Eighth Anniversary

It is eight years and forty-eight editions later since Bill Hadlock and his talented associates first struck up the RCA family dialogue which we call the RCA ENGINEER. It is a tribute to him and to his colleagues that this dialogue has not only flourished in that time, but has gained steadily in clarity of style, range of subject matter, and ability to interest.

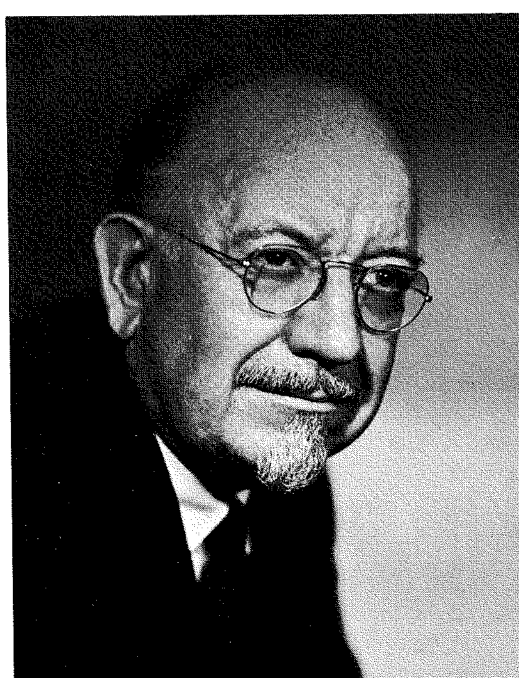
This accomplishment is especially noteworthy when viewed against the background of shifting emphasis and rapid enhancement of the engineer's role in modern society.

During the past eight years, the electronics engineer has been swept from the periphery of human affairs to the vital center of man's progress in outer space, the ocean depths, and the advance of human welfare generally.

To have struggled in the arena of these swiftly moving events with steady nerves and firm purpose has been hard enough. *However, to have reported on them sensibly with a fine feeling for their detail, their significance, and their promise has certainly been every bit as demanding and, in some ways, more important.*

I say this because, as the engineer's role has expanded and diversified, the engineering fraternity has been subjected to a mounting centrifugal force tending to push its members away from a common ground of knowledge and experience and into unfamiliar situations and obscure specializations. Uncompensated by corresponding centripetal forces, such a process would soon reduce us to a state where "all the king's horses and all the king's men couldn't put engineering back together again."

Fortunately, such countervailing forces do exist and the strongest of these, I believe, is a continuous and articulate dialogue between the growing number of specialists within our discipline. For the adroitness with which the RCA ENGINEER maintains this dialogue within RCA, for the timeliness of its articles and the cogency of their presentation, I congratulate Bill Hadlock and his staff. *Happy Anniversary!*



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Vice President
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Radio Corporation of America

RCA ENGINEER

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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.

Editor's Note: This informative report by Dr. E. W. Engstrom, President of RCA, documents RCA's dynamic progress during the past five years. It is the third in a series of articles devoted to the "History of RCA." Part I by J. C. Warner covered the years 1920 to 1938 and appeared in Vol. 3, No. 1, June-July 1957. Part II by Dr. Engstrom covered the period from 1938 through 1958 and appeared in Vol. 4 No. 1, June-July 1958.

The Engineer and the Corporation

A HISTORY OF RADIO CORPORATION OF AMERICA

PART III—THE YEARS 1958-1962

Dr. ELMER W. ENGSTROM, President
Radio Corporation of America

DR. E. W. ENGSTROM, received the BSEE at the University of Minnesota in 1923. In the early thirties, Dr. Engstrom directed RCA's television research toward a practical service. He was responsible for development and construction of apparatus used in field tests, and in the early planning and coordination of black-and-white television. Dr. Engstrom was a member of the NTSC at the time TV standards for broadcasting were established and a member of the Radio Technical Planning Board. He was a member of the NTSC which developed technical signal specifications for color television transmissions, adopted by F.C.C. Dec. 17, 1953. In 1942 when all research activities of RCA were brought together at Princeton, N.J., Dr. Engstrom became Director of General Research. On Dec. 7, 1945, he was elected Vice President in charge of research of the RCA Laboratories Division; on Sept. 7, 1951, he was elected Vice President in charge of RCA Laboratories Division; on Jan. 11, 1954, he was elected Executive Vice President, RCA Laboratories; and on June 4, 1954, he was elected Executive Vice President, Research and Engineering. In 1961, he was named President of RCA; he is a Director of RCA, of NBC, and of Radio Communications Company, Inc. The honorary degree of Doctor of Science was conferred on Dr. Engstrom in June, 1949, by New York University. In Aug. 1949, Dr. Engstrom received a silver plaquette from the Royal Swedish Academy of Engineering Research. In Oct. 1950 he received the Outstanding Achievement Award gold medal from the University of Minnesota. Dr. Engstrom is a member and past President of the Princeton Chapter of Sigma Xi, science research honor society; a Fellow of the IRE, of which he was a Director in 1949, and of the AIEE.

In considering events and developments from 1958 through 1962, the past five years of RCA history have been fully as meaningful as the two preceding time spans in terms of change, accomplishment, diversification, and growth. All of the expectations for electronics and for RCA have been more than amply fulfilled.

RCA continued to achieve conspicuous successes in its established lines of business. During the half decade, it ventured into fields where growth and profit, halting at first, began to manifest themselves with increasing strength. At the same time, it advanced importantly in new technologies whose potentialities for growth and service are as great as any of the areas in which it now operates. In brief, the five years reveal a constant progression of technological and commercial opportunities, ranging the electronics spectrum from microdevices to space systems.

These developments are measurable in many forms, and among the most readily recognizable are the traditional yardsticks of corporate accomplishment. Thus, RCA sales of goods and services rose during the half decade to an all-time high of $1.75 billion, *50 percent greater than at the end of 1957.* Profits increased to $51.5 million, 34 percent over 1957. Employment rose another 11.5 percent, to 87,000.

In ten years, 1948 through 1957, total products and services sold amounted to $7.78 billion. In the past *five* years, 1958 through 1962, the total was almost as large: $7.36 billion.

Year	*Sales* $ billion	*Fixed Assets* $ million	*People*
1938	0.1	31	19,000
1957	1.2	200	78,000
1962	1.75	264	87,000

At the close of 1962, space devoted to manufacturing was at a peak of 12 million square feet, comprising new, expanded, or renovated RCA plants in 12 of the nation's 50 states. RCA's activities reached into home instruments, electronic data processing, electron tubes and semiconductor devices, radar and microwave equipment, scientific instruments, weather and communications satellites, broadcasting, and technical services. In major part, its products and services were available throughout the Free World.

COLOR TV

The most important development by far to RCA in the past five years was the emergence of color TV as a new industry and public service of massive and mounting proportions.

Technologically, the record requires little updating, for the major research and engineering advances had been made prior to 1958. What gives color such transcendent importance to RCA is that the past five years witnessed its transformation from a $130 million investment to a major source of Corporate profits. *It vindicated the faith of one man — David Sarnoff — who staked his and the Corporation's prestige on the new medium while the rest of the industry stood aside or in opposition.*

In 1960, color TV earned a profit for RCA for the first time since its introduction in 1954, and color set profits alone were measurable in seven figures. By the following year, color TV — receivers, tubes, video tape, and other equipment —attained the status of a $100 million business, an achievement of no mean proportions in seven brief years.

By 1961, there occurred—finally—the long-awaited color breakthrough. One by one, TV receiver manufacturers abandoned the sidelines and entered the ranks. By the following year, nearly every major TV manufacturer was actively marketing color, and industry volume has reached $200 million. RCA's set sales for 1962 doubled over the year before; its profits from color manufacturing and services increased fivefold; and color sets and tubes became the *largest* single profit contributor of any products sold by the company.

It is pointless to debate which came first in color TV — the sets or the programming. In all certainty, the development was concurrent, with receiver purchases soaring because of increased color programming, and programming benefiting in turn from the increase in color set ownership. Thus, while there were 291 stations equipped for network color and a bare total of 700 hours of network programming in 1958, five years later the number of stations equipped for network color came to 406 and network color broadcast hours had risen to some 2,000 for the year.

Of the many brightly illuminated pages in RCA's history there are few that gleam more brilliantly than those dealing with color. Indeed, there are few companies which can validly claim to have created virtually single-handed a new industry, and few which more richly merit the rewards of pioneering than RCA.

ELECTRONIC DATA PROCESSING

While RCA was mounting its major effort to make color television commercially viable, another decision had been made to enter in force a new, formidable, and costly area of business—electronic data processing.

The action entailed a bold and calculated risk: the entry fees were exceedingly heavy; returns were long delayed because of the large lease nature of the business; the competition was powerful and strongly entrenched.

As Board Chairman Sarnoff subsequently explained, the decision to go forward was made:

"First, because we have a technological background in electronics that gives us a capability in many computer areas which few, if any, other companies can rival. This is a young, fast-changing technology, and the research breakthroughs of today will shape the character of the industry tomorrow. We are well-positioned to make contributions of fundamental importance to this evolution.

"Second, because electronic data processing has become a vital element of most major defense and space contracts. The company with skills in this area has a decided competitive advantage.

"Third, because the commercial computer market is growing faster than the industry itself anticipated."

In 1958, RCA launched its major venture into the electronic data processing field with the introduction of the RCA 501, a medium-sized commercial business computer and the first fully transistorized system in the industry. By 1960, the Corporation had introduced the compact RCA 301 for medium-size and small businesses, and had announced a coming third entry, the RCA 601, for large enterprises and scientific computation.

One of the greatest of RCA's strengths lay in computer communications — backed by four decades of leadership, experience, and know-how in all types of communications systems and equipment.

In 1959, RCA introduced DaSpan, a computer-to-computer communications system which could span a continent, and gather and coordinate vital data from the many plants of a large industrial enterprise.

The same computer-communications know-how made RCA the supplier to Western Union, the prime contractor, of an automatic electronic data switching system for the Air Force Combat Logistics Network (ComLogNet) linking 350 bases and stations across the country in the world's most advanced communications system.

Rapid economic expansion in other industrial nations also gave RCA an unexcelled opportunity to extend its computer activities overseas. In 1961, it concluded a series of multimillion dollar export sales agreements with three of the world's leading data processing equipment manufacturers — in Great Britain, Japan, and France. By the end of 1962, 158 computer systems had been ordered by the three companies, and further orders placed for components and peripheral equipment.

Domestically, in addition to the rental or sales of its computer systems, RCA established data-processing service centers in New York, Washington, D.C., Chicago, Cherry Hill, N.J., and San Francisco. These centers provide computer service to small businesses as well as offering programming and training services to buyers or lessees of RCA systems.

Whatever the risks and costs involved, the decision to enter data processing was extremely sound. RCA not only staked out its share in one of the major electronics growth markets but, equally important, it acquired the basis for continuing preeminence in other electronics fields where computers and computer systems were indispensible to progress. Among these were the vital areas of space and national security.

SPACE AND DEFENSE

On October 4, 1957, the first signals from a man-made object in the skies heralded the dawn of a new era — the Age of Space.

Swiftly, RCA realized that space was preeminently an electronics domain — for tracking, communications, computing and controls. Less than a year later, RCA set up a special division — Astro-Electronic Products—for the development and production of satellites, space-vehicle systems, and associated electronic ground equipment. (That organization is now called the Astro-Electronics Division.)

In December of the same year, the world's first successful satellite radio relay equipment, produced by RCA for the U.S. Army Signal Corps, lofted into orbit aboard an Atlas missile. It broadcast to the world a prerecorded Christmas message from President Eisenhower, and then performed a number of communications experiments never before attempted, looking to a new era in global communications.

Within the next four years, the Astro-Electronic Division had scored a series

Fig. 1—An RCA 601 Computer system plus four RCA 301 Computer systems process the toll records of 14 million phone calls handled monthly by the Teaneck, N.J., Office of the N. J. Bell Tel. Co.

Fig. 2—A GI utilizes a PRC-51 helmet field radio—a developmental type utilizing micromodules.

Fig. 3—Looking down at the top of the Environmental Test Chamber at the Astro-Electronics Division, near Princeton, N.J. Satellites can be placed inside for extended exposure to simulated space environment.

of achievements which quickly catapulted RCA into the front rank of space organizations.

Chief among these was a systems development of the first magnitude — an integrated ground and space complex for the televised observation of the world's weather via satellites. Between 1960 and 1962, as major elements of the system, RCA developed for the National Aeronautics and Space Administration six TIROS weather observation satellites, all of which were launched and operated with optimum effectiveness. Up to the end of 1962, the TIROS series—ranking as the nation's *most successful* space venture—provided a total of more than 200,000 televised images of cloud formations and other global weather data for use by weather scientists and forecasters. The average useful life span of the satellites was more than double the operating life called for by the initial design specifications.

Another significant feat was the RELAY communications satellite, which after launching in December 1962, experienced initial operating difficulties. These subsequently were overcome, and by early 1963, RELAY was transmitting television pictures of remarkable clarity between the United States and Europe, and conducting radio communications with Latin America.

The Astro-Electronics Division has also provided the advanced television equipment for the RANGER lunar probes, television systems and solar-cell power supplies for the second-generation NIMBUS weather satellite, and was engaged in the design and construction of the SERT vehicle for the space testing of experimental electric propulsion systems.

Portending still greater growth in years to come, an environmental test facility, most advanced of its kind in the electronics industry, was put into full operation during 1962 at RCA's Space Center, near Princeton, N.J. Space concepts and systems now germinating in various RCA research areas may undertake their initial trials in this environmental center and so provide new episodes for future RCA historians to record.

The complexities manifested in computer and space electronics are fully matched in the area of defense. From the production of relatively simple hardware for communications, electronics for military purposes has burgeoned into vast and complicated systems — frequently global in scope, integrating multiple techniques and subsystems, and employing the resources of many varied organizations.

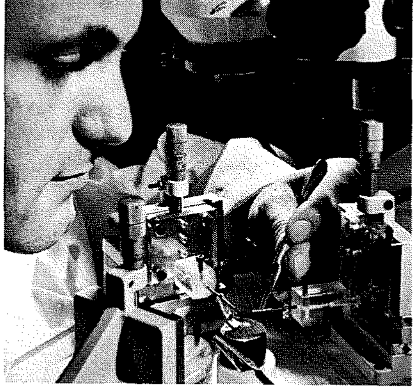


Fig. 4—An electrical probe is positioned over a silicon wafer containing 2,200 insulated-gate field-effect MOS (metal-oxide semiconductor) transistors. RCA Laboratories research produced this device which combines properties of a conventional transistor and an electron tube. It has promise for future microelectronic circuitry.

RCA's depth of experience in systems engineering and its military electronics background dating to the mid-thirties earned for it one of the lead positions among designers and constructors of such advanced systems for the armed services.

In 1958, RCA received one of the largest contracts ever awarded by the Department of Defense, to assume the project management of the Ballistic Missile Early Warning System (BMEWS) to provide advance warning of an enemy missile attack across the polar wastes. As manager of this vast undertaking, it employed 485 large companies and 2,415 smaller firms spread over 29 states to get the job done swiftly and efficiently. By the end of 1962, two installations (Thule, Greenland, and Clear, Alaska) were operative and the third was nearing completion in Yorkshire, England.

The need for virtually instantaneous warning against impending missile attack assumes similar readiness for counter-attack. In the past half decade, RCA contributed significantly to a greatly strengthened defense posture with the development of automatic programmed check-out equipment (the APCHE) and launch-control equipment for several series of the ATLAS ICBM.

Subsequently, major RCA work on the MINUTEMAN ICBM involved advanced concepts in command-and-control systems, including the sensitive-command and support-information networks, and checkout and test techniques. Especially challenging for both design and production were very high reliability goals for such sophisticated equipment—goals that pushed the state of the art.

By the end of 1962, RCA was deep into such diverse development and constructions as a flight-control system and checkout for the super-powerful SATURN booster, telemetry equipment for the two-man GEMINI space vehicle, miniaturized computers such as MICROPAC (built with micromodules) for military field use, and a variety of communications systems and test apparatus, including a lunar-landing simulator.

In 1962, RCA also could point to some 22,000 scientists, engineers, and production personnel—roughly a quarter of all RCA employees—working at eleven defense and space centers. In that year, the Corporation's total volume of government business exceeded $600 million, or more than a third of the Corporate total.

CIRCUITRY AND COMPONENTS

Basic to all RCA progress in both the old and new fields of electronics were the advances made in electronic circuitry and components.

RCA's Electron Tube Division, facing the growing competition of semiconductors, moved quickly and aggressively to sustain its position through intensified product and market development.

One decision was to concentrate production and sales in those areas where semiconductors could not yet compete. Conspicuous success was achieved in heavy-duty and special-purpose tubes. From 1958 through 1962, RCA developed some 800 new tubes of this variety.

Another decision was to compete directly with semiconductors through greatly improved low-cost vacuum tube products. In 1959, the Tube Division announced the revolutionary *Nuvistor*, a receiving tube as small as a thimble and incorporating high reliability and durability. This was followed the next year with a new line of metal-to-ceramic *Cermolox* power tubes for transmitter applications, one of which was aboard the famed PIONEER V Venus probe.

A third decision was to join the move toward semiconductors where this would blend with skills and technologies perfected in some three and a half decades of tube development. In 1960, for example, the Division began to manufacture solid-state photoconductors and silicon solar cells.

Finally, the Tube Division decided to diversify its product line and seek *wholly new products.* A new Business Development Department was set up for new items whose revenues could replace or even surpass those from older tube products. By the end of 1962, the first results were beginning to bear fruit —in thermoelectric power generation and cooling, thermionic energy conversion, superconductive magnets, electroluminescent materials, and high-speed reed switches for computer and telephone relay circuits.

Challenge and change also confronted RCA's Semiconductor and Materials Division. The challenge came in the form of intense competition where companies—old and new, large and small—thronged a market of supposedly unlimited profitability and growth. Change came in the rapid obsolescence of materials and devices under the stimulus of quickening research and development.

Organized in 1955 primarily to manufacture germanium transistor devices for consumer purposes, the Division swiftly expanded in size and scope. By 1962, for example, it had become the leading domestic producer of solid-state semiconductor devices for consumer products, and over 100 million of its germanium units were in use.

With the advent of high-power silicon devices, the semiconductor field grew to embrace industrial, computer, and military applications, and with this came corresponding growth in RCA activities. New manufacturing facilities were added, new devices developed, and new markets opened. Ultra-high-speed tunnel diodes, gallium arsenide rectifiers, and microferrites for computer memories were among the product developments of the period.

But the continuing solid-state revolution involved more than the geometric expansion of individual circuit devices and applications. Equally fundamental to the future of electronics was the emergence of materials and techniques leading from separate components to assemblies of components functioning as complete circuits and subsystems. In this, RCA played a leading role, with the U.S. Army Signal Corps, in the development of micromodules. With later developments—for example, thin-film active devices, and the insulated-gate MOS (metal-oxide-semiconductor) transistor—RCA reaffirmed its position as an industry leader in advanced integrated circuitry.

OLD AREAS—NEW OPPORTUNITIES

Change, diversification, and growth were readily evident in other divisions and services of the Corporation. New technologies, products and systems infused vigorous progress in both the older as well as the more recent RCA activities.

The RCA Victor Home Instruments Division, which in 1961 moved from Cherry Hill, N.J., to a consolidated operation in Indianapolis, Indiana, continued to advance in the design and marketing of home entertainment products. Particular emphasis during the past half decade was placed on stereophonic high-fidelity record and tape players for the growing high-fidelity music market, on transistorized pocket radios, and on black-and-white as well as color television.

One milestone was the production in 1958 of the ten millionth RCA Victor black-and-white television receiver. Another was the introduction, a year later, of the *first* miniature transistor radio to be produced entirely in the United States. By the end of 1962, Home Instruments could point to an over-all sales increase of 30 percent over the previous year, exceeding the earlier all-time record established in 1956.

The RCA Victor Record Division made significant progress in new sound-reproduction techniques at the same time that it advanced briskly into new marketing methods and areas. In 1961, Victor Records introduced a new electronic process for reproducing stereo recordings originally recorded in monaural sound. The year following, it opened the world's largest and most modern recording studio, in Rome, Italy.

Early in 1963, after two years of intensive research and development, Victor Records also announced a striking new process of music reproduction—*Dynagroove*—bringing recorded music more closely than ever before to live music.

In the five-year period, Victor Records aggressively expanded its Record Clubs around the nation, while developing new retail sales outlets such as supermarkets and drug chains. Overseas, RCA became the leading U.S. company in the international field, and by the end of 1962, Victor Records could report the largest sales volume in its history, with gains scored in all product lines.

For industry, for broadcasting and communications, RCA continued to develop new microwave systems, transistorized video tape recorders for both color and black-and-white broadcasting, and new color cameras. Among its pioneering advances were closed-circuit equipment for educational purposes.

In 1962, RCA also manufactured and delivered its 1,000th electron microscope, assembled on the same production line that completed the first commercial instrument nearly a quarter century earlier.

Fig. 5—A NUVISTOR tube production line at the Electron Tube Division, Harrison, N.J. July 1961 saw the production of the 1,000,000th NUVISTOR, a distinct RCA innovation in small ceramic-metal receiving tubes. Developmental work continued toward furthering the NUVISTOR concept in smaller and even more-reliable receiving tube products.

Fig. 6—RCA engineer Nils Oman and part of the largest electronic power supply of its type ever built—an assembly of 500-kw super-power tubes for the C Stellarator fusion-research facility. These tubes supply RF pulses to raise the deuterium in the Stellarator to some 1,000,000°C by ohmic heating process. During the period covered by this article, a joint RCA-Allis Chalmers project, called C Stellarator Associates, designed and constructed the massive C Stellarator facility for Princeton University, who will utilize it in major research on controlled thermonuclear fusion. Engineers and scientists from several RCA Divisions participated in this project.

Significant growth trends also manifested themselves at the National Broadcasting Company, which moved into commanding leadership in providing the public with a broad range of news and public affairs coverage. By 1962, 25 percent of *NBC-TV*'s schedule was in this category.

Earlier, NBC pioneered an educational experiment by presenting a college level course, "Continental Classroom," demonstrating that commercial broadcasting could perform a significant role in education. And its massive programming on behalf of color was as responsible as any single factor in hastening the ultimate mass-market breakthrough. These and other developments culminated, in 1962, with the highest sales and earnings in NBC's 36-year history.

As meaningful as any aspect of electronics' growth during the past five years was its expansion on a global scale. It was reflected in the RCA Service Company where, by the end of 1962, there were some 16,000 employees in the United States and 36 foreign countries. Its activities ranged from maintenance of the BMEWS emplacements in Alaska and Greenland to responsibility for the control and data gathering activities at the Cape Canaveral, Florida, space center. Here, incidentally, where RCA undertook its first technical assignment

10 years earlier with 26 technicians and engineers, there were approximately 4,000 RCA people in 1962.

By early 1963, the RCA Service Company was able to report that revenues for the year from installations and service on color-TV receivers could surpass for the first time revenues on black-and white sets. And with equal portent for the future, the Service Company moved into still another space activity—the design and construction of space chambers and solar simulators.

World economic expansion and the emergence of new nations were reflected by the growing demand, during the five-year period, for basic and advanced types of communications and broadcast equipment. RCA sales and installations extended to every continent—from broadcasting equipment and stations to entire national and international television and communications systems.

The same economic expansion found further expression in the global communications services of RCA Communications, Inc. By the end of 1962, it was providing more channels between this country and 100 others than any other U.S. international communications carrier. In early 1963, RCA Communications applied for permission to purchase shares in the new Satellite Communications Corporation, thus assuring for RCA still another role in the rapidly unfolding progress of electronics.

RESEARCH AND PROGRESS

Behind the extraordinary five-year record of RCA change, diversification, and growth stood the basic and applied achievements of the RCA Laboratories —ranging from revolutionary high-speed computer techniques to submarine communications to space telescope guidance.

The variety of RCA research activities may be gleaned from a few samplings of the past five years.

In 1958, RCA joined nine other companies in ownership and operation of a nuclear reactor, for the purpose of conducting radiation studies relating to RCA projects and areas of interest. That year too, RCA Laboratories joined in the design and construction of the C Stellarator, which may provide an answer to the control of thermonuclear fusion for peaceful purposes. The following year, it undertook two projects approaching the ultimate in geographic disparity. One was for the design and development of an advanced communications system for the POLARIS program; the other was to build the television guidance system for the STRATOSCOPE I and II balloon-borne telescopic observations of the sun and planets.

RCA scientists had the assignment of developing the key elements of a computer that would operate at speeds a thousand times faster than the swiftest computer yet built. On yet another tack, in 1960, they completed the "electronic highway" to demonstrate the feasability of electronics for the control and movement of road traffic.

Most significant for the long run, perhaps, were the RCA Laboratories' contributions in the areas of basic circuitry, energy conversion, superconductivity, and laser technology. These have led in the past five years to such research advances as thin-film transistors, superconductive magnets capable of generating enormous magnetic fields, superconductive thin-film memories, crystal lasers activated by natural sunlight, and new thermoelectric and thermionic generators.

To the breadth and depth of its scientific probings, RCA also added the element of greater speed in converting research to applied development. Most of the Corporation's principle operating divisions now maintain development groups of their own engineering specialists at the RCA Laboratories at Princeton. These development groups work directly with the laboratory research teams, adding a vital new perspective to many RCA scientific projects, and furnishing the link for the swift transmission of new materials, devices, and techniques to the divisions to transform them into new products and market opportunities.

LOOKING TO THE FUTURE

In reviewing the past, one's thoughts inevitably turn to the future of electronics and RCA, for it is there that the most interesting history will be written. For that future, it no longer seems sufficient to say, as in the first two segments of the RCA history, that the surface of electronics has barely been scratched. As electronics broadens its contributions to the nation and the individual, and as its influence extends around the globe and deep into space, new dimensions of service as well as new concepts of opportunity come into focus.

At the present point in time and historic development, electronics perhaps is *the single most important instrument at the disposal of mankind for the solution of present problems and the advance to new levels of well-being.* Electronics provides means of comprehension and action far beyond the capacity of the brain to grasp or the hand to move. In science, medicine, manufacturing and commerce, transportation, agriculture, education, energy, space exploration, and communications, *electronics* is the lever to still greater progress—directly or as the catalyst to other efforts. Its reach has extended far beyond the surface of technological growth to embrace virtually every activity, human or natural, affecting civilization.

In such a context of service and opportunity RCA is uniquely positioned to achieve the optimum. In these past five years, it has strengthened beyond measure its resources and capabilities for leadership in *any direction* which the science and industry of electronics may take.

Fig. 7—RCA Laboratories research produced the first practical amplifying device to be made entirely by evaporation techniques—the TFT (thin-film transistor), shown above in a test unit. The tiny device can be made so small that over 20,000 could fit in a square inch of surface. The process promises breakthroughs in the mass production of ultraminiature transistor circuits.

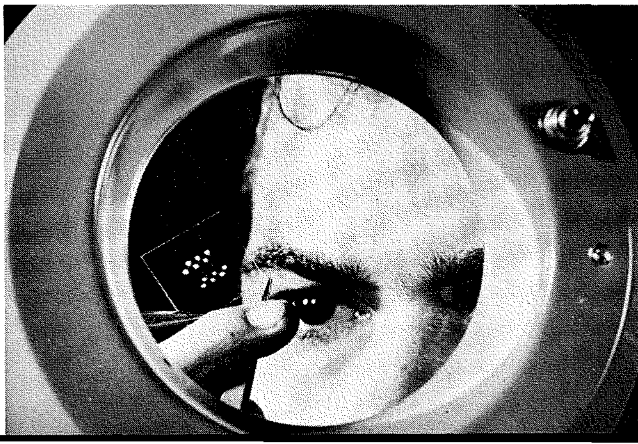
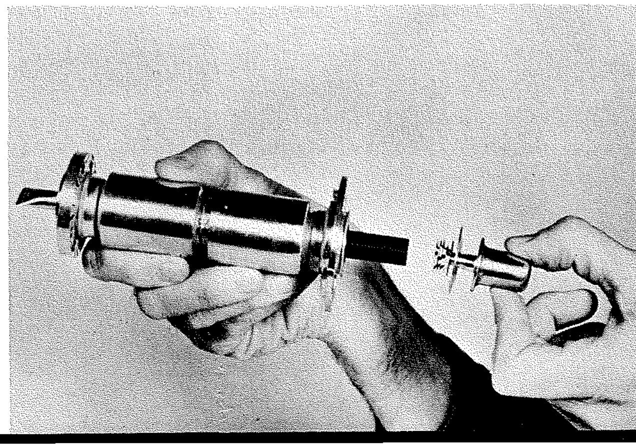


Fig. 8—Direct energy conversion came to the forefront as a major RCA effort as the 1957-62 period ended. Shown here is a thermionic convertor that converts heat (in this specific case, heat from a nuclear reactor) directly into electricity. Important advances at both RCA Laboratories and the Electron Tube Division in thermoelectric materials, methods, and production may lead to major RCA product lines in power generation.



MANAGING CREATIVE ENGINEERS

G. L. DIMMICK
Surface Communications Division
DEP, Camden, N. J.

WHEN ONE ATTEMPTS to write about *creativity*, he is challenged by the broad scope and complexity of the subject. To be most effective, he may choose to restrict himself to one particular aspect of the whole problem. A further narrowing of the subject takes place if he writes about the particular aspect of the problem in terms of his own personal experience. In the case at hand, I will discuss creativity in scientific and engineering personnel, from the viewpoint of a manager of a group of development engineers.

The problem starts with the process of recognizing native creative ability in young scientists and engineers, so that those who possess it to a sufficient degree may be placed in an environment best suited to their training and growth.

One of the oldest and best-known methods of selecting and placing creative people is to first engage them in a training program in which they may select, in rotation, a number of job assignments. In this process, it is assumed that creative people will be attracted by and will find acceptance in those sections of the company which can best use their special talents. These on-the-job training programs may be improved if other methods of recognizing and identifying creative ability are used prior to or during the training program. Personal interviews with students during the recruiting period and again after they report for work are an important source of information. Written tests have been devised for the purpose of evaluating the relative degree of creativity present in the person taking the test. Although these special tests have not been fully evaluated, it is believed that they may help materially in the preselection of trainees for special assignments in the training program, or for their initial assignment after the training program is completed.

Let us assume that a number of potentially creative engineers have been selected and are assigned to a section engaged in the development of electronic equipment. Our course of action then is to train and utilize these engineers in a manner which will permit them to grow rapidly and which will challenge them to bring their creative talents fully to bear upon the important problems at hand.

If the problems can only be solved through invention, the supervisor must make sure that the engineers are completely convinced of the *need* for a new approach or new idea. Although there may be short-cuts, it is my belief that this can best be done by having the new engineers work on the problem under the guidance of senior engineers. When the creative person is aware of the importance of solving the problem and when he has first-hand knowledge of the previous unsuccessful efforts, he is then ready to invent his way out of trouble. At first, his inventions may be of minor importance; but if he is encouraged sufficiently by those around him, and he begins to appreciate the power of his own imagination, his own creative contributions should increase both in quantity and importance.

It would be difficult to over-emphasize the importance of environment upon the attainment of the most effective creative effort. A potential inventor will probably develop much faster if he is placed in a group of creative people where a high priority is placed on the development of new systems, ideas, or techniques. He must be made to feel that he is a member of the team. If the proper atmosphere exists, there will be a mutual exchange of ideas, each building upon the other, until the complete solution of the problem emerges from the joint effort. However, the group solution to problems must not be carried too far. There should always be a proper incentive for individual effort, with the right amount of competitive spirit among the members of the group. If the competition were too keen, there would be a tendency for individuals to go off by themselves and try to solve their problems. The supervisor of a group of creative people has a very important problem of keeping the abovementioned tendencies in proper balance and in keeping the spirit of the group high.

GLENN L. DIMMICK recently retired after a distinguished 33-year professional career with RCA during which he was granted 93 patents. His work included pioneering developments in sound motion pictures, recording methods, sound-powered telephones, coated lenses, and other optical techniques, and a number of other fields of electronics. He joined RCA Victor in Camden in 1930, two years after receiving his BSEE from the University of Missouri. After 18 years in engineering development work, he became a manager in 1948, and until retirement in 1963, held a number of high managerial posts—most recently Coordinator of Applied Research and Development for SurfCom. He has published many papers. He is a member of Tau Beta Pi and Sigma Xi, and is a Fellow of the Society of Motion Picture and Television Engineers. Among his awards have been the SMPTE Progress Medal (1941); the RCA Victor Award of Merit (1949); and the Missouri Honor Award for Distinguished Service in Engineering (1955).

Some years ago one of the managers of a group of development engineers called attention to the analogy between an engineering group and the power plant of an automobile. He said that the engine is analogous to the facilities and materials with which the engineer works. The fuel is analogous to the reserve of mental and physical energy possessed by the engineer. He reasoned that a good engine and good fuel are not enough. There must be a spark to ignite the fuel. In an engineering organization, there should also be at least one person who can fire the imaginations of creative people. This person may be anyone in the organization from the Chairman of the Board of Directors to the immediate supervisor. The important thing is that he *understands creative people* and can inspire them to join him in a combined effort to solve major problems.

After the major problems have been solved and the various inventions have been properly documented, it is very important that each person receive full recognition for his accomplishments. This recognition may take place in several ways:

1. The creative person should be permitted to demonstrate his new idea or device to the various members of management and to receive their compliments on his success.
2. He should be permitted to write technical papers and to personally present them at conventions of technical societies.
3. The inventor should be recommended by his supervisor for appropriate awards which are given by his company, by technical societies, or by the colleges and universities, if his contributions are of significant importance.
4. Last, but not least, the results of a person's creative ability should have an important bearing upon his salary, rate of growth, and his promotion to assignments of higher responsibility.

Fig. 1—Reception area, Laboratories RCA, Inc., Tokyo, Japan.

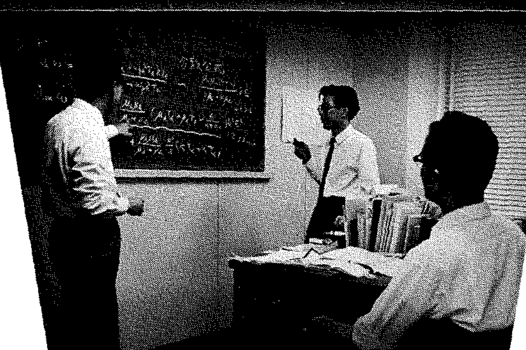


Fig. 2—Discussion between experimentalists and theoretician on the interpretation of a plasma instability.

Fig. 3—Experimental equipment for studying the interaction of microwaves with solid-state plasmas.

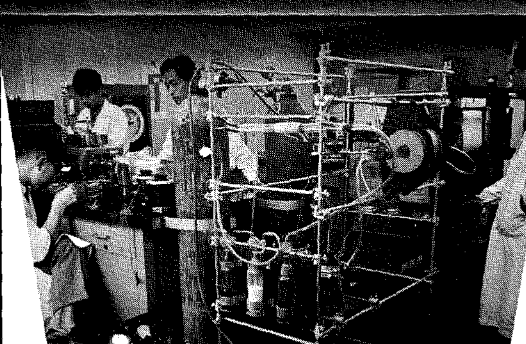


Fig. 4—Crystal preparation and examination; in the front is an alloying furnace for making p-n junctions in semiconductors.

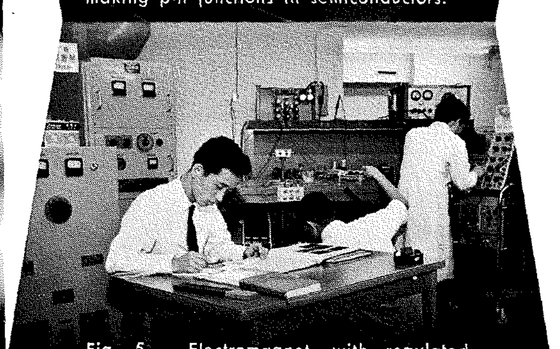


Fig. 5 — Electromagnet, with regulated power supply, in use for experiments on magneto-hydrodynamic instabilities in solid-state plasmas.

LABORATORIES RCA, INC. ...RCA Research in Japan

Dr. M. C. STEELE, Director
Laboratories RCA, Inc.
Tokyo, Japan

In the early part of 1960, RCA began to carry out its plan to open a research laboratory in Tokyo, Japan. This was to be the second such overseas laboratory for RCA and would be called Laboratories RCA, Inc. The first was opened in Zurich, Switzerland in 1955.

After being named Director of Research for the new laboratory in March 1960, this writer made a two-month visit to Tokyo to formulate plans for the physical plant and make the initial contacts for the operation. After returning to Tokyo in September 1960 and until the formal opening of the laboratory in April 1961, work centered around assembling the scientific staff, formulating the initial research program, ordering equipment, and establishing rapport with the Japanese scientific community. The research staff was to be entirely Japanese. Many visits were made to Japanese universities to acquaint them with the plans for the laboratory. Another purpose for those visits was to talk with students who would soon be graduating and looking for positions.

It was RCA's plan from the start that the work of the Tokyo laboratory would be devoted largely to fundamental research areas in physics, chemistry, and electronics. After due consideration, it was decided that the initial effort would be in the general field of solid-state phenomena, including electrical, magnetic, and optical properties. The Laboratory occupies about 4,000 square feet of floor space on the third floor of the Iino Building in downtown Tokyo.

RECRUITING AND STAFF COMPOSITION

Recruiting for the staff presented many new experiences for the Director. Visits to universities from Hokkaido to Kyushu were made in an effort to gather the initial group of scientists. In general, the procedure for recruiting involved talking with the particular professor who had students about to graduate. If the professor became convinced of the worth of the Laboratory objectives he might urge his students to consider RCA as a place of employment. By the time the Tokyo laboratory held its opening ceremony in April 1961, five members of the research staff were assembled and eager to start the research activities. Since that time, the staff has grown to seven, in addition to four technicians. The present technical staff consists of three physicists (PhD), one chemist (MS), one electrical engineer (solid state electronics, MS), and two electrical engineers (BS).

Two of the PhD's received their graduate training in the U.S.A. at Northwestern University and Oregon State University. The other PhD received his degree from Osaka University. The two MS's received their training at Tokyo Institute of Technology, while the two junior members of the staff (BS) came from Waseda University and Shizuoka University. The average age of the staff is 28 with a range from 23 to 35. There are four married men and three bachelors.

LANGUAGE PROBLEMS

An interesting aspect of Tokyo Laboratory is the language problem. Since only 50% of the staff speak and understand some English, the Director had to learn quickly enough Japanese to carry out the daily operations of the Laboratory. At present, the conversations among the staff are, naturally, always in Japanese while those with the Director are a workable blend of Japanese and English. To be sure, there have been many amusing incidents resulting from incomplete comprehension on the part of both parties in a particular conversation.

RESEARCH PROGRAM

The principal area of research in the Tokyo lab has been solid-state plasma effects. This program reflects, in a large measure, the interests of the Director, consistent with the broad objectives of RCA in the field of electronics. The Director of the Tokyo Laboratory reports to the Associate Director, RCA Laboratories, on all technical matters relating to the work in Tokyo. The Vice President and Technical Director, RCA, is a general advisor to the Laboratory on all matters. In this way the Tokyo program is closely coordinated with the activities in RCA Laboratories, Princeton, and Laboratories RCA Ltd., Zurich, to prevent unnecessary overlap of effort.

Some of the specific projects undertaken by the Tokyo Laboratory are related below.

Self-Pinch Effect in InAs

An experimental program was initiated to seek the pinch effect in the solid-state electron-hole plasma resulting in InAs after impact ionization has been attained. The pinch effect was ultimately ascertained by means of the coherent phonon generation resulting from the radial motion of the electrons and holes. A preliminary report on this work has been published in the *Journal of the Physical Society of Japan.*

Magnetohydrodynamic Instabilities

This program of experimental and theoretical research was closely coordinated with the Oscillator work at RCA Laboratories, Princeton. As a result of the Tokyo research there evolved the first direct experimental evidence for the existence of the helical instability that is the origin of the "Oscillator effect" in semiconductors. Most of this work has already been published in the *Journal of the Physical Society of Japan.* The present effort on that problem is now concerned with details of the higher modes of the instability and a critical examination of the device potential involved.

Other theoretical work in this area involves analysis of new types of instabilities that might exist in solid state plasmas.

Negative Resistance in Point-Contact Germanium Diodes.

This research was undertaken to seek an explanation of the oscillations that had been reported in such diodes by earlier workers. As a result of the experiments and analysis at the Tokyo lab, it was shown that a current-controlled negative resistance brought about by the double injection following avalanche breakdown is responsible for the oscillations. The Tokyo results have now been published in the *Journal of the Physical Society of Japan.* This program is now essentially completed.

Semimetal Research

In the belief that semimetals, such as bismuth, will ultimately be very useful electronically active materials, an experimental and theoretical study of this class of solids has been initiated at the Tokyo Laboratories. The present effort is concerned with high current effects, self-magnetoresistance and pinch effects as well as searching for a means to demonstrate the existence of added carriers. Results to date are only preliminary but suggest that further effort would be well justified. Two of the more exciting device potentials in bismuth are the generation of high-frequency radiation through the two-stream instability and the possibility of a traveling-wave "Helicon" type of amplifier. These problems are now under analysis to determine the specific experiments that should be pursued.

One other aspect of semimetal research that is now under way concerns the possibility of making p-n junctions and studying their characteristics. This problem involves the usual aspects of preparation of pure single crystals, alloying junctions, and the subsequent electrical measurements.

Microwave Interaction with Solid-State Plasmas

This is the most recent project in the laboratory and is, at present, concerned with the use of microwaves to diagnose some of the solid state plasma effects being studied. The initial experiments were designed to follow the phenomenon of self-pinching in InSb by means of the microwave reflection from a cat-whisker probe on the crystal. Preliminary results have been very encouraging. The same technique also affords a good means of measuring the relatively short lifetime of the electron-hole pairs created during the impact ionization process.

COUPLING WITH RCA LABORATORIES

Aside from the exchange of correspondence between scientists in Tokyo and Princeton, the Tokyo Laboratory turns out *Tokyo Engineering Memoranda* (TEM's) and *Tokyo Technical Reports* (TTR's) which are distributed throughout RCA. Thus far, 15 TEM's and 3 TTR's have been issued.

The over-all activity of the Laboratory is described in a *Quarterly Progress Report* that is included in the RCA Laboratories *Quarterly Reports.*

On a personal basis, exchange of ideas and coordination of programs is accomplished by visits to Princeton on the part of the Director of the Tokyo Laboratory and by having Princeton staff members on temporary assignment to Tokyo.

RELATIONS WITH JAPANESE SCIENCE

There are many opportunities to interact with the Japanese scientific community. Whenever possible, recent results and projected programs are discussed freely to the mutual benefit and interests of all parties. Some specific ways in which the Tokyo Laboratory has participated in such interaction are:

1. Publication of articles in Japanese scientific journals and presenting papers at society meetings.
2. Frequent visits of Laboratory personnel to universities doing research in the general area of interest. In particular, the institutions that have programs related to those of the Tokyo Laboratory are the Institute for Solid State Physics of Tokyo University, Tohoku University, and Osaka University. During such visits the RCA staff member often lectures on some phase of the Laboratory research.
3. Correspondingly, many Japanese scientists from universities and industrial research laboratories have visited the Tokyo Laboratory either to give their own lectures or to attend lectures by RCA staff members (including RCA scientists visiting Japan).
4. The Tokyo Laboratory helps in administering an RCA Research Grant Program in Japan. Four grants are given annually to universities for pursuing basic research projects. This program has produced much good will in addition to bringing about closer technical relations with the universities.

SUMMARY

The Tokyo Laboratory has been operating for about 24 months with a staff composed of Japanese scientists. During that time the principal area of research has been solid-state plasma effects. A recent promising project initiated in this laboratory concerns the electronic behavior of semimetals such as bismuth. The present technical staff of seven is expected to grow to ten or twelve during the next few years. In addition to doing research of interest to RCA, the Laboratory has established close ties with universities and industrial research laboratories in Japan.

DR. MARTIN C. STEELE has been Director of Research for Laboratories RCA, Inc., Tokyo since early 1960. Before that, he was the head of the Solid State Electronic Research Group at RCA Laboratories in Princeton. He received the BS in Chemical Engineering in 1940 from Cooper Union Institute of Technology, New York, N.Y. He received the MS and PhD in physics in 1949 and 1952, respectively from the University of Maryland, College Park. From 1942 until 1946, he was in the US Army. From 1947 to 1955 he worked as a research physicist at the Naval Research Laboratory, Washington, D.C., where he headed the Cryomagnetic Research Group. His major interests were in superconductivity and magnetic properties of metals at low temperatures. Since 1955 he has been at RCA Laboratories where his interests have been mainly in semiconductor physics, with particular emphasis on solid-state plasma effects. He is a member of Sigma Xi and the American Physical Society.

The exploration of space, the harnessing of thermonuclear fusion power, the understanding of phenomena associated with space vehicle reentry as well as the development of numerous microwave and quantum electronic devices is becoming more and more a study of the mutual interaction between a plasma and electromagnetic and magnetic fields. The RCA Victor Research Laboratories, Montreal, Canada are actively engaged in such studies. The areas of fundamental investigations (theoretical studies, plasma dynamics, and measurements and techniques) are described. The application of these activities to simulation of geophysical and space vehicle interaction, re-entry communication and detection problems, and to microwave and quantum electronic devices is outlined. A reference bibliography is included.

MICROWAVE PHYSICS STUDIES AT THE RCA VICTOR MONTREAL RESEARCH LABORATORIES

Dr. M. P. BACHYNSKI, Director
Microwave and Plasma Physics Laboratory
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RCA Victor Co. Ltd.
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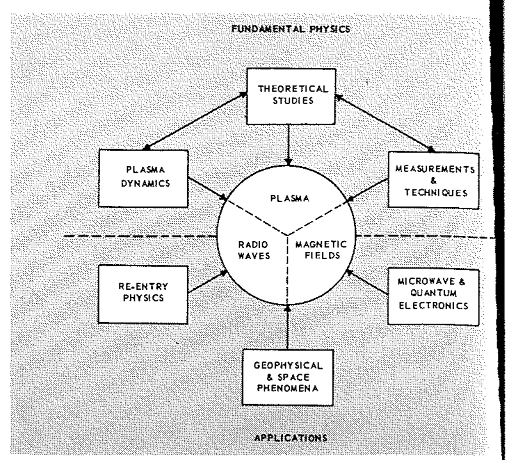


Fig. 1—The RCA Victor Microwave Physics Laboratories are devoted to studies of the mutual interaction between plasmas, high frequency radio waves and magnetic fields. The Laboratories are subdivided into three groups —Theoretical Studies, Plasma Dynamics and Measurements and Techniques. The activities of these groups are applied to the fields of geophysical and space phenomena, re-entry physics and microwave and quantum electronics.

THE EXPLORATION of space, the harnessing of thermonuclear fusion power, the understanding of phenomena associated with space vehicle re-entry as well as the development of numerous microwave and quantum electronic devices is becoming more and more a study of the mutual interaction between a plasma and electromagnetic and magnetic fields.[1]

This is because *space*, for example, consists primarily of plasma permeated by magnetic fields and their interaction with radio waves permits not only a means of studying the space environment but is also important for communications on the earth itself (via the ionosphere, for instance). These considerations apply to most of the space environment including the ionosphere, the magnetosphere, the sun environment and even to local disturbances induced by scientific vehicles and probes.

Similarly, the successful creation of thermonuclear energy by the controlled fusing together of light nuclei still requires a tremendous amount of basic knowledge of plasma properties in order to clarify the severe stability requirements, the important loss mechanisms, the necessary containment times and to develop the technology for heating and diagnosing plasmas.

A space vehicle moving at hypersonic velocities within a planetary atmosphere will be surrounded by a shock-induced layer of ionized gas and leave behind it a highly ionized trail or wake. This enveloping ionized gas, or *plasma sheath*, can have a profound influence on communications and telemetry to and from the vehicle resulting in very high signal attenuation, or *blackout* of the radio signal. The ionized wake behind a space vehicle or meteor provides a significant area from which radar signals can be reflected. A detailed knowledge of the radar scattering cross-section may provide information on the surrounding plasma and indeed on the vehicle itself thus providing a means for detection and discrimination of such vehicles as they enter the atmosphere. Basically, all these phenomena involve the interaction of electromagnetic waves and plasmas.

Numerous promising applications of the properties of plasmas occur in the guidance and generation of high frequency radio waves. The plasma can be made to perform either as a *slow-wave structure* (useful for generation and amplification of microwaves) or a *fast-wave structure* (potential plasma waveguides, switches, phase-shifters, attenuators, nonreciprocal devices). Furthermore, the successful operation of a quantum plasma device using a gas discharge (plasma) system and producing laser oscillations at optical and infrared frequencies has opened a vast new area for the application and study of plasma behaviour.

DR. 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 in the field of radar investigations of the aurora. He then joined the Eaton Electronics Research Laboratory, McGill University, where he was awarded a Ph.D. degree in 1955 with a thesis on aberrations in microwave lenses. After obtaining his Ph.D. degree, Dr. Bachynski remained at the Eaton Laboratory carrying out research on the imaging properties of non-uniformly illuminated microwave lenses. In October 1955, he joined the newly created Research Laboratories of RCA Victor Company and became Director of the Microwave and Plasma Physics Laboratories in 1958. Since this time he has conducted research on electromagnetic wave propagation, microwave and plasma physics. Dr. Bachynski is a senior member of the Institute of Electrical and Electronic Engineers, 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 Association of Physicists. He is Chairman of Commission VI of the Canadian National Committee of the International Scientific Radio Union (URSI), is listed in American Men of Science and is associated with McGill University teaching classes in antennas and electromagnetic theory. In 1963 he was awarded the "David Sarnoff Award for Outstanding Individual Achievement in Engineering."

FUNDAMENTALS INVOLVED IN MICROWAVE PHYSICS RESEARCH

Research into such important and hitherto relatively unexplored phenomena requires primarily a large portion of the effort to be devoted to fundamental physics—basic *theoretical studies*, investigations of the characteristics of plasma (*plasma dynamics*) and development of new and improved *measurements and* *techniques* for determining plasma properties and electromagnetic quantities. Each of these disciplines is a vast field in itself, yet a successful plasma physics program cannot be without a balanced interplay between each of these areas.

Consequently, the activities of the RCA Victor Microwave Physics Laboratories are loosely divided into these three divisions: theoretical studies, plasma dynamics, and measurements and techniques. Each applied program undertaken by the Laboratories falls, very often, amongst all three divisions with each group performing that portion of the program for which they are best suited. This insures effective communications, an appreciation of the overall problems involved and fruitful exchange of ideas between the personnel of the three groups resulting in an environment in which there are always far more ideas for research than there is time to work on them. These spheres of interest of the Microwave Physics Laboratories and their applications are illustrated in Fig. 1.

Theoretical Studies

The Theoretical Studies group has concentrated principally in two major regions: the interaction of electromagnetic fields and plasma, and plasma kinetics. The interaction of electromagnetic waves and plasma includes propagation of electromagnetic waves in plasma,[2-4] plasma boundary phenomena[5-10] which determine the behaviour of radio waves at a plasma boundary for arbitrary angles of incidence and in the presence of static magnetic fields, the effect of thermal transport properties of a plasma on electromagnetic waves,[11] instabilities which may arise when streaming charged particles are reflected from a magnetic barrier[12] and the behaviour of electromagnetic waves in columns of plasma[13] or guided structures. Efforts on plasma kinetics have been towards an understanding of the mutual interaction between the particles which comprise the plasma. This includes studies of the collision cross-sections and collision frequencies of the constituents of a plasma[14] for various degrees of ionization, the electrical transport properties[15-17] of a plasma including the effects due to static magnetic fields, electron density gradients, temperature gradients and energy flow due to electric fields as well as consideration of the kinetics of a plasma by using an expansion of the charged particle distribution function in the Boltzmann equation in terms of spherical harmonics.[18] Some consideration has been given to attaining charge neutralization in ionic rockets[19] by using electrons for charge mixing and to time-average acceleration of charged particles using nonuniform AC electric fields.[20] Current interests include simulation considerations (scaling laws) for geophysical and re-entry induced plasmas (see Fig. 2), the interaction of turbulent plasmas with radio waves, characteristics of plasmas containing a large percentage of heavy negative ions and the interaction of moving plasmas with steady magnetic fields. In addition, all measurement programs have corresponding theoretical studies to guide the experiments and to assist in interpreting the results.

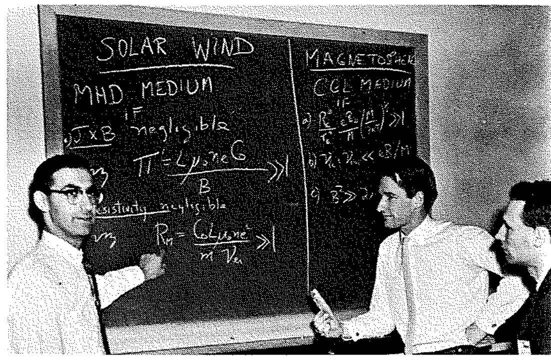


Fig. 2—The nucleus of the Theoretical Studies Group: Drs. I. P. Shkarofsky, T. W. Johnston, and J. Nuttall.

Plasma Dynamics

The Plasma Dynamics group have been concerned with methods of generation and containment of plasma and the characteristics of various plasmas. Most work has been done with gaseous plasma (helium, argon, mercury and special electronegative gases) although solid-state plasmas have merited some consideration. A variety of ways of generating plasmas have been established. These include the normal DC discharge, slowly varying discharges (60 cycle), RF excited plasma, DC arc, RF excited blow-down system for supersonic plasma, shock plasmas, and plasma guns. These plasmas have been contained in free space, glass bottles, low-loss (for microwaves) dielectric containers, and in magnetic-mirror and magnetic-cusp field configurations. (A better appreciation of the activities of this group is to be found in the later section on *Applications of Microwave Physics Studies.*)

Measurements and Techniques

Since plasma physics is in a highly exploratory state, a great number of techniques are necessary in order to diagnose what is actually happening. The Measurements and Techniques group in the Microwave Physics Laboratories have concerned themselves with three classes of diagnostic techniques: microwave, electrical and optical. A major effort has been devoted to microwave techniques with special attention given to time resolution and space resolution. A fast-acting microwave diagnostic system[21] has been developed for use with nonrepetitive plasmas such as produced by shock tubes and pulsed discharges. The technique has been used at frequencies of 9.2 Gc, 23.5 Gc and 34.5 Gc with sampling periods of 0.5 msec. to 0.1 μsec. This system, used in conjunction with a microwave polarimeter unit can be used to measure simultaneously the two orthogonal components of the electric vector of the electromagnetic field.[22] This technique gives both amplitude and phase information on the radio signal which has been affected by a plasma. A lower-frequency phase meter suitable for use with heterodyning systems has also been developed. The output of these two techniques is illustrated in Fig. 3.

Improvements in space resolution for microwave measurements of plasmas have been obtained through the use of lenses and focussing reflectors (Fig. 4) where the characteristics of focussed and unfocussed beams are compared. Microwave diagnostics of plasma through the use of transmission, reflection and polarization measurements both in free space and in waveguides are now proven techniques in the Microwave Physics Labo-

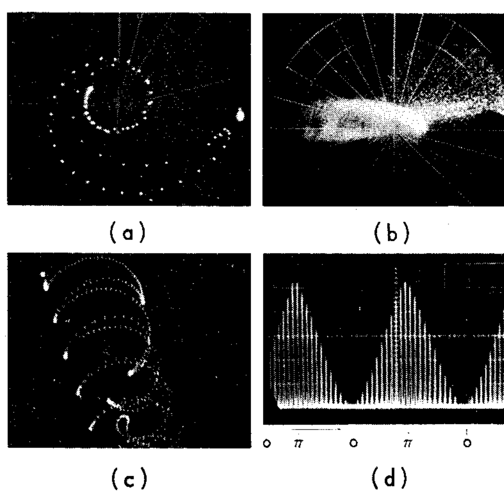


Fig. 3—Various microwave amplitude and phase measuring devices which have been developed at the Microwave Physics Laboratories: (a) Polar plot of amplitude and phase of electromagnetic wave transmitted through pulsed plasma. Plasma characteristics on decay of pulse are not the same as for rise of pulse resulting in "hysteresis" effect. (c) Displacement of vertical scale for each measurement of a sequence of pulsed plasmas. (b) Microwave scattering from a turbulent plasma showing a "time distribution" of values for the amplitude and phase of the scattered wave. (d) Display pattern of phase measured at a frequency of 1 Mc. (Local oscillator frequency 950 kc) with lower frequency phase meter.

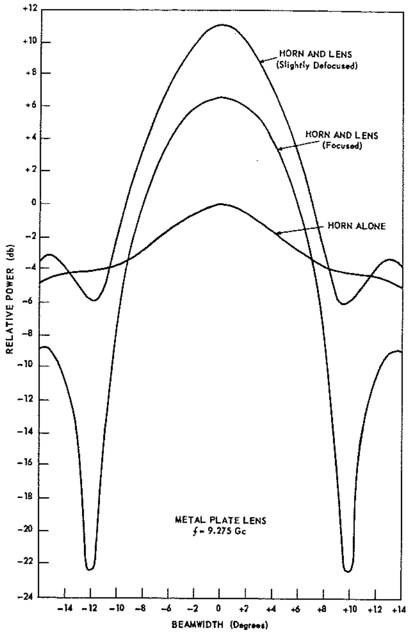


Fig. 4—Improvement in space resolution of a microwave beam using lenses is indicated by the much narrower beam possible with the use of an auxiliary lens.

ratories, as well as the measurements of microwave noise emission from plasmas using a Dicke-type radiometer. The most common electrical measurements of a plasma are, of course, the current and voltage waveforms of the discharge. More useful techniques which are actively being employed are Langmuir probes (electron temperature, electron density) double ion probes, magnetic probes, Faraday cages (total current), and time-of-flight mass spectroscopy for species identification and relative abundance of each species of ions. Optical studies range from photographic observations, photomultiplier measurements of light intensity, streak camera displays of time sequential phenomena, to diffraction grating spectroscopy and spectrophotometry. (Illustration of these techniques will be given later in this paper.)

GEOPHYSICAL AND SPACE PHENOMENA APPLICATIONS

Simulation of Geophysical and Space Phenomena

The use of satellites and rockets for the exploration of space is invariably expensive because of the sophistication of the instrumentation and because of the cost of rockets and launching. Their use is, however, essential because it is the only way in which most regions of space can be probed directly. It is, therefore, necessary to obtain the optimum results from such a programme and this can only be achieved through a proper "design of the experiment"—including the parameters to be measured and the techniques used for measurement, and through a successful interpretation of the data obtained. To achieve this, free-flight programs should be supplemented by theoretical studies and laboratory simulation experiments.

The interaction of the solar wind (plasma emitted from the sun) with the magnetosphere is one region of the solar environment which is of great interest, particularly since the discovery of the van Allen radiation belts. Experiments on the simulation of some of the solar-wind—magnetospheric phenomena are underway in the RCA Victor Microwave Physics Laboratories. Fig. 5a shows the basic arrangement of a solar wind impinging on a terrella (model earth) which is permeated by a magnetic field of dipole configuration. The laboratory arrangement is shown in Fig. 5b. A shock tube employing a Bostick-type gun and powered by a bank of condensers is used to simulate the solar wind, while the dipole magnetic field is generated by pulsing a large current through an appropriate wire loop. In this fashion, it is relatively easy to generate "blobs" of plasma of density 10^{13} electrons/cm^3 impinging on magnetic fields of 0.5 kilogauss.

Typical distributions of the plasma from the solar wind as it impinges on the magnetized terrella are shown in the Fig. 6 experimental measurements. Fig. 6a shows the unmagnetized terrella and the surrounding plasma. As the magnetic field is increased, (Fig. 6b) a *stand-off region* of plasma forms away from the terrella and some plasma still clings to the terrella. As the magnetic field increases further (Fig. 6c), the stand-off becomes better defined and the plasma on the terrella moves towards the poles of the dipole magnetic field.

Further experimental measurements are needed before firm conclusions should be drawn regarding the nature of the interaction. However, these initial results appear very promising. In an effort to ascertain the formation of the plasma about the terrella, diffraction-grating photographs (to determine the nature of the plasma in each region—i.e. from solar wind or ionization of the local environment) and streak-camera photographs (to determine the time history of the formation of the plasma—i.e. which region forms first) have been taken. These along with magnetic field probes and electrical current probe measurements are contributing to obtaining the details of the interaction. Typical results are shown in Fig. 7.

A second simulation experiment deals with the time history of a plasma trapped in a magnetic field in the presence of a static electric potential (The presence of a trapped static electrical potential has been postulated as a possible mechanism for viscous mixing of the plasma in the magnetosphere). Magnetic-mirror and magnetic-cusp fields are used for trapping the plasma which is shot into the confining region with a plasma gun. Typical trapped plasmas are shown in Fig. 8a (magnetic mirror) and Fig. 8b (magnetic cusp). Trapping times of the order of a second have been obtained in this manner. Further extension of these

Fig. 5a—Schematic diagram of experiment designed for the study of solar wind-magnetosphere interaction.

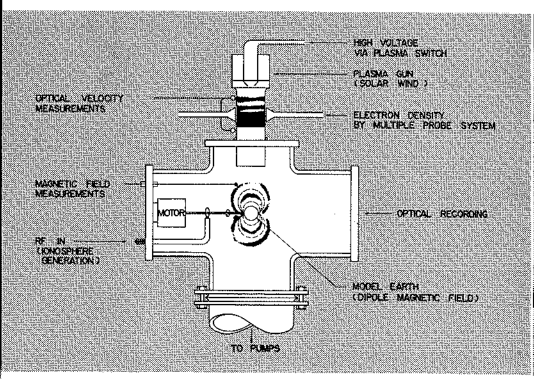


Fig. 5b—Experimental arrangement for investigations of solar wind-magnetosphere interaction showing Dr. F. J. F. Osborne (right) and F. H. Smith.

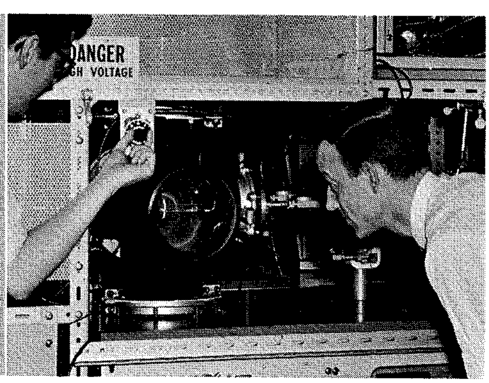
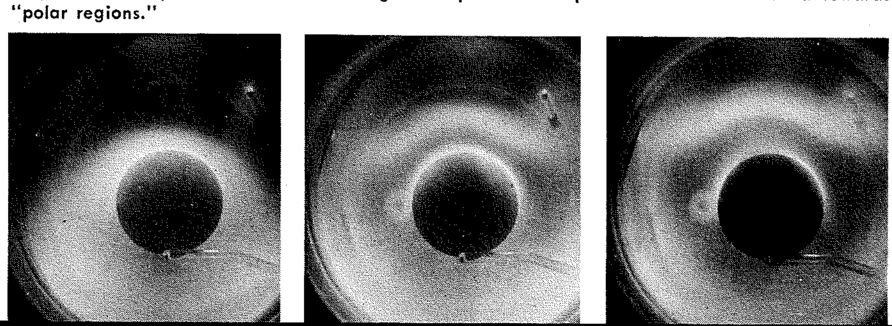


Fig. 6—Effect of solar wind (plasma) impinging on model magnetosphere and terrella: (a) no terrella magnetic field—typical bow shock wave around terrella, (b) intermediate strength magnetic field—stand-off of plasma on dipole magnetic field and second band of plasma on terrella, (c) strong magnetic field—pronounced stand-off region of plasma and plasma on terrella moved towards "polar regions."



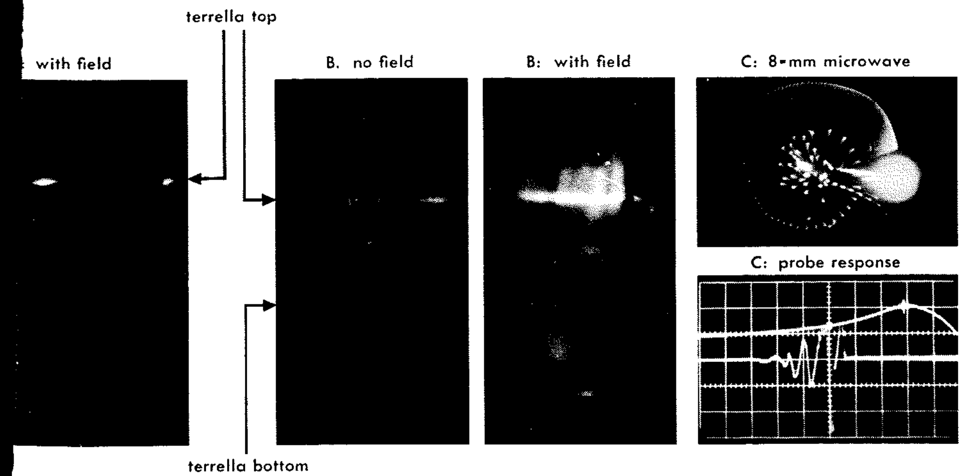


Fig. 7—Diagnostics of solar-wind-magnetosphere interaction phenomena: (a) solar-wind impinging on magnetosphere and terrella as seen through diffraction grating showing the species of plasma due to solar wind and species of plasma due to ionization of the ambient atmosphere of the terrella due to solar wind. (b) streak camera photograph of solar wind impinging on magnetosphere and terrella show time sequence of arrival of plasma with and without the presence of the terrella magnetic field. (c) measurement of electron density decay in solar wind plasma using 8-mm microwaves. Response of magnetic probe as the terrella magnetic field is pulsed on. (The oscillatory trace is an expansion of the small instability seen at the peak of the top trace.)

simulation techniques to the study of rocket and satellite induced effects are "on the drawing board."

Techniques for Studying the Space Environment

A knowledge of the upper atmosphere and planetary environments is another essential part of the exploration of space. Very often, a region can be probed by virtue of interactions which are induced in that region. In particular, the species concentration, electron content and electron energy distribution of the constituents of a region of space may be obtained by seeding techniques whereby another constituent is added to the region and by virtue of the interactions which occur, the original environment can be ascertained. The use of electronegative gases (compounds which have a high affinity for electrons thus forming heavy negative ions through electron capture) for this purpose has received little attention although some of their properties appear very interesting from this point-of-view. (As is well known, heavy negative ions can also be used for electric propulsion purposes.[23])

An experiment designed to generate heavy negative ions and to study some of their characteristics is shown in Fig. 9. Electrons (which can interact via the capture process) are generated in a variety of ways, including a DC-excited gas discharge. Quantities of the neutral molecules with a high electron affinity are introduced into the discharge and the interaction studied. Fig. 10a illustrates the formation of SF_6^- and SF_5^- ion species by direct electron bombardment as measured by a time-of-flight mass spectrometer. In a gas discharge, the SF_6 molecule dissociates resulting in formation of a large number of negative ion species as shown in Fig. 10b. The use of simpler gases (e.g., I_2) eliminates the dissociation process to some extent. Langmuir probe measurements of the current in a discharge which contains a large percentage of an electronegative gas show some remarkable features. As illustrated in Fig. 11, it is possible to have the negative ion current nearly equal to the positive ion current. This means that there are few electrons in the discharge!

RE-ENTRY PHYSICS APPLICATIONS

Re-entry Communications

The sheath of ionized gas (plasma) which is induced by and surrounds a hyper-velocity space vehicle as it traverses a planetary atmosphere has a pronounced effect on radio frequency communications to and from the vehicle.[24-25] Distortion of the antenna radiation pattern, impedance mismatch due to the plasma, an increase in antenna noise, voltage breakdown between the plasma and the antenna and even complete blackout of the transmitted signal are only some of the effects which can occur. These considerations are also important in assessing the characteristics of an antenna on a rocket or space probe.

Extensive experiments designed to examine the influence of a plasma sheath located in front of the aperture of a microwave horn antenna on the far-field radiation pattern and impedance of that antenna have been conducted.[26-29] The experimental arrangement is shown in Fig. 12 in which a plasma sheath is generated by a 60-cycle discharge in helium contained in a cylindrical container. The effect of this plasma sheath on the radiation characteristics and impedance of a horn type microwave antenna has been examined in detail at frequencies of 9.7 Gc, 25 Gc and 35 Gc using the multiple-probe system, and at 75 Gc and 150 Gc using conventional techniques. Typical measurements of electromagnetic wave transmission across the plasma at frequencies of 9.7 Gc and 25 Gc are shown in Fig. 13. It is seen that as the discharge intensity is increased, a large attenuation and phase shift is observed at X-band (9.7 Gc) while the K-band (25 Gc) signal suffers much less attenuation but still considerable phase shift.

Typical variations of the antenna impedance with plasma properties are illustrated in Fig. 14. The multiple-probe display has been expanded to correspond to a preset nominal voltage standing wave ratio (VSWR) at the outer ring of the record. The center of the display corresponds to a VSWR of one. Even at high electron densities, a good part of the microwave energy penetrates the plasma and much of it is absorbed resulting in a higher noise temperature for the antenna.[30]

Representative far-field radiation patterns (both amplitude and phase) in the presence of a plasma sheath are shown in Fig. 15. The general characteristics are a pronounced minimum at normal incidence, which increases with increasing plasma density and an increase of the side-lobe levels relative to the main lobe. A theoretical model which treats the plasma as a uniform infinite slab and which considers diffraction around the edge of the experimental plasma container is found to explain most of these important features.

Present activities are concentrated on the use of static magnetic fields to be used in conjunction with the microwave antenna in such a manner as to modify the plasma sheath and in this way per-

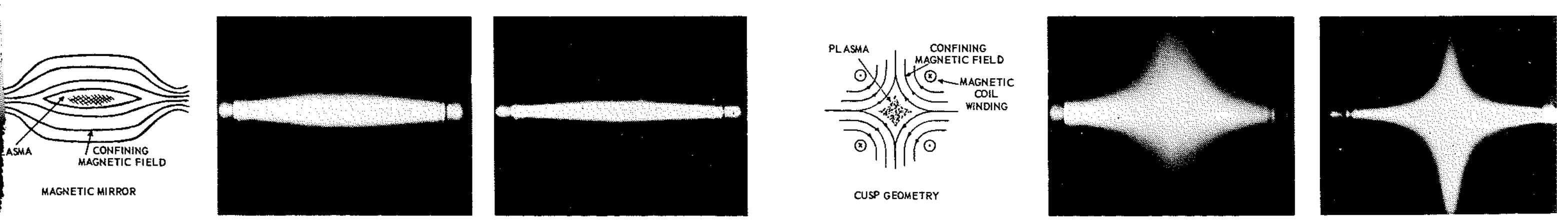


Fig. 8—Trapping of a plasma in various magnetic field configurations: Left set of three: magnetic mirror fields; right set of three: cusps geometry magnetic fields. The middle trace in each set is a weak field; the right-hand trace, a strong field.

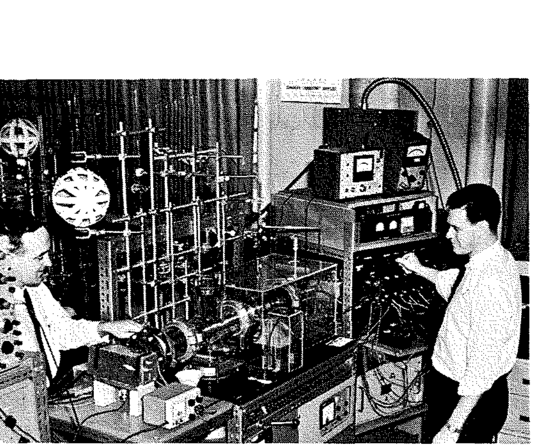


Fig. 9—Experiment for the generation of heavy negative ions in a gas discharge and their study by means of Langmuir probes and time-of-flight mass spectroscopy (with Dr. G. G. Cloutier (left) and C. Richard).

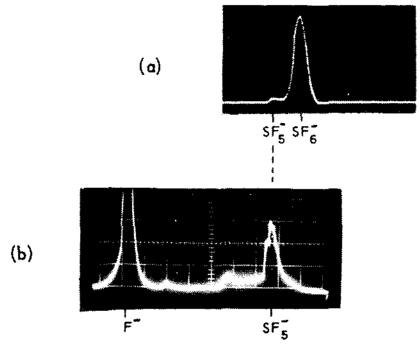


Fig. 10—Time-of-flight mass spectrometer measurements showing: (a) SF_6 and SF_5 negative ions produced by direct electron bombardment. (b) SF_6, SF_5, F and other negative ions produced in a gas discharge.

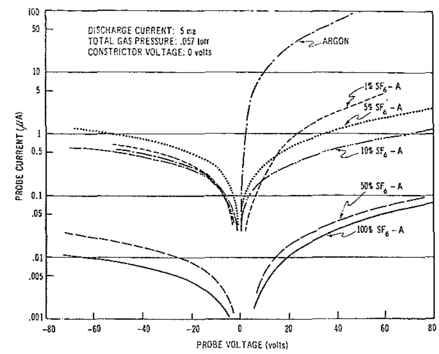


Fig. 11—Langmuir probe characteristics of a gas discharge containing various amounts of electronegative gases.

mit communication through the plasma. Magnetic fields are only one possibility to be used for opening RF windows in the plasma and other techniques such as seeding with electronegative gases are also under active investigation.

Radar Characteristics of Supersonic Plasma Flow-Fields

A body (space capsule, missile, meteor, etc.) travelling at supersonic velocities in a planetary atmosphere, leaves behind it a trail or wake of highly ionized gas. If the radar scattering cross-sections of these wakes are characteristic of the properties of the plasma of the wake and the wake plasma can be related to the vehicle parameters creating the wake, then a powerful technique exists for providing specific information on the vehicles as they enter the atmosphere.

Unfortunately, many uncertainties exist regarding the parameters involved in both full-scale measurements and in the theoretical analysis of re-entry plasmas. Hence, it is essential to make measurements in suitable laboratory systems in which many of the parameters can be accurately controlled. Because of the large number of parameters involved, exact scaling or simulation of all the geometric, aerodynamic and electromagnetic properties of the full-scale system is not possible in the laboratory. Consequently, the laboratory experiment is, in general, designed to simulate some specific important aspect of the full-scale problem.

A laboratory experiment designed for the study of microwave scattering from supersonic plasma flow-fields is shown in Fig. 16. The system consists of a low-density plasma blow-down tunnel[31] which provides RF-excited supersonic plasma flow streams with static pressures ranging over two orders of magnitude (0.1 to 10 torr). The supersonic plasma emanates from a converging-diverging nozzle which is arranged so as to be free to rotate about an axis centered in the test section so that the aspect angle relating to a fixed radar can be varied. A variety of measurements (optical, electrical probe, and microwave) have been performed on these simulated wakes.

It is possible to put obstacles into the supersonic flow and in this way determine the flow fields behind these obstacles. The wakes behind a cylindrical obstacle are shown in Fig. 17. The flow conditions are the same (mach 2) in each case except that the ambient density (corresponding to different altitude) is changed resulting in a widely different "structure" of the wake. By coating the obstacle with a thin film of material with a low ionization potential, it is relatively easy to obtain bright visual demonstrations of the flow-fields.[32]

In order to provide information on the plasma flow-field which would be of assistance in interpreting the interaction of electromagnetic waves with the plasma stream, electrical probe studies of the simulated wakes have been made. A mapping of the electron density profiles across a diameter of the stream at various distances from the nozzle exit is shown in Fig. 18. These measurements were made by appropriately biasing double electrical probes swept across the stream and give the complete distribution of electron density in the flowing plasma. Typical double-probe characteristics as measured in a laminar flowing plasma are illustrated in Fig. 19a. The flow in a supersonic plasma wake need not be laminar. It is well known that the flow can be turbulent as well. Turbulent flow conditions can be simulated in the

Fig. 12—Experimental laboratory studies of the effect of a plasma sheath on the characteristics of microwave antennas (with B. W. Gibbs).

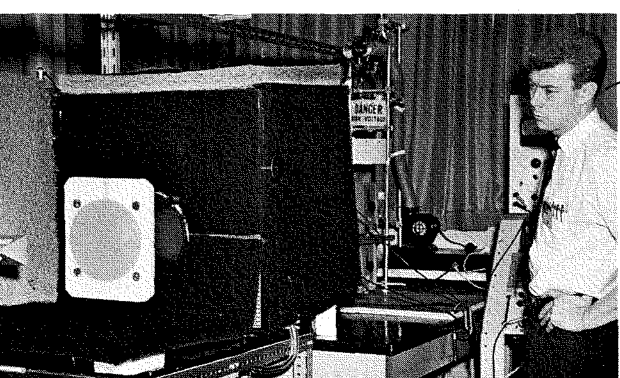


Fig. 13—Typical measurements of transmission of electromagnetic waves through a slab of plasma at frequencies of 9.7 Gc and 25 Gc.

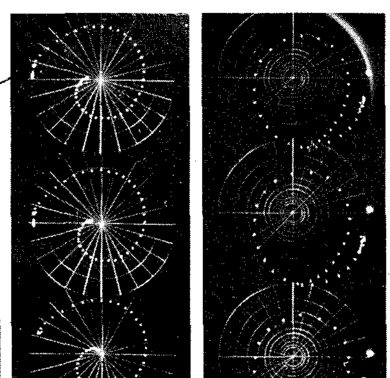
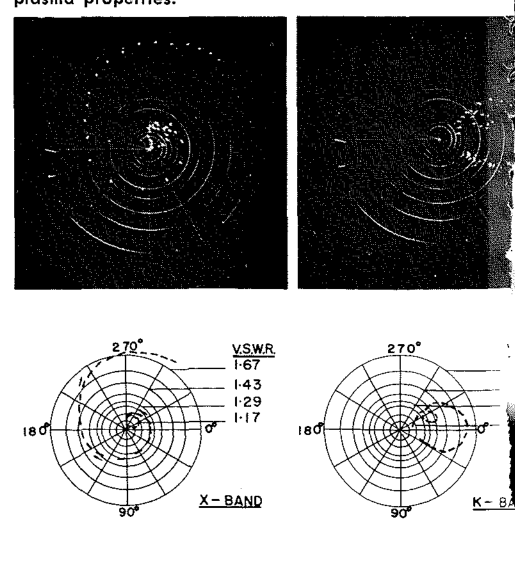


Fig. 14—Impedance introduced by a plasma sheath to microwave horn transmitter located immediately behind the plasma for various plasma properties.



laboratory and Fig. 19b shows the response of double electrical probes in a turbulent plasma indicating the fluctuation of electron density with time. With a known electron distribution (in position and time) in the supersonic plasma it is then possible to gain some insight into the scattering of radio waves from such a plasma.

The back-scattering of microwaves measured from a flowing plasma as function of aspect angle is shown in Fig. 20a. The major peak occurs (as expected) at normal incidence. The effect of turbulence on the back-scattered signal (Fig. 20b) is to provide a randomly fluctuating signal in time while the back-scatter from a laminar plasma is virtually constant. Another important consideration of radio-wave interaction with plasma is the polarization of the electromagnetic fields. In particular, if the electric vector of the incident field is oriented normal to the axis of a cylindrical plasma then resonant scattering can occur. This results in large peaks of back-scattered energy (see Fig. 20c) occurring for different values of the plasma density. An accepted theoretical explanation of this phenomena is not yet available.

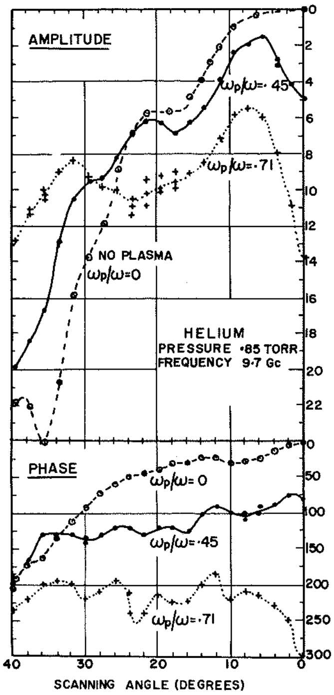


Fig. 15—Effect of plasma sheath on antenna radiation pattern is to distort the pattern decreasing the energy radiated in the forward direction and increasing the side-lobe levels.

MICROWAVE AND QUANTUM ELECTRONICS APPLICATIONS

Plasma Loaded Microwave Structures

The modification of waveguide properties by the introduction of plasmas offers interesting possibilities for microwave components, particularly at short wavelengths where conventional techniques become difficult or impractical. To date, little work has been done on fast-wave-mode propagation in waveguides, although passive microwave devices of both reciprocal and non-reciprocal types are possible.

Recent studies have been conducted on fast electromagnetic waves in isotropic plasma-loaded waveguides.[33] The parameter of prime interest in this investigation, because of its importance to practical devices and intimate dependence upon plasma density, was the guide wavelength as a function of the extent to which the plasma filled the waveguide, the electron density, and the type and pressure of gas used. The basic experiment was performed on circular cross-section waveguide excited in the TE_{11} mode at a frequency of 10 Gc (see Fig. 21). The plasma was generated in argon or helium by DC or R-F sources and was contained in appropriate cylindrical-shaped pyrex containers. Typical behaviour of the plasma-loaded guides are shown in Fig. 22, where the characteristics of a partially loaded and nearly completely loaded guide are compared. Anomalous behaviour for certain values of gas pressure and guide-filling factor is apparent, although much of the behaviour can be accounted for by a theoretical model which includes the plasma container.

More interesting possibilities are the use of anisotropic plasmas (created by the use of static magnetic fields) resulting in non-reciprocal behaviour. Experiments on the properties of anisotropic plasma waveguides are in progress. A typical experimental arrangement is shown in Fig. 23 where the static magnetic field is aligned along the direction of propagation. This type of wave mode should give rise to Faraday rotation and hence the characteristics desirable for the design of isolators and gyrators.

Plasma Lasers

It is possible through the creation of an RF discharge in certain mixtures of gases to obtain a *population inversion* suitable for stimulated emission by the excess of atoms in the excited state, thus giving rise to maser or laser action. Such "plasma" lasers have been operated in the visible and infrared spectral regions under both CW and pulsed conditions and show great spectral purity.

Such devices show considerable promise for the generation of lower frequency optical energy and for the diagnosis of plasma. For this reason, plasma-laser studies are being undertaken by

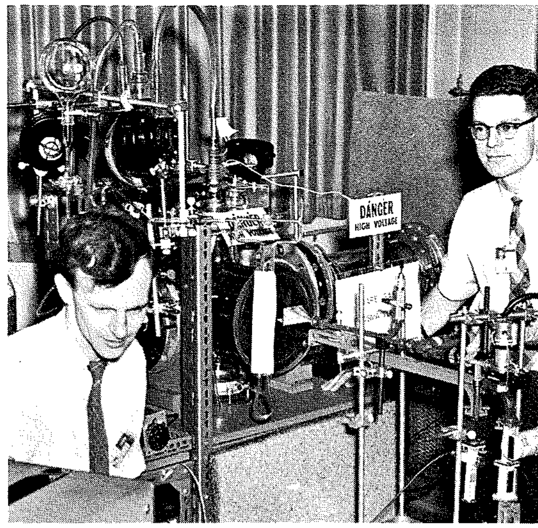


Fig. 16—"Blow-down" plasma tunnel for generating supersonic streams of plasma for simulating wakes of meteors and re-entry vehicles (with Dr. A. I. Carswell, right, and J. D. McLeod).

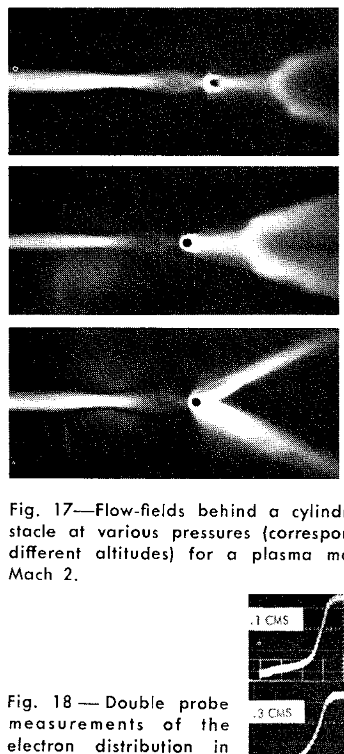


Fig. 17—Flow-fields behind a cylindrical obstacle at various pressures (corresponding to different altitudes) for a plasma moving at Mach 2.

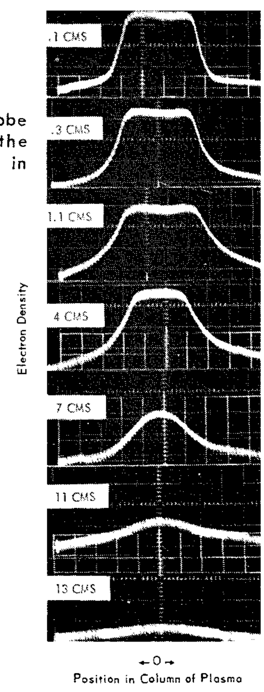


Fig. 18 — Double probe measurements of the electron distribution in the plasma flow-field.

Fig. 19—Double probe characteristics in (a) laminar supersonic plasma stream, (b) turbulent supersonic plasma stream.

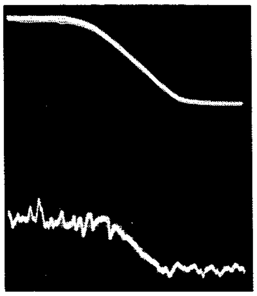


Fig. 20—Back-scattering of microwaves from supersonic plasma streams: (a) variation of back-scattered signal with aspect angle for laminar flowing plasma, (b) time variation of back-scattered signal for laminar plasma and for turbulent plasma, (c) resonance back-scattering of microwaves when polarization of incident field is normal to axis of flowing plasma stream as function of plasma density.

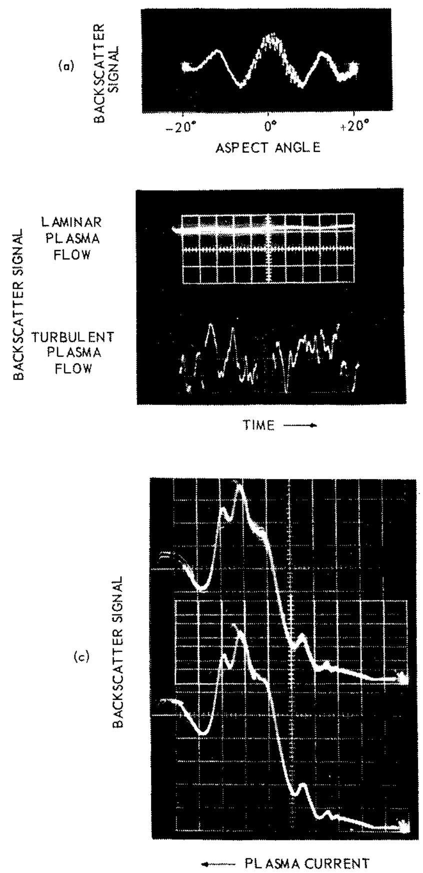
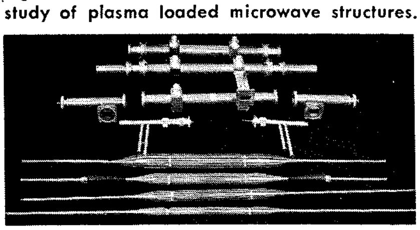


Fig. 21—Plasma containers and waveguide for study of plasma loaded microwave structures.



the Microwave Physics Laboratories. Fig. 24 shows such a typical plasma laser under construction.

CONCLUSION

It is quite evident that research in plasma physics is a field of ever-increasing scope and importance. The exploration of space, the harnessing of thermonuclear energy, the solution of problems associated with re-entry phenomena and the invention of new micro-wave and quantum electronic devices are some of its goals. Its many formidable problems present a great challenge to the physicist and engineer. In addition, plasma research offers a unique balance of fundamental physics and technological applications which are on the frontiers of today's science and engineering. This leads to an environment which breeds ideas and opportunities to explore them. It is for these reasons that members of the RCA Victor Research Laboratories view their activities primarily as "fun," for what other field has so much to offer?

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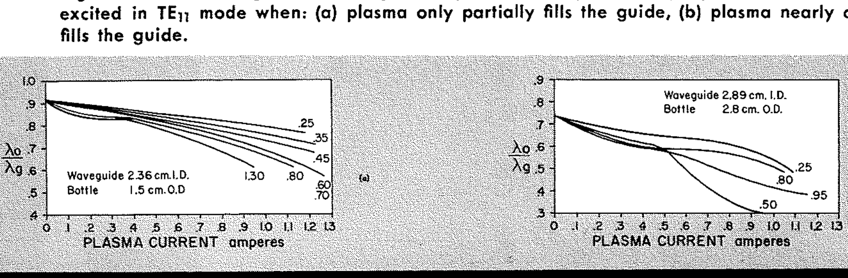
Fig. 22—Variation of guide wavelength with plasma density for isotropic plasma loaded waveguides excited in TE_{11} mode when: (a) plasma only partially fills the guide, (b) plasma nearly completely fills the guide.



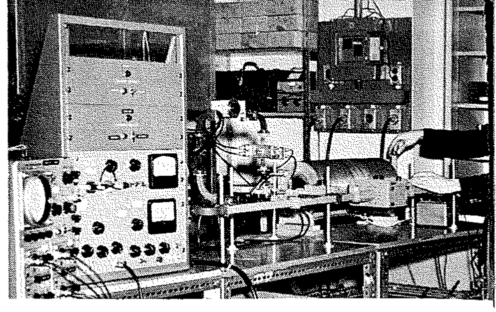


Fig. 23—Experimental arrangement for the investigation of anisotropic plasma loaded microwave structures (with J. V. Gore).

Fig. 24—A helium-neon radio-frequency excited gas laser (with A. Waksberg).

SCANDOT—HIGH-SPEED IMPACT-PRINTING PROCESS

SCANDOT is an impact printing process in which a row of seven styli scan across the page, writing dot-matrix characters (Fig. 1). The styli strike a ribbon or carbon paper, as in a typewriter, producing as many as five copies simultaneously. The print-head contains the styli and seven independent electromagnetic drivers. The impact rate of individual styli is 1,300 dots/sec or higher, equivalent to 185 characters/sec or 1,850 words/min. A potential breakthrough in high-speed on-line printers, a single SCANDOT printer could replace 15 to 30 teletype machines and their demultiplexers.

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The SCANDOT technique was developed to meet the increasing need for on-line printers capable of handling the high data rates of military and commercial data-transmission systems, which range from 750 to 3,000 words/min. This approach emerged from a 1961 RCA-sponsored project in the Subscriber and Input-Output Engineering group of the DEP Surface Communications Division; it was an outgrowth of the group's previous experience in designing transducers for military headsets and microphones. Printers utilizing this technique are expected to find wide military application: they are mechanically and electrically simple, easy to maintain, compact, and require little power. Further, a single printer can replace 15 to 30 teletype machines and their demultiplexers.

Competitive electromechanical printers operating above 100 words/min are essentially "hot-rod" teletypes or stripped-down computer printers; they suffer maintenance, timing, and wear problems of high-speed machinery. Electronic printers for this speed range produce only single copies. Further, a developing process is often required; this is unsatisfactory in many applications.

The SCANDOT printing technique results from a discovery in 1961 that a small magnetically-driven stylus assembly could produce dots through several layers of paper and carbon paper. The key engineering problem was to build a print-head containing seven styli in a row 0.1 inch long, each driven independently at high speed. This head had to be small and light enough to be rapidly scanned across a page for serial character printing (Fig. 1).

The SCANDOT technique was successfully demonstrated with the model shown in Fig. 2 and described later. The achieved impact rate of 1300 dots/sec is equivalent to 185 characters/sec or 1,850 words/min printing characters serially with a single head.

INITIAL EXPERIMENTS

Initial printing experiments were performed with a sound-powered telephone; the diaphragm was removed and the drive rod filed to a point. This was mounted on a lathe tool rest along with a photoelectric scanner (Fig. 3). Lettered copy was wrapped around a mandrel under the scanner, and layers of paper and carbon paper were wrapped around the mandrel under

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ELVIN D. SIMSHAUSER received the BS in Physics from Kent State University in 1951 and began work with RCA's Special Devices section that year. In 1956, he joined DEP's Surface Communications Division to work on acoustical engineering projects for the military. In 1958, Mr. Simshauser was appointed Leader, Transducer Engineering Unit, responsible for the design and development of miniaturized electroacoustical equipment such as, microphones, earphones, and acoustical headsets. He is currently engaged in the development of special military input-output devices.

Fig. 2—The authors R. M. Carrell, left, and E. D. Simshauser, center, and the demonstration model strip printer with P. B. Scott (right), an engineer who contributed to the SCANDOT project.

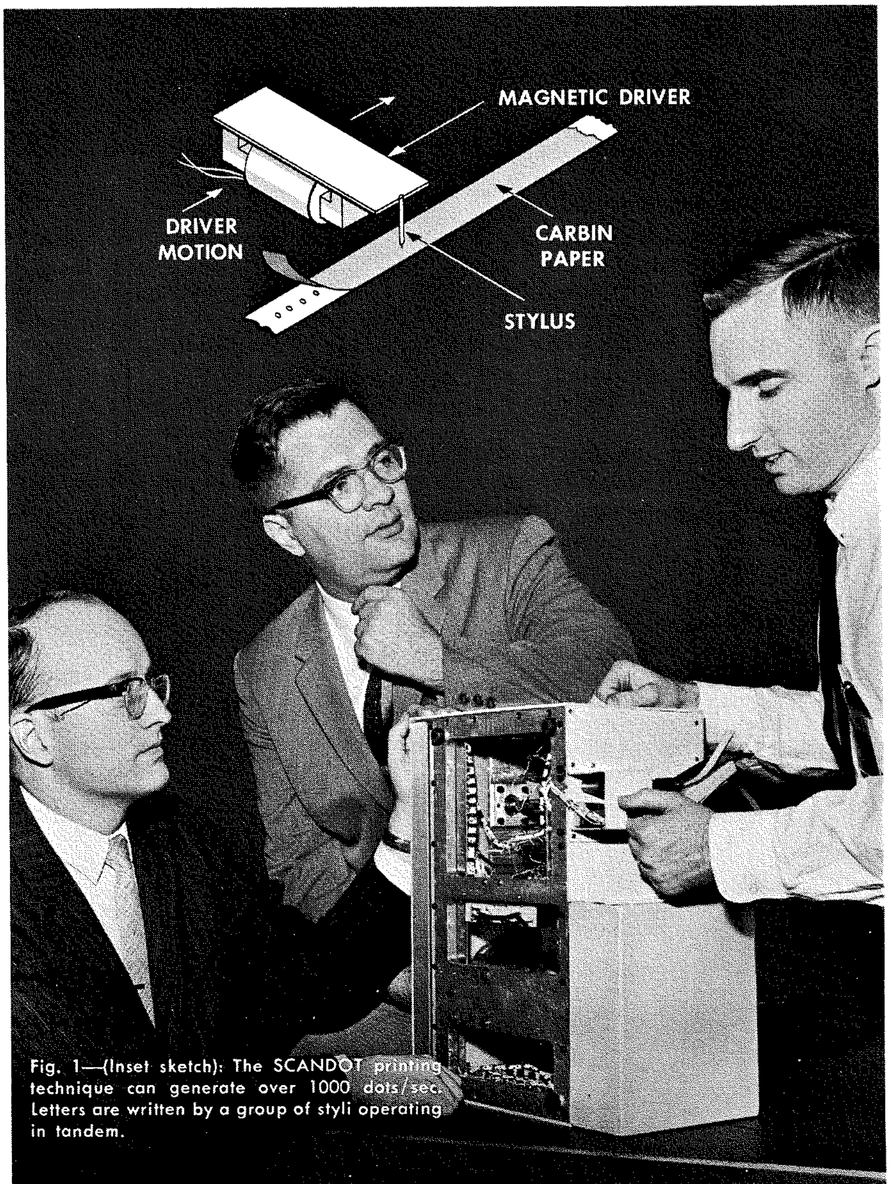


Fig. 1—(Inset sketch): The SCANDOT printing technique can generate over 1000 dots/sec. Letters are written by a group of styli operating in tandem.

the print-head. Circuits were arranged so the print-head was excited at 1,000 cps when the scanner sensed black areas. This crude experiment produced up to eight high-quality carbons, prepared hecto masters, and embossed heavy metal foil. Based on the tests, development was started on a seven-stylus head and a demonstration strip-printer for the head.

HEAD CONSTRUCTION

The first model of the head is essentially a cluster of seven sound-powered telephone structures with their armatures extending radially from the row of styli. Fig. 4 shows a rear view of the structure; inset is an enlarged view of the armature tip and the rear of the styli. Because it is so large and heavy (3-inch diameter and 12-ounce weight) it is useful only in a strip printer, but the head demonstrates the feasibility of the SCANDOT process.

Initial development and testing has been accomplished on a miniature version of a SCANDOT print-head producing high printing forces; it is capable of printing on standard teletype paper and carbons in addition to nearly all other standard types of multiple copy papers and carbons. The new unit is ⅞ inch in diameter by 2¼ inch long and weighs 2½ ounces.

HEAD TRANSPORT

Fig. 5 shows a possible transport mechanism for scanning the head across the page. The three heads are supported by a set of eight metal tapes which supply current to the stylus drivers. The idler is built of alternate conducting and insulating rings which contact with the tapes; these rings are contacted in turn by a set of brushes. The drive capstan is covered with an elastic material which equalizes differences in tension resulting from small differences in the lengths of the individual tapes. Each head is attached by an arrangement which allows the head to lift away from the tapes at the corners. A sequential-scan feature eliminates carriage return time in narrative text (i.e. nontabulated text).

At speeds of 75 characters/sec (750 words/min) and lower, a digital stepping-motor moves the heads in discrete increments on command. A magnetic-detent motor provides an adequate operating life. Asynchronous operation enables the printer to accept input data on a character-by-character basis without timing problems. The printer must be synchronized to the data source at higher speeds where fast start-stop operation is not feasible.

Fig. 6 is a block diagram of the electronics used to drive the SCANDOT print head; key circuit blocks are the *decoder, encoder, head drivers* and *tone wheel.* Input signal codes are recognized by the decoder which drives the encoder, setting a 5 x 7 matrix of cores. Signals from the tone wheel read out the core matrix in successive columns and in synchronism with the paper motion.

Both the decoder and encoder use cores for logic functions; the decoder requires one core for each character recognized. A set of 12 code windings links the cores in different patterns. For a given input code, only one core is not linked by current-carrying windings; one winding is sufficient to hold a core in the *reset* state. The single unlinked, or free, core is then set by a master winding; after the code is recognized by the single *set* core, the input currents can be removed. The decoder now stores the recognized character until the encoder is empty.

When the encoder is empty and ready to receive a new character, a master reset pulse is applied to the decoder. The core previously set now resets and a readout pulse is generated in a winding linking the core.

Each decoder core is large enough to drive the encoder cores directly. When a core is reset, the current in the output winding sets a group of cores in the encoder matrix, corresponding to the dots to be printed in the character recognized by the decoder.

The 5 x 7 core matrix contains 40 such windings. In addition to the character windings, the five columns are linked by readout windings and the seven horizontal rows are linked by sense windings. The sense windings control the print styli as the columns are read out by the readout pulses.

The styli are driven by pylistors (silicon-controlled rectifiers) triggered by the encoder cores. Only a matching transformer is necessary when sensitive pylistors are used; a single power transistor controls the printing current to all the styli, selected by the pylistors.

A tone wheel coupled to the head transport mechanism generates the timing pulses for the printer. Control functions handled by conventional transistor logic coordinate various actions of the printer. A printer designed to be compatible with the MICROPAC Computer[1] requires 120 transistors and 100 cores.

PROPOSED PRINTER CONFIGURATIONS

The printer techniques described can be designed into a very compact package; in practical cases, control logic requires up to 120 transistors. When standard electronic packaging is used, the bulk of the cards exceeds that of the mechanism and power supply. Most of the circuits can be packaged as micromodules, providing an extremely compact printer. Several proposed configurations are shown in Table I. The Communications Printer is most useful in fixed-plant installations where space and power are not critical.

The tactical microprinter is intended as a companion to micromodule tactical computers such as MICROPAC.

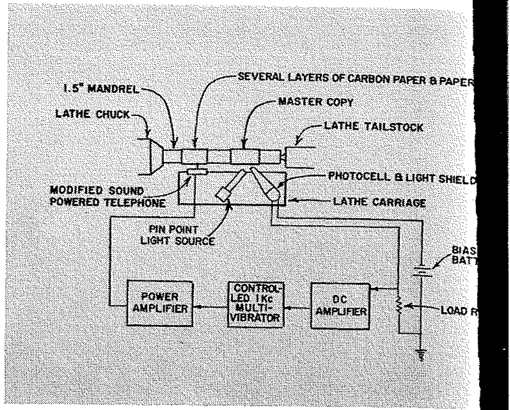


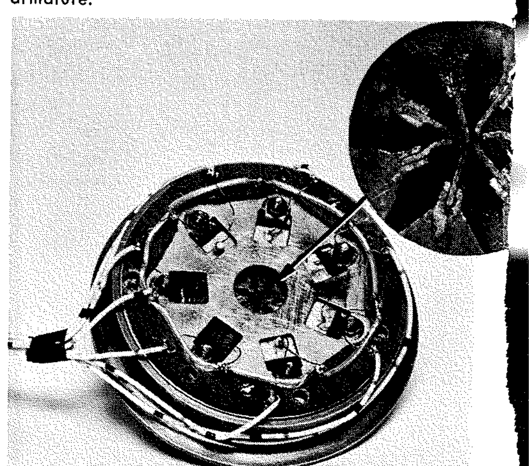
Fig. 3—Lathe setup with photoelectric scanner.

COMMUNICATIONS SYSTEMS INTERFACE

Printers used for general communications do not control the data source, as do computer printers. The printer must run continuously in synchronism with the input data rate, or be capable of a complete *standby-print-standby* cycle for each character at the highest data rate. These modes of operation are *synchronous* and *asynchronous*, respectively.

Asynchronous printers are universally applicable since they impose fewest special requirements on the system. Asynchronous operation at 100 words/min is possible with teletype printers, and about 750 words/min with SCANDOT printers, and any speed with purely

Fig. 4—Rear view of the head (at left), a cluster of seven sound-powered telephone structures; inset at top is an enlarged view of the armature.



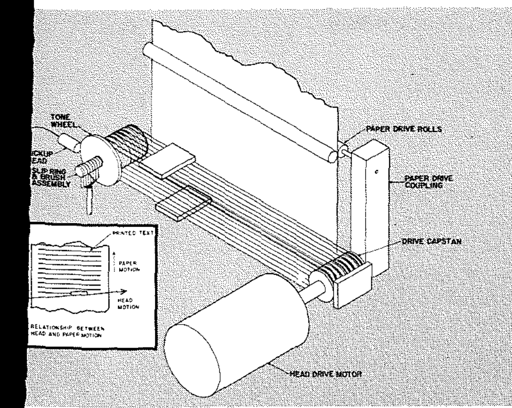


Fig. 5—The head and paper transport mechanism.

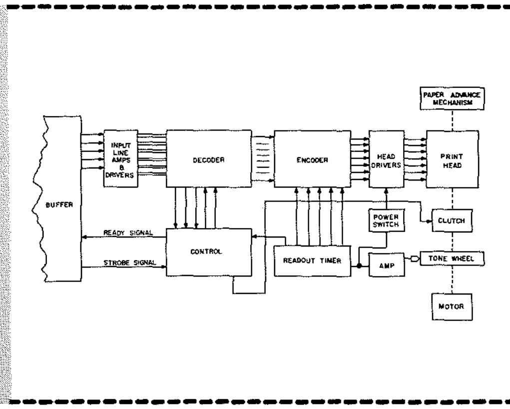


Fig. 6—The SCANDOT communications printer.

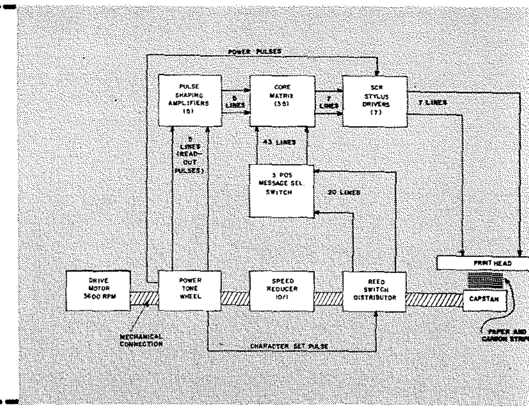


Fig. 7—The demonstrator model.

electronic printers. Electronic printers, however, do not produce multiple copy directly, and are more expensive and less compact than SCANDOT printers.

Because the SCANDOT printer requires a mechanical scanning operation, its maximum start-stop rate is limited. The equivalent of asynchronous operation can be obtained at higher speeds by connecting a buffer memory between the communications terminal and the printer. Both core and delay-line memories are suitable for this application.

APPLICATIONS

There is a trend to miniaturized tactical computer systems. MICROPAC is an example of a computer using micromodule packaging; the entire computer is in a 3-cu-ft package. Similar reductions can be made with large scale computers. In such systems, the tape stations and printers become comparable in size with the arithmetic units. Miniaturization in these areas is necessary, and the SCANDOT tactical miniprinter is a step in this direction.

The tactical microprinter and personal printers are small enough to be carried by a man.

SCANDOT DEMONSTRATOR

The first task, beyond the demonstration of principle was to build a seven-stylus head capable of making 0.1-inch-high characters at a useful printing speed. The second task was to construct a demonstration strip-printer showing overall feasibility. This included demonstrating the use of miniature power amplifiers to drive the head, and check unknown items such as print-head wear rate and printing quality. The demonstrator (see Fig. 2) has its own internal printing programs; three 20-character programs may be selected by a switch (see block diagram of Fig. 7).

The print head, drive amplifiers, and decoder are much the same as the corresponding elements in a page printer. Drive amplifiers exhibit impressive performance; all seven are contained on a 5-by-2-inch board. Each amplifier is capable of switching a 28-watt, 200-μsec pulse under the control of a 20-milliwatt, 1-μsec pulse. Control pulses are obtained directly from the encoder cores with no preamplification required.

Instead of using a decoder to set up the encoder matrix, a 20-position switch is connected to the drive capstan shaft by a timing belt. Since high reliability and long life are required, magnetically actuated reed switch capsules are used. A magnet is mounted on a long arm to actuate the switches in sequence. The 20-position switch generates a sequence of switch closures, each switch closure can set up one of three characters in the encoder, as determined by the three-position, 20-pole program selecter.

A unique feature of the demonstrator is the tone wheel, which generates the timing pulses for read-out of the encoder matrix. Five sequential pulses are required in the columns of the encoder matrix. In the demonstrator, pulses are supplied by a five-phase tone wheel, avoiding any need for counting and gating circuits. The tone wheel delivers power pulses sufficient to drive the printing styli in addition to the encoder matrix.

Actual measurements on the tone wheel show a capability of delivering 200-watt peak power phase. All electrical power requirements in the demonstrator are met by the tone wheel; no other power supply is required. The power tone wheel is not suitable for tactical equipment because of its weight and size. Instead, a small tone wheel with electronic counters will be used.

CONCLUSION

The principle of SCANDOT printing—utilization of small lightweight drivers to produce dots at rates in excess of 1,000 dots/sec with multiple copies—is potentially a major breakthrough in the high-speed printing field. It provides a simple low-cost serial-character printer for rates up to 300 characters/sec.

BIBLIOGRAPHY

1. A. S. Rettig, "MICROPAC—A Micromodule Digital Computer for Tactical Military Use," RCA ENGINEER, Vol. 8, No. 4, Dec. 1962-Jan. 1963.

TABLE I — Possible SCANDOT Configurations

Equipment	*Electronics Packaging*	*Page Width*	*Volume*	*Speed*	*Power*
		inches	cu ft	words/min.	watts
Communications Printer	Conventional	8.5	1.0	150-300	50
Tactical Miniprinter	Minimodule	5	0.2	750, asynch. 1,500, synch.	100 20
Tactical Microprinter	Micromodule	5	0.1 (less paper supply)	100, asynch.	12
Personal Printer	Micromodule	Strip	0.1	100	2

SPACE TECHNOLOGY
. . . Recent Achievements and Some Current Projects

Reviewed briefly herein are significant achievements in space technology made during 1962. Also described are many of the projects now under way at the Astro-Electronics Division.

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

VERNON D. LANDON attended Detroit Junior College. From 1922 to 1929, he was in charge of the Radio Frequency Laboratory of the Westinghouse Electric and Manufacturing Co. In 1930, he was Assistant Chief Engineer of Radio Frequency Laboratories, Boonton, New Jersey; and in 1931, became Assistant Chief Engineer of the Grisby-Grunow Company. In 1932, Mr. Landon joined the RCA Manufacturing Co., in Camden, New Jersey; and when the RCA Laboratories were established in Princeton, in 1942, he transferred there. He directed some of the studies for the ARS program (an early reconnaissance satellite study). When the Special Systems and Development Department of Defense Electronic Products was formed, Mr. Landon was in charge of satellite vehicle development. When the Astro-Electronics Division was formed in 1958, he joined them in the same capacity. Subsequently, he became Manager of Project TIROS. He is now Manager of the Technical Advisory Staff. Mr. Landon is a member of Sigma Xi, and a Fellow of the IEEE. He has 60 patents, author or co-author of 25 published papers.

Fig. 1—Scene from the integration area at AED where RELAY communication satellites are taking shape for NASA's Goddard Space Flight Center. In the foreground is the solar panel arrangement, fitted to a bare structure prior to being fastened on the RELAY flight model, to the left.

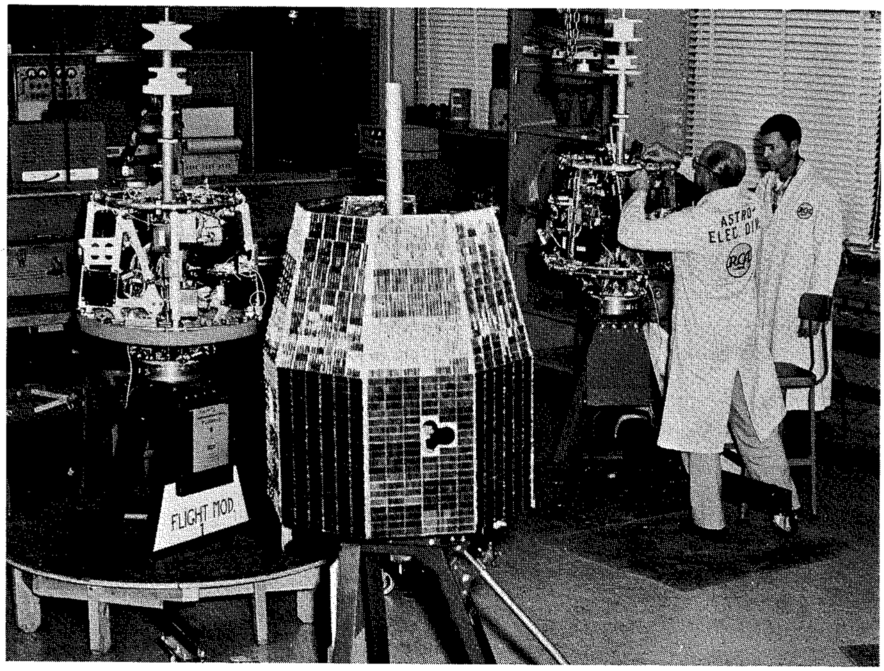
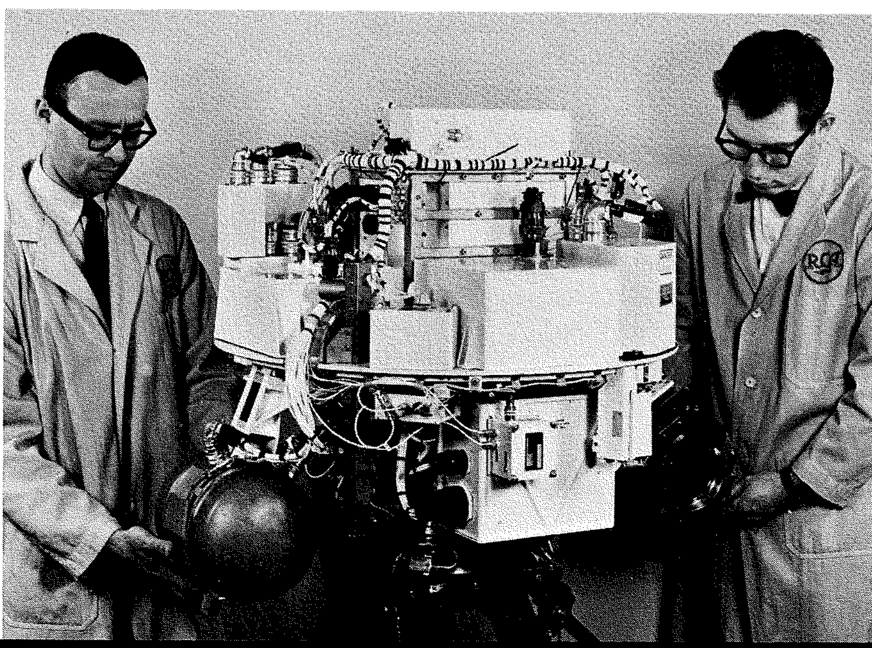


Fig. 2—The SERT capsule is shown here as it will go into flight, with the exception of the position of the electrical-propulsion engines (being held slightly out from their retracted position by Larry Golden, Project Manager, and C. Keller, Test Chief). In actual flight, the engines are extended laterally from the capsule.



THE YEAR 1962 was conspicuous not only for the significant number of firsts in the implementation of the plans and designs for space flight which had been in development over a period of several years, but also for the large number of successful repeats (usually with improvements and refinements) of earlier space flights. Of particular interest to RCA are the successful performances of the RELAY communications satellite and the three TIROS meteorological satellites (IV, V, and VI), as well as other technological successes which cannot be discussed because of security restrictions.

Much important work also has been done in the development of subsystems, components, and techniques. The emphasis on hardware reliability and testing has increased. The success of a spacecraft or a subsystem design cannot be wholly evaluated until a prototype or a production model has operated in a closely simulated space environment. Several large environmental test centers have been constructed both by government agencies and private industrial organizations. The emphasis on such environmental testing at the Astro-Electronics Division (AED) since the first TIROS design was proven in 1959 has culminated in the construction and the

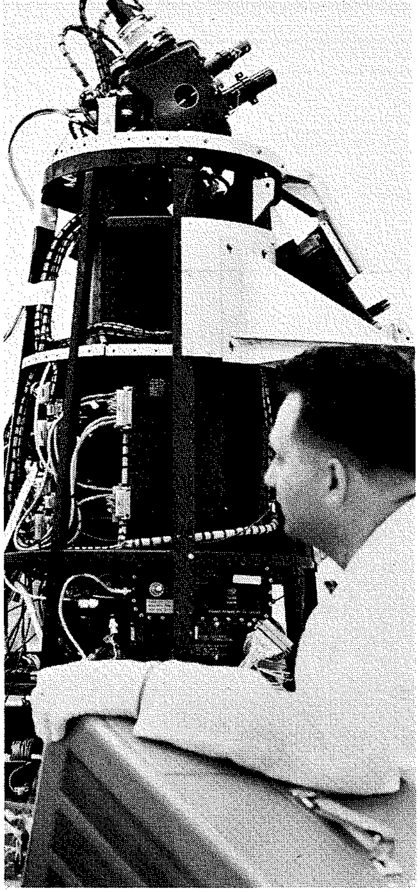


Fig. 3—The TV capsule for the RANGER 6 to 9 spacecrafts, under construction in an ultra-clean "space tent" kept inflated by air-pressure.

present operation of the AED Space Environmental Center, which is adequate to accommodate new generations of spacecraft now in the design and planning stages.

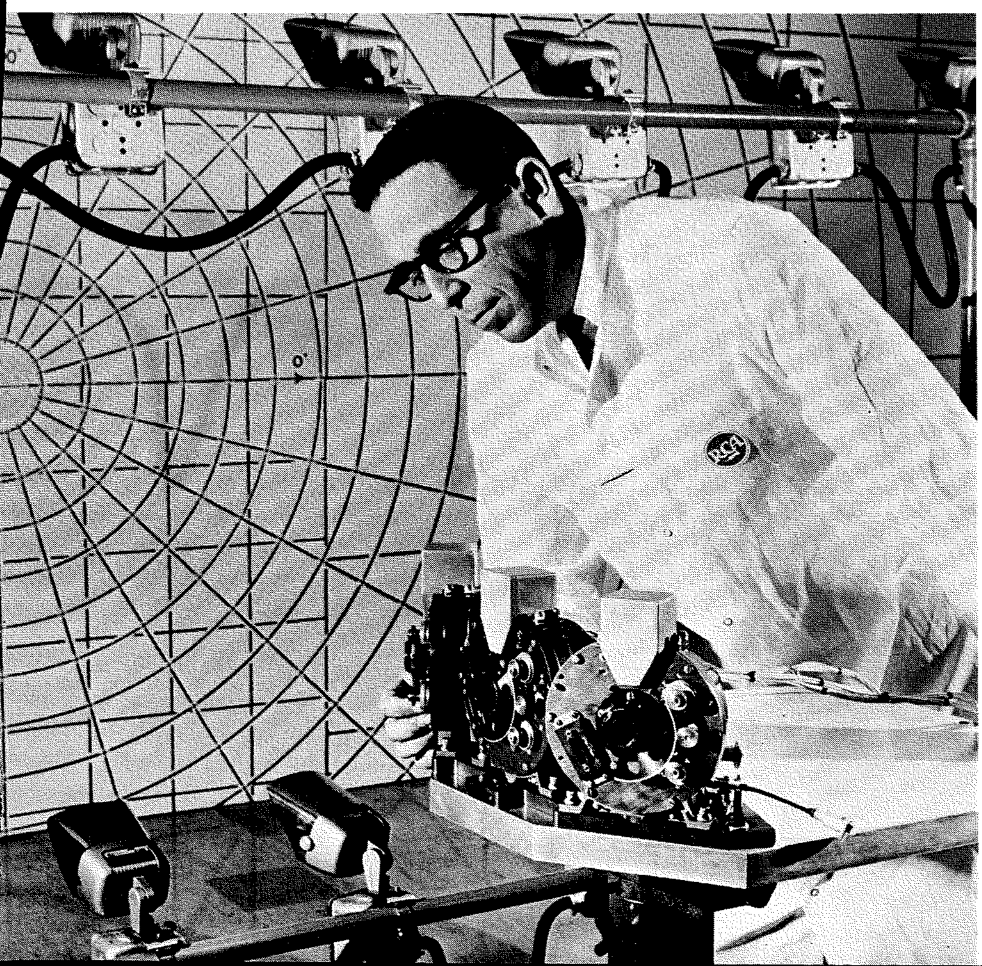
COMMUNICATIONS SATELLITES—TELSTAR, RELAY, SYNCOM

World-wide television and long-distance high-frequency communication came a little closer to realization during 1962. The TELSTAR satellite, privately owned by the American Telephone and Telegraph Company, was launched July 10. It successfully relayed high-quality live television programs and other signals between Europe and the United States, but it ceased operating for a period of several weeks due to a temporary malfunction.

The RELAY communication satellites, built by AED for NASA, will continue the basic research into the problems and techniques of satellite-relay communication begun with TELSTAR. When RELAY I was launched on December 13, 1962, an early malfunction resulted in severe discharge of the power-supply batteries which prevented its immediate operation. Approximately three weeks after launch, the power-supply capability was restored, and RELAY began operating and transmitting television pictures from the United States to France, England, and Italy. Both TELSTAR and RELAY require special ground stations with large directive antennas, although RELAY can be received over longer distances, since the repeaters carried are more powerful (10-watt repeaters for RELAY as compared to a 2½-watt repeater for TELSTAR).

The SYNCOM communication satellite, developed by Hughes Aircraft for NASA, was launched early in 1963, but unfortunately did not attain orbital operation. In the SYNCOM concepts, three satellites are spaced at 120° points in a circular earth-orbit at an altitude of about 22,300 miles. Their speed is such that they remain fixed in position, relative to the earth. One of the three satellites always will be "visible" as a radio relay from any point on the surface of the earth.

Fig. 4—The NIMBUS camera system. When the NIMBUS weather satellite is launched, it will carry an advanced vidicon camera system (AVCS) developed for NASA by AED. Here, Mort Shepetin of AED prepares the tri-camera unit for calibration. The three cameras, working in unison, will produce an oblong three-panel photograph covering 500,000 square miles of the earth's surface with each picture.



MANNED ORBITAL FLIGHTS—MERCURY AND VOSTOK

The most publicized space events were the various American and Russian man-in-space flights during 1962. The United States succeeded in orbiting Marine Lt. Col. John H. Glenn, Jr. three times around the earth in the MERCURY-ATLAS (MA-6) capsule on February 20, followed by Lt. Cdr. Scott Carpenter's MA-7 three-orbit flight May 24, and Navy Cdr. Walter M. Schirra's flawless MA-8 six-orbit flight on October 3.

The USSR launched and orbited VOSTOKS 3 and 4 piloted by Major Nikolayev and Lt. Col. Popovitch respectively, on precise, matching, but not rendezvous orbits, within 24 hours of each other. VOSTOK 3 completed 64 orbits in 94½ hours and VOSTOK 4 completed 48 orbits in 71 hours. Although the two VOSTOK craft came close enough together for visual observation (estimated distances from 1 to 10 miles apart, shortly after launch), no rendezvous was reported or believed to have occurred.

METEOROLOGICAL SATELLITES—TIROS IV-VI AND NIMBUS

The TIROS IV, V and VI meteorological satellites, built by the DEP Astro-Electronics Division under NASA's sponsorship, were successfully launched during 1962. At the end of February 1963, the last two TIROS satellites were still transmitting useful television weather photos.

TIROS IV was launched February 8, a few weeks prior to John Glenn's historic flight, and it provided some 1,600 weather-support photographs for this first U. S. manned-orbital flight. It successfully contributed to a joint U.S. Canadian ice-reconnaissance program called Project TIREC, during which the U.S. and Canadian aircraft simultaneously photographed the ice areas in the Gulf of St. Lawrence for correlation purposes. TIROS IV also participated in the Project BRIGHT CLOUD experiment, in which various cloud brightness levels were photographed for possible weather prediction uses. TIROS IV operated until June, shortly before TIROS V was successfully launched into an elliptical orbit. TIROS IV transmitted a total of 32,500 photographs in 161 days of operation.

TIROS V provided a wealth of meteorological information during the hurricane season, giving close surveillance of hurricane Alma and detecting hurricane Becky days before conventional weather radar or search aircraft. It also provided data on a series of tropical storms, general typhoons, and some photographs of arctic ice shelves.

TIROS V, and TIROS VI (which was launched September 18, two months ahead of schedule) provided maximum meteorological support to the October 3, MA-8 manned flight of Cdr. W. Schirra. The simultaneous flights of TIROS V and TIROS VI gave meteorologists their first opportunity to receive TV weather photos from two simultaneously active weather satellites for comparison and correlation purposes.

The NIMBUS meteorological spacecraft will be placed in a near-polar orbit and will be earth-stabilized, to provide full coverage of the earth each day. It will carry both television cameras and infrared sensors, in addition to a variety of subsystems to control its own operation. AED is developing and constructing three subsystems and two components for this aircraft. The solar-energy-conversion power supply subsystem utilizes highly-efficient solar-cell paddles (on a watts-per-pound basis) to provide storage-battery charging power. Also included in this subsystem are electronic charge and discharge regulator circuits, and overload-protection circuits. The advanced vidicon camera subsystem consists of three television cameras mounted with optical axes diverging to cover an area about 1,500 miles across the path of travel and 400 miles along it for each picture. The camera exposures are synchronized, and the iris openings can be set to vary automatically to compensate for differences in sun angle. A video tape recorder is incorporated in the system to store the picture information.

The third subsystem incorporates a storage-vidicon camera with an automatically triggered and sequenced picture-taking cycle, to permit the use of a greatly simplified communication techniques and ground stations for receipt and production of hard-copy cloud pictures.

The "clock" receiver for the spacecraft command subsystem, which receives and reproduces the command code from the ground station to control the operation of the spacecraft clock, also is being produced at AED. And a tape recorder, similar to that of the advanced vidicon camera subsystem but intended for use with a high-resolution infrared radiometer, is being supplied. Ground-station components required for use with spacecraft equipment also are being developed and produced by AED.

MOON PROBES—RANGER, APOLLO, LEM

The RANGER spacecraft are designed to obtain scientific information about the natural hazards expected on the surface of the moon to prepare for a lunar soft landing. None of the RANGER series launched in 1962 (RANGER 3, 4 and 5) were successful, due to either a faulty launch or a spacecraft-electronics malfunction. RANGER 4 impacted on the dark side of the moon on April 26, after a 64-hour flight, and the other RANGER spacecrafts missed the moon and went into solar orbits, preventing the taking of pictures of the moon's surface. The RANGERS 6 through 9 will each carry six vidicon cameras for obtaining sequential high-resolution television photos of the lunar-impact surface area. The resolution of the cameras is expected to be a fraction of a meter, perhaps as good as 10 cm. These television camera capsules are being developed by AED.

In the APOLLO program (designed to put a man on the moon) the NASA Office of Manned Space Flight made the important decision during 1962 to use the lunar-orbit-rendezvous (LOR) mode of approach as opposed to the previous tentative earth-orbit-rendezvous or the direct-flight mode. The booster configuration to place the APOLLO spacecraft into the moon trajectory will dwarf all previous rocket systems. It will consist of a three-stage advanced SATURN booster towering some 280-feet high, providing a total liftoff thrust of some 6 million pounds. In the LOR mode of approach to the moon, the spacecraft will consist of three major components: the *Command Module* that carries a three-man crew, together with guidance, communications and life-support systems; the *Service Module*, integral with the Command Module, that contains the propulsion systems for midcourse maneuvers, deboost into, and escape from the moon orbit; and the *Lunar Excursion Module* (LEM) in which two of the three crew members will descend to the surface of the moon for at least a day or up to a week for exploration, and return to the Command Module for their return to the Earth. During 1962, RCA participated in a joint proposal effort with Grumman Aircraft Company for development of the Lunar Excursion Module. The contract was awarded to Grumman, and RCA presently is providing systems engineering support.

Related to the APOLLO program is a slow-scan analog television development project conducted by AED for the Collins Radio Company. The purpose of the project was to demonstrate the feasibility of utilizing reduced-bandwidth transmission (requiring less satellite-transmitter power) for satisfactory analog transmission of television pictures from the moon, and to investigate the trade-off comparison for reliability, complexity, size, weight, and power requirements for the spaceborne equipment. The equipment was to be demonstrated in a side-by-side comparison with a similar system using digital techniques. Supplementary equipment provided variation of the transmitted bandwidth, introduction of controlled noise, and variable TV-line rate with noninterlaced scanning (this last supplied by the RCA Laboratories). Vidicons having controlled storage times were used in the television cameras. Also provided was a scan-conversion system which converted the slow-scan pictures to the standard 525-line, 30-frame, interlaced standards of commercial television. The analog television technique was selected for use in the APOLLO program.

SPACE PROBES—MARINER, MARS-1

One of the most spectacular space feats during 1962 was the launching of the 450-pound MARINER 2 spacecraft, which flew by the cloud-shrouded planet Venus, passing within some 21,000 miles on the 14th of December. The MARINER 2 mission used a single-impulse, midcourse trajectory-correction maneuver, which was an accomplishment of some difficulty in deep space. Interrogation of the spacecraft, which began at a distance of 25,262 miles, resulted in data on the atmosphere, gravity, and magnetism of Venus. MARINER 2 made measurements as it passed from the dark side of Venus to its sunlit side at its closest point of 21,500 miles, after which it was turned off.

MARINER 2 data prior to the interrogation indicated that the steady "solar wind" emanating from the sun (which was detected in 1958) exists in interplanetary space. MARINER 2 also indicated that the micrometeorite density in deep space is a thousandth of that around the Earth. The first scientific-experiment sensor analyzed was the magnetometer. The magnetometer data showed that there was no appreciable magnetic-field increase due to the planet Venus along the MARINER 2 trajectory. Other data confirmed the high surface-temperature on the planet, making the existence of life there extremely unlikely. MARINER 2 is continuing in a solar orbit. If it continues operational, radio communications are expected until it has traveled some 95 million miles from the earth.

Russia also launched a planetary probe designated MARS-1 which is expected to soar to within 600 miles of Mars some time late in June 1963, if it lives up to the Soviet's announced plans. It will take photographs of the planet for radioing back to the earth, presumably on its return orbit, as was the case with LUNIK 3, which photographed the far side of the Moon. The spacecraft weighs 1,970 pounds, nearly 700 pounds more than the Mars spacecraft the United States is planning to launch in 1964.

SCIENTIFIC (DATA-COLLECTING) SATELLITES—OSO, EXPLORER, ANNA, OAO, OGO

The 488.3-lb. OSO-1 (Orbiting Solar Observatory) satellite was launched March 7, 1962, into a nearly circular 357-mile orbit to help refine solar-flare predictions. The satellite contains devices for measuring solar X-rays, gamma rays and other radiation, and for detecting microscopic dust particles, neutrons and proton-electrons in the Van Allen belt. The OSO-1 satellite will contribute to our knowledge of the upper atmosphere, since the ultraviolet spectrum of the sun plays an important part in its photo-chemistry and ionization.

The 89-lb. EXPLORER 14 (S-3A) was an energetic-particle-detection satellite launched October 2. It provided excellent data that gave a new profile of the Earth's magnetic field, the interplanetary magnetosphere, and geomagnetically-trapped radiation. The profile of the Earth's magnetic field was previously thought to be symmetrical lines of magnetic flux emanating from the poles of the Earth and extending indefinitely into outer space. Evidence from the EXPLORER series satellites indicates that the effect of the "solar wind" pressing against the sunlit side of the Earth restricts the field in that direction, whereas the field on the dark side of the Earth merges into the limitless interplanetary magnetosphere.

A 99.6-lb. EXPLORER 15 satellite was launched October 27, principally to study the artificial radiation belt created by the high-altitude nuclear explosions over the Pacific on July 9, 1962. The satellite contained an electron energy-distribution detection device, an electron and proton omnidirectional detector, an electron angular-distribution determiner, a magnetometer, an ion-ion electron detector, and an electron directional detector. A high spin-rate adversely affected some of the satellite's functions.

A 355-lb. geodetic satellite designated ANNA-1-B was launched October 31, 1962, cosponsored by NASA and the Army, Navy, and Air Force. It was equipped with two xenon high-intensity optical-beacon flash tubes that produce a series of five flashes 5.6 seconds apart when interrogated by a ground station. Some 42 ground stations, including some operated by foreign countries, are participating in the program. The satellite is equipped with two other systems: a radio-ranging system, and a doppler-shift-detection system. Only limited operation is possible because of the power drain of the flash tubes. The ANNA-1-B satellite is providing information to refine and accurately measure the shape of the earth. It will enable scientists to pinpoint major geodetic sites to within about 330 feet and to relate them to the earth's center of mass. It also will enable scientists to measure the earth's magnetic fields.

The OAO (Orbiting Astronomical Observatory) scheduled to be launched late in 1963, will contribute greatly to a new branch of astronomy, *ultraviolet astronomy*, now possible only with satellites because ultraviolet light does not penetrate the earth's atmosphere. Using high-altitude rockets, a research group at the Naval Research Laboratory detected ultraviolet radiation from the sun and other sources outside the solar system in 1960.

The OGO (Orbiting Geophysical Observatory, S-6) will be an orbiting laboratory designed solely for basic research in the physics of the atmosphere. It has four sensors to measure atmospheric pressures, densities and temperatures; composition of neutral particles; electron temperatures and densities; and ion temperature and densities. The 375-pound satellite will be launched in the summer of 1963. An active life between 90 and 100 days is anticipated.

ELECTRICAL PROPULSION—SERT

The SERT capsule (Space Electrical Rocket Test), being developed and constructed by AED for the Lewis Research Center of NASA, will be used to make tests and comparisons of electrical-propulsion engines in the space environment. Each capsule will be launched into probe trajectories of about one-hour duration. The test-engines will be supplied to AED, but the remainder of the capsule, including all power equipment, command and control equipment, instrumentation, and telemetry equipment to evaluate engine performance, is being produced at the RCA Space Center.

In addition, several projects dealing with electric propulsion have been conducted, or are under way, at AED. An investigation concerned with the experimental and theoretical studies of arc discharges has resulted in an observable thrust from a mercury-particle flux with velocities up to 1.2×10^6 cm/sec (about 30,000 mph).

PHOTO-DIELECTRIC TAPE CAMERA

The electrostatic image-storage system and the photo-dielectric tape cameras using this system were further improved during the past year. Significant improvements were made in the electron gun; limiting beam resolutions were observed above 300 lines/mm. A scanning system was devised to prevent the return of secondary electrons that degrade the resolution of the insulating storage surfaces. Improvements were introduced in the fabrication of long lengths of photo-dielectric tape, and new, low-capacity photoconductors were developed. A complete "slit-type" photo-dielectric tape camera was built and demonstrated successfully, using 15 feet of 35-mm tape.

SOLAR ENERGY CONVERSION

AED has continued intensive work on the optimization of solar-cell arrays used as power sources—principally in the fabrication of gallium arsenide solar cells and cadmium sulphide photovoltaic cells. Promising results appear to lie in the direction of thinner substrates (to improve the power-to-weight ratio) and research into new photovoltaic materials. The radiation resistance of gallium-arsenide cells appears to be higher than that of *n*-on-*p* silicon, and a somewhat different pattern of degradation results.

Research projects dealing with thermionic and thermoelectric converters also have been started, since these show promise of development into lightweight, compact, and long-lived power systems.

JUSTIFICATION FOR A MANNED SPACE COMMAND AND CONTROL CENTER

Advances in space technology have many potential applications to military missions. Discussed here are several considerations that influence the degree to which man will be involved in future command and control of military space missions.

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We are all aware of the tremendous surge forward which has occurred in space technology in the past few years. We are also aware of the fact that advances in technology usually result in new ways of accomplishing military missions. Thus, it is of great importance to us to know at the earliest possible moment how the explosion in space technology will affect the means which we use to carry out military missions. So far, the only clear indications are in the support and intelligence areas: those of improving communications by means of earth satellites, of more effective surveillance of military activities on the earth from satellite vehicles, and in the close inspection of suspicious enemy space vehicles. While we are certain that the future holds much more important military roles for space than those, it is not clear today what these roles will be, nor how they will be implemented. We should note, in particular, that this decade will see the beginnings of manned space flight, but here again, it is not clear today what the significance to our military operations of such manned space flight will be.

The DEP Advanced Military Systems group has been studying what military operations might be performed more advantageously in space in the 1970's and what role man might play in these.

MILITARY SPACE OPERATIONS—1970's

Fig. 1 illustrates what some of the military space operations might be in the 1970's. We feel relatively confident that the operations of communications, surveillance (and possibly inspection), and interception will be important. It is not clear that ground bombardment from space will be used unless some unforeseen advantage turns up. Space-based AICBM (*anti*-intercontinental ballistic missile) systems, or any AICBM systems for that matter, would be extremely valuable if we could find a technically and economically feasible way of accomplishing it. Command and control as a space operation has not been specifically called out on Fig. 1, but as you will see, much of what we have to say involves command and control.

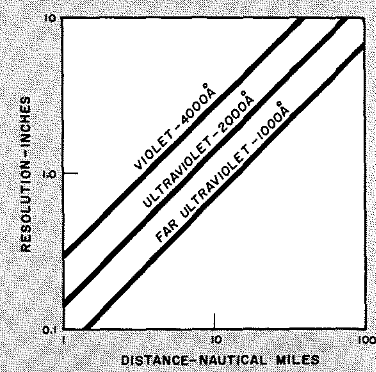
Let us now consider in which of these military space operations it might be desirable to have men in operational control. In the absence of countermeasures, it is unlikely that manual control would be needed either for communications, surveillance, or inspection. These are operations which lend themselves very readily to complete automation and can be implemented much more economically and satisfactorily if manual functions are not designed into the satellite.

COUNTERMEASURES IN SPACE

However, we expect that these functions will most likely have a degree of military usefulness in the 1970's and would therefore be subjected to more or less severe enemy countermeasures. In particular, if ground bombardment or AICBM from space come into use the incentives for the use of countermeasures become overwhelming. Thus, the enemy would be more or less strongly motivated to employ whatever countermeasures he could devise, and it is in the countering of these countermeasures that man would find his greatest usefulness.

It is not difficult to run through the countermeasures which might be employed by the enemy: *camouflage* can reduce the radar cross-sectional area or can be used to conceal from superficial examination the true purpose of an enemy space vehicle; *clouds of decoys* can be deployed to confuse us as to which of the many space objects are the ones to which to pay particular attention; *electronic countermeasures* may be used to jam our space radars and communications; *evasive maneuvers* may be employed to confuse our ability to keep track of satellites which have already

Fig. 2—Resolving power, 5-inch-diameter lens



DR. NATHANIEL I. KORMAN received his BSEE in 1937 from Worcester Polytechnic Institute, where he was graduated with "Highest Distinction." As an undergraduate at Worcester Polytechnic Institute, he was elected first, as an associate member of Sigma Xi and later, as a full member. He received his MSEE from the Massachusetts Institute of Technology in 1938, where he studied as a Charles A. Coffin Fellow. He received his Ph.D. from the University of Pennsylvania in 1958. He joined RCA in 1938 as a student engineer and has held positions of increasing responsibility after being promoted to supervision in 1945. In recognition of his work, Dr. Korman was awarded the 1951 "RCA Victor Award of Merit." In 1956, he was appointed Chief Systems Engineer of Missile and Surface Radar Engineering, responsible for the systems engineering of such major projects as TALOS and BMEWS. In 1958, Dr. Korman was appointed Director of DEP Advanced Military Systems, Princeton, N. J. In this capacity, he is responsible for the creation and development of new and advanced system concepts and for the initiation of RCA corporate action to exploit these ideas and concepts. Dr. Korman has served the Department of Defense for a number of years in various advisory roles. He is a member of the American Ordnance Association, the American Society of Naval Engineers, an Associate Fellow of the Institute of Aerospace Sciences, a Senior Member of the American Astronautical Society, and a member of Sigma Xi. He has made numerous contributions to technical journals and has been granted 33 patents. Dr. Korman is listed in "The American Men of Science" and "Who's Who in Engineering." In 1956, he was elected a Fellow of The Institute of Radio Engineers.

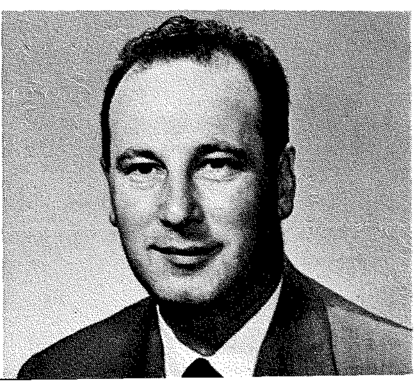


Fig. 1—Manned military space station (1975) forecast of military space operations.

	Technical and Economic Feasibility	Operational and Military Usefulness	Possible Number of Vehicles	Desirability of "Manning"
Communications	Yes	Yes	6-40	No
Surveillance	Yes	Yes	20-30	Probably Yes
Inspection and/or Interception	Yes	Probably Yes	60-100	Yes
Orbiting Ground Bombardment	Probably Yes	Probably No	40-50	Probably Yes
Spaced-Based AICBM	No	Yes	—	Not Known

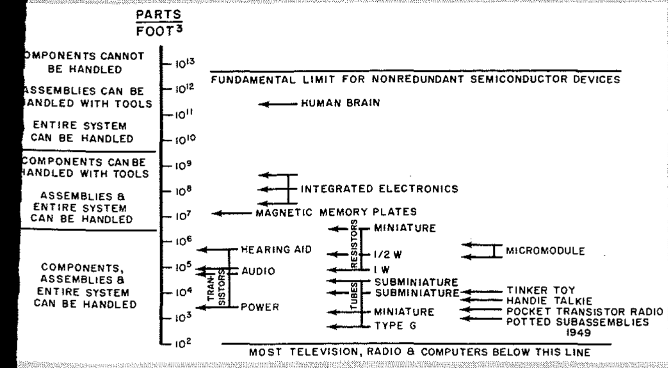


Fig. 3 — Packing density for electronic devices.

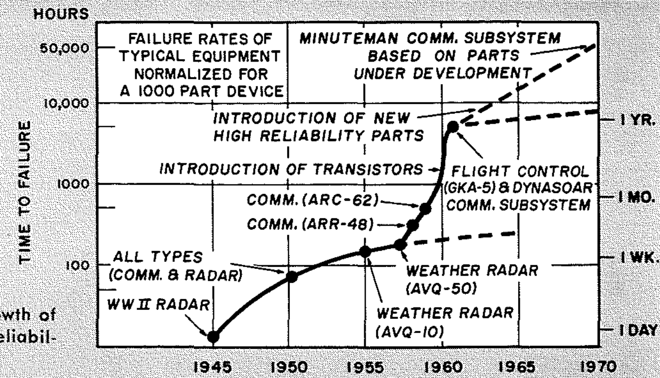


Fig. 4—Growth of electronic reliability.

been examined and classified; and *booby traps* may be used to disable our inspector vehicles. Finally, our space vehicles may be intercepted by any one of a number of weapons.

COUNTERCOUNTERMEASURES

While we have not completed a thorough analysis as to which of these countermeasures are most likely to be used in view of effectiveness, cost, and technical difficulty, we do know that there are several *counter*-countermeasures which can greatly complicate the enemy's attempts at countermeasures.

One of these is to remove our space vehicles to greater altitudes wherever possible. The ability of ground radars to detect and examine space vehicles decreases very rapidly with distance. The accuracy required of an interceptor as well as the cost and the time of flight all grow with distance. To accomplish space operations such as communications and surveillance from higher altitudes will require developments in station-keeping, attitude control, and in optical systems to maintain the degree of resolution required. Development of nuclear power supplies and electric propulsion will be desirable to realize fuel economies which offset the greater cost of booster power necessary to ascend to the greater altitudes, as well as to permit more efficient attitude control and station-keeping. The evolution to higher altitudes may also make possible and desirable the combination in one space vehicle of a number of surveillance and communication functions. For instance, upon detection of the launch of a large booster, immediate ground surveillance of the possible launch sites might reveal information useful to our weapons on a counterforce mission.

Another countercountermeasure which applies particularly to our inspector vehicles is to endow them with a capability for *faster reaction*. This would confront the enemy with a dilemma; if he were to deploy his decoys with small or moderate velocities, the inspection mission could be completed before the decoy clouds could be effectively deployed. On the other hand, if the enemy were to deploy his decoys with large velocities, we could wait for the cloud to disperse enough to permit ground-radar evaluation before carrying out the inspection mission. Faster reaction might be obtained with multiple launch sites and rapid launchability. Another interesting approach involves storage of our inspector vehicles in parking orbits, whence they may be brought into action with great rapidity. This would involve developments to extend the life expectancy of the equipment, as well as to provide for greater amounts of fuel and electric energy. The latter might very well be derived from one of the space nuclear power supplies now under development.

Another countercountermeasure of considerable interest to our inspector vehicles for use against decoys, jamming, and booby traps would be to provide for preliminary inspection from a distance. Such preliminary inspection could greatly enhance the rapidity with which a cloud of decoys could be examined and could greatly conserve the use of fuel in this examination. Inspection at a distance would involve certain changes in the inspector system, but ones which seem reasonable. The changes involved would be to provide combined radar and optical equipment on the inspector vehicle which could map out the cloud of decoys and perhaps gain some information as to the individual size, shape and rotation rates of the individual objects. The optical facilities on the satellite should also be changed to provide for detailed inspection at a distance. As is shown in Fig. 2, a reasonable optical aperture system can give good inspection up to 10 miles or so, and by the use of ultraviolet, even this performance can be enhanced. After optical inspection, probably the next most important way of distinguishing important enemy satellite vehicles from decoys would be by mass measurement. This might be done at a distance by means of a momentum exchange. Momentum exchange can be implemented in several ways: a closely collimated, high-velocity stream of gas, dust, or small pellets could be made to impinge upon the object. The change of velocity would be measured by radar.

The use of spread spectrum techniques can reduce the vulnerability of our space radars and communications to enemy jamming. On-board data processing may become important in reducing the communication bandwidth to the point where spread spectrum equipment is feasible.

Probably the most important countercountermeasure of all would be the use of human judgment to determine what countermeasures are being employed and which of the alternative countercountermeasures should then be put into use. We should dwell on this possibility at some length, but first we will digress briefly to discuss some of the characteristics which we can design into electronic equipment for space vehicles in the future and the ability of such equipment contrasted with the ability of man to perform the same functions.

ELECTRONICS VIS-A-VIS MAN

The size of electronic equipment has been steadily decreasing and will continue to do so for some years to come. Fig. 3 illustrates this decrease. Sometime in the latter part of the decade, with integrated electronics, we expect to obtain on the order of 10^8 electronic components per cubic foot. This is about four orders of magnitude less than the packing density of the human brain and of the fundamental limit for semiconductor devices. On the other hand, integrated electronics will probably achieve a reaction time on the order of 10^{-9} seconds as compared with 10^{-1} seconds for the human brain. Thus, integrated electronics will surpass the brain in being able to perform 10^{17} operations per cubic foot per second as compared with 10^{13} for the brain.

However, the greater capacity and the qualities of rapid learning and adaptability possessed by the human brain and which electronic machinery will not even approach for many decades, makes the human brain much more valuable for many purposes. But more on this later.

The reliability of electronics has been steadily increasing. An improvement on

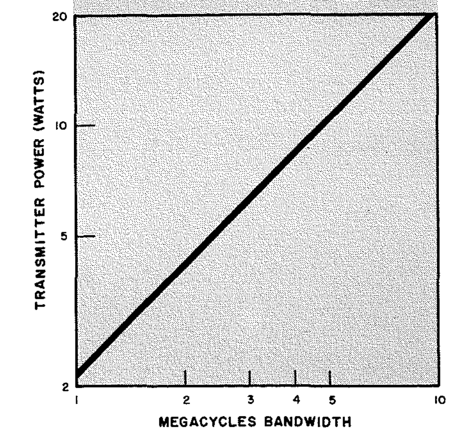


Fig. 5—Transmitter power for space communication.

the order of 10 times has been made in the last decade and we anticipate a similar improvement in the next decade. Fig. 4 depicts this situation. We see that while life expectancies for equipments with several thousand electronic components are not comparable with a man's life expectancy, they are, on the order of several months, quite comparable with length of time a man might be expected to devote to a single mission.

Our experience as to whether our electronic machinery can carry out its mission without human attention differs depending upon the degree of intelligence and judgment required of it. At one end of the scale are the simple communication relays such as the RELAY satellite whose function is mainly to receive, amplify, and transmit. These can certainly carry out their function without the assistance of human operators. Somewhat more complicated are the electronic systems such as TIROS which sense, store, process, and transmit their information upon command. These, too, do not require human operators. Further along the scale are systems such as the SATELLITE INSPECTOR system which evaluate their own performance and take action to improve their performance. These, too, do not require human operators. Actually, electronic machinery is faster, more accurate, and in general better than humans in carrying out the complex calculations necessary to efficiently close a servo loop.

However, we are now approaching the boundary line. For missions where a large number of different situations can arise, we do not know how to device electronic machinery with sufficient intelligence and judgment to make choices among the alternatives. Although we are making progress in this direction, we definitely must have men to run the show in the more complicated situations.

For instance, in some of the ground-based systems which we have designed, such as the land-based TALOS anti-aircraft system the ATLAS checkout system. and the BMEWS system, we have made strenuous efforts to arrive at a design which is completely automatic and can operate with no manual attention. But in every instance, we have found it necessary to have manual monitoring and override functions to take care of those situations which were too complex or too subtle for electronic machinery. We have even found it necessary to avoid asking our electronic machinery to perform functions which are beyond a certain degree of complexity. In these complex cases which we have had to avoid, the time taken to educate (or program) the electronics to perform the function has been so long that it started to approach the length of time for which the function would be valid. In other words, the introduction of technological and tactical innovations is proceeding at such a rapid rate that we must re-educate (or reprogram) our equipment on something approaching a yearly basis. Obviously, if it took something like a year to re-educate to a situation which is changing yearly, we would never "catch up".

SPACE OPERATIONS IN A SEVERE COUNTERMEASURE ENVIRONMENT

Coming back now to our primary thesis, the conduct of our space operations in a sophisticated countermeasure environment, we reiterate: the military space operations as we know them today (communications, surveillance, inspection) *are rather simple* and do not require men intimately with them in order to be able to perform their duties efficiently. They do not require the intimate attention of men because they are presently *not in close contact* with the enemy; they are concerned with support functions and are not yet being seriously threatened with countermeasures. *But this situation will probably change.* As we perfect our ability to carry out the functions and as they begin to have a telling effect on our military effectiveness, the enemy will begin to undertake countermeasures against them. As our space operations start to encounter enemy resistance, the sophistication required of our systems will grow rapidly to the point where man's judgment will become important if we are to prevail over the enemy. Finally, if we ever find out how to do effective AICBM from space, or if it becomes advisable to carry on ground bombardment from space, our enemy will without doubt use the most elaborate countermeasures he can conceive and afford. Then man's judgment in our space operations will become absolutely essential if we are to retain our military superiority.

LOCATION OF MAN

One might next ask whether the man has to be in the same space vehicle as our sensors and defensive weapons, or whether he might be at some remote point in space or on the ground. This is a difficult question to answer generally. It depends on the reliability and assurance with which we can count on communications. If broadband, interference-free communication with the space vehicles carrying our sensors and defensive weapons is assured at all times, the presence of men physically on board is not essential. This is fortunate because:

(1) The presence of man aboard a space vehicle complicates it.

(2) The presence of man aboard a satellite greatly increases its vulnerability to enemy action.

(3) The fraction of the total mission time that the man is actually usefully employed in tasks for which he is uniquely suited is a very small one. For instance, a ground surveillance satellite in a low polar orbit would be over the Soviet Union only 5% of the time.

From a communications standpoint, the ideal location for the men associated with our space vehicles would be in space itself. They could then be located within line-of-sight of our sensors and defensive weapons when those sensors and defensive weapons are in the area where action is likely to take place. The atmosphere would not then set limits upon the usable portion of the electromagnetic spectrum, thus making available tremendously wide bandwidths and tight beams. Indeed, the atmosphere, because of the impenetrability by certain portions of the electromagnetic spectrum, would be a most effective blanket protecting communications between space vehicles from detection, interception, or interference from the earth. As Fig. 5 shows, rather nominal communications equipment will permit such communication. (The use of narrow beams for communication will result in severe acquisition problems the solution of which may very well increase the required transmitter power above that shown in Fig. 5.)

From a logistics point of view, placement of our space men in command posts remote from the space vehicles carrying the sensors and defensive weapons has much to commend it. They can be on location either continuously or for periods which correspond with natural "watch" periods. They can be rotated on and off duty to correspond with their needs for relief and the state of alert and not to correspond with the characteristics of the space vehicle which might have either much shorter endurance as with the present design or much longer endurance which might become possible with future designs. A small group of men can probably serve a large number of space vehicles carrying sensors and defensive weapons.

From a vulnerability standpoint, the placement of our space men in command posts has much to commend it. The command posts could be at remote distances and difficult to detect. They would be few in number so that more elaborate measures could be taken to camouflage and conceal them among clouds of decoys. They would not be easily revealed by their communication links because of the use of frequencies which do not penetrate the atmosphere. They could be endowed with sufficient mobility so that locating them at the rendezvous point with supply vehicles would do the enemy little good unless he had weapons with extremely fast reaction time. The sensor and defensive weapon carrying space vehicles would remain simple because they would be unmanned, and could be correspondingly more numerous and relatively unprofitable for the enemy to negate on an individual basis. Such command posts might also be very valuable in the control of aerospace operations such as strategic bombardment by aircraft and ballistic missiles. there are many problems — and we are not at all certain at this time that a remote space station will eventually prove to be the best solution. The space environment is by far the most hostile with which man has ever had to contend. Neither the food, nor the water, nor the oxygen necessary to sustain life are present. The heat and sight-enabling radiations are there but so are the death-dealing ionizing radiations. Moreover, the amount of energy involved in placing our men and their vehicles in space is extremely large and the operation there-

DISADVANTAGES OF REMOTE MANNED SPACE STATIONS

However, while the concentration of our manpower in remote space stations appears to have many desirable features, fore a most costly one.

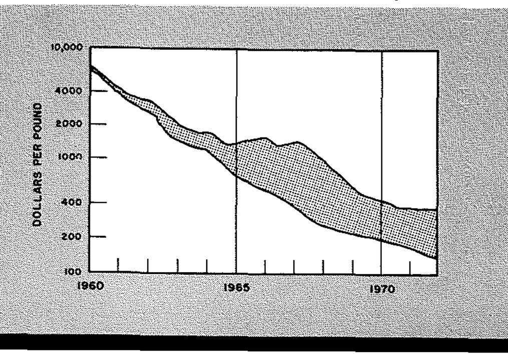
Costs cannot be estimated with any great accuracy today because of many uncertainties:

(1) the minimum crewsize, the minimum space required per crew member, and the maximum duration of space duty which is psychologically possible;

(2) the amount of shielding required against radiation;

(3) the cost of launching material into orbit in the 1970's.

Fig. 6—Trends in launching costs.



However, we can guess at these factors as follows: from extensive naval wartime experience with submarines, a crewsize of 50, a volume per man of 1,000 cubic feet, and a four-month tour of duty might be reasonable. This would require a space station on the order of 50 feet in diameter if it were spherical in form. To shield this volume against normal cosmic radiation and about one-fifth this volume against solarflare activity would require on the order of 1.5 million pounds of shielding. This would be the dominant weight of the space station. A total of 150 men would have to be transported to and from the space station each year. We can estimate the weight of the transport vehicle as 2,000 pounds per man. Supplies can be estimated at about 8 pounds per man per day. We can thus compute a total of about 450,000 pounds that would have to be transported per year. Launching costs are predicted to fall to the order of $200 per pound in the 1970's (Fig. 6). The particular set of predictions shown here are by Koelle of NASA and are for chemical boost to 300-mile altitude. The cost of chemical boost to synchronous altitude would be about six times this figure and the cost of the much slower (1 to 3 months) combined chemical and nuclear-electric boost to synchronous altitude would be about twice this figure. Total costs, if these assumptions hold, thus become on the order of $600 million for the space station and $400 million per year for supplies and rotation of personnel.

This order of cost might be justified to guarantee the effectiveness of an AICBM system or a system of bombardment satellites if such systems were to become feasible and put into large-scale usage. On the other hand, if our space systems of the 1970's have no more important functions than those of communication, surveillance, and inspection we would probably have to sacrifice invulnerability in some degree to obtain more reasonable costs.

ALTERNATIVES TO REMOTE MANNED SPACE STATIONS

For instance, if the manned stations were to be placed in low (300-mile) altitude equatorial orbits, the radiation shielding could be dispensed with and costs drop to the order of $50 million for the space station and the transportation cost drops to the order of $100 million per year. Communications would now have to be relayed via unmanned satellites but would still utilize wavelengths which do not penetrate the atmosphere and would thus remain relatively invulnerable. Interception by enemy crossing course or co-orbital space vehicles now becomes somewhat easier (because the distances and warning times are much less) but still presents some difficulty to an enemy who does not have extensive detection, analysis, tracking, and launching facilities in the tropics.

Finally, if the manned stations were to be placed on earth, costs are minimal, but communications vulnerability might seriously limit their effectiveness. *Here is a real challenge to the communications engineer.*

CONCLUSION

As the result of preliminary investigations, it is our opinion that in the absence of elaborate enemy countermeasures, the military space operations of communication, surveillance, and inspection can be performed without men in space.

But, when the enemy does eventually employ sophisticated countermeasures, we will find it necessary to have our surveillance vehicles rapidly adapt their mode of operation to suit the situation, to have our inspectors react more rapidly, to inspect many more objects, and to make preliminary inspection from a distance. To facilitate efficient operation in this more complex environment, it will be most desirable to have the superior decision-making capacity of men instantly available. Should space-based AICBM or bombardment systems become feasible and be put into use, the desirability of manning in the most invulnerable form we can devise would become overwhelming almost regardless of cost.

The decision-making functions by men might be provided most advantageously from a remote manned command post. While these command posts could be located on the ground, there might be important advantages in invulnerability if they were at some remote location in space. Communications to the individual space vehicles could be made secure by the use of very tight beams of radiation which do not penetrate the atmosphere. The manned space stations could probably be so designed, located, and used as to be most difficult for the enemy to detect, locate, and destroy. In addition, they might be very valuable in the control of military operations other than those which are carried out in space.

More thorough investigations are certainly necessary and may lead us to modify some of the conclusions arrived at in this preliminary investigation.

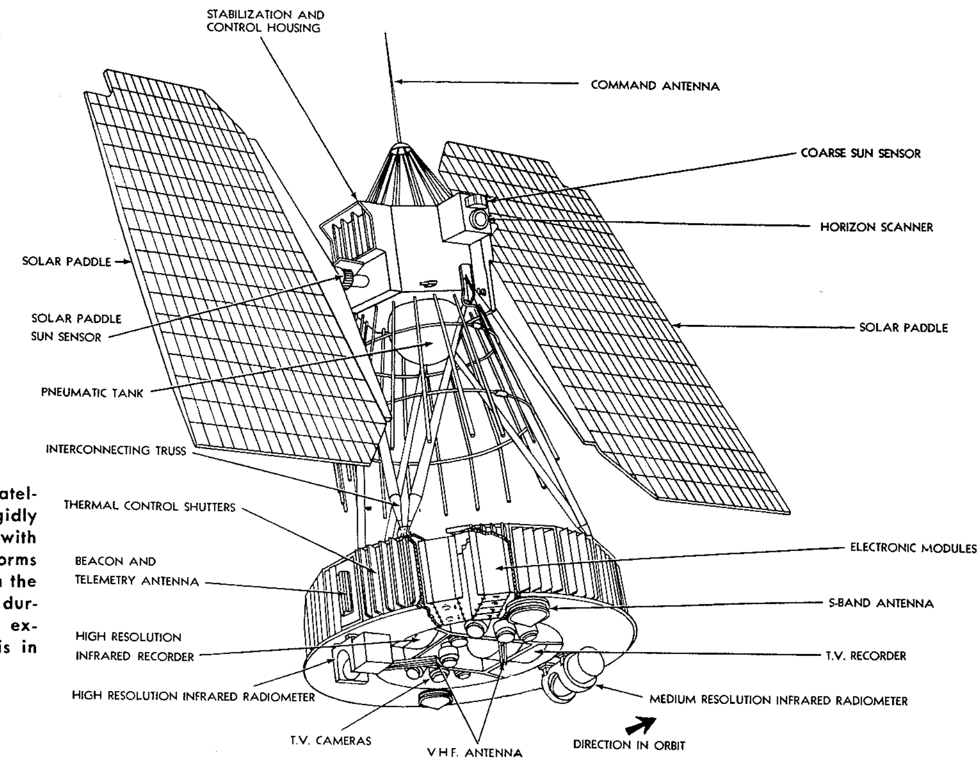


Fig. 1—The Nimbus satellite consists of two rigidly connected structures, with a set of solar platforms which are folded within the launch-vehicle shroud during launch but are extended once Nimbus is in orbit.

NIMBUS—AN ADVANCED METEOROLOGICAL SATELLITE

One of the important space projects at the Astro-Electronics Division is the NIMBUS meteorological satellite system, which is being developed to explore the earth's atmosphere. The information which NIMBUS will transmit back to earth is expected to provide scientists with pictures and data of heretofore unexplored portions of the inner-space envelope surrounding our planet. The 700-pound NIMBUS will contain more reliable and sophisticated versions of the instrumentation carried on previous meteorological satellites (e.g., TIROS). Current expectations are an orbital lifetime for NIMBUS of 6 months.

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PREPARATIONS ARE BEING MADE by the National Aeronautics and Space Administration to launch a new meteorological satellite: NIMBUS. The DEP Astro-Electronics Division is making significant contributions to the experiments that NIMBUS will perform (NASA contract numbers NAS5-434, NAS5-667, NAS5-877, NAS5-943, and NAS5-1118). These contributions include four major subsystems and a portion of two others, their associated ground-station monitoring equipment, and their associated ground checkout equipment. The entire NIMBUS project, including the satellite vehicle, its instrumentation, the ground-station equipment, and the ground checkout equipment, is being directed by the Aeronomy Meteorological Division of NASA's Goddard Space Flight Center.

NIMBUS has been designed to map the daytime cloud cover of the entire earth. It is also to provide a series of related, quantitative, electromagnetic radiation observations of the earth and its atmosphere in several regions of the infrared radiation spectrum. These observations will provide information for plotting the earth's nighttime cloud cover, for measuring the temperature of the water vapor in the earth's atmosphere, and for measuring the radiated thermal energy and reflected solar energy from the earth. (Infrared sensors measure equivalent black-body temperatures.) Besides the sensing equipment that these experiments require, NIMBUS contains additional equipment for telemetry, data storage, timing, an the programming, transmitting, and reception of commands.

The first NIMBUS spacecraft weighs approximately 700 pounds. It will be launched by a THOR-AGENA B rocket into a quasi-polar orbit at 500 nautical miles altitude. This orbit can also be described as a *high-noon retrograde orbit*—one in which the advance of the orbital plane closely matches the orbital movement of the earth about the sun, so that NIMBUS always appears directly over any point on earth at approximately the same time, local high noon. NIMBUS will be separated from the booster rocket shortly after they have gone into the proposed orbit. Then, in a pitch-up maneuver that employs compressed gas from its control nozzles, NIMBUS rotates toward its earth-oriented vertical operating position. This maneuver permits the horizon scanners and reaction flywheels of the stabilization and control subsystem to acquire the earth and stabilize NIMBUS to within 1° in any axis.

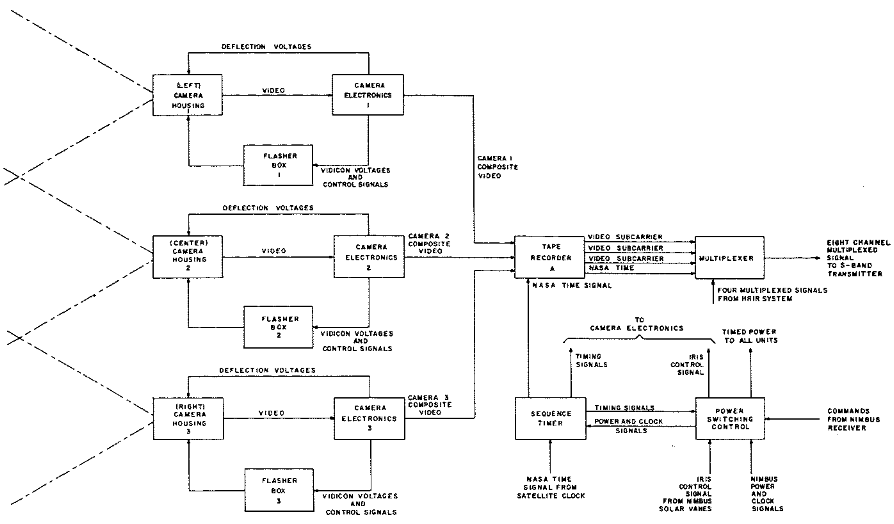


Fig. 2—The advanced vidicon camera sub-system (AVCS).

When NIMBUS is approximately over the North Pole, a set of solar platforms unfold. It will make 14 orbits every 24 hours and, during the 10 daily orbits in which it is within range of the ground station (located at Fairbanks, Alaska), it transmits the meteorological data that it has collected since its last transmission to the ground station.

The NIMBUS payload consists of two rigidly connected structures (Fig. 1). The lower and larger structure contains the meteorological sensors, telemetry equipment, and battery modules. The upper structure contains the sensors and controls for adjusting attitude and positioning the solar platforms. The DEP Astro-Electronics Division, as mentioned before, has developed and designed the advanced vidicon camera subsystem, the automatic picture transmission subsystem,* the dielectric tape camera subsystem, the solar-energy-conversion power supply subsystem, the tape recorder and multiplexer for the high-resolution infrared subsystem, and the clock receiver for the satellite command subsystem, as well as the corresponding ground equipment for pre-launch checkout and orbital operation of the system. (The dielectric tape camera subsystem will not be used in the first NIMBUS, but is expected to be used in later satellites of the NIMBUS series.)

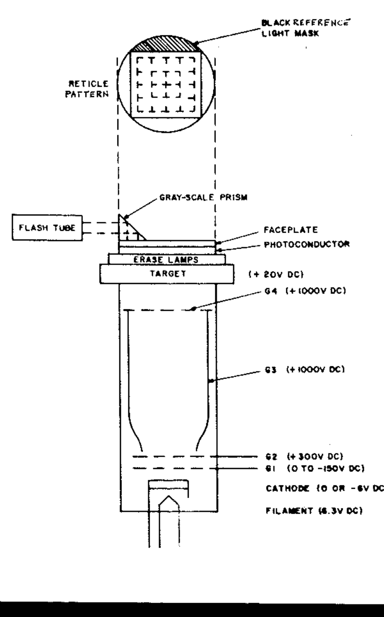
ADVANCED VIDICON CAMERA SUBSYSTEM

The advanced vidicon camera subsystem (the AVCS) is so named because its increased coverage, resolution, linearity, and sensitivity, and its reduced optical distortion represent significant advances over the TIROS satellite's television system. It provides instantaneous television coverage of an area approximately 420 nautical miles long and 1,575 nautical miles wide, and television coverage of the illuminated portion of the earth at least once a day.

The spaceborne AVCS equipment (Fig. 2) consists of three identical television cameras, a four-track magnetic tape recorder, a frequency multiplexer capable of mixing eight different signals into a common baseband, and timing and power control units. The television images produced by the three cameras are stored in the tape recorder, then multiplexed and transmitted on command when NIMBUS passes within range of the ground station. The ground-station monitoring equipment extracts the individual television camera images from the composite transmitted signal, and displays and records them.

* This subsystem, not described herein, will be described in future papers.

Fig. 3—The vidicon tube. An unusual feature of this tube is a set of "erase" lamps. These lamps are illuminated after the sweep of each image to remove any residual charge which may be present on the photoconductor due to the image.



Television Cameras

Three television cameras are arranged in a trimetrogon (Fig. 3) to obtain maximum coverage with adequate resolution, but without the distortion that is inherent in wide-angle lenses (and which was evident in pictures obtained by TIROS). Using a lens with a 17-mm focal length and a 1-inch vidicon tube, each camera obtains a ground resolution of approximately one-half mile per television line at a point directly below the satellite (not at the picture edges). Camera readout time is 6.5 seconds. Video bandwidth is 60 kc.

To obtain consistently high picture quality throughout the orbit, each camera is equipped with a variable iris. Normally, this iris is automatically adjusted in accordance with the position of the solar platforms, and varies between f/16 at the solar zenith and f/4 at 5° solar altitude. However, the iris can also be set by a command from the ground station to either of two preset openings. The vidicon is exposed for 40 msec for each picture; its exposure is controlled by a two-bladed solenoid-operated focal-plane shutter.

A unique addition to each camera is a self-contained gray-scale calibrator. A small prism, on which is etched a 16-step gray scale, is anchored at the faceplate of the vidicon. Below it is a flash discharge tube, which is fired in synchronism with the opening of the camera shutter to produce a gray-scale image at the bottom of each picture and provide a gray-scale reference for the information on the picture.

Each camera also has a self-contained sweep calibration. A precision reticle pattern is etched directly on the nonconductive side of the vidicon's photoconductor and becomes an inherent part of each picture to provide a reference for the measurement of geometrical distortion. Vertical shading of the picture (a problem inherent in slow-scan video) is reduced by clamping a portion of the video signal on every video line to a fixed voltage. This fixed voltage, or *black reference voltage*, is generated in the vidicon and is produced by a permanent light mask evaporated onto the vidicon's faceplate.

Tape Recorder

The tape recorder has four tracks for recording the readout of the three television cameras and a timing signal. The 1,200 feet of half-inch Mylar-base tape are sufficient to record two orbits of data (each orbit contains 32 picture frames), with the tape starting and stopping on each frame every 91 seconds.

A uniquely designed tape transport (Fig. 4) and all the associated electronic components are mounted within a single pressurized enclosure. The tape is stored on two coaxial 8-inch-diameter reels. The path of the tape between the two reels is controlled by a driving capstan and three rollers, so that the tape makes a 180° wrap around the capstan immediately after leaving one reel and again immediately before entering the other. With the tape wrapped twice around the capstan from opposite directions, forming a closed loop about the heads,

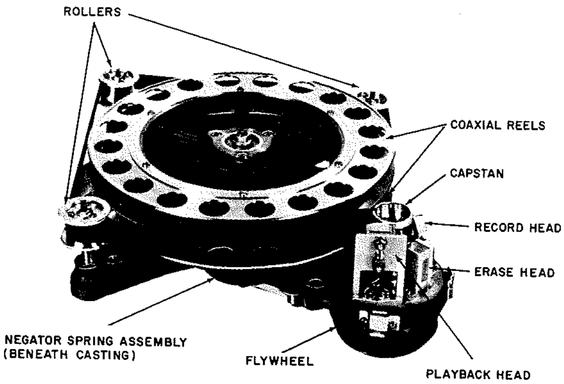


Fig. 4—The magnetic-tape transport. Coaxial reels permit a compact design.

transient changes in tape tension tend to oppose and cancel torque transients at the capstan, thus reducing recorder flutter. Negator springs, located on the opposite side of the base casting from the reels, torque the reels against each other to help maintain constant tape tension. The mean angular momentum of the tape transport is cancelled by a flywheel to maintain the uncompensated angular momentum at less than 0.004 in.-lb-sec, and so minimize the demands on NIMBUS stabilization system.

The three video signals are FM-recorded, with a subcarrier swing between 70 kc and 120 kc, including the sync tips. The tape speed of 30 ips gives a maximum tape-packing factor of 4000 cycles/inch. The standard NASA time code generated by the NIMBUS clock is recorded as amplitude modulation of a 50-kc carrier on the fourth tape track. In addition to providing a real time reference for the video data on the other three tracks, the 50-kc carrier is used as a pilot tone to indicate recorder wow and flutter for subsequent compensation in the ground-station monitoring equipment.

By a command from the ground station, when NIMBUS orbits within range, the tape recorder can be bypassed to permit the television cameras to transmit data directly to the monitoring equipment.

Multiplexer

The signals from the four channels of the AVCS tape recorder, plus another four from a separate but similar multiplexer associated with the high-resolution infrared subsystem, are frequency-multiplexed into a 700-kc composite baseband for subsequent frequency modulation of the main 1,700-Mc carrier signal. To provide the required per-channel signal-to-noise ratio of 40 db, the FM deviation ratio of each of the three AVCS video channels (which is initially restricted by the response of the tape recorder) is doubled by doubling the instantaneous frequency of the signal from each channel. Frequency translation to the proper subcarrier slot in the 700-kc composite baseband is then performed by balanced mixers and bandpass filters. The bandpass filters provide high attenuation outside the passband and linear phase response inside the passband; the high attenuation outside the passband prevents crosstalk and the linear phase response inside the passband prevents distortion of the video image.

DIELECTRIC TAPE CAMERA SUBSYSTEM

The dielectric tape camera subsystem obtains daytime pictures of specific portions of the earth and its cloud cover, when a picture is required having a higher resolution than that obtainable with the AVCS. The dielectric tape camera can obtain pictures comparable to those obtained by a conventional aerial photographic camera, and in addition to the obvious advantage of being able to transmit the pictures through space and back to earth, has numerous advantages over the photographic camera in satellite applications, which include:

1) a recording "film" which is easily erased and reused;
2) a recording "film" which is insensitive to van Allen radiation—especially to any cumulative effect over a long period of time;
3) a high information-packing density on the "film" to reduce size, weight, and power requirements; and
4) ability to operate in a vacuum, and without the use of volatile material such as chemical developers.

The recording "film" used in the camera is a continuous dielectric tape. Readout of the stored pictures is accomplished by scanning the dielectric tape with an electron beam. Recording equipment at the ground station reproduces the pictures as a permanent record on 35-mm film. (The basic principles involved in the dielectric method of recording optical images have been described[1] by Hutter, Krittman, and Moore.)

The dielectric tape is produced by coating a flexible, transparent tape with a transparent metallic conducting layer, then a photoconductive layer, and finally a transparent insulating layer. When the dielectric tape is exposed to an optical image, a charge pattern is formed on the insulating layer corresponding to the light and dark areas on the optical image. These patterns are stored on the dielectric tape and then, when NIMBUS orbits within range of the ground station, they are converted into electrical signals by a command from the ground station. The electrical signals are obtained by an electron-beam-scanning process which is quite similar to that used in the standard image orthicon. Except for the difference in scanning rate, the resulting signals closely resemble normal video signals. After the information written on the dielectric tape is read out to the ground station, the dielectric tape is erased by applying a potential between its photoconductive and insulating layers with an electron flood beam. All remnants of the previous images are removed from the insulating layer, and the camera is again ready for picture-taking.

A technique frequently used in aerial photography is being used for the picture-taking process; it employs a combination of a scanning mirror and a lens. The scanning mirror permits a narrow-angle, long-focal-length lens to obtain wide-angle coverage. The scanning mirror is rotated at right angles to the NIMBUS orbit; this changes the uniform translational motion of NIMBUS, with respect to the area being photographed, into a uniform rotational motion. During the first 90 percent of the scanning cycle, the mirror is rotated in one direction; during the last 10 percent of the scanning cycle, the mirror is returned to the starting position for another scanning cycle. Simultaneous with the mirror's scanning, the dielectric tape is moved across an optical slit (which represents the iris of the camera) in the camera housing, at a rate corresponding to the relative motion of the earth with respect to NIMBUS. This panoramic movement by the dielectric tape produces a blur-free picture.

Individual pictures are reproduced at the ground station as long, narrow strips of the earth's surface and cloud cover. Successive strips are matched and mounted next to each other to form a large map of the area being examined. The area covered by a single picture is approximately 1,500 miles wide and 50 miles in the NIMBUS direction of motion. It is recorded on the dielectric tape on an area 0.6 inch wide and 12 inches long.

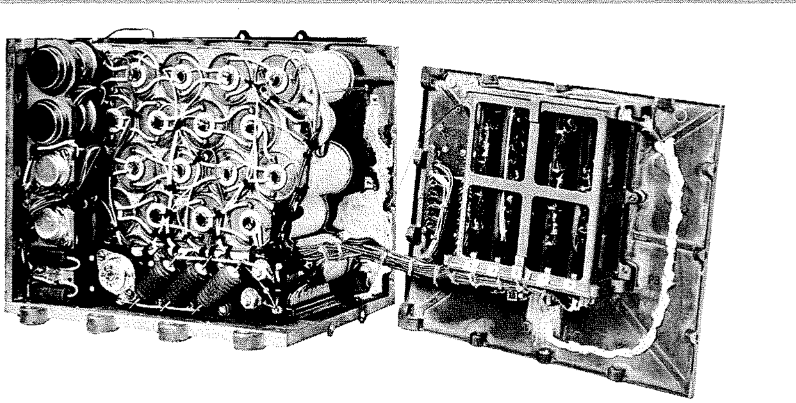


Fig. 5—The battery module. In addition to 23 battery cells, it also contains regulation and protection circuits.

HIGH-RESOLUTION INFRARED RECORDER SUBSYSTEM

The high-resolution infrared recorder subsystem (HRIR subsystem) will permit NIMBUS to record and transmit infrared radiation patterns which result from temperature differences between the earth and its cloud cover. In normal operation, these patterns will be recorded during the dark portion of the NIMBUS orbit.

The HRIR tape recorder and multiplexer are similar to the units used in the advanced vidicon camera subsystem. Video signals from the HRIR radiometer and standard NASA time codes from the NIMBUS clock are fed into the four-track magnetic tape recorder for storage, prior to transmissiin to the ground station. Except for the motor, the mechanical design of the HRIR tape recorder transport is identical to that of the AVCS tape recorder transport.

The signals from the four channels of the HRIR tape recorder are fed into the HRIR multiplexer, where they are frequency-multiplexed by circuits similar to those used in the AVCS multiplexer. The output from the HRIR multiplexer is then fed into the AVCS multiplexer for final multiplexing prior to transmission to the ground station.

SOLAR-ENERGY-CONVERSION POWER-SUPPLY SUBSYSTEM

The solar-energy-conversion power supply subsystem consists of two identical solar platforms, seven identical battery modules, and an electronics module. The basic operation of the subsystem is as follows: The solar platforms, during that portion of the orbit when NIMBUS is illuminated by the sun, generate sufficient power to operate all of the "daytime" subsystems plus enough power to recharge the battery modules to full capacity. During the portion of the orbit when NIMBUS is shaded from the sun, the battery modules discharge to operate all of the "nighttime" subsystems. Regulation circuits in the battery module provide regulated voltage of 24.5 ±0.5 volts; protection circuits in the battery modules prevent open or short circuits in the solar platforms or battery modules from affecting the regulated voltage supply. Total battery capacity is 32 amp-hr.

Solar Platforms

The solar platforms are constructed of an extremely lightweight aluminum-honeycomb sandwich, which consists of an aluminum-honeycomb core covered with aluminum skins.

Each solar platform contains 5,497 solar cells (2-cm-square boron-doped *p*-on-*n* gridded-silicon cells) which cover the outside skins and convert solar radiation into electrical energy. The cells are grouped on seven boards: six of the boards contain 82 ten-cell sections and one board contains 82 seven-cell sections. The cells in each section are connected in parallel and the 82 sections are connected in series; the seven boards are connected in parallel.

Special, optically-coated, 6-mil-thick glass covers are bonded to the outside surfaces of the solar cells. Simply stated, these blue-red glass covers prevent the heat-producing portion of the solar spectrum from penetrating the solar cells and permit the electrical-energy-producing portion of the solar spectrum to penetrate the solar cells. Actually, the portion of the spectrum that is permitted to penetrate the solar cells also produces heat, and in designing the glass covers the effect of increased heat and higher power loss due to the solar cells' negative power-temperature coefficient must be balanced against reduced heat but less available convertible energy. (The glass covers also radiate the heat produced in the solar cells with an emissivity three times greater than that of the bare cells, which enables the solar cells to remain cooler and thereby increases their available convertible energy.)

Battery Modules

Each battery module (Fig. 5) contains 23 nickel-cadmium battery cells, housed in a precision-cast housing of magnesium alloy.

Each module contains four different protective devices: 1) three strategically located battery cells contain temperature sensors that will reduce the module-charging rate to a trickle charge if a battery cell's temperature becomes excessive; 2) one battery cell contains a pressure switch which will reduce the module-charging rate to a trickle charge if the battery cells internal pressure becomes excessive; 3) a voltage-comparator circuit will reduce the module-charging rate to a trickle charge if the module's voltage falls too low (indicating that a battery cell or cells are not operating at capacity and may be temporarily malfunctioning); and 4) a voltage-surge-limiter circuit dissipates excess unregulated current developed in the solar platforms when their voltage output suddenly rises above normal. (This abnormal voltage surge can occur when NIMBUS just comes out of the nighttime portion of its orbit into the daytime portion of its orbit, and sunlight strikes the cold solar cells. As the cells warm up, their voltage output rapidly falls to normal.)

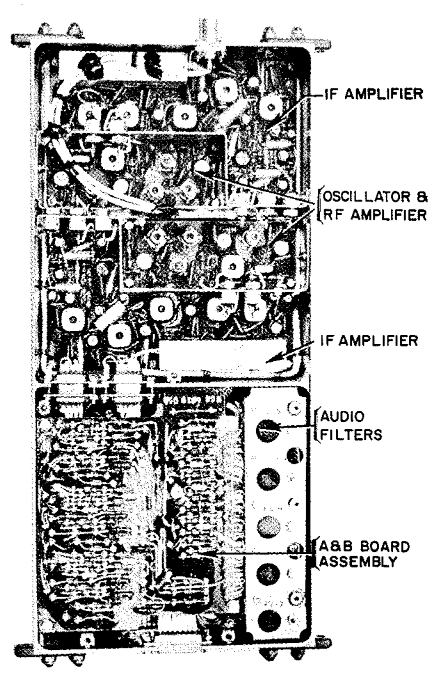
The battery module also contains five telemetry sensors for monitoring its pressure, temperature, voltage, charging current, and the operation of its voltage regulator.

Electronics Module

The electronics module contains circuits that monitor the regulated output voltage of the battery module and circuits that supply unregulated voltage to operate the clock receiver in the satellite command subsystem.

It contains two identical sensing am-

Fig. 6—The clock receiver, as seen from Nimbus' inboard side, with its side cover removed.



plifiers. Each can be used to detect the voltage level of the regulated voltage supply, compare it to a fixed reference voltage, and feed back any voltage difference (the error signal) to the battery module's voltage regulator to correct the voltage level of the regulated voltage supply. Redundant sensing amplifiers are used to increase the reliability of the subsystem. A regulated-voltage comparator monitors the operation of the sensing amplifier; if the regulated voltage of the subsystem deviates from preset limits, the comparator will switch sensing amplifiers, substituting the redundant unit for the malfunctioning unit.

The electronics module also contains an auxiliary regulator, which supplies unregulated voltage to operate the regulated-voltage comparator and also to operate the clock receiver in the satellite command subsystem. The electronics module is also equipped with six telemetry sensors for monitoring the subsystem's regulated and unregulated current and voltage.

CLOCK RECEIVER

The NIMBUS ground station encodes and transmits command information to the clock receiver. Fig. 6 illustrates its compact design—approximately 6 inches wide, 13 inches long, 2 inches thick, and weighing 5½ pounds.

The clock receiver, which is actually a combined command-receiver and -demodulator unit, demodulates this information to provide the NIMBUS command subsystem with encoded command signals. The clock receiver is fully transistorized, employs a superheterodyne circuit with a crystal-controlled local oscillator, and is powered by a minus 24.5-volt source. It is designed with a 90-percent assurance of successfully performing its task; and it contains dual identical receivers, audio amplifiers, and FM subcarrier-signal demodulators to increase its reliability through redundancy.

The encoded command information transmitted by the ground station to the clock receiver is transmitted as a modulated RF carrier signal. Seven diffierent subcarrier signals can be employed by the ground station to modulate the transmitted RF carrier signal, although no more than three of the subcarrier signals will be used simultaneously.

In normal operation, all of the clock-receiver circuits are active except the redundant FM subcarrier-signal demodulator. If a failure occurs in any of the channels in the normal FM subcarrier-signal demodulator, the redundant demodulator can be activated and the normal demodulator simultaneously inactivated by the ground station.

The command-receiver circuit is a modified version of the one that has orbited successfully in TIROS. The two identical receivers in the command receiver are single-conversion (single-intermediate-frequency) superheterodyne circuits. Each consists of: an RF amplifier, mixer, crystal-controlled local oscillator, 20-Mc IF amplifier, detector, emitter follower, and AGC loop. The AGC loop maintains the receiver output at approximately 1 volt-RMS as long as there is a signal greater than 3 μv present at the input terminal.

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SEYMOUR H. WINKLER received his BSME, Cum Laude, from the College of the City of New York in 1947, and his MSME from Purdue University in 1952. In 1951, he joined Kaman Aircraft Corporation, where he worked on K-225 and Ho K-1 helicopter rotor systems. In 1955, he joined Young Development Labs, (now Hercules Powder) where he was a project engineer on filament-wound reinforced plastic solid-propellant rocket motors such as the ABLE last-stage rocket. Since 1958, he has been with the Astro-Electronics Division, where he has been Engineering Leader in charge of solar-power systems development for the TIROS series, ECHO, NIMBUS, RANGER capsule, and RELAY satellites. He is now in charge of advanced space power systems, using nuclear, solar, and chemical energy. Mr. Winkler has published many technical papers. He is a member of the American Rocket Society, and Pi Tau Sigma. He is a registered Professional Engineer.

A. I. ARONSON graduated from Syracuse University in 1951 with a BSEE. He joined RCA, Camden, N.J. in 1951, where his design work emphasized application of transistors. He transferred to the Astro-Electronics Division in 1958 where he has worked on satellite command systems, and has had a major role in the development of the spacecraft command systems for SCORE, the TIROS I and II satellites, and STRATOSCOPE II. Mr. Aronson assumed his present position of Engineering Leader in the Satellite Communications section in 1961, where his work includes satellite command systems, data-handling systems, and related components. He has published many technical papers and holds six patents. He is a member of IEEE.

RICHARD T. CALLAIS received a BA in Physics from Brooklyn College in 1943. He subsequently attended New York University for advanced studies in Electronics and Physics. From 1943 to 1946 he served as an Officer in the Army Signal Corps. From 1946 to 1948, at the Fairchild Guided Missile Division, he worked on missile telemetry systems. From 1948 to 1958, he was with the Austin Company Special Devices Division, advancing to Chief Engineer in 1956. In 1959, Mr. Callais joined the Astro-Electronics Division of RCA, as Manager of Video and Analog Systems, concerned with satellite observational systems and the development of a high-resolution dielectric tape camera. From 1961 to 1962, Mr. Callais was Project Manager of the NIMBUS Satellite Program at AED. Currently, he is Manager of the AED Satellite Controls Group. He is a member of the IEEE, AMA, and is a licensed Professional Engineer.

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PETER H. WERENFELS received a BSEE from the Federal Institute of Technology, Zurich, Switzerland. From 1946 to 1948, he worked for Autophon, Inc., Switzerland, on the development of communication equipment. Mr. Werenfels joined the RCA Laboratories in 1949. There, he worked in the fields of ferrite and transistor research, and also on black-and-white and color television. He transferred to the Astro-Electronics Division in March 1958, and has since been engaged in the development of television cameras, optics, test equipment, and over-all systems for satellite applications. He has been with the NIMBUS Project from its beginning as Project Engineer for the Automatic Picture Transmission system. Mr. Werenfels has seven U. S. patents.

WALDEMAR J. POCH received a BSEE in 1928 from the University of Michigan and an MSEE in 1934 from the University of Pennsylvania. Since transferring to AED in 1960, he has directed photo-dielectric tape camera activities. He is Leader, Dielectric Tape Systems. Mr. Poch joined RCA's Radio Receiver Design Group in 1930. Later, he was a member of the Research Group on Television Receivers. From 1938 through 1950, Mr. Poch was responsible for the development of various types of studio and military TV equipment. From 1950 through 1955, he served as Manager of TV broadcast studio equipment engineering. From 1955 to 1960, he was a member of an RCA Corporate Staff Group investigating new product possibilities. Mr. Poch has 31 patents and several published papers. He is a member of Tau Beta Pi, Sigma Xi, and Phi Kappa Phi, a Fellow of the IEEE, and a member of the SMPTE, ISA, and Fernseh Technische Gesellschaft. Mr. Poch is a Registered Professional Engineer.

L. to R.: Poch, Werenfels, Callais, Winkler, Aronson, Keigler.

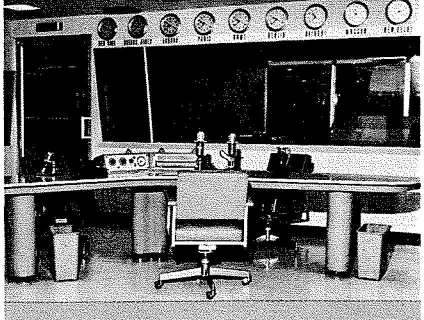
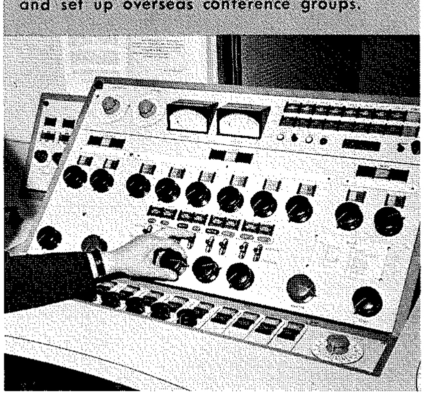


Fig. 2—The 5B studio, showing the studio commentator's console. The lamps on top of the control console are "on-air" and signal tallies operated from intercoms. Note additional headset monitoring amp located below table lip.

A NEW RADIO CENTRAL AT NBC

Fig. 3—Engineer's control panel, 5C console. All consoles are exact duplicates. Note flanker panel to left of main panel (one also located to right). These panels are used to preset incoming lines to job switcher in forward well and set up overseas conference groups.



A new centralized plant for NBC radio operations has been completed in New York City. It is modular in concept and functionally flexible, to allow central handling of varying program load with a minimum staff and the least personnel and equipment specialization.

O. S. PAGANUZZI, *Facilities Engineering, NBC, New York, N. Y.*

The NBC New York Radio Plant, as conceived in 1933, was designed to handle a large number of simultaneously switched transmissions—specifically, 48 studio sources and 14 outgoing channels. It was commonplace to find six or more programs handled along with any number of rehearsals. This heavy load made a "functionalized" system, reasonable and demanded personnel with many diverse talents: master control, transmission, communications and monitoring, test, field, maintenance, recording and studio.

The present-day reduction of radio operations does not allow such specialization; however, today's operation did exist within the remaining scattered portions of the original structure. Some relief in operational cost has been afforded in Radio City by sharing some of the existing facilities with television operations, but this same relief has created a cumbersome operation.

With these factors in mind, a new Radio Plant has been constructed in Radio City. Its major goals are:

(1) a compact minimal-sized and -staffed plant, simple in operation

(2) a plant with sufficient facilities and flexibility to allow programming expansion by merely increasing total manpower.

This, then, has been our basic design philosophy. In practical terms it requires the construction of an operating position capable of handling a variety of functions and the provision for enough positions to allow redistribution during peak-work-load periods.

GENERAL PLANT LAYOUT

As can be seen from Fig. 1, the total plant is contained within a very small floor area and consists of four control positions, three studios (Fig. 2), and three booth positions. Each control position is completely independent and may pick up any or all of the studio-booth positions at any time. Normally, however, 5A Studio is assigned to 5A Control for local radio use *(WNBC)*, 5B Studio-Control is assigned for network radio use and 5C Studio-Control assigned to news production. In addition, there is an announce booth-position provided for each of these normal assignments (5C has a news position assigned as 5N located amidst the clatter of the teletypes in the center of NBC's news room—used for "hot flash" origination).

During the week (Monday through Friday) normal NBC network radio consists primarily of news and special events. Therefore, 5C is assigned at this time as normal network origination. In conjunction with 5C tape, news recording and network programming are handled very efficiently. On the weekends, however, the network again originates from 5B Studio-Control with the monitor package. The 5B studio-control with 5B announce is used during the week for recording work or special programming from small musical combo to simple announce.

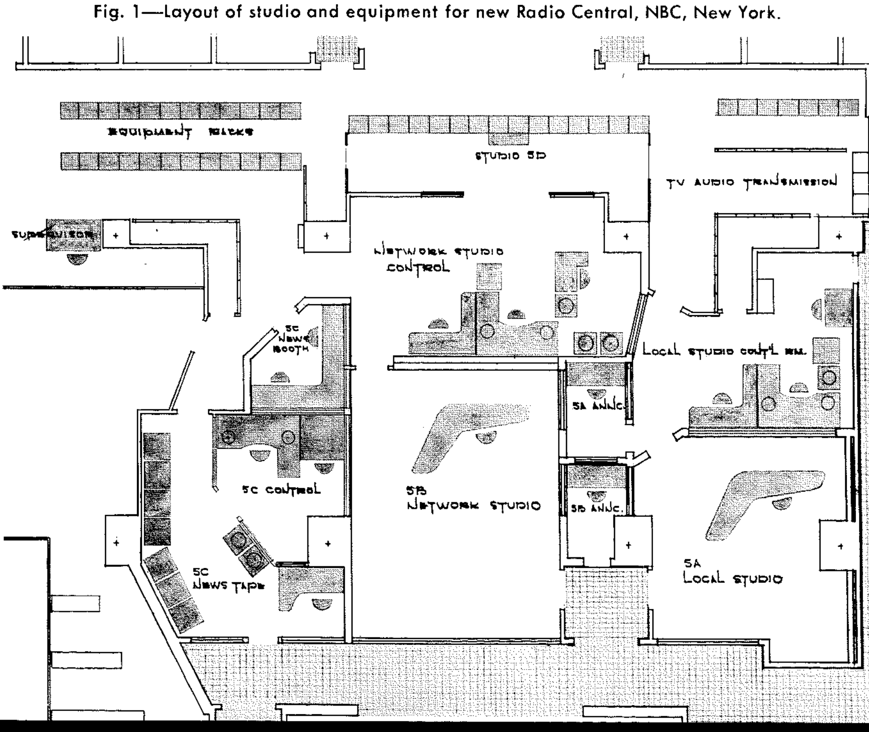
The 5D control is intended as an additional processing point to be used for any contingency (equipment breakdown, special program setup, program or nemo assembly studio, recording, etc.).

The 5C tape provides, in addition to its normal news-recording facilities, the capability of remote assignment of tape machines. Thus by assignment at the tape console, any control room may remotely do its own start-stop recording or may play back, on cue, a preset tape.

AUDIO CONSOLE

As mentioned previously, each engineer's console (Figs. 3 and 4) is within itself a complete station operation requiring no additional personnel for normal programming. By a crossbar type of switcher, all consoles may simultaneously preset and select any six of twenty-four incoming lines (nemos). Prior to switching, all lines are processed — equalized, level-set, amplified, and gain-controlled by BA-25 AGC amplifiers. These six preset "jobs" appear on a ten-

Fig. 1—Layout of studio and equipment for new Radio Central, NBC, New York.



position switcher, with four other local originations (normally, other console outputs). All ten may be switched or mixed as desired. Only the six preset jobs, however, have individual faders prior to the nemo master.

As an additional feature, each of the six jobs, when processed through the nemo mix panel, provides a feed of all other jobs without itself being present. These so-called "mix-minus" feeds (along with other types of specialized feeds) exist on a series of selectors feeding the overseas feedback lines. Thus, from a console position (Fig. 3) the audio engineer may set up, for example, a three-way program conversation with London, Berlin, and Rome correspondents merely by switch selection. The correspondents in each location can hear the other two without themselves causing regenerative feedback. The engineer would be "airing" the conversation. Knowing the incoming and feedback line numbers, the engineer could set up in a matter of seconds.

As any of the studio microphone positions may be picked up when desired, logic is included within the console (in conjunction with a relay panel) so that all *on air* lights, mutes, and studio music feedback will follow correctly the console choice. Unless a console is feeding channels or preset for recording, the studio address speaker is not muted (audition mode), but instead, control-room speakers are muted when the studio address system is used. This feature allows greater facility during rehearsals, especially when working with a group.

Control for an eight-channel switching system is included within each console. Any console desiring channels must preset into a memory system. At switching time, the studio with channels will "give" them to the preset studio by energizing a "cut" bar. If a studio with channels desires to drop them when a preset has not been made elsewhere, a release button is provided for each channel, said release providing a dummy input to channels. This dummy position may supply a number of needs—continuity service on the network lines, network feed for the local studio, delay playback in the network studio, etc.

Although a manual control, the network line reversal "radio audio circuit" keys are enabled at each console only if that console has the network channel. Also included as interlocked manual controls are "hot-line" and "chimes" keys.

Each director's console (Fig. 5) has two built-in BQ-2 turntables and three RT-7 cartridge tape recorders. As the consoles have been completely designed for stereo, and all consoles have been equipped with the new RCA stereo head. Provided on each console are two sets of eight universally wired connectors into which are plugged any turntables or tape recorders (including remotely assigned tape machines). Thus, any playback device may be made to appear on any convenient key position (of eight) on the console. These same keys will start any type of tape machine when set in *program* position. They will start RT-11/21 types when set to *audition*, but will not start RT-7 types in this position. Additionally, the keys will not stop RT-7 types when set to *off—cue stop* is the controlling factor when a cartridge is involved.

Selector switches at each console make it possible to preview (and preset) levels on all jobs, microphones, turntables, or tape recorders and monitor levels on all studios and channels. As the console has been designed for stereo use, the program volume indicator is permanently connected across the left channel output although the program speaker is fed from a selector similar to the *preview* selector. Thus the audio engineer may monitor, check and set levels at various points in the system (including his channel output) during a monaural or stereo broadcast.

The engineer's console itself (Fig. 5) was custom built by RCA to NBC's specifications and contains a total of seven BA-31 amplifiers as the only active elements. However, of these only three are necessary for each of the stereo channels (one additional amplifier is used for an "audition booster"). The two channels are separate throughout, inclusive of the program-amplifier driving channels, but are paralleled in the monaural mode at the program-amplifier output. Thus, the console is effectively two paralleled systems (in monaural) giving an additional safety factor during operation.

CENTRAL EQUIPMENT

The program amplifiers mentioned above are actually Studio amplifiers; that is, each console has an associated amplifier for each channel, but these amplifiers are used to drive the outgoing lines directly (through a pad and coil combination) via channel switching. All amplifiers are of the BA-24 type with low output impedance feeding normal 600-ohm lines a level of +8 vu (volume units). One such output combination may feed ten outgoing coils with less than ¾-db loading. Frequency response is good—the entire plant *(nemo in* to *outgoing line in)* being within a ±1 db tolerance from 20 cycles to 25 kc.

As added equipment, six 6-job dummy studios were included. These were designed as complete packages (coils, pads, volume indicators, etc.) to mount upon a standard BR-22 shelf.

Also included were six utility amplifiers which will take virtually any standard level input and convert it to three output feeds each of +8, −62, and −22 vu at 150 ohms. Actually, we have standardized at only one standard level (−22 vu at 150 ohms) within the plant. All microphone outputs are immediately routed through central preamplifiers and raised to a −22-vu level. The BA-31 preamplifiers are used as low-impedance sources (console *microphone in* positions are essentially bridging), and each feeds five positions. Therefore all console inputs are of a −22-vu level, simplifying considerably the problems of cross-patching.

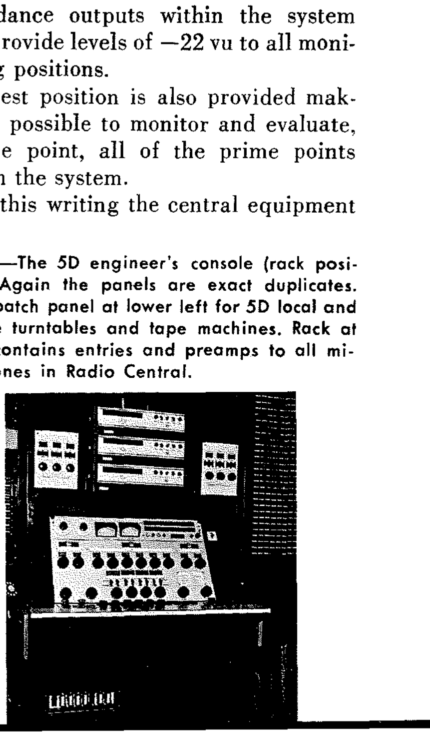
Provision for mechanical echo units is located within the central equipment racks. These units are normalled to the commentator's microphone position in 5A and 5B Studios—one microphone echo being normal setup; however, they may be patched to any position (microphone or over-all) on a central jack field.

Over and above the eight switched channels, NBC New York provides feeds to some fifty other terminations. These provide Civil Defense Network Services, New York Radio Station Services, special feeds such as Armed Forces Radio Service (AFRS) and local accommodations. Normally, these services are not switched "on time" and could be provided by patching; however, keys are provided within the jack fields, making it possible to service these feeds by simple *on-off* switching. A disconnect-type frame is located in one rack, through which are fed all monitoring selectors in the entire plant. These are fed from low impedance outputs within the system and provide levels of −22 vu to all monitoring positions.

A test position is also provided making it possible to monitor and evaluate, at one point, all of the prime points within the system.

At this writing the central equipment

Fig. 4—The 5D engineer's console (rack position). Again the panels are exact duplicates. Note patch panel at lower left for 5D local and remote turntables and tape machines. Rack at right contains entries and preamps to all microphones in Radio Central.



area has not been completed, but eventually will contain all of the *off-air* monitoring receivers, the office monitoring amplifiers, reference recorders, delay playback machines, and "juke-boxes" for network continuity. Of particular interest is the installation of a digital clock system (seconds resolution) which will provide readouts in each control room. This will provide a common time base for all personnel without the problems inherent to parallax, clock setting, time changes, etc.

DIRECTOR'S CONSOLE

A director's position (Fig. 5) exists beside each audio console position (except 5D) and additionally at the 5C tape position. They are all identical in construction and provide all of the communications devices necessary to the director. A 20-station intercom, rather than a complex relay-controlled studio address system, was selected for complete plant communication. The units, as used in the studios, are modified to provide muting when *on air*. Additionally, the intercom provides a signalling system which was amplified to provide a studio warning light. Thus, one button provides both signalling and communications possibilities. The commentator, upon seeing the light, may pick up an earpiece provided and receive instructions via intercom from the director while on the air. The signal may signify any pre-arranged order—director to commentator.

Each director's console also provides an overseas panel, enabling him to break into any of the overseas feedback lines and talkback to any of the remote points. A selector is provided to monitor the incoming lines, thus enabling the Director to hear the remote replies. The new RCA BA-78 transistorized AGC studio address amplifier is being used for the talkback function, with no complaints from the overseas correspondents—it seems ideally suited for this particular application. The director's panel also contains a selector for channel and studio monitoring, and a program-monitoring speaker with separate volume control. An analog clock is also included.

Fig. 5—5C engineer's and director's console. Note convenient position of RT-7 tape machines. Booster amps, intercom, and patch field are located within side and lower sections. Note overseas talkback panel on desk immediately before director's selector panel. The 5C studio is located at upper left.

Each director position was designed for the maximum type of workload and is therefore unnecessary to a simple operation. It does provide, however, ready access to the "news break" or the special show that is sure to come up.

COMMENTATOR'S CONSOLE

Each commentator position (Fig. 2) is identical in construction. An intercom, signal light, *on air* light, dual monitoring selectors, cough key, and speaker volume control (controls music feedback when *on air*) are included. A miniature transistor amplifier is additionally provided to allow selector monitoring via earpiece when *on air*.

The local studio is also provided with a portable plug-in control panel. This allows operation at a remote point within the studio and was specifically designed for use at a piano.

Video outlets are provided within all studios (as well as control rooms) for use by the commentator for any integrated types of broadcasts, and are fed through a central jack field.

ARCHITECTURAL

Color and lighting have been important considerations during the Radio Central layout. All console controls are color-keyed in terms of *on air*, *preset*, *transfer* and *monitoring functions*. Often neglected within a radio studio is a plan for general lighting. Recessed, louvered, dimmable fluorescents have been included.

The general color scheme consists of a light blue (matching the RCA equipment blue) and white with terra-cotta and grey accents. The attempt was made to provide (by color and construction) a feeling of efficiency and cleanliness while maintaining operational comfort and calm. All table tops are formica-covered, as are all control panels.

The wall structures consist of a steel-stud framing faced with ¾-inch transite. Then, 2-inch-square wood furring is applied to each face and covered with ¼-inch perforated transite. Insulating bats are liberally used throughout and a fiberglass sheet is applied directly behind the perforations as a dust stop. All windows are double glass, resiliently set, and tipped from the vertical. Speakers (LC-1A or SL-12 types) are set within ceiling enclosures or LC-5 cabinets, all enclosures being isolated from each ceiling space by bat insulation.

CONCLUSION

This new Radio Plant shows all signs of more than meeting original demands. Future expansion, if warranted, could be easily incorporated within the de-

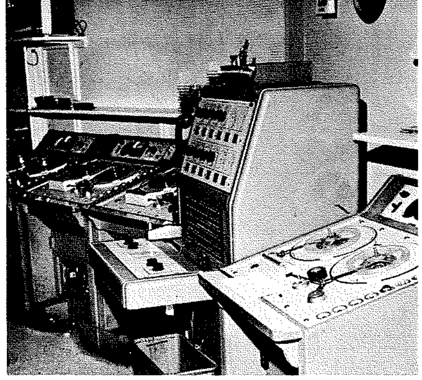


Fig. 6—The 5C Tape Area. The control console shown (center) is used for remote control assignment and audio line record/playback setup. All positions have not been installed at this writing. Foot switches have been installed at each tape machine for fast editing. On the console, the upper row of selectors determine the tape machine record input; the lower set determine control assignment and playback termination. Keys on tape machines give final "go" status.

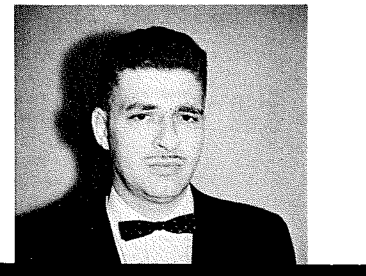
signed-for capabilities of the plant. Ground-work exists for another studio and control room and their additional facilities. In addition, existing facilities may be expanded, and space has been provided.

As the design concept is modular in nature, this method is applicable to the small station as well as that of Radio City complexity.

ACKNOWLEDGEMENTS

Credit is due W. H. Trevarthen, J. L. Wilson, D. H. Castle, and C. L. Rackey who conceived and lent impetus to the project. W. A. Howard, Project Supervisor, "backstopped" the engineering concept. Henry Krochmal's knowledge of audio techniques and operational methods made the system practical. Construction supervisor Edward Nolen's men produced an installation second to none in beauty and dependability. Thanks are extended to Harold Schneider who took all the photographs in this article.

O. STEPHEN PAGANUZZI received his AB in Physics from Columbia University in 1949. After two years experience in design and production of electronic equipment, he joined NBC as a TV Maintenance Engineer. During this period he assisted in the original installations of monochrome and color film vidicon systems and early system development in color video tape. He also worked with the Facilities Design group during various installations among which were two Presidential Nominating Conventions. In 1960 he became a Facilities Design Engineer and has since worked on the design of the telecine film system in New York and Chicago, video tape improvements, TV News and Special Events facilities, TV audio systems and recently the reconstruction of the entire New York Radio Plant. His work has covered studio facilities, camera equipment, many types of switching systems, video tape and automatic control systems. He is a Member of the IEEE.



THE RCA INSTITUTES

I. ENGELSON, and J. BRODY, Assoc. Dean
RCA Institutes, New York, N. Y.

THE TECHNICAL INSTITUTE is an institution of higher learning where: "Curricula to be considered are technological in nature and lie in the post-high-school area. They differ in content and purpose from those of the vocational school on one hand and from those of the engineering college on the other. . . . Programs of instruction are essentially technological in nature based upon principles of science and include sufficient post-secondary-school mathematics to provide the tools to accomplish the technical objectives of the curricula" . . . (From the definition as stated in the *Thirtieth Annual Report on Accredited Curricula* by the Engineers' Council for Professional Development, 1962.)

Technical institutes have been known in this country since the beginning of the century; however, it is only since the beginning of the previous decade that the technical institute has come into its own. The fact that the technical-institute graduate is capable of assisting senior engineers and scientists has caused the industry to look upon the technical institute in a serious and favorable light. The ratio of engineering technicians to engineers and scientists is constantly growing and has in many companies surpassed the ratio of one to one, thus relieving the more highly specialized people for the kind of work requiring their maximum capabilities.

The technical institute offers a student a concentrated course in the field of his choice while preparing him for a skilled position in industry. Since many of these schools are accredited by the Engineer's Council for Professional Development, graduates of these courses are frequently admitted with advanced standing to degree-granting engineering colleges and universities.

The two-year duration of the course and the lower tuition rate compared with a four-year college or university appeal to the growing student body. The students are eager for technical training and thus are quite serious in following their pursuit. They come from diverse backgrounds. Many of them are veterans and married, and thus because of family obligations could not afford the investment of time and money in a four-year college course. Many potential college students turn to the technical institutes because of lack of finances. With the recent elimination of the G.I. Bill, the number of students in the above category is increasing. The refresher courses offered by the institutes on a pre-college level attract those students who because of various reasons are incapable of doing college work immediately without such review. Many native and foreign students who have acquired a general education choose the technical institute for their technical training. The military services often train their engineering personnel at technical institutes.

To give a specific picture of the nature of the modern electronics technical institute, this article will discuss the *RCA Institutes.*

GROWTH OF RCA INSTITUTES

Tremendous developments in electronics since World War II, which have become normal applications in many fields, have created serious problems for those educators and administrators concerned with the curriculum. At RCA Institutes, we have been confronted with the problem of introducing new courses in transistors, color television, computers, magnetic amplifiers, industrial electronics, nuclear energy, etc. For example, in 1954 when color television became a commercial reality with the advent of RCA compatible color television, a course on color television replaced electron optics. Thus the students were given an opportunity to study the latest applications of electronics. Then came transistors and industrial electronics with its many facets. Computers (digital and analog), solid-state applications and ferromagnetics were arriving rapidly.

The curriculum problem was studied and revised by a committee of faculty members with periodic consultations with directors of education. The curriculum was completely revised to fit into the two-year course length. It was found that many advanced courses included topics which were studied previously in more elementary courses. For example, RF amplifiers were covered first as narrowband in one course, then as wideband in another. Laboratory time was cut from four to three hours for courses with four to five lecture hours per week by developing more-efficient experimental chassis. The one year study led to the sensible approach to scientific training: a thorough rigorous study of fundamental principles followed by applications in later terms. Thus, many new applications could be introduced as part of the curriculum without changing the course of study.

CURRICULUM AND FACILITIES

The curriculum at RCA Institutes is divided into two major parts: *basic subjects* and *applications to electronics.* The first five terms deal with the study of basic mathematics, physics and electronics; and the last four terms are concerned with applications to electronics. In the study of the basic subjects, careful consideration is given to the correlation between the mathematics, physics, and electronics courses. For example, projectiles in physics and the parabola in mathematics are discussed at approximately the same time. Similarly, while forces and velocities are studied in physics, vectors have been discussed in a mathematics course.

The student is expected to come to RCA Institutes as a high school graduate. His previous education should have included elementary and intermediate algebra, plane geometry and physics. Qualified students are admitted to the first term. Advanced standing to a higher term depends on submission of transcripts and passing of examinations. Since the duration of each term is about three months (57 school days) most students, even if exempted, choose to take the first term. Each student is interviewed by a staff counselor before admission to ascertain his capabilities and to acquaint him with the program at the school.

The first term program consists of a review of high-school intermediate algebra, trigonometry, physics, and a course in English. As part of the English course, the student learns about note-taking and the preparation of notebooks, preparation for examinations and methods of attack in the solution of physical and mathematical problems. By the use of motion pictures and tachistoscopes the student is encouraged to improve his reading ability. This unit is designed to assist the student in making the most effective use of his study time.

A high-school graduate who does not meet the mathematics and science entrance requirements would have to enroll in the preparatory sequence. This may last from one to three terms depending on the student's background.

Since the employers, in selecting candidates for employment, give considerable weight to their ability to speak and write in clear, concise, and coherent English, it was deemed advisable to include a technical writing course in the first half of the curriculum. The course in "Technical English" is designed to develop in the student the art of self-expression, particularly in writing. Since report writing is an almost daily occurrence in the electronics industry, the emphasis on formal technical reports is stressed. The student has a chance to explore his hidden ability for technical writing in every laboratory, since reports to high standards are required for all experiments.

The college-level mathematics in the curriculum begins with advanced algebra (including matrix algebra), analytic geometry and calculus, and culminates with differential equations. Other topics of advanced mathematics such as vector analysis and Laplace transforms are incorporated in the courses on electromagnetic fields and transient analysis.

The college-level physics starts with the second term and emphasizes the physical concepts of mechanics, heat, optics, and other classical topics. A special unit on semiconductor physics is given to bridge the gap between theoretical physics and electronics.

During the study of mathematics and physics, the student is introduced to electrical technology. Now that the student has mastered circuit theorems and learned Fourier analysis, he is ready to embark on a thorough study of principles of vacuum tubes and transistors. The remainder of the curriculum is devoted mainly to analysis and design of electronic circuits. These circuits range in extent from regulated power supplies, pulse techniques, narrow- and wide-band amplifiers to microwaves and transmission lines, digital and analog computers and others.

Laboratory Facilities

Visitors to the RCA Institutes from industry, other schools, U. S. Government branches, foreign countries, and ECPD representatives have often remarked how well-equipped the laboratories are. It is in the laboratory that the student finds himself in a unique, pleasant and favorable position. The laboratories are well-lighted, large, and almost self-sufficient. In visits to colleges and other institutions one does not usually encounter the comprehensive equipment found at RCA Institutes. There are laboratories in physics, electronics, basic communications, and industrial electronics. In the laboratories students, usually working in groups of three, perform experiments to verify many of the concepts learned in the classroom, and apply technical-writing skills to the reports which are submitted. While working with others, the student learns the importance of cooperation, develops a sense of responsibility and respect for people and equipment.

Job Opportunities

It is during the graduating term that the student is aware of the impending opportunities for jobs. Many companies in the electronics, space and automation areas such as Westinghouse, IBM, Burroughs, Grumman, ITT, Brookhaven Laboratories, most RCA divisions and dozens of others send representatives to interview students for job opportunities. The RCA Institutes graduate with his extensive college-level education is well suited for liaison between the technician and the engineer. Classification which have been obtained for graduates of RCA Institutes have included *engineer, field engineer, sales representative, junior engineer, laboratory technician, instructor,* and *technical writer.* A trained vocational counsellor is available at all times to help students with their interviews and other details of job-hunting. Men from different industries as well as former graduates address senior assemblies on job opportunities, furthering education, etc. A number of colleges, universities and institutes, including Brooklyn Polytechnic, CCNY, MIT, and many other fine colleges and universities from coast to coast, have recognized the level of the course at RCA Institutes and have granted advanced-standing credits to students wishing to continue towards their degree in engineering. Students have been granted as many as 65 credits in advanced standing.

Scholarships and Special Services

To help a deserving student further his education RCA selects one student each year and grants a scholarship for university study in science or engineering. The grant is $800 per year for a maximum of four years. The selection of the graduate, the university to be attended, and the extension of each scholarship beyond the first year, are subject to the approval of the RCA Education Committee. RCA Institutes is also offering six scholarships for the Electronics Technology Course.

When necessary to counsel students early in their training because of trouble with basic courses, the usual reasons are outside jobs, lack of study, improper study habits, illness or personal problems. The counsellor's task is to prevent failure and perhaps to straighten out a student before he gets too far behind and eventually quits. Here also student aid is available free for two hours per day for those students requiring help. Regular faculty members are assigned to these student aid sessions.

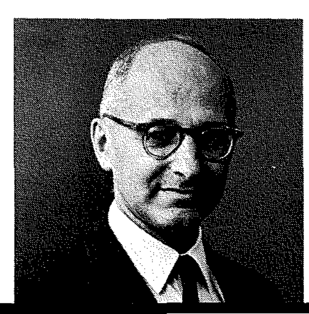
Courses on special topics are often given in the evening for those interested in a particular phase of electronics. Automation electronics, computer programming, and transistors are given at present.

RCA Institutes Home Study School provides technical programs of study for those who are not able to attend the residence classes. Correspondence courses on diverse topics in electronics are available. Kits are supplied which enable the student not only to build equipment but also to perform experiments.

Extracurricular activities during the school term enable the students to participate in varied endeavors. Bowling, baseball, chess, dancing, ham radio club, boat trips, etc., are a few of many activities carried on and organized by a fraternity. A school newspaper *Current Lines* is published quarterly and mailed to alumni, college libraries, and others. There is an active student chapter of the Institute of Electrical and Electronics Engineers which sponsors lectures and films on subjects in electronics.

IRVING ENGELSON, an honor graduate of RCA Institutes' Advanced Technology Course, also obtained a diploma through studies in Germany and Switzerland. While in Europe, he taught mathematics, radio technology, and power. He was employed by engineering firms in Europe before coming to this country and working for the Induction Motors Corporation and the Austin Company before joining the faculty of RCA Institutes in 1956. His military service included work in communications. He speaks seven languages. At RCA Institutes he served on the Curriculum Revision Committee and planned the preparatory sequence which he later supervised and coordinated. At present he is Acting Registrar, Library Supervisor, and Instructor in radio-frequency technology. Mr. Engelson holds membership in the IEEE, is co-author of "Mathematics in Electronics" to be published in the series "Practical Mathematics" by William Wise & Co., and is under contract as co-author of a textbook on electronics for Prentice-Hall. He is furthering his education by attending the Polytechnic Institute of Brooklyn in the evening.

JACOB BRODY, Associate Dean, RCA Institutes, is an electrical engineering graduate of Polytechnic Institute of Brooklyn where he subsequently took graduate courses. He holds a BS degree from the College of the City of New York, and an MS in Education from the School of Education of CCNY. Prior to his military service, he was a senior engineering aid and an instructor in radio theory at the Signal Corps Radar Labs. At the conclusion of World War II he joined the Dumont Electric Corporation as an engineer for research and development on capacitors. In 1948, he joined RCA Institutes as an instructor, becoming Chairman of the Audio-Video Department in 1956, and advancing in 1960 to his present position as Associate Dean. Presently he is serving as program coordinator of the David Sarnoff Industry Science Teaching Program. He holds membership in the IEEE.



STEREO FM SIMULATOR FOR SERVICING FM STEREO PRODUCTS

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Consumer Products Div.
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The WR51A Stereo FM Simulator described herein was designed by RCA Service Co. engineers to fill a need for a practical test instrument with which an RCA service technician could check out both the stereo and monaural operation of home FM stereo broadcast receivers. (It is also being marketed through the Electron Tube Division.) The instrument provides a precise alignment check and helps diagnose a number of operating problems, while staying well within the price range of the average service operation's budget.

Fig. 1—WR51A Stereo FM Simulator.

WITH THE ADVENT of stereo FM broadcasting and the increase in popularity of RCA home stereo receivers, it became immediately apparent that some form of test instrument would be required by the servicing technician to check the over-all operation of the receiver for stereo, as well as monaural signals, and to permit ease of diagnosis as well as verification of a successful repair.

Practical test equipment of this nature was nonexistent until recently, except for complex and costly types of laboratory instruments, which would hardly fall within the reach of the average service operation budget. In addition, the laboratory instruments lacked certain features which were considered desirable. Thus, RCA Service Company engineers proceeded to design their own. The results are typically demonstrated in the WR51A Stereo FM Simulator.

The WR51A Simulator provides test signals to permit:

1) Check over-all monaural and stereo operation at normal and subnormal RF levels and RF deviations of the receiver system.
2) Signals to sweep align the RF and IF portions of the receiver with the aid of an oscilloscope.
3) Signals to provide a rapid adjustment of the stereo bandpass, traps, and demodulation characteristics.
4) A metering circuit to check for audio balance between the two channels.
5) With the aid of a harmonic distortion meter, check the distortion products on both the main channel as well as the subcarrier channel.
6) Provide a self checking feature to insure correctness of generator signal functions.

OPERATING FUNCTIONS

The unit is shown in Fig. 1. The lower left-hand switch knob selects the modulating frequency for both the main channel oscillator as well as the subcarrier channel. The frequencies are selected to give optimum use in aligning or checking the receiver stereo function. The lower-center switch knob selects the basic mode of operation. The first position selects a sweep function to permit visual alignments of the receiver RF-IF. An IF frequency oscillator is turned on in this position to be used as a marker for IF alignment. The second position selects *main channel only* modulation to permit alignment of audio balance and stereo band-pass characteristics. The third position of the switch permits a generator self-check feature for stereo and also gives a very sensitive check of receiver stereo balance. The self-check feature consists of connecting an oscilloscope to the *comp. sig./audio*, adjusting one transformer slug to obtain a null at the center line of the composite stereo signal. This may be done without removing the chassis from the cabinet. The fourth and fifth positions provide a *left channel only* and *right channel only* signals for stereo checking. Stereo matrix, or cross-talk, can be adjusted for optimum results with these two signals.

The lower right-hand knob controls the RF center frequency (approximately 100 Mc) of the main channel oscillator in order to check for bandwidth, or to avoid a strong local signal that may be interfering with the test.

The upper left-hand knob controls the amount of RF deviation, and is calibrated

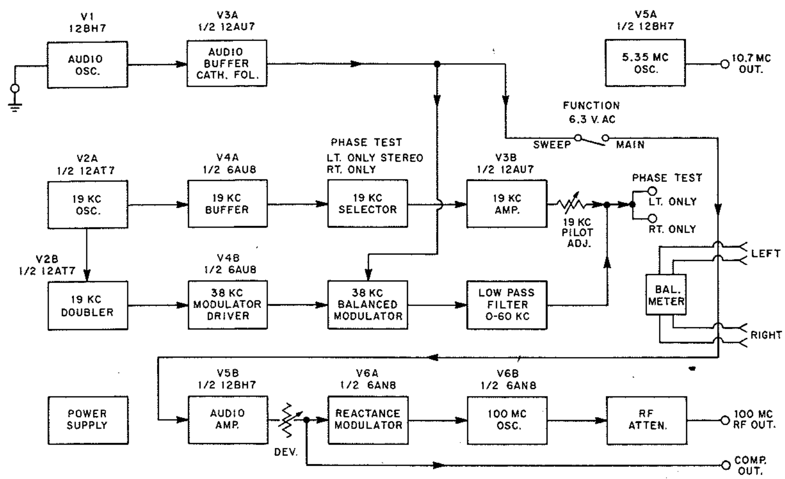


Fig. 2—WR51A circuitry.

STEVEN WLASUK attended the Drexel Institute of Technology and undertook extra-curricular work at the University of Pennsylvania. His previous background at Brown Instrument Company included a variety of student engineering courses, and later initiated a series of designs during his work in the Navy, 1944-1946 (Fleet and Training Centers). He joined the RCA Service Company in September, 1946 as a TV Technician in the Albany, New York Branch and advanced to Manager of the Bronxville Branch in 1948. In 1949, he joined the Engineering Department of the Consumer Products Division, advancing to Manager of the Development Engineering Department in 1953. In this capacity, Mr. Wlasuk received the "Award of Merit" in 1953, and frequent citations since that date, covering his achievements in developing specialized field equipment for color TV and UHF. During the past five years, his designs have included test equipment, multiple systems amplifiers and accessory items (splitting devices, remote controls, hybrid mixers, tap-offs, special outlets, etc.).

for amounts ranging up to the maximum permitted by law for FM station operation. It also controls the amount of sweep width when the function switch is set on *RF sweep and IF marker*. The maximum sweep width is about 1 Mc. The upper center of the control panel incorporates attenuator switching for reducing the normal 0.1-volt output to a low of approximately 100 μv in four steps. The upper right-hand knob controls the amount of 19-kc pilot signal injected into the stereo modulation, from a maximum of 10% to a minimum of 0%.

The meter in the center of the front panel is used to determine the *left vs. right* balance. Leads extending from the rear of the WR-51A are connected to the speaker systems. These signals are detected and used to swing the meter either left or right in the event of unbalance.

In addition, three signals are available on front panel packs. One jack provides audio to be used in aligning or checking the stereo demodulator and audio amplifiers by by-passing the receiver RF-IF. Another jack provides RF output. A third jack provides IF-RF marker every 5.35 Mc up through the FM band.

CIRCUIT DESIGN

The circuit is illustrated in Fig. 2. *V1* serves as a one-tube audio oscillator generating a sine wave frequency on each of seven frequencies as selected by the switch position. *V3A* acts as a buffer to drive signals into the main channel amplifier or into the 38-kc modulator. *V2* consists of a 19-kc crystal-controlled oscillator and frequency doubler. *V4A* drives a 19-kc signal into a three-stage phase shifter. The phase is shifted into three modes, each differing from the next by 45 electrical degrees. A total of 90-degree shift is made to go from a *left only* to a *right only* signal. This feature makes the instrument simple since, to get the same effect, the 38-kc would have to be shifted 180 degrees. *V4B* drives the 38-kc modulator (together with the selected audio frequency). The output of the 38-kc balanced modulator is filtered to remove the harmonic content.

The function switch selects one of three sources: 1) 60-cycle power line voltage (for sweep), 2) audio only (for main-channel modulation), or 3) output of the 38-kc balanced modulator together with 19-kc pilot as supplied by *V3B* (for stereo). The selected function is fed into *V5B* where the signal is amplified and delivered to an external jack as well as *V6A* which frequency modulates *V6B*, a 100-Mc oscillator. The output of *V6B* is fed, through an attenuator, to an RF output jack. The attenuator, as stated previously, gives four levels of output voltage ranging from 0.1 volt to 100 μv. *V5A* serves as an oscillator which is crystal controlled at half the IF frequency in common use. This frequency was selected to provide markers through the FM band as well as a marker for IF alignment. The balanced meter circuit is made with detectors to sense an unbalance between the two stereo channels in a typical receiver.

CONCLUSION

The WR51A not only permits a precise alignment check, but helps identify problems relative to customer operation, broadcasting problems, and receiver adjustment. As with a number of other RCA Service Company designs, this instrument is being marketed through the Electron Tube Division to supply the needs of other servicing agencies.

THE OPTICAL TUNNEL, A VERSATILE ELECTRO-OPTICAL TOOL

A unique and versatile electro-optical tool, the optical tunnel, can create a multitude of identical optical images from a single presentation and merge many optical presentations into one. The former enables parallel processing of a given optical image. The latter allows multiplication of the resolutions of conventional electro-optical devices having readily obtainable resolving power. Applications incorporating these advantages are included in a Multi-Font Reading Machine, a Random Access Memory, and a Chinese Ideographic Composing Machine, discussed herein.

L. J. KROLAK, Ldr., and D. J. PARKER, Mgr.

Applied Research

DEP, Camden, N. J.

DONALD J. PARKER, Manager, DEP Applied Research, received a BS in Optics from the Institute of Optics, University of Rochester, N.Y., in 1950. He joined the Applied Research Section of RCA at that time, becoming supervisor of the Optics Group in 1954 and Manager of Applied Physics in 1957. He was promoted to Manager of Applied Research in 1963. He has directed applied research and development in electro-optics, electrostatic printing, superconductivity, molecular resonance, and plasma physics. Recent projects include solid-state masers, molecular frequency standards, plasma propulsion devices, electronic reading machines, electro-optical memories, fiber optics, television systems, and electrostatic color map printers. Mr. Parker's experience includes the development of many types of military and commercial optical systems, such as optics for the first color-television cameras, color-film broadcast equipment, large-screen television and color-kinescope recording, airborne equipment, television gunsights, high-resolution scanning of color separations, television aerial reconnaissance, and radar recording. Mr. Parker is a member of the Optical Society of America, the Society of Photographic Engineers, the American Physical Society, The Society of Motion Picture and Television Engineers, and is a Senior Member of the IEEE.

LEO J. KROLAK graduated from the University of Rochester in 1949 with a BS in Optics. He worked for the Atomic Energy Project of the University of Rochester until 1956, at which time he joined RCA. While working for the AEC, he received his MS in Optics from the University of Rochester. His work for the AEC included infrared studies, design of infrared radiometers for A-bomb tests, and evaluation of the data from the tests. Since joining RCA, Mr. Krolak has done work in airborne infrared seeking and tracking systems, and infrared transmitting materials and detectors. As Leader, Optics Group, he has directed work on optical systems, fiber optics applications, evaporation of thin films for integrated electronic circuits and magnetic recording heads, superconductivity, Electrofax, and solid-state displays. He recently presented an invited paper before the NATO Advisory Group for Aeronautical Research and Development in Paris, France on "fiber optics." Mr. Krolak has written papers for the Journals of the Optical Society of America and the Society of Motion Picture and Television Engineers.

The authors, L. J. Krolak (left) and D. J. Parker discussing an application of the optical tunnel in an electro-optical memory.

DURING THE PAST several years, information processing has proceeded inexorably toward the utilization of many parallel processing channels to achieve the required number of operations per unit time. The limited processing rate of available channels and the ever-increasing demand for faster computation and control processes have created this evolution.

Many parallel operations can be performed with one electrical signal, but the electrical signals handled are usually one-dimensional with time. Many high-information-rate processes, on the other hand, demand two-dimensional processing. Two examples are the location of a bit of information in an *XY* space and the recognition of the shape of a two-dimensional pattern.

Two-dimensional information is picture information, so the problem becomes one of providing parallel processing channels for pictures. The normal solution to this problem is, "do it with mirrors." Input pictures may certainly be duplicated by mirrors, but in a conventional optical layout, each channel requires a lens (Fig. 1). If a large number of parallel channels are desired, the lenses used in each channel must be complex and expensive, since they are required to cover a wide field with good quality. The lenses become bulky and cannot be spaced as close as is necessary. As a result, the basic cost of the lens system is very high. Adding to the cost is the precision mounting and focusing required for each lens.

BASIC PRINCIPLES

A very large number of parallel optical channels can be provided at moderate cost, however, by an extremely versatile and trustworthy device called the *optical tunnel*. The optical tunnel is basically a mirror tool, and can best be described by referring to Fig. 2. Fig. 2a represents multiple objects being imaged at 1:1 by a lens. Fig. 2b, indicates what happens when two parallel mirrors, both perpendicular to the plane of the paper, are interposed between the lens and the image. All of the dotted images are now superimposed, one on the other, on the axial image. A second pair of mirrors can be introduced to form a square cross-sectional tunnel. It is now possible to image a two-dimensional multiple object in such a way that all of the objects are superimposed on axis, as illustrated in Fig. 2c. The cross section of the tunnel need not be restricted to a square; it can also be rectangular or triangular, and its length depends on the magnification and the focal length of the lens used.

An image of an object, depending on the number of reflections and its position, may be inverted and/or reverted in the image plane. However, this is of no concern in most applications because provisions can be made to compensate for this effect. In summary, an object placed at the entrance face of such a tunnel will be duplicated by successive reflections from the mirror walls *ad infinitum.* An observer looking into the other end of the tunnel will see a continuous reproduction of the central image extending out to the horizon. Similarly, a lens placed at the end of the tunnel will re-image the plane of images at any desired point in space, depending on the focal length of the chosen lens. The total number of comparison channels provided by the optical tunnel-lens combination is determined by three factors:

1) the focal length of the lens
2) the cross-sectional dimensions of the tunnel
3) the angular field which the lens can cover with sufficient quality to meet the demands of the optical processing to be performed on the individual channels.

An optical-tunnel system, in common with other optical systems, may also be used in reverse. For example, a different object may be stored in each of the comparison channels, and images of all these objects superimposed simultaneously at what would normally be considered the input end of the optical tunnel. By selective lighting or masking, one of many hundreds or thousands of stored images can be obtained, with the selected image always appearing at the same point in space.

A typical optical tunnel will provide up to 1,000 channels, with optical resolutions in each channel varying from 100 to 500 or more picture elements per channel height. Critical design considerations are the angular tolerances between the walls which form the tunnel, the reflectivity of the surfaces, the flatness of the surfaces, and the quality of the associated lens. For certain applications, the angular tolerances and the required reflectivity become very critical. Nevertheless, the optical tunnel has proven itself a very economical and practical device. The authors and their coworkers have used optical tunnels in a number of applications, three of which are described below.

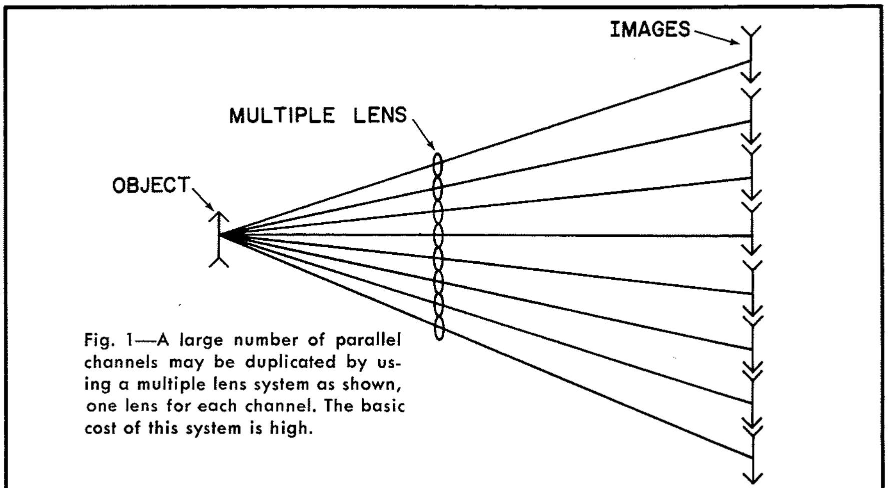


Fig. 1—A large number of parallel channels may be duplicated by using a multiple lens system as shown, one lens for each channel. The basic cost of this system is high.

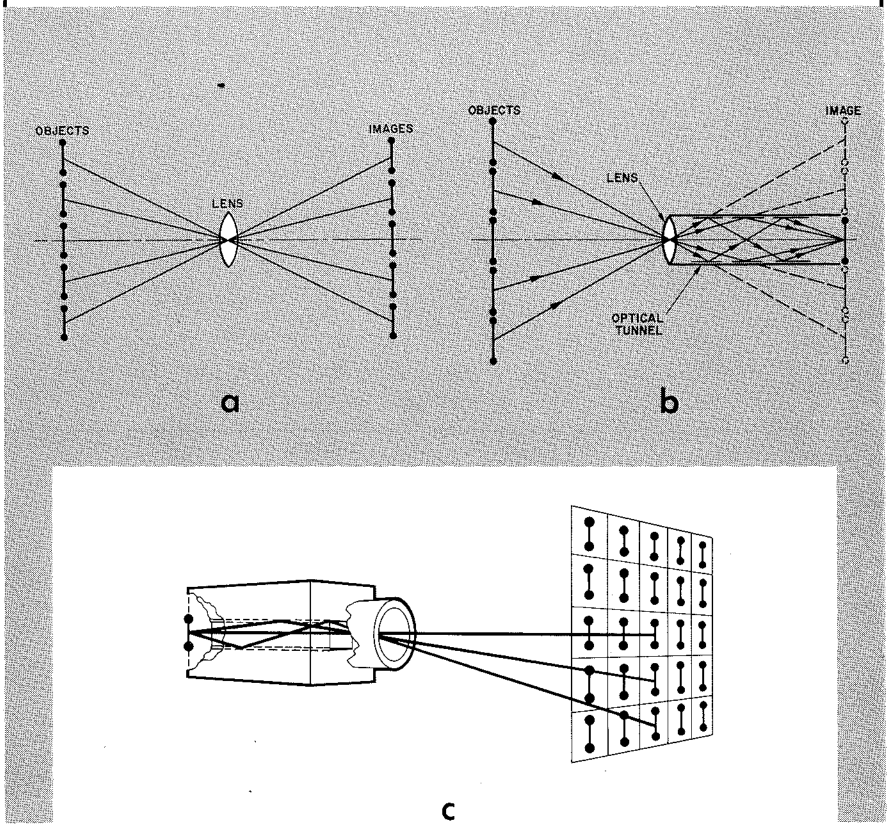


Fig. 2—Description of optical tunnel operation: a) single lens imaging multiple object into multiple image; b) superposition of images in plane of page by two parallel mirrors which are perpendicular to the plane of the page; c) superposition of images in two dimensions after addition of second pair of mirrors to form square cross section tunnel.

APPLICATIONS OF THE OPTICAL TUNNEL

The attractiveness of the optical tunnel can best be shown by briefly describing several applications. The first is in the RCA Multifont Reading Machine.

RCA Reading Machine

Individual characters to be recognized by the reading machine are selected by a television system which automatically delivers a centered picture of the character to the optical recognition system. Both a positive and negative image of the character is provided side by side on the face of a cathode ray tube for presentation to an optical cross-correlator. The cross-correlator has an optical-tunnel system which projects multiple images of the cathode-ray-tube presentation to a photographic plate containing correlation masks. Fig. 3 shows the tunnel system with parts of the multiple image, but no correlation mask. The cross correlator is shown in Fig. 4. It contains 49 separate channels, each channel equipped with a multiplier phototube An image quality equivalent to 100 TV lines per height per image was required in each of these channels; this was readily obtained with the optical tunnel shown in the lower-left-hand corner of Fig. 4. The tunnel was made from four glass mirrors, bonded together permanently with thermal setting cement.

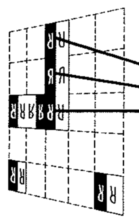


Fig. 3—Optical tunnel used in reverse of that described in Fig. 2. A negative and positive letter R is displayed on a cathode ray tube at the position of the image in Fig. 2. A multiple image is then projected as shown to be used for parallel comparison with other characters contained in a mask placed in the image plane (See Fig. 5). The images are in various combination of inversion and reversion depending on the number and kind of reflections within the tunnel.

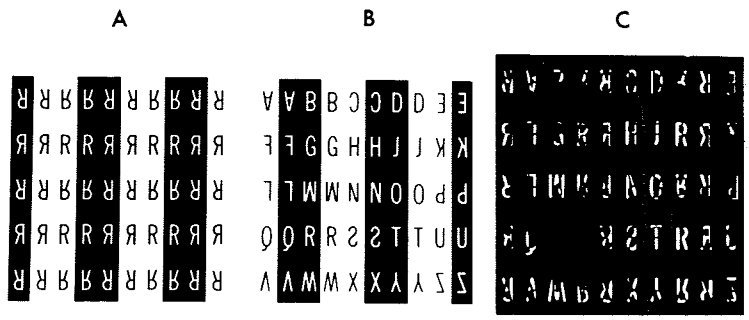


Fig. 5—Multifont Reading Machine correlation method: a) aerial image of negative and positive "R" which is to be identified; b) comparison mask with no image; c) aerial image in 5a superimposed on comparison mask. Note the absence of light at the "R" channel indicating identification.

The internal surfaces are protected from dust and vapor by thin glass windows cemented across the end faces. This is a typical example of optical-tunnel construction.

A 25-character image array of a projected *R* and comparison mask are shown in Fig. 5a and 5b, respectively. Fig. 5c is a photograph taken from behind the mask with the image array superimposed on it. Note that some light comes through all of the channels except the *R* channel. This null at the *R* channel identifies the letter being displayed on the cathode ray tube.

In the reading machine, the optical tunnel provides a simultaneous cross correlation of 49 channels with high quality and relative economy. The resolution obtained with this tunnel system is of sufficient quality for the channel capacity to be increased by a factor of four without increasing the number of phototubes. This is an important feature because of the cost of the phototubes and associated circuitry. An increase can be effected simply by making the input images on the cathode ray tube half the original size, both horizontally and vertically, thus making it possible to put four characters in the cross correlator area previously taken by one character. The displayed characters may be placed in any one of the four quadrant positions, either sequentially or by predetermination of the classification of the characters; for example, all capital letters might be located in the top left-hand corner of the object window on the cathode ray tube.

The Electro-Optical Memory

Although the optical tunnel was originally described as a means for producing a number of optical comparison channels from a single input, its greatest application appears to be the reverse. For example, consider the electro-optical memory (Fig. 6). The memory in this system consists of individual binary bits of density on a photographic matrix plate. Electronic access to and inquisition of a specific bit on the memory plane is desired. Normally, the resolution required to electronically scan the complete plate with a flying spot scanner, or similar device, would be far too great. The optical tunnel can be utilized, however, to provide a selected look at a smaller matrix cell of the plate shown in Fig. 7. The smaller cell can be handled adequately with available resolution in a conventional flying spot scanner.

Briefly, the memory system works in the following manner. The cathode ray tube is designed to produce a square spot. By proper addressing, any desired cell of the matrix can be individually and fully illuminated by this spot. The lens and optical tunnel act to superimpose images of the cells at the same place, so that regardless of which cell is illuminated, its image appears at a common location; namely, at the photocathode of the image-dissector. Thus, by simultaneously addressing the image-dissector deflection, the desired bit position in the cell is interrogated.

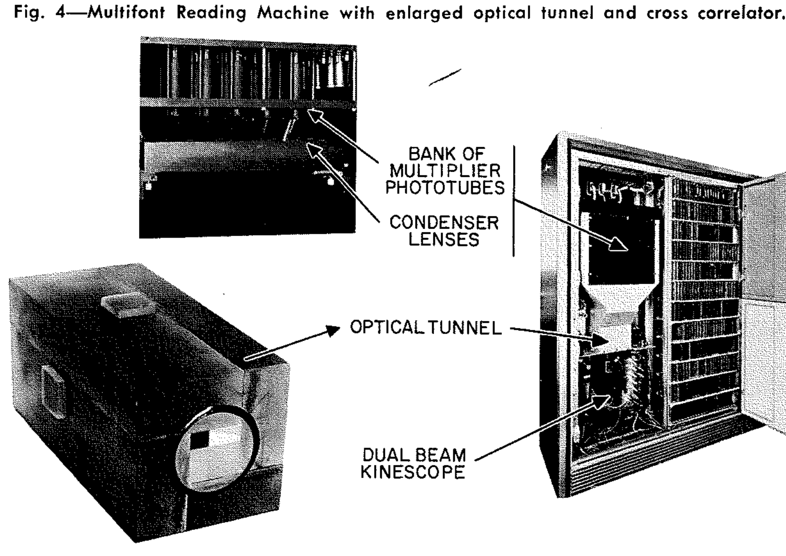
In summary, *the optical tunnel has made possible a completely nonmechanical memory combining a very large capacity with rapid, truly random access.* The large capacity is obtained with basically conventional electro-optical devices having readily obtainable resolving power. This is accomplished by a unique two-stage address operation in which the resolutions of the two addressing devices, the cathode ray tube and the image dissector, are effectively multiplied by each other.

Chinese Ideographic Composing Machine

A Chinese Idiographic Composing Machine is being developed for the Army Quartermaster Command at Natick, Massachusetts.

In this application of the optical tunnel, it is desired to obtain rapid access to a photographic storage library containing reproductions of as many as 10,000 ideographs (Chinese characters). No matter which of the 10,000 characters is selected, it is desired to have the image of the character appear on a vidicon camera tube so that a television reproduction of the character may be used for composition of a printing plate by exposure of an intermediate photographic film. In this system, shown schematically in Fig. 8, the optical tunnel views a photographic memory having 625 separate channels, each channel containing 16 characters. Selection of the illuminating lamp having a given channel thus selects 16 characters which appear on the face of the vidicon. Selection of the area to be scanned on the

Fig. 4—Multifont Reading Machine with enlarged optical tunnel and cross correlator.



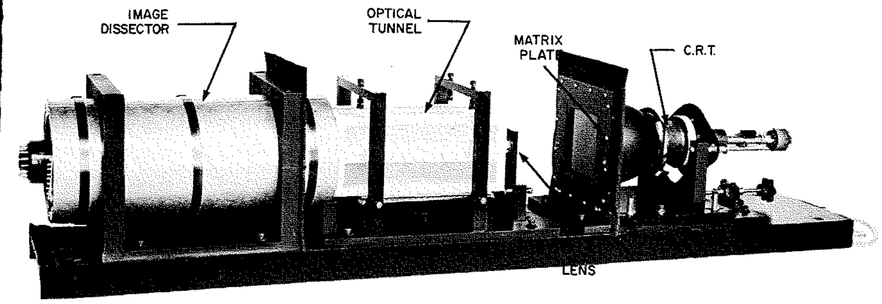


Fig. 6—Electro-Optical Memory employing an optical tunnel.

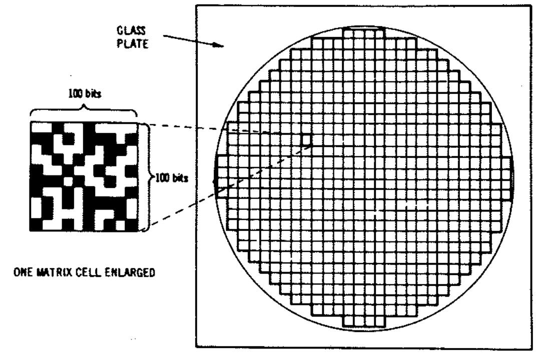


Fig. 7—Electro-Optical Memory storage plate showing one matrix cell with binary bits.

vidicon completes the selection process. High-speed access is thus gained to a very-high-capacity memory without any mechanical moving parts.

The optical tunnel used in this manner multiplies, in effect, the resolution of the vidicon. If there were no optical tunnel present in the system, the vidicon would have to choose from approximately 3,300 characters. No television system would have sufficient resolution to provide the required resolution for each ideograph.

TOLERANCES FOR VARIOUS APPLICATIONS

The above applications show the optical tunnel to be a very versatile device. Because of its basic attractiveness, the authors initiated a number of studies, both theoretical and experimental, of the tolerances required for given applications. The results of these studies have indicated that angular tolerance is the most difficult problem of tunnel fabrication.

If a point source on axis were being imaged by a lens and a perfect optical tunnel combination, the image produced would be made up of many point sources all equidistant from each other in a square similar to that shown in Fig. 9. The vertical and horizontal rows of images of the point source passing through the center image are formed only by opposite parallel faces of the tunnel, while all of the other images are the result of some corner reflections. If there is an error in one of the corners, the single image will split in two upon one reflection and in four at the next reflection, etc. If the tunnel images something other than point sources, a character for instance, this spreading will degrade the resolution. As an example, consider a tunnel system with a ½-inch cross section, the extreme corner image of which is 12 images removed from the center image (25 x 25 matrix). To get a resolution of 500 elements per inch, or a spread of a point source of no more than 0.002 inches, the total error must not be more than 2 seconds of arc in opposite corners. This error is additive and cannot be cancelled by an error in the opposite direction in the opposite corner.

The illumination of a given channel will fall off the most for channels on a diagonal. For example, in a 25 x 25 array with aluminized mirrors having a reflectivity equal to 0.90, the illumination of the corner channels will be 0.90^{24}, as compared to the center channel. This means that the illumination will be down to 8% of the center channel illumination. Add to this the drop off due to the $\cos^4$ law for a lens covering 30°, and the extreme channel will have about 5% of the illumination of the center channel. Because there has been more than enough illumination available in the applications cited, this shading can be compensated for by the electrical circuits in the Multifont Reading Machine and the Electro-Optical Memory, and by varying the intensity of the light sources in the matrix illuminator in the Ideographic Composing Machine.

In addition to the above design parameters, careful consideration must be given to the optical flatness of the walls of the tunnel. Nonflatness leads to astigmatism in the final image.

SUMMARY

This unique and versatile electro-optical tool, the optical tunnel, has the capability of creating a multitude of identical optical images from a single presentation, or of merging many optical presentations onto one. The former feat enables one to perform parallel processing on a given optical image. The latter makes it possible to multiply the resolutions of conventional electro-optical devices having readily obtainable resolving power. Applications incorporating these advantages are included in a Multi-Font Reading Machine, a Random Access Memory, and an Ideographic Composing Machine.

Fig. 8—Ideographic (Chinese character) Composing Machine. Schematic shows selection of desired character from the optical memory. First step is the selection of the proper channel, each of which contains 16 characters, by the optical tunnel. Secondly, the proper character is scanned from the 16 characters presented to the vidicon picture tube.

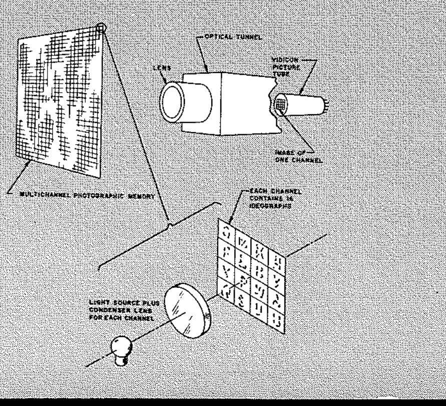
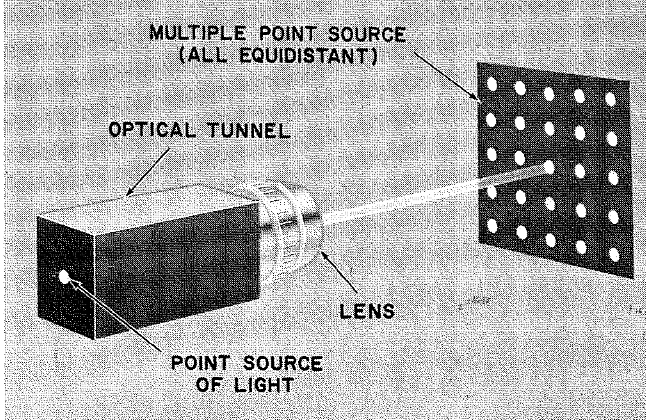


Fig. 9—Point source (dimension exaggerated) on axis being imaged by a lens and a perfect optical tunnel combination.



DESIGN OF PRECISION ANTENNA SYSTEMS FOR SHIPBOARD ENVIRONMENT

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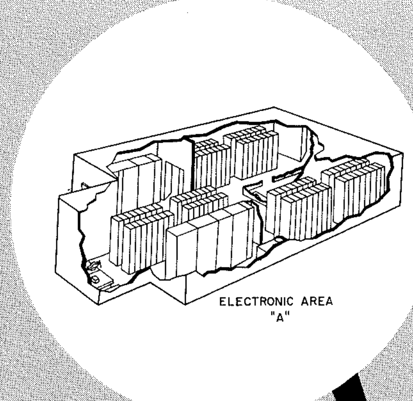
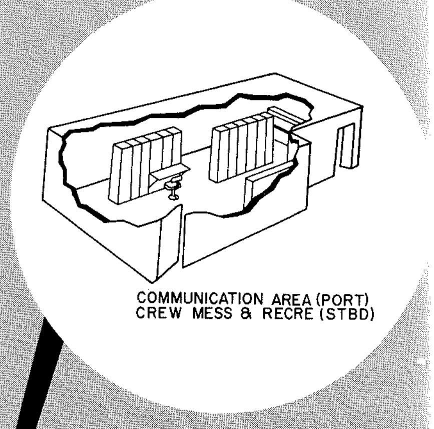
A shipboard precision antenna system must perform in accordance with special design criteria. Tactical vessel installations usually consider the electronic system to consist of "black boxes" fitted in where they do not conflict with the ship's fire-power mission. However, precision antenna systems designed for an instrumentation ship must also provide tools for the vessel's prime mission — acquisition of data. It is not sufficient to consider the vessel as merely a platform on which equipment is to be installed. The antenna-system design approach for an instrumentation vessel is an integrated one: the vessel, the equipment, and the personnel must be considered. RCA success in designing these shipboard systems supports the validity of this approach, as described herein.





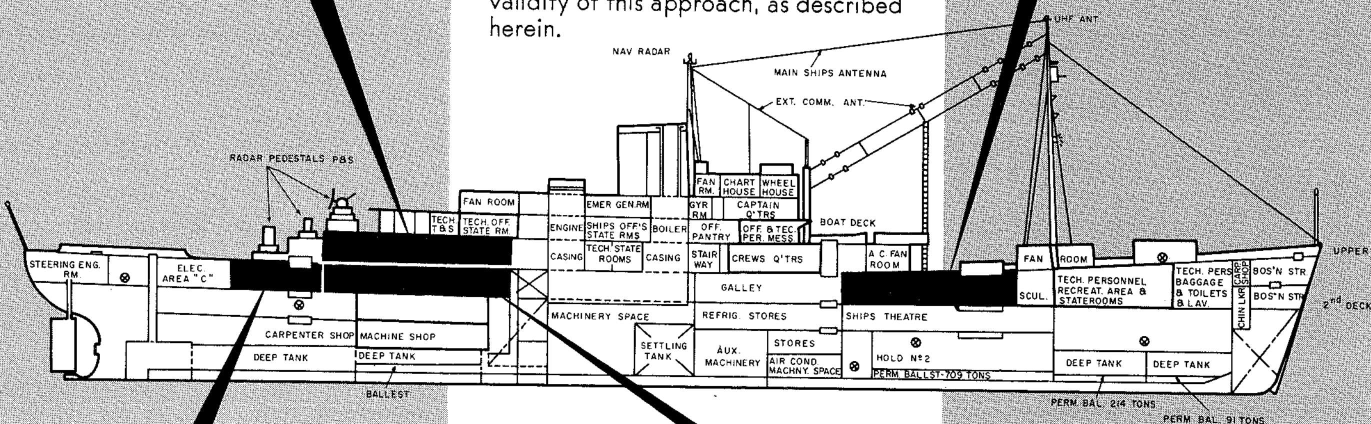
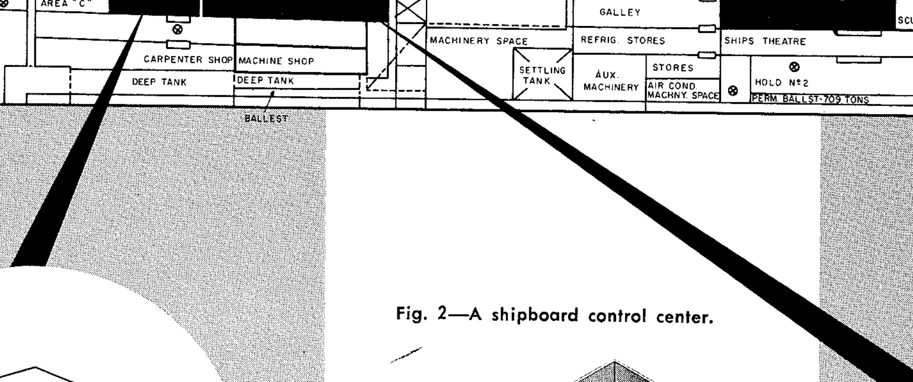
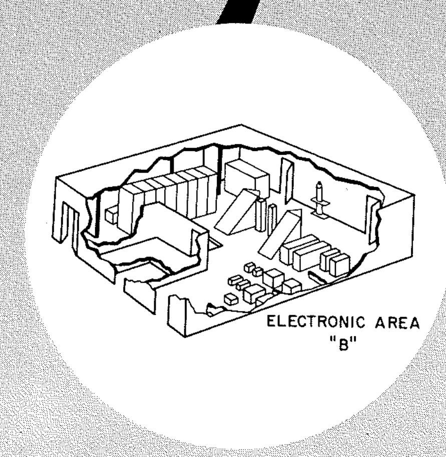


Fig. 1—Layout of the precision antenna system equipment installed aboard the S.S. American Mariner.





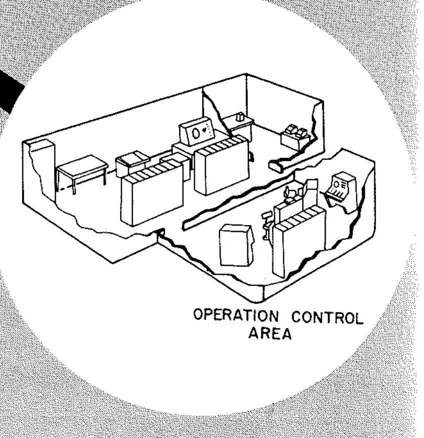
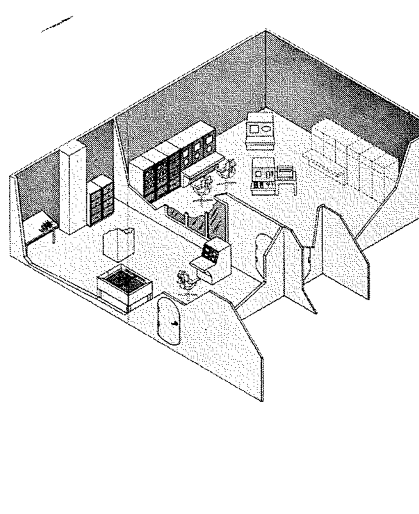


Fig. 2—A shipboard control center.



SHIPBOARD INSTALLATIONS can be categorized as follows: conversion of an ordinary vessel to an instrumentation ship, new vessel construction, and shipboard expansion of an existing electronics system. Each category of installation requires specialized design criteria based on the following design principles:

1) Provide maximum fields-of-view for the radar antenna without compromising the vessel's navigational system.
2) Integrate electronic and living space arrangements utilizing engineering trade-offs as required.
3) Locate independent electronic subsystems adjacent and accessible to each other.
4) When expanding existing ship auxiliaries, locate the new machinery adjacent and accessible to the existing services.
5) Provide additional prime power, air conditioning, and other auxiliaries compatible with existing ship's services.
6) Arrange all quarters, messing, recreational facilities for economical support of the many classes of personnel on board without creating morale problems.
7) Use existing ship structure and facilities to achieve maximum economy of conversion and to maintain the vessel's seaworthiness.
8) Arrange electronic equipment areas so that the ship's operation and the equipment operation are compatible.
9) Provide room for future expansion with a minimum of change to existing equipments.
10) Provide easy accessibility to all equipments—mast-mounted equipments should have maintenance platforms and ladders.
11) Design and install equipment so as to minimize the effect of all ship-induced forces such as roll, pitch, yaw, and vibratory loadings.
12) The addition of structures and equipment should be done in a manner to maintain a desirable ship stability and seaworthiness.

ANTENNA SYSTEM CLASSIFICATIONS

A precision antenna system is a network of interrelated subsystems, each having specific requirements which must be considered whenever engineering trade-offs occur between vessel and equipment. Classifications of the subsystems are different for each precision antenna system considered. The following system classifications usually comprise a complete installation:

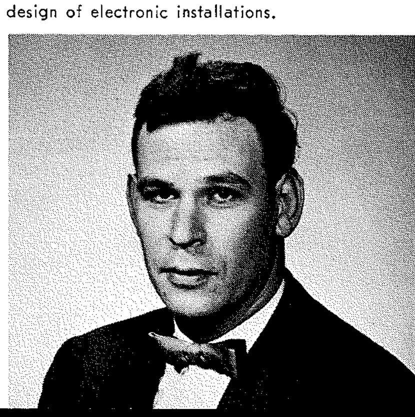
1) RF transmitting systems comprising transmitter equipment and respective antennas;
2) basic electronic systems comprising acquisition, tracking, timing, navigation, and data recording functions; and
3) ancillary electronic systems, including telemetry, communications, weather recording, and photography laboratory.

A vertical stacking of equipment areas should be provided wherever possible; such an arrangement minimizes signal distribution problems between holds where watertight integrity must be maintained as well as provide a convenient central storeroom and maintenance area.

PACKAGING AND LOADING FORCES

Electronic equipment packaging must always consider the shipboard environment. Although instrumentation systems need not be packaged for shock loads imposed by gunfire, the ships vibratory characteristics must be taken into account. Amplitudes of vertical and athwartship (across the ship) vibrations show relatively sharp peaks, rising from approximately 0.005 inches to 0.030 inches at the vessel's fundamental resonant frequency. For example, a ship of 15,000-ton displacement has the following fundamental frequency characteristics: *vertical*, 0.75 to 1.50 cps; *athwartship*, 1.00 to 3.50 cps; and *torsional*, 4.00 to 6.00 cps. Impacting waves induce transient hull vibrations whose ampli-
equipment location, correct design of
tudes may approach 0.10 inches. Proper
structures, and proper planning of the ship's course and speed during the tracking of a "shoot" can minimize the effects of the ship's motions on the antenna system and thus enhance the quality of the data obtained during the mission.

HERBERT A. MAGNUS received his BME in 1951 from the College of the City of New York and his MSME in 1954 from the University of Pennsylvania. Prior to joining RCA, he was employed for three years as a mechanical design engineer responsible for the theoretical analysis and experimental design and development of mechanical aircraft devices. While engaged in these activities he designed several unique devices which have been patented by the government. For the next two years he was unit Chief of the Guidance Control Section at the Redstone Arsenal where he was responsible for the design of missile guidance controls. His next position was project engineer responsible for the development of aircraft survival systems including hydraulic, electromechanical, and ballistic actuating devices. After joining RCA in 1958, Mr. Magnus served as the RCA resident mechanical engineer in charge of supervising the DAMP Ship conversion and in this capacity he was also responsible for the coordination and integration of the radar equipment with a shipboard environment. He is presently in charge of a mechanical design group responsible for the design of shipboard radar systems, antenna ranges, mechanical design support for re-entry programs, design of radar pedestal support structures, and design of electronic installations.



Practical experience gained from the *USAS American Mariner* (liberty ship conversion performed in 1958 under the direct supervision of RCA Moorestown for DAMP[1]) equipment installation can be used as an example of proper design. Electronic equipment is secured to the deck to avoid transmission of external loadings due to co-planar ship deflections (e.g., deck-to-overhead deflections of approximately 1.00 inch, and bulkhead deflection-to-deck of 0.50 inch). Electronic components should be individually designed for the anticipated vibration spectrum applicable to shipboard installation. Moreover, equipment retaining mechanisms such as doorstays, module locks and connector locks should be designed to withstand the ship dynamic forces of roll, pitch, and yaw during survival conditions.

The shipboard equipment layout should be considered as a complete vessel equipment system with each individual equipment location evaluated with respect to its sensitivity to the forces induced by the ship's dynamic motion, including *roll*, *pitch*, *slam*, and *yaw*. Antenna pedestals should be located on an area of the deck not subject to "green seas."

ENVIRONMENTAL CONSIDERATIONS

Precision antenna electronic equipment must be protected against a salt-laden atmosphere. Closed-cycle air-conditioning systems are best for below-deck equipment installation; this permits a more complete removal of atmospheric contaminants and allows optimum inlet and outlet air temperatures for cooling the electronic system. Topside equipment locations must consider all sources of corrosion such as stack gases and green water. Corrosion due to salt spray has not been found to be a serious problem for topside equipment protected in accordance with RCA's standard finish specifications. The proper selection of materials and finishes, preventative maintenance and provisions for periodically washing down the topside equipment must be incorporated in the ship arrangement. Of particular concern is avoidance of any degradation of internal microwave components such as waveguide and tuners. Proper protection of these components can be achieved during operational periods by the use of dry-air pressurization. Special care is exercised in mounting waveguide runs to avoid deformation.

MAINTENANCE CONSIDERATIONS

The system installation must consider and provide maintenance for the removal of any contaminants which could affect the system performance. Maximum fire protection must be provided. Main panels containing circuit switches must be readily accessible and power cabling should be visible and consistent with equipment entry locations.

Critical equipment requiring operator monitoring should be located in quiet areas having adjustable lighting; critical areas should have adequate sound-controlling material applied.

Test equipment must be accessible for ease of maintenance yet adequately secured against ship's motions without impairing the operator's movements.

Above-deck equipment installations of the precision radar and equipment pedestals require close coordination of the antenna system requirements with those of the ship. The location and design of the antenna pedestal support involves such items as the natural frequency of the structure; the relative deflections of those portions of the hull supporting critical antennas and pedestals, and the inertial reference; and the fields-of-view required for the antenna.

ANTENNA PEDESTAL SUPPORT MECHANICAL DESIGN

RCA utilizes several different design approaches for antenna pedestal supports. Each design satisfies different system requirements with respect to static alignment, dynamic alignment and dynamic frequency response. Antenna configurations derived for existing ships such as the *Twin Falls Victory*, *Range Tracker*, *American Mariner*, have met the stringent requirements of a precision antenna system at sea.

On the *USAS American Mariner*, the two C-band radars were mounted (one port and one starboard) on structures spanning the main deck between two main structural bulkheads. The inertial reference was mounted two decks below on one of the bulkheads, which became in effect the web of a large I beam. Two slave pedestals were also mounted on the same port and starboard structures supporting the C-band radars. Tests at sea indicate that dynamic deflections due to the ship's motion between the radars is less than 0.05 mil under *state-3 sea* conditions. [*State-3 Sea:* Gentle winds of 8-12 mph with 3- to 5-foot wave heights; occasional white caps.] In addition to the primary radars, there is a 28-foot diameter L-band antenna mounted on a modified gun mount; this mount is located high on the vessel at the navigating bridge level overlooking the C-band radar antennas. The structures supporting this 55-ton antenna mount is a torque-tube type formed by fully enclosing an existing stairwell which extends below-deck into the ship's primary structure.

On the *Range Tracker* (formerly the *Skidmore Victory*), two AN/FPS-16 radar pedestals were designed for mounting on an independently supported structure. An inertial reference is installed within this structure at the ships centerline. The entire structure is supported by a three-point suspension from the ship's structure thereby tending to reduce the effects of hull deflections.

The *Twin Falls Victory* employs a modified three-point suspension design. The inertial reference is mounted directly below the AN/FPS-16 radar pedestal on a common base structure so that any ship deflections affect both units to the same extent.

STABILIZATION APPROACHES

The choice of support structure design must consider the antenna system performance requirements together with the expected stability characteristics of the vessel. Considering the vessel-antenna system there are several methods of compensating for ships motion:

1) Use of antenna-mounted gyros to isolate the ship's motion from the tracking function.
2) Use of optical or stress monitoring of the support structure.
3) Establish maximum speed and operational wind velocities to minimize the ships-roll angle regulating maximum elevation depression.
4) Install roll stabilization devices aboard ship.

The use of monitoring devices together with regulation of maximum mission conditions usually negates the need for roll stabilization; however, roll stabilization is a desirable feature which would improve the system accuracy.

There are three general types of roll stabilization:

1) *Gyro fin stabilizers:* This system utilizes extensible lifting fins with angle of attack varied in response to the ship's roll. Moments are produced to counter the instantaneous rolling moments produced by wave action, thereby damping up to 95 percent of the roll motion. This system is very effective for high ship speeds.
2) *Activated anti-rolling tanks:* An arrangement of port and starboard tanks interconnected by a pumping system. Liquid is transferred from one side of the vessel to the other in sufficient volume to damp the roll of the vessel. This system reduces roll by about 50 percent.
3) *Passive anti-rolling tanks:* An arrangement of port and starboard tanks interconnected by a duct, or flume. The regulation of the tanks water level is tuned to the ship's rolling characteristics. Damping is obtained by the surge of liquid from one side to the other, out-of-phase with the roll action. This system also reduces roll motion by about 50 percent, and is used on the *Range Tracker* vessel.

OPERATING PERSONNEL

An adequate precision antenna system ship installation must consider the shipboard personnel as well as the equipment. Operational efficiency of the crew must also be considered. Adequate facilities must be provided for the full mission function. Ships officers quarters should be provided topsides. Crew quarters should be near their work stations. Problems concerned with messing and food handling must be considered. Adequate recreational facilities must be considered. Technician quarters should be planned in accord with their respective work organization. In considering the men, every effort must be made to minimize the psychological differences between the various types of personnel aboard the ship. The ship arrangement should be planned to maintain the original ship functions without imposing any additional tasks on the operating personnel.

Precision antenna systems which go to sea must be integrated with the electronic system within the ship. Existing RCA equipment installations aboard instrumentation vessels have been made successfully in accordance with the design principles discussed in this article and have demonstrated effectively their operational capability during the intended period of use.

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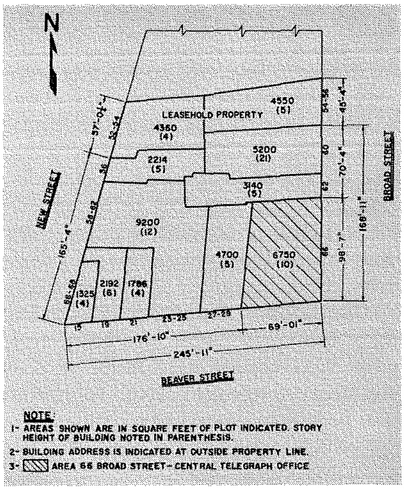

Fig. 1—Former properties and leaseholds of RCA Communications, Inc.

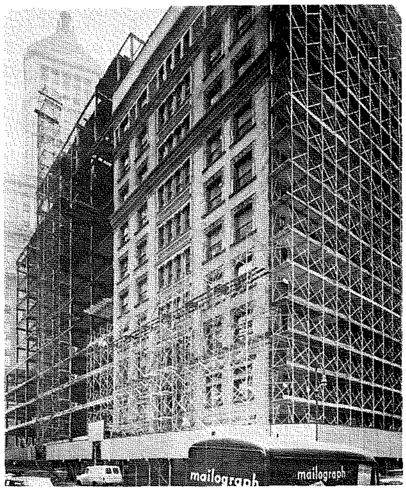

Fig. 2—66 Broad Street, Central Telegraph Office, scaffolding installed for demolition and erection of new facade.

Fig. 3—66 Broad Street, new facade.

A NEW CENTRAL TELEGRAPH OFFICE FOR RCA COMMUNICATIONS INC.

Creation of a new headquarters for RCA Communications Inc. on the site of the old one in New York's financial district—without interrupting 24-hour-per-day international communications services—involved some complex engineering, architectural, and legal feats. The familiar old 10-story building at 66 Broad Street was swallowed up—literally—as a new 39-story skyscraper was constructed around and over it, with the old "66" being integrated into the new structure. The new RCA Communications facilities involve the second through seventh floors—a total of some 250,000 sq ft designed as a modern nerve center for the international communications services of tomorrow.

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and

E. M. GAETANO, Mgr.
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In the fall of 1962, an ingenious engineering and architectural feat was completed—a new 39-story skyscraper at 66 Broad Street. Without interruption to the intricate international communications services of RCA Communications, Inc., surrounding buildings were demolished and a new building was constructed as a "jacket" around RCA Communications' ten-story building at 66 Broad Street—the "nerve center" of the company's operations. A new skin was grafted on the ten-story framework and a modern look given to the entire area.

NEED FOR EXPANSION

The demand for international telegraph communications services is growing, especially in the customer-to-customer services such as TELEX and LEASED CHANNEL, and newer services are being introduced, such as DATATELEX, WEATHERFAX, and CABLEPHOTO. Since more than half of the total volume of international traffic is generated by a small percentage of the world's population, traffic and services are expected to increase at a rapid rate as new areas and countries are developed.

Fortunately, technology also is developing at a rapid pace. Automation, including the use of electronic computers, the impending Space Age in which radio repeater satellites are to be employed, and the utilization of lasers, will increase considerably the flexibility and capacity of communication systems. These and other innovations in the art of communications are multiplying the methods of interconnecting human beings and, more recently, machines. It is evident that the international communications business is on the threshold of a new era of development. Space for plant and personnel to accommodate this growth is of utmost importance for efficient and economical operation.

The nine buildings owned by RCA Communications, plus the two it leased at the corner of Broad, Beaver, and New Streets in New York City (Fig. 1) would not provide adequate space for long-term expansion. In 1959 the communications business, auxiliary services, and headquarter departments of RCA Communications were spread over 49 different floors in seven buildings. Different floor elevations, structural deficiencies, and building obsolescence presented major problems for a practical building integration and modernization program.

Although the leasehold on the two parcels of land had a termination date in the year 2026, these leases contained several cumbersome clauses which restricted structural development of a new building.

Studies showed that it was mutually important to RCA Communications and to its customers that the Main Central Telegraph Office and the Headquarters Staff remain in the Financial District. Based upon this decision, RCA Communications proceeded to negotiate for adequate space. On November 20, 1959, after many other negotiations had proved impractical, agreements were executed with Uris Broad and Beaver Corporation. These agreements provided for the sale of land, buildings, and assignment of leaseholds owned by RCA Communications, and a long-term lease to RCA Communications of approximately 250,000 sq ft of space in a new 39-story modern office building to be erected at a cost of approximately $50 million. The space includes the second through the seventh floors, approximately 10,000 sq ft in the basement, and 2,000 sq ft on the first floor with store frontage on Beaver Street. Plans are to sublease on a short-term basis portions of the 4th, 6th, and 7th floors, approximately 60,000 sq ft, which will be recaptured as requirements for expansion develop.

The entire transaction is said to be one of the most complicated ever signed in New York City—in fact, some 26 documents had to be signed at the real estate closing. The Real Estate Board of New York cited the broker for "the most ingenious real estate transaction of 1959." This sale was unique in that Uris Broad & Beaver Corporation was to demolish all the structures except the 66 Broad Street building which housed the main Central Telegraph Office. The one remaining structure was to be integrated with the new building, with a skin installed about the periphery to match that of the new construction. Elevators, stairwells, peripheral walls, shaftways, air conditioning rooms, and plumbing were to be removed in *66* and new floor construction provided. All this was to take place without interfering with the international communications facilities inside the building which operate 24 hours per day, every day of the year.

INTERIM PROGRAM, PROTECTION, AND DEMOLITION

After the lease had been signed in 1959, priority attention was given to the consolidation of operations in 66 Broad Street and to the problem of leasing space in near-by buildings for an interim period to accommodate the auxiliary operating services and the Headquarters Staff. Immediate steps were also taken to protect the personnel and equipment in *66* during the demolition and construction phases of the building program.

It was planned to use the upper floors of *66* for the expansion of operations until the new building space was completed. The equipment installed above the fifth floor would later be transferred by an "in-service" move to lower floors in the new building. This relocation of equipment had to be accomplished within a limited time in order to meet the builder's construction schedule for rehabilitation of the upper floors for other tenants. In anticipation of the future moves to final locations, temporary installations were made so that equipment disconnect and relocation could be accomplished expeditiously.

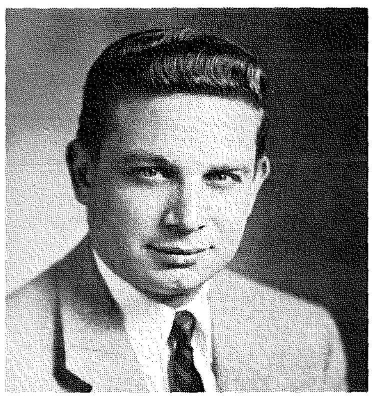
Since the operations were to expand horizontally from old to new building areas on the lower floors, it was essential that floor elevations be identical. Spandrel beams on the peripheral walls of the old building adjoining the new construction presented a problem because they extended 3 to 4 inches above the finished floor. A plan was evolved to cut the webs of these beams to the required height, and then replace structural strength by welding new flanges to the top of the remaining web.

An interim air conditioning system was also designed for *66* to replace cooling capacity lost due to the removal of window units in preparation for the demolition of the peripheral walls. This system also provided additional capacity for new equipment installations on the upper floors. The excessive dust caused by demolition was one of the prime considerations in the design of the interim system. All fresh-air intakes to existing fan rooms were blanked off and these fan rooms, as well as the remainder of the building, were supplied with fresh air from one central point. The air was processed through special filtering equipment, and was precooled to add to the capacity of existing fan rooms. Large air quantities were provided to pressurize the entire building and thereby minimize dust infiltration. Since there was no space available in the *66* basement or on the existing operating floors, two 80-ton air conditioning units with associated evaporative condensers were installed on the roof. The fresh air supply duct was routed down the outside of the building with appropriate tapoffs at each floor.

The replacement of the original and interim air conditioning systems with facilities from the new building presented a formidable engineering challenge. This phase of the installation had to be accomplished while maintaining air conditioning around-the-clock. Since much of the work involved areas that

JAMES M. WALSH graduated from Manhattan College in 1943 with a BEE degree. After military service, Mr. Walsh joined RCA Communications, Inc. as a Jr. Design Engineer. From 1946 to 1956 he was involved with plant design of radio station and antenna installations; 1956 to 1957, Administrative Assistant to the Vice President and Chief Engineer; and 1957 to 1960 Manager, Terminal Facilities-Installation Design. In 1960, Mr. Walsh was promoted to his current position of Manager, Terminal Plant Engineering. His responsibilities include installation design and construction of facilities for system-wide central telegraph offices. He is also responsible for major maintenance of teletype and electronic equipment, installation of wireline facilities, and the operation and maintenance of the air conditioning and electrical plants in the New York Central Telegraph Office. He is a licensed Professional Engineer of New York State, and was a member of the Radio Communications Systems Committee of the AIEE. From 1953 to 1955 he was a member of the evening teaching staff of RCA Institutes.

EUGENE M. GAETANO began his engineering education at Princeton University and later attended the Polytechnic Institute of Brooklyn, where he was awarded the BME, Cum Laude, in 1956. After military service, he joined RCA Communications in 1946 and has held various engineering positions, including Design Engineer and Assistant Manager, Terminal Facilities-Installation Design. In 1960 he was promoted to his current position of Manager, Terminal Facilities-Installation Design. His responsibility is in the installation design of facilities for system-wide central telegraph offices. This includes installation of radio-cable multiplex and channeling equipment, automatic telex and telegraph switching systems, and associated power and air conditioning plants. Mr. Gaetano is a member of the ASME.



were congested with active equipment and operating personnel, a detailed plan and time schedule were prepared and adhered to. The day finally arrived when *66* was completely air conditioned from the new building plant; and the interim system, after meeting requirements for three years, was removed from the roof of the old building.

Demolition of the peripheral walls of *66* was another operation which required extensive engineering attention. An interlocking metal partition was designed and installed in each bay inside the existing brick walls to seal the operating areas from dust and debris. The entire facade was removed and a modern aluminum and glass skin was installed from exterior scaffolding (Figs. 2 and 3). All demolition, the erection of the new skin, and most of the interior finish were completed from the exterior side of the temporary metal partitions to obviate any possibility of interruption to the communications operations.

NEW FACILITIES

After three years of demolition and construction, and the resolution of seemingly endless architectural, electrical, and air conditioning problems, the building was essentially ready for occupancy. Personnel and shops were moved to the new building from temporary quarters in near-by buildings.

Specific requirements of RCA Communications dictated many of the unique features included in the building, and for this reason the area occupied by RCA Communications is often referred to as "a building within a building." This reference is perhaps justified by such obvious factors as the separate address, the private entrance and lobby, and the bank of four private elevators. Several hidden features which contribute to making the RCA Communications portion of the building a separate and distinct entity include special architectural treatment and independent air conditioning and electrical systems.

In order to sustain the weight of the communications equipment, floors were reinforced above minimum office building code requirements. Hung ceilings were specified with an exposed spline carrier so that acoustic tile can be removed in any location, thereby making the space between the hung ceiling and the slab readily accessible for installations and maintenance of facilities.

Several shaftways, including one to the roof, are reserved for the exclusive use of RCA Communications. These shaftways facilitate the installation and maintenance of inter-floor services such as electrical bus ducts, signal cabling, pneumatic tape tubes, and condenser and chilled water piping for the air conditioning system.

A 1500-ton independent air conditioning plant, consisting of three 500-ton electric-driven centrifugal refrigeration machines, was installed to satisfy the novel requirements of the communications center. The communications business necessitates a system which can operate continuously, is extremely reliable, and has built-in emergency back-up facilities. Other special requirements include the circulation of abnormally large quantities of air, special filtering, and precise temperature and humidity control to satisfy the critical operating ranges of the communications equipment. The basic system must also provide cooling during intermediate and winter seasons to offset the high equipment heat loads, and it must be flexible to meet the ever-changing pattern of types and quantities of equipment.

Since the initial load was calculated at approximately 1,000 tons, 500 tons of machine capacity is available as a standby reserve. The relative size of this plant may be obtained by comparing it to the 2,400-ton refrigeration plant installed by the builder to serve the remainder of the building.

The conditioned air is supplied from fifteen fan rooms containing a total of twenty-six separate air handling systems. Office areas may be shut down after hours, while those serving communication areas are operated continuously. Chilled water may be diverted to the air handling systems in the various fan rooms serving critical operating areas in the event of an emergency.

The large air conditioning supply ducts for the operating areas could not be installed above the hung ceiling because the resulting low ceiling height would be intolerable. Therefore, a hung ceiling was installed four inches below the lowest *I*-beam to permit passage of conduits, tape tubes, and pneumatic tubes, and the ducts were mounted below it. Flexibility is insured since ducts may be rerouted to meet changing heat loads without removing ceilings. Streamlined ducts with concealed seams improved the esthetics of the installation.

The basic reasons for an independent air conditioning system are also valid for an independent power supply. Accordingly, a 460/265-volt, 3-phase, 4-wire, 60-cycle system with a special grounding network was installed for exclusive use of RCA Communications.

The main service gear in the basement is supplied from the public utility company 4,500-ampere tabs via high reactance bus ducts. Main switchboard *A* supplies the refrigeration plant in the basement, cooling towers on the roof, and other miscellaneous loads via a 3,000-ampere bus duct. Main switchboard *B* provides power to the first through the sixth floors for all the communications equipment via two 3,000-ampere bus ducts; and for lighting, receptacles and fan room equipment via a 4,000-ampere bus duct. These low-impedance bus ducts are routed up one of the RCA Communications' shaftways to switchgear installed in power distribution rooms on the second through the sixth floors. Parallel switching facilities and protective devices have been incorporated on the load side of switchboard *B* to provide flexibility of operation and to insure transfer of service during preventive maintenance and emergency periods.

Circuit breakers have been installed in the power distribution rooms to facilitate the transfer of the communication loads to any one of the three bus duct risers. Similar facilities are also available to transfer the lighting, receptacle and fan room loads to one of the two communications equipment bus duct risers. The communications equipment is connected to load centers in the various operating areas, which are supplied from the power distribution room. Each load center contains a step-down transformer to reduce the 460/265 volt supply to 208/120 volts. These load centers also contain secondary circuit breakers and bus ties to other load centers to provide further flexibility and protection. In addition, a 120/60 volt rectifier system with spare back-up facilities was installed to provide direct current necessary for communication signal and control.

SUMMARY

RCA Communications expects to share fully in the technological advances ahead and the new communications center has been designed with this in mind. A computer system—an electronic message handling system—will automate the processing of international message telegrams. This equipment will be similar to the RCA 601. Through the more efficient use of facilities and equipment and constant investigation of new methods of operation, service to RCA Communications' customers will be further improved and expanded.

WELDPLATE—A MINIATURE CIRCUIT CONSTRUCTION

J. A. STROM

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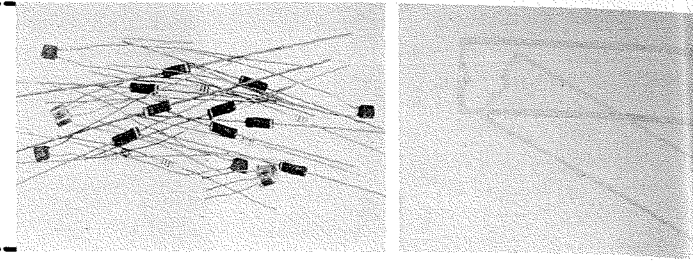


JOHN A. STROM attended Lowell Institute, 1932-1936, and later completed specialized courses while employed by the Division of Industrial Cooperation, Massachusetts Institute of Technology, 1941-1954, as Member of the Technical Staff. Mr. Strom left the Engineering Department of General Radio Company in November 1955 to join the RCA Airborne Systems Laboratory in Waltham, Mass. He is presently Senior Member, Technical Staff, ACCD, Burlington, Mass. He has eleven patent disclosures and one patent pending. He is a member of DEP Design Standards Committee, the IEEE and the IEEE Professional Group on Product Engineering and Production.

To be competitive in electronic equipment, one basic rule applies: *Design for maximum quality at the lowest cost.* With this principle and a number of desirable performance goals in mind, work on the miniature-circuit module to be described herein—the *Weldplate module*—was initiated at ACCD-Burlington in December 1960. At that time, available circuit-module concepts could not meet, or be altered to meet, the many design characteristics sought. The objectives demanded a fresh new concept, designed from the ground up. The Weldplate module design that evolved has had its materials, processes, and standards improved and proved since that time. The result is a competitive product in all respects.

Now, at ACCD-Burlington, an equipment for the U.S. Army Signal Corps is in production. Each of ten systems contain 33 Weldplate modules of thirteen different designs, one of which, a high speed (37-Mc) flip-flop, is illustrated in Figs. 1, 3, and 5. Fig. 2 shows other approaches to the module. Fig. 4 shows an equipment application. Figs. 6 and 7 illustrate production techniques.

DESIGN PROBLEMS AND SOLUTIONS

The early design approach chosen approximated the modules shown in Fig. 2. Upon constructing evaluation models, it was found that yield could be greatly increased by using molded supports for the circuit. One trouble encountered was destruction of semiconductors caused by an occasional high resistance weld cycle. The contributing factor was the presence of a short provided by the support area of the plate. Excessive voltage was applied to the semiconductor and burnout resulted. The answer to this problem was to design a molded glass-fiber filled dialyl phthalate support that could be used in pairs to support the circuit. Now, the support area of the plate is sheared off before the active parts are welded in place.

This approach at the same time solved another problem area—that of the encapsulation mold. A number of molds were required, their life was short, and they involved considerable clean up time. The molded supports now become a dam for potting. After electrical test a piece of Scotch tape No. 810 is adhered to one side, and resin is poured in the other. Cleanup is simple—the tape is just stripped off when the resin is cured.

Layout of the Weldplate may be compared to standard printed-circuit techniques. A standard 0.025 grid was chosen and has accommodated all circuits designed. Spacing is normally 0.025; however, when additional heat removal is required, 0.012 may be used. The encapsulant provides an adequate breakdown barrier. Component mounting lengths are reduced, and there are no curves or holes to locate. Only tape is used to produce the rectangular patterns of the photomaster (Fig. 1).

A reproduction of the photomaster, at an appropriate scale, is further worked to provide an assembly drawing (Fig. 5) with associated material list. Pertinent information is also noted on this drawing.

The plate is an alloy of 70% copper, 30% nickel chosen for weldability, solderability, and good etching and stamping qualities—and as a heat-transfer medium compatible with these four fabrication criteria. The plate material is supplied in flat strips 0.010 inch thick and 3 inches wide, the long dimension of the standard 2 x 3 Weldplate. Six plates are obtained from 1 lineal foot of this strip at a small-quantity cost of 8.3¢ each. (The price is 3.3¢ each in large quantities.) These figures are attractive when compared to printed-circuit or weld-stick techniques.

The encapsulant is also used as a cement for joining the molded supports to the plate. The resin chosen is clear, for identification purposes, and is of very low viscosity. It is a three-component Epon system which may be oven cured at 90°C in 2 hours when used as a cement. For encapsulation, the same formula is used, and will set in 3 to 4 hours at room temperature. The exotherm is very low at the volume level used.

ASSEMBLY AND TEST

Components are 100% tested before use to ensure circuit parameters and eliminate in-line rework. The yield is very high. Each part lead is precut and formed with tools designed by ACCD-Burlington manufacturing personnel. Such precutting reduces the time the weldplate module is at the weld station during assembly. For large

Fig. 1—Photomaster.

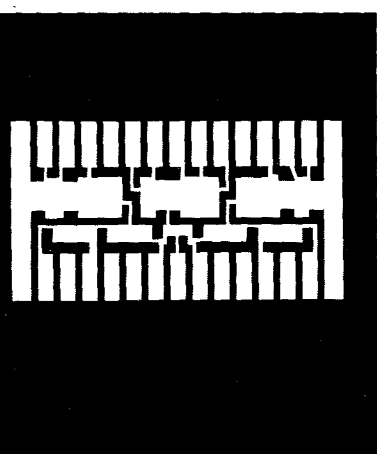
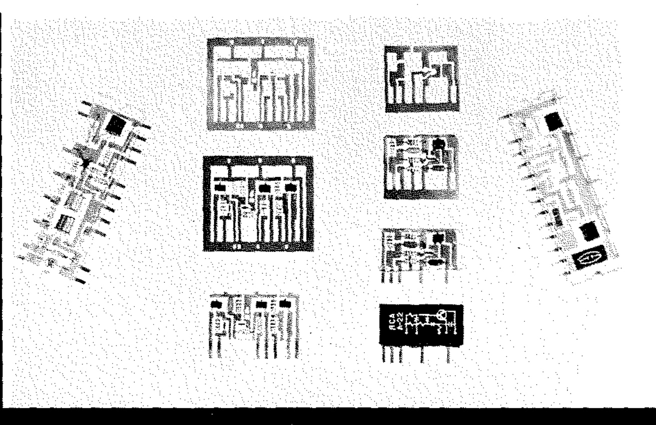


Fig. 2—Other designs.



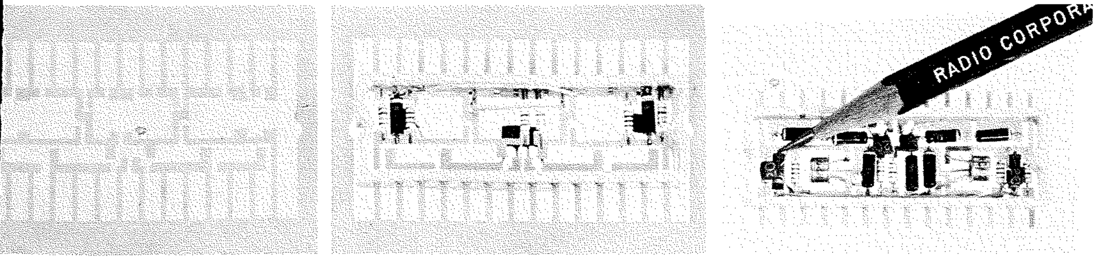


Fig. 3—Weldplate module.

quantities, mechanization is envisioned as using a vacuum jig to hold parts in place. This jig becomes the lower electrode of the welding machine, and is programmed in X and Y coordinates. A control tape transport may also program the weld cycle.

At present, weld schedules are developed by manufacturing personnel, while a quality-control group evaluates welds on a sampling basis in which each joint is inspected under a microscope.

An assembly jig (Fig. 7) is used in production to hold the molded supports on either side of the plate while the cement cures. The small pins protruding from the base hold each part in alignment. Nine modules are processed at a time. Each jig completes 36 modules in an 8-hour period. The upper and lower supports are identical, so only one type is required in stock.

Electrical test is dynamic and is performed in a jig (Fig. 6). The contacts are berylium copper with a final rhodium plating. It is adaptable to automatic-checkout equipments.

Encapsulation, as described earlier, is simple. The resin is poured in a thin stream at the center of the module. As the resin flows to the sides air is excluded so that no bubbles are entrapped. One or many Weldplates may be encapsulated at a time.

CONCLUSION

In addition to the features listed in Table I, the Weldplate geometry lends itself to packaging techniques of many varieties when compared to some other types of modules. This is especially true of three-dimension types having leads on one side that are spaced so that interconnection is difficult. Usually they require multilayer printed circuit parent boards or, as in some designs, a module nest. The Weldplate mounting is simple, as are interconnections (Fig. 4). Test points are readily available.

Flexibility of design in Weldplates allows a wide choice of function termination. Where required, internal jumpers are used (nickel wire 0.015-inch diameter with 0.004-inch Teflon insulation). The 28 terminations offer great flexibility.

TABLE I—WELDPLATE FEATURES

1. Two-dimension design, simplifying layout procedure, drafting requirements, and manufacturing methods.
2. Uses approved, available, and reliable parts of miniature and micro-miniature types. Available parts reduce delivery schedules.
3. Used commercially proven materials and processes. Eliminates complex procedures and methods.
4. Adaptable to design standards and programmed assembly by mechanization.
5. May use three alternate methods to produce the plate; by sand abrading, etching, or stamping. Breakout quantity for use of punch and die is 26,000 pieces. Present production quantities use a double side ferric chloride etch.
6. Designed so that component parts are resistance welded in place, thus taking advantage of increased joint reliability and strength. In the absence of welding equipment, parts may be soldered in place for laboratory use.
7. May be tested and easily repaired prior to encapsulation. Three dimensional designs are difficult, and sometimes impossible to repair; the cost, in these cases, is prohibitive.
8. No encapsulation molds are used. The molded supports become the potting dam.
9. Weldplate geometry lends itself to a multitude of packaging techniques. The half holes at each end enhance this feature.
10. The standard 28-lead terminations eases the design and interconnection problems (Fig. 4). If desired, connectors may be used, either for swift replacement at the module level, or for electrical test. The inexpensive test fixture shown in Fig. 6 is presently in use.
11. Maximum internal heat sink and positive method of heat transfer is provided by the plate, an alloy of 70% copper, 30% nickel. Although some leads may have no function and may be removed, more cooling is available when left in place.
12. Weldplate is a highly competitive product. Compared with some other module designs, Weldplate modules can effect significant savings in manufacturing costs both small and large quantities. Tooling is presently available for the standard Weldplate, and no additional charge is anticipated.
13. Excellent volumetric efficiency. One design achieves a component density of 345,600 per cubic foot. Micro-transistors and micro-diodes are used, and leads are limited to one edge; this module is 0.10 inch thick.

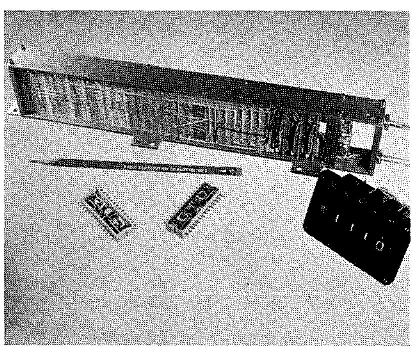


Fig. 4—Weldplate equipment.

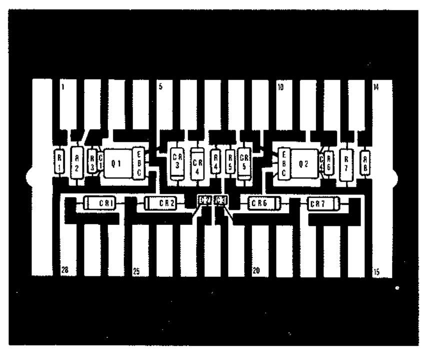


Fig. 5—Assembly drawing.

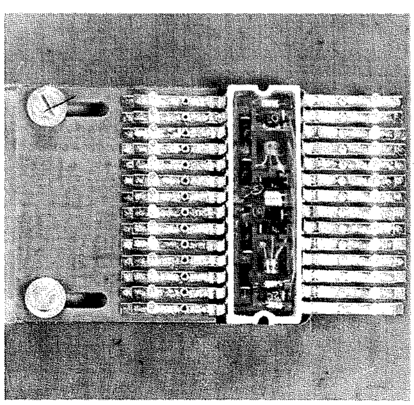


Fig. 6—Test jig.

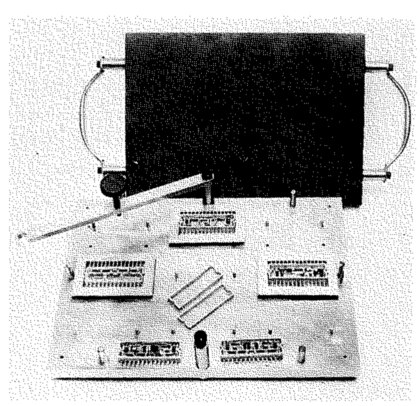


Fig. 7—Assembly jig.

NEW ULTRA-LOW-NOISE PARAMP . . . 1.5 db at 3 Gc

Early parametric amplifiers had noise figures ranging from 4 to 5 db in S-band, partly as a result of lossy circulators, inadequate varactors, and circuits of excessive complexity. Subsequent improvements in circuit design and components resulted in reproducible noise figures in the range of 2.5 to 3.5 db. The developmental parametric amplifier (paramp) described in this paper has further reduced the operational noise figure to the 1.5-to-2-db range at 3 Gc, a range close to the theoretical minimum. This performance, which can be achieved over substantial bandwidths, has been obtained by the use of a low-forward-loss garnet circulator and a KU-band pump, as well as optimum circuit design and excellent coupling to the varactor at the signal, idler, and pump frequencies. In addition to low noise figure, the paramp has a stable 2 percent bandwidth.

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PARAMETRIC AMPLIFIERS (paramps) have been under development in several RCA divisions since the first use of varactor paramps—as a result of a pioneering analysis published by Bloom and Chang[1] of the RCA Laboratories. Work by Matthews, Luksch, and Ver Wys[2] at Defense Electronics Products in Moorestown culminated in the development of UHF and L-band paramps, the former consisting of a parametric upconverter used in BMEWS. At the DEP Surface Communications Systems Laboratory in New York City, Pettai, Bossard, and Weisbaum[3] achieved 10-percent bandwidths in the UHF band with a parametric upconverter in 1959; Pettai and Bossard[4] continued this work and announced almost half-octave bandwidths in S-band in 1962.

In the Electron Tube Division, Sterzer and Eckart[5] devised an upconverter-downconverter type of circuit, and Cuccia and Chang[6] (from work previously done by Chang at RCA Laboratories) developed a helix-type paramp. During this period, Kampf and others in Defense Electronic Products in Camden developed an X-band paramp, and a group under Bussgang at DEP in Burlington, Mass., conducted extensive system tests on paramps relating to stability and phase tracking.

All of these efforts have contributed to the design of the new ultra-low-noise paramp described herein. It incorporates features of the BMEWS paramp (the basis of the extremely low-noise idler circuit) and the SurfCom paramp, (used in the input circuit).

NONDEGENERATE DESIGN

The developmental parametric amplifier shown in Fig. 1 conforms basically to the classical three-frequency nondegenerate model in which an RF signal frequency and an RF pump frequency are applied to a varactor in a circuit structure which also supports a difference, or idler, frequency across the varactor. The result is amplification of the signal frequency. The new paramp has a signal frequency of 3 Gc, a pump frequency of 17 Gc, and an idler frequency of 14 Gc. Because both idler and pump frequencies are in KU-band, the circuits use KU-band waveguides. The signal circuit at 3 Gc uses a coaxial-line structure.

Fig. 1 shows the compact structure of the ultra-low-noise paramp. Excluding the pump-circuit power supply, the structure is suitable for installation in an enclosure only 6 by 6 by 11 inches. The pump circuit includes a klystron, immersed in an oil bath on which the paramp is mounted.

Fig. 2 shows the general circuit of the paramp structure. The pump circuit includes a KU-band klystron, a KU-band isolator, an attenuator, a directional coupler and crystal used to measure pump power, and a pump filter and transducer which couple the pump to the varactor. The idler circuit consists of a 14-Gc cavity resonator and tuner. The varactor is positioned at an optimum match point to permit transmission of the pump signal through the cavity to the varactor.

The input-signal circuit includes a specially designed four-port circulator. The paramp is coupled to the second port of the circulator through an impedance transformer and pump filter. The circulator includes a DC block permitting a bias voltage to be applied to the varactor. The circulator has a forward insertion loss of the order of 0.1 db. This low-loss performance, together with high reverse insertion loss, is an important factor in the ultra-low-noise characteristic.

The input-signal circuit includes a lowpass filter of the coaxial type described by Cuccia and Hegbar[7] and by Cohn[8] during the 1940's. This filter consists of a disk-loaded coaxial line with a cutoff frequency sufficient to prevent leakage of idler and pump energy into the input signal circuit. The use of this filter in association with the varactor in a paramp (Fig. 3) was first proposed by Kurzrok[9] in 1959.

A ten-turn Duo-Dial is used to tune the idler cavity and change frequency of amplification; *this adjustment is the only tuning required.*

Replacement of varactor diodes is facilitated by a large knurled knob opposite the coaxial input line. When the knob is unscrewed, the diode and its spring-chuck mounting can be removed. The parts are designed to insure positive seating and locking. The entire structure is bracketed together for rigidity, and can be bolted to a heat-transfer surface which is in contact with the flanged bottom of the oil bath.

The paramp requires only the klystron power supply for stable, reliable operation at ultra-low-noise figures substantially below 2 db at 3 Gc. The design of the paramp permits operation at other frequencies in the ranges from 1 to 5 Gc with only minor changes in the circulator and the input circuit, and a shift in the klystron frequency.

STABLE PUMP

The KU-band Klystron that supplies the pump power is immersed in an oil bath for temperature and frequency stabilization and does not require forced-air cooling. The use of an oil bath for the klystron, which operates at approximately 17 Gc with a power output of less than 50 mw, is an effective method of stabilizing klystron frequency and power and preventing deterioration of performance and reliability. Fig. 4 shows a typical curve of frequency and temperature for a klystron operated in an oil bath. Ten to fifteen minutes after being turned on, the klystron temperature stabilizes at 55°C, the oil bath case at 40°C and the frequency variation at approximately 1 Mc.

Temperature stabilization of the klystron is no *substitute* for a voltage-stabilized klystron power supply; however, it reduces the demands made on the klystron power supply.

VARACTORS

After the design had been optimized and excellent matching to the varactor had been achieved in the signal, idler, and pump circuits of the paramp, it was evident that extremely high-cutoff varactors were not required. The double-ended cartridge-type varactors (manufactured by Semiconductor Devices Inc., Newport Beach, California) which were used had cutoff frequencies of the order of 70 Gc at zero bias and capacitances of approximately 0.8 pf. The use of large double-ended cartridges in KU-band waveguide eased, to a great extent, the problems of mounting, handling, and replacement normally encountered with pill-type varactors.

NOISE FIGURE AND PUMP FREQUENCY

The noise figure of a paramp depends on the insertion losses of the circulator and input circuit and the noise contributed by the varactor and idler circuit. These losses, in the order of 1 db, add to the fundamental minimum theoretical noise figure established by the ratio of idler frequency to signal frequency.

The lowest noise figure, NF, which a parametric amplifier can provide when operated at ambient room temperature and with a lossless input circuit, circulator, and idler cavity can be calculated from[1]:

$$NF = 1 + \frac{Ws}{Wi}$$

where: Ws and Wi represent the signal and idler frequencies, respectively. For a signal frequency of 3 Gc and an idler frequency of 14 Gc, the noise figure of the lossless paramp is 1.214, or 0.85 db. This value is the excess idler noise.

For a practical paramp circuit, the losses and noise which directly contribute to the noise figure are:

Forward insertion loss of input port to paramp port of circulator	0.15 db
Excess idler noise (see above)	0.85 db
Input filter loss	0.10 db
Idler cavity wall loss (approx.)	0.05 db
Varactor resistive loss (approx.)	0.05 db
Misc. Connector losses in input circuit	0.05 db
(Total paramp theoretical noise figure)	1.25 db

Thus, the 1.3-to-1.9-db noise figure measured for the paramp, when the varactor is at room temperature, approach theoretical optimum performance.

PERFORMANCE

The performance of the paramp was measured with the three different varactors (listed in Table I). Gain measurements were made with a swept-frequency system in which the gain-versus-frequency characteristics were displayed on the calibrated face of an oscilloscope. The klystron was powered with a laboratory-type universal klystron power supply.

Noise figure was measured in a circuit in which the paramp was used to drive an S-band low-noise traveling-wave tube. The traveling-wave tube was operated at substantial gain to minimize noise-figure deterioriation in the stage following the paramp and to provide the paramp with a stable load.

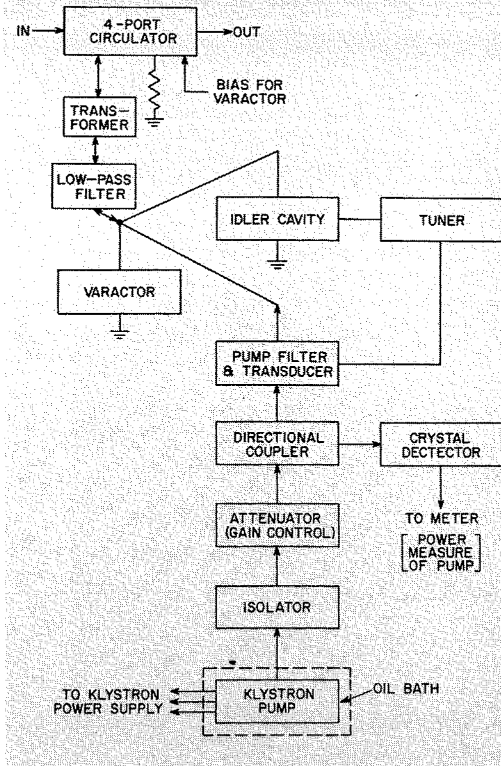
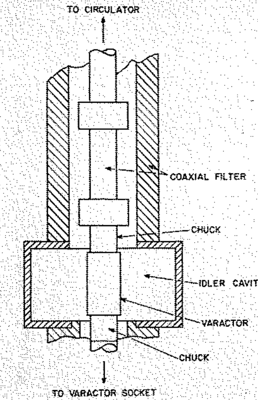


Fig. 2—Elements of the paramp.

Fig. 3—Low-pass coaxial filter and varactor structure used in the signal input circuit.



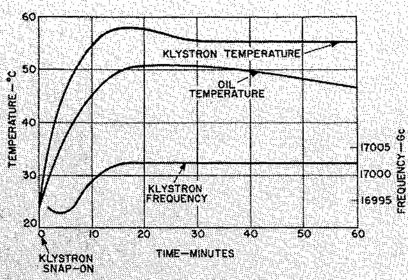


Fig. 4—Frequency and temperature vs. time for klystron in the oil bath of the developmental paramp.

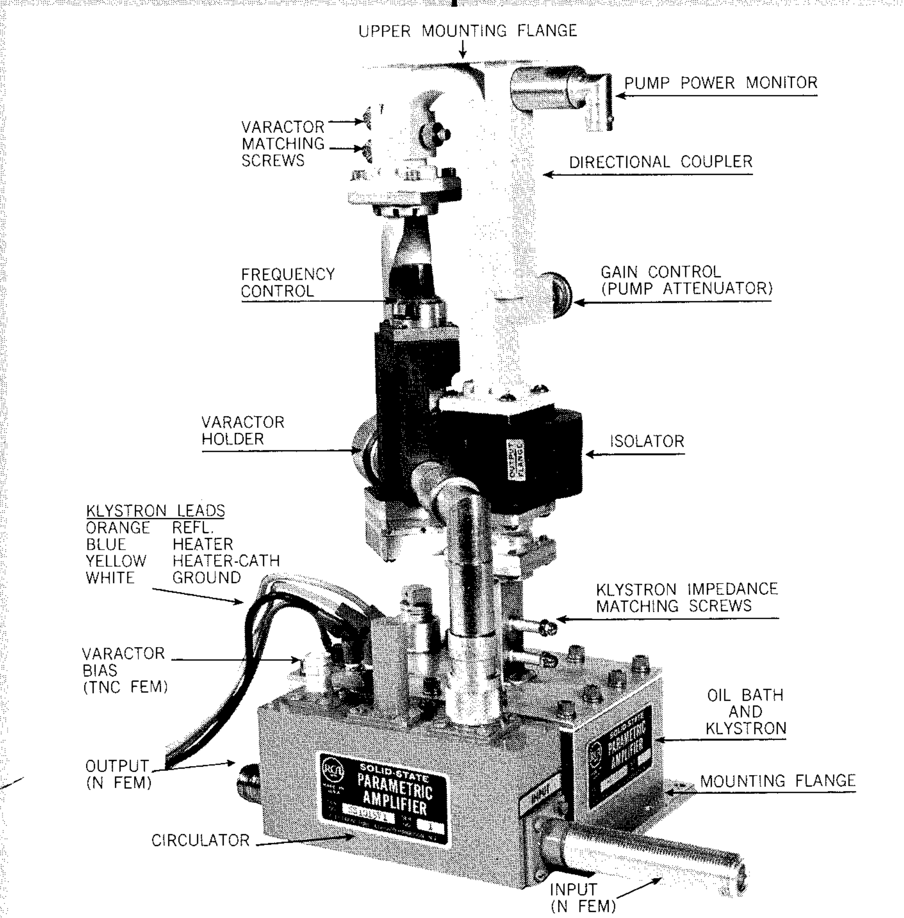


Fig. 1—The RCA developmental ultra-low-noise S-band paramps.

TABLE I — PARAMP PERFORMANCE

Varactor Number*	Center Freq. *Gc*	Band-width *Mc*	Gain *db*	Noise Figure *db*	Varactor Bias *Volts*	Klystron Beam *Volts*	Klystron Beam *ma*	Klystron Reflector *Volts*	Pump Frequency *Gc*	Pump Power *mw*
685	3	53	17	1.9	+0.7	570	52	175	17.05	40
710	3	45	17	1.5	+0.7	570	52	175	17.05	40
709	3	60	17	1.5	+0.5	570	51	175	17.05	15

*These diodes are manufactured by Semiconductor Devices, Inc. and have cutoff frequencies of the order of 70 Gc and capacitances of approximately 0.8 pf, measured at zero bias.

Noise figure was measured with a Hewlett-Packard Model 340B noise-figure meter operated with a calibrated noise source. The test sėtup was calibrated with noise figures that are accurately determined by the hot-and-cold-load method.

The three varactors listed in Table I were interchanged in the paramp with no retuning. Single-channel noise figures of 1.5 db were obtained with two of the varactors; the third provided a noise figure of 1.9 db. These extremely low noise figures have been corroborated in actual field testing of models of the paramp.

With the signal and idler circuits single-tuned, bandwidths in the 45 to 70 Mc range were measured. The bandwidth was extremely stable for normal operating temperatures of 40°C. With the paramp heated to 70°C, no gain change was observed, and the shift in center frequency was less than 3 Mc. During repeated tests of several models of the paramp, valid single-channel noise figures as low as 1.3 db were measured under highly stable operating conditions with the amplifier operated for many hours. Occasional snap-on and snap-off were introduced without change in any operating parameter.

When double tuning was used in the signal and idler circuits, bandwidths as great as 100 Mc were observed without increase in noise figure, and bandwidths as large as 200 Mc were measured with the noise figure still in the 2-db range. The latter measurements, obtained with a pill type varactor, indicate the capability of the paramp.

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7. C. Cuccia and H. Hegbar, "An Ultra-High-Frequency Low-Pass Filter of Coaxial Construction," *RCA Review*, Dec. 1947.
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ACKNOWLEDGEMENTS

The writers wish to acknowledge the aid of A. Solomon of RCA Semiconductor and Materials Division for his contributions in specification and evaluation of varactors for low noise performance, and to B. Bossard of RCA Surface Communications Division for contributions to the signal input circuit of the amplifier.

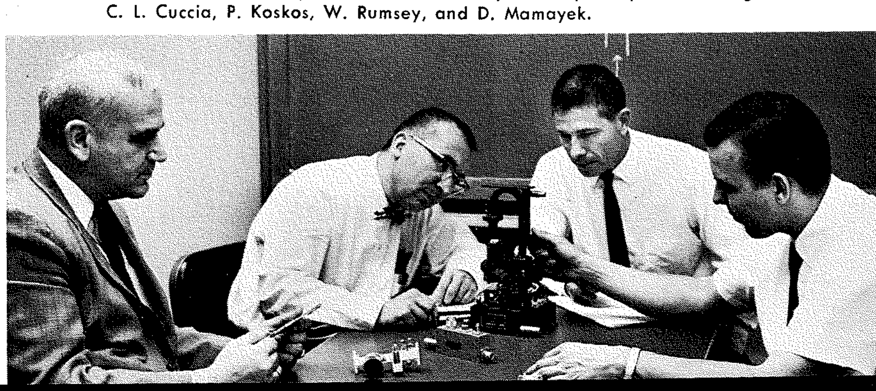
PAUL KOSKOS received his BSEE from Columbia University in 1943, and the MEE from New York University in 1956. From 1943 to 1949, he was product Engineer on Carrier Tubes at the Western Electric Co. During 1949 and 1950, he worked as a development engineer on Geiger tubes for Bendix Aviation, Inc. From 1950 to 1957, he worked for Sylvania Electric Products, Inc., as the engineer in charge of fuze-tube and gas-tube engineering and development of ceramic-metal stacked receiving tubes. From 1957 to 1958 he was with General Electric Company, and was responsible for development of a 10-watt, 1000-Mc ceramic-metal tetrode. He joined the RCA Microwave Tube Engineering in Harrison in 1958 and became project manager on the design, development, and manufacture of four types of traveling-wave-tubes. In 1961, he transferred to the RCA West Coast Microwave Engineering Laboratory. In 1962, he was project engineer on the successful development of a very-low-noise S-band parametric amplifier. He is now project engineer in charge of developing an advanced L-band parametric amplifier. Mr. Koskos holds a number of patents on his work, has published several papers, and taught Electrical Engineering for several years as a member of the evening staff of the Polytechnic Institute of Brooklyn. He is a member of the IEEE.

D. MAMAYEK received his BSEE from California State Polytechnic College in May 1961. For his senior project he made an analysis of a microwave parametric amplifier, and during his senior year he taught a course in microwave components. In 1959 he worked as a development engineer for the Convair Division of General Dynamics Corporation on dielectric-filled waveguides and miniature microwave components. From 1959 to 1960, he worked as a microwave engineer for the DeMornay-Bonardi Corporation. He then joined the RCA West Coast Microwave Engineering Laboratory after his graduation in 1961. He has worked on a 1.5-watt, 300-Mc transistor amplifier-varactor frequency doubler, and on a 1.5-db-noise-figure S-Band parametric amplifier. He was project engineer in the development of an X-Band parametric amplifier and a variable power C-Band frequency multiplier. He is now responsible for final packaging and qualification of an advanced L-Band parametric amplifier. Mr. Mamayek is a member of the IEEE.

W. E. RUMSEY, JR., received his BSEE from the West Coast University College of Engineering at Los Angeles in 1953. He joined Douglas Aircraft as a member of the Antenna Laboratory Staff and became Project Engineer on Radome Development and Evaluation in 1954. He joined the North American Aviation's Antenna and Microwave Unit in 1956, and engaged in Microwave Antenna development for research vehicles. In 1957 he was transferred to the newly formed Autonetics Division as a member of the Fire Control Group. From 1958 to 1959, he did research on high-power breakdown of microwave-frequency antennas at extreme altitude and temperature conditions. He joined the RCA West Coast Microwave Engineering Laboratory in mid-1961. He has worked on tunnel-diode circuit development, designed a 300-Mc solid-state amplifier, and completed a study of a high-power frequency converter at S-band. He is now assigned to parametric amplifier development. Mr. Rumsey has written several papers on antenna techniques and radome evaluation. He is a member of the IEEE.

C. L. CUCCIA received his BSEE from the University of Michigan in 1941, and the MS from the University in 1942. He has also done graduate work in theoretical physics at Princeton University. He joined RCA in 1942 as a development engineer at the RCA Laboratories, Princeton, New Jersey. He produced the first 2J51 magnetron; developed new frequency-modulated magnetrons and injection-locked, grid-controlled magnetrons; and was one of the pioneers in the development of a type of high-power, transverse-field traveling-wave tube known as the "Electron Coupler". From 1954 to 1957, he worked as an engineer in the color-television activity of the RCA Patent Department. In 1957, he joined the RCA Microwave Tube Operations at Harrison, and was put in charge of all traveling-wave-tube and backward-wave-oscillator design and development. Since 1960, he has been manager of the RCA West Coast Microwave Engineering Laboratory, which is engaged in the design and development of new solid-state parametric amplifiers and tunnel-diode oscillators. Mr. Cuccia has written more than 30 articles and has received 25 patents for his work on microwave tubes and circuits. In addition, he has 9 patents pending. He is the author of a book entitled "Harmonics, Sidebands, and Transients in Communications Engineering", published by the McGraw-Hill Book Company in 1952. In addition, he has taught courses in Electronics at Rutgers University. He is a member of the IEEE, and is currently Vice Chairman of the Los Angeles Chapter of the IEEE Professional-Technical Group on Microwave Theory and Techniques.

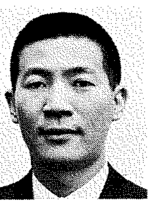
The authors with components of the developmental paramp. Left to Right: C. L. Cuccia, P. Koskos, W. Rumsey, and D. Mamayek.



Engineering and Research NOTES

BRIEF TECHNICAL PAPERS OF CURRENT INTEREST

New High-Frequency Silicon Power Transistor




Z. F. CHANG AND
S. SILVERSTEIN,
Semiconductor and Materials Division, Somerville, N. J.

The developmental device described in this *Note* is unique in that it combines excellent high-frequency performance with outstanding power-handling capability. It adds an entirely new area to today's family of high-frequency transistors, and permits applications which are not feasible using presently available commercial transistors. The high-frequency transistors now on the market have substantially more-limited current and voltage ratings.

The new construction features of this mesa transistor (RCA Dev. No. TA2110) make it possible to control breakdown voltage and frequency response independently. This independent action is not possible in a simultaneously diffused or alloy transistor. The *NPIN* structure of this developmental transistor is produced by use of a triple-diffusion technique, which permits variation of the high-resistivity or intrinsic layer *I* to control the breakdown voltage. The frequency response can be independently controlled by variation of the base width. In addition, the base region can be highly doped to reduce the equivalent base-lead resistance r_{bb}' and increase the punch-through voltage.

Fig. 1 shows an exploded view of the device. The interdigitated pattern of the emitter and base provides a long emitter periphery which is responsible for the high current-handling capability and excellent current gain. At higher current densities, injection of carriers takes place essentially at the emitter edge only, because the transverse field initiated by the base current flows outward from under the active emitter region.

A molybdenum platform is used to match the thermal expansion of the silicon die to that of the copper header. The mounting technique employed results in a junction-to-case thermal resistance of less than 1°C/watt. Adequate protection for currents up to 35 amperes is provided by the large gold straps which connect the active device to the emitter and base lead terminals.

Fig. 1 shows the device mounted in an industry-accepted cold-seal, double-ended stud package. The shell features high-strength ceramic seals in the feedthrough terminal leads. The zirconium-copper stud permits a torque limit on the threads of 75 inch-pounds. Case leaks and troublesome weld splash, which are normally associated with semiconductor transistor packages, are virtually eliminated by the cold-seal technique; thus the reliability of the transistor is enhanced. All finished units are subjected to severe conditioning tests, including a 100-percent helium leak check and drop test, prior to shipment.

Much new technology has been applied to the development and manufacture of this transistor. Diffusion, photo-engraving, evaporation, bonding, and other techniques have been adapted to standard manufacturing practices and then performed by skilled production operators. This standardizing was accomplished without loss of the precision and care essential for the fabrication of this class of device.

The unique RCA Dev. No. TA2110 operating-range chart (Fig. 2) completely defines the operating region of the device. The upper boundary of the operating range is defined in terms of the maximum period of time for which the desired voltage and current can be simultaneously applied. Circuit design within the rated conditions can assure freedom from *second breakdown*—which occurs in all transistors, and is characterized by an abrupt reduction in collector-to-emitter voltage V_{CE} when the transistor is swept through its collector voltage current characteristics. A pre-processing test which measures second breakdown insures that it will not occur within the region defined by Fig. 2. The locus of second-breakdown current has been determined empirically for this device as $I_{SB} = KV^{-2.66}$, where: $K = 5.25 \times 10^4$ watts. The low saturation resistance of 0.1 ohm and beta of 12 at a collector current of 10 amperes, together with the 400-volt collector-to-base breakdown, make the TA2110 ideal for switching an inductive load, such as the yoke of a cathode-ray-tube deflection circuit. The high-frequency response of the device ($fT = 20$ Mc), and its high power-capability ($P_{max} = 175$ watts), can be utilized to increase the efficiency of a pulse-width-modulated regulator. Samples distributed to the field for such industrial and military designs have generated favorable response. Other applications include the output stage of an all-transistorized AM transmitter, power oscillators, and other forms of power amplifiers.[1]

1. For less-stringent circuit requirements, the RCA Dev. No. TA2314 can fulfill most designers' needs. The TA2314 also has outstanding characteristics, such as a collector-to-base voltage (with emitter open) of 300 volts, a saturation resistance of 0.15 ohm, and a common-emitter forward current-transfer ratio of 10 at a collector current of 10 amperes.

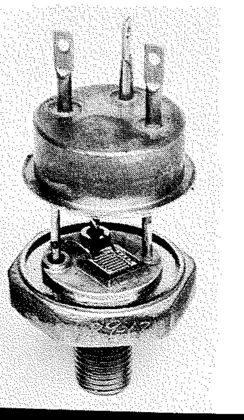


Fig. 1—"Exploded" view RCA Dev. No. TA2110 high-frequency silicon power transistor.

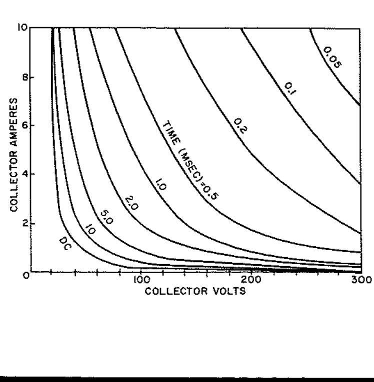


Fig. 2—Safe operating range vs. pulse width or steady-state time duration (25°C case temperature).

A Method of Determining the Conductivity Type of Compound Semiconductors

by DR. F. H. NICOLL,
RCA Laboratories, Princeton, N. J.

Compound semiconductors, such as gallium arsenide and gallium phosphide, are used in radiation-resistant solar cells, in diodes and transistors that must withstand high temperatures, and in electrically-pumped semiconductor lasers. There has now been developed a simple, practical method of determining whether the current in a compound semiconductor is predominantly carried by electrons (n-type conductivity) or by holes (p-type conductivity). Knowledge of the conductivity type is vital when impurities are to be introduced into a semiconductor to tailor it for device use.

The standard scientific method for determining conductivity type is the Hall method, in which the carriers are identified by the direction in which they are deflected by a magnetic field. However, this method is delicate and time consuming. A simpler method has been used for many years on germanium and silicon. Here, a heated point is pressed against the surface of the material to give a temperature difference through the sample; this temperature difference develops a thermoelectric current that is in opposite directions for a n-type and p-type materials. Unfortunately, the thermoelectric currents are too small to give reliable results for compound semiconductors.

The new method has been developed by the author with help from A. Keenan and R. M. Williams. It uses two point-electrodes pressed against the sample (Fig. 1). One point, held at room temperature, forms a point-contact rectifier; the other, heated to about 200°C, forms an ordinary ohmic contact to complete the circuit through the sample. A low voltage source of AC between the points gives half-wave rectification at the point contact in a direction that depends on whether the sample is n-type or p-type. A center-zero DC microammeter in series with the circuit then indicates the conductivity type directly.

The new method has proved to be particularly useful in work

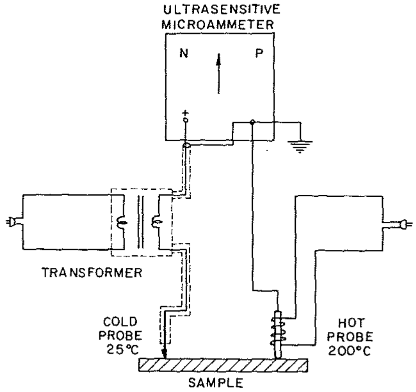


Fig. 1—Probe for determining conductivity type.

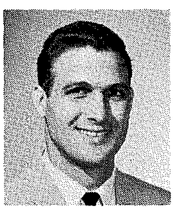
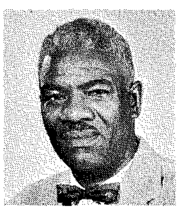
on gallium arsenide epitaxial layers on germanium. In this case, the layers were shown to be n-type rather than p-type because of the unexpected doping by the germanium. As the work has continued, the technique has been applied to [gallium arsenide]-[gallium phosphide] alloys and to gallium phosphide itself. In this way it has contributed to the development of semiconductor injection lasers and light-emitting diodes.

The Semiconductor and Materials Division has duplicated our equipment and is using it in work on methods of preparing gallium arsenide. They have found that the method not only will indicate the conductivity type but also will give the approximate electron or hole concentration in the sample.

1. A. Keenan, F. H. Nicoll, and R. M. Williams, RCA Labs., *Private Communication*.

A Novel Micromodule Ejection Tool

by G. Rezek, F. Cavalier, and C. Coates, *Surface Communications Division, DEP, Camden, N. J.*

An important consideration in micromodule construction is the need for an economical micromodule replacement procedure. A micromodule ejection tool was designed and constructed by the authors to fill this need. The requirements for unsoldering and removal of a micromodule from a printed-circuit board are:

1) The local temperature to which the particular micromodule pattern is exposed must be of proper magnitude. If it is too high, the board material may be burned. Delamination of copper conductors may also occur.
2) Most effective and uniform heat transfer from the unsoldering tool to each of the riser wires must be assured. If any of the twelve holes of the module pattern is underheated, the module cannot be separated from the board.
3) The force applied to remove a micromodule while unsoldering must be of controlled and limited magnitude. Too great a force would cause stripping of the metal in a plated-through hole.

These requirements dictated certain relatively minor considerations in micromodule printed-circuit-board design.

1) The circuit-board hole pattern for each micromodule includes not only the eyeleted plated holes for connection of the peripheral riser wires, but also an access hole directly under the center of the micromodule.
2) Riser wires protrude only 0.025 inch beyond the soldering face of the circuit board and they are not clinched or distorted.

Since micromodules can be removed by dipping the soldered side of an assembled circuit board in a solder bath, the problem thus resolved itself to one of constructing a small portable solder bath—temperature-controlled and fitted to apply the proper removal pressure to the micromodule.

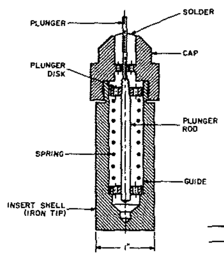


Fig. 1—Unsoldering and ejector head.

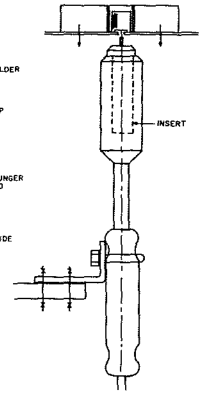


Fig. 2—Unsoldering and ejecting technique.

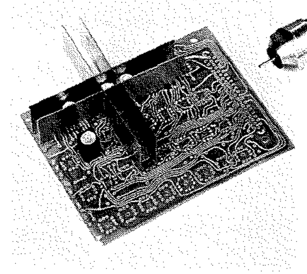
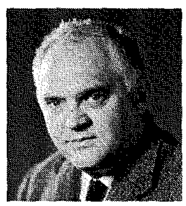


Fig. 3—Ejector tool, and ejection guide in position on a micromodule printed-circuit board.

The tool (Fig. 1) evolved as a special insert for a Vulcan type 75, 300-watt soldering tool. The insert contains a pool of solder maintained in the molten state. With the tool clamped in a vertical position, lowering the assembled board onto the insert as shown in Fig. 2 introduces the riser-wire tips into the pool of solder. Simultaneously, the plunger passes through the access hole in the board, and with the temperature of the solder at 544°F and the plunger exerting a pressure of 8 pounds/inch of deflection, the micromodule is ejected almost instantly. An ejection guide (Fig. 3), prevents the micromodule from becoming cocked during ejection.

Certain refinements in the tool have been proposed and implemented. These include sensing the temperature of the solder pool and regulating the supply voltage to maintain a stated temperature. An indexing fixture has been proposed to insure quick accurate positioning of the tool. Since the pool of solder occupies the entire head of the tool (except for the plunger area) the tool is useable with any known riser wire configuration. The tool, which was designed with the 12-wire micromodule in mind, is now being used with the various 28-pin advanced micromodule configurations.

A Solid-State Traveling-Wave Amplifier



by Roland W. Smith, *RCA Laboratories, Princeton, N. J.*

In the course of a fundamental study of semiconductors at the RCA Laboratories, we have found new evidence of an interaction between electrons and gigacycle acoustic waves. An experimental observation was merely that the current through a piezoelectric semiconductor such as cadmium sulfide increases according to Ohms law at low electric fields, but then saturates sharply at a field that depends on the mobility of the carriers in the sample. The interpretation of this result has uncovered a *heretofore unknown mechanism.*

It was found, first, that the electron velocity at the saturation field is equal to the velocity of sound in the crystal, which suggested an interaction with acoustic waves. There are acoustic waves with a wide range of frequencies, in any crystal, arising from thermal vibrations of the crystal lattice. It is believed that as the electrons and the sound waves move along together, the electrons are bunched in the troughs of the acoustic waves by the local piezoelectric fields. Entrained in the acoustic waves, the bunched electrons are constrained to move with the velocity of sound, even at higher fields. With the velocity of the carriers thus limited, the current saturates.

Bunching of the electrons in the troughs of the acoustic waves would have an important consequence. The bunched electrons push on the acoustic waves, continuously exciting the waves to greater amplitude. The acoustic wave is thus amplified. The band of frequencies amplified depends on the crystal conductivity and the carrier mobility. For the cadmium sulfide crystals used, this frequency band is about a gigacycle (10^9 cps).

This simple solid-state device is in several respects analogous to the more familiar traveling-wave tube. Additional theoretical and experimental work is continuing on the interaction of electrons and acoustic waves.

Thermocouple Attachment With Convenience and Accuracy

by R. C. TURNER AND G. D. GORDON, *Astro-Electronics Division, DEP, Princeton, N. J.*

A new thermocouple attachment method has been developed foı spacecraft tests, to measure surface temperatures. The assembly can conveniently be attached with slight pressure to any solid surface. Tests show higher accuracy than most methods commonly used.

In thermal vacuum tests of spacecraft, temperatures are measured at many internal points. A variety of methods have been used to attach thermocouples for this purpose. They should be easily installed and removed, and be unaffected by incident radiation or by the rate of change of surface temperature. The thermocouple described here has a few novel features, has proved practical in use with spacecraft tests, and has been tested and found to be surprisingly independent of incident radiation.

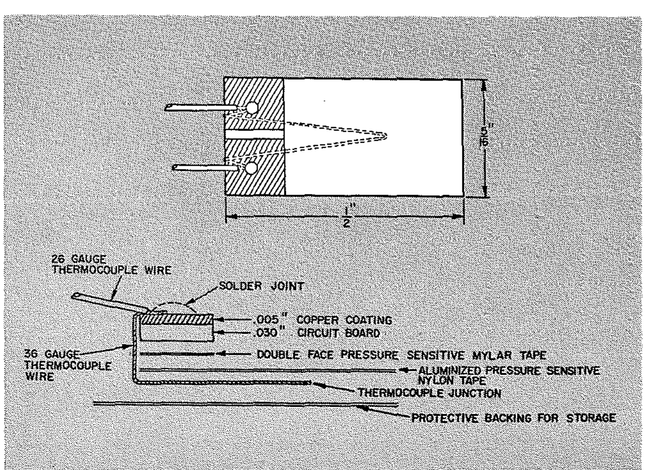
The thermocouple is a welded junction made of 36-gauge (0.005-inch-diameter) copper-and-constantan wire. This junction is secured to the surface by an aluminized nylon tape, which also shields the junction from extraneous sources. The smallness of the wire minimizes the effects of conduction along the leads, radiation from the junction surface, and the time delays due to thermal mass. The practicality is obtained by using 26-gauge wire (0.016-inch-diameter) for leads and hook-up, and joining it to the 36-gauge wire about ½ inch from the junction. A small piece of circuit board is used for the connections of the two wires. The completed assembly, nicknamed a *Turnercouple*, is shown in Fig. 1.

To test the effect of incident radiation, two flat walls were used in a vacuum chamber at different temperatures. Between these was placed an 0.032-inch painted copper plate, parallel to the walls; on each side of the plate a thermocouple was attached, back to back. With one wall at 100°C and the other wall at −185°C, the plate was allowed to come to equilibrium. The measured temperature difference between the two test thermocouples was only 0.5°C; hence, the thermocouples were within a quarter of a degree of the surface temperature. The calculated temperature gradient through the copper was only 0.001°C, and therefore negligible. A thermocouple efficiency e is defined by:

$$e = \frac{T_T^4 - T_W^4}{T_P^4 - T_W^4}$$

Where: the subscripts T, W, P refer to a thermocouple, the corresponding wall, and the plate respectively. The efficiency of the present thermocouple was found to be 99.7%. Other methods commonly used for thermocouple attachment have been tested and measured efficiencies have ranged from 50% to 98%.

Fig. 1—Thermocouple assembly.



To test the transient response, a reference temperature was measured by spot welding 36-gauge copper-and-constantan wires to an aluminum plate 1/32 inch apart. The test thermocouple was then attached on top of the reference thermocouple. In a vacuum, the plate was cycled in temperature from −160°C to +100°C. Various rates of temperature change were imposed upon the plate to determine the maximum rate of change at which no difference (± 0.2°C) between the reference temperature and the test thermocouple temperature could be detected. The maximum acceptable transient for this thermocouple was found to be 0.5°C/sec.

Improvements of this thermocouple assembly are being studied and tested, to improve the transient response and to simplify the construction. In particular, a flattened junction about 0.002 inch thick is being studied. A forthcoming article is planned with these improvements, test results for other methods of thermocouple attachment, and a theoretical analysis of the present system. Meanwhile, this thermocouple is being used in many spacecraft tests with excellent results.

A Comparison of Proton and Neutron Irradiation Effects in Semiconductor Devices

by D. A. GANDOLFO, *Applied Research, DEP, Camden, New Jersey*

There exists at present only a small amount of experimental information relating the performance of semiconductor devices, such as transistors, to irradiation by a flux of high energy protons. This situation reflects the difficulty of securing beam time in the high-energy particle accelerators, as well as the only recently generated interest in the effects of proton irradiation.

There is, on the other hand, a rather large quantity of data concerning the effects of neutron bombardment on transistors[1]. One is tempted, in view of the relative ease of obtaining neutron irradiation data, to search for some correlation between neutron and proton irradiation damage which will permit the application of neutron data to the problem of predicting the effect of proton irradiation on transistors. Permanent damage in semiconductor crystals may be traced ultimately to the displacement of atoms from equilibrium sites in the lattice and the subsequent formation, by some of these displaced atoms, of electrically active defect sites. Therefore, *the comparison between proton and neutron irradiation reported here is based on the relative effectiveness of the particles in producing lattice displacements.*

Our hypothesis may be stated more accurately and generally as follows: It is assumed that the lifetime damage constants which characterize the degradation of devices during irradiation are directly proportional to the amount of energy expended by the incident particles in elastic displacement producing collisions. Implicit in this hypothesis is the assumption that device degradation depends on a gross aspect of the irradiation, i.e., the number of displacements introduced, rather than on the precise nature of the individual defects. Our procedure is as follows:

1) the energy expended by protons in the form of displacement producing collisions is calculated not from the classical Rutherford scattering law, but from measured cross sections which include the effects of both Coulomb and nuclear forces;
2) the energy expended by fission neutrons in displacement producing collisions is calculated from measured angular distributions of the elastic scattering cross section;
3) the ratio of the quantity calculated in (1) to that in (2) is obtained and multiplied by the lifetime damage constants measured in neutron irradiation experiments.

The products are calculated lifetime damage constants which should be characteristic of the proton irradiation. This procedure yields calculated damage constants which agree reasonably well with those obtained from the proton irradiation experiments reported by the NASA Langley Research Center[2].

We conclude, therefore, that our hypothesis is a reasonable one which may be used to derive useful information concerning the effects of proton irradiation on transistor performance.

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1. See, for example, D. A. Hicks, et al., *Radiation Damage to Transistors*, Boeing Airplane Company, Report D5-2880, December 1958 and Robert Puttcamp, *Nuclear Radiation Damage to Transistors*, DOFL Report TR-975, November 1961.
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Plasma Quenching by Electronegative Gas Seeding

by G. G. CLOUTIER and A. I. CARSWELL, *Research Laboratories, RCA Victor Company, Ltd., Montreal, Canada.*

In some recent experimental measurements, rather striking alterations of the properties of a supersonic plasma stream have been achieved by seeding the plasma with an electronegative gas. The application of seeding techniques to various plasma systems is well known and to date the major emphasis in this work has been on generating plasmas of increased ionization by seeding (particularly with the alkali metals).[1]

In the present investigation, the aim has been to seed supersonic plasma streams with electronegative gases to reduce the electron density in the system. The results of such studies are of particular interest because of their possible application to re-entry and space communication problems. In particular, the seeding of argon plasma streams with sulphur hexafluoride (SF_6) has been studied under various conditions. The choice of SF_6 for this purpose was based on its exceptionally high electron capture cross-section for low-energy electrons[2] and its stable chemical properties.

The experiments reported here were carried out in an RF-excited (electrodeless discharge), low-density plasma tunnel using argon gas at velocities of approximately Mach 2. The static steam pressure was 1 torr and the diameter of the stream at the exit of the nozzle was 1.7 cm. Under these conditions, the argon flow rate in the tunnel was 1.4 litre—atmosphere/minute. Double-probe[3] measurements indicate that the electron density at the nozzle exit is in the range of 10^{12} to 10^{13} electrons/cm^3.

The basic arrangement for seeding the argon plasma with SF_6 is illustrated in Fig. 1. The small ceramic seeding tube (0.2 mm ID, 0.5 mm OD) is introduced in the plasma stream from the side so that the orifice is positioned in the centre of the stream at a distance of 1.0 cm from the nozzle exit.

In a first set of measurements, the back-scattering of a microwave signal (9.2 Gc) from the plasma stream was measured as a function of the amount of SF_6 introduced into the argon flow. To ensure that only microwave scattering from the plasma would be observed, the RF power used to excite the plasma was modulated at 1 kc, and only this component of the reflected microwave signal was detected.

Fig. 2 is a series of curves of the signal back-scattered from the plasma stream as a function of the position of the seeding tube in the plasma. These curves were obtained by sweeping the tube across a constant argon stream at various injection rates of SF_6. The ratio SF_6/A in Fig. 2 refers to the relative rate of SF_6 molecules injected, to that of argon atoms flowing through the nozzle. It is seen that for a ratio of SF_6 to argon of 3.7×10^{-4}, the back-scattered signal from the plasma is essentially reduced to zero thus indicating a very large drop of electron density in the plasma resulting from the capture of the electrons by SF_6.

Similar tests were carried out using air and oxygen as the seeding gas and even for injection rates an order of magnitude larger than those used for SF_6, no appreciable effect was observed on the back-scattering of the microwave signal.

In a second series of measurements the properties of the flowing plasma were examined by sweeping a double-probe across the stream. The double-probe was introduced into the plasma stream as shown in Fig. 1. The probe could be moved both along and across the stream thus enabling the sampling of the plasma before and after the point of seeding. The probe unit was made of two parallel tungsten wires (0.075 mm diameter) 0.4 mm apart, imbedded in a ceramic rod and protruding 0.5 mm. A sufficiently large constant voltage was applied between the electrodes to insure that the probe unit was operating under conditions of ion saturation current.

Fig. 3 shows the effect of SF_6 seeding on the probe current as a function of the probe position across the stream. These measurements were performed in a steady argon plasma stream with an SF_6/A ratio of 4×10^{-4}. In one case the probe is located 0.5 cm upstream from the seeding tube and in the other it is 1.0 cm downstream. In the first case, the ion concentration at the centre of the stream, as indicated by the probe saturation current, is essentially not affected. However, the ion concentration at the edge of the stream is reduced because of the presence of the small amount of SF_6 gas which has diffused from the stream into the test section. When the probe is located downstream from the feed the effect of seeding is very pronounced. It is seen that the probe current at the centre of the stream is reduced by seeding to about 6% of its value in the unseeded stream. Measurements further downstream show that this percentage decreases to zero in a distance of a few centimetres. The two maxima near the edge of the stream are real and define the "shadow" of the SF_6 stream being swept by the argon flow. The quenching of the plasma can also be observed visually as a dark region in the luminescent plasma behind the seeding point. Similar tests have been carried out by seeding the argon plasma with air and oxygen and no appreciable change has been found in the ion concentrations across the stream even with seeding flow rates ten times greater than those used with SF_6.

These results seem to indicate that when the argon plasma is seeded by very small amounts of SF_6 not only the electron density (as shown by the microwave measurements) but also the positive ion density is markedly reduced. This conclusion is based on the fact that the double-probe saturation current is a measure of the ion density in the plasma and a simple replacement of electrons by negative ions should not radically change the probe saturation current. Even including the effect of the low mobility of heavy negative ions in the plasma, the very large changes in probe current that have been observed can only be explained by a reduction in the ion density. This suggests that the capture of electrons in the plasma by SF_6 to form negative ions is quickly followed by a charge exchange process between the argon positive ions and the SF_6 negative ions. In addition, the efficiency of both these processes appears to be very high since the SF_6/A ratio is of the same order of magnitude as the ratio of electron to argon concentration in the unseeded plasma.

Acknowledgement: The authors wish to express their appreciation to Dr. M. P. Bachynski, for the many useful discussions concerning this investigation.

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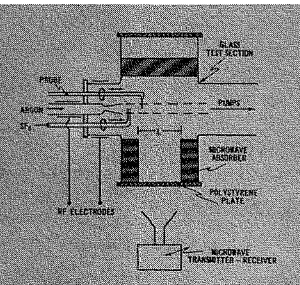


Fig. 1—Schematic diagram of the apparatus. The length L indicates the portion of the plasma stream irradiated by the microwave beam.

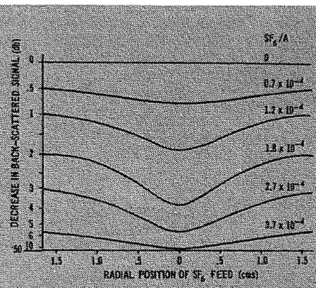


Fig. 2—Effect of SF_6 seeding on microwave (9.2 Gc) back-scattering from the stream. The curves show the microwave return as the seeding tube is swept through the stream at different SF_6 injection rates.

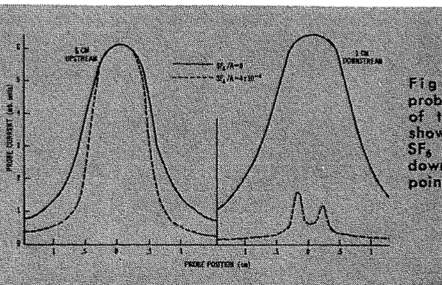
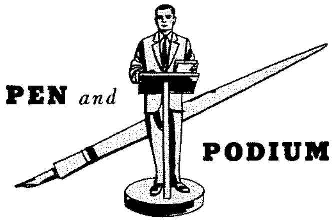


Fig. 3—Doub probe measurem of the plasma showing the effec SF_6 upstream downstream from point of seeding.



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Sept. 9-12, 1963: 18TH ANN. ISA INSTRUMENT-AUTOMATION CONF. AND EXHIBIT; McCormick Place, Chicago, Ill. *Prog. Info.:* Public Relations Dept., Instrument Soc. of Amer., Penn-Sheraton Hotel, 530 Wm. Penn Place, Pittsburgh 19, Pa.

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Patents Granted TO RCA ENGINEERS

As Reported By RCA Domestic Patents, Princeton

RCA LABORATORIES

3,084,224—Magnetic Recording, April 2, 1963; R. F. Sanford

3,084,264—Switching Systems, April 2, 1963; W. F. Kosonocky and L. S. Onyshkevych

3,084,335—Readout Circuit for Parametric Oscillator, April 2, 1963; W. F. Kosonocky and L. S. Onyshkevych

3,085,243—Radar Tracking and Display System, April 9, 1963; D. S. Bond

3,089,126—Negative Resistance Diode Memory, May 7, 1963; J. C. Miller

3,090,737—Plasma Heating Apparatus and Process, May 21, 1963; G. A. Swartz

3,090,956—Steerable Antenna, May 21, 1963; O. M. Woodward, Jr., and J. B. Rankin

3,091,660—Television Magnetic Tape Reproducing System, May 28, 1963; W. D. Houghton and R. E. Morey

RCA LABORATORIES, LTD., Switzerland

3,085,184—Ferroelectric Devices, April 9, 1963; R. Nitsche and E. Fatuzzo

ELECTRON TUBE DIVISION

3,084,274—Electron Tube, April 2, 1963; R. A. Krey

3,085,175—Cathode Assembly for Electron Tube, April 9, 1963; H. V. Knauf

3,085,239—Radio-Frequency Switching, April 9, 1963; M. V. Hoover

3,085,325—Method of Brazing, April 16, 1963; J. F. Slepitis

3,086,892—Semiconductor Devices and Method of Making Same, April 23, 1963; R. L. Huntington

3,087,082—Cathode-Ceramic Assembly for Electron Guns and Method of Making, April 23, 1963; R. W. Osborne and T. J. Morris

3,087,289—Method of Processing Articles or Materials in a Continuous Flow Operation, April 30, 1963; W. J. Helwig

3,088,105—Radar, April 30, 1963; W. R. Beam

3,089,234—Method of Making Metal-to-Ceramic Seals, May 14, 1963; M. M. Deevy

3,089,600—Transfer Apparatus, May 14, 1963; A. Fischer, Jr.

3,089,973—Electroluminescent Device, May 14, 1963; P. G. Herold and R. A. Nolan

3,090,882—Electron Gun, May 21, 1963; R. E. Benway

DEFENSE ELECTRONIC PRODUCTS

3,085,240—True-Motion Radar Display System, April 9, 1963; W. F. Turnow

3,085,253—Ear Pads, April 16, 1963; R. E. Ulrich and E. R. Ware

3,087,123—Negative Resistance Diode Multivibrators, April 23, 1963; H. Rubenstein and A. G. Samusenko

3,091,468—Tone Arm Stop System for Automatic Record Changers, May 28, 1963; E. J. Sperber

***3,054,927—Means for Extending Coverage in an Area Moving Target Radar**, September 18, 1962; H. M. Scott and C. H. Phillips (*Assigned to the Government)

BROADCAST & COMMUNICATIONS PRODUCTS DIVISION

3,085,241—True-Motion Radar Display System, April 9, 1963; C. E. Moore

3,085,244—Iso-Contour Circuits, April 9, 1963; N. D. Kay

3,088,668—Binary Adder Employing Minority Logic, May 7, 1963; A. Harel

3,089,978—Deflection Circuit, May 14, 1963; S. L. Bendell and W. J. Cosgrove

HOME INSTRUMENTS DIVISION

3,085,806—Dual Stylus Phonograph Pickup, April 16, 1963; A. A. Sariti and D. E. Laux

RECORD DIVISION

3,087,988—Simulated Stereophonic Sound Translating and Recording System, April 30, 1963; J. A. Somer

SEMICONDUCTOR & MATERIALS DIVISION

3,089,793—Semiconductor Devices and Methods of Making Them, May 14, 1963; E. L. Jordan and D. J. Donahue

ELECTRONIC DATA PROCESSING

May 28, 1963; M. C. Arya

3,091,392—Binary Magnitude Comparator,

The Design of Instructional Equipment: Two Views—H. W. Leverenz and M. G. Townsley: The Department of Audiovisual Instruction National Education Association

Thermal Conductivity of Ge, Si and III-V Compounds at High Temperatures—D. S. Beers, G. D. Cody and B. Abeles: *Report of the International Conference on the Physics of Semiconductors Held at Exeter*, July 1962

Reflectivity of Semiconductors with Wurtzite Structure—M. Cardona: *The Physical Review*, Feb. 1, 1963

Recombination and Trapping in Normal and Electron-Irradiated Silicon—J. A. Baicker: *The Physical Review*, Feb. 1, 1963

New Type of Loop Tracer for Ferroelectrics—H. Roetschi: *Journal of Scientific Instruments*, Apr. 1962

Isocon Scan—A Low-Noise, Wide-Dynamic-Range Camera Tube Scanning Technique—A. D. Cope and H. Borkan: *Applied Optics*, Mar. 3, 1963

Switching Properties in Ferroelectrics of the Family $Bi_4Ba_{m-2}Ti_{m+1}O_{3(m+2)}$—P. H. Fang and E. Fatuzzo: National Bureau of Standards, Washington, D. C.

Measured Values of Noise Spectra, S and Π, of Ultra-Low-Noise Beams—J. M. Hammer: *Proceedings of the IEEE*, Feb. 1963

The Crystal Structure and Luminescence of -Zinc Orthophosphate—C. Calvo: *International Journal of the Physics and Chemistry of Solids*, 1963

Optical Maser Action in an Eu^{+3}-Containing Organic Matrix—N. E. Wolff and R. J. Pressley, Apr. 15, 1963

Hot Electrons in Indium Antimonide—M. Glicksman and W. A. Hicinbothem, Jr.: *The Physical Review*, Feb. 15, 1963

Two Crystal Forms of ZnP_2, Their Preparation, Structure, and Optoelectronic Properties—I. J. Hergyi, E. E. Loebner, E. W. Poor, Jr. and J. G. White: *International Journal of the Physics and Chemistry of Solids*, 1963

Properties of p-Type InSb in Pulsed High Electric Fields—M. C. Steele and M. Glicksman: *The Physical Review*, Apr. 15, 1963

Reflectivity Measurements on InSb-In_2Te_3 and InAs-In_2Te_3 Alloys and on Pure InSb, InAs and In_2Te_3—D. L. Greenaway and M. Cardona: *Report of the International Conference on the Physics of Semiconductors held at Exeter*, July 1962

Engineering NEWS *and* HIGHLIGHTS

TUBE AND SEMICONDUCTOR ACTIVITIES REALIGNED INTO NEW 5-UNIT ORGANIZATION

Realignment of the Electron Tube Division and the Semiconductor and Materials Division into a new organization consisting of five major operating units was announced on June 11, 1963 by **Douglas Y. Smith,** Vice President, Electronic Components and Devices. The five new major operating units, under Mr. Smith's direction, are: *Commercial Receiving Tube and Semiconductor Division; Industrial Tube and Semiconductor Division; Television Picture Tube Division; Special Electronic Components Division,* and *Distributor Products.* Headquarters of the Electronic Components and Devices organization will be located at Harrison, N.J.

The new units will be responsible for the engineering, manufacturing, and marketing of all products previously made and sold by ETD and SC&M. Staff functions have been established to coordinate activities which are common to all of the major operating units, such as general sales, personnel, finance, engineering and technical guidance, and operations planning. This staff also will provide specialized functional guidance, recommend broad policy, and plan on a consolidated basis.

"With this new arrangement," Mr. Smith said, "RCA will capitalize more effectively on product capability and the skills of its employees. Heading up the new major operating units will be five RCA veterans who collectively have over 130 years of experience in the electronic components business. With this experienced leadership, we will be able to improve service to customers and strengthen our organization for profitable business growth on an immediate and long-range basis."

The activities of the five major operating units are:

1. *Commercial Receiving Tube and Semiconductor Division* will have responsibility for the engineering, manufacturing, marketing, and sales of receiving tubes, memory products and semiconductors for computers and consumer products. This division will also be responsible for sales of television picture tubes. **William H. Painter** has been named Division Vice President and General Manager, Commercial Receiving Tube and Semiconductor Division. He was previously Division Vice President, Operations Planning for the RCA Semiconductor and Materials Division.

2. *Industrial Tube and Semiconductor Division* will have responsibility for the engineering, manufacturing, marketing and sales of conversion tubes, microwave tubes, power tubes, and industrial semiconductors. **C. E. Burnett** has been appointed Division Vice President and General Manager, Industrial Tube and Semiconductor Division. Mr. Burnett was formerly Division Vice President, Industrial Tube Products Department, RCA Electron Tube Division.

3. *Television Picture Tube Division* will have responsibility for engineering, manufacturing, and marketing of black-and-white television picture tubes and color television picture tubes. **John B. Farese** has been named Division Vice President and General Manager, Television Picture Tube Division. Prior to his new appointment, Mr. Farese was Division Vice President, Entertainment Tube Products Department, RCA Electron Tube Division.

4. *Special Electronic Components Division* will be the building-for-the-future unit with special emphasis on the advanced development of new and special electronic components and devices. This organization will have responsibility for directing and integrating the following programs: direct energy conversion (thermoelectrics, thermionics, superconductors, solar cells, and fuel cells), integrated circuits, micromodules, minimodules, "Minireed" switches, laser devices, and ceramics. **Lloyd R. Day** has been appointed General Manager, Special Electronic Components Division. He was previously Manager, Direct Energy Conversion Department, RCA Electron Tube Division.

5. *Distributor Products* will continue its present responsibilities for the sale of all RCA electronic components and devices to authorized distributors. These products include electron tubes, semiconductor devices, batteries, test instruments, special sound products, parts and accessories. **Harold F. Bersche** will become Division Vice President, Distributor Products. He was formerly Manager, Distributor Products Department, RCA Electron Tube Division.

The following appointments have been made to the newly created staff which will furnish specific services to all five major operating units.

G. C. Brewster has been appointed Manager, Operations Planning and Support. He was formerly Manager, Administrative Services, RCA Electron Tube Division. The new Operations Planning and Support activity will be responsible for over-all facilities, management engineering, purchasing, warehousing, traffic, data processing and systems activities.

Dr. Alan M. Glover has been appointed Division Vice President, Technical Programs. He was previously Vice President and General Manager, RCA Semiconductor and Materials Division. The new Technical Programs activity will be responsible for directing new business development, providing over-all guidance to all technical activities, maintaining liaison with RCA Laboratories, and directing the general product assurance function.

L. A. Kameen, has been appointed Manager, Personnel, for the new organization. He was previously Manager, Personnel, RCA Electron Tube Division. The new Personnel activity will be responsible for providing all common personnel functions including wage and salary activities, labor relations, organization development, training and security.

Joseph E. Kelley has been named Division Vice President, General Sales. He was formerly Manager, Marketing Distributor Products Department, RCA Electron Tube Division. The new General Sales activity will be responsible for maintaining high level sales contacts, as well as for providing market research, publicity, advertising and sales promotion services.

Julius Koppelman has been named Controller, Finance, for the new organization. He was formerly Controller, Finance, RCA Electron Tube Division. The new Finance activity will provide centralized budgeting, accounting, credit and collection, government pricing, auditing and management controls.

L. S. Thees, who has been Division Vice President, General Sales, RCA Electron Tube Division, will continue on Mr. Smith's staff as Division Vice President.

RCA LABS DOCTORAL STUDY AWARDS

The following members of the RCA Laboratories technical staff have been named recipients of *Doctoral Awards* for the academic year 1963-1964:

Robert V. D'Aiello, to continue studies for the Ph.D. in electrophysics at Polytechnic Institute of Brooklyn.

Edward P. Helpert, to continue his doctoral work at Princeton University.

Thomas J. Nelson to attend Princeton University for the Ph.D. in electrical engineering.

David M. Perkins, to continue his doctoral studies in electrical engineering at Princeton University.

Ronald B. Schilling, to pursue doctoral work in electrical engineering at the Polytechnic Institute of Brooklyn.

Hillel Weinstein, will continue doctoral studies in electrical engineering at Polytechnic Institute of Brooklyn.

The *Doctoral Study Award* was adopted as a supplement to the *David Sarnoff Fellowship* and is consistent with the Laboratories' policy of encouraging technical staff members to continue graduate study in fields relating to their present or anticipated assignments with RCA. The following criteria are used in selecting employees for the Award: demonstrated research ability of the candidate, relevance of the graduate study to RCA's field of research and potential for professional growth. Approvals for the Award are given by the employee's Laboratory Director and the Vice President, RCA Laboratories.

The Award recipients are given full-time leave for graduate study, with the Laboratories providing half salary, tuition, fees, and a book allowance.

ALELYUNAS CITED FOR ARTICLE ON PROPOSALS

Paul Alelyunas, M&SR, Moorestown, received an "Author's Award" from the magazine *Aerospace Management* for his article "The Secret of Successful Proposals," which appeared in the December 1962 issue.

G. A. Kiessling

KIESSLING NAMED TO PRODUCT ENGINEERING STAFF

Appointment of **George A. Kiessling** as Administrator, Product Engineering Professional Development, was recently announced by **C. M. Sinnett,** Director, Product Engineering Professional Development. Mr. Kiessling will be active in Professional Development Programs involving engineering and engineering management communications, recognition, rewards, and, in collaboration with Personnel and Staff, training, performance evaluation and measurement, and employee relations.

Mr. Kiessling received the BEE degree from Manhattan College, New York, in 1951 and the MSIE degree in Engineering Management from the Stevens Institute of Technology, Hoboken, N.J. in 1953. He was a member of the technical staff of the Physics Laboratories, Sylvania Electric Products, Inc. before joining RCA's Engineering Products Division as Administrator, Engineering Financial Planning in 1954. Upon formation of Commercial Electronic Products in 1956, Mr. Kiessling was made Manager, Engineering Standards and Services, continuing this assignment with the successor, Industrial Electronic Products, organization. In 1961 he joined Electronic Data Processing as Staff Engineer, and in 1962 was named Manager, Product Administration, Custom Projects Marketing.

Mr. Kiessling is a member of the IEEE and the IEEE Professional Technical Group on Engineering Management.

APPLIED RESEARCH OPEN HOUSE

Open House was held on Saturday, May 18, from 3:00 p.m. to 5:30 p.m. to give Applied Research members an opportunity to show their families where they work. The Open House area included all Applied Research laboratories on 10-8, plus the 10-4 thermoelectric lab. and the 10-roof magnetic recording lab. Secret labs were excluded. Refreshments were served to the 400 who attended.

—M. G. Pietz

ACCD SEMINARS IN BURLINGTON

The first of a series of seminars to be given at ACCD-Burlington, was held on May 22. **A. D. Beard,** Chief Engineer of EDP, described his product lines, including the RCA 301, 501 and 601 computers. In addition, he described some of the advanced development work on input output devices, taped stations, and the like. *—R. Glendon*

NEW SOUTH JERSEY AIIE CHAPTER FORMS

H. R. Headley of Missile Support Program, Moorestown was the charter speaker at the initial meeting on April 23, 1963 of the newly formed Southern New Jersey chapter of the American Institute of Industrial Engineers. Mr. Headley's talk on PERT and related management control techniques was very well received by the more than 50 members of his organization at their initial meeting at Colonial Inn. **F. G. Adams** and **P. W. Coben** of M&SR are active as temporary officers of the newly formed chapter.

—T. G. Greene

REGISTERED PROFESSIONAL ENGINEERS

F. G. Adams, DEP, PE-9007-E, Penna.

A. H. Barnard, RCA Int'l., PE-2433, Portland, Oregon

P. Bergquist, BCD, PE-1189, Washington, D.C.

J. T. Cimorelli, ETD, PE-12797, New Jersey

P. W. Coben, DEP, PE-9004-E, Penna.

W. H. Petri, DEP, PE-8986-E, Penna.

J. T. Nessmith, DEP, PE-10285, New Jersey

P. V. Smith, SVC.CO., PE-12795, New Jersey

DR. HILLIER NAMED PRESIDENT OF INDUSTRIAL RESEARCH INSTITUTE

Dr. James Hillier, Vice President, RCA Laboratories, was named as the new president of Industrial Research Institute, Inc., at the organization's annual meeting in May 1963. Industrial Research Institutes, Inc., held its 25th Anniversary Meeting at the Fairmount Hotel in San Francisco in May 1963. Composed of the nation's leading industrial research executives representing more than 180 major manufacturing companies, the Institute has as its purpose the improvement of the techniques of industrial research organization and management. At that meeting, Dr. Hillier served as Program Chairman and moderated a panel session on "A 25-Year Look Into the Future of Research in the Nation."

C. P. SMITH HEADS NEW RCA LABS. GROUP

C. Price Smith has been appointed to the newly established position of Director, Process Research and Development Laboratory. Mr. Smith will be responsible for conducting necessary research and development to demonstrate the feasibility of new processes which will have future significance for the manufacture of RCA products and to help transfer them to large-scale manufacturing. Mr. Smith will report to **Dr. James Hillier,** Vice President, RCA Laboratories.

DEGREES GRANTED

R. F. Hall, DEP-MSR	BS, Drexel Institute of Technology
R. W. Ahrons, RCA Labs	PhD, EE, Polytechnic Institute of Brooklyn
J. R. Macy, RCA Labs	PhD, Applied Math., Stevens Institute of Technology
P. Chase, RCA Labs	MSEE, Rutgers University
K. Keller, RCA Labs	MSEE, Rutgers University
E. P. Helpert, RCA Labs	MSEE, Princeton University
D. Perkins, RCA Labs	MSEE, Princeton University
R. Schilling, RCA Labs	MSEE, Princeton University
F. Zonis, RCA Labs	MSEE, University of Pennsylvania
L. J. Clayon, DEP-MSR	MSEE, University of Pennsylvania
A. Bezgin, DEP-MSR	MSEE, University of Pennsylvania
E. J. Hartnett, DEP-MSR	MSEE, University of Pennsylvania
J. G. Kammerer, DEP-MSR	MSEE, University of Pennsylvania
I. Maron, DEP-MSR	PhD, University of Pennsylvania
R. L. Segall, DEP-MSR	MSEE, University of Pennsylvania
A. E. Franz, DEP-MSR	MSEE, University of Pennsylvania
M. J. Lutz, DEP-MSR	BSME, Drexel Institute of Technology
C. E. Profera, DEP-MSR	MSEE, Drexel Institute of Technology
J. Bisaga, DEP-MSR	MSEE, Drexel Institute of Technology
I. Bardash, DEP-MSR	MSEE, University of Pennsylvania
H. V. R. Pierce, DEP-MSR	BSME, Drexel Institute of Technology
J. A. Alai, DEP-MSR	MSME, Villanova University
J. J. Curran, DEP-MSR	BS, Drexel Institute of Technology
B. R. Orzechowski, DEP-MSR	MSME, Drexel Institute of Technology
J. B. Palmer, DEP-MSR	MBA, Drexel Institute of Technology
R. A. Suomala, DEP-MSR	BSME, Drexel Institute of Technology
J. E. Sainsbury, DEP-MSR	BS, Physics, La Salle College
B. P. Lubow, DEP-MSR	MSEE, Drexel Institute of Technology
R. Jones, DEP-MSR	BSEE, Drexel Institute of Technology
E. L. Danheiser, DEP-MSR	MSEE, Drexel Institute of Technology
E. E. Fox, DEP-MSR	MS in EE, University of Pennsylvania
L. A. DiPaolo, DEP-MSR	Villanova University
F. C. Squire, DEP-MSR	MS, Physics, University of Pennsylvania
E. G. McCall, DEP-MSR	MSEE, University of Pennsylvania
G. E. Skorup, DEP-MSR	BA, Bus. Adm., University of Pennsylvania
G. Saatdjian, DEP-MSR	MS, Physics, Temple University
G. R. Rittersbach, DEP-MSR	BS, Bus. Adm., Temple University
I. Chyzowych, DEP-MSR	BA, Math., Temple University
A. Antos, DEP-MSR	BA, Math., La Salle College
J. Fedak, DEP-MSR	BS, Electrophysics, La Salle College
C. J. Hughes, DEP-MSR	MSEE, University of Pennsylvania
R. N. Adams, DEP-App. Res.	MSEE, University of Pennsylvania
D. A. Gandolfo, DEP-App.Res.	MA, Physics, Temple University
J. Solomon, DEP-MSR	MA, Physics, Temple University
P. JP Gayet, DEP-MSR	MSEE, Villanova University
G. J. Ammon, EDP	MS, Moore School of Electrical Engineering
E. Gloates, EDP	MS, Moore School of Electrical Engineering
D. E. Roop, EDP	MS, Moore School of Electrical Engineering

. . . PROMOTIONS . . .

to Engineering Leader & Manager

As reported by your Personnel Activity during the past two months. Location and new supervisor appear in parenthesis.

RCA Service Company

M. Breier: from Assoc. Engr. to *Ldr., Engineers* (C. D. Ettinger, Reliability Facility)

K. R. Lewis: from Ldr., Engrs. BMEWS to *Mgr., Facilities Design & Construction* (A. J. Gustry, Facility & Support)

T. D. Petty: from Ldr., Systems Svc. Engr. to *Mgr., Tech. Operations* (T. G. Whitney, Radar Projects)

A. G. Saprasa: from Engr. to *Ldr., Engineers* (J. Vilmerding, BMEWS—Site 1)

J. M. Soich: from Sr. Engr. to *Mgr., Radar* (J. D. Callighan, Equipment Engineering)

H. D. Tilley, Jr.: from Engr. to *Ldr., Engineer* (J. W. Martin, Radar Engineering)

Semiconductor & Materials Div.

R. Ryan: from Engr. Prod. Dev. to *Engineering Ldr.* (G. S. Lozier, Somerville)

B. Vonderschmitt: from Mgr., Module Dev. to *Mgr., Eng.* (R. E. Koehler, Somerville)

Electronic Data Processing

R. O. Austin: from Ldr. Prod. Support to *Mgr. Prod. Support* (H. Kleinberg, West Palm Beach)

L. Limbaugh: from Sr. Mbr., D&D Eng. Staff to *Ldr., D&D Eng. Staff* (H. Morris, West Palm Beach)

Aerospace Communications & Controls Div—DEP

T. Taylor, Jr.: from Eng. Scientist, Tech. Staff to *Ldr., Technical Staff* (O. T. Carver, ATE Projects Eng., Burlington

Missile and Surface Radar—DEP

R. P. Cheetham: from Ldr., Systems Eng. to *Mgr., Adv. Systems Dev.* (H. W. Collar, Weapons Sys. Analysis, Moorestown)

M. R. Paglee: from Engr. to *Ldr., Eng. Sys. Projects* (W. J. Rose, Jr., Development Projects, Moorestown)

K. Sittel: from Engineer to *Ldr., Sys. Eng.* (O. L. Patterson, Systems Research, Moorestown)

Astro-Electronics Division—DEP

J. Mallin: from Sr. Engr. to *Ldr., Engineers* (M. Kerpchar, Systems Eng. Hightstown)

M. Shepetin: from Engr. to *Ldr., Engineers* (M. V. Sullivan, Video Systems, Hightstown)

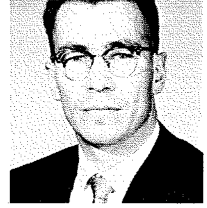
Data Systems Division—DEP

M. Felman: from Sr. Mem. D&D Eng. Staff to *Ldr., D&D Eng. Staff* (G. Grondin, Digital Engineering, Van Nuys)

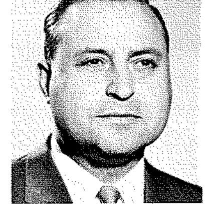
J. Hall: from Pr. Mem. D&D Eng. Staff to *Staff Eng. Scientist* (J. Murphy, Van Nuys)

R. W. McKelvey: from Sr. Mem. Projects Eng. Staff to *Ldr., Projects Eng. Staff* (W. M. McCord, Van Nuys)


L. S. Beeny


D. G. Hymas


R. L. Kauffman


P. L. Farina

NEW EDITORIAL REPRESENTATIVES

The following men have been named RCA ENGINEER Editorial Representatives for the engineering areas noted in parenthesis after their names.

L. S. Beeny *(RCA International Division, Clark, N.J., replacing C. G. Mayer)* is Manager of Communications Systems Engineering. He received a BEE Degree in 1950 from Rensselaer Polytechnic Institute. Upon grduation he worked four years in Arabia with Aramco. He joined RCA International in 1954. He was Project Engineer for the Colombian VHF Project until his return in 1960, when he was appointed to his present position. He is a Senior member of the IEEE.

D. G. Hymas *(Microwave Engineering, B&CP Division, Camden)* graduated from the University of Alberta (BSEE) in 1949 and from the University of Pennsylvania (MSEE) in 1960. Since joining RCA in 1954 he has been planning microwave radio relay communications systems. He became Group Leader, Systems Engineering in 1949. He is currently responsible for systems engineering proposals and contracts. He is a member of IEEE, a registered Professional Engineer in the Province of Ontario, and co-holder of a U. S. Patent.

Robert L. Kauffman *(Conversion Tube Operations, Lancaster, replacing* **George Delong***)* received his BA in English Literature from Lebanon Valley College in 1950. After service in the Navy, he joined RCA Lancaster in 1954. Since 1962 he has been with Conversion Tube Operations, working on proposals and contract reports.

Patrick L. Farina *(Receiving Tube Operations, Harrison, replacing* **T. M. Cunningham***)* graduated from RCA Institutes in 1941 and received his BSEE from Polytechnic Institute of Brooklyn in 1953, and his MSME in 1956 from Newark College of Engineering. He joined RCA in 1941 and from 1942-1945 served in the Air Force. In 1945 he returned to RCA. In 1950 he became Manager, Equipment Development Technical Services at Harrison. In 1961, he was responsible for mechanization of nuvistor manufacturing and initial facilitation for thermoelectrics. In 1962, he joined Receiving Tube Product Engineering as Mgr., Engineering Administration. He is a Senior Member of the IEEE.

G. Earl Morris, Jr., *(Advanced Military Systems, DEP, Princeton)* joined RCA in in August 1962. His duties are the coordination of technical reports. Prior to joining RCA, he was with Allstates Design and Development Co., where he worked on publications with RCA-AED and Thiokol Chemical Corp.

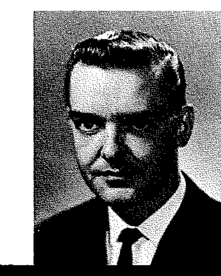
John L. Swentzel *(Microelectronics, Somerville, replacing* **Rhys Samuel***)* Publications Engineer, received his BS in biology from the University of New Mexico in 1956. He then worked for the Southwest Potash Corporation in Carlsbad, New Mexico, the Tennessee Valley Authority, the Aloe Scientific, St. Louis, Reaction Motors Division of Thiokol Chemical Corporation, and the Astronautics Division of General Dynamics Corp. in San Diego, California. He returned to New Jersey in late 1960 as assistant manager of sales promotion with Thermo Electric Co., Inc. He joined the RCA Semiconductor and Materials Division, Somerville, N. J., in 1962, where his work includes reports and proposals. He is a member of ACS and the STWP.

Arnold Lee Christen *(EDP Service Dept. RCA Service Co., Cherry Hill, replacing* **John Lawler***)* received his BSEE from Princeton University in 1951. After working for American Bosch-Arma Corporation, he joined the RCA Service Company in August 1953. He was associated with RCA BIZMAC installations, and was the Camden-Philadelphia EDPS District Manager until August 1962 when he attended the Program for Management Development at Harvard Business School. He is currently Manager, EDPS Engineering. He is a registered engineer in New York and New Jersey and has been certified by the National Bureau of Engineering Registration. He is a member of NYSSPE, NSPE, and IEEE.

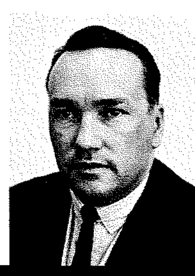
H. E. Gihring *(Broadcast Transmitter and Antenna Engineering, B&CP, Camden, replacing* **C. D. Kentner***)* received his BSEE from Washington University in 1926. In 1929, he joined RCA and in 1930 the newly formed Broadcast Transmitter Section. Until 1935 he was assigned to propagation and antenna work. In 1936, for a year to work on the Empire State television transmitter installation, and from 1937 to 1940 was engaged in television transmitter development. In 1940, he supervised the Television Transmitter Group which expanded into radar activities until 1944. Since 1944, he has supervised television transmitter and antenna work, presently as Manager, Broadcast Antenna Group. He is a Senior Member, IEEE.

Irving M. Seideman *(Astro-Electronics Division, Princeton, N.J., replacing* **L. A. Thomas,** *who continues as an* RCA ENGINEER *consultant Engineering Editor)* received his BS in Physics from Carnegie Institute of Technology in 1941. That year, he joined RCA Victor in Camden, and in 1946, the advertising staff of RCA International. Subsequent to 1947, he was in technical writing, advertising, and sales management for several firms, until he returned to RCA in 1956 as an engineering writer at Moorestown. He joined the Astro-Electronics Division upon its inception in 1958 and for two years, handled all publications for the TIROS Project. In February 1962, he was appointed a Leader, Publications Engineers.

G. E. Morris, Jr.

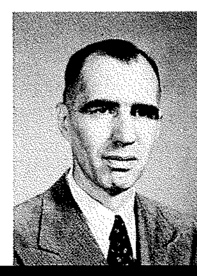


J. L. Swentzel



A. Lee Christen

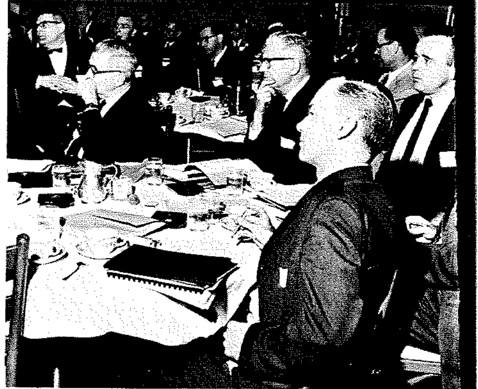
H. E. Gihring



I. M. Seideman

Dr. G. H. Brown, Vice President, Research and Engineering, (left) and a group participate in the symposium.

Moderator, W. O. Hadlock, and panelists during discussion, "The RCA ENGINEER" (see details of program, this page).



D. F. Schmit, Vice President, Product Engineering (at left of foreground table) with oth Symposium participants.

CORPORATE TECHNICAL PAPERS SYMPOSIUM

On May 23, 1963, the first *RCA Technical Papers Symposium* was held in Camden, attended by representatives of RCA engineering and research activities throughout the Corporation. The object of the day-long Symposium was to consider the many aspects and details of the writing, approval, editing, and publication of technical papers authored by RCA scientists and engineers. A major feature was a discussion of the RCA ENGINEER — its editorial policies and procedures, and requirements for papers. The majority of the program was given over to panel discussions which were open to questioning and discussion from the audience at all times.

The theme of the Symposium was the means for a continuing improvement in the quality of RCA technical papers. With the RCA technical staff accounting for over a thousand technical papers annually, it is evident that the technical papers program is one of major importance to the Corporation — since it is largely through such papers that RCA presents its technical image to the industry and others in the engineering profession.

Readers who wish to learn more details about any of the material on the program should contact the representative in their area who attended the Symposium, as listed on this page.

The Symposium was sponsored by the Product Engineering Staff, Research and Engineering. It was coordinated by the editorial staff of the RCA ENGINEER.

ATTENDANCE AT THE RCA TECHNICAL PAPERS SYMPOSIUM

RCA STAFF
Dr. G. H. Brown, Vice Pres., Research and Eng., Princeton, N.J.
D. F. Schmit, Staff Vice Pres., Product Engineering, Camden, N.J.
O. V. Mitchell, Director Domestic Patents, Princeton, N.J.
W. O. Hadlock, Editor, RCA ENGINEER, Camden, N.J.
E. R. Jennings, Assistant Editor, RCA ENGINEER, Camden, N.J.
A. L. Pinsky, Assistant Editor, *Trend*, Camden, N.J.
P. C. Farbro, Mgr., Professional Personnel Programs, Camden, N.J.
R. E. Slough, Jr., Adm., Personnel Services, Camden, N.J.

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J. D. Ashworth, Lancaster, Pa.
J. T. Cimorelli, Mgr., Eng., Rec'ing Tube Oper., Harrison, N.J.
T. M. Cunningham, Harrison, N.J.
G. A. DeLong, Lancaster, Pa.
P. L. Farina, Harrison, N.J.
J. F. Hirlinger, Harrison, N.J.
E. C. Hughes, Harrison, N.J.
R. L. Kauffman, Lancaster, Pa.
J. Koff, Woodbridge, N.J.
J. H. Lipscombe, Marion, Ind.
R. J. Mason, Cincinnati, Ohio
R. W. McMurrough, representing H. Wolkstein, Harrison, N.J.
C. A. Meyer, Harrison, N.J.
G. G. Thomas, Lancaster, Pa.

ELECTRONIC DATA PROCESSING
D. R. Crosby, Pennsauken, N.J.
C. E. Frizol, Pennsauken, N.J.
T. Patterson, Camden, N.J.
B. Singer, Pennsauken, N.J.

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H. J. Carter, Bethesda, Md.
D. Dobson, Burlington, Mass.
E. Enfiejian, AED, Hightstown, N.J.
J. Epstein, Moorsetown, N.J.
C. W. Fields, Camden, N.J.
J. Gillespie, Camden, N.J.
R. Glendon, Burlington, Mass.
T. Greene, Moorestown, N.J.
J. J. Lamb, Camden, N.J.
G. Lieberman, Camden, N.J.
J. Molieri, Camden, N.J.
G. E. Morris, Princeton, N.J.
D. Oda, Van Nuys, Calif.
M. G. Pietz, Camden, N.J.
W. E. Pilgermayer, Camden, N.J.
W. Praeger, representing P. J. Riley, Cambridge, Ohio
M. P. Rosenthal, New York City, N.Y.
I. M. Seideman, Hightstown, N.J.
L. A. Thomas, Hightstown, N.J.
F. D. Whitmore, Camden, N.J.

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J. L. Parvin, Art Director, RCA ENGINEER, Camden, N.J.
P. F. Gallo, Art and Production, RCA ENGINEER, Camden, N.J.
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E. Stanko, Cherry Hill, N.J.

RCA COMMUNICATIONS, INC.
W. C. Jackson, N.Y.

PROGRAM

MAY 23, 1963; 10 AM - 3 PM
Camden, N.J.

"Welcome Address," D. F. Schmit, Staff Vice Pres., Prod. Eng.

"History of the RCA ENGINEER," J. T. Cimorelli, Mgr., Eng. Receiving Tube Operation, Electron Tube Division.

"The RCA ENGINEER (A Panel Discussion)," Moderator, W. O. Hadlock, Editor; Panel: J. T. Cimorelli; E. R. Jennings, Ass't. Editor, RCA ENGINEER; J. L. Parvin, Art Director, RCA ENGINEER; and Consulting Editors: C. A. Meyer (ETD-Hr.), F. D. Whitmore (DEP-Camden); T. T. Patterson (EDP-Camden); and C. W. Sall (RCA Labs., Pr.)—Editorial Representatives: Don Oda (DSD-Van Nuys); T. Cunningham (ETD-Harrison), and T. G. Greene (M&SR-Moorestown).

Objectives, Organization — Structure, Role of Editorial Representatives, Content of Journal, Distribution, Published Format, Graphic Arts, Reprints, Gaining Management Support for Writing Papers, Technical Papers Guide.

"Patents and Legal Requirements," O. V. Mitchell, Director, Domestic Patents, Princeton.

Copyrights and Trademarks, General Approval Needs, Patent Approval—Talks Publications, Editorial Relationship to Patents, Special Cases—Foreign Publications—Export of Data.

"How to Place More and Better Presentations and Publications, (A Panel Discussion)"—Moderator, C. A. Meyer, Mgr., Commercial Eng. Tech. Svcs., (ETD). Panel: C. C. Foster, Mgr., *RCA Review*, Technical Publications Administrators: F. D. Whitmore (DEP); T. T. Patterson (EDP); C. W. Sall (RCA Labs.); RCA ENGINEER Editorial Representative Guest Panelists: C. W. Fields (SurfCom); D. B. Dobson (ACCD, Burlington); and W. O. Hadlock (RCA Staff).

Publication in Outside Journals, Publication in RCA Journals, How to Publish a Paper Both Inside and Outside RCA, Society Meetings, Reslanting and Rewriting for Additional Placements.

"TREND," A. Pinsky, Ass't. Editor.

Purpose, Content, Scope; Relationship to Other RCA News Media; How Ed. Reps. Can Help; How Distributed.

Clip out and Mail to Editor, RCA ENGINEER, #2-8, Camden

RCA ENGINEER

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