17	2.4	0	0	0	0
Avg. of 11		89%	70	49	29	17	8.9	4.6	3.4	1.1
Rayleigh $E_m = 35$	O	88%	70	50	32	18	9.1	4.1	1.7	0.63

Fig. 1—Fast-fading signal-level distribution, second-to-second samples, 1 minute sets.



Antennas in a Magneto-Plasma

DR. H. STARAS, *RCA Laboratories, Princeton, N. J.*

Final manuscript received June 18, 1965

Over the years, a very extensive literature has been developed on antennas in isotropic media—usually free space but occasionally also in conducting media (such as underground or in the ocean). Only in the past five years has some start been made in evaluating performance characteristics of antennas imbedded in a highly anisotropic medium, because present satellite technology makes accessible the vast ionospheric region that is highly anisotropic at VLF.

An anisotropic medium such as the ionosphere at VLF is a very strange one. For one thing, at least two different types of radio waves can exist at any one frequency, the so-called *ordinary* and *extraordinary* waves. Furthermore, each of these waves has a refractive index (or wavelength) which is a function of direction with respect to the earth's magnetic field. The interesting thing about the ionosphere at VLF is that one of these waves is *evanescent* (does not propagate, as in a waveguide below cut-off) while the other wave sees a very high refractive index although it is variable with direction. The minimum refractive index is likely to be about 100 or so. This implies that the wavelength in the medium should be less than 1/100 its size in free space—suggesting that a short dipole (10 feet, say) in the ionosphere should be as effective a radiator at VLF as one several thousands of feet tall at the surface of the earth. Without trying to carry the analogy too far, since anisotropic media can be fundamentally different from isotropic media, note that the ratio l/λ (where l is a dimension of the dipole and λ is the wavelength in the medium) is a very significant parameter in determining the impedance of an antenna. The impedance, in turn, is a very important parameter affecting the ability to drive the antenna. In free space, a VLF antenna 100 feet tall is essentially a capacitance, with a radiation resistance of the order of 10^{-4} ohms or less and a reactance of 10^5 ohms. Such an impedance is practically impossible to drive. For the reasons outlined earlier, it was felt that a similar antenna in the ionosphere may have an impedance which would be much easier to drive.

It was to investigate this intriguing possibility that a research program was undertaken at RCA Laboratories directed at studying the performance of dipoles in magnetoplasmas. The initial results of that study, recently published in the *IEEE Transactions on Antennas and Propagation*[1], indicate that a short VLF dipole can be driven to radiate much more efficiently in a magnetoplasma than in free space. The results also indicate that the Q of the antenna is fairly low and, somewhat more surprisingly, that its reactance may be inductive instead of capacitive, as it is in free space. More recent work by the same group concerning the far field pattern of the antenna indicates that because of the guidance of the energy along the direction of the magnetic field lines, even a short dipole may have the effect of a fairly narrow beam, and, therefore, some gain over an isotropic antenna (about 15 dB). Table I gives the results of mathematical computations of impedance for several specific cases. Further work is continuing in this interesting area.

1. H. Staras, "The Impedance of an Electric Dipole in a Magneto-Ionic Medium," *IEEE Trans. on Ant. and Prop.*, Vol. AP-12, pp. 695-702, November 1964.

Table I—Antenna Characteristics

$f = 5$ kc/s, $f_p = 9$ Mc/s, $f_b = 1.4$ Mc/s, $\nu = 0$; MKS units throughout

	Impedance, dipole aligned with Mag. field				Resistance, dipole perp. to Mag. field	
	Radiation resistance		Reactance			
Dipole l	$w = 0.03$	$w = 0.3$	$w = 0.03$	$w = 0.3$	$w = 0.03$	$w = 0.3$
0.03	0.09	—	+ 6.2	—	0.0015	—
0.3	9.4	0.009	+ 78	+ 0.6	0.05	9.4
3	816	0.94	+2,000	+ 7.0	94	2.7
30	2,500	82	+6,000	+162	14	150
300	280	245	+2,000	+380	3	50

DATES and DEADLINES

PROFESSIONAL MEETINGS AND CALLS FOR PAPERS

Meetings

Sept. 8-10, 1965: 13TH ANN. INDUS. ELEC. & CONTROL INST. CONF., IEEE, G-IECI, Phila. Section; Sheraton Hotel, Phila., Pa. *Prog. Info.:* Prof. P. L. Balise, Dept. of Mech. Eng., Univ. of Wash., Seattle 5, Wash.

Sept. 13-17, 1965: 6TH NATL. ELECTRICAL INSULATION CONF., IEEE, G-EI-NEMA, et al.; N. Y. Hilton at Rockefeller Ctr., N. Y., N. Y. *Prof. Info.:* H. W. Marquardt, NEMA, 155 E. 44th St., N. Y., N. Y.

Sept. 13-14, 1965: 13TH ANN. JOINT ENG. MTG. CONF., IEEE-ASME, et al.; N. Y. Hilton Hotel, New York, N. Y. *Prog. Info.:* T. Marble, Toronto Star Ltd., 80 King St., Toronto, Ont., Canada.

Sept. 19-22, 1965: NATL. POWER CONF., IEEE-ASME; Sheraton-Ten Eyck Hotel, Albany, N. Y. *Prog. Info.:* IEEE Headquarters, Box A, Lenox Hill Station, N. Y., N. Y.

Sept. 22-24, 1965: INTL. CONVENTION ON MILITARY ELECTRONICS (MIL-E-CON 9), IEEE, G-MIL; Wash. Hilton Hotel, Wash., D. C. *Prog. Info.:* L. H. King, Jansky & Bailey Div., Atlantic Res. Corp., Alexandria, Va.

Sept. 23-25, 1965: 15TH IEEE BROADCAST SYMP., IEEE-G-B; Willard Hotel, Wash., D. C. *Prog. Info.:* S. Bergen, 103 Fairchester Dr., Fairfax, Va.

Sept. 24-25, 1965: 13TH ANN. COMMUNICATIONS CONF., IEEE, Cedar Rapids Sect.; Cedar Rapids, Iowa. *Prog. Info.:* IEEE Headquarters, Box A, Lenox Hill Station, N. Y., N. Y.

Sept. 28-29, 1965: 7TH BIENNIAL ELECTRIC HEATING CONF., IEEE, G-IGA; Hotel Carter, Cleveland, Ohio. *Prog. Info.:* A. F. Leatherman, Bettelle Memorial Inst., 505 King Ave., Columbus 1, Ohio.

Oct. 4-6, 1965: 1965 CANADIAN ELECTRONICS CONF., IEEE, Region 7; Automotive Bldg., Toronto, Ont., Canada. *Prog. Info.:* Canadian Elec. Conf., 1819 Yonge St., Toronto 7, Ont., Canada.

Oct. 4-6, 1965: 1965 FALL URSI-IEEE MTG., IEEE; Dartmouth College, Hanover, New Hampshire. *Prog. Info.:* Prof. T. Laaspere, Radiophysics Lab., Dartmouth College, Hanover, New Hampshire.

Oct. 5-7, 1965: 2ND INDUSTRIAL & COM. POWER SYSTEMS CONF., IEEE, G-IGA; Statler-Hilton Hotel, Buffalo, N. Y. *Prog. Info.:* J. A. Hart, Allison Div. of Gen. Motors, Box 894, Indianapolis 6, Ind.

Oct. 6-8, 1965: 6TH ANN. SYMP. ON SWITCHING CIRCUIT THEORY & LOGICAL DESIGN, IEEE, G-C Univ. of Mich.; Univ. of Mich., Ann Arbor, Mich. *Prog. Info.:* Dr. J. Hartmanis, G.E. Res. Lab., Schenectady 1, N. Y.

Oct. 11-13, 1965: 1965 IEEE NATCOM (COMMUNICATIONS SYMP.), IEEE, C-Com-Tech Mohawk Valley Section; Utica, N. Y. *Prog. Info.:* IEEE Headquarters, Box A, Lenox Hill Station, N. Y., N. Y.

Oct. 11-23, 1965: INTL. ORGANIZATION FOR STANDARDIZATION, SMPTE; Milan, Italy. *Prog. Info.:* SMPTE, 9 E. 41st St., New York, N. Y.

Oct. 12-14, 1965: 1965 PROTECTIVE RELAYING CONF., IEEE, Twin Cities Sect. & Univ. of Minn.; Univ. of Minn., Minneapolis, Minn. *Prog. Info.:* IEEE Headquarters, Box A, Lenox Hill Station, N. Y., N. Y.

Oct. 18-20, 1965: 12TH NUCLEAR SCIENCE SYMP., IEEE, G-NS; San Francisco Hilton Hotel, San Fran., Calif. *Prog. Info.:* J. M. Harrer, Argonne Natl. Labs., Argonne, Ill.

Oct. 18-20, 1965: JT. MATERIALS HANDLING CONF., IEEE, G-IGA-ASME; Pittsburgh Hilton, Pittsburgh, Pa. *Prog. Info.:* IEEE Headquarters, Box A, Lenox Hill Station, N. Y., N. Y.

Oct. 20-22, 1965: ALLERTON CONF. ON CIRCUIT & SYSTEM THEORY, IEEE, G-CT, Univ. of Ill.; Conf. Center, Univ. of Ill., Monticello, Ill. *Prog. Info.:* Prof. ME Van Valkenburg, Univ. of Ill., Monticello, Ill.

Oct. 20-22, 1965: ELECTRON DEVICES MEETING, IEEE-G-ED; Sheraton Park Hotel, Wash., D. C. *Prog. Info.:* IEEE Headquarters, Box A, Lenox Hill Station, N. Y., N. Y.

Oct. 25-27, 1965: NATL. ELECTRONICS CONF., IEEE, et al.; McCormick Place, Chicago, Ill. *Prog. Info.:* R. G. Brown, EE Dept., Iowa State Univ., Ames, Iowa.

Oct. 25-27, 1965: 4TH SYMP. ON DISCRETE ADAPTIVE PROCESSES, IEEE, G-IT, G-AC; McCormick Place, Chicago, Ill. *Prog. Info.:* J. H. Eaton, IBM Res. Labs., Monterey & Cottle Rds., San Jose, Calif.

Oct. 25-27, 1965: 2ND SYMP. ON CONSUMER ELEC., IEEE, G-BTR, G-ED; McCormick Place, Chicago, Ill. *Prog. Info.:* IEEE Headquarters, Box A, Lenox Hill Station, N. Y., N. Y.

Oct. 27-29, 1965: EAST COAST CONF. ON AEROSPACE & NAVIG. ELEC. (ECCANE), IEEE, G-ANE, Baltimore Section; Holiday Inn, Baltimore, Md. *Prog. Info.:* R. Allen, Westinghouse Elec. Corp., Molecular Elec. Div., Baltimore, Md.

Oct. 31-Nov. 5, 1965: 98TH TECH. CONF. & EQUIPMENT EXHIBIT, Soc. of Motion Picture & Television Engrs. (SMPTE); Queen Elizabeth Hotel, Montreal, Quebec, Can. *Prog. Info.:* R. S. Rekert, Natl. Film Board of Canada, c/o SMPTE, 9 E. 41st St., N. Y. 17, N. Y.

Nov. 2-4, 1965: IEEE INTL. SPACE ELECTRONICS SYMP., IEEE, G-SET; Fontainbleu Hotel, Miami Beach, Fla. *Prog. Info.:* Thos. Broskie, NASA, Cape Kennedy Complex, Cocoa Beach, Fla.

Nov. 3-5, 1965: NEREM (NORTHEAST ELE. RES. & ENG. MTG.), IEEE, Region 1; Sheridan Boston & Civic Auditorium, Boston, Mass. *Prog. Info.:* NEREM, IEEE Boston Office, 313 Washington St., Newton 58, Mass.

Nov. 10-12, 1965: 18TH ANN. CONF. ON ENG. IN MEDICINE & BIOLOGY, IEEE, G-BME-ISA; Univ. of Penna. & Sheraton Hotel, Phila., Pa. *Prog. Info.:* Dr. H. Schwan, Moore School of EE, Univ. of Penna., Phila., Pa.

Nov. 15-18, 1965: 11TH ANN. CONF. ON MAGNETISM & MAG., IEEE-AIP; Hilton Hotel, San Francisco, Calif. *Prog. Info.:* IEEE Headquarters, Box A, Lenox Hill Station, N. Y., N. Y.

Nov. 18-19, 1965: 1965 MAECON, MID-AMERICA ELECTRONICS CONF., IEEE; Kansas City, Missouri. *Prog. Info.:* Mr. Wallace Wiley, Bonzer Inc., 11111 W. 59th Terrace, Shawnee, Kansas.

Nov. 30-Dec. 1-2, 1965: FALL JOINT COMPUTER CONF., IEEE, AFIPS, ACM; Convention Center, Las Vegas, Nevada. *Prog. Info.:* IEEE Headquarters, Box A, Lenox Hill Station, N. Y., N. Y.

Jan. 25-27, 1966: 12TH ANN. SYMP. ON RELIABILITY, IEEE, G-R, ASQC, et al.; Sheraton Palace Hotel, San Francisco, Calif. *Prog. Info.:* A. R. Park, General Precision, Inc., 1370 Encinitas Rd., San Marcos, Calif.

Calls for Papers

Oct. 9-17, 1965: PAN AMERICAN CONGRESS OF ELECTRICAL, ELECTRONICS, & MECHANICAL ENGINEERING, IEEE, ASME, SAE, Mexico Sections; Hotel Del Prado and the Auditoria Nacional, Mexico City, New Mexico. **Deadline:** Papers, **9/15/65.** *TO:* Ing. Jorge Espinoza, Colegio De Ingenieros Mecanicos Y Electricistas, Culiacan No. 115, Mexico City, New Mexico.

Oct. 11-13, 1965: 11TH NATCOM SYMP., IEEE Mohawk Valley Section; Utica, N. Y. **Deadline:** Abstracts, 6/7/65; Manuscripts, **9/1/65.** *TO:* G. E. Brunette, Tech. Prog. Chairman, Communications Div., (EMCT), Rome Air Development Center, Griffiss AFB, N. Y.

Jan. 31-Feb. 2, 1966: SYMP. ON INFORMATION THEORY, IEEE, G-IT; UCLA, Los Angeles, Calif. **Deadline:** Abstracts, **10/1/65** *FOR INFO.:* A. V. Balakrishnan, 7609 W. 91 Place, Los Angeles, Calif.

Feb. 9-11, 1966: INTL. SOLID STATE CIRCUITS CONF., IEEE, G-CT, Univ. of Pa.; Phila., Pa. **Deadline:** Papers, **10/15/65.** *FOR INFO.:* IEEE Headquarters, Box A, Lenox Hill Station, N. Y., N. Y.

Mar. 2-4, 1966: SCINTILLATION & SEMICONDUCTOR COUNTER SYMP., IEEE, G-NS; Shoreham Hotel, Wash., D. C. **Deadline:** Abstracts, **11/30/65.** *TO:* W. A. Higinbotham, Brookhaven Natl. Labs., Upton, L. I., N. Y.

Be sure deadlines are met—consult your Technical Publications Administrator or your Editorial Representative for the lead time necessary to obtain RCA approvals (and government approvals, if applicable). Remember, abstracts and manuscripts must be so approved BEFORE sending them to the meeting committee.

Mar. 21-24, 1966: IEEE INTL. CONVENTION, IEEE, All Groups TAB; Coliseum & N. Y. Hilton, N. Y., N. Y. **Deadline:** Abstracts, approx. **10/19/65.** *FOR INFO.:* IEEE Headquarters, Box A, Lenox Hill Station, N. Y., N. Y.

Apr. 20-22, 1966: 1966 INTL. NONLINEAR MAGNETICS CONF. (INTERMAG), IEEE, G-Mag VDE; Stuttgart, Germany. **For Deadline Info.:** IEEE Headquarters, Box A, Lenox Hill Station, N. Y., N. Y.

Apr. 20-22, 1966: SOUTHWESTERN IEEE CONF. & ELEC. SHOW (SWIEEECO), IEEE, Region 5; Dallas Memorial Auditorium, Dallas, Texas. **Deadline:** Abstracts, approx. **10/1/65.** *FOR INFO.:* IEEE Headquarters, Box A, Lenox Hill Station, N. Y., N. Y.

Apr. 26-28, 1966: SPRING JOINT COMPUTER CONF., IEEE, AFIPS, ACM; Boston Civic Ctr., Boston, Mass. **For Deadline Info.:** IEEE Headquarters, Box A, Lenox Hill Station, N. Y., N. Y.

April 26-28, 1966: 1966 REGION SIX ANN. CONF., IEEE; Tucson, Ariz., Pioneer Intl. Hotel. **Deadline:** Abstracts, **12/1/65;** 300-500 wds. *TO:* Dr. L. O. Huelsman, Tech. Papers Chairman, 1966 IEEE Region Six Ann. Conf., c/o Department of EE, Univ. of Ariz., Tucson, Ariz.

May 3-4, 1966: PACKAGING INDUSTRY CONF., IEEE; Hartford, Conn. **For Deadline Info.:** IEEE Headquarters, Box A, Lenox Hill Station, N. Y., N. Y.

May 4-6, 1966: 1966 ELECTRONIC COMPONENTS CONF., IEEE, G-CP, EIA; Marriott Motor, Washington, D. C. **Deadline:** Abstracts, approx. **10/9/65.** *FOR INFO.:* IEEE Headquarters, Box A, Lenox Hill Station, N. Y., N. Y.

May 10-12, 1966: NATL. TELEMETERING CONF., IEEE (Host) AIAA-ISA; Prudential Center, Boston, Mass. **Deadline:** Abstracts, approx. **9/15/65.** *FOR INFO.:* Dr. A. J. Kelley, NASA-ERC, 575 Tech. Square, Cambridge, Mass.

May 16-18, 1966: NAECON (NATL. AEROSPACE ELEC. CONF.), IEEE, G-ANE-AIAA, Dayton Section; Dayton, Ohio. **Deadline:** Abstracts, approx. **12/15/65.** *FOR INFO.:* IEEE Dayton Office, 1414 E. 3rd St., Dayton 3, Ohio.

May 16-18, 1966: 1966 NATL. SYMP. ON MICROWAVE THEORY & TECH, IEEE, G-MTT; Palo Alto, Calif. **Deadline:** Abstracts, approx. **11/15/65.** *FOR INFO.:* IEEE Headquarters, Box A, Lenox Hill Station, N. Y., N. Y.

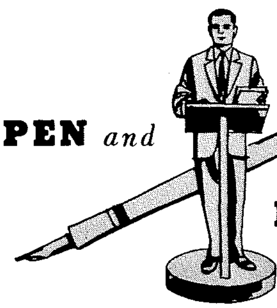
June 15-17, 1966: 2ND IEEE INTL. COMMUNICATIONS CONF., IEEE, G-ComTech., et al.; Sheraton Hotel, Phila., Pa. **For Deadline Info.:** A. E. Joel, Jr., Bell Telephone Labs., Holmdel, N. J.

June 20-22, 1966: SAN DIEGO SYMP. FOR BIOMEDICAL ENG., IEEE, U.S. Naval Hosp.; San Diego, Calif. **For Deadline Info.:** Dean L. Franklin, Scripps Clinic & Res. Found., LaJolla, Calif.

June 20-25, 1966: 3RD IFAC CONGRESS, IEEE, IFAC; London, England; **For Deadline Info.:** IEEE Headquarters, Box A, Lenox Hill Station, N. Y., N. Y.

June 21-23, 1966: CONF. ON PRECISION ELECTROMAGNETIC MEASUREMENTS, IEEE, G-IM NBS; NBS Standards Lab., Boulder, Colorado. **For Deadline Info.:** IEEE Headquarters, Box A, Lenox Hill Station, N. Y., N. Y.

July 18-21, 1966: 1966 AEROSPACE CONF. (AEROSPACE & ELECTRONIC SYSTEMS CONF.), IEEE; Olympia Hotel, Seattle, Washington. **Deadline:** Abstracts, **9/15/65.** *TO:* T. J. Martin, 3811 E. Howell St., Seattle, Washington. *FOR FURTHER INFO.:* D. B. Dobson, RCA, Burlington, Mass.



PEN and PODIUM

A SUBJECT-AUTHOR INDEX TO RECENT RCA PAPERS

Both published papers and verbal presentations are indexed. To obtain a published paper, borrow the journal from your library—or write or call the author for a reprint. For information on verbal presentations, write or call the author. This index is prepared from listings provided bimonthly by divisional Technical Publications Administrators and Editorial Representatives—who should be contacted concerning errors or omissions (see inside back cover).

ACOUSTIC THEORY; PHENOMENA

Passive and Active Acoustics in Architectural Enclosures—H. F. Olson (Labs, Pr.) Acoustical Society of America, Wash., D. C., June 3, 1965

AMPLIFICATION

Avalanching Silicon Diode Microwave Amplifier—L. S. Napoli, R. J. Ikola (Labs, Pr.) Solid-State Device Res. Conf. Princeton Univ., Princeton, N. J., June 1965; *Proc. IEEE* (Correspondence), August 1965

Microwave Power by Parametric Frequency Multiplication in a Single Transistor, Generation of—M. Caulton (Labs, Pr.), H. Sobol, R. L. Ernst (RCA Comm., N. Y.) *RCA Review*, Vol. XXVI, June 1965

Superconducting Films, On the Mechanism of Amplification in—A. S. Clorfeine, A. H. Nethercot, Jr. (Labs, Pr.) *Proc. of IEEE*, Vol. 53, No. 4, Apr. 1965

Transistor (MOS): Application to Untuned Amplifiers, Attenuators, and Special Circuits—D. M. Griswold (ECD, Som.) Seminar on Field-Effect Transistors, Naval Research Labs., Wash., D. C., June 14-15, 1965; *NRL Seminar Booklet*, June 1965

Transistor (MOS) High-Frequency Amplifiers—R. W. Ahrons (ECD, Som.) Seminar on Field-Effect Transistors, Naval Research Labs., Wash, D. C., June 14-15, 1965; *NRL Seminar Booklet*, June 1965

ANTENNAS

Spiral Top-Loaded Antenna—B. E. Keiser (Labs, Pr.) *Proc. IEEE*, Vol. 53, No. 4, Apr. 1965

Tilt and Deflections of Tapered Polygonal Towers—R. J. Pschunder (DEP-MSR, Mrstn.) *J. of the Structural Division Proc. of the American Soc. of Civil Engrs.*

Ultrawideband Cassegrainian Feed for Satellite Communications—P. Foldes, S. Komlos (RCA Ltd., Montreal) IEEE Annual Comm. Conv. on Globe Communications, Boulder, Colo., June 7, 1965; *Convention Preprints.*

ATOMIC THEORY; PHENOMENA

Atomic Hydrogen, Two-Photon Ionization of (II)—W. Zernik, R. W. Klopfenstein (Labs, Pr.) *Journal of Mathematical Physics*, Vol. 6, No. 6, Feb. 1965

Streaming Instabilities in Solids and the Role of Collisions—B. Vural, S. Bloom (Labs, Pr.) Solid-State Device Res. Conf., Princeton Univ., Princeton, N. J., June 1965

BIOMEDICAL ELECTRONICS

New Opportunities in Bio-Technology—Dr. G. H. Brown (Labs., Pr.) Fourth Intl. Television Symp., Montreux, Switzerland, May 25, 1965

BIONICS

Adaption Theory—J. Sklansky (Labs, Pr.) IEEE Mtg. at the University of Penna., May 1965

Learning Systems for Automatic Control—J. Sklansky (Labs, Pr.) *IEEE International Conv. Record*, Mar. 1965

Threshold Learning, Simple—J. Sklansky (Labs, Pr.) Intern'tl. Federation for Information Processing Soc., N. Y., May 24-29, 1965; *Conf. Record*

CHECKOUT; MAINTENANCE

Automatic Testability, Designing Equipment for—F. Liguori (DEP-ASD, Burl.) Automatic Support Systems Symp., St. Louis, Mo., June 7-9, 1965; *Conf. Record.*

Checkout Measurement Techniques for Large-Scale Electronic Systems—F. X. Beck (DEP-MSR, Mrstn.) Univ. of Pa. Automatic Checkout Techniques, June 14, 1965

Decision-Table Structure as the Input Language Format for Programming Automatic Test Equipment Systems, Using a—B. H. Scheff (DEP-ASD, Burl.) *IEEE Transactions on Electronic Computers*, Vol. EC-14, No. 2, Apr. 1965

Equipment Availability—An Improved Method of Prediction—W. J. O'Leary (DEP-MSR, Mrstn.) Univ. of Pa. Automatic Checkout Techniques, June 22, 1965

Transistors, Power—Physics of Failure—G. F. Granger, E. W. Karlin (ECD, Som.) Seminar on Automatic Checkout Techniques, Univ. of Penna., June 23, 1965

CIRCUIT THEORY; ANALYSIS

Frequency Converters Using Combinations of Parametric Elements, Theory and Design of—Dr. J. Klapper (DEP-CSD, N. Y.) *Thesis, Doctor of Eng. Science*, Elec. Eng. Dept., N. Y. Univ., Jan. 1965

Transient Analysis Using Optical Processing of Instantaneous Power Spectra—R. P. Perry (DEP-MSR, Mrstn.) 1965 Transient Acoustic Signal Processing Conference, Wash., D. C., May 7, 1965

CIRCUIT INTERCONNECTIONS; PACKAGING

Forced-Air Cooling: Suction vs. Pressure—G. Rezek (DEP-CSD, Cam.) *IEEE Trans. Product Engineering and Production*, Vol. Pep-9, No. 1, Apr. 1965

Temperature Evaluation in Microelectronic Structures Using Analog Networks—G. Rezek (DEP-CSD, Cam.) *IEEE Trans. Product Engineering and Production*, Vol. PEP-9, No. 1, Apr. 1965

COMMUNICATIONS, DIGITAL

Continental Data Communications System, Expansion of a—D. I. Caplan, H. P. Guerber (DEP-CSD, Cam.) IEEE GLOBECOM VII, Boulder, Colo., June 8, 1965; *Convention Preprints*

Data Communications System, The Role of the Communicator in a—E. J. Tomko (DEP-CSD, Cam.) AMA Seminar, June 21, New York

COMMUNICATIONS SYSTEMS; THEORY

Frequency Spectrum Utilization—N. C. Colby, W. L. Behrend (BCD, Meadow Lands) Utility Radio Assoc. of New England, Maine, May 20, 1965

High-Efficiency Voice Communication System, Research Towards a—H. F. Olson (Labs, Pr.) Acoustical Soc. of America, Wash., D. C., June 1965

Manned Spacecraft on Interplanetary Voyages, Communication Requirements Between—S. Gubin, R. B. Marsten, D. Silverman (DEP-AED, Pr.) 2nd AIAA Annual Mtg., San Francisco, Calif., July 26, 1965

Microwave Path Planning for Long Overwater Paths—G. Y. Tice (BCD, Cam.) *MSEE Thesis*, Univ. of Penna., Moore Sch., June 1965

Radio Interferences, Systems Concepts of—Dr. W. Y. Pan, B. B. Bossard, S. Yuan, L. Becker, P. Torrione (DEP-CSD, N. Y.) Univ. of Penna. Seminar, June 17, 1965

RELAY Satellite, Space Communications and the—R. B. Marsten (DEP-AED, Pr.) Engineering Extension & Physical Sciences Extension, Univ. of Calif. Extension, Los Angeles, Calif., July 29, 1965

Tactical FDM Techniques—E. J. Sass (DEP-CSD, Cam.) Tutorial Talk at MSR, Mrstn., Mar. 11, 1965

TV Communications, Electro-Optic—W. J. Hannan, J. Bordogna, T. P. Penn, T. E. Walsh (DEP-AppRes, Cam.) *Proceedings of the IEEE*, Feb. 1965

COMMUNICATIONS, VOICE SYSTEMS

High-Frequency Speech Sounds as Carriers of Intelligence, A Study of—W. E. Rodda (Labs, Pr.) *MSEE Thesis*, The Moore School of Elec. Eng., Phila., Pa., May 1965

Military Telephone System, Operational Analysis of a—W. J. Lawrence (DEP-CSD, Cam.) *MSEE Thesis*, Univ. of Pa.

COMMUNICATIONS, EQUIPMENT COMPONENTS

(Attenuators): High-Speed Solid-State Automatic Signal Attenuator and Its Application—W. Farrell (DEP-AED, Pr.) 11th Annual IES Tech. Mtg., Sherman House, Chicago, Ill., Apr. 21-23, 1965; *Conf. Proceedings*

Frequency Converters Using Combinations of Parametric Elements, Theory and Design of—Dr. J. Klapper (DEP-CSD, N. Y.) *Thesis, Doctor of Eng. Science*, Elec. Eng. Dept., N. Y. Univ., Jan. 1965

Microwave Adjustable-Delay Device—E. F. Belohoubek (ECD, Pr.) Electronics Div. Seminar, Naval Res. Labs., Washington, D. C., June 7, 1965

Isolator (New) Using a Solid-State Plasma Waveguide—M. Toda (Labs, Pr.) *IEEE Trans. on Microwave Theory and Techniques*, Vol. 13, No. 1, Jan. 1965

(Mixers): Multiple-Input Large-Signal Mixer Analysis—P. Torrione, S. Yuan (RCA Comm., N. Y.) *RCA Review*, Vol. XXVI, June 1965

Parametric Elements, Properties of—M. S. Ghausi, Dr. J. Klapper (DEP-CSD, N. Y.) *IEEE International Conv. Record*, Vol. 12, Part 1, 1964, pp. 357-363.

Parametric RLC Converters, Maximum Gain and Isolation in—Dr. J. Klapper, M. S. Ghausi (DEP-CSD, N. Y.) *Proceedings of the IEEE*, 53-2, Feb. 1965, pp. 207-208.

Receiver Distortions and Reductions—Dr. W. Y. Pan, B. B. Bossard, S. Yuan, L. Becker, P. Torrione (DEP-CSD, N. Y.) Univ. of Penna., Seminar, June 17, 1965

Sea-Water Return Cable, Analysis of a—C. N. Vallette (DEP-CSD, Cam.) *MSEE Thesis*, Villanova Univ., 1964

Transistorized Shipboard Equipment, A Prognosis of—N. L. Barlow (BCD, Meadow Lands) Radio Tech. Comm. for Marine Services, Calif.; *Proceedings of RTCM Assembly*, May 5, 1965

Transistor (MOS): Application to Untuned Amplifiers, Attenuators, and Special Circuits—D. M. Griswold (ECD, Som.) Seminar on Field-Effect Transistors, Naval Research Labs., Washington, D. C., June 14-15, 1965; *NRL Seminar Booklet*, June 1965

Transistor (MOS) High-Frequency Amplifiers—R. W. Ahrons (ECD, Som.) Seminar on Field-Effect Transistors, Naval Research Labs., Wash., D. C., June 14-15, 1965; *NRL Seminar Booklet*, June 1965

Waveguide Coupler (Contradirectional) With High Directivity and Tight Coupling—J. S. Daglian (DEP-MSR, Mrstn.) *MSEE Thesis*, Univ. of Pa., May 24, 1965

Varactor Frequency Multiplier for an All-Solid-State Satellite Communications System—E. E. Bliss, C. D'Elio (ECD, Hr.) IEEE Comm. Conv., Boulder, Colo., June 7-9, 1965; *Convention Preprint*, June 1965

COMPUTER APPLICATIONS

Computer-Controlled Range Tracking, A System for—J. M. Chambers (DEP-ASD, Van Nuys) *MS Thesis*, Univ. of Penna., May 24, 1965

Digital Computer Control Systems from the Control-Oriented Point of View—A. S. Robinson (DEP-MSR, Mrstn.) Int'l. Fed. of Info. Processing Societies, N. Y. C., May 24-29, 1965; *Conf. Record.*

Simulation on RCA Spectra 70 Systems—W. R. Lonergan (EDP, Cam.) WESCON, San Francisco, Calif., Aug. 24-27, 1965; *Proceedings*

(Spectroscopy): Data Processing for the Mass Spectrographic Analysis of Solids—J. R. Woolston (RCA Labs., Pr.) 13th Ann. Conf. on Mass Spectrometry & Applied Topics, St. Louis, Mo., May 1965

Testing Equipment, Unsophisticated Data Processing System for—B. Scheff (DEP-ASD, Burl.) Southeastern Regional Assn. for Computing Machinery Conf., West Palm Beach, Fla., June 10, 1965

COMPUTER CIRCUITRY; DEVICES

(Transistors, MOS): Application of Metal-Oxide-Semiconductors to Logic Circuits—R. D. Lohman (ECD, Som.) Seminar on Field-Effect Transistors, Naval Res. Labs., Wash., D. C., June 14-15, 1965; *NRL Seminar Booklet*, June 1965

COMPUTER INPUT-OUTPUT

Character Readers, High-Speed Optical—A. J. Torre (EDP, Cam.) WESCON, Aug. 24-27, 1965; San Francisco, Calif.; *Conf. Proceedings*

COMPUTER LOGIC; THEORY

Adaptation Theory—J. Sklansky (Labs, Pr.) IEEE Mtg., Univ. of Penna., May 1965

Learning Systems for Automatic Control—J. Sklansky (Labs, Pr.) *IEEE Intern'tl. Convention Record*, Mar. 1965

Threshold Functions, Chebyshev Approximation and—K. R. Kaplan, R. O. Winder (Labs, Pr.) *IEEE Trans. on Electronic Computers*, Vol. EC-14, No. 2, Apr. 1965

Threshold Learning (Simple)—J. Sklansky (Labs, Pr.) Intern'tl. Federation for Information Processing Soc., N. Y., May 24-29, 1965; *Conf. Record*

Theshold Functions, Properties of—R. O. Winder (Labs, Pr.) *IEEE Trans. on Electronic Computers*, Vol. EC-14, No. 2, Apr. 1965

COMPUTER PROGRAMMING

Complexity in Program Translation—F. P. Larkin (Labs., Pr.) Assoc. for Computing Machinery Symp. on Reprogramming, Princeton, N. J., June 1965

Decision-Table Structure as the Input Language Format for Programming Automatic Test Equipment Systems, Using a—B. H. Scheff (DEP-ASD, Burl.) *IEEE Trans. Electronic Computers*, Vol. EC-14, No. 2, Apr. 1965

Predictor-Corrector Algorithm with an Increased Range of Absolute Stability—R. L. Crane, R. W. Klopfenstein (Labs, Pr.) *Journal of the Assoc. for Computing Machinery*, Vol. 12, No. 2, Apr. 1965.

COMPUTER STORAGE

Cavity Sensing of Cryoelectric Memory Planes—L. L. Burns, A. R. Sass (Labs, Pr.) *Journal of Applied Physics*, Vol. 36, No. 3, Mar. 1965

Integrated Magnetic and Superconductive Memories—A Survey of Techniques, Results and Prospects—J. A. Rajchman (Labs, Pr.) MITRE Corp., Computer Languages Systems and Tech. Seminar, Bedford, Mass. June 1965 *also:* Int'l. Federation of Info. Processing Soc., N. Y., May 24-29, 1965, *Conf. Record*

Memory Applications—Advantages, Circuits, Problems, The Future, Etc.—G. B. Herzog (Labs, Pr.) Seminar on Field-Effect Transistors, Wash., D. C., June 14-15, 1965; *NRL Seminar Booklet*, June 1965

Random-Access Mass Memory System—J. F. Gates (DEP-ASD, Van Nuys) IFIPS Congress, N. Y., May 24-29, 1965, *Conf. Record*

COMPUTER SYSTEMS

Optical Computer Research, Progress in—W. F. Kosonocky, O. A. Reimann (Labs, Pr.) *IEEE Spectrum*, Vol. 2, No. 3, Mar. 1965

RCA Spectra 70 Basic Design and Philosophy of Operation—A. D. Beard (EDP, Cam.) WESCON, San Francisco, Calif., Aug. 24-27, 1965; *Proceedings*

Small Engineering Computers—D. B. Mayer (DEP-MSR, Mrstn.) *Electro Technology*, July 1965

CONTROL; AUTOMATA

Digital Computer Control Systems from the Control-Oriented Point of View—A. S. Robinson (DEP-MSR, Mrstn.) Int'l. Fed. of Info. Processing Societies, N. Y., May 24-29, 1965; *Conf. Record*

Electronic Heat Controls for Appliances and Domestic Heating—G. D. Hanchett (ECD, Som.) IEEE 16th Annual Appliance Tech. Conf., Columbus, Ohio, May 18-19, 1965; *Conference Preprint,* May 1965

Learning Systems for Automatic Control—J. Sklansky (Labs, Pr.) *IEEE Int'l. Convention Record,* Mar. 1965

Railroad Presence Detector—G. W. Gray (Labs, Pr.) Assoc. of American Railroads, Comm. & Signal Section, Wash., D. C., May 1965

TACAN-Compatible Accurate DME for Short Ranges—C. J. Hirsch (Labs, Pr.) *IEEE Trans. on Aerospace and Nav. Electronics,* Vol. ANE-12, No. 1, Mar. 1965

EDUCATION

Challenges of Tomorrow—M. V. Hoover (ECD, Lanc.) Zerbe Township High School (Commencement Address), Treverton, Pa., May 28, 1965

ELECTROMAGNETIC THEORY; PHENOMENA

Axial-Velocity Distributions in Electron Beams, Retarding-Field Analyzers for the Measurement of—M. Caulton (Labs, Pr.) *RCA Review,* Vol. XXVI, June 1965

Cyclotron Harmonic Regions, The Dispersion of Waves in—I. P. Shkarofsky (RCA Ltd., Montreal) Amer. Physical Soc., June 23-25, 1965

Cyclotron Harmonics, Time Decay of—T. W. Johnston, I. P. Shkarofsky (RCA Ltd., Montreal) Amer. Physical Society, June 23-25, 1965

Cyclotron Resonance (Electron), Plasma Acceleration by—H. Hendel, T. Faith, E. C. Hutter (AED, Pr.) *RCA Review,* Vol. XXVI, June 1965

Microwave Path Planning for Long Overwater Paths—G. Y. Tice (BCD, Cam.) *MSEE Thesis,* Univ. of Penna., Moore Sch., June 1965

RF Wave Decay and Landau Damping in Electron Beams with Large Velocity Spreads—M. Caulton (Labs, Pr.) 23rd Annual Conf. on Electron Device Res., Univ. of Ill., Urbana, Ill., June 1965

Magnetic Focusing of Coherent Light Beam Through Lorentz Field Radiation—K. K. N. Chang, H. J. Prager (Labs, Pr.) 23rd Annual Conf. on Electron Device Res., Univ. of Ill., Urbana, Ill., June 1965

Transient Analysis Using Optical Processing of Instantaneous Power Spectra—R. P. Perry (DEP-MSR, Mrstn.) 1965 Transient Acoustic Signal Processing Conference, Wash., D. C., May 7, 1965

ELECTROMECHANICAL COMPONENTS

The Eternal Triangle: The Original Equipment Mfgr.—The Parts Mfgr.—The Military—A. Siegel (DEP-CE, Cam.) *Electromechanical Design,* Apr. 1965, p. 24.

Minimum Current Level Testing—A. Siegel (DEP-CE, Cam.) *Electromechanical Design,* Mar. 1965, p. 20

New Revisions of the MIL-Specs: MIL-S-3786—A. Siegel (DEP-CE, Cam.) *Electromechanical Design,* June 1965, p. 14

Something New Under the Sun—A. Siegel (DEP-CE, Cam.) *Electromechanical Design,* May 1965, p. 24

ELECTRO-OPTIC SYSTEMS; TECHNIQUES

Infrared Vidicon Airborne Reconnaissance System—N. Aron (DEP-ASD, Burl.) *Proceedings of the IR Information Symposia* (Secret), Vol. 9, No. 3, Sept. 1964 (Uncl. title; Confidential paper)

Infrared Vidicon Reconnaissance System, Evaluation of an—L. Arlan (DEP-ASD, Burl.) *Proceedings of the IR Information Symposia* (Secret) Vol. 9, No. 3, Sept. 1964 (Uncl. title; Confidential paper)

Infrared Vidicon, Resolution Measurement of the RCA—N. Aron (DEP-ASD, Burl.) *Proceedings of the IR Information Symposia* (Secret), Vol. 9, No. 4, Jan. 1965

TV Communications, Electro-Optic—W. J. Hannan, J. Bordogna, T. P. Penn, T. E. Walsh (DEP-AppRes, Cam.) *Proceedings of the IEEE,* Feb. 1965

ENERGY CONVERSION; SOURCES

Freeze-Drying (Accelerated) of Foods Using UHF Dielectric Heating, Engineering and Experimental Aspects of—W. N. Parker (ECD, Lanc.) with M. W. Hoover and A. Markantonatos of N. Carolina State Univ. Inst. of Food Technologists, Kansas City, Mo., May 16-20, 1965

Inverters, Tunnel-Diode Low-Input-Voltage—R. Feryszka, P. Gardner (ECD, Som.) Power-Sources Conf., Atlantic City, N.J., May 18-20, 1965

Microwave Power by Parametric Frequency Multiplication in a Single Transistor, Generation of—M. Caulton (Labs, Pr.) H. Sobol, R. L. Ernst (RCA Comm., N.Y.) *RCA Review,* Vol. XXVI, June 1965

Microwave Power Sources, Progress in Solid-State—F. Sterzer (ECD, Pr.) IEEE Symp. on Microwave Theory and Techniques, Clearwater, Fla., May 5-7, 1965; *Conf. Digest*

Thermionic Energy Converter, Development of a Reservoirless—W. E. Harbaugh, A. Basiulis (ECD, Lanc.) Conf. on Applied Thermionic Technology, Germantown, Maryland, May 13-14, 1965

(Thermionics): Recent Advances in Emitter-Shell Materials for Fossil-Fuel-Heated Thermionic Converters—G. Y. Eastman, J. A. Fox (ECD, Lanc.) Power-Sources Conf., Atlantic City, N.J., May 18-20, 1965

Thermoelectric Generator, A 100-Watt Silicon-Germanium—O. H. Schade, Jr., H. P. Van-Heyst (ECD, Hr.) Power-Sources Conf., Atlantic City, N.J., May 18-20, 1965

Thermoelectric Power Generation, Silicon-Germanium Alloys for—A Review—J. P. Dismukes, F. D. Rosi (Labs, Pr.) Amer. Inst. of Chem. Engrs., London, England, June 1965

Thermoelectric Properties of Niobium in the Temperature Range 300-1200°K—V. Raag, H. V. Kowger (ECD, Hr.) *Journal of Applied Physics,* June 1965

ENVIRONMENTAL FACTORS

(Clean Rooms): Problems in Designing and Constructing a 20,000-Square-Foot Down-Flow Laminar Clean-Room Complex—F. C. Weisbach (ECD, Lanc.) Amer. Assoc. for Contamination Control, Miami, Fla., May 25-28, 1965

Designing Equipment for Operation Under Outer-Space Constraints—L. B. Garrett (DEP-CSD, Cam.) Engineering Lecture, Camden, June 9, 1965

Shakers, Electro-Dynamic, Shock Capabilities of—J. McClanahan, J. Fagan (DEP-AED, Pr.) 11th Annual IES Tech. Mtg., Sherman House, Chicago, Ill., Apr. 21-23, 1965; *Conf. Proceedings*

Suction vs. Pressure Forced-Air Cooling—G. Rezek (DEP-CSD, Cam.) *IEEE Trans. Product Engineering and Production,* Vol. Pep-9, No. 1, Apr. 1965

Transportation Environments Revisited—A. S. Baron, A. Schilling (DEP-AED, Pr.) 11th Annual IES Tech. Mtg., Sherman House, Chicago, Ill.; *Conf. Proceedings*

FILTERS

EMI Filter Design, Short Cuts to—A. W. DiMarzio (DEP-ASD, Burl.) IEEE Nat'l. Symp. on Electromagnetic Compatibility, N.Y., June 18-20, 1965, *Conf. Digest*

INSTRUMENTATION; LAB EQUIPMENT

Electron Microscopy, Defects in Phosphorus Doped Si-Ge Alloy by—M. D. Coutts (Labs, Pr.) Symp. on Electron Microscopy, RCA Labs, Princeton, N.J., June 1965

Grid-Controlled Power Tubes in Particle-Accelerator Applications—M. V. Hoover (ECD, Lanc.) *IEEE Trans. on Nuclear Science,* June 1965

Microphotography—G. L. Finne (ECD, Som.) Eastman-Kodak Symp., Rochester, N.Y., June 3-4, 1965; Society of Photographic Instrumentation Engineers, N.J. Chapter, New Brunswick, N.J., June 24, 1965

Shakers, Electro-Dynamic, Shock Capabilities of—J. McClanahan, J. Fagan (DEP-AED, Pr.) 11th Annual IES Tech. Mtg., Sherman House, Chicago, Ill., Apr. 21-23, 1965; *Conf. Proceedings*

Radiation on Instrumentation Electronics, The Influence of—A. Holmes-Siedle (DEP-AED, Pr.) IEEE-GN's Conf. on Nuclear Radiation Effects, Univ. of Mich., Ann Arbor, Mich., July 15, 1965; *IEEE Trans. on Nuclear Science*

(Spectroscopy): Data Processing for the Mass Spectrographic Analysis of Solids—J. R. Woolston (Labs, Pr.) 13th Annual Conf. on Mass Spectrometry and Applied Topics, St. Louis, Mo., May 1965

Spectroscopy (Tuned Laser) of Organic Vapors—H. J. Gerritsen (Labs, Pr.) Quantum Electronics Conf., San Juan, Puerto Rico, June 1965

(Transistors, MOS): An Economical Method of Simultaneously Displaying Positive and Negative Drain Characteristics of MOS Transistors—F. Rosi (ECD, Som.) *Electronic Design,* May 10, 1965

X-Ray and Neutron Diffraction in Inorganic Chemistry—J. G. White (Labs, Pr.) Amer. Chemical Society Staten Island Subsection at Wagner College, N.Y., May 1965

X-Rays in Chemical Analysis—J. A. Amick (Labs, Pr.) Princeton Area Scientific Education Committee, FMC, Princeton, N.J., May 1965

INTERFERENCE; NOISE

Radio Interferences, Systems Concepts of—Dr. W. Y. Pan, B. B. Bossard, S. Yuan, L. Becker, P. Torrione (DEP-CSD, N.Y.) Univ. of Penna. Seminar, June 17, 1965

Receiver Distortions and Reductions—Dr. W. Y. Pan, B. B. Bossard, S. Yuan, L. Becker, P. Torrione (DEP-CSD, N.Y.) Univ. of Penna. Seminar, June 17, 1965

LASERS

Coherent Radiations, Engineering Control of—H. Rosenthal (Labs, Pr.) Occupational Health Research and Training Facility of U.S. Public Health Service, Cinn., Ohio, May 1965

Continuous Room-Temperature Nd^{3+}:$CaMoO_4$ Laser—R. C. Duncan (Labs, Pr.) *Journal of Applied Physics,* Vol. 36, No. 3

Cr^{3+}—Nd^{3+}: YAG Cross-Pumped Laser—Z. J. Kiss (Labs, Pr.) Physics of Quantum Electronics Conf., Puerto Rico, June 1965

Electron Beam Excitation of Noble Gas Ion Lasers—J. M. Hammer, C. P. Wen (Labs, Pr.) 1965 Electron Device Research Conf., Univ. of Ill., Urbana, Ill., June 1965

Lasers—The New Light—Dr. J. Vollmer (DEP-AppRes, Cam.) Awards Dinner of Phila. Science Council, June 7, 1965, Franklin Inst., Phila., Pa.

Optical Computer Research, Progress in—W. F. Kosonocky, O. A. Reimann (Labs, Pr.) *IEEE Spectrum,* Vol. 2, No. 3, Mar. 1965

Spectroscopy (Tuned Laser) of Organic Vapors—H. J. Gerritsen (Labs, Pr.) Quantum Electronics Conf., San Juan, Puerto Rico, June-July 1965

Threshold Dependency on Reabsorption Loss in Injection Lasers—M. F. Lamorte, H. Junker, T. Gonda (ECD, Som.) *Journal of Quantum Electronics,* May 1965

MANAGEMENT; BUSINESS

BuWeps Reliability Requirements and Demonstrations—Current Status—T. P. Speas, G. Kuznick, R. Myers (DEP-CSD, Cam.) BIMRAB Conf., Wash., May 11, 1965

Competitive Pricing—A Systematic Approach—H. N. Garber, F. Edelman (Labs, Pr.) AMA Seminar No. 6227-01 on Simulation, N.Y.C., June 1965

Data Communications System, The Role of the Communicator in a—E. J. Tomko (DEP-CSD, Cam.) AMA Seminar, June 21, N.Y.C.

Industrial R&D—Dr. J. Vollmer (DEP-AppRes, Cam.) Eastern Penna. Section Mtg. of AAPT, May 8, 1965, Temple Univ., Phila., Pa.

Reporting Financial Data to Management in a Research Environment—W. R. Breeze (Labs, Pr.) AMA Course, NYC, May 1965

MASERS

Microwave Masers—Dr. J. Vollmer (DEP-AppRes, Cam.) Modern Physics Seminar, Ft. Monmouth, N.J., June 14, 1965

MATHEMATICS

Chebyshev Approximation and Threshold Functions—K. R. Kaplan, R. O. Winder (Labs, Pr.) *IEEE Trans. on Electronic Computers,* Vol. EC-14, No. 2, Apr. 1965

"Del" Operator in Curvilinear Coordinates—R. B. Schilling (Labs, Pr.) *Amer. Journal of Physics,* Vol. 33, No. 3, Mar. 1965

MECHANICAL COMPONENTS; STRUCTURES

Elastic Wave Propagation in Rods of Arbitrary Cross Section—R. L. Rosenfeld, J. Mikolwitz (Labs, Pr.) Applied Mech. Conf., Wash., D.C., June 1965

Tilt and Deflections of Tapered Polygonal Towers—R. J. Pschunder (DEP-MSR, Mrstn.) *J. of the Structural Division Proc. of the American Soc. of Civil Engrs.*

PLASMA

Electron Cyclotron Resonance, Plasma Acceleration by—H. Hendel, T. Faith, E. C. Hutter (AED, Pr.) *RCA Review,* Vol. XXVI, June 1965

Instabilities and Growing Waves in Solid State Plasmas—M. Glicksman (Labs, Pr.) *Proc. of 7th Intern'tl. Conf. on Phys. and Semicon.,* Paris, July 1964 (published in 1965)

Isolator (New) Using a Solid-State Plasma Waveguide—M. Toda (Labs, Pr.) *IEEE Trans. on Microwave Theory and Techniques,* Vol. 13, No. 1, Jan. 1965

RADAR

Optical Signal Processing for Radar Systems—E. C. Farnett (DEP-MSR, Mrstn.) American Ordnance Assoc. Spring Meeting (Electronics Div.), San Diego, May 13, 1965

Simulating Free Space for Measuring the Amplitude and the Phase of Backscattered Radar Energy—N. R. Landry (DEP-MSR, Mrstn.) *MSEE Thesis,* Drexel Institute of Technology, Phila., Pa., June 19, 1965

Target Recognition, An Introduction to—C. M. Brindley (DEP-MSR, Mrstn.) *Space/Aero,* June 1965

Tilt and Deflections of Tapered Polygonal Towers—R. J. Pschunder (DEP-MSR, Mrstn.) *J. of the Structural Division Proc. of the American Soc. of Civil Engrs.*

(Transmitters): Solid-State Radar Transmitter Units for the Lunar Excursion Module, Design of—E. E. Bliss, M. Fromer (ECD, Hr.) IEEE Electronics Components Conf., Washington, D.C., May 5-7, 1965; *Conf. Record,* May 1965

Waveguide Coupler (Contradirectional) With High Directivity and Tight Coupling—J. S. Daglian (DEP-MSR, Mrstn.) *MSEE Thesis,* Univ. of Pa., May 24, 1965

RADIATION DETECTION

Photomultipliers (New) for Scintillation Counting, Evaluation of—H. R. Krall (ECD, Lanc.) *IEEE Trans. on Nuclear Science,* Feb. 1965

RADIATION EFFECTS

Instrumentation Electronics, The Influence of Radiation on—A. Holmes-Siedle (DEP-AED, Pr.) IEEE-GN's Conf. on Nuclear Radiation Effects, Univ. of Mich., Ann Arbor, Mich., July 15, 1965; *IEEE Trans. on Nuclear Science*

Transistors (Silicon), High Energy Radiation Damage in—G. Brucker, W. Dennehy, A. Holmes-Siedle (DEP-AED, Pr.) IEEE-GNS Conf. on Nuclear Radiation Effects, Univ. of Mich., Ann Arbor, Mich., July 12, 1965; *IEEE Trans. on Nuclear Science*

RADIO RECEIVERS, ENTERTAINMENT

Vehicular Radio, Transistors in—S. Matyckas (ECD, Som.) IEEE Section Mtg., Cleveland, Ohio, May 18, 1965

RECORDING, DIGITAL

Magnetic Recording for Space Communications—A. S. Katz (DEP-CSD, Cam.) Camden Eng. Lecture, June 29, 1965

RELIABILITY; QUALITY CONTROL

Equipment Availability—An Improved Method of Prediction—W. J. O'Leary (DEP-MSR, Mrstn.) Univ. of Pa. Automatic Checkout Techniques, June 22, 1965

Reliability Prediction—Its Validity and Application as a Design Tool—T. C. Reeves (DEP-CSD, Cam.) 1965 Annual Mtg. of the Amer. Society for Engineering Education, Chicago, Ill., June 22, 1965

SIMULATION

Simulating Free Space for Measuring the Amplitude and the Phase of Backscattered Radar Energy—N. R. Landry (DEP-MSR, Mrstn.) *MSEE Thesis*, Drexel Institute of Technology, Phila., Pa., June 19, 1965

Simulation on RCA Spectra 70 Systems—W. R. Lonergan (EDP, Cam.) WESCON, San Francisco, Calif., Aug. 24-27, 1965; *Proceedings*

SOLID-STATE DEVICES

Components, The New Look in—E. O. Johnson (ECD, Som.) *Industrial Research*, May 1965

(Diodes) Microwave Phonon-Assisted Tunneling in Superconducting Diodes—B. Abeles, Y. Goldstein (Labs, Pr.) *Physical Review Letters*, Vol. 14, No. 15, Apr. 1965

Ferroelectric Field Effect Device—G. H. Heilmeier, P. M. Heyman (Labs, Pr.) Solid State Device Res. Conf., Princeton, N.J., June 1965

Microwave Adjustable-Delay Device—E. F. Belohoubek (ECD, Pr.) Electronics Div. Seminar, Naval Res. Labs., Wash., D.C., June 7, 1965

Semiconductor Doping Densities, Use of Transient Measurements in Metal-Insulator Semiconductor Structures to Determine—A. Waxman (Labs, Pr.) *Proc. of the IEEE*, Vol. 53, No. 3, Mar. 1965

Solid-State, A New Look at—F. A. Barton, R. Potyka (BCD, Meadow Lands) Petroleum Inst. Elec. Assoc., Texas, Apr. 29, 1965

Transistor (MOS): Application to Untuned Amplifiers, Attenuators, and Special Circuits—D. M. Griswold (ECD, Som.) Seminar on Field-Effect Transistors, Naval Res. Labs., Wash., D.C., June 14-15, 1965; *NRL Seminar Booklet*, June 1965

Transistor (MOS) High-Frequency Amplifiers—R. W. Ahrons (ECD, Som.) Seminar on Field-Effect Transistors, Naval Res. Labs., Wash., D.C., June 14-15, 1965; *NRL Seminar Booklet*, June 1965

(Transistors, MOS): An Economical Method of Simultaneously Displaying Positive and Negative Drain Characteristics of MOS Transistors—F. Rosi (ECD, Som.) *Electronic Design*, May 10, 1965

(Transistors, MOS): Application of Metal-Oxide-Semiconductors to Logic Circuits—R. D. Lohman (ECD, Som.) Seminar on Field-Effect Transistors, Naval Res. Labs., Wash., D.C., June 14-15, 1965; *NRL Seminar Booklet*, June 1965

Transistors (MOS), Operating Principles and Construction of—F. P. Heiman (Labs, Pr.) Seminar on Field-Effect Transistors, Naval Res. Labs., Wash., D.C., June 14-15, 1965; *NRL Seminar Booklet*, June 1965

(Transistor, MOS): Characterizing the Field-Effect Transistor—J. A. Olmstead (ECD, Som.) Seminar on Field-Effect Transistor, Naval Res. Labs., Wash., D.C., June 14-15, 1965; *NRL Seminar Booklet*, June 1965

(Transistor, MOS): Characteristics and Applications of RCA Insulated-Gate Field-Effect Transistors—D. M. Griswold (ECD, Som.) IEEE Conf. on Broadcast and TV Receivers, Des Plaines, Ill., June 14-15, 1965; *IEEE Trans. on Broadcast and TV Receivers*, July 1965

(Transistor, MOS): Introduction to Field-Effect Transistors—E. O. Johnson (ECD, Som.) Seminar on Field-Effect Transistors, Naval Res. Labs., Wash., D.C., June 14-15, 1965; *NRL Seminar Booklet*, June 1965

Transistors, Gallium Arsenide Double-Diffused—H. Becke, D. Flatley, D. Stolnitz (ECD, Som.) *Solid-State Electronics*, Mar. 1965

Transistors, Insulated-Gate Field-Effect—R. W. Ahrons (ECD, Som.) IEEE Boston Chapter of Electron Devices Group, Waltham, Mass., May 13, 1965

Transistors, Physical Limitations on Frequency and Power Parameters of—E. O. Johnson (ECD, Som.) *RCA Review*, Vol. XXVI, June 1965

(Transistors): Physics of Failure—Power Transistors—G. F. Granger, E. W. Karlin (ECD, Som.) Seminar on Automatic Checkout Techniques, Univ. of Penna., June 23, 1965

Transistors (Silicon), High Energy Radiation Damage in—G. Brucker, W. Dennehy, A. Holmes-Siedle (DEP-AED, Pr.) IEEE-GNS Conf. on Nuclear Radiation Effects, Univ. of Michigan, Ann Arbor, Mich., July 12, 1965; *IEEE Trans. on Nuclear Science*

(Tunnel Diodes): Deterioration of GaAs Esaki Diodes, Comments on the—L. R. Weisberg, R. Gold (Labs, Pr.) *Solid-State Electronics*, Vol. 8, 1965, p. 455

Tunnel Junction Triode, The Insulated Gate—S. R. Hofstein, G. Warfield (Labs, Pr.) *IEEE Trans. on Electron Devices*, Vol. ED-12, No. 2, Feb. 1965

Varactor Frequency Multiplier for an All-Solid-State Satellite Communications System—E. E. Bliss, C. D'Elio (ECD, Hr.) IEEE Comm. Conv., Boulder, Colo., June 7-9, 1965; *Convention Preprint*, June 1965

SOLID-STATE MATERIALS—MAGNETIC PROPERTIES

Heisenberg Ferrimagnets Having Inter- and Intra-sub-lattice Exchange, High-Temperature Susceptibility of—P. J. Wojtowicz (Labs, Pr.) *Proc. of the International Conf. on Magnetism*, Sept. 1964

Site Preference of Ge^{4+} in Magnetic Spinels—M. Robbins (Labs, Pr.) *J. Phys. Chem. of Solids*, Vol. 26, 1965

SOLID-STATE MATERIALS—ELECTRONIC PROPERTIES

Activation Energy in $B\text{-}Ag_2Te$—R. Dalven, R. Gill (ECD, Pr.) Amer. Physical Soc. Mtg., N.Y.C., June 23-25, 1965

Alfven Waves in Bismuth—B. W. Faughnan (Labs, Pr.) *Journal of the Physical Society of Japan*, Vol. 20, No. 4, Apr. 1965

Avalanche Multiplication Noise in Semiconductor Junctions—R. J. McIntyre (RCA Ltd., Montreal) Solid State Device Res. Conf., Princeton, N.J., June 21-23, 1965

Charge Motion and Instability in the Metal-Silicon Oxide-Silicon Structure, A Model for the—S. R. Hofstein (Labs, Pr.) Solid-State Device Res. Conf., Princeton, N.J., June 1965

Energy Levels of Dy^{2+} in the Cubic Hosts of CaF_2, SrF_2, and BaF_2—Z. J. Kiss (Labs, Pr.) *Physical Review*, Vol. 137, No. 6a, Mar. 1965

"Hall" Drift Velocity at High Electric Fields in Indium Antimonide—M. Glicksman, W. A. Hicinbothem, Jr. (Labs, Pr.) *Proc. of 7th Inter'l. Conf. of Phys. and Semicon.*, Paris, July 12-24, 1964 (published in 1965)

Hydrogen-Induced Surface Space-Charge Regions in Oxide-Protected Silicon—J. Scott, J. Olmstead, P. Kuznetzoff (ECD, Som.) *IEEE Trans. on Electron Devices*, Mar. 1965

Photoemission of Electrons from Silicon Dioxide—R. Williams (Labs, Pr.) Solid-State Device Conf., Princeton, N.J., June 1965

Microwave Dielectric Constant of Liquids, Precision Measurement of—E. Fatuzzo, P. R. Mason (Labs, Pr.) *Journal of App. Phys.*, Vol. 36, No. 2, Feb. 1965

MOS Device Characteristics, The Influence of Oxidation and High-Temperature Treatment on—A. G. Revesz, K. A. Zaininger (Labs, Pr.) Solid-State Device Res. Conf., Princeton, N.J., June 1965

Scattering of Acoustical by Optical Phonons in Ge, Si and III-V Compounds—I. Kudman, E. F. Steigmeier (Labs, Pr.) Swiss Physical Soc. Mtg., Berne, Switzerland, May 1965

Semiconductor Surface Physics—S. R. Hofstein (Labs, Pr.) Seminar on Field-Effect Transistors, Naval Res. Labs., Wash., D.C., June 14-15, 1965; *NRL Seminar Booklet*, June 1965

Streaming Instabilities in Solids and the Role of Collisions—B. Vural, S. Bloom (Labs, Pr.) 1965 Solid-State Device Res. Conf., Princeton Univ., Princeton, N.J., June 1965

Surface Capacity of Oxide-Coated Semiconductors—R. Hall, J. White (ECD, Som.) *Solid-State Electronics*, Mar. 1965

Surface-Induced Two-Stream Instabilities in Longitudinal Magnetic Fields—B. Vural, M. C. Steele (Labs, Pr.) Solid-State Device Res. Conf., Princeton Univ., Princeton, N.J., June 1965

Thermoelectric Properties of Niobium in the Temperature Range 300-1200°K—V. Raag, H. V. Kowger (ECD, Hr.) *Journal of Applied Physics*, June 1965

Tunneling in III-V Compound p-n Junctions—J. Shewchun, R. M. Williams (Labs, Pr.) Amer. Phys. Soc. Mtg., N.Y., June 1965

Zeeman Effect Studies of the 5_{17}—5_{18} Transition in CaF_2:Dy—Z. J. Kiss, C. H. Anderson, R. Orbach (Labs, Pr.) *Physical Review*, Vol. 137, No. 6a, Mar. 1965

SOLID-STATE MATERIALS—OPTICAL PROPERTIES

Double Exciton Photoconduction in Triphenylene—S. E. Harrison, N. Almeleh (Labs, Pr.) Organic Crystal Symp., Chicago, Ill., May 1965

Electroluminescent Phosphors Under High-Frequency Pulsed Excitation, Performance of—S. A. Harper (ECD, Lanc.) Electrochemical Society Mtg., San Francisco, Calif., May 10-12, 1965

Interband Transitions in Anisotropic Semiconductors—G. Harbeke (Labs, Pr.) Enrico Fermi Summer School on Optical Properties of Solids, Varenna, Switz., June 1965

Optical Absorption Edge of GaAs—J. I. Pankove (Labs, Pr.) Symp. on Lasers and Related Materials, San Francisco, Calif., May 1965

Optical Activity in the Broad Absorption Bands of Paramagnetic Centers in Crystals—C. H. Anderson, E. S. Sabisky, H. A. Weakliem (Labs, Pr.) Physics of Quantum Electronics Conf., San Juan, Puerto Rico, June 1965

Oscillator Extrinsic Photoconductivity of Copper-Doped Germanium—M. L. Schultz (ECD, Pr.) IRIS Detector Specialty Group Mtg., Syracuse, N.Y., June 14-15, 1965

Photoconductors Applied to a Camera Tube, Low-Energy-Electron Scattering from—A. D. Cope, W. Bruce (AED, Pr.) *RCA Review*, Vol. XXVI, June 1965

Scattering of Acoustical by Optical Phonons in III-V Compounds—E. F. Steigmeier, I. Kudman (Labs, Pr.) Swiss Physical Soc. Mtg., Berne, Switzerland, May 1965

Wurtzite-Type Crystals and Rutile, Optical Properties and Band Structures of—M. Cardona, G. Harbeke (Labs, Pr.) *Physical Review*, Vol. 137, No. 6a, Mar. 1965

SOLID-STATE MATERIALS—PHYSICAL-CHEMICAL STRUCTURE

Cation and Cation Vacancy Distribution in $MgAl_2O_4$—Al_2O_3—R. H. Arlett, H. T. Smyth (Labs, Pr.) Amer. Ceramic Soc. Annual Mtg., Phila., Pa., May 1965

Charge Compensation of Rare Earth Ions by Alkali Metal Ions in Group II-VI Lattices—P. N. Yocom, S. Larach (Labs, Pr.) Electrochemical Society Luminescence Symp., San Francisco, Calif., May 10-12, 1965

Cooperative Jahn-Teller Distortions in the Systems $ZnMn_2O_4$-Cu_2GeO_4 and $ZnMn_2O_4$—M. Robbins, P. K. Baltzer (Labs, Pr.) *Journal of Applied Physics*, Vol. 36, No. 3, Mar. 1965

Defects in Phosphorus Doped Si-Ge Alloy by Electron Microscopy—M. D. Coutts (Labs, Pr.) Symp. on Electron Microscopy, RCA Labs., Princeton, N.J., June 1965

Group II-VI Phosphors Containing Rare Earth Activators—I. Dysprosium, R. E. Schrader, S. M. Thomsen, P. N. Yocom (Labs, Pr.) Electrochemical Society Luminescence Symp., San Francisco, Calif., May 10-12, 1965

Homogeneous Solidification of Ge-Si Alloys—J. P. Dismukes, L. Ekstrom (Labs, Pr.) *Transactions of the Metallurgical Society of AIME*, Vol. 233

Ionic Configurations in $CuMn_2O_4$ and $Zn_{0.5}Ge_{0.5}CuMnO_4$, Characterization of the—P. K. Baltzer, E. Lopatin (Labs, Pr.) *Proc. of the International Conf. on Magnetism*, Sept. 1964

Metal-Semiconductor Barrier Height Measurement by the Differential Capacitance Method Without Ohmic Reference Contact—One-Carrier Systems—A. Goodman (Labs, Pr.) *Journal of Applied Physics*, Vol. 36, No. 4, Apr. 1965

Microstructures in CdS:Au Single Crystals—A. Dreeben (Labs, Pr.) *Journal of the Electrochemical Society*, Vol. 112, No. 5, May 1965

Oxidation-Reduction Processes in Rare-Earth-Doped CaF_2, Dynamics of—Z. J. Kiss, D. L. Staebler (Labs, Pr.) *Physical Review Letters*, Vol. 14, No. 17.

Semiconductor Doping Densities, Use of Transient Measurements in Metal-Insulator Semiconductor Structures to Determine—A. Waxman (Labs, Pr.) *Proc. of the IEEE*, Mar. 1965, Vol. 53, No. 3

Supersonic Domain Wall Motion in Triglycine Sulfate—B. Binggeli, E. Fatuzzo (Labs, Pr.) *Journal of Applied Physics*, Vol. 36, No. 4, Apr. 1965

Trigonal Field Splitting of B-Site Ions in Spinel, Sign of the—S. B. Berger (Labs, Pr.) *Journal of Applied Physics*, Vol. 36, No. 3, Mar. 1965

Vapor Phase Transport and Epitaxial Growth of $GaAs_{1-x}PX$, Using Water Vapor—G. E. Gottlieb (Labs, Pr.) *Journal of Electrochemical Soc.*, Vol. 112, No. 2, Feb. 1965

SOLID-STATE MICROELECTRONICS

Photomask Inspection, Use-Test Method for—G. L. Finne (ECD, Som.) ASTM Mtg., San Francisco, Calif., May 13-14, 1965

Temperature Evaluation in Microelectronic Structures Using Analog Networks—G. Rezek (DEP-CSD, Cam.) *IEEE Trans. Product Engineering and Production*, Vol. PEP-9, No. 1, Apr. 1965

SOLID-STATE, THIN FILMS

Superconducting Films, On the Mechanism of Amplification in—A. S. Clorfeine, A. H. Nethercot, Jr. (Labs, Pr.) *Proc. of IEEE*, Vol. 53, No. 4, Apr. 1965

Temperature Coefficient of Vacuum-Deposited Thin-Film Resistors as Patterned with Abrusive-Jet and Electron-Beam Milling—E. Casterline, H. Schwarz (ECD, Som.) IEEE Microelectronics Symp., St. Louis, Mo., May 24-26, 1965; *Conf. Record*

SPACE COMPONENTS

Attitude Control for the TIROS Weather Satellite—W. P. Manger (DEP-AED, Pr.) Intern'l. Federation of Automatic Control, Symp. on Automatic Control in the Peaceful Uses of Outer Space, Stavanger, Norway, June 22, 1965; *Proceedings*

Designing Equipment for Operation Under Outer-Space Constraints—L. B. Garrett (DEP-CSD, Cam.) Engineering Lecture, Camden, June 9, 1965

Horizon Sensing from a Spin-Stabilized Spacecraft—J. J. Horan, F. Gordon, M. Dwork (DEP-AED, Pr.) *Proceedings of IRIS Infrared Information Symp.*, June 1965

Magnetic Recording for Space Communications—A. S. Katz (DEP-CSD, Cam.) Camden Engineering Lecture, June 29, 1965

RANGER Program in the Communications Systems Division—C. Alexoff (DEP-CSD, Cam.) Engineering Lecture, Camden, June 23, 1965

RANGER TV Subsystem—B. P. Miller (DEP-AED, Pr.) Detroit Engineering Society, Detroit, Mich., June 11, 1965; ALSO: Engineering Educational Lecture Series, RCA, Marion, Ind., June 6, 1965

Solid-State Radar Transmitter Units for the Lunar Excursion Module, Design of—E. E. Bliss, M. Fromer (ECD, Hr.) IEEE Electronics Components Conf., Wash., D.C., May 5-7, 1965; *Conf. Record*, May 1965

Telemetering Transmitter, A Single-Transistor L-Band—C. D'Elio, J. Poole (ECD, Hr.) International Telemetering Conf., Wash., D.C., May 18, 1965; *Conf. Proceedings*, May 1965

Ultrawideband Cassegrainian Feed for Satellite Communications—P. Foldes, S. Komlos, (RCA Ltd., Montreal) IEEE Annual Comm. Convention on Globe Comm., Boulder, Colo., June 7, 1965; *Convention Preprints*

Varactor Frequency Multiplier for an All-Solid State Satellite Communications System—E. E. Bliss, C. D'Elio (ECD, Hr.) IEEE Comm. Conv., Boulder, Colo., June 7-9, 1965; *Convention Preprint*, June 1965

SPACE NAVIGATION; TRACKING

Computer-Controlled Range Tracking, A System for—J. M. Chambers (DEP-ASD, Van Nuys) *MS Thesis*, Univ. of Penna., May 24, 1965

Navigation—H. J. Woll (DEP-ASD, Burl.) IEEE Aerospace Technical Conf., Houston, Texas, June 20-24, 1965; *IEEE Trans. on Aerospace*

Telemetry Systems, RELAY and GEMINI—R. G. Erdmann (DEP-CSD, Cam.) Engineering Lecture, Camden, June 16, 1965

SPACE VEHICLES; SATELLITES

Communication Requirements Between Manned Spacecraft on Interplanetary Voyages—S. Gubin, R. B. Marsten, D. Silverman (DEP-AED, Pr.) 2nd AIAA Annual Mtg., San Francisco, Calif., July 26, 1965

SPACE SYSTEMS

RELAY Satellite, Space Communications and the—R. B. Marsten (DEP-AED, Pr.) Engineering Extension and Physical Sciences Extension, Univ. of Calif. Extension, Los Angeles, Calif., July 29, 1965

Satellite Communications and the Space Environment—R. B. Marsten (DEP-AED, Pr.) Franklin Inst. Summer Work Shop, Phila., Pa., July 8, 1965

Space Communications—R. G. Erdmann (DEP-CSD, Cam.) Barclay School Lecture, June 4, 1965, Cherry Hill, N.J.

SUPERCONDUCTIVITY; CRYOELECTRICS

Amplification in Superconducting Films, On the Mechanism of—A. S. Clorfeine, A. H. Nethercot, Jr. (Labs, Pr.) *Proc. of IEEE*, Vol. 53, No. 4, Apr. 1965

Cavity Sensing of Cryoelectric Memory Planes—L. L. Burns, A. R. Sass (Labs, Pr.) *Journal of Applied Physics*, Vol. 36, No. 3, Mar. 1965

(Diodes) Microwave Phonon-Assisted Tunneling in Superconducting Diodes—B. Abeles, Y. Goldstein (Labs, Pr.) *Physical Review Letters*, Vol. 14, No. 15, Apr. 1965

Integrated Magnetic and Superconductive Memories—A Survey of Techniques, Results and Prospects—J. A. Rajchman (Labs, Pr.) MITRE Corp., Computer Languages Systems and Technology Seminar, Bedford, Mass., June 1965

Specific Heat of Type II Superconductor—L. J. Vieland (Labs, Pr.) *Physics Letters*, Vol. 15, No. 1, Mar. 1965

TELEVISION BROADCASTING; TRANSMISSION

Color Television—1965—Dr. G. H. Brown (Labs., Pr.) Fourth Intl. Television Symp., Montreux, Switzerland, May 26, 1965

Color Television—W. Carrell (ECD, Marion) Purdue Univ. Panel Discussion, Lafayette, Ind., May 6, 1965

Electro-Optic TV Communications—W. J. Hannan, J. Bordogna, T. P. Penn, T. E. Walsh (DEP-AppRes, Cam.) *Proceedings of the IEEE*, Feb. 1965

TELEVISION, NON-ENTERTAINMENT

High-Definition Television Systems, A 60-Megacycle Video Chain for—O. H. Schade, Sr. (ECD, Hr.) *RCA Review*, Vol. XXVI, June 1965

TELEVISION RECEIVERS

Destructive Circuit Malfunctions and Corrective Techniques in Horizontal Deflection—C. F. Wheatley (ECD, Som.) IEEE Conf. on Broadcast and TV Receivers, Des Plaines, Ill., June 14-15, 1965; *IEEE Transactions on Broadcast and TV Receivers*, July 1965

(Transistor, MOS): Characteristics and Applications of RCA Insulated-Gate Field-Effect Transistors—D. M. Griswold (ECD, Som.) IEEE Conf. on Broadcast and TV Receivers, Des Plaines, Ill., June 14-15, 1965; *IEEE Transactions on Broadcast and TV Receivers*, July 1965

TESTING

Shakers, Electro-Dynamic, Shock Capabilities of—J. McClanahan, J. Fagan (DEP-AED, Pr.) 11th Annual IES Tech. Mtg., Sherman House, Chicago, Ill., Apr. 21-23, 1965; *Conf. Proceedings*

TUBE DESIGN

Color Picture Tubes and Their Manufacture—D. J. Ransom (ECD, Marion) Workshop Session for Vocational Instructors, Purdue Univ., Lafayette, Ind., June 18, 1965

Color Picture Tubes, Development of the RCA Family of 90-Degree Rectangular—A. M. Morrell (ECD, Lanc.) IEEE Conf. on Broadcast and TV Receivers, Des Plaines, Ill., June 14-15, 1965; *IEEE Trans. on BTR*, July 1965

Color-Television Picture-Tube Phosphor Screens, The Colorimetry of—A. E. Hardy (ECD, Lanc.) Electrochemical Society Mtg., San Francisco, Calif., May 10-12, 1965

Color-Television Picture-Tube Phosphor Screens, the Performance of—A. E. Hardy, (ECD, Lanc.) IEEE Conf. on Broadcast and TV Receivers, Des Plaines, Ill., June 14-15, 1965; *IEEE Trans. on BTR*, July 1965

Color TV Screen by the Slurry Process—T. A. Saulnier (ECD, Lanc.) Electrochemical Society Mtg., San Francisco, Calif., May 10-12, 1965

Color TV Screens, Emulsion Filming for—T. A. Saulnier (ECD, Lanc.) Electrochemical Society Mtg., San Francisco, Calif., May 10-12, 1965

Grid-Controlled Power Tubes in Particle-Accelerator Applications—M. V. Hoover (ECD, Lanc.) *IEEE Trans. on Nuclear Science*, June 1965

HELPER—An Automatic Linear Comparator for Measuring Uniform Increments—M. Fromer (ECD, Hr.) ASME Production Engineering Conf., Berkeley, Calif., June 9-11, 1965

Infrared Vidicon Airborne Reconnaissance System—N. Aron (DEP-ASD, Burl.) *Proceedings of the IR Information Symposia* (Secret) Vol. 9, No. 3, Sept. 1964 (Uncl. title; Confidential paper)

Infrared Vidicon Reconnaissance System, Evaluation of an—L. Arlan (DEP-ASD, Burl.) *Proceedings of the IR Information Symposia* (Secret), Vol. 9, No. 3, Sept. 1964 (uncl. title; Confidential paper)

Infrared Vidicon, Resolution Measurement of the RCA—N. Aron (DEP-ASD, Burl.) *Proceedings of the IR Information Symposia* (Secret), Vol. 9, No. 4, Jan. 1965

Photoconductors Applied to a Camera Tube, Low-Energy-Electron Scattering from—A. D. Cope, W. Bruce (AED, Pr.) *RCA Review*, Vol. XXVI, June 1965

Photomultipliers (New) for Scintillation Counting, Evaluation of—H. R. Krall (ECD, Lanc.) *IEEE Trans. on Nuclear Science*, Feb. 1965

Traveling-Wave-Tube Helices, Automatic Pitch-Measuring Instrument for—M. Fromer (ECD, Hr.) *Proceedings of 1964 Tube Techniques Conf.*, Apr. 1965

Traveling-Wave Tubes, Automation Applied to the Manufacture of—K. Karol (ECD, Hr.) *Proceedings of the 1964 Tube Techniques Conf.*, Apr. 1965

TUBE MATERIALS; THEORY

(Seals): Stress Analysis of Butt-Type Ceramic-to-Metal Seals—S. W. Kessler (ECD, Lanc.) *RCA Review*, Vol. XXVI, June 1965

Quench Firing of Ceramics for Electron-Tube Applications—T. F. Berry, L. P. Garvey, W. F. Griffin, A. L. Dorf (ECD, Hr.) *Proceedings of 1964 Tube Techniques Conf.*, Apr. 1965

VACUUM TECHNOLOGY

Vacuum Technology—J. T. Mark (ECD, Lanc.) ASEE/NASA Summer Faculty Fellowship Program, Auburn Univ., Ala., June 14, 1965

AUTHOR'S INDEX

Subject listed opposite each author's name indicates where complete citation to his paper may be found in the subject index. Where an author has more than one paper, his name is repeated for each.

ELECTRONIC COMPONENTS AND DEVICES

BROADCAST AND COMMUNICATIONS PRODUCTS DIV.

DEP ALLIED RESEARCH DIV.

DEP AEROSPACE SYSTEMS DIV.

DEP ASTRO ELECTRONICS DIV.

DEP CENTRAL ENGINEERING

DEP COMMUNICATIONS SYSTEMS DIV.

DEP MISSILE AND SURFACE RADAR DIV.

ELECTRONIC DATA PROCESSING

Beard, A. D. computer systems
Lonergan, W. R. computer applications
Torre, A. J. computer input-output

RCA COMMUNICATIONS, INC.

Ernst, R. L. amplification
Sobol, H. amplification
Torrione, P. communications, equipment components
Yuan, S. communications equipment components

RCA LABORATORIES

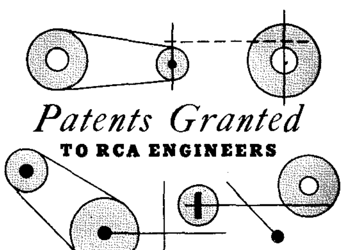
Abeles, B. solid-state devices
Almeleh, N. solid-state materials—optical properties
Amick, J. A. instrumentation; lab equipment
Anderson, C. H. solid-state materials—optical properties
Anderson, C. H. solid-state materials—electronic properties
Arlett, R. H. solid-state materials—physical-chemical structure
Baltzer, P. K. solid-state materials—physical-chemical structure
Baltzer, P. K. solid-state materials—physical-chemical structure
Berger, S. B. solid-state materials—physical-chemical structure
Binggeli, B. solid-state materials—physical-chemical structure
Bloom, S. atomic theory; phenomena
Breeze, W. R. management; business
Burns, L. L. computer storage
Cardona, M. solid-state materials—optical properties
Caulton, M. electromagnetic theory; phenomena
Caulton, M. electromagnetic theory; phenomena
Caulton, M. amplification
Chang, K. K. N. electromagnetic theory; phenomena
Clorfeine, A. S. amplification
Coutts, M. D. instrumentation; lab equipment
Crane, R. L. computer programming
Dismukes, J. P. solid-state materials—physical-chemical structure
Dismukes, J. P. energy conversion; sources
Dreeben, A. solid-state materials—physical-chemical structure
Duncan, R. C. lasers
Dysprosium, I. solid-state materials—physical-chemical structure
Edelman, F. management; business
Ekstrom, L. solid-state materials—physical-chemical structure
Fatuzzo, E. solid-state materials—electronic properties
Fatuzzo, E. solid-state materials—physical-chemical structure
Faughman, B. W. solid-state materials—electronic properties
Garber, H. N. management; business
Gerritsen, H. J. instrumentation; lab equipment
Glicksman, M. solid-state materials—electronic properties
Glicksman, M. plasma
Gold, R. solid-state devices
Goldstein, Y. solid-state devices
Goodman, A. solid-state materials—physical-chemical structure
Gottlieb, G. E. solid-state materials—physical-chemical structure
Gray, G. W. control; automata
Hammer, J. M. lasers
Harbeke, G. solid-state materials—optical properties
Harbeke, G. solid-state materials—optical properties
Harrison, S. E. solid-state materials—optical properties
Heilmeier, G. H. solid-state devices
Heiman, F. P. solid-state devices
Herzog, G. B. computer storage
Heyman, P. M. solid-state devices
Hicinbothem, Jr., W. A. solid-state materials—electronic properties
Hirsch, C. J. control; automata
Hofstein, S. R. solid-state devices
Hofstein, S. R. solid-state materials—electronic properties
Hofstein, S. R. solid-state materials—electronic properties
Ikola, R. J. amplification
Kaplan, K. R. computer logic; theory
Keiser, B. E. antennas
Kiss, Z. J. lasers
Kiss, Z. J. solid-state materials—physical-chemical structure
Kiss, Z. J. solid-state materials—electronic properties
Kiss, Z. J. solid-state materials—electronic properties
Klopfenstein, R. W. atomic theory; phenomena
Klopfenstein, R. W. computer programming
Kosonocky, W. F. computer systems
Kudman, I. solid-state materials—optical properties
Kudman, I. solid-state materials—electronic properties
Larach, S. solid-state materials—physical-chemical structure
Larkin, F. P. computer programming
Lopatin, E. solid-state materials—physical-chemical structure
Mason, P. R. solid-state materials—electronic properties
Mikolwitz, J. mechanical components; structures
Napoli, L. S. amplification
Nethercot, A. H., Jr. amplification
Olson, H. F. communications systems; theory
Olson, H. F. acoustic theory; phenomena
Orbach, R. solid-state materials—electronic properties
Pankove, J. I. solid-state materials—optical properties
Prager, H. J. electromagnetic theory; phenomena
Rajchman, J. A. computer storage
Reimann, O. A. computer systems
Revesz, A. G. solid-state materials—electronic properties
Robbins, M. solid-state materials—magnetic properties
Robbins, M. solid-state materials—physical-chemical structure
Rodda, W. E. communications, voice systems
Rosenfeld, R. L. mechanical components; structures
Rosenthal, H. lasers
Rosi, F. D. energy conversion; sources
Sabisky, E. S. solid-state materials—optical properties
Sass, A. R. computer storage
Schilling, R. B. mathematics
Schrader, R. E. solid-state materials—physical-chemical structure
Shewchun, J. solid-state materials—electronic properties
Sklansky, J. bionics
Sklansky, J. bionics
Sklansky, J. bionics
Smyth, H. T. solid-state materials—physical-chemical structure
Staebler, D. L. solid-state materials—physical-chemical structure
Steele, M. C. solid-state materials—electronic properties
Steigmeier, E. F. solid-state materials—optical properties
Steigmeier, E. F. solid-state materials—electronic properties
Thomsen, S. M. solid-state materials—physical-chemical structure
Toda, M. communications, equipment components
Vieland, L. J. superconductivity; cryoelectrics
Vural, B. atomic theory; phenomena
Vural, B. solid-state materials—electronic properties
Warfield, G. solid-state devices
Waxman, A. solid-state devices
Weakliem, H. A. solid-state materials—optical properties
Weisberg, L. R. solid-state devices
Wen, C. P. lasers
White, J. G. instrumentation; lab equipment
Williams, R. solid-state materials—electronic properties
Williams, R. solid-state materials—electronic properties
Winder, R. O. computer logic; theory
Winder, R. O. computer logic; theory
Wojtowicz, P. J. solid-state materials—magnetic properties
Woolston, J. R. computer applications
Yocom, P. N. solid-state materials—physical-chemical structure
Yocom, P. N. solid-state materials—physical-chemical structure
Zaininger, R. A. solid-state materials—electronic properties
Zernik, W. atomic theory; phenomena

RCA VICTOR CO., LTD.

Foldes, P. antennas
Komlos, S. antennas
Johnston, T. W. electromagnetic theory; phenomena
McIntyre, R. J. solid-state materials—electronic properties
Shkarofsky, I. P. electromagnetic theory; phenomena
Shkarofsky, I. P. electromagnetic theory; phenomena

RESEARCH & ENGINEERING (STAFF)

Brown, G. H. television broadcasting
Brown, G. H. biomedical electronics



As Reported By RCA Domestic Patents, Princeton

RCA LABORATORIES

DEFENSE ELECTRONIC PRODUCTS

Minimum Signal Detecting Circuit—F. J. Putzrath (DEP-CSD, Cam.) *U.S. Pat. 3,174,051*, Mar. 16, 1965 (assigned to U.S. Gov't.)

Signal Deviation Detector—D. D. Freedman, W. J. Hess (DEP-MSR, Moores.) *U.S. Pat. 3,184,729*, May 18, 1965 (assigned to U.S. Gov't.)

Logic Circuit—A. Feller (DEP-AppRes, Cam.) *U.S. Pat. 3,189,757*, June 15, 1965

Apparatus for Determing the Algebraic Sign of a Residue Coded Number—R. A. Baugh, E. C. Day (DEP-MSR, Moores.) *U.S. Pat. 3,191,011*, June 22, 1965

Random Access Memory—G. Rezek (DEP-CSD, Cam.) *U.S. Pat. 3,191,099*, June 22, 1965

Optical Memory—D. J. Parker, T. I. Ress (DEP-AppRes, Cam.), H. J. Woll (DEP-ASD, Burl.) *U.S. Pat. 3,191,157*, June 22, 1965

Remote Motor Control System for T. V. Tuner—D. A. Tannenbaum (DEP-CSD, Cam.), A. J. Torre (EDP, Cam.) *U.S. Pat. 3,193,743*, July 6, 1965

Bistable Circuit—H. T. Gnuse (DEP-ASD, Van Nuys) *U.S. Pat. 3,193,805*, July 6, 1965

AGC Parametric Amplifier Using Negative Bias and Detuned Circuits—T. Murakami (DEP-MSR, Moores.) *U.S. Pat. 3,195,062*, July 13, 1965

RCA LABORATORIES

Tunnel Diode Memory with Nondestructive Readout—J. C. Miller, K. Li (Labs, Pr.) *U.S. Pat. 3,188,485*, June 8, 1965 (assigned to U.S. Gov't.)

Signal Translating System—K. K. N. Chang (Labs, Pr.) *U.S. Pat. 3,189,828*, June 15, 1965

Thin-Film Field Effect Device Employed as Active Element in Integrated Structure Circuits—P. K. Weimer (Labs, Pr.) *U.S. Pat. 3,191,061*, June 22, 1965

Cryoelectric Circuits—G. A. Alphonse (Labs, Pr.) *U.S. Pat. 3,191,160*, June 22, 1965

Electrostatic Printing Apparatus—C. J. Young (Labs, Pr.) *U.S. Pat. 3,192,897*, July 6, 1965

Voltage and Phase Memory System—T. G. Marshall, Jr. (Labs, Pr.) *U.S. Pat. 3,193,770*, July 6, 1965

Personal Microphone Line Transformer—J. Preston (Labs, Pr.) *U.S Pat. 3,194,887*, July 13, 1965

Low-Noise High-Gain Stabilized Negative Conductance Diode Frequency Converter—K. K. N. Chang (Labs, Pr.) U.S. Pat. *3,195,051*, July 13, 1965

ELECTRONIC COMPONENTS AND DEVICES

Method of Sealing and Joining—S. Y. Husni, Jr. (ECD, Hr.) *U.S. Pat. 3,188,720*, June 15, 1965

Method of Assembling Electron Discharge Tubes—C. W. Lindsley, E. R. Larson (ECD, Hr.) *U.S. Pat. 3,188,723*, June 15, 1965

Micromanipulator—E. W. Conley (ECD, Som.) *U.S. Pat. 3,188,879*, June 15, 1965

Method of Getter Flashing—J. B. Fitzpatrick, W. O. Zvonik (ECD, Hr.) *U.S. Pat. 3,189,397*, June 15, 1965

Switching Device—W. T. Ackermann (ECD, Hr.) *U.S. Pat. 3,189,799*, June 15, 1965

Frame Grid and Method of Fabrication—G. Samuels (ECD, Hr.) *U.S. Pat. 3,189,779*, June 15, 1965

Method of Making Multilayer Circuits—H. W. Stetson (ECD, Som.) *U.S. Pat. 3,189,978*, June 22, 1965

Apparatus for and Method of Fabricating Electron Tube Stems—H. V. Knauf, Jr. (ECD, Hr.) *U.S. Pat. 3,189,980*, June 22, 1965

Article Handling Apparatus—A. Fischer, Jr. (ECD, Hr.) *U.S. Pat. 3,191,781*, June 29, 1965

Method of Fabricating a Cathode Ray Tube—D. M. Linn (ECD, Marion) *U.S. Pat. 3,192,005*, June 29, 1965

Methods for Manufacturing Multilayered Monolithic Ceramic Bodies—W. J. Gyurk (ECD, Som.) *U.S. Pat. 3,192,086*, June 29, 1965

Multigrid Electron Tube and Method of Assembly Thereof—W. F. Griffin (ECD, Hr.) *U.S. Pat. 3,192,428*, June 29, 1965

Cathode Heater for Electron Discharge Devices—W. A. Hassett (ECD, Hr.) *U.S. Pat. 3,195,004*, July 13, 1965

Constant Power Output High Frequency Tuning Circuit and Apparatus—R. Steinhoff (ECD, Hr.) *U.S. Pat. 3,195,071*, July 13, 1965

HOME INSTRUMENTS DIV.

Indicator Mechanism—T. D. Smith (H. I., Indpls.) *U.S. Pat. 3,192,779*, July 6, 1965

Transistor Radio Signal Receiver with Means for Reducing Distortion in the RF Amplifier—J. B. Schultz (H. I., Pr.) *U.S. Pat. 3,193,767*, July 6, 1965

Engineering NEWS *and* HIGHLIGHTS

NEW RCA GRAPHIC SYSTEMS DIVISION HEADED BY S. W. COCHRAN, WITH DR. N. I. KORMAN AS CHIEF ENGINEER

The newly formed RCA Graphic Systems Division has the objective to develop, manufacture, and market new electronic equipment and systems for handling all types of printed information. RCA President **Elmer W. Engstrom** has announced the appointment of **Stanley W. Cochran** as Division Vice President and General Manager, RCA Graphic Systems Division, and of **Dr. Nathaniel I. Korman** as the new organization's Chief Engineer.

Utilizing RCA's experience in such areas as facsimile transmission and reproduction, electronic printing, and computerized typesetting, the new Division will at the same time explore new methods for applying electronic to handling all information that is to be recorded in permanent form—in print, pictures, or code. It will relate these new techniques and systems to the needs of the printing industry for improved methods of composition and reproduction. Eventually, it will also embrace the electronic storage and retrieval of library information, and the automatic preparation of photographic printing plates directly from images transmitted electronically over long distances. The new Division is expected to generate major new business for RCA by the end of the present decade. It occupies facilities at the David Sarnoff Research Center, Princeton, N.J., and reports to **Arthur L. Malcarney,** RCA Group Executive Vice President, whose responsibilities also include RCA Electronic Data Processing. Establishment of the group in close proximity to the RCA Laboratories will assure strong research support. It also will permit the Graphic Systems Division to take full advantage of the effective communications that already exist between RCA Laboratories and other RCA product divisions of the company.

The new division will be equipped to originate, build, and market all of its own products and systems with the exception of the computers provided by the RCA Electronic Data Processing and any system components that may already exist in RCA product lines.

Mr. Cochran, an electrical engineering graduate of the University of Washington, has been with RCA since 1930. He has advanced successively through positions of increasing responsibility as Manager of Special Devices Engineering at RCA in Cam den; Manager of Advanced Development Engineering, and General Manager, Surface Communications Divisions, RCA Defense Electronic Products. In August 1960, he was appointed Vice President and General Manager, Surface Communications Division. In September, 1963 he was named Division Vice President and General Manager, Communications Systems Division, RCA Defense Electronic Products, holding this position until his appointment to head the new RCA Graphic Systems Division.

Dr. Korman was graduated from Worcester Polytechnic Institute and received his master's degree in electrical engineering from the Massachusetts Institute of Technology and his Ph.D. degree from the University of Pennsylvania. He joined RCA in 1938 as a student engineer and has held positions of increasing responsibility after being promoted to a supervisory position in 1945. He was Chief Systems Engineer of Missile and Surface Radar Engineering for RCA during the development of the Ballistic Missile Early Warning System, and was appointed in 1958 to be Director of Advanced Military Systems, RCA Defense Electronic Products, at Princeton, N.J.

RCA AWARDED $7 MILLION CONTRACT BY JAPANESE FIRM FOR FIGHTER-AIRCRAFT COMMUNICATIONS

RCA has been awarded a contract of more than $7 million by the Japanese firm of Hitachi, Ltd., to supply airborne digital data link equipment for Japan's F-104J Self Defense Forces aircraft. The equipment will be developed and manufactured in part by the DEP Communications Systems Division, Camden, N.J. Partial production of the equipment will be done in Japan. The equipment, designated the ARR-662, is a version of similar equipment built by RCA for U.S. interceptor aircraft. It will employ such new techniques as multilayer board construction and integrated circuitry.

APPLIED RESEARCH GETS CONTRACT FOR GEMINI LASER TRANSMITTER

DEP Applied Research, Camden, has received a NASA contract for three 8-watt (peak power) laser transmitters for the Gemini GT-7 flight. Plans call for an astronaut to aim the 3-milliradian laser beam at an optical receiver slaved to an RCA AN/FPS-16 radar at the White Sands Missile Range.

Using a telescope mounted in the laser transmitter, the astronaut will attempt to sight an argon laser that will be used as a ground beacon. He will steady the 3 by 6 by 8.5-inch unit with a bite plate held in his mouth as he aims the laser with two extended handles. A pushbutton in one handle will enable the astronaut to switch the laser beam from 100 to 7,000 pulses per second.

LICENSED PROFESSIONAL ENGINEERS

J. T. Kane, RCA Service Co., Thule, Greenland, PE-2071, Vermont

R. F. Trump, DEP-CSD, Camden, PE-13842, N.J.

F. R. Shirak, DEP-ASD, Burl., PE-20125, Mass.

J. Gale, ECD, Hr., PE-14086, N.J.

P. Van Sickle Smith, RCA Service Co., Cherry Hill, PE-10164-E, Pa.

BCD EXPANDS CAMDEN FACILITIES

The Broadcast and Communications Products Division is expanding its Camden production facilities to meet unprecedented demands from broadcasters for new color television cameras. **C. H. Colledge,** Division Vice President and General Manager, said the new facilities include "clean rooms" where camera modules are assembled under dust-free conditions, and additional test positions for proving camera performance and reliability before shipment.

He reported that BCD now has nearly $20 million in orders on the books for its two types of color four-tube cameras.

J. B. FARESE NAMED V.P. OF ECD; D. Y. SMITH MOVES TO CORPORATE POST

Promotion of **John B. Farese** to Division Vice President, Electronic Components and Devices, has been announced by **W. Walter Watts,** Group Executive Vice President. Mr. Farese, formerly Division Vice President and General Manager, Television Picture Tube Division, succeeds **Douglas Y. Smith.** Mr. Smith, an RCA Vice President, will move to New York for special assignments on Mr. Watt's staff.

As head of all RCA electron tube and semiconductor operations, Mr. Farese will continue to direct the company's color television picture tube production. Mr. Smith, in his new staff position, Mr. Watts said, will provide RCA at the corporate level with "unparalleled depth and range of experience for the exploration and development of new opportunities in the fields of electronic components and tube and semiconductor devices."

J. B. Farese joined RCA in 1930 as office manager of accounting for engineering activities, Electron Tube Division, Harrison, N.J. After receiving several promotions he was appointed assistant to the Controller of the division in 1947. In 1953, Mr. Farese was promoted to Manufacturing Manager, Receiving Tube Operations Department, and 3 years later was named Manager of Personnel. He became Manager, Entertainment Tube Products Department in 1957, and was promoted in 1960 to Division Vice President, Entertainment Tube Products.

D. V. Smith has been with RCA since 1930, when he joined the company's tube engineering activities at Harrison. He rose through a series of engineering and Marketing positions of increasing responsibility, becoming Merchandise Manager for the RCA Tube Department in 1944, and subsequently Manager of the RCA tube plant at Lancaster, Pa. He was named Vice President and General Manager, RCA Electron Tube Division, in 1954, and was appointed Vice President, RCA Electronic Components and Devices, in 1963.

R. E. PATTERSON HONORED BY NSIA

Russell E. Patterson, Manager of DEP-CSD Documentation and Engineering Publications Department in Camden, has been awarded a *Certificate of Merit* from the National Security Industrial Association. The certificate was the only one of its kind awarded in 1965.

It was presented " . . . *with appreciation and in recognition of outstanding achievements to the defense of our nation through military-industry cooperation while contributing to the NSIA report, 'The Military Technical Manual Industry—A Profile of Its Management and Cost'.*"

GILDEA HELPS TRAIN BLIND PROGRAMMERS

Robert J. Gildea, Manager, Programming, ASD Burlington, has been extremely active in aiding blind persons to become experienced computer programmers. This has been done partially through the auspices of the Association for Computing Machinery's Committee on the Professional Activities of the Blind. Gildea and an associate conducted a training program at MIT for five blind persons. After 42 hours of training, the students ran their program; the output was in Braille.—*D. Dobson.*

RCA SALES AND EARNINGS SET ALL-TIME HIGHS FOR SECOND QUARTER AND FIRST HALF OF 1965

RCA profits and sales rose to all-time record levels during the second quarter and first half of 1965. RCA's second-quarter and first-half dollar earnings increased by 18% and 17%, respectively, over last year's levels. The quarter was the 17th consecutive three-month period in which profits improved over the comparable quarter of the preceding year.

New all-time sales records were set for a month, a quarter, and a half-year. June sales volume of $186,000,000 was the highest for any single month in RCA's 45-year history. It exceeded by $17 million the previous monthly record set in October, 1962.

Profits after taxes in the second quarter were $18,900,000, as against $16,000,000 in the same period last year. For the first half, after-tax profits were $43,900,000, compared to last year's first-half record of $37,600,000.

Sales in the first six months were $963,-900,000, setting a new mark for any half year. The previous high was $913,300,000 in the second half of 1964. Second quarter sales were $488,400,000, an all-time record for any quarter. The best previous quarterly total was $486,200,000 in the fourth quarter of 1962. In comparison with the same periods last year, the gains in sales volume were 12% for the second quarter and 7% for the first half.

The record performance during the first half and second quarter of 1965 was credited to these principal developments:

1) *Continued RCA leadership in all aspects of color television, resulting in record sales and profits in color tubes and receivers, and color studio equipment.* The dollar volume of RCA color set sales at the factory level rose during the first half of 1965 by 54% over the first half of 1964. The demand for color television sets has risen phenomenally, with the rate of increase even greater than the most optimistic estimates in the industry. Among the other effects of the upsurge in color are the backlog of orders for RCA color television cameras, which reached a record high of $20 million during the second quarter.
2) *Record profits of the National Broadcasting Company, which increased its second quarter earnings by 19 per cent over those of the same period in 1964.*
3) *Sustained momentum in RCA electronic data processing sales, highlighted by mounting orders for the new RCA Spectra 70 computer series.* More than 925 RCA systems have now been delivered or are on order. The new RCA Spectra 70 series is gaining wide acceptance, and that continuing new orders have led to an upward revision in production schedules for the earlier 301 and 3301 systems.
4) *All-time record first-half and second-quarter earnings by RCA's Electronic Components and Devices, paced by color television picture tubes.*
5) *Substantial sales increases and continued profit improvement by the RCA Victor Record Division and the RCA Service Company.*

BEECH ORDERS 50 DME SYSTEMS

Beech Aircraft Corporation, Wichita, Kan., has purchased 50 systems of RCA's new AVQ-75 Distance Measuring Equipment (DME). The order brings to 100 the number of AVQ-75's ordered by Beech. The equipment will be built by the DEP Aviation Equipment Department in Los Angeles, Calif. The facility also manufactures the AVQ-10, AVQ-20, and AVQ-55 airborne weather radars, the AVQ-70 DME, the AVQ-60 air traffic control transponder, and other commercial airbone electonic equipment.

U.S. COMMUNICATIONS LEADERSHIP IMPERILED, GEN. SARNOFF STATES

Only a fundamental change in the policies and regulations governing America's international communications can safeguard this nation's leadership in satellite and global communications against the impending challenges of Russia and other foreign nations. This is what **David Sarnoff,** RCA Chairman, told the annual banquet of the Armed Forces Communications and Electronics Association.

General Sarnoff said that America's outmoded international communication structure could be modernized and strengthened through the unification of the nation's present international voice and record facilities into a single, privately owned independent company. Such a company would be separate from the Communications Satellite Corporation and would function under appropriate government regulations.

The RCA Chairman emphasized that, despite technological change, arbitrary barriers continue to exist between voice and nonvoice communications in the international filed and between the full interconnection of international communications with domestic telephone facilities.

"Faced by the prospect of increased competition from abroad, America cannot, in my judgment, successfully operate a system of global communications with one company responsible for international voice transmission, five others for international record transmission, and with unresolved jurisdictional lines between the single American satellite entity and all the international communications carriers. We require a fundamental change in the policies and regulations under which we now operate," General Sarnoff said.

He suggested that a single unified American company in the International voice and record field would be in keeping with the historic tradition of private enterprise in American communications and would possess these advantages: 1) Permit the United States to deal on equal terms with foreign government monopolies, 2) Simplify relationships with COMSAT to the benefit of the unified carrier, COMSAT, and the public, 3) Advance and strengthen both the voice and record services now rendered to the public, 4) Avoid the danger of the single voice carrier capturing the traffic of the competing record carriers—a danger that will develop if AT&T is permitted to render both record and voice services, and 5) Give new cohesion to our entire communications structure and automatically solve the problem of providing interconnection for the flow of international traffic with the established domestic facilities.

Looking beyond the present, General Sarnoff asserted that "within a decade, and possibly less, I believe it will be technically feasible to broadcast directly into the home from synchronous satellites. All of the basic components and technology already exist for radio and television broadcast transmitters to operate in space."

RCA TO SPEND RECORD $50 MILLION TO DOUBLE COLOR TV CAPACITY

RCA has undertaken the largest single expansion program in its 46-year history—a $50 million outlay to increase production facilities for color television receivers and picture tubes.

The expansion program is designed to more than double RCA's color TV set production capacity within 2 years and to double color tube output within 3 years, according to **W. Walter Watts,** Group Executive Vice President.

A total of $36.4 million will be spent to expand color TV picture tube facilities, and $13.3 million will be used to expand color TV receiver facilities. This record capital expenditure will help create approximately 2,000 new jobs at RCA's color TV plants.

The $36.4 million allocated for color tube expansion will be broken down this way: 1) $24.7 million to provide added manufacturing equipment and support facilities for color tube operations at Marion, Ind., including 264,000 square feet of additional manufacturing and warehousing space, and 2) $11.7 million to provide added facilities as well as 23,000 square feet of new manufacturing space at the Lancaster, Pa., plant.

In the RCA Victor Home Instruments Division, the four months prior to March 1965 produced such an accelerated growth in color television sales that color receiver production requirements exist now which had not been anticipated before 1967. The $13.3 million allocated for the expansion of color TV set production would be spent this way: 1) $5.9 million to provide 400,000 square feet of additional production space at the Bloomington, Ind., color receiver plant—biggest of its kind in the world, 2) $4.7 million to provide 121,000 square feet of manufacturing space at the television receiver components facility in Indianapolis, Ind., and 3) $2.7 million to provide 62,000 square feet of additional engineering space, also in Indianapolis.

TECHNICAL INFORMATION CLEARINGHOUSE

An activity of the U.S. Department of Commerce, the *Clearinghouse for Federal Scientific and Technical Information* was set up to supply the industrial and technical community with *unclassified* information about Government generated science and technology. The Clearinghouse's main service is to provide more than 50,000 reports a year based on federally sponsored R&D and about 25,000 translations a year of foreign technical material. The new documents are announced semimonthly in "U.S. Government Research Reports," "Nuclear Science Abstracts," and "Technical Translations." In addition, there is a monthly consolidated index to government sponsored technical literature. For additional information about these services contact your RCA Library or write to Clearinghouse, U.S. Department of Commerce, Springfield, Va., 22151.

DR. BROWN PRESENTS TWO PAPERS IN EUROPE AND RECEIVES CITATION

Dr. G. H. Brown, Executive Vice President Research and Engineering, presented two papers at the Fourth International Television Symposium, in Montreux, Switzerland: "New Opportunities in Bio-Technology" on May 25, 1965, and "Color Television—1965" on May 26, 1965. At this symposium, Dr. Brown also received a citation for his contributions to international television.

. . . PROMOTIONS . . .

to Engineering Leader & Manager

As reported by your Personnel Activity during the past two months. Location and new supervisor appear in parentheses.

Broadcast and Communications Products Division

G. B. Waters: from Engr., Design & Dev., to *Ldr., Design and Development Engrs.* (A. C. Luther, Tape Equipment, Projector & Scientific Instruments Eng., Camden.)

DEP Aerospace Systems Division

M. J. Cantella: from Eng. Scientist to *Ldr., Tech. Staff* (R. B. Merrill, Electro-Optical Eng., Burl.)
R. Allen: from Sr. Project Member to *Ldr., Tech. Staff* (E. B. Galton, Systems Support Eng., Burl.)
D. K. Gilbertson: from Ldr., Tech. Staff to *Mgr., Radiation Systems* (N. L. Laschever, Radar & Controls Eng., Burl.)
M. C. Kidd: from Eng. Scientist to *Ldr., Tech. Staff* (S. Kolodkin, Radar and Controls Eng., Burl.)
J. B. Lynch: from Sr. Project Mbr., Tech. Staff to *Ldr., Tech. Staff* (R. D. Crawford, Mgr., Reliability & Standards Eng., Burl.)
J. S. Sink: from Eng. Scientists to *Ldr., Tech. Staff* (P. Toscano, E. Galton, Systems Support Eng., Burl.)

DEP Astro-Electronics Division

A. G. Holmes-Siedle: from Engr. to *Ldr. Engrs.*, Radiation Physics (E. C. Hutter, Mgr., Phys. Res., AED, Princeton)
J. Sternberg: from Sr. Engr. to *Admin., Nimbus Systems & Equipment Dev.* (I. Brown, AED Princeton)

DEP Communications Systems Division

J. A. Dale: from Ldr., Programming Planning to *Mgr., Programming Planning* (A. M. Fleishman, Mgr., Data Comm. Programming, Camden)
J. C. Deppe: from Engr. to *Ldr., Programming Planning* (J. A. Dale, Mgr., Programming Planning, Camden)
H. C. McBriar: from Ldr., Tech. Staff to *Administrator, Tech. Projects Coordination* (G. Gerlach, Mgr., Product Support, N.Y.)
A. W. Yonda: from Engr. to *Administrator, Tech. Projects Coordination* (D. I. Caplan, Mgr., Data Comms. Project, Camden)

Electronic Components and Devices

R. H. Geary: from Assoc. Engr., Manufacturing to *Mgr., Quality Control* (Mgr., Quality and Reliability Assurance, Lanc.)
R. Holford: from Sr. Industrial Engr. to *Mgr., Industrial Eng.* (G. Longacre, Mgr., Manufacturing Standards, Som.)
A. P. Hummer: from Engr., Manufacturing to *Superintendent, Buildings and Power Svcs.* (W. H. Bliss, Mgr., Plant Eng., Marion)
H. P. Lemaire: from Mgr., Core and Matls. Eng., to *Mgr., Memory Products Eng.* (Mgr., Memory Products Oper. Dept., Needham)
N. C. Turner: from Eng. Ldr., Product Dev. to *Mgr., Transistor Design* (Dr. J. Hilibrand, Mgr., Eng., Som.)

RCA Service Company

R. L. Glendinning: from Engr. to *Ldr., Engrs.* (W. G. Kolter, Down Range Instrumentation, MTP, Cocoa Beach, Fla.)
W. R. Hayford: from Planning & Installation Engr. to *Mgr., COCOM Svc. Project* (F. Atlee, Gov. Svcs. Oper., Aerospace Sys., Cherry Hill)
D. J. Kerrigan: from Ship Instr. Engr., Shipboard to *Mgr., Radar, Shipboard* (L. F. Dodson, MTP, Signature Oper., Cocoa Beach, Fla.)
L. Litman: from Engr. to *Mgr., Telecommunications* (G. M. Ward, Management Services Project, Huntsville, Alabama)
J. J. Molloy: from Engr., Facilities to *Ldr., Engrs., BMEWS* (G. R. Sauer, Civil Eng. BMEWS)
W. N. Todd, Jr.: from Sys. Service Engr., to *Mgr., Computer Site Operations* (J. M. James, Eng. and Tech. Svcs.)

RCA Communications, Inc.

A. A. Avanessians: from Group Ldr. to *Mgr., Advanced Systems* (J. C. Hepburn, New York)

RCA Victor Home Instruments Division

V. F. Hoskins: from Liaison Engr. to *Ldr., Liaison Engr.* (J. Wright, Resident Eng., Bloomington)

PROFESSIONAL ACTIVITIES

DEP Central Engineering, Camden: **J. W. Kaufman** has been elected to a two-year term as Treasurer of the American Society for Metals, Philadelphia Chapter. He is the RCA Sustaining Member Representative in the American Society for Metals. ASM is the "spokesman" for the metalworking industry, with the objective of the advancement of scientific and technical knowledge, particularly with respect to the manufacture, use and treatment of metals.

ECD, Lancaster: **R. D. Faulkner,** Manager, Conversion Tube Advanced Development General Processing, attended the annual meeting of the American Association for Contamination Control in Miami Beach, Florida, on May 24-28, 1965. **L. A. Ezard** attended the J.T. 42 subcommittee meeting at Ft. Belvoir, Va., on April 15, 1965. **H. R. Kroll** attended the FASEB (Biological experiments) conference held in Atlantic City, N. J. on April 10-12, 1965.—*R. Kauffman*

H. J. SCHRADER RETIRES

Harold J. Schrader retired recently after 40 years of service with RCA and predecessor companies. He had been a Staff Engineer at the DEP Missile and Surface Radar Division, Moorestown, responsible for guiding the division's Independent Research and Development activities.

Mr. Schrader had made a number of contributions to air navigation and traffic control. In 1954 he was elected a *Fellow of the IRE* for his applications of information theory to navigation and television systems. He holds 18 patents.

While attending the University of Nebraska, he announced college football games in the early days of broadcasting. After college, Mr. Schrader went to work for General Electric, doing research in radio measurements. In 1930, he was transferred to RCA in Camden where he designed test equipment. During World War II, Mr. Schrader was in charge of research and development of test equipment for the Mark V IFF System. Later he participated in the development of RCA's Teleran System for air navigation and traffic control.

ECD, Harrison: ECD presented a seminar on solid-state device application at Dallas, Texas, operated concurrently with the 1965 Southwestern IEEE Conference also held in Dallas. Papers on high-frequency small- and large-signal silicon transistors were presented, along with a paper on silicon thyristors for low-frequency power applications. The presentation was made by **E. O. Johnson, T. J. Robe, R. Minton,** and **D. Burke.** —*D. H. Wamsley*

DEP-CSD Systems Labs., N. Y.: **Seymour Krevsky** was elected Vice Chairman of the New Jersey Coast Chapter (formerly Monmouth Subsection) of the IEEE Prof. Group on Communications Technology (PGCOMM /TECH), for year 1965-1966. Mr. Krevsky had been Treasurer for the year 1964-1965. —*M. P. Rosenthal*

BCD, Camden: **M. K. Wilder** has been named sponsor representative for the Philadelphia Section of the IEEE to the 1966 IEEE Communication Conference to be held in June 1966 in Phila., Pa. This conference is to become an annual affair and is international in content.—*D. Hymas*

A short seminar discussion session was held at RCA Camden by the Microwave Section B.C. and D on a new approach to network design by the use of matrix transportation. Representatives from the major RCA activities hear **T. G. Marshall** and **F. M. Brock** discuss a mathematical concept with broad potential use in solving network design and general analytical problems.

M. Wilder, (*BCD, Camden*), elected Chairman and **Ralth E. Bailey,** (*CSD, Camden*), System Division, Vice Chairman of the Phila. Chapter of the Group on Communication Technology/Vehicular Communication, IEEE for the 1965-66 term.

DEP-ASD, Burlington: At a Burlington Engineering Seminar, **T. L. Falvey,** Manager of Signal Processing, Applied Research, Camden, discussed the AR organization and activities. He discussed work on neural networks as applied to target discrimination and optical information storage & retrieval systems.

David B. Dobson is now Executive Editor of the new *IEEE Transactions on Aerospace and Electronics Systems.* The G-AED is the surviving entity of the four-way merger of Aerospace, Aerospace and Navigational Electronics, Military Electronics, and Space Electronics and Telemetry. Combined membership about 11,000.

L. Arlan is an active member of the working panel of an IRIS committee engaged in formulating measurement and specification standards for infrared camera tubes.

A. Baumann has been acting as a part-time lecturer at Northeastern University, Lincoln College, since 1958. He currently teaches communications engineering.

John L. Pierce is Treasurer of the Greater Boston Chapter, National Society for Programmed Instruction.

DEGREES GRANTED

J. M. Assour, RCA Labs.	Ph.D., Electrophysics, Polytechnic Institute of Brooklyn
W. Kosonocky, RCA Labs.	DSc, Electrical Eng., Columbia University
J. Pearl, RCA Labs.	Ph.D., Electrical Eng., Polytechnic Institute of Brooklyn
E. S. Sabisky, RCA Labs.	Ph.D., Electrical Eng., University of Pennsylvania
T. E. Seidel, RCA Labs.	Ph.D., Physics, Stevens Institute of Technology
J. Corra, RCA Labs.	MSEE, Princeton University
T. Farinre, RCA Labs.	MSEE, Princeton University
G. K. Goldberg, RCA Labs.	MS, Physics, Temple University
P. Heyman, RCA Labs.	MSEE, Princeton University
H. S. Kurlansik	MS, Physics, University of Pennsylvania
F. Marlowe, RCA Labs.	MSEE, Princeton University
J. E. Meyer, RCA Labs.	MSEE, University of Pennsylvania
F. B. Micheletti, RCA Labs.	MSEE, Princeton University
E. Nester, RCA Labs.	MSEE, Princeton University
K. Petzinger, RCA Labs.	MS, Physics, Columbia University
D. Ressler, RCA Labs.	MSEE, University of Pennsylvania
W. E. Rodda, RCA Labs.	MSEE, University of Pennsylvania
H. Christoffersen, RCA Labs.	LL.B., Law, Seton Hall University
P. Furgang, RCA Labs.	LL.B., Law, New York University
A. L. Plevy, RCA Labs.	LL.B., Law, Brooklyn Law School
H. E. McCandless, RCA Labs.	AB, Chemistry, Rutgers University
P. J. Buckley, RCA Comms.	MSEE, Polytechnic Institute of Brooklyn
D. P. Schnorr, DEP-CE	MS, Business Administration, Drexel Institute of Technology
G. Clubine, DEP-AppRes.	MS, Physics, University of Pennsylvania
G. Zinn, DEP-AppRes.	MS, Physics, University of Pennsylvania
A. Gilewitz, DEP-AppRes.	MS, Engineering, University of Pennsylvania
G. Y. Tice, BCD	MSEE, University of Pennsylvania
P. C. Noll, BCD	MSEE, Drexel Institute of Technology
R. M. Cooper, DEP-MSR	MSEE, Villanova University
R. Cowperthwaite, DEP-MSR	BSEE, Drexel Institute of Technology
S. Eaton, DEP-MSR	BA, Temple University
W. L. Hendry, DEP-MSR	BS, Electronic Physics, LaSalle College
J. V. Hess, DEP-MSR	Assoc. Degree, Bus. Administration, Rutgers University
E. Hoffman, DEP-MSR	MBA, Ind. Management, Temple University
J. T. Koen, DEP-MSR	BS, LaSalle College
T. A. Kutchar, DEP-MSR	BSEE, Drexel Institute of Technology
D. H. Lewis, DEP-MSR	BSEE, Drexel Institute of Technology
J. Mark, DEP-MSR	BS, LaSalle College
J. McGlinn, DEP-MSR	BSEE, Drexel Institute of Technology
A. J. Miller, DEP-MSR	BS, Management, Rutgers University
W. G. Newman, DEP-MSR	MSEE, Villanova University
R. F. Palumbo, DEP-MSR	Assoc. Degree in Science, Rutgers University
J. O. Reid, DEP-MSR	MSEE, Villanova University
W. D. Savitsky, DEP-MSR	MBA, Temple University
E. Schwartz, DEP-MSR	BSEE, Drexel Institute of Technology
F. Wylen, DEP-MSR	BSEE, Drexel Institute of Technology
N. R. Landry, DEP-MSR	MSEE, Drexel Institute of Technology
R. R. Lorentzen, ECD	MSEE, Newark College of Engineering
R. P. Lorentzen, ECD	BSME, Fairleigh Dickinson University
D. D. Mawhinney, ECD	MSEE, Newark College of Engineering
D. McCandless, DEP-AED	MME, Villanova University
C. N. Vallette, DEP-CSD	MME, Villanova University
J. Klapper, DEP-CSD	Ph.D., EE, New York University
W. J. Lawrence, DEP-CSD	MSE, EE, University of Pennsylvania
R. A. Holt, DEP-ASD	MSEE, University of California at Los Angeles
M. Ventimiglia, DEP-CSD	BSME, Polytechnic Institute of Brooklyn
C. P. Skinner, DEP-CSD	BSEE, Polytechnic Institute of Brooklyn
J. S. Daglian, DEP-MSR	MSEE, University of Pennsylvania
M. Rotolo, Jr., EDP	MSEE, Drexel Institute of Technology

Clip out and Mail to Editor, RCA ENGINEER, #2-8, Camden

RCA ENGINEER

HAVE WE YOUR CORRECT ADDRESS?

If not indicate the change below.

PLEASE INDICATE THE CODE LETTER(S) THAT APPEAR NEXT TO YOUR NAME ON THE ENVELOPE.

Name ______________________ Code __________

Street or Bldg. ______________________

City and State or Plant ______________________

IDEP CAMBRIDGE SERVICES MOVED TO CAMDEN

IDEP (Inteservice Data Exchange Program) file and information center has been moved from CSD Cambridge, Ohio, to CSD Engineering Services in Building 1-4 at Camden. This file contains an index and abstracts of over 5,000 engineering texts and results from over 500 participating manufacturers. Microfilm permits instant preparation of the entire text of any report in file. The addition of this file brings to four the number of such files in the RCA Camden complex. (For general information on IDEP, see RCA ENGINEER, Vol. 11, No. 1, June-July 1965, page 62.)—*J. Gillespie*

SERVICE SEMINAR HELD ON COLOR TV FILM CAMERA

An RCA Service Company seminar was held during May in the Camden Studio facilities to familiarize Field Representatives with the new TK-27 transistorized Color Film Camera. Those attending the week long session were: **J. Lundquist, R. R. Jirinec, A. Freeman, P. Brucoliere, J. N. Thayer, E. L. Carson, R. J. Fry, F. M. Smith, M. J. Payne,** and **W. B. Martin,** Broadcast Administrator, Cherry Hill.—*E. Stanko*

TRAINING PROGRAM ON DATA RECORDERS

The RCA Service Co. Technical Products Service Engineering Activity just completed a training program that covered the entire U.S. to provide service on 374 Robert Hall Source Recorders, which are used for inventoy control. The information developed by them is sent to New York City and fed into a computer that totalizes all sales and provides information for inventory control. The field training was conducted by **P. V. Smith, E. G. Holub,** and **R. J. Heacock,** all from Cherry Hill.—*E. Stanko*

TIROS 10 LAUNCHED AS TIROS 7 DAILY WEATHER WATCH BEGINS THIRD YEAR

TIROS 10 was launched on July 1, 1965, and a week later was taking operational weather pictures (despite initial difficulties with its command system), thus marking the tenth consecutive success in this remarkable RCA-built NASA series of weather satellites. (The RCA TIROS project is still being engineered at the Astro-Electronics Division, Princeton, N.J., as it was originally.

TIROS 7, oldest American weather satellites in orbit is now in its third year of daily weather observation. TIROS 7 has taken and transmitted 110,000 pictures of cloud formations, storms, hurricanes and typhoons from 500 miles above the earth. Its two wide-angle television cameras are still fully operational and the NASA infrared experiment carried aboard has been utilized over this span of time.

The other, orbiting weather satellites are TIROS 8, launched 18 months ago, TIROS 9, the first polar orbiting, wheel-oriented weather satellite, and the latest, TIROS 10.

In what has been termed as "the nation's most successful unmanned space program," the reliable performance of these satellites for periods of time well beyond their original mission goal of three months has meant TIROS-scheduled launching rockets could be assigned to other important space programs. In addition, the U.S. Weather Bureau, as principle user of TIROS information has been able to depend upon the satellites for the advanced report of major storms brewing in remote parts of the globe. *Since 1962, not a day has passed without the Weather Bureau being able to obtain* TIROS *pictures.*