OBJECTIVES

To disseminate to RCA engineers technical information of professional value.

•

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

•

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

•

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

•

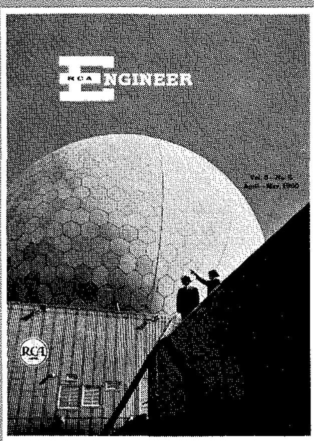
To help publicize engineering achievements in a manner that will promote the interests and reputation of RCA in the engineering field.

•

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

•

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



OUR COVER

The 140-foot diameter BMEWS radome, standing 15 stories high, holds the attention of two engineering managers of the Missile and Surface Radar Division, DEP, Moorestown, N. J.: at left, Edward N. Lichtenberg, Mgr., Mechanical Equipment Integration, who had key responsibilities for the mechanical design, and at right, Dudley M. Cottler, Mgr., Tracking Radar Development, who had key responsibilities in the electronic design of the huge AN/FPS-49 Tracking Radar, which the radome encloses. For the BMEWS story, see Pages 5-23.

ENGINEERING: GROWTH AND FUTURE

The technological revolution of the past few decades has its origin in creative science and engineering. The growth of engineering, particularly in the last twenty years, has far outstripped the population rate of growth, and the ratio of engineers to nonengineers in over-all industry has increased during this period from 1 in 100 to 1 in 32. In the electronics industry, the current ratio is much higher, being in the order of 1 in 7. This evolution and the continued growth of basic technical knowledge has rapidly increased the engineering content of our products.

With the continued development of nuclear science and the wonders of the Space Age ahead, the frontiers have been vastly extended, and future progress is almost certain to dwarf the past both in rate of growth and depth of engineering and scientific skills required.

The last decade has seen a 60-percent growth in the number of engineers, and during the next decade, it is predicted that this continued growth will further increase the number of engineers by at least 75 percent, to approximately a million and a half engineers by 1970.

There is a trend toward the merging of engineers and scientists more closely in the process of developing products of the present and the future. This phenomenon has been experienced in major programs of today that involve actual implementation as well as research and development. The organization teams required include an increasing number of scientists to work along with the engineers in carrying out the program.

Certainly, then, we can evaluate these trends and their influence on our future needs.

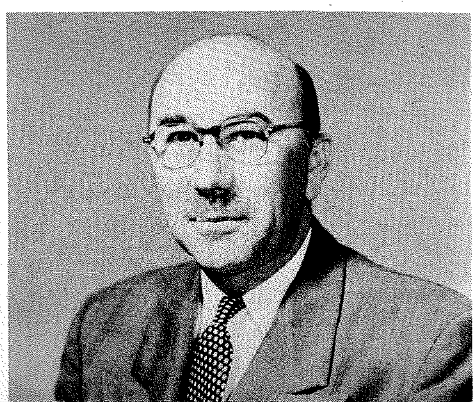
First, there is the need for a longer period of training. Advanced degrees will continue to become more of a necessity, and these involve longer periods of basic training.

Second, there will be the need for more specialization, in order to make it possible to probe the depths of future scientific needs. However, there will be much broader fields in which to apply these specialized skills, thereby offering opportunities, to best suit the temperament and interest of the individual.

Third, with increased specialization, there is also a need for the engineer who can take the broad look, to combine the contribution of many scientists and specialists and to synthesize new systems so that they may be harnessed to serve a useful purpose.

Fourth, there is an ever increasing need for the management of these technical efforts, by those particularly suited to technical management. Management of engineers, in particular, is another profession, just as engineering itself is a recognized profession. In this age where large group effort is required for big programs, the proper joining of these two professions is the key to capitalizing on scientific and engineering creativity.

Fifth, further changes are needed and, undoubtedly, will evolve in organizational concepts whereby the specialist, the creative systems engineer, and the management engineer can be recognized and rewarded on a comparable basis. These changes will occur as there develops a better understanding and evaluation of their respective contributions by those outside engineering, particularly in the business world. This understanding can only come about through the efforts and actions of the engineers themselves. This prestige can only be acquired through highly professional conduct at all times and the concerted effort of every engineer to do his share in raising the esteem in which he and his work are held by others.



H. R. Wege,
Vice President and General Manager,
Missile and Surface Radar
Radio Corporation of America

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VOL. 5, NO. 6 • APRIL-MAY, 1960

RCA ENGINEER

A TECHNICAL JOURNAL PUBLISHED BY **RADIO CORPORATION OF AMERICA**, PRODUCT ENGINEERING, CAMDEN, N. J.
Send all inquiries to Bldg. 2-8, Camden, N.J.

The Engineer and the Corporation

PREPARATION, APPROVAL, AND PUBLICATION OF TECHNICAL PAPERS

by R. F. GUY
Senior Staff Engineer, and Technical Publications Administrator
National Broadcasting Company, New York City, N. Y.

To achieve success and satisfaction from the practice of his profession, no engineer can be self-sufficient. Except for the meager information gleaned by direct observation of objects or events, knowledge is obtained through the spoken or written words of others. Every engineer is dependent upon them for a broad foundation of technical knowledge; with this background acquired, creative ability may be fruitfully applied in the contribution of new techniques or devices, or new theoretical knowledge.

Institutional success in industry is to a large degree measured by the ability of a research and engineering staff to contribute attractively packaged and well-engineered products, or to provide technical excellence in the operation of services. The success of the engineer or scientist as an individual is measured, first, by his ability to contribute to the design and production of marketable commodities and, second, by the commensurate recognition of his technical abilities and efforts in his profession and by his employer.

Recognition of merit in a marketable product requires that it be advertised. Similarly, recognition of personal accomplishment comes only when it is made known to others. Written media or oral communications will come to the attention of employers and members of the engineering profession through dignified and forthright disclosures of contributions of value and interest.

Publication of the fruits of technical effort through papers and talks is one of the keys to the success of the engineer and scientist. *RCA encourages such publication as a corporate policy and implements it in corporate practices.*

THE NEED FOR CORPORATE REVIEW AND APPROVAL

Any author of a technical paper whose work is identified with an employer will wish to conform with the policies and practices of that employer. Obviously, encouragement given to the engineer to publicize his work carries with it the responsibility to assure conformance with established policy.

But to meet this obligation without loss of initiative, the author will often need information, advice, and counsel from a readily accessible and authoritative source that functions efficiently and quickly. RCA has recognized and met this need: The Corporation's policies and practices regarding papers and talks authored by RCA personnel are embodied in a system of review and approval which is handled by *Technical Publications Administrators* in the various branches of the Corporation.

In a small, closely-knit organization, company policies and practices are generally well known to staff personnel, and prospective authors encounter or create few problems with respect to observance. Individuals may be well informed on such matters by word-of-mouth, bulletin-board postings, and memoranda. Review and approval of technical writings may be conveniently accomplished by department heads or supervisors readily accessible to the writer.

Understandably, such simple administrative procedures become totally inadequate in an organization as large as RCA; in such a widespread organization, it is not possible for those responsible for the observance of policies and practices to be accessible in a comparable degree. Among the operating activities in RCA there are many Chief Engineers or executives responsible for large departments; within the framework of over-all corporate policies and practices, their individual activities have considerable latitude to adopt formats best suited to their own operations. It would be very difficult for one operating unit to keep fully informed of the policies and practices of all other operating activities—as a practical matter, they are not expected to do so. It is equally impractical for individuals to keep fully informed of all activities in every corner of the Corporation, or on patent matters which affect the rights of others and his own company.

In a large organization, it is apparent that the formidable amount of technical writing requires the assignment of knowledgeable and experienced personnel to coordinate the processing and distribution, and provide information and counsel to engineer-authors in their areas.

THE TECHNICAL PUBLICATIONS ADMINISTRATOR

Each major branch of the RCA organization from which engineering papers or talks may originate has designated an experienced person to function as a Technical Publications Administrator.

Each such Administrator is a member of an over-all RCA Technical Publications Administration Board, which was created to ensure that corporate policies and practices are honored and followed, to assist authors where possible in the preparation and distribution of meritorious contributions, and to coordinate all such activities among the originating units. The present makeup of this board is shown in the chart. *These are the men* that the prospective engineer-author should work with to gain helpful review, official corporate approval, and efficient placement of his paper or presentation. In the large major operating units, the Administrator may have an Editorial Board to assist him, representing the various engineering sections.

The Technical Publications Administrator in each originating activity has a broad knowledge of the technical programs and functions of his area and the Corporation as a whole, and has had many years of experience in writing. He is familiar with the internal and external publications which constitute the technical press, the various professional societies, the national and regional conventions, and the policies and practices societies observe in accepting and scheduling papers submitted by individual contributors. When given the opportunity, he will gladly provide counsel and guidance in the planning and preparation of technical papers and the placement of them in desirable media. Engineer-authors throughout the Corporation depend upon their Technical Publications Administrators for these services.

TECHNICAL PUBLICATIONS ADMINISTRATION BOARD

Except for the Chairman and the Assistant Chairman, the individual members are the Technical Publications Administrators representing the various operating activities shown.

E. T. Dickey .... RCA Laboratories, Princeton, N. J.

E. C. Hughes, Jr. .....RCA Electron Tube Division and Semiconductor and Materials Division, Harrison, N. J. (Bldg. 51-2)

M. G. Gander .... RCA Service Company, Cherry Hill, N. J. (Bldg. 204-1)

R. F. Guy .... National Broadcasting Company and RCA Institutes, New York, N. Y.

S. F. Dierk .... Industrial Electronic Products, Camden, N. J. (Bldg. 15-3)

L. C. Simpson .... RCA International Division, Clark, N. J.

K. A. Chittick .... RCA Victor Home Instruments, Cherry Hill, N. J. (Bldg. 204-2)

L. A. Thomas .... Astro-Electronics Products Division, Princeton, N. J.

F. D. Whitmore ...... Defense Electronic Products, Camden, N. J. (Bldg. 10-7)

E. R. Jennings .... Assistant to Chairman, RCA Staff, Camden, N. J. (Bldg. 2-8)

W. O. Hadlock .... Chairman, RCA Staff, Camden, N. J. (Bldg. 2-8)

HOW THE SYSTEM WORKS

The Administrator carries the responsibility to ensure that engineering papers and oral presentations intended for use outside of his own originating activity conform with corporate policies and practices. In both content and journalistic construction, papers and presentations must be worthy of their identification as a contribution of the organization of which their authors are a part. The manner in which these requirements are implemented is simple.

The individual contributor is expected to make sure that his supervisor is informed concerning the contribution and its proposed publication, and gives his approval. Written approval and the required number of manuscript copies of the paper or written version of the talk are then submitted to the Technical Publications Administrator for further review. Although carrying the responsibility for review, he is not in a position to know fully the problems which may be raised within *all other* operating segments of the Corporation if the material is approved. Therefore, he exercises his judgment in determining to which other operating units the writing should be submitted. Such routing is normally made through the appropriate Technical Publications Administrators, who in turn exercise their own judgment concerning review in their own area.

These procedures are short, direct, and efficient. By obtaining sufficient copies for simultaneous distribution, the other activities may review it concurrently, thus avoiding consecutive routing with attendant loss of time. Authors are urged to recognize this problem and, in their own interest, provide the number of copies considered by the Technical Publications Administrator to be necessary for concurrent review. The importance of prompt review is recognized by all Administrators, and submissions are processed as quickly as possible.

In reviewing submissions constructively to serve both the author and the Corporation, the Technical Publications Administrator is guided by several considerations:

1) good planning and construction, technical accuracy, and timely disclosure of information
2) freedom from statements which would be derogatory to other institutions or individuals
3) defense classification and patent status
4) over-all merit

If a reviewing activity raises objections to portions of a submission, the author is given an opportunity to make the revisions and then receives written approval from his Technical Publications Administrator to release his paper.

BENEFITS TO THE AUTHOR

The engineer-author may, by consulting his Technical Publications Administrator, receive counsel which will minimize the time and effort required to produce a paper suitable for publication. He is also in a position to determine the journals in which there will be the greatest demand for the writing submitted.

The RCA review-and-approval system was established to meet most efficiently, smoothly, and quickly the objectives described. The procedures are reviewed at frequent intervals in the interest of making them more useful and modernizing them to conform with changes in the corporate organization. The Technical Publications Administrator may be looked upon *not* as an obstacle to quick and easy publication of papers, but as an experienced, well-informed, and helpful counselor who will expedite approval, keep the engineer-author out of trouble, and help to place his writings advantageously.

COMPANY PUBLICATIONS

In addition to the publication of papers in outside journals, RCA engineers are encouraged to prepare and submit contributions for company publications such as the RCA ENGINEER, the *RCA Review*, and *Broadcast News*. Material for such company publications requires, of course, the *same* review and approval as applies to material for outside use. It is recommended that in preparing such contributions, the author keep in mind the possibility that they may also be desirable for outside publications. By working with his Technical Publications Administrator, the engineer can often prepare his article so that with minor modification, or no modification, it would appeal to outside journals. Such duplication of publication is desirable, since it greatly broadens the distribution and more effectively publicizes the work of the writer and the Corporation.

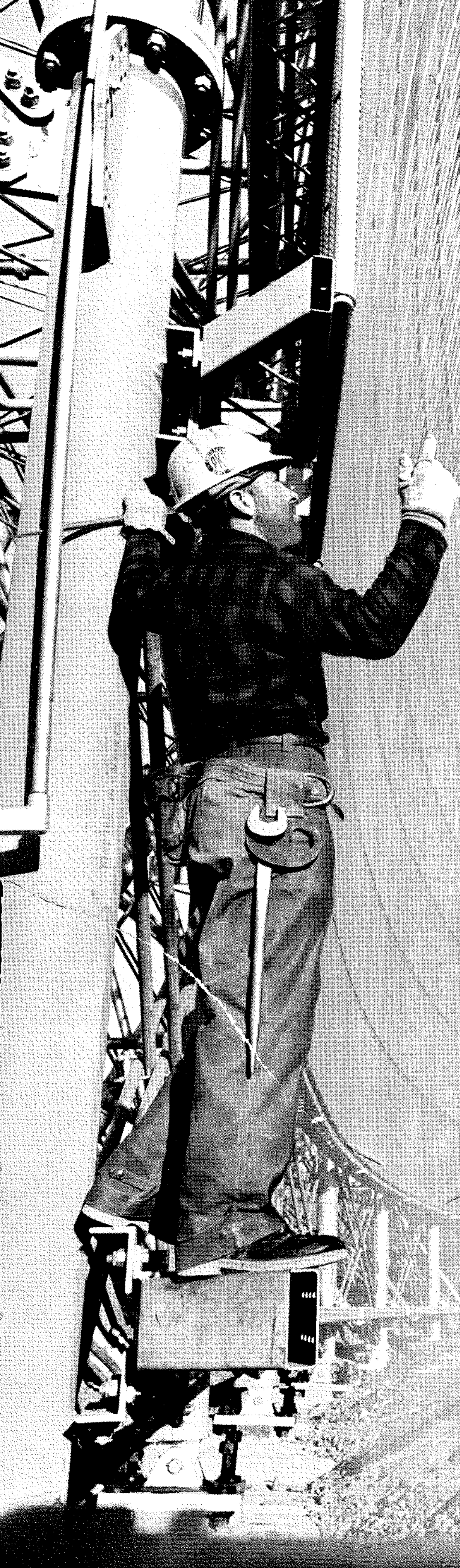
OTHER MEDIA: RCA TECHNICAL REPORTS AND ENGINEERING MEMORANDUMS

In addition to technical articles and oral presentations, there is another important category of engineering writing: the *Technical Reports* and *Engineering Memoranda* for internal RCA use.

Technical Reports and Engineering Memoranda are the direct responsibility of the Chief Engineer of an operating activity and his engineering management. These writings form a system for formally recording and distributing important research and engineering information within the Corporation.

Such writings are covered by corporate policies and procedures separate from those described herein for papers and talks, although they may involve some of the same approvals. A future issue of the RCA ENGINEER will cover these in *The Engineer and the Corporation* series, describing policies and basic techniques of preparation, approval, and distribution, and their value in engineering work. Engineers who propose to write such documents should obtain from their manager or designated authority an outline of the procedures currently in effect, so that they may become familiar with them.

RAYMOND F. GUY, Senior Staff Engineer of the National Broadcasting Company, was on the original staff, composed of only a few persons, at WJZ when it was opened in 1921 by the Westinghouse Company in Newark, as the world's second broadcasting station. Before the beginning of broadcasting, Mr. Guy had worked with the Marconi Wireless Telegraph Co., the Shipowners Radio Service, and the Independent Wireless Telegraph Co. During the concluding engagements of World War I, he served in France in the Regular Army. He entered Pratt Institute upon discharge, graduating in Electrical Engineering in 1921. In 1924, he joined the engineering staff of the RCA Research Laboratories. For 25 years of his career he directed the planning and construction for all services of all NBC transmitting facilities, including frequency allocations and other allied activities. Mr. Guy was President of the IRE in 1950 after many years as an Officer and Director. He is a member of the Broadcast Advisory Committee and Chairman of the Engineering Subcommittee of the *Voice of America*, and was for many years Chairman of the Engineering Advisory Committee of the National Association of Broadcasters. As an RCA Technical Publications Administrator, Mr. Guy represents NBC and the RCA Institutes in all editorial matters. He is active in the engineering writing field, being the author of numerous technical papers and textbooks. He is a Fellow of the Radio Club of America and the IRE, a charter member of the Twenty Year Club and the Broadcast Pioneers of which he is Secretary and past President, a life member and First Vice President of the Veteran Wireless Operators Association, and a member of the Society of Professional Engineers and of many other professional societies. He was recently elected a Fellow of the American Institute of Electrical Engineers, and received a Citation from the Broadcast Pioneers. He is currently President of the De Forest Pioneers.



RCA AND BMEWS

The award of the prime contract for the Ballistic Missile Early Warning System (BMEWS) to RCA marked a milestone in RCA's engineering, management, and marketing history. It is the largest single contract ever awarded the Corporation.

The selection of RCA by the U.S. Air Force is an outstanding example of the emphasis on the newer concept of competent systems-integration management, as opposed to the older principle of hardware-manufacturing management, for the most efficient development of a major defense system.

RCA's development of major defense system capabilities had its beginnings shortly after World War II, when a few engineers were engaged in government radar work. Ensuing years saw increasing activity on increasingly complex systems. This building process developed the broad capabilities necessary to deal with a huge, complex system like BMEWS, as well as to investigate sophisticated defense systems of the future.

BMEWS system management is concentrated in the Major Defense Systems activity of the Missile and Surface Radar Division, DEP, Moorestown, N.J. This integrated management group had its conceptual beginnings in the project-engineering approach evolved on the earlier radar contracts. Under this concept, capable engineering teams are made responsible for a program from its specifications stage through completion of field operations—monitoring development, design, production, installation, and field-support activities as the system evolves from paper concepts to a fully operational system. Subcontractor and allied activities are no small part of this effort—for BMEWS, some 485 large companies and 2415 small firms are involved, spread over 29 states of the nation.

Pages 6 through 23 of this issue offer a look at the system concepts and technical features of BMEWS.

THE BALLISTIC MISSILE EARLY WARNING SYSTEM

by **H. W. PHILLIPS, Mgr.**

BMEWS Operations Administration
Missile and Surface Radar Division
DEP, Moorestown, N. J.

THE DEVELOPMENT of the inter-continental ballistic missile placed the United States well within range of such missiles from the USSR. As shown in Fig. 1, vital potential targets in the United States are located at ranges of 3,000 to 5,000 miles from possible Russian launch points, well within the range capability of ICBM's known to have been developed. It is obvious that an effective early-warning system, well-integrated with all components of the defense and retaliation concepts of the United States Armed Forces, is a vital first step in being able to defend against such a potentially devastating attack.

The BMEWS system is conceived primarily for warning against such a mass ballistic missile attack and specifically to alert the Strategic Air Command. However, it has been designed and implemented for growth to serve the whole defense system. For example, it is possible that data from BMEWS regarding ICBM's may be evaluated and required information relayed to active defense systems. BMEWS can later play a greater role in meeting the space threat.

In developing BMEWS, it was determined early in the program that a single site would not be sufficient. With a one-site configuration, because of curvature of the earth and other radar limitations, ballistic missiles could be fired to go around the radar coverage sector to the United States without being detected. For BMEWS, three sites are used to provide complete radar coverage against ballistic missiles which may be fired toward the United States and Southern Canada from Russia or Russian-controlled territory (Fig. 2). The first BMEWS site is at Thule, Greenland; the second site is at Clear, Alaska; and the third at Fylingdale Moor in Great Britain.

BASIC SYSTEM REQUIREMENTS

First, BMEWS must gather detection data at the three forward sites, and a certain amount of data processing and analyzing must also take place there. Then the data must be communicated or relayed to the zone of interior in the United States for further evaluation. If there is an alert, the alert information must be immediately relayed to those who are interested and who need it in order to take retaliatory action.

One of the basic components of BMEWS is a *detection radar*, a fixed piece of equipment designed to provide coverage for a specific sector (Fig. 3). It consists of a parabolic antenna 165 feet high by 400 feet wide. Each pulsed-doppler detection radar consists of this reflector, a scanner building, and the associated transmitter equipment. The building houses scanner switches and arrays of feed horns which bounce beams off the face of the reflectors. These beams form horizontal stationary fans, which spread across the polar regions to detect airborne objects. Impact prediction on missile targets can be obtained by extrapolating the missiles path from the range, azimuth, bearing, and time sequence data recorded as the missile passes through the fans of the detection radar.

Another basic component is the *tracking radar*, which is enclosed by a large radome to protect the antenna from adverse weather conditions (see Fig. 4, 6, and cover). The actual radar antenna is a 84-foot dish which can be rotated in both azimuth and elevation. The building houses the transmitter and other electronic equipment.

The tracking radar (Fig. 6) provides an indication of the magnitude of the mechanical problems that were added to the electronic problems on so complex a system. The antenna and pedestal weigh nearly 375,000 pounds, with the hydraulic servo-driven rotating section comprising over 200,000 pounds of this weight.

Fig. 5 is a simplified diagram showing a tracking radar and a detection radar hooked up to data take-off equipment, which takes data from the radars and feeds it to a computer. The computer serves to initiate tracking by the tracking radar and computes information which is communicated to the zone of interior control center. Fig. 7 shows a typical forward site consisting of four detection radars with slightly overlapping fans to provide complete sector coverage. This is a theoretical illustration, as actual specific sites may differ from the layout shown. It also shows tracking radars, each of which can be used to replace a detection radar in case of a failure.

Fig. 8 shows the interior of the pres-

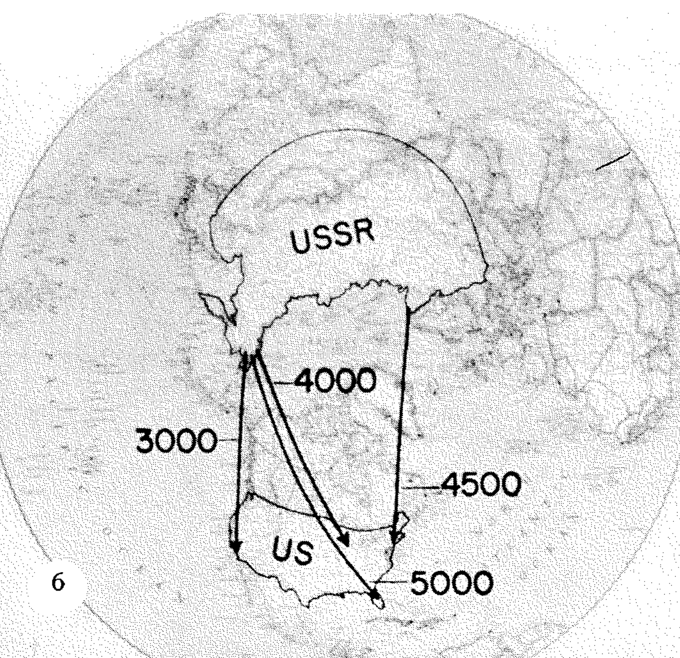


Fig. 1—ICBM ranges from USSR.

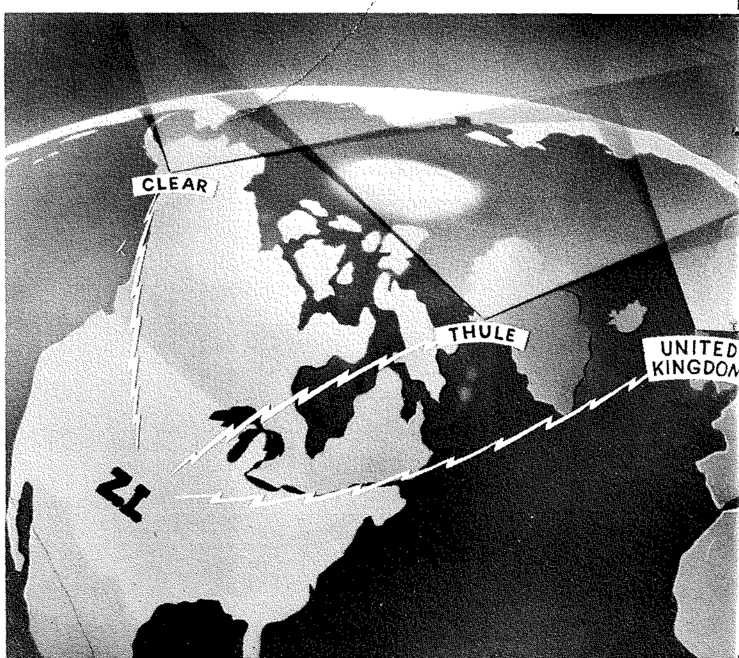


Fig. 2—Three-site configuration of BMEWS.

ent Strategic Air Command Combat Operations Center at Colorado Springs. The plotting board at the right is the main manual plotting board which is currently in operation. It is to be replaced by an automatic plotting board, and in the vacant board at the left, a BMEWS display will be installed. The BMEWS display will be automatic and will not require manual plotting.

SUPPORT REQUIREMENTS

With the construction of high-power radar stations at far-northern sites, there was the problem of supplying the large amount of electrical power needed. In this case, an oil-fired turbine-generator power plant system was constructed on board a ship by the Navy and was assigned to the Air Force for use on the BMEWS program. The power supply from this ship is run through high-tension transmission lines to the BMEWS site. At the site, an auxiliary plant provides for emergency power in case the transmission lines fail. Also, it supplements the power ship to provide the total amount of power that is required for this installation. The power requirements for one BMEWS site is equivalent to that required for a city of 30,000 people.

Support areas at each site provide maintenance for the technical facilities. Direct support includes electronic and mechanical maintenance shops, vehicle repair and storage, and power generation and distribution. These latter areas are connected to all of the technical buildings by covered passageways which offer complete protection from the elements and from possibly dangerous r-f energy levels from the radar.

At the zone of the interior facility, data from the forward radar sites are decoded, evaluated, modified by other intelligence, and displayed. Thus, the warning of impending enemy ICBM attacks can be generated. It is here that a threat evaluator provides an indication of the threat level and degree of confidence in the incoming data.

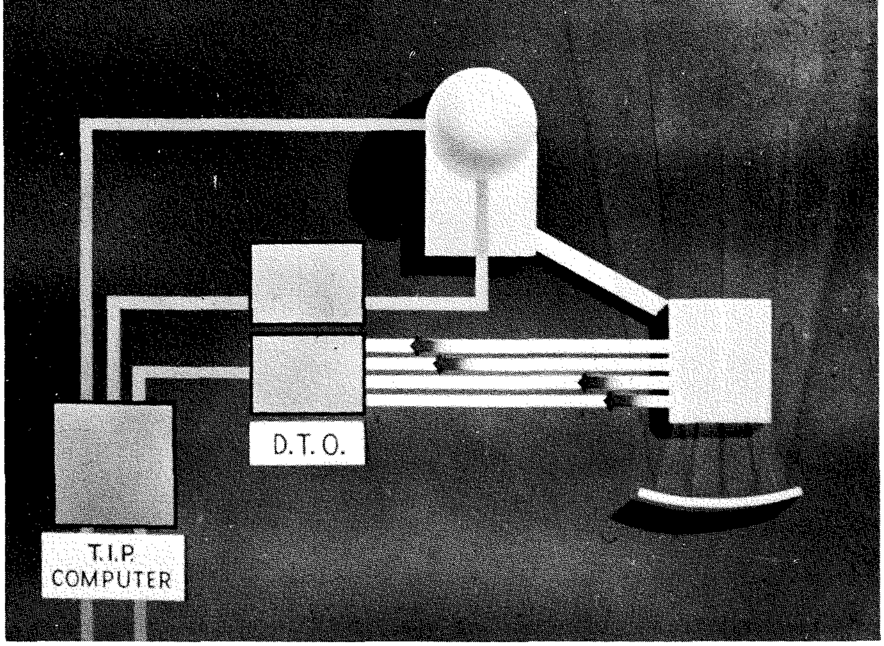


Fig. 5—Data take-off system.

The combination of forward sites and the zone of the interior results in a system which will warn the United States and southern Canada of impending ICBM attack within seconds after detection of the attacking missiles. This alert will supplement such aircraft detection systems as the DEW Line, Mid-Canada Line, and Pine Tree Line.

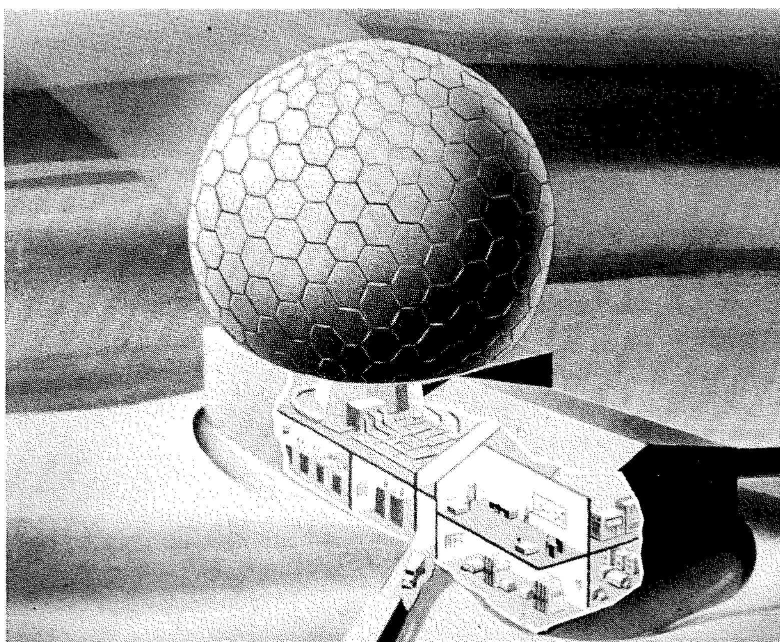
INSTALLATION PROBLEMS

Construction for the Arctic portions of this BMEWS project is being accomplished under the most extreme hardships imaginable. Nature is man's enemy in the Arctic wastes with winds that can reach 185 mph and temperatures that can dip below −65°F. Construction materials, such as metals, that will be exposed to extreme low temperatures must be designed especially to meet the cold weather requirements. Ordinary metals become very brittle in the extreme cold, and special alloys have to be developed to withstand the wind forces that are prevalent.

In addition to the extreme cold, *permafrost* presents a major construction problem. Permafrost is a continually frozen layer of earth which is to be found at all seasons of the year. In the summer it is several feet below the surface, but in the winter it extends to the surface. To set concrete foundations in this frozen layer is very difficult. One means for doing so is to use live steam to melt the frozen earth so that it may be excavated. Once the foundation has been excavated, the ground re-freezes. The concrete is then poured; however, the setting concrete gives off heat and, left to itself, would melt enough of the permafrost to enable the foundation to

Fig. 3—Detection radar.

Fig. 4—Tracking radar.



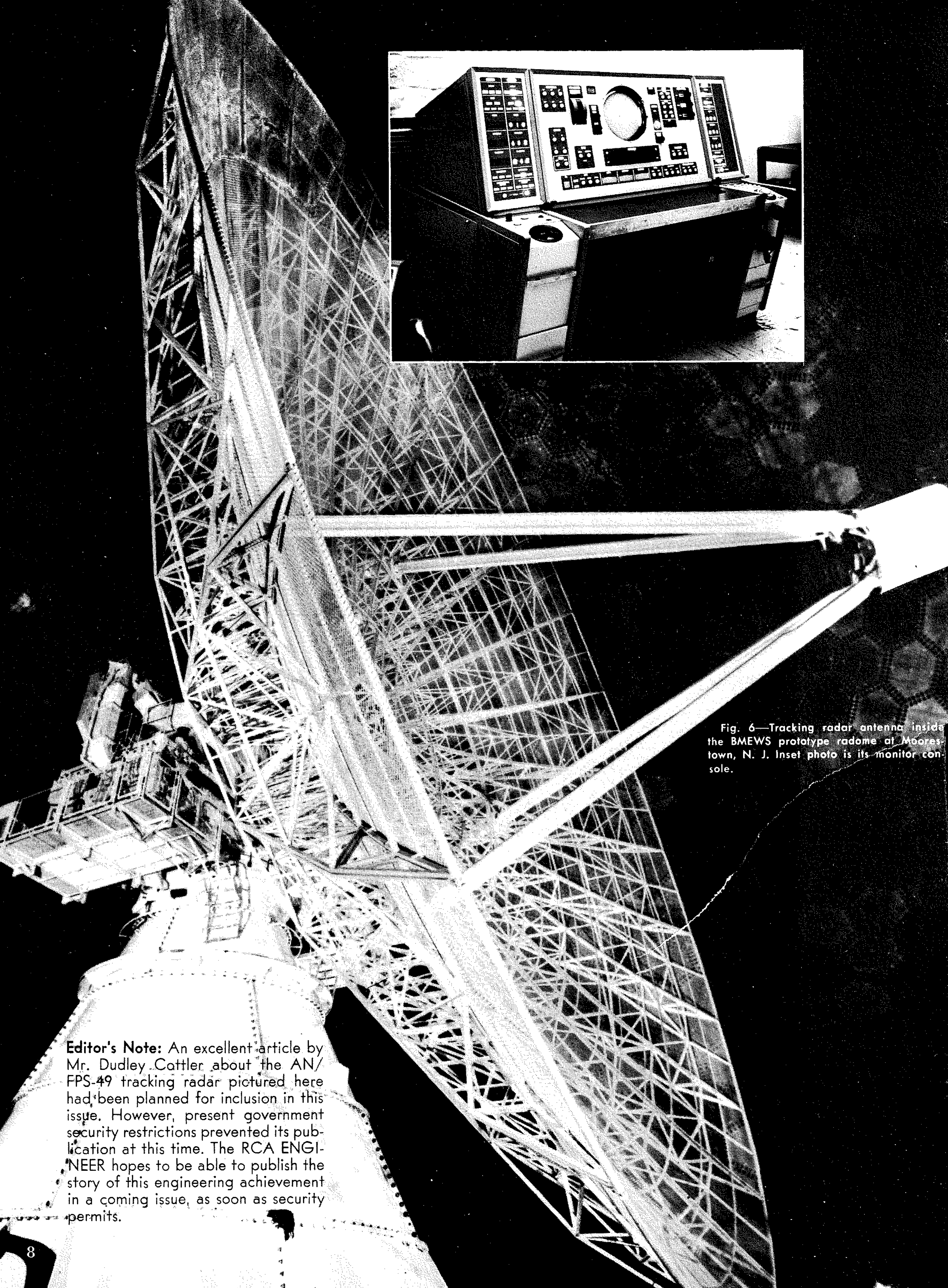


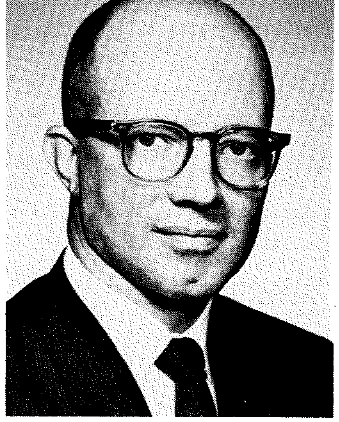
Fig. 6—Tracking radar antenna inside the BMEWS prototype radome at Moorestown, N. J. Inset photo is its monitor console.

Editor's Note: An excellent article by Mr. Dudley Cottler about the AN/FPS-49 tracking radar pictured here had been planned for inclusion in this issue. However, present government security restrictions prevented its publication at this time. The RCA ENGINEER hopes to be able to publish the story of this engineering achievement in a coming issue, as soon as security permits.

shift. Thus, a refrigeration unit is needed to keep the ground frozen until the concrete is firmly set.

The concrete is poured under rubber shells the size of circus tents which are supported by hot air blown into them under pressure. These shells permit construction under conditions that would normally be too cold for construction. After the foundation is finished, the exterior part of the building is quickly finished so that construction inside can continue during the winter months. But, in completing the buildings, they must be insulated from their foundations so that heat from the buildings cannot escape into the ground to melt the permafrost and cause settling.

Another factor in the BMEWS construction is the large size of several of the buildings. The radome for the tracking radar has a 140-foot diameter and stands approximately 15 stories high. This radome is located atop the transmitter computer building which in itself is three stories high. The detection radar reflector is 400 feet by 165 feet, or as high as a 16-story building. The immensity of the project begins to be seen when one thinks such construction under adverse conditions.



HENRY W. PHILLIPS received his B.S.M.E. at the University of Virginia in 1940. He was with the General Electric Company throughout World War II in the Aeronautics and Ordnance Systems Division. He joined the American Machine and Foundry Co. in 1946, and shortly afterwards was appointed head of engineering for their Buffalo Plant, where automatic machinery of various types, including the automatic pinspotter for bowling, was developed and designed for production on which he holds two patents. He was later assigned to manage a project for this company at the AEC Hanford Works, Richland, Washington, involving the development of equipment for the production of plutonium. He was a consultant during an early study for the Navy on the feasibility of Atomic Power for Submarines. In 1949 Mr. Phillips accepted a position at the Knolls Atomic Power Laboratory where he contributed to the G.E. Experimental Power Breeder Reactor Program. Later he was appointed to the management staff for the Shipboard Intermediate Reactor Program for a submarine application of nuclear power. In 1951 Mr. Phillips became the Chief General Staff Engineer for F. H. McGraw and Company, the prime engineering and construction contractor for the one-billion dollar highly automated U-235 plant at the AEC Paducah area. On the completion of this assignment, he joined RCA in 1953 and, initially, managed the RCA bumblebee and terrier programs. He served as Secretariat of the RCA Guided Missile Committee in 1954. When RCA became the prime contractor for the TALOS Land Based System program, Mr. Phillips was assigned as Coordinator. He is now Manager, BMEWS Operations Administration, Major Defense Systems, at the RCA Moorestown Plant. He is a member of Tau Beta Pi and the National Society of Professional Engineers and a licensed Professional Egnineer in New York, New Jersey, and Kentucky. He is a past Vice President of Kentucky Lake Chapter, Ky., Society of Professional Engineers, and was Chairman of Publications and Legislative Committees for this Society. He is a member of American Society of Mechanical Engineers, American Society of Naval Engineers, and the Armed Forces Communications and Electronics Association. He is a Trustee for the Engineering Society of Southern New Jersey and Chairman of their Public Relations Committee.

PROTOTYPE FACILITY

In connection with the BMEWS program, it was necessary to construct an engineering model facility (see cover) at the Moorestown Plant to test the tracking radar and other basic components to assure that the system will perform properly when it is installed at the forward sites. In addition to this test facility at Moorestown, tests are being carried out at other RCA plants, at General Electric, at Sylvania Electronic Products, and at Goodyear. Some government facilities are being used.

The complete radome at Moorestown consists of 1,646 four-, five-, or six-sided bolted pieces (Fig. 9) Each piece is about five feet across and weighs about 125 pounds. Within the building is the transmitter for the radar, a computer, data take-off equipment, and other equipment to test the radar, as well as the entire system.

The tracking radar assembly (Fig. 6) was completed at the Goodyear Aircraft Plant in Akron, Ohio, where a series of mechanical tests were conducted to check the mechanical performance of the radar pedestal and the antenna. It was found to meet the specification requirements, and then the antenna and pedestal assembly was disassembled and shipped to Moorestown.

ADMINISTRATIVE ORGANIZATION

The U.S. Air Force BMEWS Project Office has two main subdivisions consisting of an AMC representative as the executive head of the project and an Air Research and Development Command representative as the technical head of the project. RCA is the prime weapon system contractor and the Western Electric Company is prime contractor for the rearward communications; RCA has three major subcontractors, General Electric Company, Sylvania Electric Products, Inc., and Goodyear Aircraft Corporation.

A BMEWS Project Management Office was set up at the RCA plant in Moorestown. The direct project management team consists of a number of RCA units, both at Moorestown and at other plants of the Corporation. The RCA units contribute over-all program management, specifications, and system development, systems integration, and a number of hardware and service items.

The General Electric Company furnishes detection-radar subsystems and continental transmitters. The Goodyear Aircraft Corporation furnishes tracking radar pedestals, antenna assemblies, and the radomes for the tracking radars. Sylvania Electric Products furnishes IBM computers and certain data-processing equipment. The RCA Service Company furnishes field support, logistic, and operation and maintenance service activities.

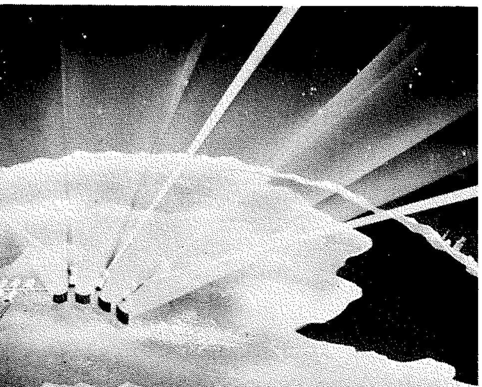


Fig. 7—Theoretical site configuration with four detection radars and three radome-enclosed tracking radars.

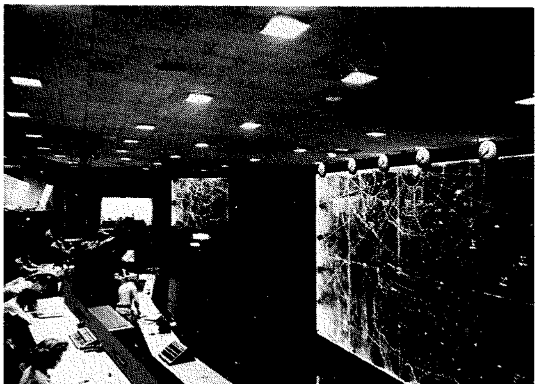


Fig. 8—SAC operations center in Colorado Springs. An automatic BMEWS display will be added in the vacant space.

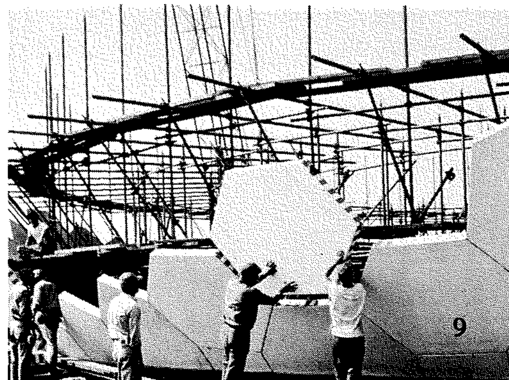


Fig. 9—Erection of the radome shell for the tracking radar.

A HIGH-POWER, LONG-PULSE UHF RADAR TRANSMITTER

by **T. P. TISSOT**
BMEWS Transmitter Projects
Missile and Surface Radar Division
DEP, Moorestown, N. J.

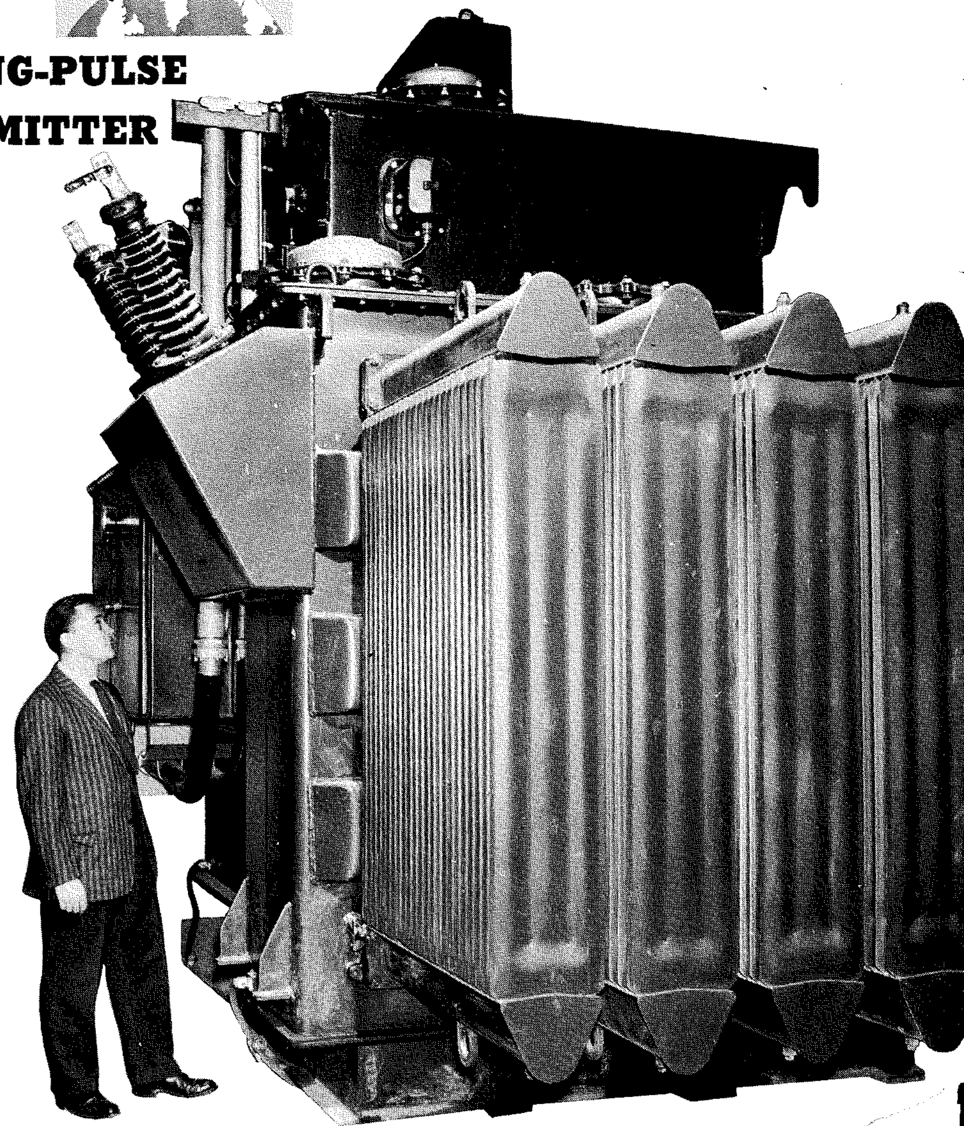


Fig. 1—D. Foster is dwarfed by the transformer and rectifier assembly for supplying transmitter plate power.

The high-power, long-pulse uhf radar transmitter which the DEP Missile and Surface Radar Division has designed for BMEWS is of a magnitude approaching an industrial complex. Some idea of this can be gotten from Fig. 1, which shows the transformer and rectifier for supplying plate power.

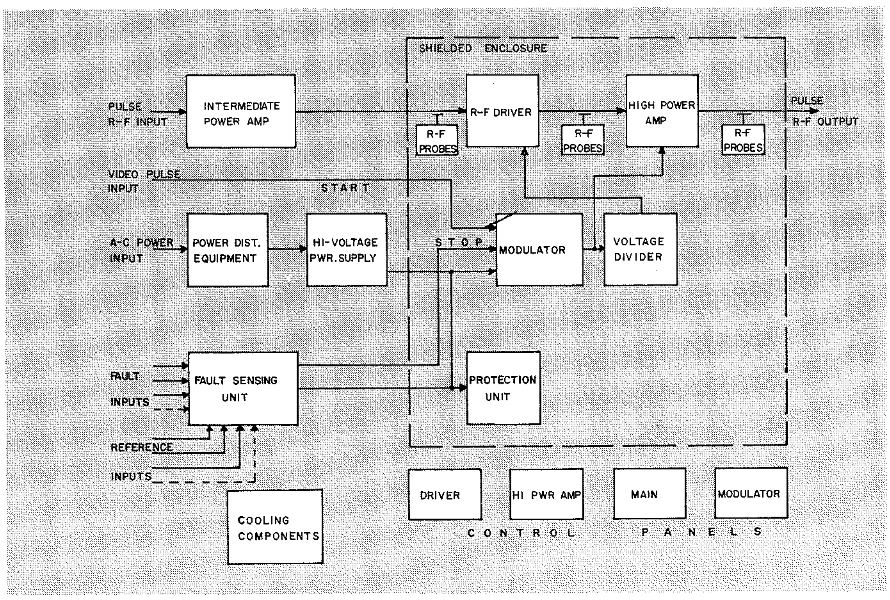
Formal design effort was begun in mid-1958 with design completion of this formidable task by the end of the year. A purchase and fabrication cycle followed, and installation of a prototype at the Moorestown Engineering Model Facility was completed during the summer of 1959 for testing and checkout.

ENGINEERING ORGANIZATION

To take advantage of the specialization of engineering groups, work tasks were divided into five categories: 1) high-voltage power supply, power distribution, and main control circuitry; 2) cooling system, installation planning, and installation material; 3) fault sensing and protection; 4) hard-tube modulator; and 5) high-power-amplifier–room integration. Emphasis in the design was on the modulator, which is the hard-tube type, rather than the line type.

Design was coordinated by a project Engineering Group, who specified the design concept and monitored its implementation. In addition, a Design Integration Group selected suitable components and monitored electrical and mechanical design reviews. Actual emplacement and installation of this hard-tube-modulated transmitter at the test site was supervised by a separate Construction and Emplacement Group. Testing of the transmitter, either at the equipment unit or group level has been the responsibility of the Missile and Surface Radar Engineering Department under the direction of the Project Engineering Group.

Fig. 2—Transmitter functional block diagram.



TRANSMITTER FUNCTIONS

Fig. 2 is a functional block diagram of the transmitter. Input signals are shown to the left. The fault and reference inputs are derived internal to the transmitter and are part of the fault-sensing and protection system. The 4160-volt, 3-phase, 3-wire primary power input is fed directly to a connection cabinet from the external power substation. The r-f and video-pulse inputs are obtained from a source external to the transmitter and are properly related in time. The pulse input is a short pulse which functions as a start trigger while the r-f pulse is of a duration slightly longer than the desired transmitter output pulse width. A variable delay is introduced into the modulator start line to permit proper pulse-bracketing, as required.

The intermediate-power amplifier consists of three r-f amplifier stages and provides an output level sufficient to drive the r-f driver stage. Plate and screen voltages are continuously applied to the three amplifier stages, and the intermediate-power amplifier (IPA) simply "follows" the r-f pulse input. The IPA is physically located outside the high-power-amplifier (HPA) room, a shielded enclosure.

The r-f driver stage further amplifies the r-f signal and, by means of $6\frac{1}{8}$-inch coaxial line, feeds the grid of the high-power amplifier. The r-f directional couplers and diode detectors are installed on both the input and output coaxial lines and provide signals for refectometer functions (*forward power, reverse power, VSWR*) and fault-sensing indications. The r-f input to the driver is applied through a variable line stretcher and swamping loads. The line stretcher will allow the matching of transmitter r-f output in the event that it is necessary to combine, or diplex, the output of two or more transmitters. The swamping loads assist in isolating the driver from the IPA and provide a convenient means of adjusting input-cavity bandwidth. The r-f driver employs a tetrode in a grounded-cathode configuration. An impedance-matching transformer in the output transmission line, and a fixed distance in terms of wavelengths from the cavity plate circuit, sets the output-circuit impedance and, consequently, the bandwidth. This transformer and all other driver tuning adjustments are controlled remotely at the driver-control panel.

The input to the HPA cavity is at the top and is seen in Fig. 3 along with the output waveguide. Note the waveguide directional couplers which perform the same function here as for the r-f driver. All HPA tuning adjustments are performed remotely at the HPA control panel. The HPA cavity is of the symmetrical type and employs an RCA-2346 triode operating grounded grid. [See R. E. Reed, *Super-power UHF Pulse Triode*, this issue.] Its filament power supply is regulated, and turn-on surges are eliminated by programming the output from zero.

The r-f output from the transmitter feeds a waveguide complex consisting of a harmonic filter, r-f dummy load, E/H tuner, waveguide switches, and the other plumbing associated with a transmitter intended for radar applications. (Fig. 4). The waveguide switch is remotely activated and selects the *radiate or dummy-load* mode of operation. The function of the E/H tuner, which has preset adjustments, is to make the working load of the HPA independent of a particular plumbing configuration.

The modulator, which will be discussed further, provides a pulse voltage output which is, directly, the plate voltage for the HPA. A voltage divider steps down the voltage to the proper value for the plate and screen of the r-f driver. The shape of the modulator pulse determines the r-f output characteristic, since this pulse is slightly shorter in width than the IPA pulse to the r-f driver. The modulator is located inside the HPA shielded enclosure but has an associated control panel located outside.

The fault-sensing and protection unit act together to provide microsecond protection to the r-f driver and HPA, and the switch tube of the modulator. Any r-f faults in the driver or HPA will be detected and processed by the fault-sensing unit and the pulse in progress will be stopped by "opening" the switch tube of the modulator. In this case, the

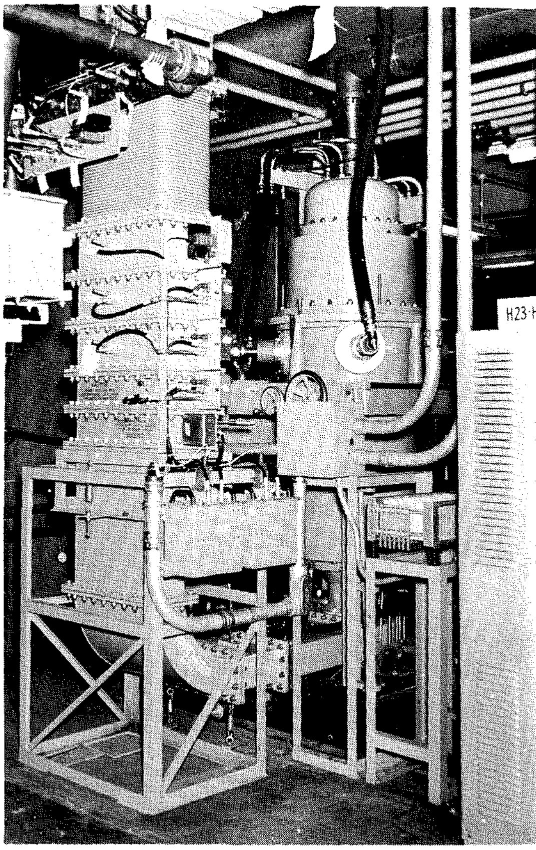
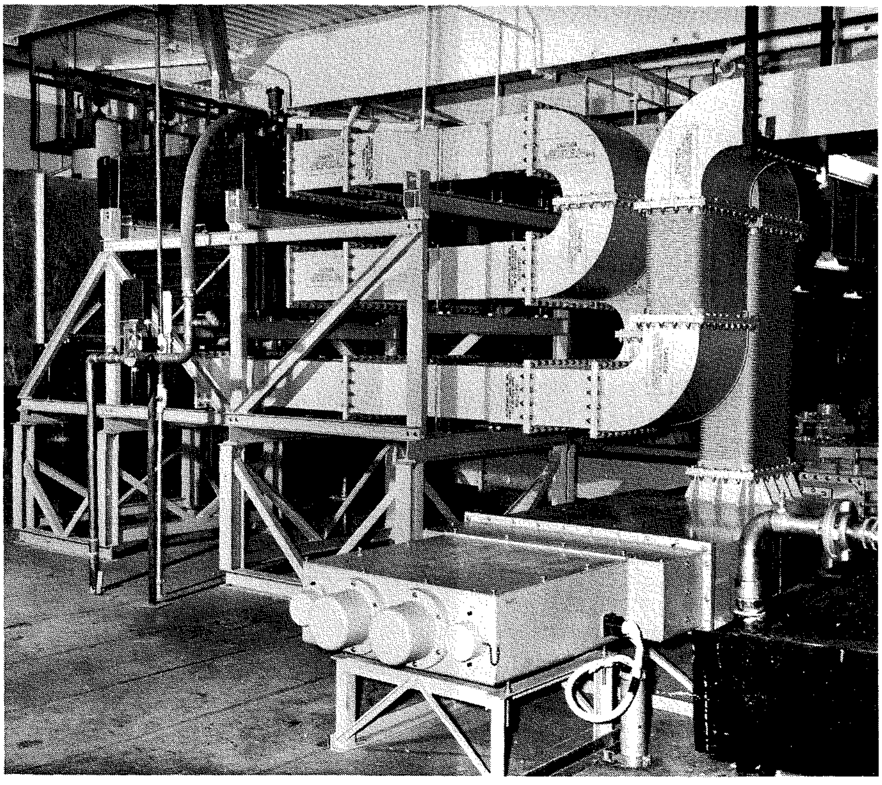


Fig. 3—Cavity for high-power amplifier, with output waveguide in foreground.

Fig. 4—Waveguide complex for handling r-f output.



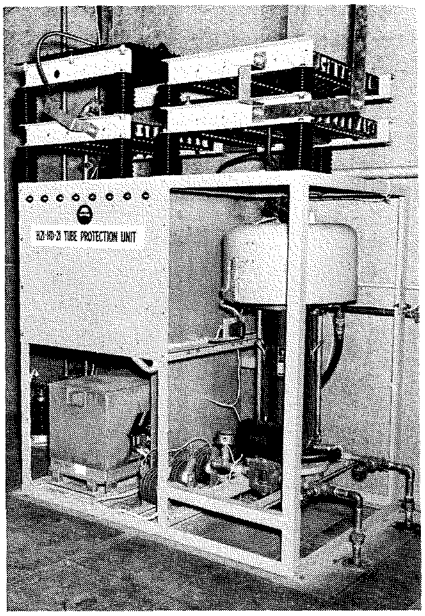


Fig. 5—Protection unit, consisting of a trigger amplifier, and an ignitron across the output of the high-voltage power supply.

protection unit is not used. The protection unit (Fig. 5) consists of a trigger amplifier and an ignitron which is across the output of the high-voltage power supply. Any fault in the switch tube of the modulator requires the removal of energy stored within the capacitors of the high-voltage power supply within microseconds of detection of a fault. In this instance, the fault is sensed, processed by the fault-sensing unit, and a signal is sent to the protection unit causing the ignitron to "dump."

The main control panel is the center of operation of the transmitter, and its function in conjunction with the high voltage power supply will next be considered.

CONTROL CIRCUITRY: HIGH-VOLTAGE POWER SUPPLY

It was realized at the start of the program that the simplest approach to the design of the control circuitry for the whole transmitter would be to consider each major unit as a subsystem with its individual control ladder. This allowed parallel design effort in the subsystems; it was only necessary to state the method of relating the subordinate control ladders to the main control ladder, part of the Main Control Panel.

The method by which this has been done is illustrated by the arrangement of the Main Control Panel (Fig. 6). In the upper portion of the panel, indicator lamps are arranged in a functional flow pattern. When the transmitter *Ready* button is depressed, the start cycle commences and lights the associated lamp. The distribution circuit breaker closes and primary power is applied to the distribution transformer. The secondary of the transformer delivers 480-volt, 3-phase voltage to the Main Control Center and, through limiting air-core reactors, to the induction regulator. Power from the Main Control Center is fed to the Coolant System Control Center for distribution to the cooling components and to the Regulated Voltage Control Center, where it is distributed as required and stepped down to 120-volt, single phase for the control ladders. The *control power* lamp is now on, and, simultaneously, *start* signals are sent to the following units, each represented by a horizontal line on the panel (top to bottom, Fig. 6): IPA, r-f driver, HPA, modulator, protection unit, and fault-sensing unit.

After a period of time, depending upon unit warm-up–delay requirements, a *ready* signal is received from each unit control ladder. The main control ladder then sums the return signals and the panel indicates *transmitter ready*. The main control ladder performs the remaining functions as required. Considerable flexibility of control functions is available, and unit testing of the modulator, IPA and r-f driver is possible. This has been achieved with a minimum complication to the total control circuitry. Considerable human engineering effort was expended on the functional layout of the control panels.

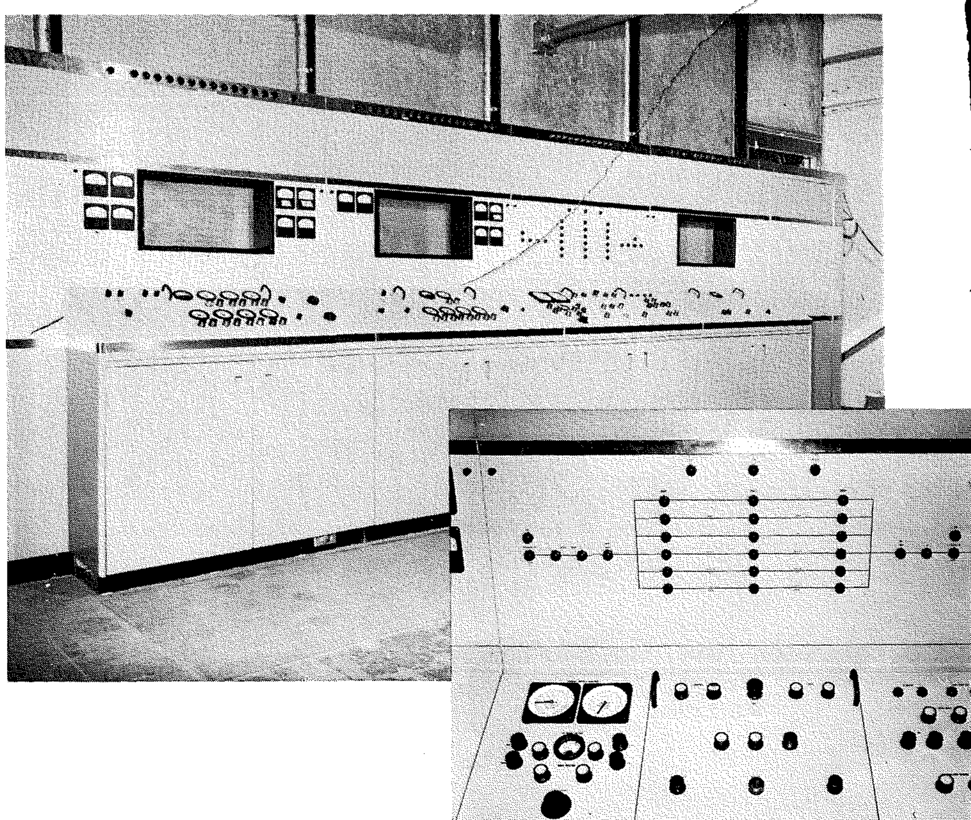
The high-voltage power supply is controlled from the Main Control Panel when the *auto-man* switch is in the *manual* position. In the *automatic* position, the high-voltage supply operates as part of the overall control system and cycles up to any predetermined d-c voltage from any preset lower voltage below half the maximum d-c output.

Voltage adjustments are made by tap changers, both coarse and vernier, which are a part of the auto, series, tertiary, and rectifier transformers. Operation is automatic (or manual, if desired) and *follow* indications are available at the main control panel. Automatic voltage-regulating apparatus is included to maintain the average d-c voltage within $\pm 1\frac{1}{4}$ percent of any set value near maximum voltage output.

Considerable plate power is required in this transmitter and the high-voltage power supply, of necessity, assumes large proportions. The transformer and rectifier assembly are located inside a vault which permits shielding, if required, and provides safety for operating personnel. (The size of the transformer and rectifier assembly can be visualized by examination of Fig. 1.)

The rectifier consists of six legs of silicon rectifiers immersed in transformer oil. The inverse voltage is properly distributed by means of balancing resistors across each cell. Any transient is properly distributed by a small capacitor across each rectifier. The use of silicon rectifiers reduces the over-all voltage drop normally associated with tube-type rectifiers. An added advantage is the elimination of filament power and filament warm-up time. The short-circuit current of the rectifiers is limited by the impedance

Fig. 6—Control-panel complex. Inset: the Main Control Panel.



of the magnetic components. However, a high-speed two-cycle breaker feeds primary power to the rectifier transformer assembly and is capable of 1.5-to-2.0-cycle (60-cycle base) clearing of faults in the power supply.

The high-voltage capacitor (one bank of which is seen in Fig. 8), is made up of series-parallel combinations with fuse protection for individual capacitors. The power-supply ripple specification is 1 percent at full output. The high capacity, which is necessary to keep the pulse droop within specification limits, provides more than adequate ripple attenuation without the necessity of a separate lumped reactor—the effective series inductance of the magnetic components is sufficient. A one-ampere bleeder resistor is tied across the output to limit the full load–no-load voltage change.

A d-c battery supply of 120 volts, with a trickle charger, is included as part of the switchgear and supplies power to operate the two main circuit breakers.

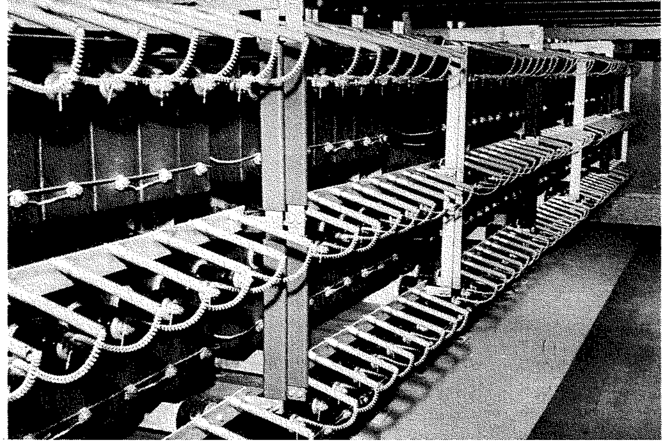


Fig. 8—One bank of the high-voltage capacitor.

PULSE MODULATOR

The modulator is of the hard-tube type. A simplified block diagram is shown in Fig. 7. The pulse generator receives a *start* pulse from the synchronizing unit of a particular system and generates a pulse of the required system length. The pulse is fed through a high-voltage isolation transformer, since the modulator platform is riding up and down with the pulse voltage. A *stop* trigger or *fault* trigger is accepted by the pulse generator to stop the pulse in progress, under r-f stage fault conditions, or terminate the pulse at the end of a normal pulse.

During the interpulse interval, the first stage of the modulator is conducting, holding the second stage and the switch tube at cutoff. A modulator input trigger results in a negative pulse at the grid of the first stage of sufficient amplitude to reduce the plate current to zero. The second stage, therefore, returns to the zero bias condition, with resultant plate current conduction through the grid resistor of the switch tube and in such a direction as to drive the switch-tube grid positive with respect to the cathode. The resultant positive pulse causes heavy conduction and, by virtue of the low tube drop, essentially ties the high-voltage power supply to the load for the duration of the pulse. The switch-tube section of the modulator is shown in Fig. 9.

The electronic crow-bar principle is employed to protect the switch tube. The diode is part of the protection system, and when it conducts, a fault signal is sent to the fault-sensing cabinet and to the protection unit where the ignitron is dumped, transferring the energy of the filter-capacitor bank from the faulted tube to the ignitron. Under normal operation the diode will not conduct, since its cathode, tied to a reference divider, is at a more-positive potential than the plate.

The level of the modulator output is adjusted by varying the screen voltage of the driver stage. This can be done from the modulator control panel.

COOLING

Water and air cooling are required for the transmitter. Three water systems supply cooling for plate, filament, and dummy load circuits. Each system consists basically of a pump, storage tank, and heat exchangers, in addition to make-up water tanks and associated pumps (Fig. 10). Demineralizers are

Fig. 7—Block diagram of the hard-tube modulator.

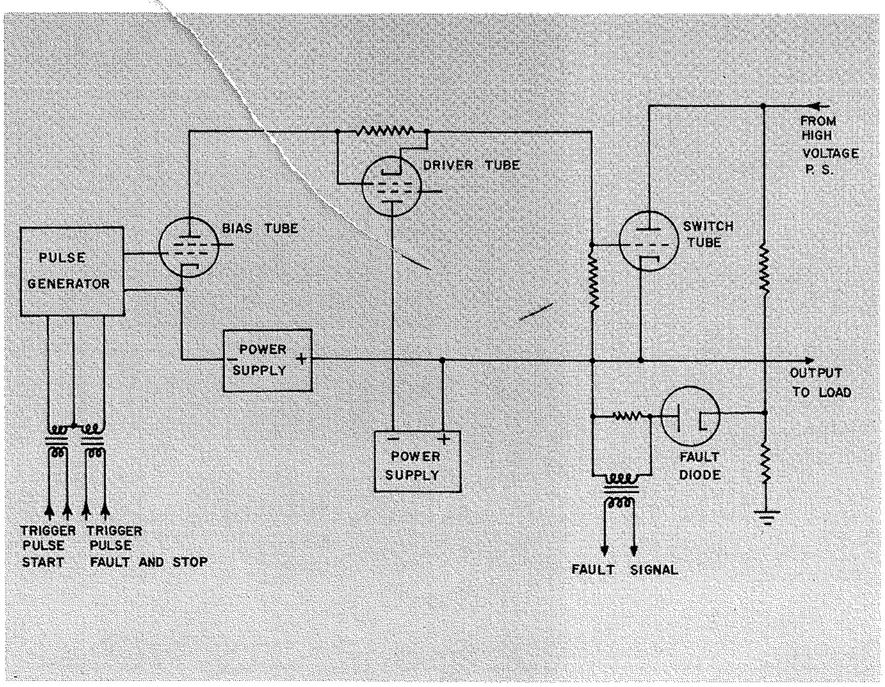
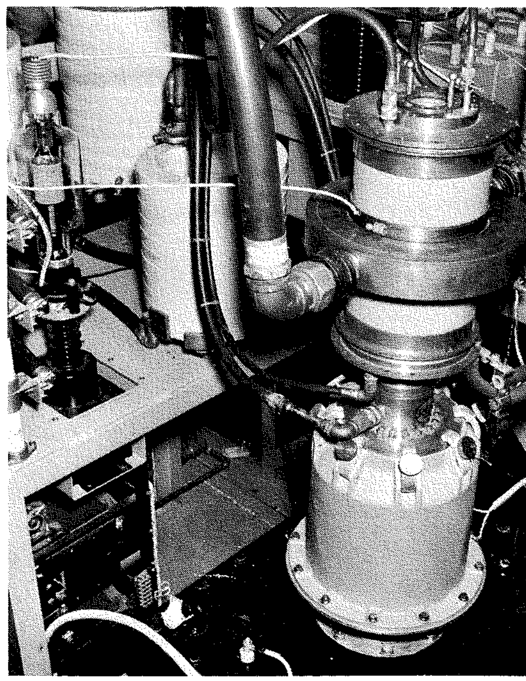


Fig. 9—Switch-tube section of the hard-tube modulator.



used with the plate and filament water systems to provide high-resistivity water, as required. Cabinet air cooling is supplied by two blowers, each one of which is capable of supplying the transmitter requirement.

SAFETY PRECAUTIONS

Safety precautions have been amply considered. All enclosures containing high voltages are interlocked, and unauthorized access is prevented. The first level of personnel protection is provided by means of locked enclosures, access to which is by means of a properly obtained key. The second level of protection is by door-type electrical interlocks.

A key-lock system has been applied to the HPA shielded enclosure, the transformer vault, the capacitor vault and the video-dummy-load vault doors. To obtain access to any of the locked enclosures, a supervisory key is removed from the Main Control Panel, which turns off all high voltages, and the key is carried to and inserted in a second lock assembly. Operation of the second lock and a companion lever places a fast-discharge resistor across the capacitor of the high-voltage power supply. A second key—the first key is held by the lock-key system and cannot be removed—is inserted into a companion lock. It permits operation of a lever which places a direct short across the high-voltage power supply, grounds the output of the modulator, and allows the removal of a third key—while locking in the second. This third key opens a key bank and the proper vault key can be selected. To reverse the procedure, all keys must be returned to the key bank by properly closing and locking vault doors. The high-voltage–supply short-circuit and fast-discharge resistor levers are next operated in the proper sequence. The supervisory key is now available for use at the Main Control Panel to allow high voltage to be turned on.

Shielded enclosures protect personnel from exposure to r-f fields, and interlocks external to the transmitter prevent r-f generation when the external plumbing is in an unsafe condition.

SUMMARY

This transmitter, within its intended scope of applications, represents the latest design accomplishments in the field of super-power transmitters, with emphasis on high reliability and simplicity of operation. Many have contributed to the design and it is not possible here to individually acknowledge the many contributions.

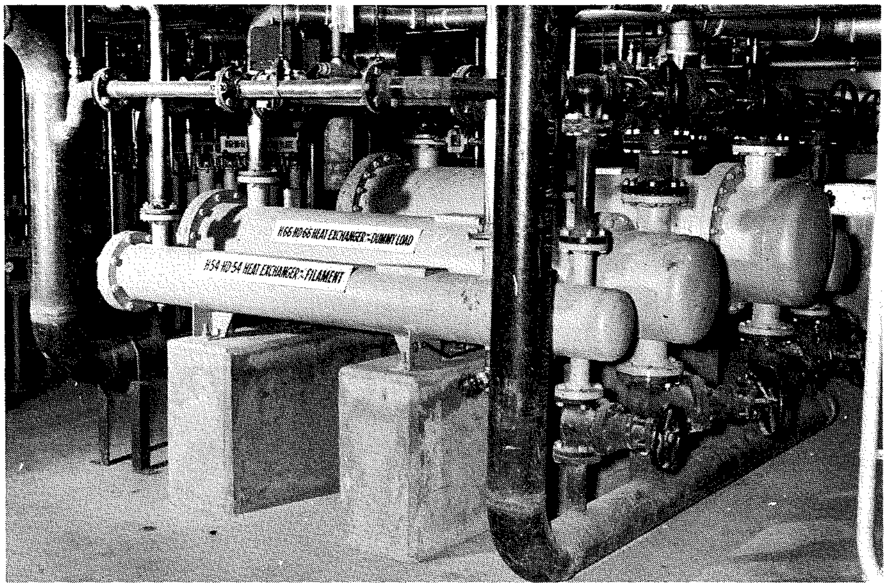
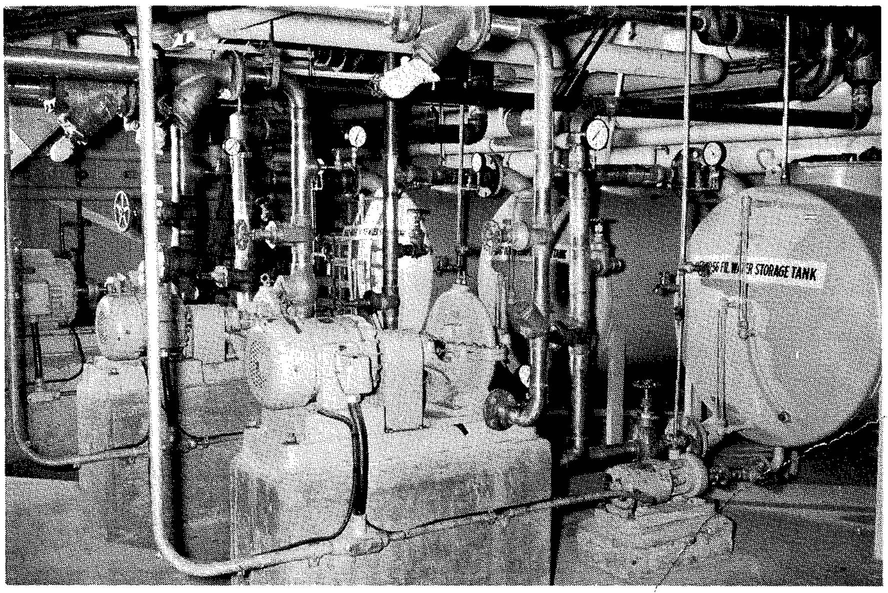


Fig. 10—Above: Heat-exchanger system. Below: Water-storage and pump system. These form part of the cooling system for plate, filament, and dummy-load circuits. In addition, cabinet air cooling is provided.



T. P. TISSOT received his B.S. in E.E. in 1949 from Leland Stanford University. Previous to this, he served four years with the U.S. Navy during World War II as an officer attached to the Radio Material School, Treasure Island, California. Here he served as an instructor on Loran, countermeasures, radar, and related subjects. In 1941, he was a technician at broadcast station KVCV, Redding, California. Mr. Tissot first joined RCA in 1949 and was associated with the Broadcast Engineering group, where he worked on RCA's first developmental and commercial uhf television transmitters. Between 1952 and 1958 he was with the Allen B. DuMont Labs., Inc., where he worked on uhf and vhf television transmitters. He served on industry committees related to transmitter standards, both color and monochrome, and was active in installing television equipment, including a cross-country network in Cuba. He represented his company on several occasions in Venezuela. He rejoined RCA, with the DEP Missile and Surface Radar Division, in September 1958 as a BMEWS Project Engineer and is now an Engineering Leader in the BMEWS Transmitter Projects group. He is the author of a number of articles which have been presented at technical conferences and a Senior Member of the IRE.

SUPER-POWER UHF PULSE TRIODE

by **R. E. REED**
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THE DEVELOPMENTAL uhf pulse triode shown in Fig. 1 is one of the latest members of the Electron Tube Division's growing family of super-power tubes that have been developed to provide increasingly higher outputs at increasingly higher frequencies.[1] The tube is rated for long-pulse operation at ultra-high frequencies. One of the applications for this tube is in the high-power-amplifier stage of the BMEWS transmitter. In many respects, it is a scaled-up version of the proven design of a 100-kilowatt triode previously described.[2]

The structural elements of the triode are arranged for operation in the fundamental TEM coaxial mode with external cavity resonator circuits. The use of a double-ended configuration greatly extends the tube's power-producing capabilities. This arrangement enables the active tube elements to be placed at the electrical center of a half-wave-length portion of the cavity resonator circuits.

The complete tube is 14 inches in diameter and 17 inches long, and weighs 180 pounds.

ELECTRON-CONTROL SYSTEM

A total of 96 triode units are combined in a common vacuum envelope to provide the total electron current required without exceeding a practical electrical length for uhf operation. A cross-sectional sketch of the triode units is shown in Fig. 2. Integral wire-support fins extend from the control-grid cylinder on each side of the thoriated-tungsten filament strands. Active grid wires are wound in tiny grooves across the fins in a circumferential manner on the outside diameter of the grid cylinder. The wires, wound at a pitch of 72 turns per inch, are then fastened in place by a firm rolling operation.

This construction provides a short thermal-conduction path for the flow of grid heat to the water-cooled grid cylinder and effectively overcomes the problems of excessive grid temperature and dissipation. The possibility of grid emission is also minimized with this cooling arrangement.

Each filament strand is a directly heated thoriated-tungsten cathode individually suspended from a pantographic support. Thoriated tungsten is the standard material used in high-power tubes to provide high emission, long life, and economical operation. The total area of the 96 cathodes produces an emitting area that is the largest in any power tube in the world. Thorough water-cooling of the cathode-support structures provides a thermally stable structure for uniformly high emission and long life.

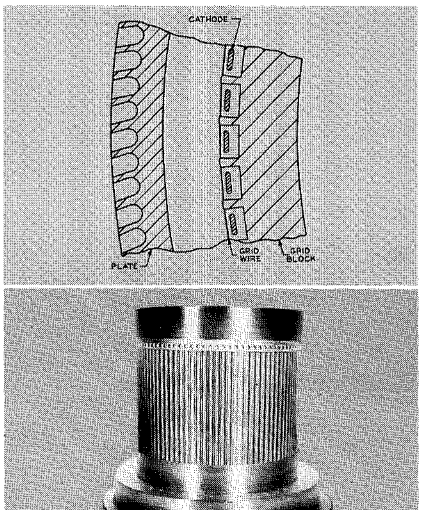

Fig. 2 — Top: Cross-section of the electronically active section of the tube. Bottom: Grid-cathode mount assembly.

ROBERT E. REED received the B.S. in Electrical Engineering from the University of Oklahoma in 1952. He joined RCA the same year as a Specialized Engineering Trainee, and was subsequently assigned as a product development engineer in the power-tube activity of the Electron Tube Division in Lancaster, Pa. Since then, he has been instrumental in the development and manufacture of several uhf super-power tube types, and has also worked on application problems and on tube specifications. He was appointed Manager, Specifications and Project Engineering in July 1958, and moved to his present job of Senior Engineer in Product Development in September 1959. He is presently leader of a project team of design and application personnel responsible for high-frequency super-power triode tube types. Mr. Reed is a Member of the IRE and of Sigma Tau and Eta Kappa Nu.

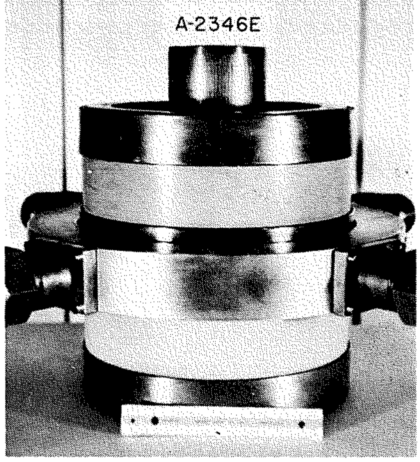

Fig. 1 — Developmental super-power uhf pulse triode.

High performance is achieved with this tube through the use of relatively close grid-to-cathode spacings. The grid-cylinder diameter is about 6.8 inches over the active length of 4 inches (Fig. 2).

The high-dissipation plate is intensively water-cooled by a water flow of 150 gallons per minute to provide for long life and reliable operation under the very high dissipation powers encountered. The plate can adequately handle the highest concentration of power known outside of uncontrolled atomic reactions. The plate is centered about the electronically active region of the tube on insulating ceramic bushings, and forms the outer conductor of the portion of the coaxial output circuit located within the tube.

The ceramic-to-metal seals that form the vacuum envelope are of the radial-compression type.[3] This type of seal is a reliable, high-conductivity seal that is especially suited for large diameters such as those used in this tube. The reliability of the radial-compression seal has been proven in several years of successful use in other super-power tube types.

TYPICAL OPERATION

When operated as a grounded-grid pulse power amplifier, this tube develops extremely high power output with a power gain of 20 to 30 and a conversion efficiency of about 50 percent in long-pulse service. Modified versions of the same tube are suitable for short-pulse or continuous-power-output applications requiring very high power output.

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DESIGN OF THE RADOME

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Although this article is concerned with the mechanical-design aspects of the radome, it is difficult to develop the rationale of the design without touching upon the electronic requirements.

In essence, a radome is a shelter used to mitigate the environmental effects upon the antenna and pedestal and other external components of a radar system. Elimination of the effects of the wind permits a decrease in the sizes of the antenna structural members, in addition to eliminating the effects of wind-induced vibration, which may be a problem in some radar systems. This decrease in size reduces the inertia of the antenna as reflected at the elevation and azimuth drives of the pedestal. Less inertia, together with the elimination of the wind torques, permits a substantial decrease in the size of these drives.

For the BMEWS tracking radar, for example, the use of the radome permitted 40-HP and 300-HP motors for the elevation and azimuth drives, respectively. Should the pedestal have to operate in a 40 MPH wind, it has been estimated that these values would double. The astronomical values that would be required for these drives for operation in a 130 MPH or a 185 MPH wind can be easily calculated. Elimination of the heavy snow and ice loads on components of systems located in arctic regions reduces the design problems and hence the costs associated with the radar system, per se.

However, attractive as all the foregoing may seem, the rule of Mother Nature that "you can't get something for nothing" cannot be violated. In this case, the advantages outlined above are paid for by a degradation in electronic performance, which results when additional material is located in the path of the radar beam. These adverse effects are the absorption and reflection of the electromagnetic radiation with a consequent loss of energy and, hence, range; distortion of sidelobes; and bore-sight shift with the consequent loss of accuracy. Depending on the type of system (search, tracking, navigation, etc.) the relative importance of these factors will vary. Qualitative determination of these factors for large structures is usually accomplished by electrical tests on scaled models of various forms of construction. Results of these tests are then weighed together with factors such as reliability, size, economics, environmental conditions, delivery schedules, and use of the electronic system in determining the actual type of radome selected for a particular application.

BMEWS RADOME CHARACTERISTICS

Consideration of these factors, several of which changed over a period of time, led to the ultimate selection of the honeycomb sandwich construction of the BMEWS radome. Because the BMEWS installations were to be made at three different sites, two at arctic areas and a third in England, it was decided to prepare two basic designs: one for a maximum wind of 185 mph and the second for a maximum wind of 130 mph. These two designs will most economically provide for the variations expected at the different sites.

The BMEWS radome is basically a spherical shell 140 feet in diameter. It is truncated by a horizontal plane 46 feet below the equator, to form the base ring. It is supported by a structural-steel mounting ring fastened to the top of a 38-foot-high building which houses the transmitter and the balance of the tracking radar system, as well as some of the other systems comprising the BMEWS complex (see cover, and Fig. 1; also *The BMEWS System*, by H. Phillips, this issue).

The radome spherical shell is formed by bolting together a number of spherically curved panels. The panels are of various sizes and have four, five, or six sides, depending on their location in the radome. These panels are of sandwich construction 6 inches thick, having two polyester-resin fiberglas-reinforced skins separated by a waterproof-resin-impregnated, ¾-inch-cell paper honeycomb. The cells of the honeycomb are formed of two plies of 60-lb Kraft paper on each side of a 1-mil-thick polyethylene film. The edges of the panels are enclosed by fibreglas channels. The panels are held together by ½-inch-diameter bolts, pairs of which are spaced at 6.0 and 6.5 inches along the edge of the panels at the bolted connection. Narrow, individual, aluminum bearing plates under each pair of bolts transmit and distribute the loads from the skins into the channels and bolts. A strip of special caulking is added to the outside of all joints to assure water-tightness. The outside of the panels are painted with *Radalon*, a special paint developed by the U.S. Air Force for radomes.

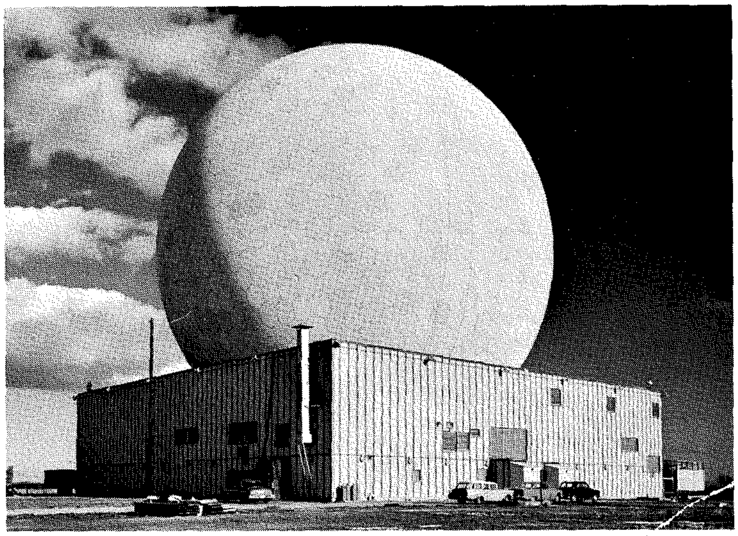


Fig. 1—The BMEWS radome (prototype at Moorestown, N.J., for evaluation and checkout).

In a complete sphere, there are twelve basic repeating sections, each composed of five spherical isosceles triangles having a common apex panel, Point A as shown in Fig. 2. These are comprised of the actual panels, which are made as identical as permitted by the geometrical properties of the sphere. For erection purposes, the panels are coded, as shown

*The BMEWS Engineering Model radome was designed, fabricated, and erected by the Goodyear Aircraft Corp., of Akron, Ohio, under the supervision of RCA Missile & Surface Radar Division, Moorestown, N. J. Directly involved were the BMEWS Tracking Radar Project Engineering Group, and the Microwave and the Antenna Equipment Units of the Radar Design and Development Dept.

in Fig. 3. At the base ring, because of the truncation, the basic isosceles triangles are modified to form five basic repetitive patterns, shown in Fig. 4. The base panels, in contact with the base ring, are standard panels modified to provide for the intersection of the sphere with the plane of the base ring. The pattern of these base panels, together with their coding, is shown in Fig. 5.

DESIGN CRITERIA

The design of a radome must provide for both strength and elastic stability.

Sufficient strength must be developed by the basic panel and joint design to withstand the 1) maximum membrane stresses developed by windloading; 2) stresses induced by vertical deflection of the structural supporting base ring, due to varying degrees of support provided by the structural framework of the building itself; 3) stresses induced by or at the truncation of the sphere, including the effects of radial restraint, weight, and moment at the base; and 4) thermal stresses.

The design must assure sufficient stiffness so that the shell of the radome does not buckle elastically. This criterion is significant, and might at times be critical. However, it is difficult to evaluate realistically, because of the peculiar pattern of loading induced by the wind. (Considerable effort is being expended by various agencies to determine less-conservative methods of evaluation than have heretofore been employed.)

WIND LOAD, OR PRESSURE DISTRIBUTION

In order to minimize the effect of the radome structure upon the electronic performance, the factor of safety of the structural design should be held to the minimum dictated by good judgment and knowledge of the actual loading. The more data that may be available and the more exhaustive the stress analysis, the lower the factor of safety can be held. The lower the factor of safety, the less is the material interposed in the radar beam, and the less is the electronic effect.

Although the literature records the results of many wind-tunnel tests upon radomes, these were based upon configurations of radomes and supports differing in significant aspects from the BMEWS radome. Wind-tunnel tests were therefore conducted on a scale model of this radome and its supporting building. Data obtained from these tests included lift, drag, moment, and a plot of pressure distribution over the surface of the radome. Values of these loads as calculated from the wind tunnel data for a 200-mph condition are: moment, 58,350,000 ft-lbs; lift, 1,486,000 lbs; and drag, 1,138,000 lbs.

Pressure distributions are shown in Figs. 6 and 7. The stress analysis was accomplished for 200 mph, and subsequently scaled down for the 185-mph and 130-mph criteria.

In order to calculate the membrane stresses, it is necessary to determine a wind-load function that adequately approximates the measured pressure distribution over the radome surface. It is possible to develop a function that will closely approximate the distribution on the upwind portion of the radome where the stresses are most important. This function is also shown in Figs. 6 and 7 to permit correlation between the distribution calculated from the wind tunnel study and the distribution resulting from the load function.

Assuming symmetry about the horizontal axis through the forward stagnation point (valid from wind tunnel study), the pressure distribution over the wind-loaded radome is approximated by the Fourier expansion

$$\frac{p}{q} = A + B \sin \gamma + C \cos 2\gamma$$

or, with $\gamma = \frac{\pi}{2} - \phi$,

$$\frac{p}{q} = A + B \sin \phi - C \cos 2\phi$$

where p = intensity of pressure at any point on the spherical surface and q = intensity of pressure at the forward stagnation point where $\phi = \pi/2$.

The values of the coefficients A, B, and C, are determined by solving simultaneous equations for total drag, total lift, and a third equation, $p/q = 1$ at the forward stagnation point.

The wind-load function may be written as

$$p/q = -0.61102 + 0.49825 \cos \gamma + 1.11277 \cos 2\gamma.$$

The overturning moment from wind tunnel data is 58,350,000 ft-lbs. The calculated overturning moment is 52,348,000 ft-lbs. The load function does not account for skin friction, as evidenced by the difference in the measured and the calculated overturning moments. A moment correction (ΔM) was therefore included in the analysis to account for this:

$$\Delta M = 58{,}350{,}000 - 52{,}348{,}000 = 6{,}002{,}000 \text{ ft.-lbs.}$$

MEMBRANE STRESSES

The membrane stresses in the radome are produced by each of the terms of the wind-load function, boundary conditions at the base plane, and by weight. Stresses resulting from the application of each term of the wind-load function were superimposed on the stresses result-

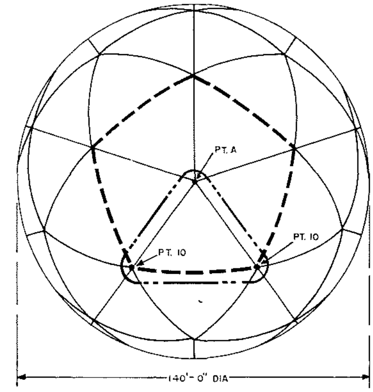


Fig. 2—Basic repeating spherical section and constituent isosceles triangles.

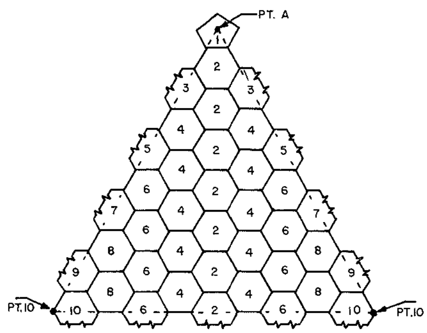


Fig. 3—Typical radome panel layout of basic isosceles triangles.

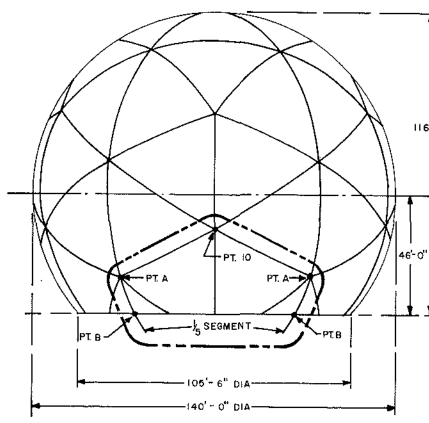


Fig. 4—Repeating radome base section.

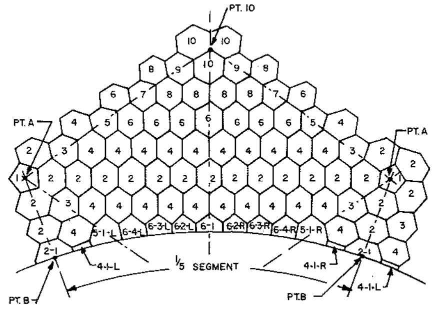


Fig. 5—Typical radome panel layout of repeating fifth segment at base.

TABLE I. EFFECT OF VERTICAL DEFLECTION OF BASE RING

All units of stress are lbs/lin. ft.

EFFECT	AT THE BASE			4 FT. ABOVE BASE		
	Basic	Total	Conc. Factor	Basic	Total	Conc. Factor
N max. (tension)	18,590	20,610	1.11	16,180	17,030	1.05
N min. (comp.	–10,200	–12,100	1.19	–8,310	–9,070	1.09
N shear	13,780	15,700	1.14	11,470	12,270	1.07

ing from the boundary conditions and skin-friction moment correction. These stresses, calculated for the 200-mph wind loads, were corrected to the site wind-load criteria, 185 mph and 130 mph, and the membrane stress due to weight were then added to give to total membrane stresses. These stresses were then resolved to principal stresses.

The membrane stresses were calculated on the assumption of a rigid base support. Since the base support is actually elastic, corrections were later applied to the calculated stresses.

Stresses were calculated for various levels throughout the radome. It was determined that the highest stresses occur around the base ring. Curves showing these base ring stresses for the 185-mph radome are shown in Figs. 8 and 9. Stresses at other levels, values for the 130-mph radome, and the detailed method for determining the membrane stresses are shown in Reference 7.

STRESSES FROM BASE-RING DEFLECTION

The stresses induced by vertical base-ring deflections were significant in developing the total stresses at the base of the radome. The stresses shown in Figs. 8 and 9 are those calculated on the basis of pure membrane theory and assuming a uniform base support whose stiffness is large compared to the radome. Inasmuch as the building structure does not fit this category, it was necessary to evaluate the stress concentrations caused by the "hard points" over the supports of the structural base ring.

The process involved in determining these stress concentrations included a series of trial-and-error calculations, and is described in Reference 7. A summary of critical values is shown in Table I.

The basic membrane stresses hitherto calculated have neglected the effects of the radial restraint of the base ring. The restriction of the radial deflections which would otherwise occur as a result of consideration of pure membrane theory introduces flexural stresses into the radome base.

These stresses were calculated by consideration of a cylindrical vessel with hemispherical ends. Membrane theory was applied to both the cylindrical and the hemispherical parts. The resulting stresses were compared and discontinuities at the joints observed. These discontinuity stresses were eliminated by shearing stresses and bending moments uniformly distributed around the circumference of the joint. The flexural stress resulting was applied to the basic membrane stress at the base of the radome. The principle stresses were next calculated, and the corresponding stress concentration factors determined.

These factors are not precise because of the computational method employed. However, they are closely approximate and are conservatively assumed to be valid in the region from the base to a height 4 feet above the base. The actual equations and calculations are contained in Reference 7.

JOINT DESIGN

The joints in a radome contribute the major electronic effects. If a design could achieve a purely *isotropic* construction, *i.e.*, no discontinuities, the electronic effects of the radome would be significantly decreased. The joints for the BMEWS radome were designed with this as a corollary criteria of importance equal to structural integrity.

It is of interest to note that the stress analysis of the joint was used to prepare a design that was modified as a result of physical tests. Samples of the joint were prepared on the basis of the initial design, and this was modified in successive steps until the current design was achieved. This joint possesses the tensile strength required with an adequate margin of safety. In addition, the results of many tests indicate that a balanced design has been achieved. By this statement is meant that if a large number of samples were to be tested to destruction, equal numbers of failures would be recorded between tensile failure of the skins, the bond between the skin and the channel, and in the channel itself. In the construction of the panels, the bond between the honeycomb core and the skin was developed to the point where the skins failed in compression.

The base clip is shown in Fig. 10. A series of these clips is bonded into each base panel to make the joint from the radome to the structural base ring. From the diagram can be seen the method used to transfer the hoop tension at the base of the radome into the base ring by shear through the forward bolt. Subsequent to the erection of the complete radome, the shear plate to which the clip is fastened by body-bound bolts is welded to the base ring. In this manner, the total drag of the radome is transferred from the panel to the clips, from the clips to the shear plate by shear through the bolts, and from the shear plate to the base ring by shear through the weld. This method obviates the necessity for field-reaming the base ring to match the base panels prior to the erection of the complete radome and before the full deflections have taken place. The clips were designed for web bending and were made of heat-treated 4340 steel because of the high bending stresses that must be resisted.

ELASTIC STABILITY (BUCKLING)

The formula for the critical pressure that will produce buckling is

$$P_{cr} = KE \frac{t^2}{R^2} \qquad (1)$$

Where, P_{cr} = critical pressure, E = modulus of elasticity, t = thickness of shell, and R = major radius of radome. The classical value for K is given by Timoshenko[1,2] as 0.6. Experimental work by Von Karmen[3] and Hsue-Shen

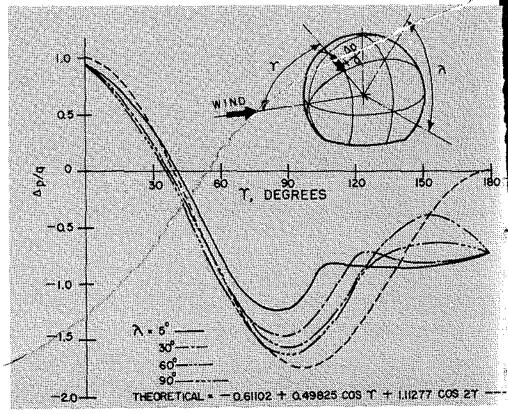


Fig. 6—Pressure distribution on wind-loaded spherical radome above equator. L = 1,486,000 lbs; D = 1,138,000 lbs; M = 58,350,000 ft-lbs.

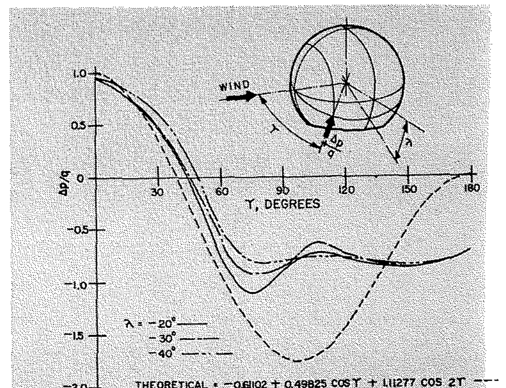


Fig. 7—Pressure distribution on wind-loaded spherical radome below equator. L = 1,486,000 lbs; D = 1,138,000 lbs; M = 58,350,000 ft-lbs.

Tsieu[3,4] show the value of K, based on uniform loading of hemispheres, to be a function of t/R, with a value of $K = 0.3$ for the region of t/R for the BMEWS radome. Because of the unequal stresses existing at the stagnation point, resulting from the wind loading seen by the BMEWS radome, the value of K used was 0.25. The allowable p resulting from this value was shown to be conservative on the basis of an independent study made by Prof. Bijlaard, as a consultant to RCA.

Another item that must be accounted for is the fact that the above formula is derived for a homogeneous shell, differing from the honeycomb sandwich construction actually used. Modification of the formula for use with sandwich construction is shown below, together with the margin of safety resulting from its application to the radome for 185-mph winds.

For sandwich construction,

$$P_{cr} = KE_e \frac{t_e^2}{R^2}$$

Where E_e = effective modulus of elasticity, and t_e = effective thickness of sandwich.

Letting (EI) solid = (EI) sandwich,

$$\frac{E_e t_e^3}{12} = \frac{t}{2}(c+t)^2 E$$

$$E_e = \frac{6tE\,(c+t)^2}{t_e^3}$$

Fig. 8—Membrane stresses around base. $\gamma = 131°\ 5'$; Wind velocity 185 mph; $W_t = 4.80$ lbs/ft².

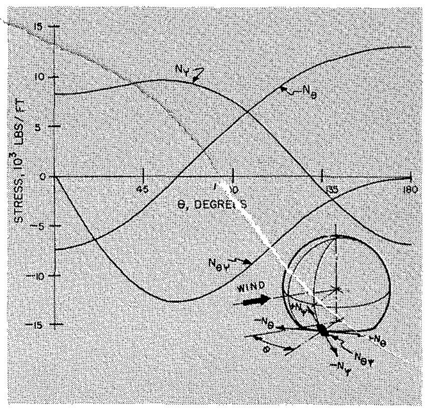
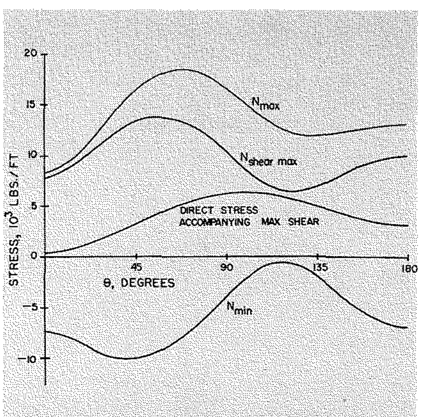


Fig. 9—Principal stresses around base $\gamma = 131°\ 5'$; Wind velocity 185 mph; $W_t = 4.80$ lbs/ft².



Where c = core thickness of sandwich, and t = skin thickness of sandwich.

Letting (EA) solid = (EA) sandwich,

$$E_e t_e = 2tE$$

$$E_e = \frac{2tE}{t_e}$$

Therefore,

$$\frac{2tE}{t_e} = \frac{6tE\,(c+t)^2}{t_e^3}$$

$$t_e = \sqrt{3}\,(c+t)$$

$$E_e = \frac{2tE}{\sqrt{3}\,(c+t)}$$

$$P_{cr} = KE_e \frac{t_e^2}{R^2}$$

$$= K\,\frac{2\sqrt{3}\,(c+t)tE}{R^2}$$

$$P_{cr} = 3.464\,K\,\frac{(c+t)tE}{R^2} \qquad (2)$$

For elastic stability in *185-mph wind*, the following values were used in Equation (2): $K = 0.25$, $c = 6.000$, $t = 0.056$, $E = 2.0 \times 10^6$, and $R = 70$ feet, giving $P_{cr} = 119.9$ lbs/ft². But,

$$q = q_{200} \times \left(\frac{185}{200}\right)^2$$

$$= 120.7 \times .85562 = 103.3 \text{ lbs/ft}^2$$

$$M.S. = \frac{P_{cr}}{q} - 1 = \frac{119.9}{103.3} - 1$$

$$= 0.16$$

MISCELLANEOUS FEATURES

Ventilation amounting to 8000 cfm of outside air is provided to the interior of the radome. This feature serves a number of purposes. First of all, the heat resulting from the operation of the pedestal, which might amount to as much as 100,000 Btu/hr, is removed. A second and by no means secondary benefit is the equalization of inside and outside temperatures for the radome within approximately 12° F. This equalization brings the thermal stresses that might otherwise exist in the skins to negligible values. And last, but not least, is the providing of breathable air to those persons whose duties would keep them inside the radome for any period time. The entrance nozzles give a high velocity (1500 ft/min.) to the entering air, thus assuring circulation by induction and preventing stagnation of the air at the upper levels within the radome.

Because of the large volume of air within the radome and the difference in air pressure between the outside and inside that might result because of the time lag in venting the radome, the exhaust ducts for the ventilation system for the sites are sized to limit the maximum differential pressure to 0.02 psi. The outlet to which these ducts are connected is designed and located from wind-tunnel data so that the exit of the duct is always exposed to static barometric pressure. Thus, the structural integrity of the radome is made independent of automatic devices that might fail at crucial times.

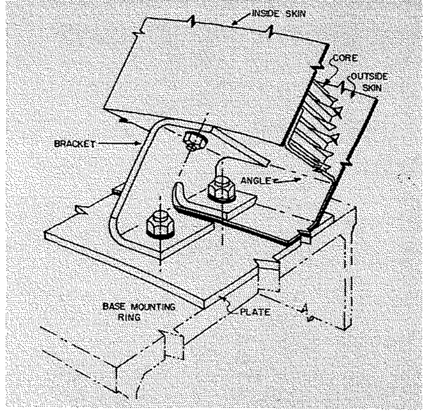


Fig. 10—Base clip for attaching radome base panels to structural base ring.

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HERMAN J. SIEGEL received his B.M.E. from the College of the City of New York in 1938, and his M.M.E. at Polytechnic Institute of Brooklyn in 1945. While attending school, Mr. Siegel was employed for two years as a designer of automatic machinery and materials handling equipment. He spent eight years with the New York Naval Shipyard as an Ordnance Engineer, and the next seven years as a construction engineer, superintendent, and consulting engineer in Florida. Mr. Siegel joined RCA in 1954. Assignments have included work on the Talos land-based units, Talos missile-handling system, and preliminary planning and final design of the AN/FPS-16 instrumentation radar installation. Since early 1957, Mr. Siegel has been leader of the Antenna Equipment Group in the DEP Missile and Surface Radar Division, with supervisory design responsibility for the BMEWS tracking radar pedestal tower, the BMEWS tracking radar radome, the design of the modifications of the ship "American Mariner" for DAMP, and currently is involved with the structural design of the fixed antenna reflector for the Madre project, a structure 140 feet high x 330 feet long. He has Professional Engineers licenses for New York and for Florida.

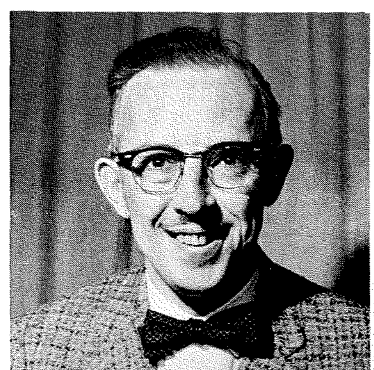


Fig. 1—This aerial view at one of the Sites shows much of the technical complex. Shown are scanner and radar transmitter and computer buildings in addition to the huge antennas. The antennas are larger than a football field.

THE RCA SERVICE COMPANY'S ROLE

by **W. F. GIVEN, Mgr.**
BMEWS Service Project
RCA Service Co.,
Riverton, N. J.

JANUARY OF 1960 marked the second anniversary of RCA as Weapon Systems Manager of BMEWS for the U.S. Air Force. With the selection of RCA as prime contractor, the need for an organization to assume the tremendous engineering responsibilities was presented. Within RCA, the Missile and Surface Radar Division of DEP was given this responsibility. In turn, they delegated to the RCA Service Co. the on-site tasks of the installation, checkout and test, integration, and operation and maintenance BMEWS

Thus, the BMEWS Service Project came into being and began the task of starting from scratch to build, in one year, an organization which normally takes many years. The home-office headquarters in Riverton, New Jersey, now occupies three buildings of over 85,000 square feet—an indicator of the necessary extent of this activity.

To fulfill these responsibilities, the Service Company's efforts have been concentrated into two basic organizations, Engineering and Operations, and Logistics, whose accomplishments are a measure of the progress of the Service Project. Other groups, such as Plans and Requirements, Project Administration, and Personnel, play their important role in supporting these basic organizations.

ENGINEERING AND OPERATIONS

The structure of this organization, in order to meet the varied site requirements, was set up with a wide range of skill levels, including engineering, equipment specialists, and technical levels. All engineers who became part of the organization had to fulfill the same academic and experience requirements as engineers in other RCA divisions.

All technician and specialist personnel must pass through a comprehensive battery of technical tests administered by the Personnel Department and, if qualified, are given additional training as described in the *Technical Training* portion of this article.

A "twin-brother" concept was fostered and developed as a plan to provide the best training for *project engineers* and *equipment integration engineers.* The RCA Service Co. project engineers study equipment with the DEP project engineering groups, and thus obtain on-the-job training with their DEP "twin brothers." Through these assignments, the RCA Service Co. engineer learns from actual experience and, at the same time, develops a working relationship with the DEP project-engineering group that he will functionally represent at one of the forward sites. The RCA Service Co. equipment integration engineers perform in a similar manner under the "twin-brother" concept with DEP design and development engineers.

During the training period, the engineering organization continuously plans and prepares for work at the BMEWS site. The engineer must originate comprehensive technical procedures for the installation, checkout and test, and integration of the BMEWS equipment. He must assure that proper and sufficient tools, test equipment, drawings, specifications, and material are being provided for use. He must help in forming the teams of engineers and technicians required to do the task. He must furnish technical information to the Technical Training and Technical Publications Groups.

To fulfill their BMEWS responsibility with respect to other subcontractors, RCA Service Co. engineers and technicians are receiving essential instruction at General Electric and Sylvania on the equipment furnished by these subcontractors. General Electric provides the detection radar, while Sylvania produces data-take-off and missile-impact-prediction equipment. The RCA Service Co. engineers and technicians work with General Electric and Sylvania during the installation, checkout, and test of their equipment so that when the operation and maintenance phase begins, RCA can assume complete operational control. In addition, the RCA Service Co. insures that the subcontractors successfully execute their responsibilities.

SUPPORTING SERVICES

Major emphasis has been placed on the engineering organization at this phase of the project. But, as the BMEWS network reaches the operation and maintenance phase, the requirements of the engineering organization will decrease. At this point, the Operations organization will take over to direct, supervise and plan for the operating effort at all of the sites. Currently, the organization is responsible for planning, facilities engineering, and the various support activities. Included in the site support activities are the machine and carpenter shop, electronics repair shop, as well as the cafeteria and housing responsibilities.

It would be impossible for the BMEWS Service Project to function without such other organizations as dining services, housing and billeting, motor pool, and quality control. Food at the sites is provided at no cost to the employee. At Site I in Thule, Greenland, the support services are now in operation. The most modern cafeteria facilities are utilized, and the Danish personnel who do the cooking are masters in the preparation of soups and desserts, as well as the basic entrees. In addition to the large dining facility on the Thule Air Base, there is a smaller emergency cafeteria located at the technical building complex. A well-planned diet includes such items as roast beef, steak, shrimp, and a complete line of fresh fruits and vegetables. Modern dormitory buildings featuring comfortably furnished semi-private rooms are another feature. Emergency dormitory facilities are available at the technical site if bad weather or any other such occasion should arise.

Another support activity that should not be overlooked is the site warehouse facility where all items are safely protected from the Arctic weather. The 30,000-square foot base warehouse and technical site storerooms provide technical personnel immediate access to replaceable parts. All of these facilities play a most important part in the site operations organization. The responsibilities of this organization will greatly increase as the project reaches the operation and maintenance phase.

Fig. 3—Just one of many construction problems.

TECHNICAL TRAINING

A major achievement to be accomplished by the BMEWS Service Project is the training of hundreds of technical people in the specialized jobs they will have to do at the sites. The word "trainee" in this instance may be misleading, as trainees are selected by specially designed test batteries. The vast concentration of technological know-how put into the equipment is an important factor in the success of the BMEWS Project. Because of the lack of training time allowed, it is virtually impossible for the average technician to learn all there is to know within the period set aside for training. Hence, only those who qualify in the comprehensive testing system are selected for the project.

The RCA Service Co. has gathered together technical people with wide range of experience in electronics, radar, computers, communications, and many other fields closely associated with the BMEWS equipment. With a well-designed program of training, development, assimilation, and communications, these men are being trained to do their technical jobs as well as being welded into a coordinated team.

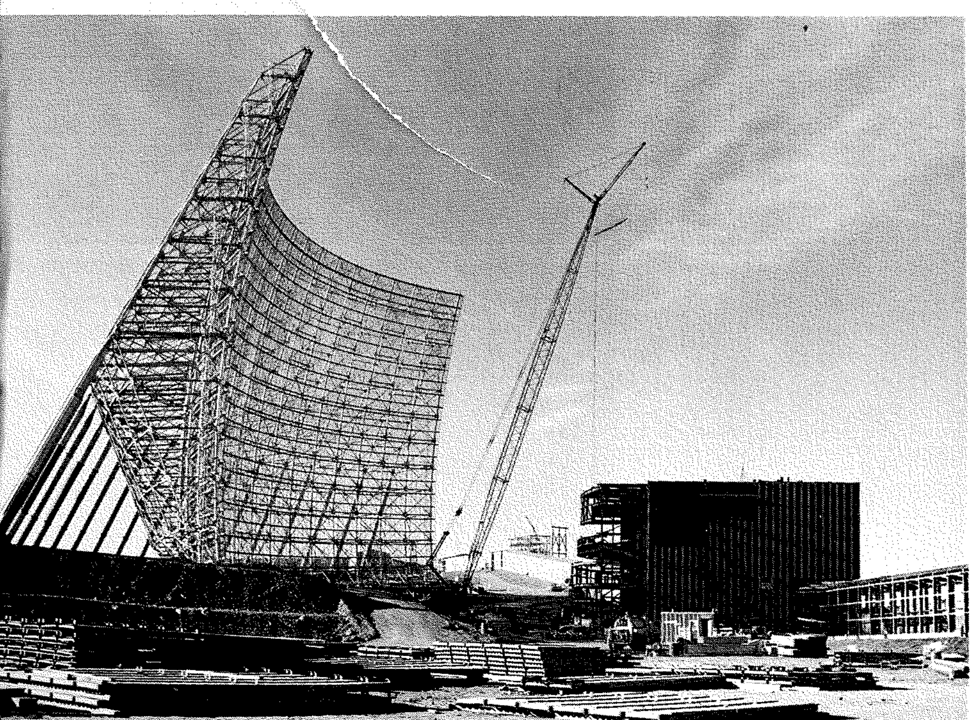
To accomplish this ever-increasing requirement, additional classrooms are being built, training aids and films are being procured and produced, and courses are being prepared. Hundreds of slides have been made, as well as block diagrams and schematics to supplement each training course.

Some of the specialized courses being taught are: Checkout and Automatic Monitoring, Detection Radar, Missile Impact Prediction, Communications (telephone and radio), and Programmer-Operators.

The Technical Training organization has personnel undergoing training at the Sylvania plants in West Roxbury and Needham, Massachusetts and at the Syracuse, New York plant of General Electric. Other special training for BMEWS personnel has been received at the North Electric Company and Goodyear Aircraft Company, as well as other manufacturers training schools who make equipment used at the Sites.

Technical Training instructors are specially selected on the basis of their teaching ability and technical background. They are thoroughly orientated in the overall BMEWS system and maintenance philosophy and assigned to specific equipment areas. They prepare course outlines, lesson plans and develop training aids. They also prepare demonstrations units and prepare themselves for teaching by visits to laboratories and production facilities as well as discussion with RCA Service Co. engineers, and DEP engineers and designers. They study theory and schematic manuals produced especially for BMEWS, as well as standard military and commercial texts. Instructors are sent to subcontractor plants and make visits to the sites so as to present a comprehensive

Fig. 2—Construction scene at one of the Sites during the summer of 1959. Feedhorn side of Scanner Building is being erected. Antenna is shown completed to the left.



training program. They receive training in not only individual equipment components but also in system and subsystem configurations.

The Technical Training organization is expected to reach peak operation in mid-1961. At the peak, 18 major courses, consisting of over 200 subcourses, will be taught. As the program reaches the peak, the training staff will be increased from the present 30 to 46 personnel.

Technical Training is constantly searching for and applying the most advanced techniques in its endeavor to supply to sites technically trained personnel capable of adequately maintaining all the equipment of the BMEWS Project.

TECHNICAL PUBLICATIONS

With specialized equipment at remote sites, the importance of comprehensive technical publications becomes greatly increased. One of the main functions of the Maintenance Control and Technical Publications organizations is the production of thousands of pages of technical data.

RCA Service Co. personnel at the Riverton location will publish over 35,000 pages of technical information over the next two years in the fulfillment of the provisional handbook program. Publications are developed by RCA Service Company personnel and cover RCA-built equipment. Other BMEWS subcontractors have similar publications programs for their own equipment. All of the manuals and handbooks turned out at the Riverton location are directed toward experienced technicians. In contrast, the military technical manual is written in a much more simplified form and is directed toward personnel with much less experience in technical fields.

As a projection however, when the BMEWS reaches the operation and maintenance phase, military-type technical manuals on all equipment will be written following the basic military format. At this time, the provisional handbooks will be supplemented by information gained in the installation and initial operation of the equipment. The transitional cost of the provisional handbook to the "end item" technical order is minimized by paralleling the two approaches, insofar as possible. All technical publications turned out by RCA Service Company, General Electric, and Sylvania are coordinated by the Missile and Surface Radar Division of DEP.

At Riverton, the provisional handbook program is divided into six general classifications: operational instruction, service instructions, overhaul and repair instructions, parts lists, diagrams, and descriptive theory. The handbook program takes the integrated approach and is designed to be produced on a minimum budget.

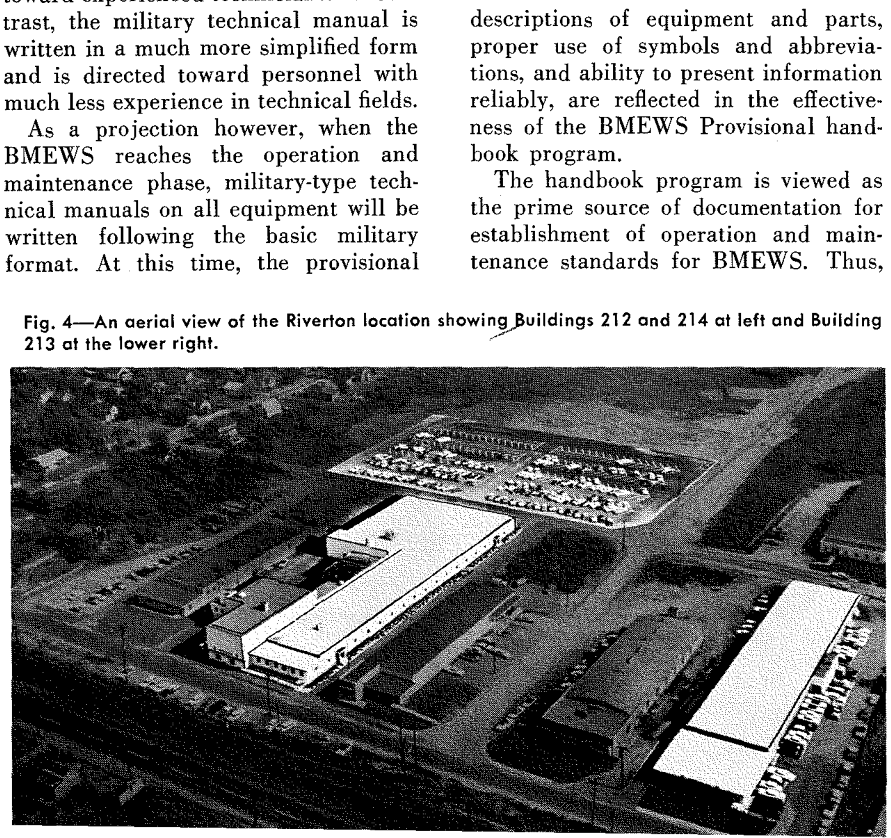
A vigorous revision program is planned to keep the handbook coverage current at all times thereby assuring maximum information availability. The provisional handbook program during this, the contractor phase of the project, is most necessary to the eventual operations and maintenance of the system by the military.

In connection with the technical publications function, there is a requirement for maintenance control. It is the responsibility of this organization to establish and continue to evaluate maintenance effectiveness and efficiency throughout the system.

Each technical writer is indoctrinated as to the BMEWS handbook specifications. It is extremely important that all handbook information be written clearly and in a uniform manner. The writers' descriptions of equipment and parts, proper use of symbols and abbreviations, and ability to present information reliably, are reflected in the effectiveness of the BMEWS Provisional handbook program.

The handbook program is viewed as the prime source of documentation for establishment of operation and maintenance standards for BMEWS. Thus, great care is being taken to not only assure accurate details, but also to assure a fully integrated systems approach.

Fig. 4—An aerial view of the Riverton location showing Buildings 212 and 214 at left and Building 213 at the lower right.



LOGISTICS

When it was decided that BMEWS was to become a reality, the task of the logistic support of this gigantic undertaking appeared enormous. How many personnel will be required? Where will they live? Where will they sleep? What kind of a diet is needed in the Arctic? What is the best transportation available? How do we establish a supply system for complex gear in the Arctic that is one-hundred-percent effective? All of these questions had to be answered immediately, yet they had to be answered accurately. It was at this point that the RCA Service Co. was assigned the task of providing complete logistic support.

It was only natural, therefore, that one of the first activities to be established was the Support Planning Group. With the realization that it would cost somewhere in excess of $25,000 per year to support each individual in the Arctic, and facing the tremendous cost of Arctic construction, it became almost rudimentary for this group to adopt the slogan "Never do anything in the Arctic that can be accomplished in the U.S."

Planning

Prior to the first BMEWS contingent arriving at Thule Air Base, planning had to be accomplished for their transportation, living quarters, dining room, mail, laundry, medical care, religious services, and other miscellaneous support. Simultaneously, requirements for the procurement of material and equipment had to be generated for such activities as a cafeteria, machine shop, electronics repair shop, utilities shop, test equipment laboratory, and a floating power ship. All of these requirements for personnel, equipment, and material then had to be phased into a master construction schedule to assure that the arrival of personnel and material coincided with the completion and the availability of the necessary facility.

How many beds, spoons, paper clips, and other commodities are involved in such an effort? In this area alone, the RCA Service Co. has procured, packaged and shipped since July, 1958 over 6000 measured tons of support material. Even this figure is insignificant when compared with the volume of the construction and installation material.

Storage

The receipt of all this material at the forward site presented an even more formidable logistic problem. Once all of

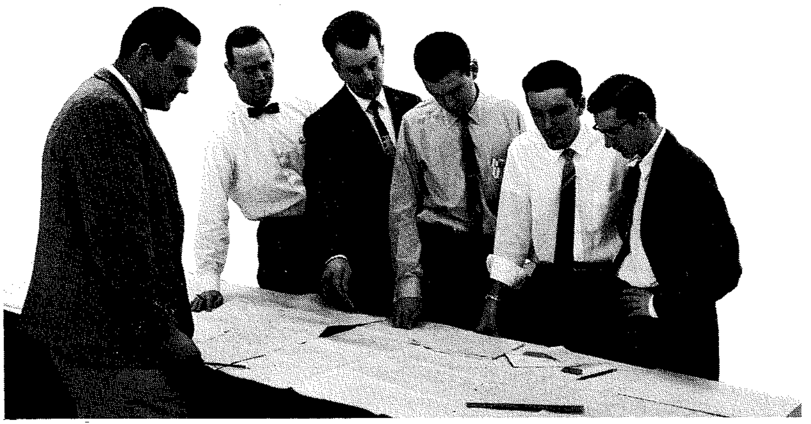


Fig. 5—A group of technical writers at Riverton look over a digital logic circuit. Left to right: Henry Wagner, Thomas Mullen, Vern Skare, Nicholas Bodley, Don Van Hoesen and Robert Vivian.

these pieces of material were constructed into an end item of equipment, plans had to be formulated on a system to be adopted for the continuance of the supply support. With over 50,000 separate line items to be considered, the supply system must not only assure that the needed part was in the right place at the right time, but it was necessary to devise an identification and storage system that would preclude future mishandling and loss of parts.

To accomplish this task, a Weapons System Storage Site (WSSS) operated by the RCA Service Co. was established at Griffiss Air Force Base, Rome, New York. Within this activity, the function of Material Control, Warehouse, and Procurement were all formulated into a mechanized supply which will eventually be integrated with a high-speed digital computer. The warehouse, consisting of 100,000 square feet of space, provides a six-month backup of supplies for all BMEWS technical equipment. All material accounting functions for all the forward sites are provided for them from the WSSS.

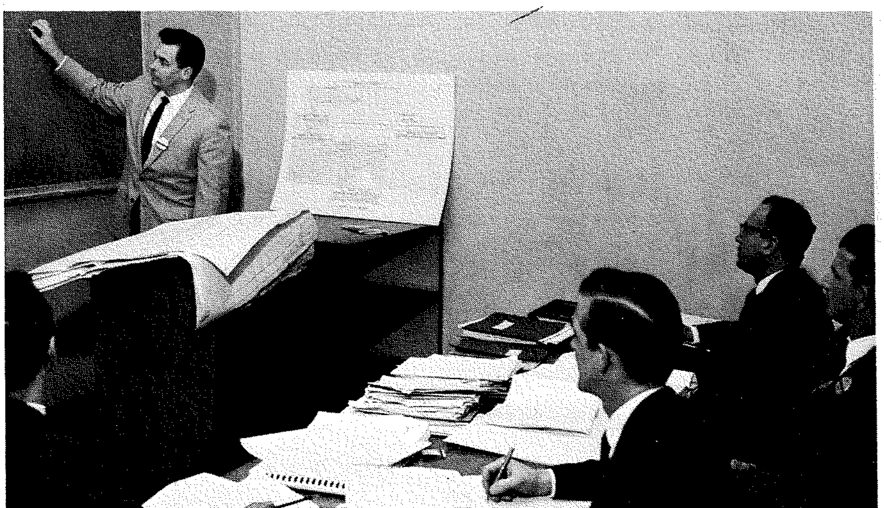
Re-order by Computer

Under the supply system, it is not necessary for the personnel at the sites to be concerned with the responsibility of reordering parts. A daily report of parts used is transmitted by the manager of Warehousing at the sites over a transceiver net to Rome. At this point, the information is fed into the digital computer, where it is compared with previous consumption and reliability factors. Parts reaching the reorder level are automatically recomputed and reordered, and all transactions against anticipated usage are recorded for reappraisal of back-up inventories. The amount of supply inventory is automatically controlled through the data-processing center, and the maintenance of manual stock records is not required.

This material control function not only insures against shutdown of BMEWS equipment because of lack of parts, but also places the huge supply and resupply system on a most efficient economical basis.

Using a unique system utilized by RCA Service Co. Supply personnel, the 50,000 separate items that will eventually be stocked at the Rome warehouse will be stored without any problem in filling orders efficiently. The system consists of categorizing parts in numerical sequence by their technical values. This not only affords rapid recognition of parts but precludes dual stocking under different numbers.

Fig. 6—A BMEWS instructor (Walter Edminster) goes over a diagram explaining part of the 210-hour Checkout Data-Processing course. Left to right: Jose Calva, Don Lavallee, Bill Howard and John Meehan around table.



Other significant responsibilities of the supply system include inspection and packaging. When supplies are received, each part is thoroughly inspected. It is extremely important that each and every part is in perfect order when it leaves the warehouse.

However, once the item leaves the warehouse enroute to site, there is still the possibility of damage in transit. To cope with this problem, RCA Service Co. personnel utilize special packagings to protect merchandise in transit and in storage. Special cartons, waterproofing materials, and sealing methods are used to protect parts from penetrating arctic cold and moisture. A waterproof barrier paper and heat-sealing method has been developed. With over $8 million worth of merchandise shipped to Greenland via the sea lift this past summer, little damage has been reported.

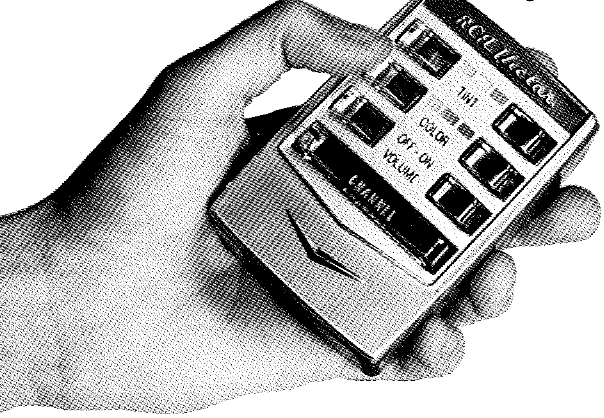
SUMMARY

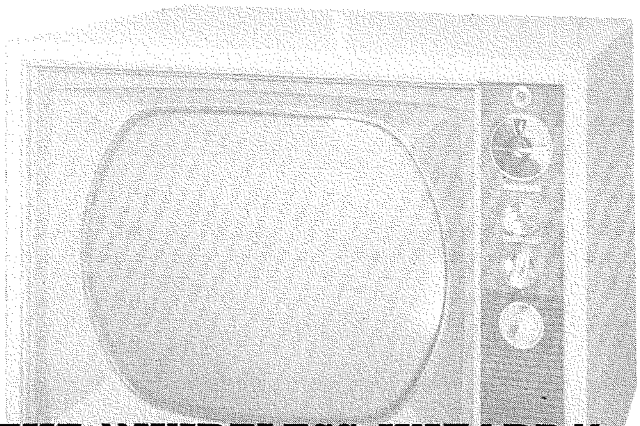
In summary, the RCA Service Company is assuming the on-site engineering responsibilities for installing, checking out, and integrating BMEWS. When the operation and maintenance phase begins, the task of the RCA Service Co. will be to operate and support the sites.

Even as responsibility shifts from the engineering organization to operations, the support organizations will continue to play a most important part. The requirements for the training of technical personnel, writing and publishing technical handbooks and manuals, recruiting personnel and maintaining site support services will still be essential to the project.

WILLIAM F. GIVEN graduated in 1943 from Lafayette College with a BS in Engineering Physics and later served in the U. S. Army during World War II as a first lieutenant. During his military career, he studied advanced electronics and math at Harvard University and advanced radar at M. I. T. He was with the Philco Corporation for 12 years, advancing to Manager of Communications Engineering. Mr. Given joined RCA in February, 1959, as Manager of Engineering for the BMEWS Service Project. The following November he became Manager of the BMEWS Service Project.

Fig. 1 — The "Wireless Wizard"





Consumer interest in remote control as a convenience for TV viewing has created a new vehicle for TV merchandising. Remote-control systems for various applications using wires, cables, etc. are familiar; however, it is apparent that for home TV, a system without the inconveniences inherent in a "wired" system is necessary. To achieve this, the Color TV Product Engineering Group designed the "Wireless Wizard," utilizing ultrasonic energy as the link between the remote-control device and the TV receiver. Mobile, reliable, and simple, it provides continuous color-TV control at the touch of a button. (For application of this principle to black and white TV, see R. J. Lewis, "A 17" Portable TV Receiver with Remote Control," Vol. 5, No. 1.)

THE "WIRELESS WIZARD"— REMOTE CONTROL FOR COLOR TV

by **E. D. FOX, J. A. KONKEL, J. L. MILLER, and D. A. TANNENBAUM**

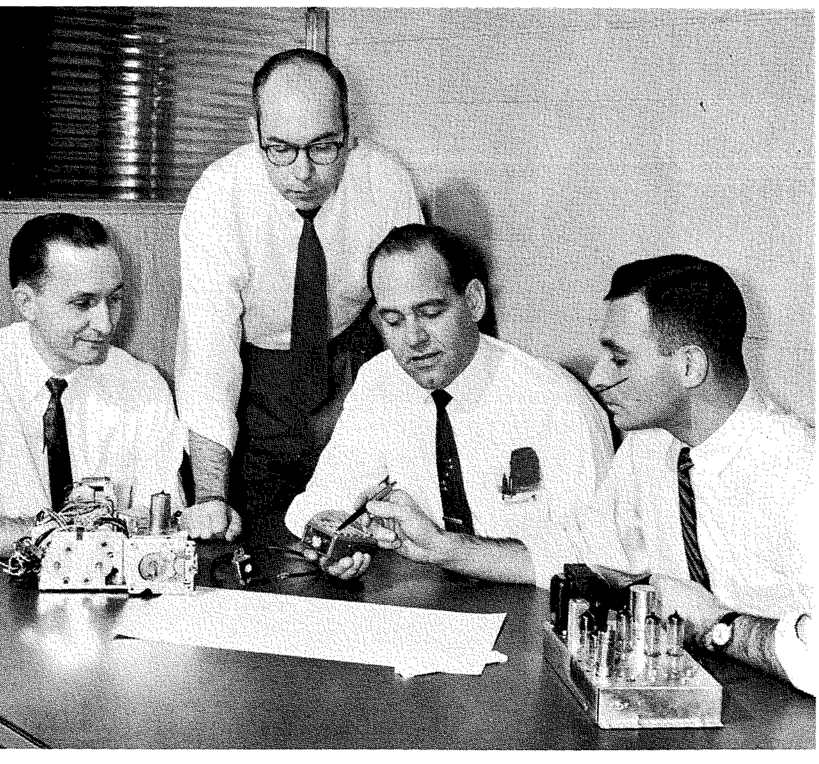
Color TV Product Engineering, RCA Victor Home Instruments, Cherry Hill, N. J.

In a "wireless" remote-control device for TV, it is important to restrict the transmitted energy essentially within one room, to avoid interference with other receivers that might be in the vicinity. To accomplish this, *ultrasonic energy* was selected to "couple" the remote unit and the TV receiver, since sonic energy above the audible range is greatly attenuated by walls, closed doors, and windows; an electronic link could cause interference in adjacent rooms.

In seeking a practical, low-cost ultrasonic system, many possibilities arose: One employed a combination of several carrier frequencies, each pair describing a particular operation; since this system required co-existence of two carrier frequencies and, therefore, two transmitters, it did not qualify as a low-cost device. In another utilizing only one carrier with selected modulation frequencies, receiver decoding became too costly.

The system finally chosen employs selected carrier frequencies for function control, and the presence or absence of a modulation for their direction of rotation. It consists of a push-button trans-

Fig. 2—The authors (left to right), Miller, Konkel, Fox, and Tannenbaum, and the color-TV remote-control system. Left to right: electromechanical coupler assembled to tuner; ultrasonic transducer; portable control (transmitter); amplifier.



ERNEST D. FOX received his B. S. in Electrical Engineering from the University of Pittsburgh in 1952. At that time he joined RCA as a Specialized Trainee. Following the training program, he was assigned to the Color Television Section of the Home Instrument Division where he has been engaged primarily in i-f circuit work. Currently, he is associated with the design of ultrasonic transducers and transmitters.

JOHN A. KONKEL received the Bachelor of Science degree in Electrical Engineering from the University of Minnesota in 1950; and joined RCA as a Student Trainee. After completion of this program he was assigned to the Color Product section of the Home Instruments Division. He is currently engaged in remote-control development. He is a member of Eta Kappa Nu and Tau Beta Pi.

JAMES L. MILLER received the B. S. degree in Electrical Engineering (Iowa State) in 1948 and is presently working toward the M.S. degree (Drexel Institute) in the same field. Upon completion of the RCA Student Training program in 1948, he was assigned to the Parts Department, Coil Development Section working on printed circuit development and the application of this technique to tuners, i-f amplifiers, etc. In June 1953 Mr. Miller transferred to the Home Instrument Division working on color TV, i-f and video amplifiers, and remote-control devices.

D. A. TANNENBAUM received his BSEP from the University of Michigan in 1949. Mr. Tannenbaum joined the RCA Specialized Training Program in 1950. After training he was assigned to the Export Radio Section where he contributed to the development of radio receivers for use in foreign countries. In 1951 he joined the newly formed Color Television Engineering Section. Certain of his articles were used in petitioning before the FCC for acceptance of the RCA Color Television System. In 1957 he became a member of a group formed to develop Remote Control devices for use with Television receivers. He is a member of IRE and has patents awarded and applied for in the areas of Television and Remote Control.

mitter for the TV viewer (Fig. 1) and a receiver and electromechanical coupler for the TV set (Fig. 2).

ULTRASONIC TRANSMITTER

The selected remote-control system employs a coded 20-kc oscillator to produce selected ultrasonic signals that vary around 40 kc. A given signal drives an electrostatic transducer, thereby transmitting a double-frequency acoustic pressure that impinges on the surface of a similar transducer at the TV receiver. Here, an electrical signal proportional to the acoustic pressure is generated, amplified and decoded to electromechanically operate the proper functions.

For direction of rotation, continuous-wave (c-w) carriers cause the selected function to rotate in a clockwise, or up, direction; amplitude-modulated (AM) signals cause a counter-clockwise, or down, direction. The functions and their corresponding coded signals are:

Function	*Signal (kc)*	
	Up	*Down*
Tint	35.75	35.75 + 60-cyc mod.
Color	38.25	38.25 + 60-cyc mod.
Volume	43.25	43.25 + 60-cyc mod.
Channel	40.75 + 60-cyc mod.	

The transmitter (Fig. 3) is composed of an oscillator, function-selection switches, and an electro-acoustical transducer. The major design factors were size, weight, shape, power consumption, ruggedness, and cost. Other requirements were: transmission of large ultrasonic outputs to minimize noise factor, gain and impulse noise considerations of the remote-control receiver, and design of a nondirectional transmitter for use at all normal TV viewing angles.

Basic Oscillator Circuit

The ultrasonic transmitter employs a transistor-type Hartley oscillator with a tapped voltage–step-up collector coil. Selected capacitors are tuned to produce oscillation at the various frequencies corresponding to each function. The emitter circuit has an associated r-c time constant and bias voltage which periodically (at a 60-cycle rate) quenches oscillation, supplying an AM signal. The c-w signal is produced by resistively shunting the emitter circuit to stop the quenching action.

Oscillator Tuning

The oscillator collector coil assembly employs a ferrite *cup-core* with an air gap in the center post to allow tuning and minimize saturation of the cup. The cup-core also acts as an extremely good magnetic shield. Coil Q and maximum inductance are very high relative to its small coil-assembly size and weight. The coil circuit is tuned with C_1, the transducer capacitance, the distributed and stray capacitance, and the selected capacitors that correspond to the receiver functions. Variations in circuit stray capacitances are held to a minimum to allow the use of economical trimmers for adjustment of selected frequencies. The oscillator is powered by a 4.2-volt, 500-ma-hr mercury battery with a shelf-life expectancy in excess of two years. The circuit drain is less than 10 ma, which enables the battery to realize its full shelf life under normal operation.

When a particular function-selector button is depressed, the oscillator provides a signal of 225 volts peak to the transducer at the frequency and modulation percentage selected.

Function Selection Switch

The function switch is a series of 22 electrically connected, flexible, phosphor-bronze fingers (Fig. 3). Gold-plated contacts affixed near the extremities of these fingers ensure adequate electrical contact for dry circuit switching. Stationary rhodium-plated contacts are attached to the bakelite board and connected by a copper pattern.

Depressing a button will complete at least the battery circuit and a circuit selecting the proper frequency. In addition to this, the clockwise (up) buttons close a switch, producing a c-w oscillator signal for application to the transducer.

Transmitter Transducer

Of the many types of ultrasonic transducers—piezoelectric, magnetostriction, reluctance, electromagnetic, and electrostatic—the electrostatic was chosen for cost, size, simplicity, and performance. Unlike most others, it has a wide-bandpass characteristic, permitting multiple frequencies as a coding system. Its capacitance is 135 ±15 mmf, and its sensitivity is relatively high.

The transducer (Fig. 4) requires two conductive plates (one movable) and an insulating dielectric. The mylar film is stretched smoothly over the surface of the grill after assembly by exposure to 170°C air. Its materials of like thermal expansion minimize capacitance changes with temperature, and were selected to be insensitive to humidity.

The transducer is employed in a novel manner to serve as a frequency doubler in the transmitter: An electrical signal of 20 kc, applied to the transducer, produces a 40-kc ultrasonic output by omitting the polarizing voltage used in con-

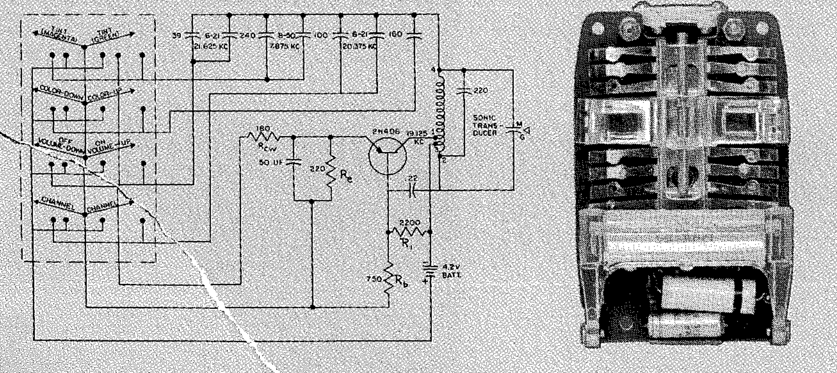
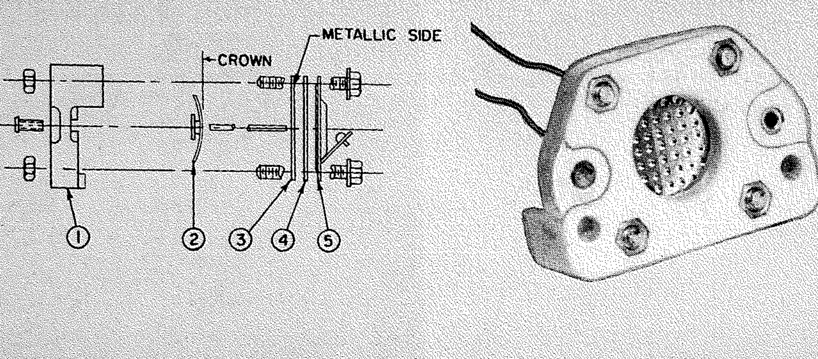


Fig. 3—Transmitter schematic and (right) view with case removed.

Fig. 4—Ultrasonic transducer: 1) glaskyd base; 2) perforated grill; 3) flexible mylar film with conductive aluminum coating on one side; 4) washer; 5) back plate.



ventional applications. This is possible because the acoustic output of the transducer is proportional to the square of the applied voltage. In conventional applications, the applied voltage is the sum of a sinusoidal signal voltage and a substantially greater polarizing voltage. Consequently, when squaring this sum, the term containing the signal-voltage squared is negligible, the amplitude output is proportional to the cross-product, and the frequency is the frequency of the applied signal voltage. However, if the polarizing voltage is zero the cross-product is zero, and the output is proportional to the square of the signal voltage. Since this is a $\sin^2$ function, it resolves to essentially the second harmonic of the applied signal frequency. This is developed and shown graphically in Fig. 5.

In addition, when restricted by a maximum instantaneous-peak-voltage limitation, an equal output can be realized from either type of transducer operation. Therefore, in this application, the frequency-doubling, or second-harmonic, operation is used to effect a reduction in cost and in size by eliminating the rectifier circuit necessary to provide a polarizing voltage.

The transmitter (Figs. 1 and 3) is small (1½ x 2½ x 4 inches) and weighs less than 12 ounces. It is housed in an "impac" plastic case and is very rugged. Its normal output is sufficient for reliable operation at a distance of 85 to 110 feet with normal receiver circuitry. The large dispersion angle of the transducer (6 db within an angle of ±45°) and the high sensitivity of the system minimizes the need for aiming the transmitter.

ULTRASONIC RECEIVER

When an ultrasonic signal impinges on the electrostatic transducer in the receiver (Fig. 6), the electrical signal produced is amplified, stepped down to a low impedance, and applied to the appropriate series-tuned circuit. A series rectifier, connected to this tuned circuit, produces a d-c voltage that is applied to the control-tube grid. This positive voltage causes the keyer tube to conduct, closing the relay for the desired function.

To operate a given function in a counter-clockwise (down) direction, the AM signal reverses the motor through a relay.

40-kc Amplifier

The 40-kc amplifier section contains four resistance-coupled amplifiers utilizing 12AX7 twin triodes. The gain of the resistance-coupled amplifier is 120 db. The gain bandwidth was determined conventionally. The response gives adequate cut-off of the lower audible spectrum and sufficient attenuation to the horizontal oscillator fundamental. Above 40-kc, the amplifier has a conventional r-c roll-off characteristic. The values of the interstage coupling capacitors are small enough to provide a capacity tap into the amplifier grid circuits. Miller effects, therefore, become appreciable and provide enough negative feedback to stabilize the amplifier, making the amplifier-section gain relatively constant and independent of component variations.

Noise immunity is excellent in the r-c amplifier because there are no tuned circuits to provide harmonic noise components within the pass-band of the function-selector channels. In addition, agc control voltage is obtained from this

$$W = \frac{1}{2} C V^2$$

$$\frac{dw}{dx} = f - \frac{V^2}{2}\frac{dc}{dx}$$

$$\frac{dc}{dx} = \frac{CA}{(D-X)^2} \approx \frac{CA}{D^2}$$

(for $X << 1$).

$$f = \frac{V^2}{2}\frac{CA}{D^2} = \frac{EA}{D^2} V^2$$

W	= energy, joules
C	= transducer capacitance, farads
V	= voltage across transducer
f	= force, dynes
C	= EA/d
E	= permittivity of dielectric
A	= plate area
d	= plate separation = $D - X$

If: $V = V_p + E_s \sin \frac{wt}{2}$

$$V^2 = V_p^2 = 2V_pE_s \sin \frac{wt}{2} + E_s^2 \sin^2 \frac{wt}{2}$$

but: $\sin^2 \frac{wt}{2} = \frac{\cos wt - 1}{2}$

$$V^2 = \left[V_p^2 + \frac{E_3^2}{2}\right] + \left[2V_pE_s \sin \frac{wt}{2}\right] + \left[\frac{E_s}{2} \cos wt\right]$$

$$f_r = \left[\frac{EA}{2D^2}\left(V_p^2 + \frac{E_2^2}{2}\right)\right] + \left[\frac{EAV_pE_s}{D^2} \sin \frac{wt}{2}\right] + \left[\frac{EAE_s^2}{4D^2} \cos wt\right]$$

$$= [f_{d\text{-}c}] + [f_{fund}] + [f_{2nd\ harm.}]$$

Because of voltage-breakdown limitations (instantaneous value): $E_s + (V_p \leq 225 \text{ volts}) = E_o$

When a polarizing voltage is used: $V_p = E_o \leq E_s$

Substituting: $f_{fund} = \frac{EA}{D^2}(E_oE_s - E_s^2) \sin \frac{wt}{2}$

For max. force:

$$\frac{df_{fund}}{dE_s} = \frac{EA}{D^2}(F_o - 2E_s) \sin \frac{wt}{2} = 0$$

$$E_s = \frac{1}{2} E_o = 112.5 \text{ volts}$$

$$V_p = E_o - \frac{1}{2} E_o = \frac{1}{2} E_o = 112.5 \text{ volts}$$

$$f_{fund}\ (max) = \frac{EAE_o^2}{4D^2}$$

$$f_{2nd\ harm.} = \text{negligible}$$

When polarizing voltage is omitted: (*inst. value*) $E_s + V_p = E_o$

but: $V_p = 0$, and $E_s = E_o$

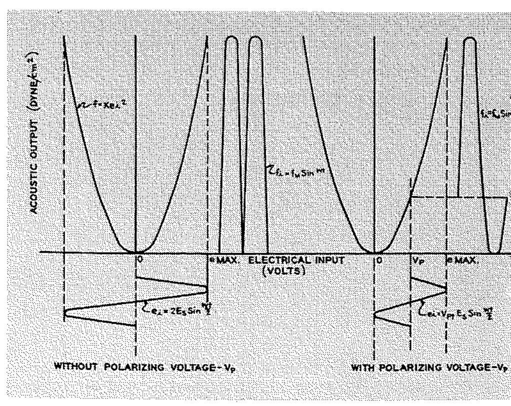
$$f_{2nd\ harm.}\ (max) = \frac{EAE_o^2}{4D^2}$$

$$f_{fund.} = 0$$

By inspection, the maximum output from each of the two cases are equal if: 1) instantaneous sum of voltage is limited by E_o and 2) the driving source delivers E_o volts across transducer. The output force for the 2nd harmonic is:

$$f = \frac{EAE_s^2}{4D^2} \cos wt$$

Fig. 5—Left: mathematical basis of frequency-doubling technique. Below: acoustic output vs. input showing frequency-doubling characteristic in absence of V_P.



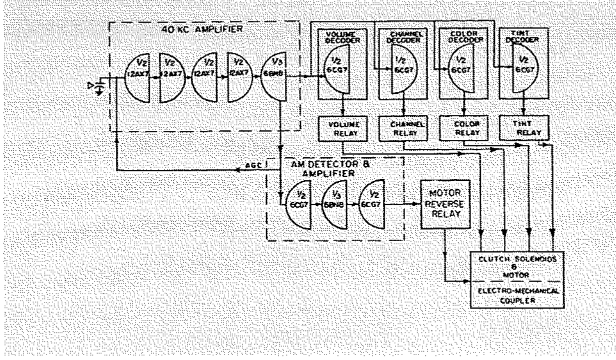


Fig. 6—Receiver signal flow chart.

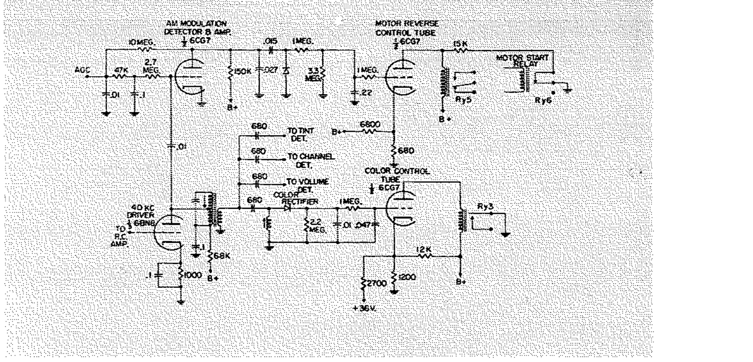


Fig. 7—Amplifier simplified schematic.

wideband source, which provides an effective degree of noise cancellation.

The 6BN8 output stage (Fig. 7) serves two purposes: it provides a wideband source ($Q=4$) for the operation of the reversing channels, and a low-impedance source for the function-control channels.

Function Selector Channels

The function-selector channels are composed of four series-tuned circuits connected in parallel across the low-impedance driver link. The low-impedance is required to provide a minimum of interaction between the series-tuned circuits and to keep their Q as high as possible. A series rectifier is connected at the junction of the inductance and capacitance of the series-tuned circuit (Fig. 7) with a voltage stepup to this junction from the link that is approximately equal to the Q ratio. In this circuit, the stepup is approximately 40:1. Because of this high selectivity, very little of this voltage appears at the rectifier of other functions (Fig. 8). The clockwise, or c-w, signal of the desired function is rectified and filtered, and the positive d-c voltage is applied to the grid of the appropriate keyer tube (normally cut off). This positive voltage causes the keyer tube to conduct, thereby closing the relay and completing the circuit for the electromechanical coupler.

High selectivity for the series-tuned circuits is required to prevent extraneous signals from operating the keyer tubes. Integrating networks are used between the detector and keyer tubes to keep sharp bursts of unwanted signals, which may be exactly at the function frequency, from turning it on.

The tuned-circuit coils are universal-wound on a paper form and covered with an iron-core hat. The iron-core hat increases inductance in addition to providing a shielding effect, preventing a loss in Q. Coil Q's of 80 to 120 can be realized, while circuit Q's of 40 to 60 are obtained. Higher Q's increase the rejection of adjacent signals, but are not practical; maintenance of stability is more difficult because of temperature and humidity variation.

Bias for the function relay stage is obtained from a $B+$ bleeder and a common cathode resistor. To prevent excessive cathode degeneration and maintain a low bleeder current, the bias is obtained from two sources: the 170-volt $B+$ supply and the $+36$-volt d-c solenoid supply. Regulation of the 36-volt supply is in the direction to lower the bias on the relay stage when the electromechanical coupler is activated. The drop in bias provides positive relay closure and prevents relay chatter. The relay is one of the high-sensitivity type: 2000-ohm plate impedance and 5-ma closing current.

Automatic Gain Control

The AM detector is fed from the 40-kc driver stage, and detection of the AM reversing signal envelope is accomplished by grid detection in the 6CG7 buffer-amplifier stage. The negative d-c voltage developed at this point is fed back to the r-c amplifier stages for agc (Fig. 7). The agc positive delay voltage is derived from the plate circuit. The detector action of this circuit provides a variable positive delay voltage proportional to signal level. As signal level increases, the positive plate voltage drops, which increases the gain of the agc loop and gives a constant output over a wide range of signal levels. In addition, the delay voltage helps provide for an increase in output amplitude of the AM signal, by increasing with an increase in AM signal level. This reduces the gain of the agc loop, making the peak amplitude on a modulated signal substantially higher in the driver plate. The increase is needed to provide a constant d-c output from the function-selector detectors independent of modulation percentage.

AM Detector and Amplifier Channels

The 60-cycle envelope detected at the grid of the 6CG7 is amplified in the plate circuit of the same stage. The output from this buffer amplifier is again detected, and the positive voltage is fed to the grid of the motor-reverse relay stage through an appropriate filter network. Since the control voltage for the reversing function is derived from a broadband source, this function is not noise-immune, and random bursts of noise would intermittently cause the reversing relay to close. To prevent this, the reversing relay is latched closed by permitting hold-in current to flow through the relay and the normally closed contact of the motor start relay. This, in effect, provides the reversing channel with the equivalent noise immunity of the function channels. When either an AM or c-w signal is received, the reversing relay is unlatched. The c-w signals keep it open, while plate current from an AM signal causes it to close.

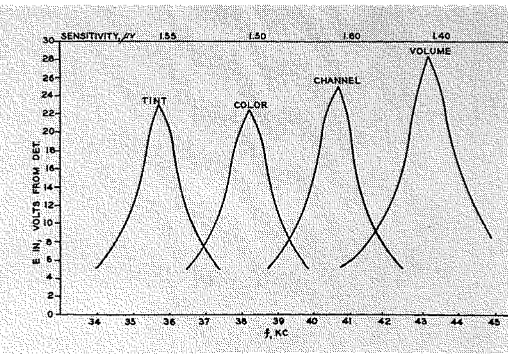
The over-all sensitivity of the receiver is such that each function will operate when a 2-μv signal of the appropriate frequency is applied at the input. This corresponds to 85 to 110 feet in distance when used with a nominal receiver transducer and transmitter. This is not considered excessive, even though the transmitter and receiver separation is seldom greater than 20 feet in actual practice. The additional sensitivity provides enough reserve to allow for signal variation due to multipath reception, directivity pattern of the receiving transducer, and aging; it eliminates the need for aiming the transmitter.

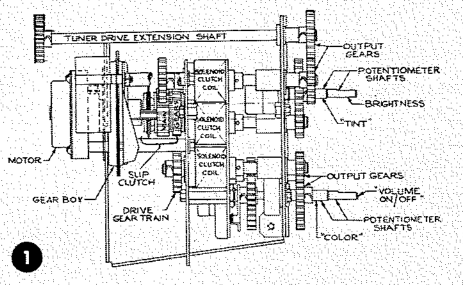
ELECTROMECHANICAL COUPLER

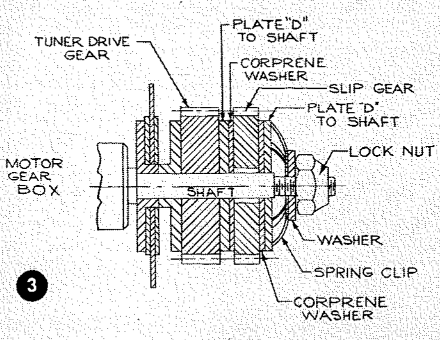
The final link in the system is the electromechanical coupling mechanism (Fig. 9). Using the decoded information from the receiver, this mechanism selectively allows the tuner and control potentiometers, manually variable at the receiver, to be continuously remote controlled.

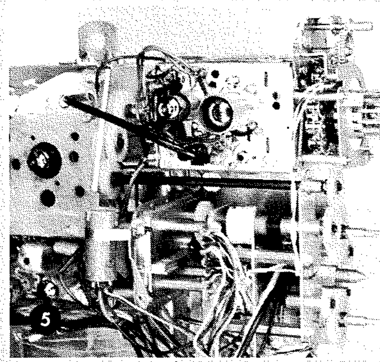
The physical package design for this device is dictated by the functionally styled arrangement of the operational controls on the TV receiver, and the space limitations of the cabinet. With the exception of the wiring to the potentiometers and tuner, this package is a completely separate entity which can be added (in production only) to a standard nonremotely controlled color-TV

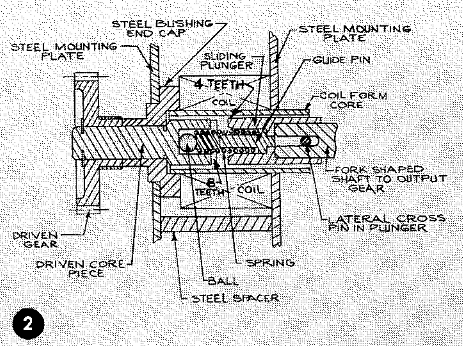
Fig. 8—Amplifier, point-by-point agc operative.











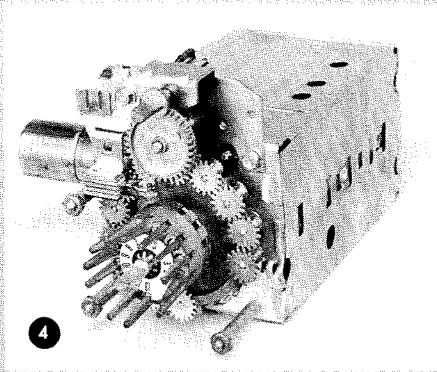


Fig. 9—Electromechanical coupler: (1) coupler assembly; (2) solenoid clutch; (3) slip-clutch gear drive for potentiometers; (4) tuner (showing 13-key channel programmer); (5) coupler-tuner assembly in TV receiver.

chassis. The styling concept also dictates that certain potentiometer controls be mechanically dualed: *volume on-off* with *color*, and *brightness* with *hue*. For purposes of remote control, all but *brightness* are remotely adjustable.

Motor

The reversible motor is a 2500-rpm, two-pole, four-coil, 24-volt induction type, fitted with a 250:1 ratio gear box having a nominal output shaft speed of 10 rpm. Its minimum torque capability is 120 oz-in to drive the tuner (90–100 oz-in) potentiometers (1–3 oz-in) and a-c snap switch (15–20 oz-in). Current requirements are in the order of 1 ampere. The 40-mfd nonpolarized running capacitor represents the phase-shift device needed for reversible action; its value is chosen for minimum power input consistent with the desired minimum torque requirement. The reversing action of the motor is reasonably fast—about 50 milliseconds for complete reversal. This type of motor is attractive because of its low cost, simplicity of control switching circuits, and good life characteristics.

Gear Train

Two outputs are obtained from the gearbox shaft: one is a gear fixed to the shaft and drives the channel solenoid directly; the second, used to drive the other solenoids, is obtained from a slip-clutch gear. The latter is a sandwich of two end-plates fixed to the shaft and holding between them two corprene washers and a gear free to rotate about the shaft. A spring clip and an adjustment nut allows the sandwich to be torque-wrench tightened to a predetermined value where the center gear will just slip at torques above 60 oz-in. This slip gear is a necessary protection against the possibility of breaking the stop on the potentiometer when it has been rotated to its maximum positions. The slip action is not required in the case of the tuner drive, since it is a continuously rotatable device.

Solenoid Clutch

The driven core member is a stepped shaft free to rotate in a plate-mounted steel bushing which also serves as the magnetic end-cap for the solenoid coil. Affixed to one end of the shaft is a gear linked with the other gears being driven at 10 rpm by the motor output shaft; the opposite end has eight equally spaced clutch teeth of triangular shape.

The magnetically-activated plunger is a sliding cylindrical collar with four matching clutch teeth on one end. This collar is spring-loaded away from the drive teeth at a predetermined distance of 0.188 inch, trough to trough — the prime gap in the magnetic circuit, occurring in the middle third of the coil (for best efficiency). The spring is seated on a ball, held captive within a recess in the core, and is held in alignment by a brass guide pin inside the plunger. Spring material is piano wire which, although magnetic in character, indicated little or no effect on the magnetic flux path. The ball permits free rotation and eliminates the possibility of spring wind-up and consequent binding. This magnetically-activated collar, then, couples the motor to the potentiometer shaft.

Final coupling is accomplished through an output shaft held centered in a plate-mounted brass bushing and having a fork-shaped, open-ended slot at one end and a gear affixed to the other end. The fork-shaped slot passes inside the back end of the plunger where it engages the lateral cross pin. A brass output bushing is used so as not to short-circuit the flux path. The output gear then drives a secondary gear affixed to the shaft of the potentiometer. A 2:1 reduction in speed to 5 rpm is used here in the interest of correct "feel" for the controls; that is, their rate of change when motor driven. The coil placed around the core and plunger is held captive by the plate-mounted bushing end-cap on one end, and a flush-seating steel plate on the other end. Keyed steel spacers between these two plates establish the basic mechanical alignment for the structure, as well as completing the external magnetic-flux circuit. All magnetic parts used in the clutch are machined from PS-53 cold rolled steel, best for high permeability, low retentivity, availability, and machinability. The surface finish used is oxide black, which is noncorrodable, adds no foreign materials to the surface, and is self-lubricating.

Solenoid Coil

The pull power and stroke of a device of this nature are principally dependent on and proportional to the area of the cross section of the plunger, and the ampere turns in the coil. Additionally, the location of the air gap between plunger and core, the relative coil length to coil diameter, the quality of the magnetic return path, and the magnetic quality of the core and plunger parts will determine the efficiency of the design. Considerable experimentation and evaluation of parameters was required before selecting the specific characteristics of each element. Diameter, length, shape of the core and plunger, and the consequent coil form factor were determined for the most part by mechanical loads involved, space factors, dimensional tolerances, and cost. With these parameters established, 500 ampere-turns are required for maximum reliability. Having a practical-maximum d-c current of 250 ma, a coil of 2000 turns (# 33 wire, random-wound) was required. The d-c resistance is approximately 82 ohms. Materials for the coil form were selected to minimize the effects of temperature and humidity.

Solenoid Power Supply

In the power-supply circuit, under open-circuit conditions, the capacitor is charged to approximately 36 volts d-c. Closing any one of the relay contacts instantaneously causes the discharge of a high-peak surge-current pulse into the coil. This surge action improves the efficiency of the solenoid by applying high-peak current when the solenoid is in its weakest state; that is, the magnetic gap at maximum opening. The series resistor serves to limit the average current and thereby reduce the continuous watts dissipated in the coil, and protects the power supply against coil short circuits.

Switching Control Circuits

Fig. 10 shows the basic electrical arrangement for selective switching. Using the *color* control circuit for illustration, sensitive relay R_y3 closes on reception of a continuous wave signal. The relay contacts supply the ground return for a series circuit composed of the *color* solenoid coil and the coil of a low-resistance motor-start relay (R_y6). With both these coils energized, the clutch pulls in, engaging the motor gear train to the potentiometer gear train, and at the same time the ground return supplied by R_y6 contacts to the motor control circuit causes the motor to start in a clockwise direction. An AM signal which activates the reverse channel relay R_y5 would reverse the motor direction.

Automatic Programmer for Tuner

A special switching case exists when operating the *channel* control circuit. Once energized by signal, this circuit must provide automatic electrical latching of the solenoid and the motor power to permit the tuner to proceed to the next programmed channel and come to rest properly detented. Programming of desired channels is customer-selected.

The 13-key lever programmer device is affixed to the shaft of the tuner with one key per channel (Fig. 9). Lifting the lever associated with the desired channel causes the station stopper switch to open when this channel is encountered during the rotation of the tuner. The tuner then comes to rest in detent. Depressing the key would cause the switch to remain closed during rotation, thereby representing an undesired channel, hence causing the tuner to continue rotating until the next open-switch condition occurs. This open-seeking switch then is the latch-unlatch sensor whose contacts are part of a series control circuit made up of resistor R_l, contacts *c* and *d* on relay R_y1, and the coil of relay R_y1 (Fig. 10).

Operationally, when a *channel* control signal is received, relay R_y1 closes, thereby supplying the ground return for the *channel* solenoid and motor control circuits. Additionally, this double-pole relay supplies the ground return for the latching circuit. Latching contacts *c* and *d* on R_y1 are required to deactivate the circuit when the tuner is manually operated. Otherwise, the selection of an unprogrammed channel manually would cause the station stopper switch to close activating the coupler and directing the tuner to the next programmed channel. The signal must be of a duration sufficient for the tuner to start out of detent and begin rotating. The instant the tuner is out of detent, the sensing switch closes, completing the series loop back to the top of the control relay R_y1.

This establishes a d-c current path, independent of the original plate current signal, and hence acts to hold control relay R_y1 energized. As a result, the *channel* solenoid remains energized and the motor continues to run until such time as the station-stopper sensing switch is caused to open by the detection of the next programmed channel. At this time, R_y1 opens and all power is removed from the circuit, leaving the tuner at rest and in detent.

Standby and Master Power Switching

One of the unique features of this system is the method for remotely controlling the a-c power to the TV chassis and to the remote control chassis. A double switching arrangement is mechanically associated with the *volume* control potentiometer. One a-c snap switch serves for *master power on-off*. A second a-c snap switch serves for TV *power on-off*. The switch actions are displaced by an angle of 60° which means that as the volume control is rotated, at 5 rpm, in a counterclockwise (down) direction, the TV *power off* switch first operates. At this time, the TV viewer can stop the system, leaving the remote-control receiver in standby and allowing the TV receiver to be turned on again by remote control.

To turn off all power to the instrument, it is necessary to continue the rotation of the volume control in the counterclockwise (down) direction until the master power switch activates. At 5 rpm, a two-second interval is involved, an average time required for the viewer to respond in the event he desires only to turn the TV off. Once the *master* switch has acted, it is necessary to manually turn the instrument on. This desirable *master off* feature prevents the wireless receiver from continuously drawing standby power.

ACKNOWLEDGEMENTS

The authors wish to acknowledge the contributions of the many people, in and out of the Color Television Group, without whose efforts the system would not have been possible. Particular appreciation is due A. G. Lazzery of the Television Division for mechanical assistance.

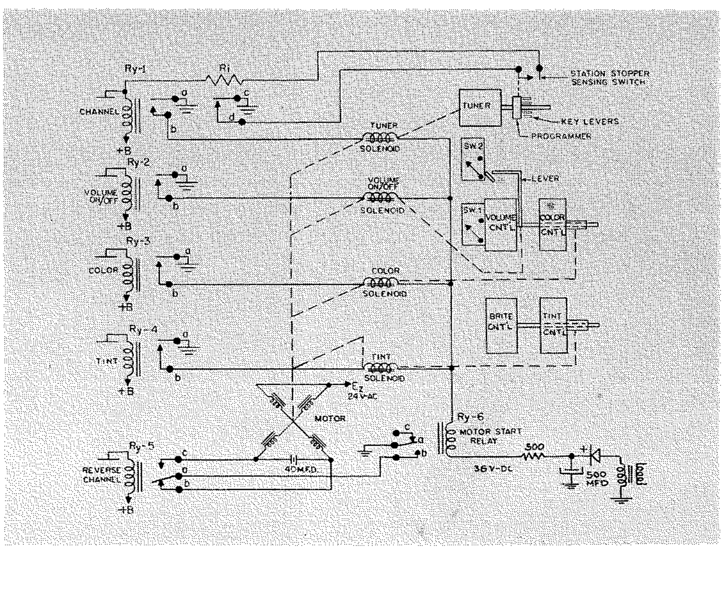


Fig. 10 Switching diagram.

At 6:40 AM on April 1, 1960, the TIROS I satellite was launched from Cape Canaveral, Fla., entering a near-circular orbit of about 450 statute miles altitude shortly thereafter. TIROS I makes roughly 14 passes each day, and is expected to do so for decades; it is planned that use will be made of its instrumentation for about 90 days. TIROS I represents an outstanding achievement for the engineering groups of V. N. Landon, Mgr. Staff Engineering, and E. A. Goldberg, Mgr., Space Vehicle Systems, at the RCA Astro-Electronic Products Division, Princeton, N.J., where it was developed and built. Its success stands as a major step forward in space technology. The Editors are indebted to I. M. Seideman of AEP Engineering for compiling the material presented here.

RCA-DEVELOPED NASA WEATHER SATELLITE A SUCCESS

TIROS I Television Satellite Sending Valuable Cloud Pictures

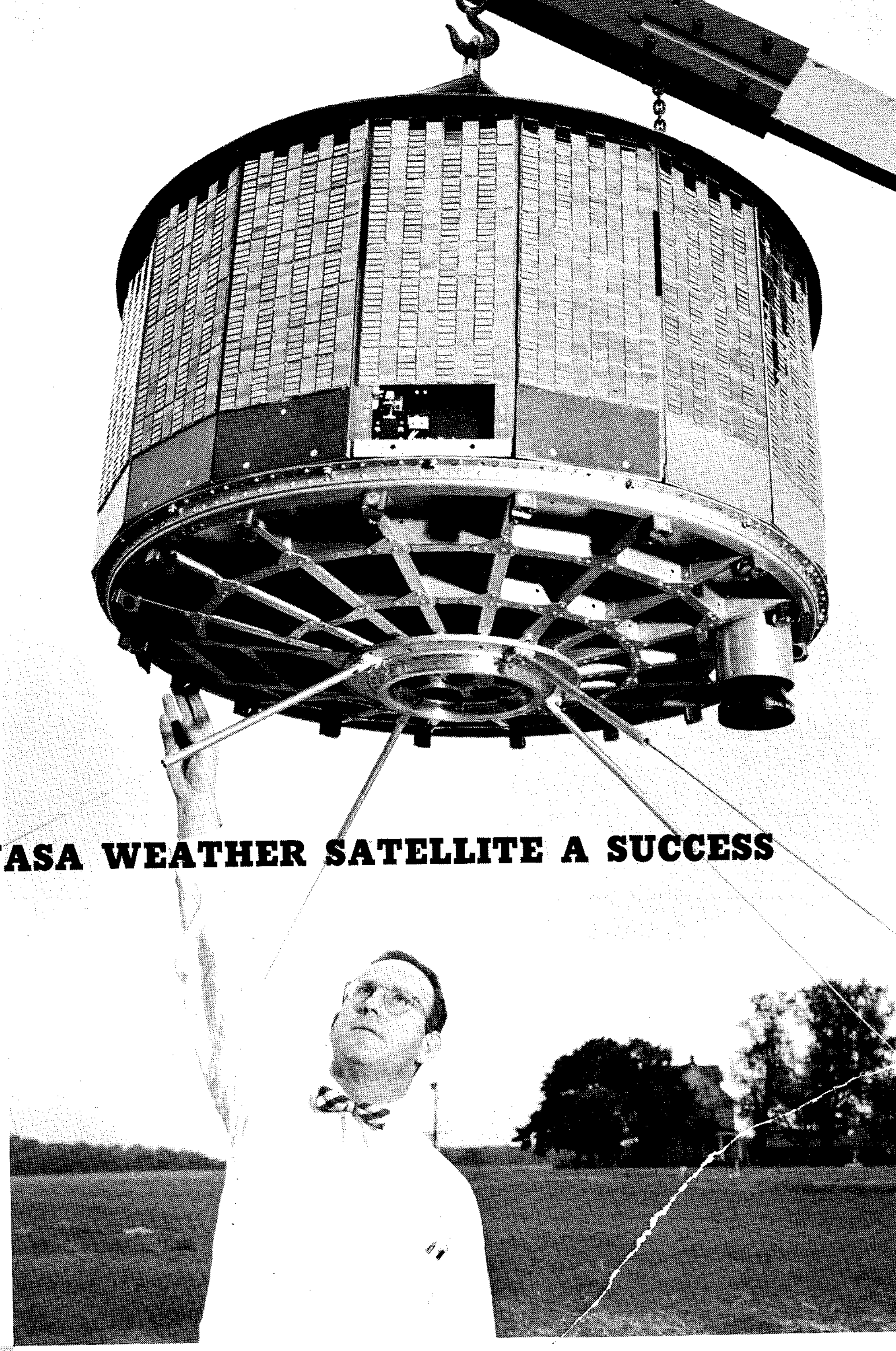


Fig. 1—A. Schnapf, Ass't Manager for the TIROS project at the RCA Astro-Electronic Products Division, inspects an exterior component of the TIROS I satellite. This view shows a good portion of the more than 9000 solar cells constituting the primary electrical power supply; the four elements of the transmitting antenna, shared by all r-f subsystems; and the optical system of one of the TV cameras. Nearly all major components are mounted, through a base plate, to the structural ribs showing on the bottom.

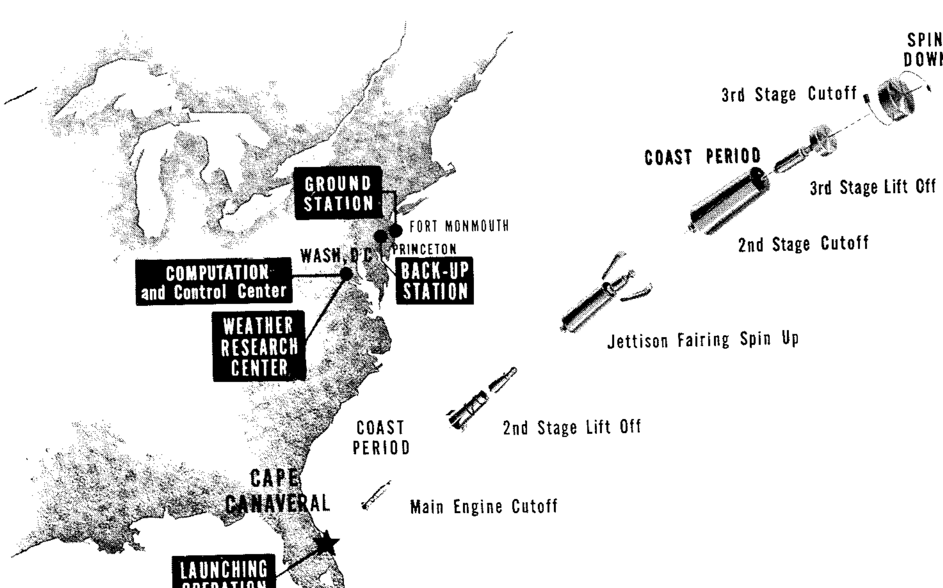


Fig. 2—TIROS I was launched from Cape Canaveral, Fla., by a three-stage Thor-Able rocket system. During the initial launch phase, the third stage and satellite were protected by a shroud, or fairing. This fairing was dropped after second-stage burn-out, and the stabilizing spin-up of the solid-fuel third stage was started. Third-stage separation, propulsion cut-off, and satellite lift-off then occurred; and, after an interval of several minutes, a de-spin mechanism reduced the satellite spin rate to 12 rpm —fast enough for stabilization, but slow enough to take sharp pictures. At this time, the satellite was operational, traversing its first orbital path.

TIROS I, WHICH HAS been successfully launched into orbit from Cape Canaveral, is an important satellite experiment expected to provide meteorologists with additional data for weather forecasting. Until now, adequate weather reporting from ocean areas and uninhabited land areas of the earth has not been practical. Now, however, the cloud pictures taken by the TIROS I satellite can be interpreted, by analysis and by comparison with known weather conditions, to reveal the weather and weather movement in hitherto inaccessible areas. Cloud systems and their movement are observed by the TV cameras aboard the satellite; major storms and hurricanes, for example, now can be followed closely over large areas.

GOVERNMENT AND INDUSTRY SHARE IN SUCCESS

Although the TIROS satellite and its instrumentation were developed and produced by the RCA Astro-Electronic Products Division in Princeton, N. J., many other organizations were necessary for the success of the TIROS project. The National Aeronautics and Space Administration (NASA) had over-all management control; and the U.S. Army Signal Research and Development Laboratories (at Ft. Monmouth, N. J.) provided the technical direction for the satellite development. The Space Technology Laboratories, in conjunction with Douglas Aircraft and under technical direction of the U.S. Air Force Ballistic Missile Division, were responsible for providing the three-stage Thor-Able launching vehicle and for the launching itself. The Space Operations Control Center of NASA is directing the operational phase of the program, with support from the NASA Computing Center and the U.S. Weather Bureau's Meteorological Satellite Section. Meteorologists representing many agencies (including the Air Force Cambridge Research Center, the Navy Research Weather Facility, and the U.S. Army Signal Corps) are located at the Kaena Pt., Hawaii, and Ft. Monmouth, N. J., ground stations.

DATA RECEIVED AT HAWAII AND FT. MONMOUTH

The two primary ground stations of the TIROS I system, operated for NASA under the technical supervision of the U.S. Army Signal Corps, are located at Kaena Pt., Hawaii, and at Ft. Monmouth, N. J. The Hawaii station is operated by the Lockheed Missile and Space Division and its consultant, the Philco Corp., under contract to the U.S. Air Force Ballistic Missile Division; the Ft. Monmouth station, by the U.S. Army Signal Corps. Both have full control and programming facilities for the satellite, and have receiving and data-processing facilities for data returned by the satellite. Contact with the satellite can be maintained by at least one of these stations for all but three of its orbits (which take about 90 minutes each) every day. In addition, a back-up station is being operated by NASA at Cape Canaveral, Fla., and a station at Princeton, N. J., is being operated by AEP personnel to obtain test and evaluation data. Satellite position and altitude data will be obtained by established radars, and stations of the Minitrack network.

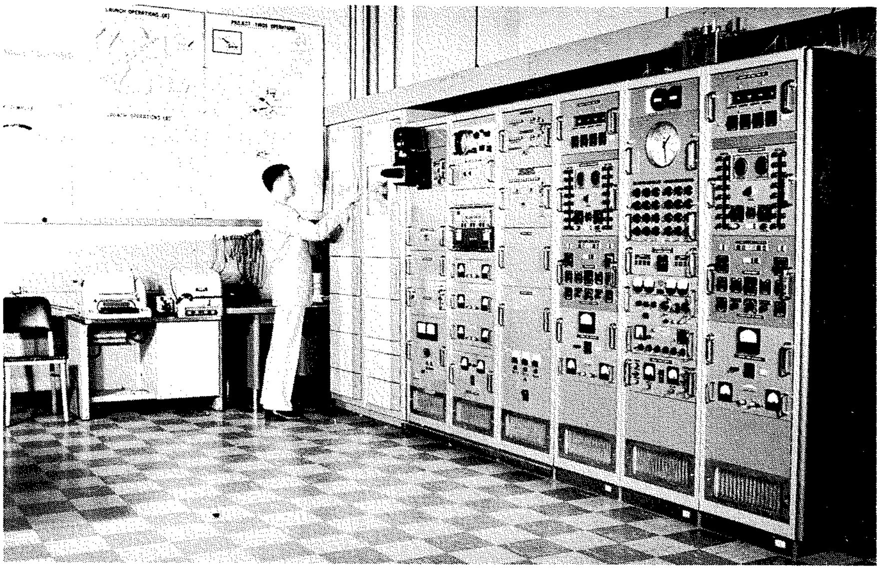


Fig. 3—P. Binstock observes the operation of a tape recorder at the TIROS ground-station installation at AEP.

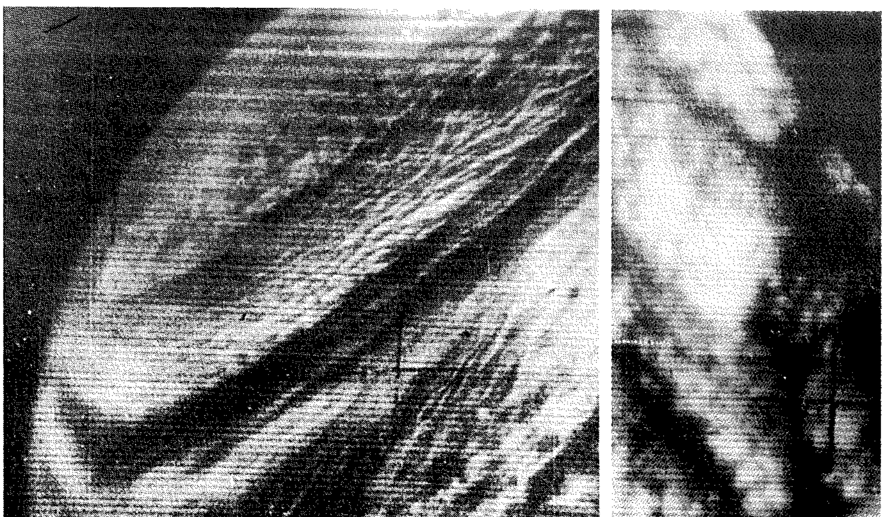
SATELLITE FUNCTIONS CONTROLLED FROM EARTH

The TIROS satellite is within communication range of a ground station for only a small portion of each orbit. During this time, it receives instructions for 1) automatic operation of the TV camera systems during the succeeding orbit (i.e., the time to start operation, the sequence of operation of the cameras, etc.); 2) the transmission of stored picture data to the ground station; and 3) direct transmission of the camera pictures while the satellite is still within range. Since this involves a considerable number of instructions to be sent from the ground station in rapid sequence, facilities are provided for pre-programming complete sets of instructions at each ground station. This permits both a careful check beforehand of what is set up on the equipment and an uninterrupted sequence of transmission once it has started.

TIROS WEIGHT TOPS 250 LBS.

The TIROS satellite is roughly cylindrical in shape (actually an 18-sided polyhedron), about 42 inches in diameter and 19 inches high, and weighs over 250 lbs. The four-element transmitting

Fig. 4—Actual TIROS I cloud-cover TV pictures of the central Pacific Ocean. Left: The wide-angle TV-camera shows giant cloud bands. Right: Narrow-angle TV-camera detail of the cloud structure in the center of the left photo.



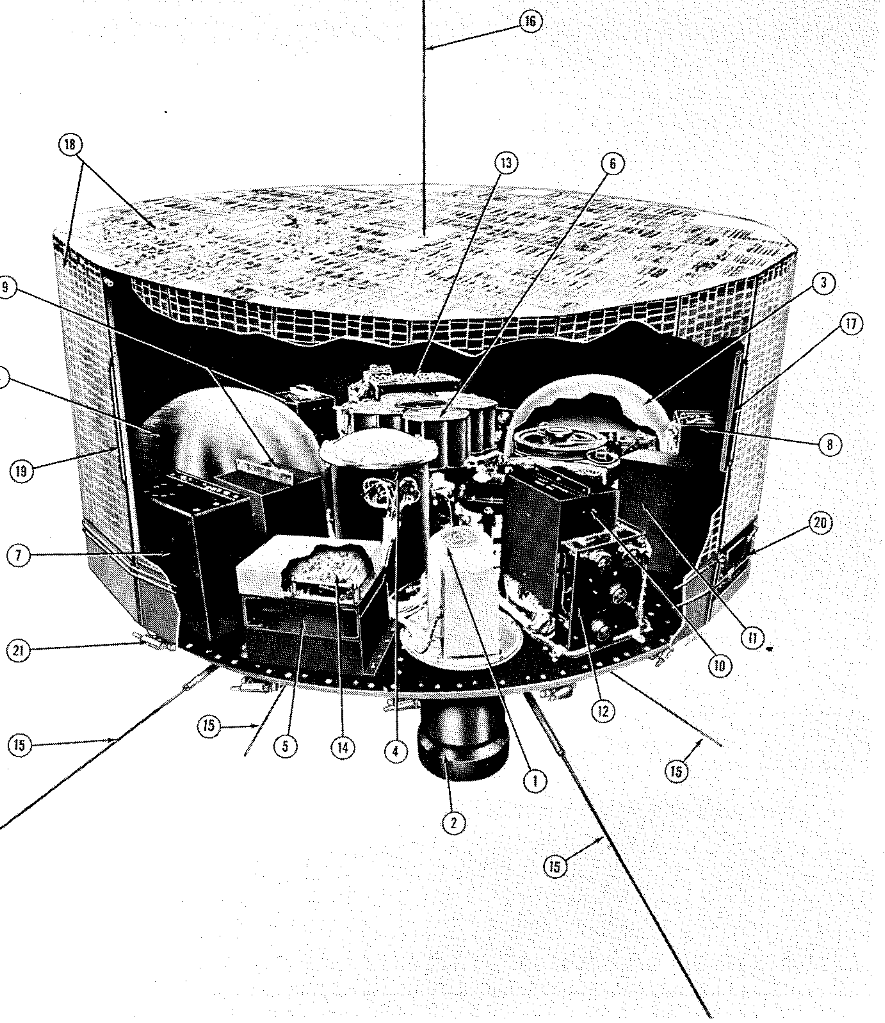


Fig. 5—Cutaway of the TIROS satellite, showing: 1) one of the two half-inch vidicon TV cameras; 2) TV camera lens; 3) video tape recorders; 4) electronic "clock" for timing the operational sequence of the system; 5) TV transmitter; 6) power-supply batteries; 7) TV camera electronics; 8) tape-recorder electronics; 9) and 10) control circuits; 11) power converter for tape motor; 12) voltage regulator; 13) battery-charging regulator; 14) auxiliary synchronizing generator for TV; 15) transmitting antennas; 16) receiving antenna; 17) and 19) solar sensor for detecting sun angle at time of picture-taking; 18) solar cells; 20) de-spin "yo-yo" mechanism to slow spin rate; 21) spin-up rockets to boost spin rate as desired.

Fig. 6—Sidney Sternberg, Chief Engineer of AEP, inspecting the first assembly of a TIROS I satellite. This is not a flyable model, although identical in construction, because of the severe tests to which it was subjected.

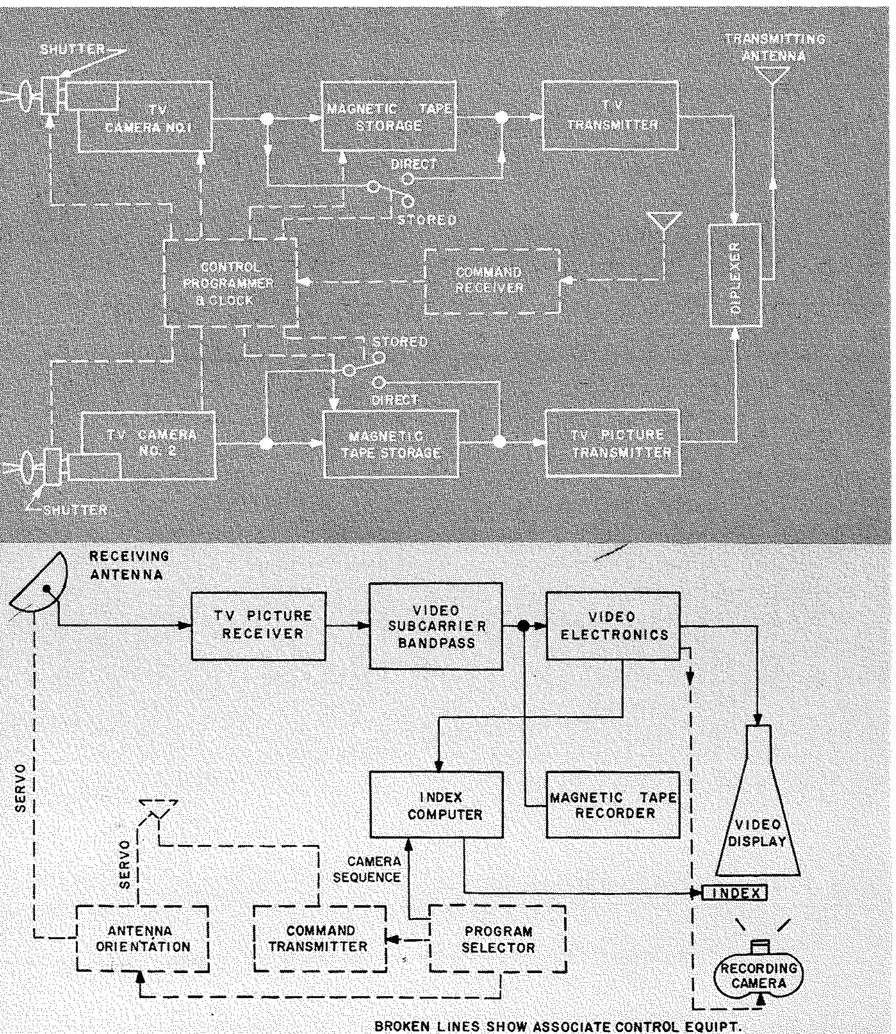


Fig. 7—TV picture subsystem. Top: in the satellite; bottom: in the ground station. Dashed lines indicate associate control equipment. The output of the two radio-controlled TV camera systems are received, sequentially, by a single TV channel at each ground station. Pictures are displayed and photographed as they are received, and are tape-recorded for future play-back.

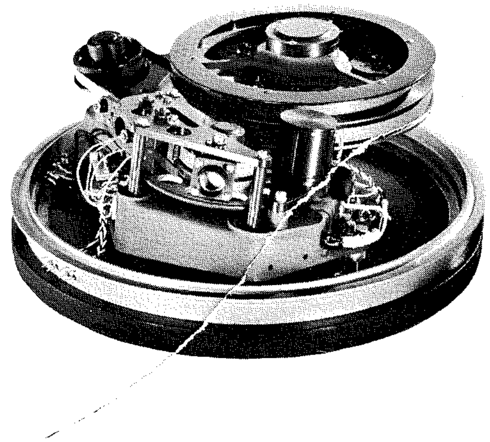


Fig. 8—The light-weight, low-power magnetic-tape transport.

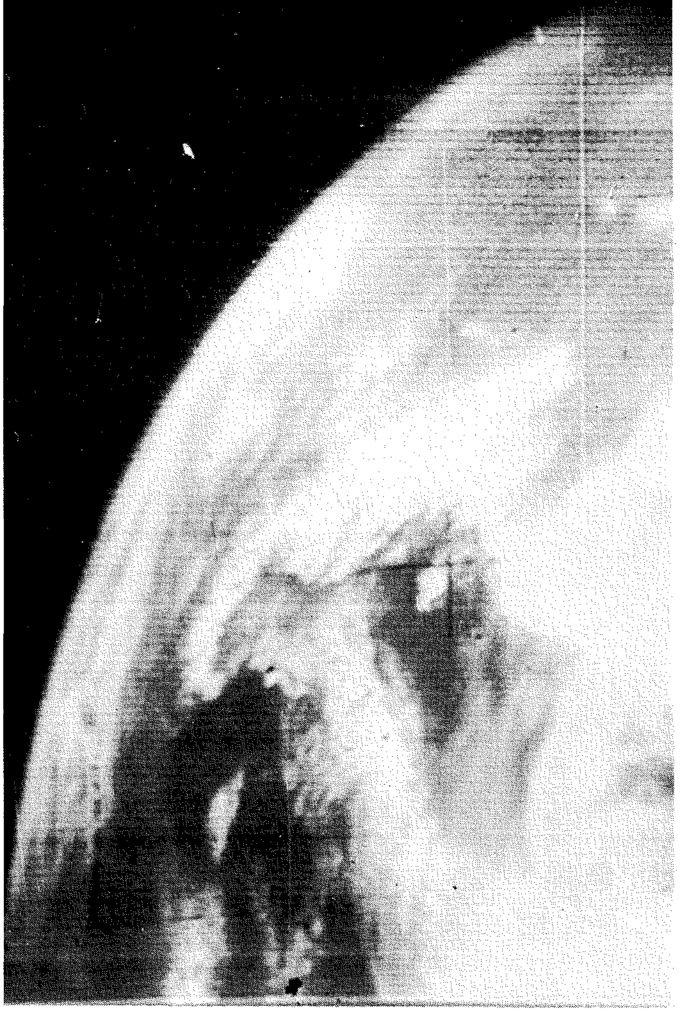


Fig. 9—Actual TIROS I wide-angle TV-camera picture taken over the Mediterranean looking toward the Alps (heavy cloud layer in center of photo). At center is the Italian peninsula.

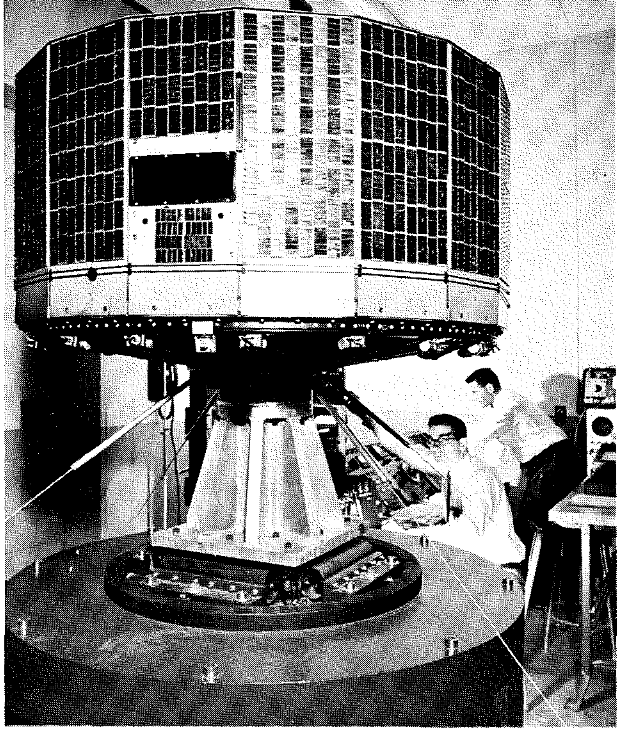


Fig. 10—The TIROS satellite on a vibration table at AEP, with G. Hieber at the controls and E. Grzegorzewski monitoring test readings.

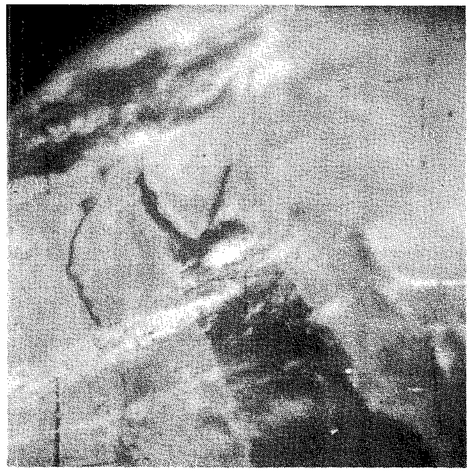


Fig. 11—Actual TIROS I wide-angle TV-camera picture of the Red Sea area, with the Nile River the dark strip at left. The Mediterranean is at the upper left.

antenna and TV cameras project through the bottom surface. The top and sides are covered with solar cells for the power supply, and the receiving antenna projects upward along the axis line. The instrumentation, practically all of which is mounted on the base plate, is of special light-weight and miniaturized construction. Although TIROS I does not carry infrared instrumentation, space was provided so that the next TIROS satellite to go aloft can be equipped to measure the earth's heat reflection and radiation.

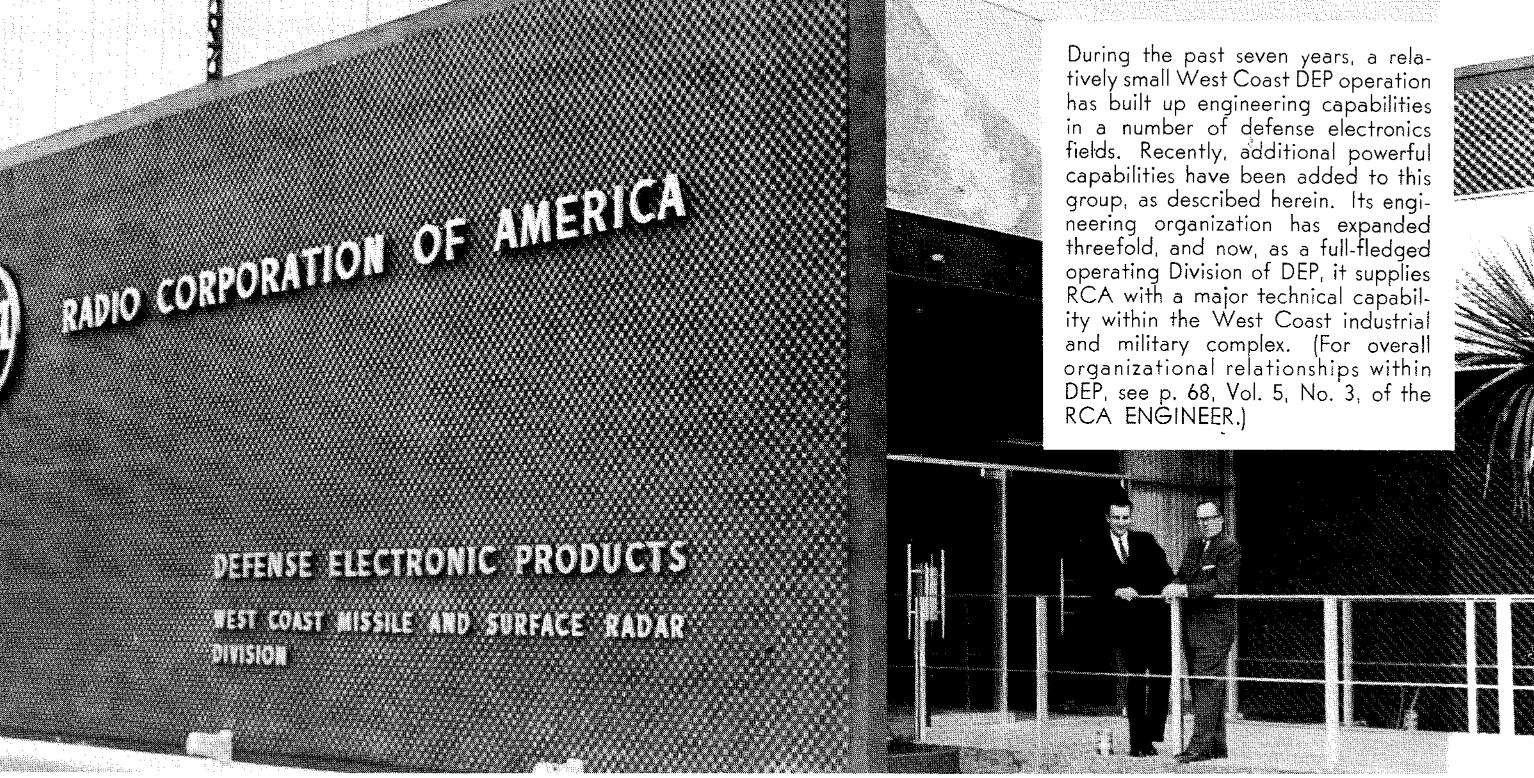
The average power requirements of 18 watts for the TIROS satellite instrumentation must be generated by the solar cells on the illuminated portion of the satellite while it is not in the shadow of the earth. This is accomplished by more than 9000 solar cells connected in a gigantic series-parallel network. The maximum voltage generated is close to 33 volts. The solar-cell output charges a bank of storage batteries, the output of which, in turn, is 1) used directly, 2) voltage-regulated, or 3) converted to other a-c or d-c voltages.

TELEMETRY REPORTS SATELLITE CONDITION

Forty parameters of the satellite (i.e., temperatures and voltages) are measured and transmitted serially to the ground station at least once during each contact period. For reliability, all measurements are sent twice, through separate beacon transmitters during the telemetry period. An FM-AM telemetry system is used. All data is plotted automatically on a paper chart recorder at the ground station as a deviation from zero volts. An overlay showing the correct deviation makes possible a quick comparison and easy recognition of a variance outside of tolerance limits.

SATELLITE "FLIGHT-TESTED" ON GROUND

All possible precautions were taken before the launching of TIROS I to ensure that the instrumentation would both survive the shock of launching and operate properly for the life of the satellite. The environmental conditions actually encountered were simulated at the AEP test laboratories, and models of the satellite were subjected to conditions far more severe than those actually anticipated. Among the commercial test equipment used were a vacuum chamber large enough to house the entire satellite, and a vibration machine, or "shaker." A structural load test device was designed and assembled at AEP and, so far as is known, is the only one of its kind.



During the past seven years, a relatively small West Coast DEP operation has built up engineering capabilities in a number of defense electronics fields. Recently, additional powerful capabilities have been added to this group, as described herein. Its engineering organization has expanded threefold, and now, as a full-fledged operating Division of DEP, it supplies RCA with a major technical capability within the West Coast industrial and military complex. (For overall organizational relationships within DEP, see p. 68, Vol. 5, No. 3, of the RCA ENGINEER.)

WEST COAST MISSILE AND SURFACE RADAR DIVISION

by **R. E. ROBERTSON, Mgr.**
Advanced Projects
West Coast Missile and Surface Radar Division
DEP, Van Nuys, Calif.

Expansion of RCA Defense Electronic Product activities within the West Coast industrial and military complex has been an inevitable part of RCA growth. The proximity to major airframe and missile manufacturers, to military installations and test ranges, to universities, and to large numbers of electronic suppliers and users was an important factor behind this expansion.

Recognition of these expanding requirements was reflected early in 1959, when ground was broken for an entirely new plant at Van Nuys, California. This 235,000-square-foot facility, located on acreage sufficient for additional expansion, now houses the West Coast Missile and Surface Radar Division. Construction progressed sufficiently in 1959 to allow establishment of the Engineering Department and supporting activities. Production, marketing, administrative, and cafeteria facilities were occupied in early 1960.

ENGINEERING GROWTH

Initially, the West Coast operation had built capabilities in the fields of light radar, navigation, missile controls, electronic countermeasures, simulators, radar altimeters and beacons. Now, its additional capabilities allow a grouping of interests as follows:

1) Electronic Countermeasures
2) Data-Processing Equipment
3) Electronic Displays
4) Missile Launch Control, Automatic Checkout and Ground Support Systems
5) Airborne Radar and Navigation Equipment

A major element in the new engineering responsibility of the West Coast Missile and Surface Radar Division is the Atlas missile checkout and launch control equipment program. It was transferred from the Moorestown Missile and Surface Radar Division. At the same time, a number of engineering personnel were transferred from RCA locations on the east coast—the nucleus of the Atlas project engineering organization and the nucleus of several design and development engineering groups whose interests and capabilities extend to data processing, digital computers, electronic displays, and associated products and techniques. The engineers who transferred, together with a larger number who have recently joined the West Coast staff through an effective recruiting program, have expanded the engineering organization more than threefold.

ENGINEERING FACILITIES

Initial action leading to the construction of the new facilities at Van Nuys was taken nearly five years ago. RCA purchased the 53-acre plot of ground in 1955, since it was apparent that expansion on the West Coast was inevitable. The Department of Defense decentralization in 1956 and the business recession in 1957 deferred action on the expansion. Approval to go ahead with the present construction was granted by the RCA Board of Directors early in 1959.

The present complex of buildings being constructed in Van Nuys under Phase I of the building program includes the eight separate buildings shown in Fig. 1. A Phase II construction program, scheduled for the future, includes the additional buildings shown.

Although the basic design of the engineering buildings was undertaken five years ago, the concept of flexibility was sound enough to permit its use basically unchanged. With the exception of permanent rooms

G. F. Breitwieser, Chief Engineer, and A. N. Curtiss, General Manager, West Coast Missile and Surface Radar Division, and the new Administration Building at the Van Nuys facility.

such as conference rooms, halls, utility rooms, etc., the buildings have complete flexibility in interior layout. The major avenue for foot traffic is located outside the buildings, with an overhang providing weather protection. Lighting and air conditioning are designed to permit interior realignment of equipment and personnel locations. Both the north and the south sides have continuous windows running the length of the building. As shown in Fig. 1, the Engineering Tower acts as a communications hub for the three Phase I engineering buildings and the fourth one planned for Phase II.

The three Engineering buildings accommodate approximately 400 engineers. The offices of the Division General Manager and his staff, marketing, and engineering employment are located in the Administration building. The Plant Operations building houses the financial personnel, purchasing, and manufacturing operations, with approximately 5000 square feet for the model shop. Two of the engineering buildings accommodate the design and development engineering staff and the laboratories. The third houses systems engineering, engineering projects, engineering administration, engineering services, and the auditorium.

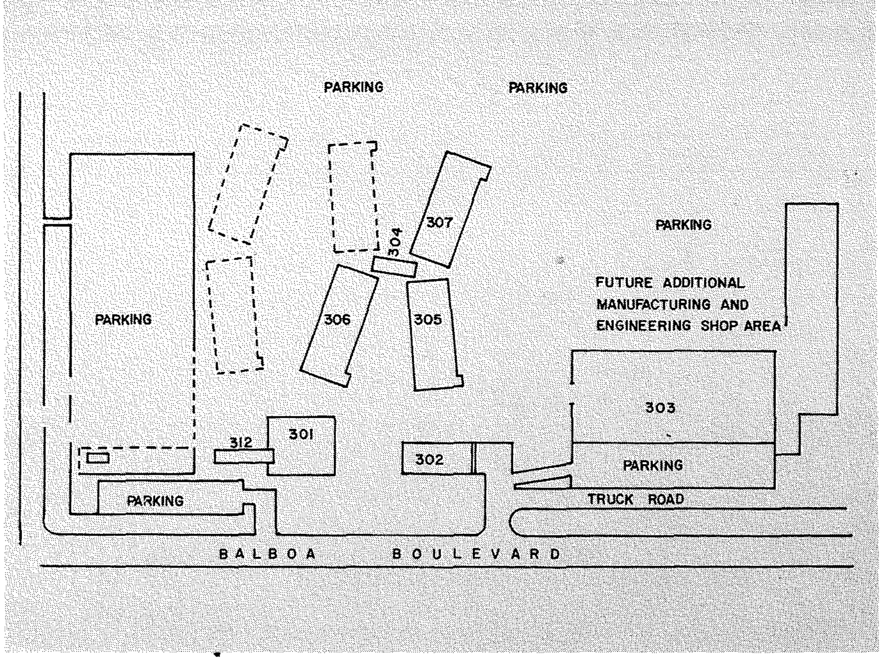


Fig. 1—Layout of new West Coast Missile and Surface Radar Division's Van Nuys, California facility, located at 8500 Balboa Blvd. Future development is shown in dashed lines. Legend: 301, Administration; 302, Cafeteria; 303, Manufacturing; 304, Tower; 305, 306, 307, Engineering; 312, Cooling Tower.

ENGINEERING ORGANIZATION

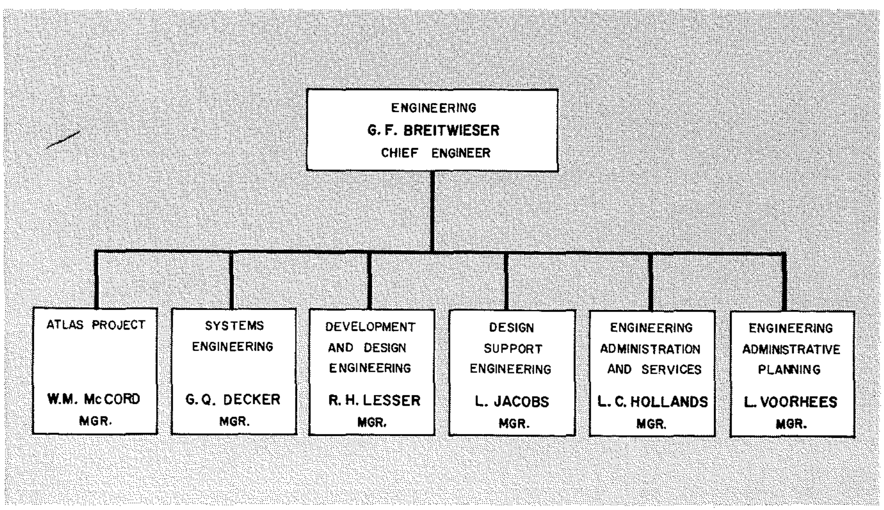
A realignment of the engineering organization has accompanied this growth. It now follows roughly the phases of the development process, beginning with systems requirements studies, proceeding through systems synthesis and analysis, through development and design, and culminating in a product design to satisfy the requirements. In all of its phases, the work program is integrated by appropriate systems engineering and project management. In the engineering of defense systems and subsystems, a foundation is provided by the contributions which come from past or present engineering programs. There is always the need for new and better components and techniques in the design of new and improved defense systems. Conversely, the introduction of these components and techniques allows the design of improved defense systems. It is the recognition of this inter-relationship and the need for proper integration of activities that provide the basis for the present engineering organization and its activities. (See Fig. 2).

Systems engineering performs a technical integration function through all phases of the development process, from initial conception to the final field evaluation of the engineered product. Systems engineering is a reiterative process in which each new phase of development in a component or subsystem feeds back into the overall system design, allowing trade-offs between the various components and subsystems in order to more nearly approach an optimum design. The combination of existing engineering strengths in component and techniques design, together with the growth in these and in systems engineering, has brought together a strong team for attacking and carrying out engineering responsibilities.

ENGINEERING PROGRAMS

By virtue of its size, the principal West Coast program is the equipment for the Atlas ICBM launch control and checkout. It includes design and development work for particular system elements, project engineering for items which are produced by subcontractors or other RCA plants, and field operations in the installation

Fig. 2—Basic engineering organization.



and initial operation of equipment at Air Force bases, such as Vandenberg and Warren. The equipment presently in the production stage is for fixed installations. Currently, the principal design effort is concentrated on the logical extension to mobile equipment, together with the vehicles which will house it. These combined programs will be in engineering and production through 1960 and beyond.

Considerable attention is being given to the product potential of other missile and satellite checkout and ground-support system designs. There are a number of military programs in progress with requirements for this type of equipment. Included are Dynasoar, Minuteman, Supersonic Low Altitude Missile, and a variety of satellites.

In electronic countermeasures (ECM) equipment, the engineering activity has extended to a number of different contracts. These include study contracts for automatic jamming, for detection countermeasures, and, most recently, for the use of ECM on a satellite in orbit. As a result of this and earlier work in ECM techniques, the AN/ULQ-5 Countermeasures Set and The AN/ULQ-6 ECM Repeater equipments are now being developed for the Navy. These are scheduled to reach the production phase in 1960. In addition, several RCA General Engineering and Development projects are in progress for advancing the state-of-the-art in ECM techniques and systems.

In the area of military data-processing and electronic-display equipment, there have been a number of separate design efforts which were transferred from the Moorestown Missile and Surface Radar Division. Included is data processing equipment for: BMEWS, the Automatic Ground-to-Air Communications Systems (AGACS), the Atlantic Missile Range and Pine Tree Digital Data Processing, AN/EPS-16 Digital Data Read-out, and DAMP Ship Data Converter Print-out and Decimal Display. Extensions of these capabilities in data processing and displays have placed West Coast Missile and Surface Radar Division in the center of consideration for data-processing and display equipment for the support of missile ranges, future combat operations centers, and early-warning systems.

Design activities have been extended in providing simulation equipment for training military personnel in decision-making functions. Presently, the design of the AN/GPS-T2A radar and ECM simulator-trainer is being modernized for a third round of service procurement. Recent engineering activities have included production support of maintenance supplies for these initial equipments, a modification design to adapt this simulator to the AN/FPS-3 radar, and the new contract to modernize the design. Study programs and proposal efforts in progress are examining the use of simulation equipment to provide a system model for the study of overall missile systems and to provide means for training and exercising personnel in combat operation centers.

A contracted engineering study is making a basic investigation of propagation through ionized media, as a part of the effort to solve the radar-antenna design problem for missiles such as Dynasoar. Its experimental phases are being carried out in the new hypersonic wind tunnel at the University of Southern California. This investigation is in support of the lightweight-radar work, in which this Division has been well known for the AN/APS-42 and the RCA AVQ-10 Weather Radar. The latter has provided United Airlines with the familiar nickname of the "Radar Line."

In the airborne electronic component product area, the Thor missile autopilot has been receiving engineering support for production and product improvement programs. A small, transistorized version was demonstrated recently to the Thor project engineers. Other products in production which require engineering support include AN/APN-70 Loran Receivers, CV-402 Waveform Converters for the AN/APS-42 Radar, MX-1646 Communications Adapters, and r-f test units for BMEWS. Extensions of this product area include proposals for low altitude radar altimeters, coherent radar beacons, and missile autopilots. Several of these have been projected as equipment which will use RCA micromodule techniques for compact, lightweight designs.

Thus, in these new Van Nuys facilities, a wide variety of engineering experience and technical background is contributing to a broad but related group of product designs in the West Coast Missile and Surface Radar Division. RCA engineering is certain to play an even more important future role in the swift industrial expansion of the West Coast. The establishment of this expanded organization and facilities in the San Fernando Valley has been a major step in keeping pace with this growth.

R. E. ROBERTSON received the BS and MS degrees in Electrical Engineering from the Massachusetts Institute of Technology, and the LLB degree from George Washington University. He extended his technical and management training in General Electric's Advanced Engineering and Professional Business Management programs. His nineteen years of industrial experience include both engineering design and management contributions. His early design experience was on airborne radar fire control at General Electric, and missile guidance at Bell Aircraft and the National Bureau of Standards. Returning to General Electric, he was Supervisor of Radio Guidance and Computer Engineering for the Hermes Missile Program and Manager of Instrumentation Engineering for the ICBM and IRBM nose cone programs. He was also Assistant Project Manager for the MA-1 Weapon System supplied by Hughes Aircraft for the F-106 Interceptor. Sponsored by Booz, Allen and Hamilton Management Consultants, he was Chief Engineer of the B & H Instrument Company, makers of Jetcals and Ta'pots. He joined RCA in 1958, and is now responsible for project management of systems engineering and preliminary design efforts during the study, proposal, and early contract phases of new engineering programs. He is a member of Eta Kappa Nu, Delta Theta Phi, and AIEE, a Senior Member of the IRE and was an officer of the Philadelphia Section. He is a registered professional engineer, is admitted to the bar of several United States Courts (including the U. S. Court of Customs and Patent Appeals), and is a licensed pilot.

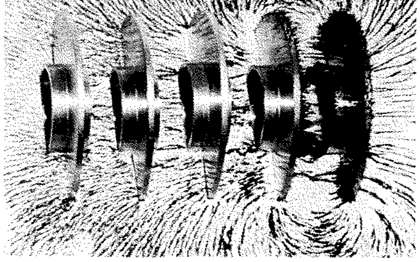


Fig. 1—Iron filing pattern of a stack model.

A NOVEL TECHNIQUE FOR ANALYZING TWT MAGNETIC FOCUSING

by **Dr. M. J. SCHINDLER**
Microwave Engineering
Electron Tube Division
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ORIGINALLY, traveling-wave tubes were placed inside solenoids, and the uniform magnetic field of the solenoid focused the electron beam; however, their resulting bulk and weight made them very unattractive for many applications. Now, instead of a tube-solenoid power-source package weighing about a hundred pounds, tubes using *periodic permanent-magnet focusing* weigh only one to a few pounds, and some smaller tubes even less. Periodic focusing is possible because the magnetic field appears in the second power in the focusing formula. As a result, the direction of the field is of no interest, and a series of short fields having alternating directions have essentially the same effect as one long, uniform field. Such a periodic field can be produced by a number of pole pieces, as in Fig. 1, to which alternating magnetic charges are applied.

The periodic field is achieved by permanent-magnet rings placed between metal disks, or shims, so that neighboring magnets repel each other. In Fig. 1, half of one ring magnet has been placed underneath the paper on which the iron-filing pattern is displayed, between the first and second shims from the right. This arrangement was used to investigate the influence of one magnet upon the neighboring magnetic cells. Each cell acts as a magnetic lens focusing the electron beam very much as a convex optical lens focuses a light beam. Generally, about 40 cells are needed to keep the beam in focus throughout the length of the helix. Because of the high intensity of the beam, the repelling forces between the electrons spread the beam rather quickly. This action would find its optical analogy in a concave, or negative, lens.

HELIX INTERCEPTION

An electron beam in a periodically focused traveling-wave tube is thus like a light beam passing through 80 lenses. Consequently, proper alignment and focal length of the magnetic lenses are required to maintain the beam straight and of uniform diameter between the electron gun and the collector.

In the development of a new tube, therefore, focusing poses a problem. Often, when first inserted into its magnet stack, a tube either exhibits poor focusing or does not draw a beam at all; i.e., not enough of the electrons reach the collector, and full voltages cannot be applied without helix damage. There are many possible causes for such a malfunction, each of which disturbs the beam in a different manner, distributing the interception along the helix in a characteristic pattern. However, it is cumbersome to exclude one possible malfunction after another, since the *total* interception may be similar in several cases.

VISUAL OBSERVATION OF INTERCEPTION

A very simple technique has been developed by the Microwave Engineering Chemical and Physical Laboratory to make the beam-interception pattern visible. A thin coat of a phosphor is applied to the helix, and striking electrons immediately become visible. These phosphors can be outgassed easily and do not interfere with the operation of the tube.

When the tube is made of glass, observation of the fluorescing helix is no problem if the bulb is accessible, as in the case of electrostatically focused tubes. For observation inside a solid, opaque magnet stack, a sleeve of photographic paper, for instance, can be inserted between bulb and stack, and exposed. Direct visibility is the preferable approach, however, and slits are ground into the ring magnets. The bulb is then viewed through the gaps between the pole pieces.

In Fig. 2 (taken at a demonstration of this method at the 1960 IRE Convention in New York) this technique has been applied. The tube exhibits *sub-periodic scalloping*, a rather regular fluctuation of the light intensity along the helix (arrows in Fig. 2), caused by improper beam-entry conditions; for instance, by a converging or diverging beam instead of the required parallel beam. In Fig. 3, a ring magnet has been placed on top of the capsule, approximately in the middle of the stack. The pattern in the right half of the stack is still the same as in the case of Fig. 2. The left half, however, shows an altogether different pattern. Because of the transverse field caused by the external magnet, the beam is deflected and intercepted by the helix. This effect causes that section of the tube to be brightly illuminated.

Such a tube has been used for studies of beam focusing as well as of secondary emission. It is interesting that secondary electrons, obtained by a reduction of the collector voltage, travel almost all the way back to the beam-entry region, where they finally cause the coated helix to fluoresce. Functional tests performed on the phosphor-treated tube revealed perfect high-frequency performance.

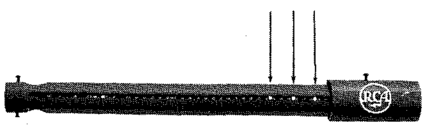
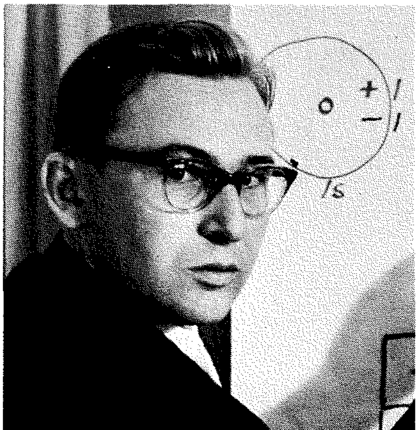


Fig. 2—Effect of improper beam-entry conditions, indicated by fluctuation of light intensity along helix (arrows).

Fig. 3—Effect of a ring magnet placed at middle. Right half: light fluctuates as in Fig. 2; left half: bright helix illumination indicates proper beam interception.



DR. M. J. SCHINDLER received his MS in Electronics in 1951 from the Institute of Technology of Vienna, Austria. He remained there in the Department of Metal Physics until 1954, under sponsorship of the Austrian Ministry of Energy, and in 1953, received his Doctor's Degree. From 1954 to 1957, he was with the Tungsram-Watt tube plant in Vienna, first as a development engineer and later as Head of Quality Control, working on aspects of receiving tube manufacture. In 1957-58 he was at the Wright Air Development Center, Dayton, Ohio, investigating the a-c magnetization process. In September 1958, he joined the Chemical and Physical Laboratory of the RCA Microwave Operation at Harrison, where he has worked on a number of physical problems related to the design of traveling-wave tubes, as well as thin magnetic films and a variety of technological investigations. He is chairman of the Microwave Engineering Education Committee.

GLASS IN RECEIVING TUBES

by **J. GALLUP**
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GLASS IS AN ancient material. It was formed naturally in the core of the earth as obsidian or volcanic glass long before man evolved, and made artificially by the Egyptians more than 4000 years ago. These first examples of glass were used by the people of the early eras as tools, weapon-points, and for adornment.

Structurally, glass is an amorphous material usually composed of a mixture of oxides with silicon dioxide. It is often transparent or translucent, and possesses the properties of an undercooled liquid. Thus, it has no definite crystal structure, but is characterized by a random network of silica tetrahedra of infinite extent. It has no melting point, but rather a long softening range. It conducts electricity by the movement of ions, just as in the case of other more-normal liquids. It is very strong in compression, but rather weak in tension—characteristic of the low cohesive strength which distinguishes liquids.

Chemically, the majority of stable glasses are a balance of acidic and basic oxides. Most commercial glasses are usually composed of 60 percent or more by weight of silicon dioxide, with smaller additions of the network modifiers. These modifiers — the alkaline earths, the alkalies, and lead oxide—are added to obtain the melting range, the thermal expansion, and the other properties desired.

VALUABLE PROPERTIES

Glass is admirably suited to its major role as the envelope and electrical insulation between lead wires in electron receiving tubes for several reasons.

First, its lack of crystal structure ensures that it will be impervious to the passage of most gases (very high silica glasses are slightly pervious to helium) and thus will maintain the vacuum in an electron tube indefinitely. Second, because glass is a solution of oxides rather than a chemical compound, its composition can be varied linearly to obtain a material having a thermal expansion that will match almost exactly the expansion of the lead wires to which it must be sealed. This match prevents any rupture caused by differential expansion when the tube is heated and cooled in subsequent use. Third, because glass is a material with a long softening range (i.e., a large variation of viscosity over a long range of temperature) it can be worked on automatic machinery at almost any rate. Thus, a machine running at a production rate of 400 units per hour must be run with the glass much cooler than the glass for one running at 1200 units per hour for each to turn out a satisfactory product. Fourth, because glass conducts electricity by the actual movement of ions through the glass, and because the ions have very limited mobility at room temperatures, glasses have high electrical resistance at normal tube operating temperatures. Furthermore, small ions with high mobility (such as sodium) can be eliminated to produce glasses of very high resistivities for special applications, such as in stems of high-voltage rectifiers.

Glasses used in receiving tubes are normally those termed *soft* glasses; i.e., they are lower melting (1300 to 1400°C) or are less refractory than the *hard* glasses (melting range 1400 to 1600°C). The soft glasses normally are worked in the range below 1000°C and the hard glasses above 1000°C. Also, the soft glasses have coefficients of thermal expansion of the order of 90×10^{-7} inches per inch per degree centigrade, which adapts them to match platinum, chrome-iron, and dumet lead wires. The *hard* glasses have thermal expansions below 50×10^{-7} inches per inch per degree centigrade and are adapted to fit metals like tungsten, molybdenum, and Kovar.

ANNEALING AND TEMPERING OF GLASS

Because glass is weak in tension, it is frequently desirable to anneal such glass articles as flat-press stems to remove dangerous tensions. Table I lists the annealing temperature for each glass. Heating the glass at this temperature for 15 minutes will remove 90 percent of the strain. At the strain point, a similar strain removal will require four hours heating.

JOHN GALLUP received the BS in Ceramic Engineering from Alfred University and the MS in Ceramics from Rutgers University. He has been a ceramic engineer and glass technologist in the Chemical and Physical Laboratory at Harrison since 1932, and is the senior glass technologist in the Electron Tube Division. He is a member of the American Ceramic Society, The National Institute of Ceramic Engineers, the American Optical Society, and the Society of Glass Technology. He is the author of a number of scientific papers and holds a number of U.S. and foreign patents. Mr. Gallup is a Licensed Professional Engineer in the State of New Jersey.

The need for annealing can be determined by measurement of the strain type and intensity in a polarimeter utilizing crossed light polarizers. Fig. 1 shows the interference figure produced by polarized light on a strained stem. An unstrained stem produces no effect on polarized light and is invisible in a polarimeter.

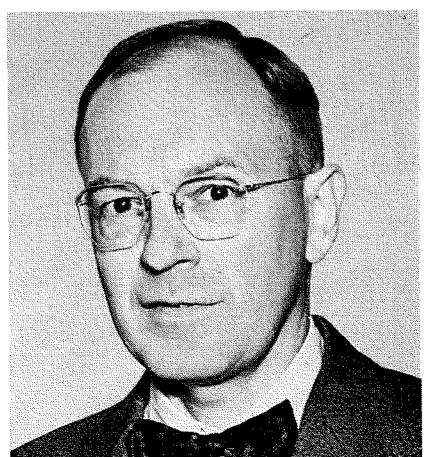
The strain in glass bulbs is measured in a similar manner, except that the curvature of the bulb wall requires that the tube be immersed in a liquid having the same index of refraction as the glass for accurate observation.

Although glass in tension is weaker than unstressed glass, glass in compression is stronger than unstressed glass. These properties lead to the use of quenching methods to produce thermally toughened glass of superior strength, such as that used in auto windows and steam gauges. The glass used in receiving tubes having button stems is compressed and strengthened by blowing jets of air against the tops of stems as they start to cool on the stem machine and against the bottom of tubes as they start to cool on the Sealex machine.

STRENGTH TESTS

The efficacy of the strain induction treatments is measured by thermally shocking the finished tubes at the same time that the lead wires are stressed mechanically (spread 5° by the insertion of a metal cone between them). Fig. 2 shows a number of tubes in place on the cones, ready to be inserted into a container of boiling water for 10 seconds, a step followed by insertion into a container of room-temperature water. If the strain distribution has been properly controlled, none of the tubes will crack. Strain-free and improperly strained tubes will not stand as much shock as those with the proper compression strain.

Because the tips of miniature tubes are exposed to external shocks, they must be made stronger than those which are protected within a bakelite base. A test device designed in the laboratory to measure the side load which such miniature tips will stand without failure



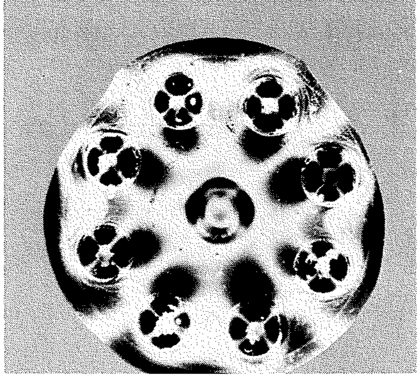


Fig. 1—Interference figure of one-inch button stem in the polarimeter.

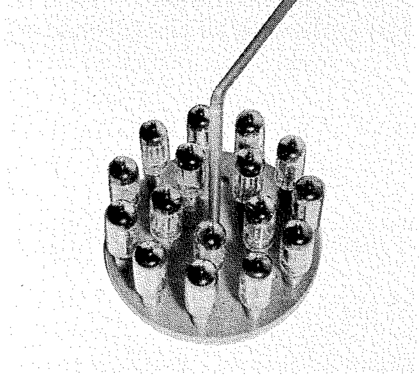


Fig. 2—Thermal-shock "B" test device for miniature tubes.

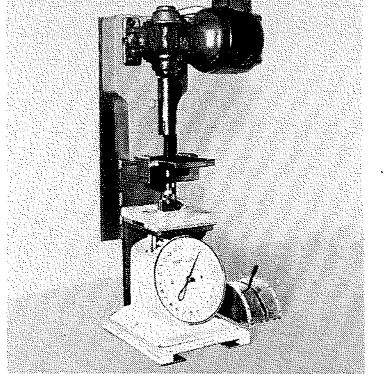


Fig. 3—Tip-strength test device for miniature tubes.

is shown in Fig. 3. Good tips support a load in excess of 20 pounds. This machine can either measure the strength of exhaust tubing or that of the finished tips. Information gained from its use has tripled the average strength of miniature tips in recent years.

Recently, the Harrison Chemical and Physical Laboratory has made a study of the crushing pressures which glass receiving tubes can stand without imploding. An autoclave pressured from tanks of commercial compressed nitrogen was used for the measurements. The largest receiving tubes, such as the 6BG6G (volume 130 cubic centimeters) imploded in the range from 450 to 700 psi, while smaller GT tubes (volume 40 cubic centimeters) failed in the range from 450 to 1050 psi. Miniature tubes (volume 7 to 16 cubic centimeters) start to fail in the range from 1500 to 2200 psi. Subminiature tubes having a volume of only 2 cubic centimeters could not be crushed with 2260 psi.

HYDROGEN TREATMENT OF LEAD GLASS

With the advent of higher-voltage rectifiers (such as the 1B3-GT) it has been necessary to protect the inner glass bulb wall from the disruptive effects of high-voltage bombardment. Experiments in the laboratory showed that hydrogen treatment of lead bulb glass imparts a protective layer to the bulb which shields it against the disruptive effects of the bombardment. All higher-voltage rectifier bulbs are now treated in this manner.

SPECIAL GLASSES

Low-melting solder glasses initially made in the Harrison laboratory have been applied to some special uses in the receiving-tube field. These glasses are essentially lead-borates and lead-borosilicates having working temperatures below a red heat (550°C and below). Two applications include marking a tube envelope with an ink made from such a low-melting glass, and sealing of transducer tubes.

Glasses that soften at higher temperatures than the lead borate solder glasses are sometimes used as solders. Recently a Kovar sealing glass (code #7052) has been used to cement fine grid wires to the grid frame side-rods.

As higher tube operating temperatures have become common, the increased damage from electrolysis in rectifier tube stems has necessitated the use of glasses of higher electrical resistivity. Table I shows that the newest high-resistance glass (code #8161) has 75 times the resistivity of the normal (code 0120) stem glass at 250°C. This increased resistance has made it possible to produce hot tubes which will operate for ten times as long as the usual tube life without loss of vacuum due to glass decomposition.

A LOOK AHEAD

Some of the tantalizing glass problems confronting the glass technologist for future achievement are: 1) a cheap infrared-transmitting glass—its attainment would materially lower operating temperatures of hot tubes; 2) a flexible glass—such a glass would obviously solve breakage troubles; 3) a glass with thermal conductivities approaching those of metals—such a glass would not develop strains from thermal gradients and would have a high resistance to thermal shock; 4) a glass having a low melting range and a low coefficient of expansion—such a glass could be sealed to fused quartz and would have the advantages of fused quartz without its excessive cost and high melting range; and 5) a glass which would weld or solder to metal solders. The liquid nature of glass, with its almost limitless variations in miscible-solution compositions, and the increased pace of glass research in recent years promise much in future progress.

TABLE I—PHYSICAL PROPERTIES OF SOME REPRESENTATIVE GLASSES

Code No.*	Lab. No.	Use	Density (g/cc)	Coeff. Exp. (10^{-7} in/in/°C)	Working Point (°C)	Soft. Point (°C)	Anneal Point (°C)	Strain Point (°C)	Refra. Index	Specific Resistance (10^6 Ohm-cm) @250°C	@350°C
Soft:											
0010	G-1	Lead exhaust tubing	2.85	91	970	626	428	397	1.542	1,190	13.3
0080	G-8	Lime bulb	2.47	92	1000	696	510	475	1.512	2.27	0.148
0120	G-12	Lead stem	3.05	89	975	630	433	400	1.557	11,900	95.5
8160	G814KW	High resis. stem	2.98	91	975	627	433	399	1.553	36,300	237
8161	814UD	Very high resis. stem	4.02	89	862	601	434	403	—	891,300	7080
1991		Iron sealing	3.18	127	—	539	393	366	—	—	21.6
Hard:											
7040	G705BA	Kovar sealing	2.24	47.5	—	702	484	450	1.480	5,310	88.1
7052	G705FN	Weather resistant	2.29	46	1115	708	480	442	1.484	501	20
7070	G707DG	Low-loss tungsten sealing	2.13	32	1100	—	490	455	1.469	150,000	1300
7720	G702P	Nonex	2.35	36	1110	755	518	484	1.489	653	15.8
7740	G726MX	Chemical Pyrex	2.23	32.5	1220	820	553	510	1.474	141	4.73
7900		96% Silica-Vycor	2.18	8	—	1500	910	820	1.458	5,012	100

*The code and laboratory numbers are those of the Corning Glass Works, who furnished the above data.

TERMINATIONS IN THE MICROMODULE

by **W. H. Liederbach**
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Semiconductor and Materials Division
Somerville, New Jersey

Within Micromodule Engineering at Somerville, a small group called **Terminations** is responsible for the metalizing used to bring the micromodule into electrical and mechanical continuity. Some of their problems stem from the extremely close spacings within the micromodule. The two described here—silver migration and metallic-whisker growth—have required extensive investigation.

One of the requirements of the micromodule is reliable performance under exposure to severe environmental conditions. Early in the development program,* it became apparent that silver migration and metallic-whisker growth might have extremely detrimental effects upon performance. In recent months, concentrated effort has revealed some highly interesting aspects of both problems and has led to the understanding of those factors necessary for their control.

SILVER MIGRATION

The micromodule was designed to utilize materials and techniques available in the current state of the art. However, the drastic size reduction of the micromodule as compared with previous modular designs created unforeseen problems. Fig. 1 shows the difference in size between an early "Tinkertoy" module and wafer, and the RCA micromodule and its wafer. An area for immediate and continued investigation was the application of fired-on conductive silver paints to ceramic materials for electrodes, terminals, and printed circuits. Similar techniques were used in the proximity fuse of World War II and in the Tinkertoy module.

Silver is known to migrate, or move as a positive ion, through a water or other ion-mobile film when it is exposed to the influence of either an a-c or d-c potential. It is deposited as metallic silver at the cathode, and grows in tree-like fashion until a low-resistance path, or short circuit, develops. Because electrical potentials always exist between terminals within a module, silver migration can be controlled only through elimination or control of the water or ion-mobile film.

The central wafers of the micromodule are 0.310 inch square, and the end wafers are 0.350 inch square. Although the central wafers are encapsulated in the final assembly step, the end wafers are not coated because their metalized terminals provide the electrical contacts for subsequent module joining. Consequently, the end wafers are unprotected from moisture and are very susceptible to migration. This problem is exaggerated by the extremely close spacing between metalized terminals in the micromodule (0.015 to 0.020 inch).

Voltage and Humidity Tests

For evaluation of the various factors involved in silver migration, humidity cells were constructed so that individual wafers could be subjected to controlled voltage and humidity (Fig. 2).

Two adjacent notches of micromodule alumina wafers were metalized with silver so that a 0.015- to 0.020-inch spacing was maintained. Other factors, such as encapsulation, cleaning, and solder coverage, were then varied on individual wafers. By means of such tests, it was found that soluble salts, or hygroscopic materials, left on the surface of the metalized area can cause the formation of a conductive water film even after encapsulation. In a highly humid atmosphere, water vapor penetrates the organic coating to condense on or dissolve the hygroscopic material below it. This film of moisture is difficult to remove, even at high temperatures, and recondenses when the micromodule is cooled. Cleaning of the metalized ceramic decreases its susceptibility to silver migration.[1] Complete solder coverage of the metalized area also helps to delay migration.

Cleaning Techniques

A cleaning technique suitable for production and control was also evaluated. In this technique, the metalized wafers are inserted for one minute in an ultrasonic deionized water bath containing 0.5 percent detergent, rinsed in a deionized water bath consisting of three stages arranged for counter-current cascade rinsing, treated for one minute in an ultrasonic denatured-alcohol bath, and then rinsed in alcohol and oven-dried for one hour at 85°C.

The effectiveness of the cleaning procedure was determined by tests on unencapsulated silver-metalized wafers in the humidity-voltage cells under conditions of 100-percent relative humidity and a d-c voltage of 50 volts. The wafers were considered to fail if visible, continuous lines of migration residue appeared between terminals. Resistivities across such residue paths have been found to be as low as 24,000 ohms. Fig. 3 shows a wafer contaminated with fingerprints which failed in four hours. A similar wafer, cleaned by the procedure described above after it was metalized and test leads were attached, did not fail until after 346 hours of test time; this wafer is shown in Fig. 4. (The migration residue is difficult to see in this photograph because it is on the corner of the wafer between the test terminals.)

Complete solder coverage of the silver-metalized terminals was also evaluated. A typical test piece (Fig. 5) processed with solder coverage and subsequent ultrasonic cleaning had an extended life of 576 hours in the humidity-voltage cell.

Resin Protection

Silver-metalized test wafers encapsulated with a 0.020-inch thickness of selected resins have been exposed to 4550 hours of voltage-and-humidity cell conditions. Resistivity measurements were taken throughout the test period with a megohm bridge, which recorded both a *wet* and a *dry* reading. The wet measurements were taken across the terminals while the encapsulated test wafer was in the cell. The dry measurements were taken across the same terminals after the piece was removed from the cell and dried for 48 hours. The lowest wet reading was 11,000 ohms, and the lowest dry reading was 50 megohms. Initial readings on all samples were infinity. Highly erratic readings, which can be attributed to corrosion of the lead wires, occurred at the end of the test period. Wafers hav-

Fig. 1—RCA micromodule (at right) compared to an early "Tinkertoy" module.

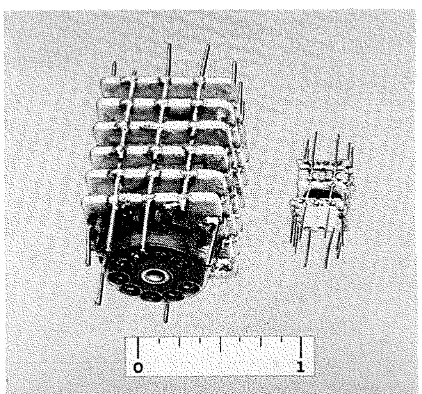
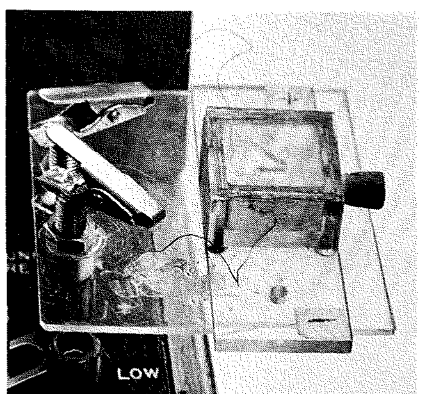


Fig. 2—Individual humidity test cell being measured on a resistance bridge.



*Sponsored by the U.S. Army Signal Corps.

ing gold-plated and pure-gold wire leads to eliminate wire corrosion are currently being tested. After the wafers are removed from the voltage-humidity cells, they are examined by means of nondestructive techniques for visual observation of the electrode areas. X-ray studies appear most promising for observation through the black, opaque encapsulants.

Substitute Metals

At the present time, a substitute metalizing material, *Gold-Platinum No. 7553*, developed in conjunction with and available from the DuPont Company, has been on test for 2700 hours with no migration evidence (Fig. 6).

At this time, DuPont *Gold-Platinum No. 7553* is being used on the unprotected end wafers of the module, and silver within the encapsulated portion. The change to a substitute metal within the module depends on current work concerning encapsulation protection, ceramic capacitor electrodes, and resistor terminals. An arbitrary change from silver would be unwise. A poorly chosen substitute material could adversely influence capacitance, power factor, voltage breakdown, temperature coefficient, etc.

METALLIC WHISKER GROWTH

Another of the important material considerations which can affect module reliability is metallic-whisker growth from tin or tin-rich solders. Reference information[2] indicates that the low-resistance metal whiskers (300 ohms, ⅜-inch long) which grow from tin, zinc, or cadmium-rich surfaces result in shorts or electrical disturbances within a circuit. The whiskers grow as single or twinned crystals from a metal-surface imperfection (crystal dislocation) under conditions of temperature and pressure. Voltage or magnetic stresses apparently are not involved. Pressure need not be any more than the inherent lack of equilibrium present in most films caused by the mode of film formation or by temperature differentials.

Metallic-whisker growth was first recognized as a factor in the failure of communication equipment in 1946. It is very probable that this phenomena has always been an intermittent source of trouble, but it is difficult to pinpoint because whiskers burn up when 10 to 12 volts are applied, and normal operation is restored.

Temperatures also affect whisker growth—even gold grows whiskers at 400 to 500°C. At room temperature or slightly above, however, only tin, zinc, and cadmium are particularly troublesome. Resinous or wax coatings of less than 1/16 inch do not inhibit the growth.

Evaluation Tests

The present module design comprises the following factors that could be conducive to whisker growth: close spacing of metal elements (0.005 to 0.010 inch); conventional tin-rich solders; pressure caused by encapsulation shrinkage; and low voltage (under 10 to 12 volts).

A two-inch-diameter hardened-steel ring was used to evaluate materials, substrates, and pressures in relation to whisker growth.[3] The test specimens, in this case steel shim stock 10 mils thick having appropriate electroplated or hot-dipped coatings, are placed between the cross-pieces and compressed. The surface of the specimens and rings are polished to aid test observation. This accelerated ring test, under a pressure of 5000 psi, produced tin whiskers, shown in Fig. 7, which were 8 to 10 mils long in two to three days.

Some Indicated Solutions

Electroplated tin-lead (60-40) steel shim stock has been in the same test configuration for more than three months with no evidence of whisker growth. Similarly, solder-dipped (60 Sn, 37 Pb, 3 Ag) silver-metalized alumina wafers show no whisker growth after more than three months. As a result of studies to date, 60-40 tin-lead-coated copper riser wires have been substituted for tin-coated copper wire for module assembly.

Bell Telephone Laboratories have reported the growth of whiskers from tin-lead solders used in the construction of a quartz crystal oscillator. A quartz crystal in microelement form using tin-lead-silver solder (60-37-3) has been breadboarded in an oscillator circuit operating at 45.1 megacycles; in one test, continuous oscillation produced no malfunction after 2000 hours.

ACKNOWLEDGMENT

Major contributions to this program in the areas of silver migration and whisker studies should be credited to Dr. Leo Pessel at Camden, and Dr. Arthur Roswell at Somerville. [Editor's Note: Dr. Pessel wrote on *Whiskers on "Gangs"—A Metallurgical Mystery* in Vol. 1, No. 2 of the RCA ENGINEER.]

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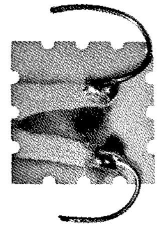


Fig. 3—Silver-metalized wafer contaminated with fingerprints that failed in 4 hours under 50 volts d-c and 100-percent relative humidity.

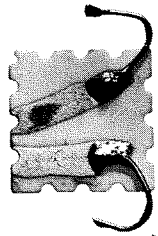


Fig. 4 — Ultrasonically cleaned, silver-metalized wafer that withstood 50 volts d-c.

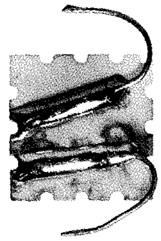


Fig. 5—Wafer in which migration was retarded by complete solder coverage of silver-metalized area. It withstood 50 volts d-c and 100-percent relative humidity for 576 hours.

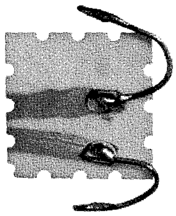
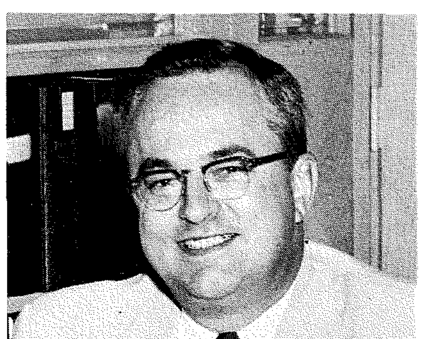


Fig. 6 — Gold-Platinum-metalized wafer showing no evidence of migration after exposure to 50 volts d-c and 100-percent relative humidity for 2700 hours.

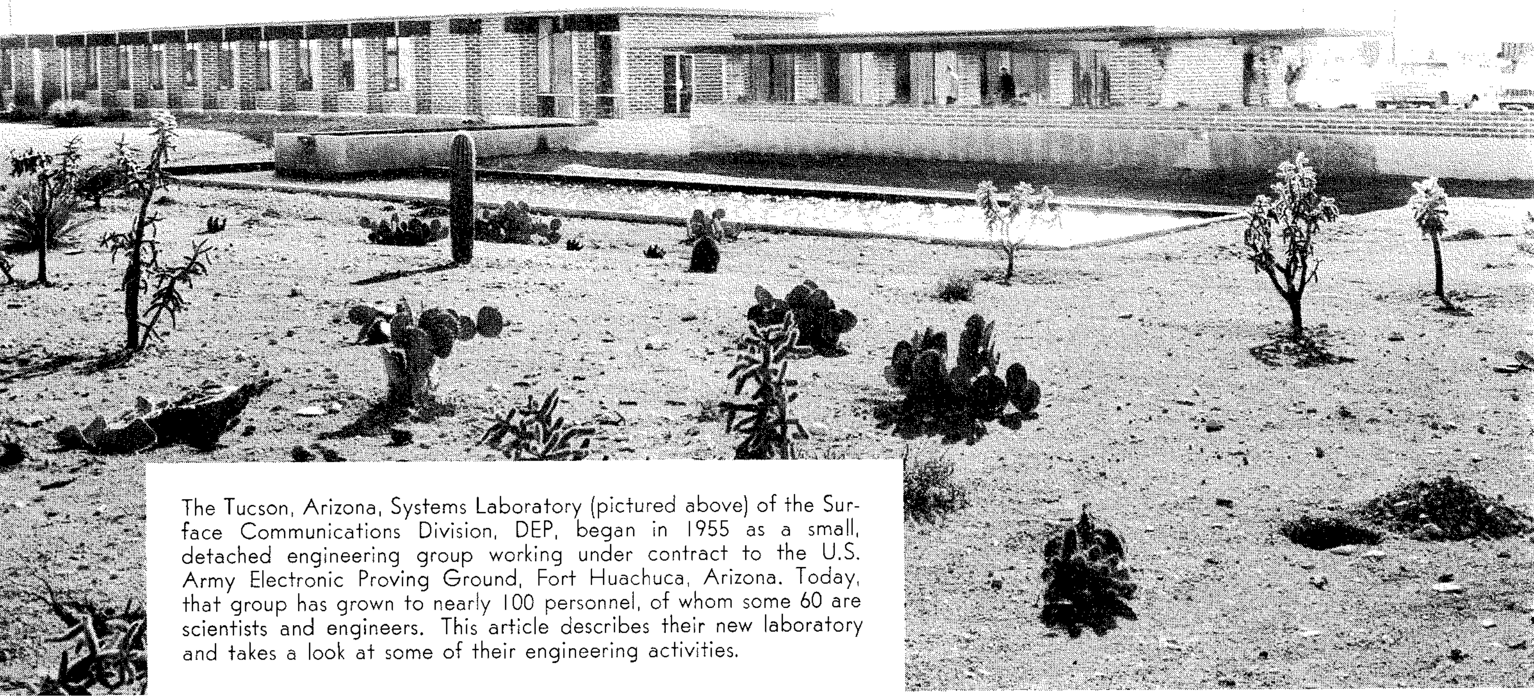
Fig. 7—Tin whiskers growing from an electro-plated tin film (200X).

WILLIAM H. LIEDERBACH received the B.S. degree in ceramic engineering in 1948 from Iowa State College. From 1948 to 1956, he was employed by the DuPont Company, concerned with precious-metal compositions for three years, and then for four additional years as a sales engineer. From 1956 to 1958, he was employed by the Centralab Division of the Globe-Union Company, where he headed a development group in research on the metalizing of alumina ceramics for hermetic-seal applications in the fields of solders and brazed assemblies. He joined the Semiconductor and Materials Division in December, 1958, and is presently Leader of the Terminations group. Mr. Liederbach is active in the National Institute of Ceramic Engineers and with ASTM metal-ceramic committee work. He is a member of the American Ceramic Society, Keramos, and Tau Beta Pi.



CACTUS AND COMMUNICATIONS

by **A. M. CREIGHTON, Mgr.**
Surface Communications Systems Laboratory,
DEP, Tucson, Arizona



The Tucson, Arizona, Systems Laboratory (pictured above) of the Surface Communications Division, DEP, began in 1955 as a small, detached engineering group working under contract to the U.S. Army Electronic Proving Ground, Fort Huachuca, Arizona. Today, that group has grown to nearly 100 personnel, of whom some 60 are scientists and engineers. This article describes their new laboratory and takes a look at some of their engineering activities.

SURROUNDED BY DESERT vegetation and ringed by 9,000-foot mountain peaks rising abruptly from the valley floor is the Tucson Systems Laboratory — the newest engineering facility of the Surface Communications Division, DEP.

This new ranch-style building of adobe brick is a modern expression of traditional southwestern architecture and commands a panoramic view of the mountains to the north. It provides approximately 13,000 square feet, divided into a systems lab, design and development lab, model shop, drafting, library, cafeteria, and offices. To provide for future growth, it is located on 100 acres, with access both to the highway and the railroad.

WHY ARIZONA

Students of history and students of TV westerns will identify Fort Huachuca as a cavalry post near Tombstone, Arizona, to protect the early settlers from marauding Apaches. Today, Fort Huachuca is a busy Army Electronic Proving Ground, operated by the Signal Corps; and neighboring communities, such as Tombstone, now list electronic engineers and scientists in their census.

In recent years, SurfCom-Tucson has assisted the Proving Ground in carrying out its mission—to develop and prove new electronic concepts, and to test and prove new electronic equipment for military use. This has involved a complete determination of communications requirements for present and future field armies. Based on these requirements, Army area communication systems have been designed and evaluated by a combination of analytic procedures and field tests.

ENGINEERING METHODS

Two basic analytic approaches have been used in designing and developing complex communication systems: simulated tests and mathematical models, each having particular areas of utility. Simulated tests are especially suited for the study of systems of large scope in which the physical entities in the test system have a one-to-one correspondence or a statistical relation with a computer number or word in the simulated test program. Mathematical models are, initially, more applicable to subgroups of the systems, and as understanding develops, the models are extended to larger groups of the systems.

In addition to the analytic approaches, equipment and personnel evaluations are made. Equipment evaluations can determine applications within existing systems and provide guidance for future systems. Personnel evaluations involve equipment operation and maintenance, and depend on careful human-engineering considerations.

At present, the engineering managers at the Tucson Systems Laboratory are:

A. M. Creighton, Mgr., Surface Communications, Systems Laboratory

D. R. Green, Mgr., Systems Projects

R. J. Meyer, Mgr., Systems Engineering

B. A. Trevor, Administrator, Technical Projects Coordination

L. J. Flodman, Mgr., Design and Development

CURRENT ACCOMPLISHMENTS

Application of these systems-engineering and operations-research approaches has resulted in major contributions to Signal Corps communications and to the scientific study of the many physical situations in which military communications systems must function.

Tactical Communications

Recommendations have been presented to the Signal Corps providing complete communication systems for tactical field armies operating during the present-to-1962 and the 1962-1965 time frames. Scientific contributions in the realm of queuing systems and congestion problems have been such original ideas as the two-way traffic models, the concepts of saturation and effective switching rates, and the use of both queuing theory and simulation methods for analytical solutions.

Field tests are designed and executed to evaluate the results of theoretical studies. These are usually conducted at Fort Huachuca. In the spring and summer of 1959, *Operation Sandburr* was run as a test of the ability of an Army area signal center to operate under field conditions and provide service to meet communication requirements. This involved the deployment and realistic tactical movement of a large number of signal troops and equipments. The entire operation was monitored and data collected by RCA observers.

Support Equipment

Design and development activities at the SurfCom Systems Laboratory have been concerned with providing instrumentation and data-collection devices for field tests and training. A complete timing system and ancillary items were developed to provide precise real-time information throughout a 150-square-mile area. Devices for monitoring manual switchboard traffic and automatically indicating circuit faults during field operations were developed. A switchboard signal device has been designed to provide plug supervision on the Switchboard SB-86/P when used on carrier trunks provided by the AN/TCC-3 or -7 carrier equipment.

Present design and development work also includes effort on the Minuteman and 480L programs, and RCA General Engineering and Development (GE&D) of a very stable frequency synthesizer for single-sideband use.

Automatic Pictorial Instruction Device

A pictorial instructional device, to be known as the *Auto Briefer*, has been developed for the Signal Corps. This is an automatically controlled system of photographic slide projectors, motion-picture projectors, and lighting and audio equipments for training purposes. This equipment will automatically present a complete training lecture with visual aids and live or recorded voice. The device will overlay slides and movies in any desired sequence in order to show the development of complex systems and relationships. Sequencing is done with a standard computer-type patch board. Several programs can be stored in the machine and any one presented by inserting a prepatched board. A feature of particular novelty and utility is a random-access provision whereby the lecturer can call or recall any slide for viewing simply by dialing its code number. It is shown in Fig. 1.

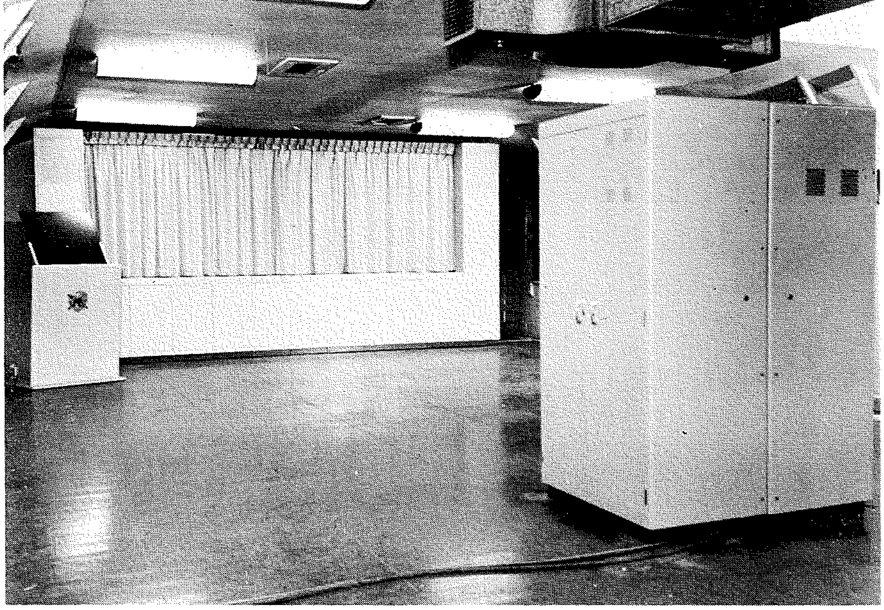


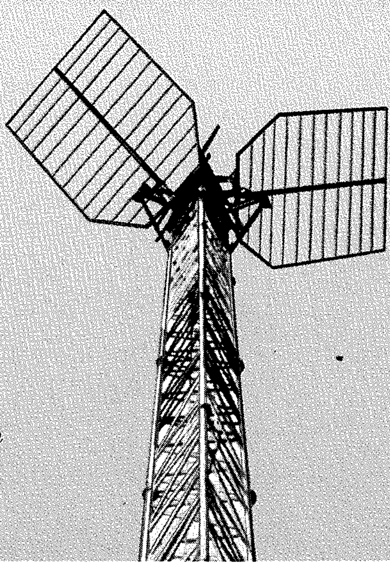
Fig. 1—Automatic pictorial instruction device developed for the U.S. Army Signal Corps. This system of slide, motion-picture, and audio equipment will automatically present lectures with visual aids and live or recorded voice.

FUTURE PLANS

Looking to the future, Surf Com-Tucson plans continued growth with broader participation in the technical programs at Fort Huachuca, including work in data processing, combat surveillance, and electronic warfare, and product-area diversification among other customers in the West and Southwest. This broadened outlook is made possible by the new facility and particularly capable staff of communications engineers. The Laboratory also hopes to make increasingly important contributions within RCA, through intimate knowledge of Army tactical communications, by making use of a geographic location which provides an excellent climate and electromagnetic environment for all-year outdoor testing of antennas and equipment, and by performing forward-looking GE&D to maintain and improve future product capabilities.

ALLEN M. CREIGHTON, JR. obtained his BS in EE from the University of Arizona in 1949. Prior to that time, his experience included radio component sales, Airborne Communications with the USAAF, and manager and part-owner of Trans-Asiatic Airlines in Manila. From 1948 to 1950, he was Staff Engineer at Philco Corp., involved with a Radar Modification System for submarine detection, responsible for display system-sweep generation, slowing circuits, etc. The following eight years were spent at the Western Military Electronics Center of Motorola, Inc. where he served as Project Leader, Military VHF Communications System Development and Section Head, Avionics and Communication Section in charge of all USASEL communication projects at the Center. He directed Army Avionics projects and was Manager of Airborne Combat Surveillance which included programs on Side Looking Radars, Drone Navigation and Guidance, and Data Links. He joined RCA in 1958 and presently manages the DEP Surface Communications Systems Laboratory in Tucson. He is a Senior Member of the IRE.

MULTI-HOP MICROWAVE RELAY SYSTEM



by **J. B. BULLOCK**
Broadcast and Television Equipment Engineering
IEP, Camden, N. J.

LONG-HAUL RELAYING of TV signals by multi-hop microwave systems is a service ordinarily performed by common carriers, using equipment of their own design and manufacture, closely tailored to the very demanding performance requirements. In recent years, however, the growth of TV broadcasting and the appearance of a surprisingly large number of community TV distribution companies has created a great demand for lower-cost, medium-haul facilities to supplement the common carriers.

RCA's TVM-1 microwave relay equipment is being utilized for such applications. Initially, it was developed for studio-to-transmitter–link and portable-TV-pickup service. In these services, it is only occasionally necessary to have more than one hop in a circuit; for example, when the intervening terrain presents an obstacle to line-of-sight transmission, or when it is desired to route the signal via a common switching point.

The initial design of the TVM-1 looked forward to medium-haul, multiple-hop TV relaying, and the distortions per hop were kept low. Since that time, continuing improvement has been achieved in performance, so that today it is possible to put a considerable number of hops in series and still preserve a high degree of over-all performance—this in spite of the demodulation and remodulation which takes place at every repeater.

TV RELAY APPLICATIONS

There are today many applications of the TVM-1 equipment to medium-haul multi-hop relaying of TV signals, some of which are described in the following paragraphs. In addition to TV relaying, tests have shown that the equipment is suitable for multi-hop relaying of multi-channel telephony. In that application, a system is, of course, required to be two-way, and accessories which permit two-way operation on a single set of antennas are available.

Rebroadcasting by "Off-Air" Pickup

In those cases where common-carrier facilities do not exist, or cannot be economically provided, a TV station may obtain its network programs by rebroadcasting the signals of one or more other stations. In this application, a high-quality TV receiver is located in the Class A reception area of the station whose programs are to be utilized. The receiver's output is then relayed via microwave to the using station for rebroadcast. If more than one station's programs are to be relayed, the general practice is to employ more than one TV receiver and remotely switch the desired receiver output to the microwave system.

"Off-Air" Feed for a CATV System

Community Antenna TV Systems distribute video within an area via coax lines. The video is modulated in the normal manner on a very-low-power TV transmitter whose output is fed to the distribution system. The system then feeds conventional TV receivers simply by connection to the antenna terminals. In the United States, these systems are now nearly as numerous as TV broadcast stations themselves. The typical subscriber pays an installation charge of about $50 and then a monthly rate of $3.00 to $8.00. These CATV systems are largely confined to the wide-open spaces of the West and to mountainous areas where signal strengths of TV stations are low or where programming is poor. In many cases, three-channel microwave systems are in use in order to carry all the major networks to an area. As in the network-source case, the CATV operator will locate a high-quality receiver where received signal strength is good and feed its output to the microwave link, which then carries the program to the desired area.

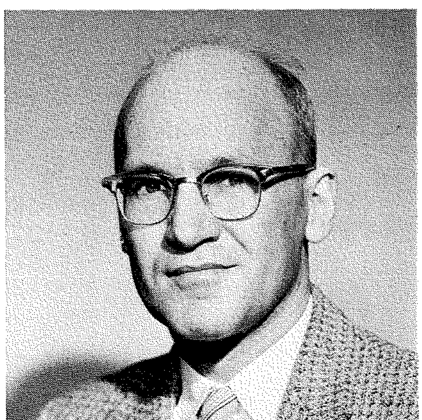
Interconnection Between TV Stations

This type of system is most generally installed between stations under common ownership. Reversible links are often provided so that either station can feed program to the other.

Local or Regional Network Connection

This service might involve either *off-air* pickup or direct connection to the com-

JOHN B. BULLOCK received the BSEE from North Carolina State College. During World War II, he was an instructor at the U.S. Army Electronics Training Center at Cruft Laboratory, Harvard University. Following this, he was Officer-in-Charge of the AFWESPAC Transmitter Station at Manila, P.I. Returning to the U.S., he worked at the Allen D. Cardwell Co. in Plainville, Conn. and the Connecticut Telephone and Electric Co. as project engineer on the design and development of vhf signal generators and h-f receivers for the Signal Corps. In 1952 he joined the radar section of RCA and later transferred to the Camera Equipment group in Camden. There, he assisted in the latter development stages of the TVM-1A microwave relay equipment and in the conversion of the TTR relay equipment for transmission of color TV. He has been the principal author of a systems concept for the TVM equipment and in the design of accessory units required to implement this. He has acquired postgraduate credits at Yale University and the University of Pennsylvania and is a licensed Professional Engineer in the state of New Jersey. At present, he is a Project Engineer on TV Microwave Relay Equipment.



mon-carrier system. It may have one or more branching points and may have to be reversible in whole or in part.

TVM-1 EQUIPMENT CHARACTERISTICS

The TVM-1 equipment operates in the 5925-to-8500-mc frequency range, covering completely the frequency bands allocated to common carriers, broadcasters, business, and governmental services. The transmitter utilizes a directly frequency-modulated klystron with one watt of r-f power output. The receiver is a superheterodyne, employing a klystron local oscillator, crystal mixer, and an i-f centered at 130 mc with a nominal width of 25 mc. The equipment is physically mountable in portable carrying cases or in standard 19-inch racks. The latter mounting is generally used in fixed-station installations—the usual type in multi-hop service.

Performance

The performance characteristics of a single hop of TVM-1 equipment and a standard which may be taken as typical of common-carrier intercity service are shown in Table I.

The first column shows performance of a single TVM-1 transmitter and receiver, when no pre-emphasis is employed. In this situation, multiple-hop service for color TV equal to the standard could only be attained over about two hops. The limitation comes in the differential phase and gain performance; these items are, of course, important in preserving the quality of color information. They are also important in keeping cross-talk from the video channel into the audio at a low level, as will be discussed later.

Low-frequency de-emphasis at the transmitter input to shape the TV signal is standard practice in TV microwave relaying so as to lessen the effects of both amplitude and phase nonlinearity; that is, the differential phase and differential gain. This is done by passing the signal through a low-frequency de-emphasis network—often called a *predistortion* network. The effect of this network, as illustrated in Fig. 1, is to reduce the amplitude of low-frequency components of the signal, thus compressing the signal so that video amplifier plate current swings and r-f and i-f deviations (the TVM-1 is an FM system) are reduced. In the receiver, a complementary *restorer* network restores the system video response to flatness. The amount of predistortion used in the TVM-1 is optionally 8 or 12 db.

The improvements in differential gain and differential phase characteristics are apparent in looking at the second and third columns of Table I. The improvement is sufficiently significant to extend the useful range of the equipment to four hops with the 8-db networks, or to twelve hops with the 12-db for the relaying of color-TV signals and their accompanying sound.

The predistortion in the transmitter leads to a poorer S:H (signal-to-hum ratio) if any significant amount of hum is generated within the system. For this reason, the 12-db networks normally do not de-emphasize at 60 cycles, The restorer network then must attenuate at 60 cycles and thus attenuates hum generated within the system. Table I illustrates this case, showing S:H in the 12-db case to be identical to that when no predistortion is used.

Sound Channel

Program sound is carried on the TVM-1 microwave on a subcarrier at 6.8 mc. The subcarrier is frequency-modulated and then simply added to the video signal through a filter network. Subcarrier level is normally run at about 20 percent of peak-to-peak video level, and at the receiver, it is extracted from the video by means of a filter and fed to a demodulator. Excellent audio transmission is possible; i.e., a 15-kc channel, with 1 percent or less distortion and S:N of 65 db or more. Standard 75-μsec pre-emphasis is employed in the sound modulator prior to modulating the audio on its subcarrier. Flat frequency response at the output of the receiver is restored by a de-emphasis network in the subcarrier demodulator.

S:N is the only cumulative distortion in the audio channel. It is specified as an rms:rms ratio, since that is the meaningful ratio as far as the ear is concerned, and cascades in a multi-hop system at the same rate as the S:N in the video channel. Therefore, the S:N ratio decreases by 3 db every time the number of identical hops is doubled.

The noise in the audio contains two major components. One, the *random noise*, is a function of the microwave system, the subcarrier level, and the demodulator design. The other major

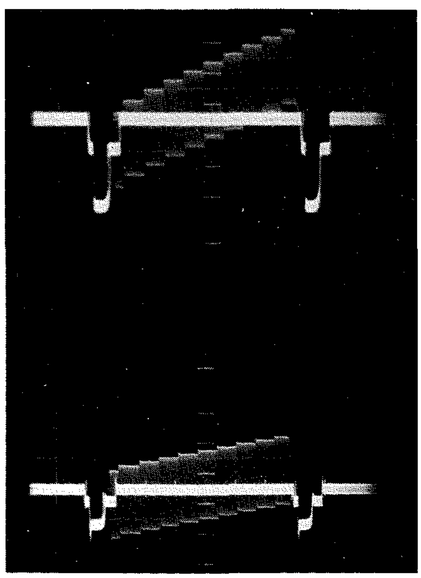
TABLE I — SINGLE-HOP TVM-1 PERFORMANCE

Characteristic	*Predistortion*			*Standard*
	None	*8 db*	*12 db*	
Video Channel				
Differential gain @ 3.58 mc, db	0.5	0.25	0.1	1
Differential phase @ 3.58 mc, degrees	3	1	0.3	4
Amplitude-frequency response**:				60 cy to 4.2 mc ±0.5
60 cy to 6 mc without sound, db	±0.25	±0.25	±0.25	
60 cy to 4.5 mc with sound, db	±0.25	±0.25	±0.25	
L.F. Window Tilt, pct. max	1	1	1	2
S:N (p/p : rms, 8 mc band)*, db	65	65	65	50
S:H (p/p : p/p), db	52	46	52	46
Audio Channel (s)				
Amplitude-frequency response:				
50 cy to 13 kc, db	+0,−0.5	+0,−0.5	+0,−0.5	—
to 15 kc, db	−2	−2	−2	—
Harmonic distortion, pct. max.	1	1	1	—
S:N (rms : rms)*, db	67	73	70	—
S:H (rms : rms), db	75	75	75	—

*Both video and audio S:N are a function of the r-f level into the receiver. The figures shown are for a 22-mile path using 6-foot parabolic antennas on both transmitter and receiver, with negligible waveguide feeder losses.

**The narrowing of the video channel with sound is due to the filters required at each end of a system to exclude sound subcarrier from the video channel.

Fig. 1—Differential phase and gain test signal before (top) and after (bottom) predistortion. Viewed on a monitor, this test signal would appear as a series of vertical bars all of the same "color" but increasing in brightness.



component is the *cross-talk component* from the video channel. It occurs at both the horizontal and vertical sync rates and on any abrupt change in picture brightness. It is caused by phase nonlinearity in the video channel (differential phase at the sound subcarrier frequency.) This can be understood by visualizing the sound subcarrier riding one moment on the video signal at white level and the next moment being moved almost instantly to blanking and then to the tip of sync. If the subcarrier undergoes any change in phase during this excursion, the transient is phase- (and frequency-) modulated on it and cross-talk into the audio channel has been created. This cross-talk component is lessened by the use of the video predistortion, except that if the 12-db networks are used without de-emphasizing at 60 cycles, then the cross-talk at that rate is not improved. For this latter reason, Table I shows a poorer audio S:N with the 12-db networks than with the 8-db networks.

Audio is not demodulated from its subcarrier at a repeater unless sound drop-off is required, and then it is only demodulated to feed the drop-off. Thus, there is no contribution to audio distortion at a repeater.

A second sound channel can be added to the TVM-1. It is identical to the first, except for its subcarrier frequency, 6.2 mc. The second channel permits the sound for an FM transmitter at the TV transmitter location to be accommodated on the studio-transmitter-link, or the second sound channel may be used for fault alarm or switching control tones. These latter applications are discussed in following sections.

Fault Alarms

A multi-hop microwave system must have sensing devices at various points to enable a user to identify trouble quickly—preferably to locate the unit or station in trouble, or at the very least the hop in trouble. Obviously, the more specific the means for identification of trouble are, the more complex and costly the alarm system becomes.

The alarm units, which are optional parts of a TVM-1 system, provide for the detection of video at the transmitter input, transmitter monitor output and/or receiver output; for the detection of low r-f power output from the transmitter; and for the detection of low i-f signal level at the receiver. The transmitter monitor output is an *off-air* monitor which provides high-level quality video derived from the actual outgoing FM signal via an r-f discriminator and broadband amplifier. This output provides a check point for both modulation and r-f failure.

It is desirable that the low-signal and low-power alarms sound in *advance* of actual failure, and for this reason, the low-signal alarm indicates when received signal drops 15 db or more (nominally one-half the fade margin) and the low-power alarm when transmitter output drops 6 db or more.

Standby Service

If the highest possible reliability is desired, complete standby must be provided. Automatic switchover to standby units are another optional feature of the TVM-1 system. A typical arrangement is illustrated in Fig. 2 and 3.

Fig. 2 shows a transmitter system wherein both transmitters operate on the same frequency, the one in standby for the other. The *transmitter standby switcher* senses the outputs of the two transmitter monitors. If either should fail or drop over 6 db in level below its companion, the switcher will operate the waveguide switch (and/or the radiation attenuators) to place the nonfailed transmitter on the air. Switching will take place whether the level differential is due to video or to r-f trouble, since there is no limiting ahead of the discriminator which feeds the transmitter monitor.

Fig. 3 shows a receiver system wherein automatic provision for switchover to standby has been provided. Here again, a one-frequency system is assumed. The receivers are fed from separate antennas to take advantage of space diversity to combat fading. At 7 kmc, a spacing of only 15 to 25 feet vertically is required between antennas. The TVM-1 is also adaptable to frequency diversity, but in the TV relay service, the assignment of two frequencies for a single hop is generally difficult to obtain in the continental United States because of the scarcity of channels; hence, space diversity is more commonly used. If diversity is not desired, the two receivers may be fed from a common antenna through a waveguide directional coupler.

The *receiver standby-diversity switcher* senses both the agc and the video output of each receiver. If either receiver signal falls below a predetermined mini-

Fig. 2—TVM transmitter station with fault sensing and automatic standby switching.

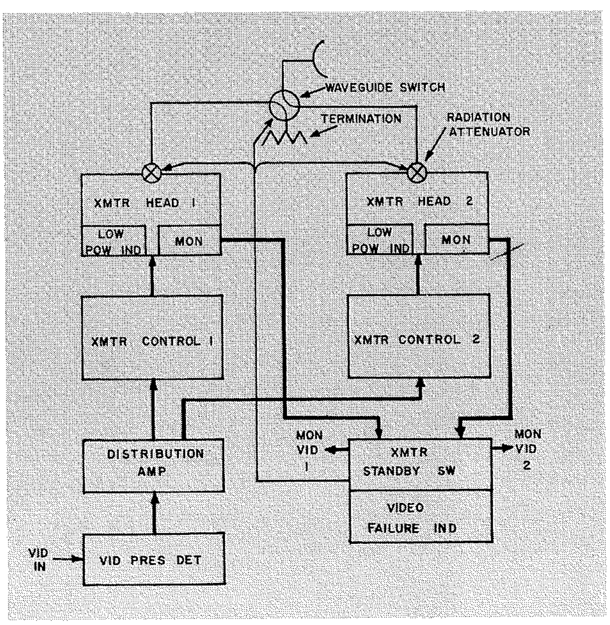
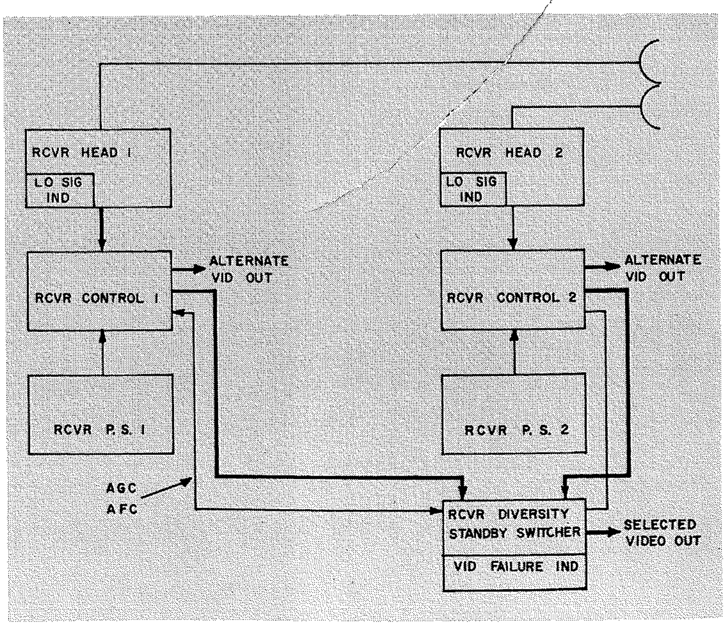


Fig. 3—TVM receiver station with fault sensing and standby.



mum usable S:N ratio, as indicated by agc voltage, the switcher operates to select video from the nonfaded receiver; or, if the video level of either receiver falls more than 6 db below its companion, the switcher selects the nonfailed video. The switcher will not operate if the two agc voltages drop together (simultaneous fades) or if both video voltages go down together (simultaneous video failure), nor will it switch *to* a failed video or *to* a signal faded below the preset agc level (minimum usable S:N). Also, upon loss of signal by either receiver, that receiver's afc is turned off to prevent its local oscillator from being carried off frequency by the output of the open afc loop.

The fault alarms discussed earlier may, of course, be incorporated in the automatic switchover systems. Some are indicated on the diagrams.

Fault Alarm Transmission

The fault indications discussed earlier would be useless at unattended stations unless some medium were provided for forwarding them to an attended location. The TVM-1 system provides two general philosophies for forwarding this fault information. The more elegant is diagrammed in Fig. 4 and involves the use of a wire line or radio link external to the microwave system. The second method involves less equipment, uses the microwave system itself as a transmission medium, and is aimed at merely identifying the *link* which is in trouble. It is diagrammed in Fig. 5.

In the system of Fig. 4, all fault reports are gathered together at the *delay timer* (or *junction panel*). Each fault actually provides a contact closure. These closures are then fed on to the *Indicon coder* which translates each into a pulse code. Whenever a fault (closure) occurs, the coder starts a cycle of operation by sending a series of five pulses to identify its own location. It then follows with a series of ten pulses to identify the particular fault. In this manner, as many as ten faults may be reported from each of 31 stations. The five station-identifying pulses are used in combination, long or short; the ten fault pulses are long (360 milliseconds) if their particular fault exists, short (90 milliseconds) if it does not. The Indicon units are a long-established part of RCA's Commercial Communications Microwave product line and were well suited for use in the TVM-1 system.

The delay timer acts to prevent simultaneous transmission of fault information from several stations at once. For example, if modulation failure occurs at the first station, the delay timer does not permit reports from other stations until after the first station has reported. It does this by delaying the Indicon coder operation at each station until the preceding stations have had time to report. It does not protect from *coincidental* faults at two stations causing simultaneous reporting. Such protection can be provided if a more elaborate lockout provision of the Indicon units is utilized. However, in a system where the number of hops is not great, the probability of coincidental faults is quite low; hence, the delay-timer scheme of Fig. 4 is generally used.

The pulse output of the coder modulates a tone generator, and the tone is forwarded to the attended terminal via wire line or radio link where it is detected in the tone receiver. The pulse trains are then decoded and displayed in lights by the Indicon Decoder.

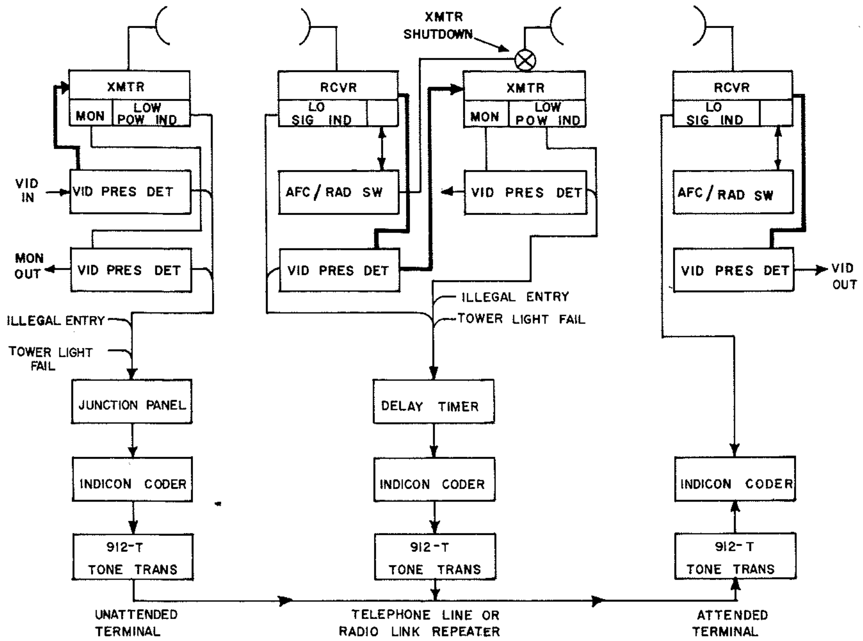


Fig. 4—Fault reporting system via wire line or radio link.

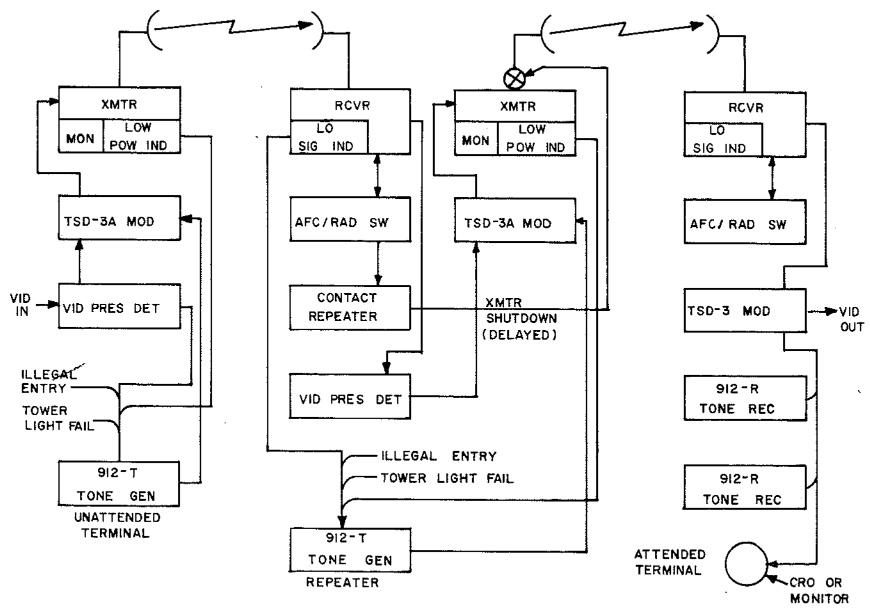


Fig. 5—Fault location reporting via subcarrier on microwave video.

In the less-costly reporting system of Fig. 5, all fault closures are tied in parallel and used to key a tone generator. A different frequency tone is used at each station. The output of the tone generator is then fed to a sound subcarrier modulator whose output is fed into the video line itself. At the attended terminal it is only necessary to connect an oscilloscope across the subcarrier demodulator output to identify the frequency of the tone being received to know which station is reporting trouble. Or, as Fig. 5 shows, tone receivers may be used to give a pilot light display of the trouble location. The light display is desirable in the event of simultaneous reports.

In the case of this "internal" reporting system, transmitter *outage* can only be indicated by the following receiver, since the transmitter itself is required for forwarding the report. Transmitter *low* power, however, can be reported. Therefore, the system can report the *station* which is *failing*, but only reports the *link* that *has failed.*

If a microwave system has complete standby, then a combination of the two reporting schemes could be used. The Indicon unit would be used to identify each fault and station as per Fig. 4, but the output of the keyed tone generator would be fed to the subcarrier modulator as in Fig. 5. Transmitter failure would now no longer interrupt fault transmission, and therefore complete reporting is again possible.

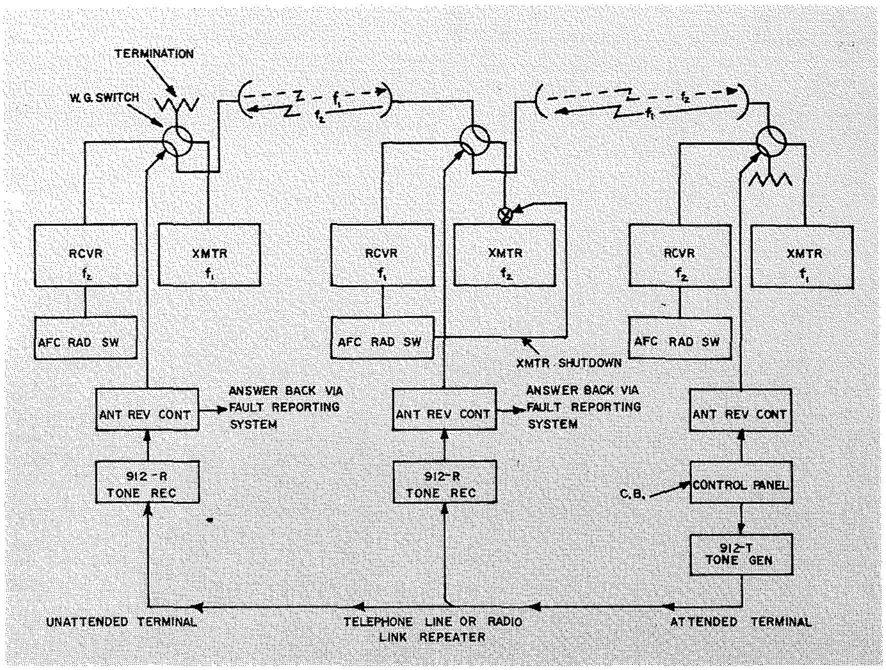


Fig. 6—Reversible system via wire line or radio link.

System Shutdown

It will be noted that in Fig. 4 and 5, a unit identified as the *afc radiation switch* is associated with each receiver. This unit performs two important functions for an unattended receiver.

The first of these functions is the disabling of receiver afc in the event of loss of signal. This is actuated by operation of a trigger circuit in the unit which trips if the receiver agc voltage drops below a preset level. This removes $B+$ from the receiver's afc amplifier. With afc turned off, the receiver klystron local oscillator remains at its manual tuning setting, and when signal reappears producing agc, afc is again turned on. Thus any significant drift of the local oscillator tuning due to the open afc loop in the absence of signal is prevented. This action also prevents the afc from locking the receiver to a microwave transmitter on an adjacent channel in the event of loss of its own signal.

The second function of this unit is to permit remote shutdown of a multi-hop system when it is not in use. This is required by FCC regulations. In this case the operator turns off radiation from the first transmitter in a system, perhaps by remote means, and the subsequent loss of signal agc by each receiver turns off radiation of its following transmitter. This *turn off* is delayed, so that short fades do not shut down the system. The turn off is effected by actuating the transmitter's radiation attenuator. This drops the r-f output by an approximate 45 db, but otherwise leaves the transmitter active and ready for instant use when resumption of service is desired.

Where two TVM-1 receivers are used in standby for one another, the receiver standby-diversity switcher performs the above two functions (Fig. 3).

Reversible System

When a TV relay microwave link is for use between two cooperating broadcast stations, it is sometimes the case that it will be desirable to transmit a program at one time in one direction, and at another time in the opposite direction. A TVM-1 multi-hop system can be made reversible by providing an additional transmitter and receiver, one at each terminal, and a few minor accessories at each station. A reversible system is illustrated in Fig. 6.

Reversing is accomplished via a control wire line or radio link, or via a subcarrier on the microwave link itself. Fig. 6 shows a system using a telephone line for control.

In either reversible system, reversing is accomplished by means of an audio tone sent through the control channel. A tone which may be shifted in frequency is used and is left on at all times to minimize the possibility of accidental switching due to noise bursts or spurious tones. The basic operation is very simple. Whenever a *mark* tone is on the line the system will be oriented in the *A* direction, and if the tone is shifted to *space* frequency, all the waveguide switches operate to switch transmission to the *B* direction. A tone detector is provided in each tone receiver so that failure of the tone disables the switching circuitry and the system then remains as it was until the switching tone is restored.

If the switching tone is transmitted via subcarrier on the microwave itself, then it is necessary to effect switching from *both* ends of the system. The tone sent from the then-transmitting end of the system actually initiates switching, but if the system is to remain switched as directed, the tone generator at the new transmitting end must be set for the same direction. Here, also, an FM system is used and tone is left on the subcarrier at all times to protect against accidental switching due to noise bursts, etc.

It is possible to combine the switching and fault reporting on the same telephone line or radio link by simply using different tone frequencies for the two functions. If fault reporting is included, then the waveguide switches may report back when they have switched via the fault reporting system. The report is turned off by time delay relays in the *antenna reversing control* after a nominal 5-minute interval.

Remote Switching

Previously, it was noted that it is sometimes desirable to remotely switch the input to a microwave system. This switching, unfortunately, cannot be done on the microwave system itself, since the switch to be actuated is at the transmitting end. It can, of course, be done by wire line or radio link. It can also be done on an FM broadcast channel, providing the broadcast station is on the air for program purposes at the required times and the switching tone does not interfere with programming.

High reliability in this switching is always required, and the general system is to use a frequency shiftable tone which is left on at all times to provide noise immunity. Each time the tone is shifted, for example to *mark* frequency, a step switch will be actuated and the microwave transmitter's input changed.

R-F Multiplexing

At any installation where r-f signals are either to go to, or come from, a common distant point it is almost always desirable to use a common antenna. Circulators and filters are used with TVM-1 equipment to accomplish this r-f multiplexing. Fig. 7a, b, and c illustrate typical systems.

In Figure 7a, three transmitters are placed on a common antenna, with negligible addition to system distortions. The method takes advantage of the unique ability of a ferrite circulator to accept a signal at one port and pass it clockwise (only) to the next port. If it is reflected from that port, it tries the next clockwise port, etc. Thus in Figure 7a, a signal from transmitter 3 enters port 4, tries to exit at port 1, but is reflected by the waveguide bandpass filter which is tuned to transmitter 2. It then tries to exit at port 2 but is again reflected from the bandpass filter on that port. Finally it exits at port 3 to the antenna. A similar analysis will show that signals from transmitters 1 and 2 are delivered to the antenna. A nominal loss of 0.5 db per pass through the circulator is encountered. The bandpass filters used have a nominal passband of 30 mc in order not to contribute to the system differential phase distortion. The TV relay channels allocated by the FCC are normally spaced 25 mc apart. Thus, for proper functioning of this multiplexing scheme a spacing of one guard channel is required.

Figure 7b shows how three receivers can be placed on a common antenna and Figure 7c illustrates how both a transmitter and receiver can be connected to a common antenna. In this latter case, it is necessary to bolster the isolation provided by the circulator (20 db) by the addition of a bandpass filter. Obviously, the cascading of circulators and filters can make possible much more complicated r-f multiplexing arrangements.

TABLE II — MAJOR TVM-1 MULTI-HOP INSTALLATIONS

Owner	*No. Hops*	*From*	*To*	*Features*
WBTV	4	Charlotte, N.C.	Florence, S.C.	Reversible, with fault reporting. Provides interconnection between WBTV and WBTW.
Radio Tupi	8	Rio de Janiero	Bello Horizonte, Brazil	Reversible, with fault reporting. Provides interconnection for regional network.
WLEX	3	Cincinnati, Ohio	Lexington, Ky.	Fault reporting and remotely selected video input. Provides network video for WLEX.
WMTW	4	Boston, Mass.	Mt. Washington, N.H.	Fault reporting, and remotely selected video input. Provides network video to WMTW.
Saskatchewan Telephone Company	4	Grenfell, Sask.	Yorkton, Sask.	Diversity on each hop. Provides network video to broadcaster.
British Columbia Telephone Company	4	Hedley, B.C.	Kamloops, B.C.	Automatic standby on each hop. Provides network video to broadcaster.
Midwest Video Company	5	Pine Bluff, Colo.	Rapid City, S.D.	Three channels on common antennas. Provides community TV video feed.

FIELD INSTALLATIONS

A few of the multi-hop TVM-1 installations which have been made using the systems discussed above are listed in Table II.

In addition to these installations, there are many multi-hop systems which do not include multiplexing or any automatic functions, and there are a great many single hop systems wherein the fault alarm, diversity and standby, r-f multiplexing, etc., features have been utilized.

Only a few of the many possibilities for utilizing the TVM-1 equipment in multiple-hop systems have been illustrated. The potential and flexibility of the equipment have been shown, however, and it is surely apparent that many special applications are possible. These will be developed as the needs for TV relaying by microwave continue to grow.

Fig. 7a—Three transmitters placed on a common antenna.

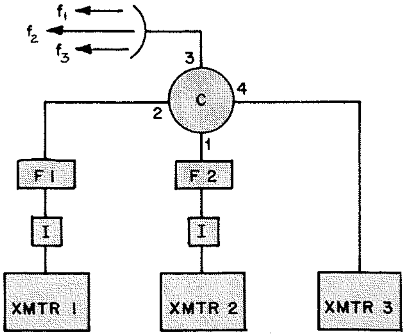


Fig. 7b—Three receivers placed on a common antenna.

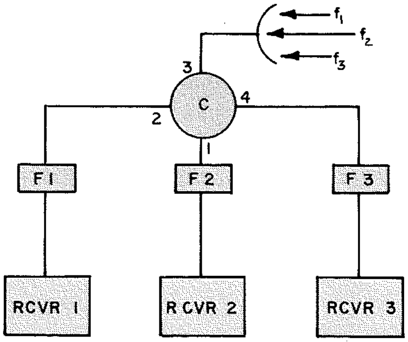
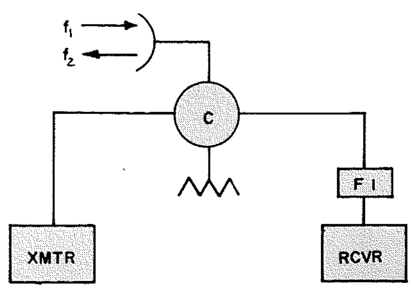
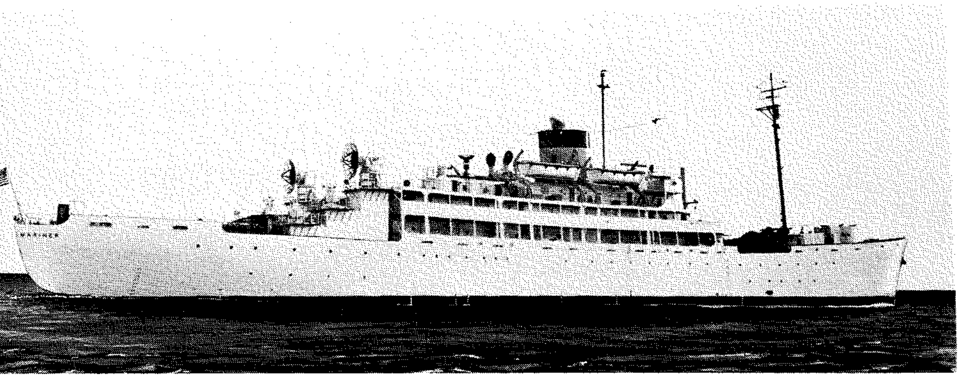


Fig. 7c—Transmitter and receiver placed on a common antenna.



RCA engineers go to sea—in the USAS **American Mariner,** a floating laboratory of data-gathering equipment for missile flight tests at the Atlantic Missile Range. DAMP is an integrated data-handling program managed by RCA and sponsored by the DOD's Advanced Research Projects Agency. Some 60 engineers and technicians, many of them from the DEP Missile and Surface Radar Division and the RCA Service Co., are assigned to the ship to man the DAMP instrumentation. This article describes the DAMP system, while in the following article, W. R. Isom and F. E. Shashoua describe a special DAMP radar-video tape recorder.



DAMP—Down-range Anti-ballistic-missile Measurement Program

by **L. FARKAS**

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Missile and Surface Radar Division
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At the Atlantic Missile Range, the impact area for missile flight tests extends from a few hundred to several thousand miles from Cape Canaveral (Fig. 1), the operating area for DAMP. It was because of the wide geographic separation of these areas and the necessity for a flexible measurement facility that DAMP was conceived.

The U. S. Army Ship *American Mariner* is outfitted as a floating instrumentation site for DAMP, forming the source point for a data-handling system that includes the Cape Canaveral launching site and RCA's Data Reduction Center at Croydon, Pa. From there, the reduced and analyzed data is fed to the government agencies and companies involved in the ballistic missile program. Very close integration of the activities of these widely separated locations is of utmost importance, just as is timely feedback of significant results to the *American Mariner* to ensure the most accurate future data.

DOWN-RANGE . . .

The wide expanse of the ocean range and the scarcity of suitable island bases immediately suggested a ship as a platform for the DAMP instrumentation. A Liberty-class ship was transformed into what may be called a floating laboratory. As with any other scientific laboratory, experiments are planned in order to prove or disprove specific hypotheses, measurement equipment is available, and the results of the measurements are carefully analyzed to ascertain their validity. In this shipboard laboratory, the primary measurement instruments are high-precision instrumentation radars.

A ballistic-missile trajectory measured with respect to a rolling and pitching ship would obviously be of little value, per se. What is desired is a trajectory measured not with respect to the moving platform—the reference for the pedestal of the radar—but rather with respect to an earth-fixed coordinate system. This was achieved by instrumenting the ship with precision gyros to measure its roll, pitch, and yaw, which can then be used as correction factors. To further enhance the accuracy of data, a program was initiated—still under way—to investigate shipboard-radar calibration. One precedure, based on optical and radar tracking of a sphere of known cross-section, has been utilized which allows a simultaneous calibration of both agc and angle error signals.

Although there are many problems in utilizing a shipboard high-precision measurement radar, there are corresponding advantages in having a floating laboratory. First, it permits investigation of the terminal phase characteristics of re-entering bodies, important both from the design and discrimination standpoints. Secondly, it provides shorter-range radar measurements, with the corresponding increased accuracy of trajectory measurements with respect to the radar. Finally, it allows for great flexibility in measuring bodies impacting in different areas and also enables observation of the re-entering bodies from different aspect angles.

. . . ANTI-BALLISTIC-MISSILE

As with any experimental program, DAMP measurements have a wider applicability than just for the specific experiments performed—e.g., trajectories.

For the anti-missile effort, the information obtained can be utilized to assist in the development of more-sophisticated discrimination techniques against various re-entry bodies. The discrimination can be based upon either active radar measurements, or passive optical and infra-red detection devices. Also, information regarding re-entry behavior of various types of bodies can be determined and catalogued, as well as the aerodynamic characteristics of various body configurations, as an aid to the design of re-entry bodies.

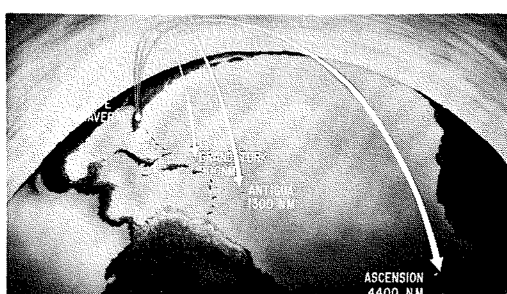
. . . MEASUREMENT

The DAMP instrumentation has been designed to flexibly implement the broad program objectives cited. The DAMP ship is equipped with two four-horn, monopulse, C-band, modified FPQ-4 radars. In addition, there are pedestals that can be slaved to the radars and adopted for mounting optical, infrared, ultraviolet and other passive measurement devices. Meteorological data-gathering equipment, as well as communication equipment, is also provided.

Radar Equipment

The primary measurement instrument is the RCA FPQ-4 instrumentation-type radar—essentially the same as the RCA FPS-16 range instrumentation radars. The tracking accuracy of a properly calibrated land-based radar is 0.1 milliradian-rms in azimuth and elevation, and 5 yards-rms in range. However, in shipboard operation, the accuracy of the computed trajectory also depends on the accuracy of the special roll-pitch-yaw gyros and the ship's naviga-

Fig. 1—Atlantic Missile Range.



tion system. Thus, measured azimuth, elevation, and range data may be somewhat less accurate, even though the radars themselves are operating perfectly within these tolerances.

The FPQ-4 tracks with a very narrow beamwidth—the order of one degree. Therefore, the DAMP system contains a designation and an acquisition mode to initially detect and lock on the target before going into the automatic track mode.

Acquisition Techniques

Designation is based upon a prior knowledge of the desired acquisition point on the re-entry trajectory of the missile. The range, azimuth and elevation of this point with respect to a theoretical non-atmospheric impact point, based upon trajectories computed at Cape Canaveral, are transmitted to the ship. This information, together with the ship's position with respect to the same non-atmospheric impact point, is inserted into the ship's designation computer, a chain of resolvers which performs the necessary coordinate transformations so that the radar is directed in elevation and azimuth to the correct point in space. One source of inputs to the designation computer is the stabilization gyro: the ship's roll, pitch, and yaw signals are utilized to stabilize the line of sight during the designation mode. At the launch site, the outgoing trajectory of the missile is measured by radars in the vicinity of and down range from Cape Canaveral. Based upon this information, a revised estimate of the DAMP acquisition point is calculated at the Canaveral digital-computer facility. This fine, corrected information is immediately sent to the ship and inserted into the designation computer only moments before the missile arrives.

An acquisition scan is then necessary, since even if the positions of the ship and target were known exactly, errors due to noise in the stabilization system and errors in computations in the designation computer would change the position of the radar line of sight from the desired one. The acquisition scan is centered about the designated line of sight, which causes the radar line of sight to spiral outward and then inward (Fig. 2). The parameters for this scan are chosen to maximize the probability of detection and acquisition.

Another acquisition problem is created by the very high velocity of the target, which can traverse a fixed, 100,000-yard acquisition display very rapidly and thus increase the probability that it would not be detected. This has been solved by incorporating a moving acquisition display into the system. Together with the designation data from the launch site, a missile arrival time and velocity at the designated point is included. At the expected instant of arrival, 90 percent of the expected velocity is inserted into the radar range system, causing the acquisition display to move down in range and effectively resulting in a target with only 10 percent of the actual target velocity. This greatly improved the probability of detection and acquisition.

Data Recording

Assuming that the designation and acquisition modes perform as they should (and they have proven their performance many times) the actual measurement portion can begin with the occurrence of target lock-on, at which time the radar goes into its automatic tracking mode. It is only from this instant that the radar is performing its measurement function. All other operations were solely for the purpose of assuring a successful and meaningful track.

A measurement of prime importance is the trajectory; but, in addition, the cross-section and scintillation characteristics of the body are also measured. In this radar, an agc section is utilized to dynamically adjust the gain of the receivers on the basis of the received signal power. An increase of signal power results in an increase of voltage, which causes a decreased receiver gain. This action is necessary in order to maintain proper signal levels in the tracking section when the signal strength varies radically. The agc voltage is thus a direct measurement of the received signal power and may be calibrated as a function of the received-signal-to-noise power ratio. To understand the manner in which cross-section measurements are derived from the agc signal, it is only necessary to refer to the classic radar equation, from which it can be shown that $S{:}N = KA/R^4$, where A = radar cross section of target, R = range, and K is a known constant dependent only on various characteristics of the radar.

Data Processing

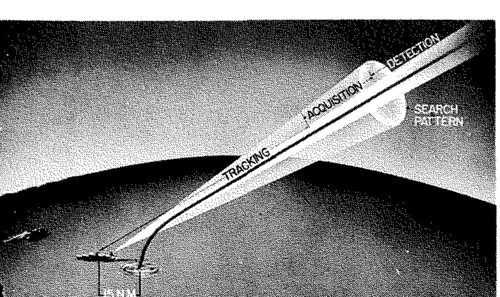
The ability of the radar to make accurate and precise measurements is meaningless unless the data-processing system is of the same high quality as the radar. This necessitated a careful evaluation and implementation of both the data-recording and data-reduction procedures.

The primary radar outputs (range, azimuth and elevation) are available in digital form through digital shaft encoders. All other required quantities, which are not available as outputs of digital shaft encoders, are fed into a series of analog-to-digital converters. The data-sampling frequency is established by a master clock, synchronized with WWV. All data quantities are sampled at the same instant of time and are recorded, together with real time, by multichannel digital recording equipment. The data tapes are then returned to the data-reduction facility at Croydon, Pa. Semiautomatic screening and sorting procedures are utilized and calibrations are automatically applied.

. . . PROGRAM

It is at this point that DAMP earns the right to be called a *Program*—a coordinated and integrated effort with specific output requirements and output-input feedback. The product of DAMP —*information*, from the reduction and analysis of data—may then lead to coordination of ship measurement schedules and missile firings in order to obtain further information for verification of measurement results. Results may be compared and correlated with various studies and associated research as a practical verification of existing theories. The theoretical results then leading to suggestions regarding program augmentations in order to obtain additional data. Thus, the cycle is completed by returning to its starting point, the actual tracking of the target—however, with the new, modified measurement goals. The integrated, *closed-loop* nature of DAMP measurement techniques indicate its great utility and importance to the ballistic-missile program. Its operation is an outstanding example of interservice-industry cooperation.

Fig. 2—Typical test geometry.



LEONARD FARKAS received the B.E.E. degree, cum laude, from the City College of New York in 1956. After a year at the Emerson Research Laboratories in Washington, D.C., and service as a 2d Lt. in the Corps of Engineers, he returned to school and received his Masters' degree from Stanford University in 1958. He is presently working towards a Ph.D. at the University of Pennsylvania. Mr. Farkas joined RCA in 1958, and his work has included the shipboard radar stabilization computer in conjunction with the radar scan and acquisition problem. This work included both analog and digital computer simulation of various portions of the DAMP system. He was responsible for the initial establishment of DAMP data reduction procedures and for the analysis of missile cross-section data. He is currently working on statistical radar techniques in conjunction with tracking and satellite navigation systems.

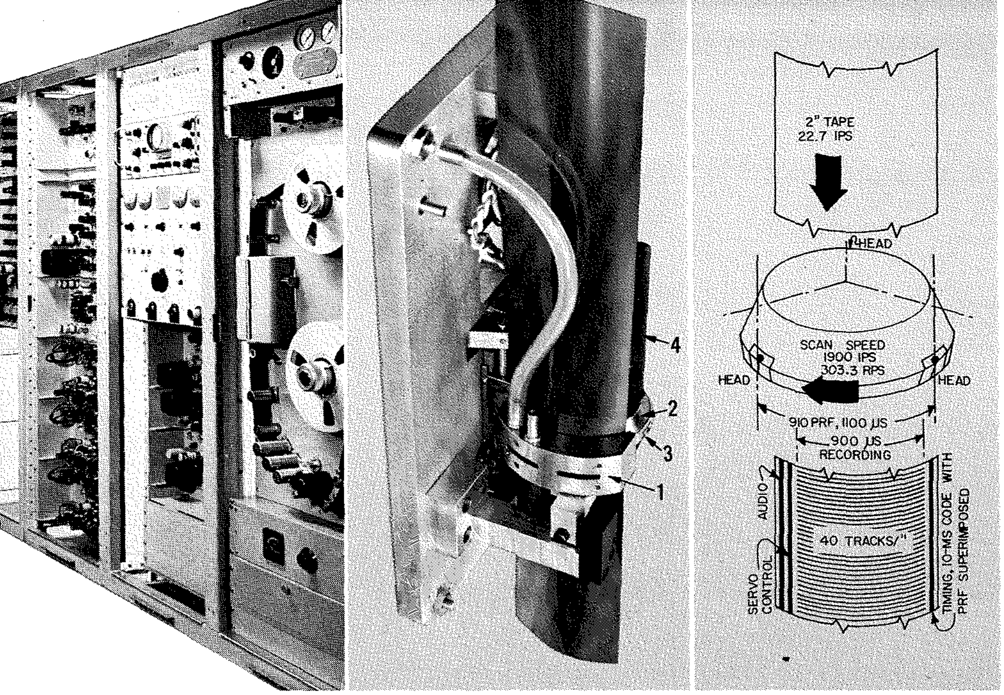


Fig. 1—Left to right: DAMP recorder equipment racks. Scanning head, showing (1) vacuum shoe holding 2-inch tape in contact with (2) head wheel; (3) one of three record-playback heads; (4) head-wheel motor. Head-tape relationship and tape format.

A RADAR VIDEO RECORDER FOR DAMP

by **F. E. SHASHOUA and W. R. ISOM, Mgr.**
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IN THE EARLY stages of the Down-range Anti-ballistic-missile Measurement Program (DAMP), there arose an immediate need for a recorder capable of accepting six 4-megacycle channels of information from two FPS-16 radars. This radar normally operates in two modes, one at a pulse-repetition frequency of 285, and the other at 910. A recording time of 15 minutes was required. Since the equipment had to be installed in the USAS *American Mariner* within three months, it was decided to modify a commercial video recorder.

In essence, the commercial video recorder is a 4-megacycle equipment making use of a high head-to-tape speed of 1600 inches per second. This high tape speed is achieved by transverse-scanning a 2-inch-wide tape at the rate of 960 scans per second, or 64 scans per inch of linear tape speed. The scanning assembly consists of a head wheel 2 inches in diameter, with four heads equally spaced about its circumference. In operation, the tape is constrained so that its width is in direct contact with 90° of the head wheel. The rotation of the head causes the tape to be scanned successively and continuously by the four heads. With a head wheel speed of 14,400 rpm and a linear tape speed of 15 inches per second, 64 tracks per inch are scanned at a head-to-tape speed of 1600 inches a second. This is sufficient to record the 5-megacycle carrier frequency of the 4-megacycle video signal.

MODIFICATIONS NECESSARY

Drastic modifications and redesign of the basic commercial video recorder were necessary. First, the commercial version was a single-channel recorder, but six channels were needed for DAMP. The duty cycle of each of the six channels was limited to approximately 60 microseconds at both pulse-repetition-frequency rates. The duty cycle, however, was simultaneous for all six channels. To solve this problem with a single channel, time-division multiplex was selected. Each of the five channels following the first one was delayed progressively so that the one channel of the recorder was adequate for all the information. Either a quartz delay line or a multichannel magnetic drum could have accomplished the time-division multiplex, but the immediate availability of the quartz delay line recommended its choice. Signal attenuation resulting from this method of delay was regarded as a problem of less magnitude than that of designing and building a multichannel magnetic memory drum.

The DAMP tape format is shown in Fig. 1. A tape speed of 22.7 inches per second was required, instead of 15 inches per second, to allow for a wider transverse track width of 20 mils, instead of 12 mils. The center-to-center track spacing of 15 mils was increased to 40 mils, and the usual 64 tracks per inch reduced to 40. This change was calculated to give a 3- to 6-db advantage in signal-to-noise ratio. Three heads were used on the scanning wheel instead of four, to take full advantage of the fact that the radar signal is pulsed and not continuous. The scanning-head wheel speed was increased to 18,000 rpm from the 14,400 rpm of the commercial machine. A 10½-inch reel of tape gave 32 minutes of playing time, which satisfied the 15-minute requirement.

PROBLEMS AND SOLUTIONS

Meeting the delivery schedule was the number-one problem. Its solution was the full use made of the prior development and design work on the commercial recorder and quartz delay lines.

Delay Lines

The use of the quartz delay line caused a 36-db attenuation of the 40-megacycle carrier signal. On top of this, the f-m carrier signal was very narrowly deviated (2½ percent). In the overall system, it was advantageous to use the quartz delay line with the narrowly modulated 40-megacycle carrier before it was translated down to 5 megacycles for recording on the tape. A 36-db attenuation of the delay lines required the development of a *Vari-Cap* modulator. (The standard reactance-tube approach to the design of the modulator was not feasible.) The Vari-Cap modulator resulted in satisfactory signal amplitude. A great deal of effort was spent to determine the linear operating region of the modulator and the equalization of its response characteristics to obtain the necessary flat output.

Signal Multiplexing

The time-division-multiplex system superimposed on the video recorder was simple in concept (Fig. 2). Following each radar "bang," six signals appear simultaneously at the input of the recorder: *reflected-pulse radar 1, azimuth error 1, elevation error 1, reflected-pulse radar 2, azimuth error 2*, and *elevation error 2*. Reflected-pulse radar 1 is recorded directly. The others are progressively delayed and recorded serially in a time slot of 100 microseconds for each. Thus, reflected pulse 1 is in the 0-to-100-microsecond time slot; azimuth 1 in the 100 to 200 slot, etc. While 60 microseconds would have been sufficient to accommodate the rate, 100 microseconds was used, an easy-operating margin to accommodate irregularities introduced by transients. The synchronizing generator for the delay line, the recorder, and the radar system were common. This simplified the system tremendously, particularly the servo problem.

As stated, a time slot of 60 microseconds would have been sufficient for the recording of the signal return in any condition. However, at a pulse repetition frequency of 910, there are approximately 1100 microseconds between bangs. By reducing the number of heads on the scanning wheel to three and increasing the head-wheel speed to 18,200 rpm, each head is in contact with the tape for about 1000 microseconds. Allowing for auxiliary longitudinal tracks along the tape edges (Fig. 1), a recording time of about 900 microseconds is available, ample for the six 100-microsecond signal slots. Thus, the radar returns are synchronized so that six simultaneous returns are put in corresponding 100-microsecond slots during this 900-microsecond segment.

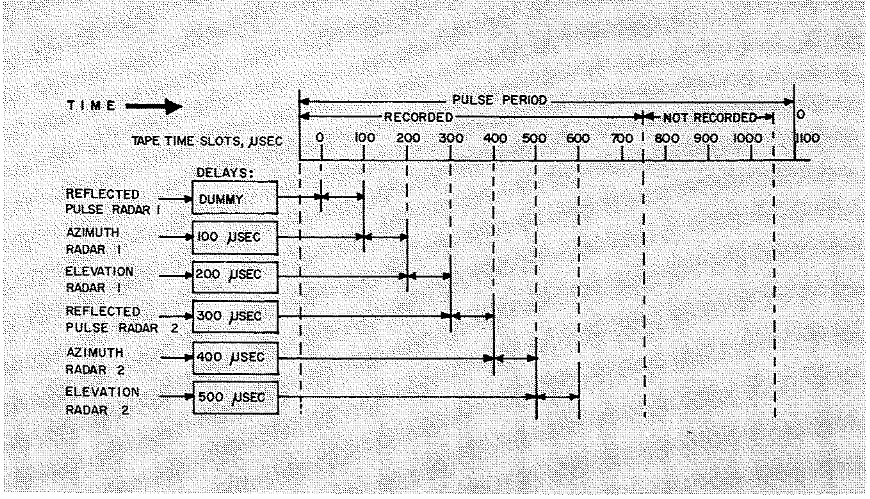


Fig. 2—Time-division multiplexing of video channel.

Scanning Technique

The use of three record-playback heads instead of four was advantageous in accommodating a pulse repetition frequency of 285. By the simple expedient of using only one out of every three time segments for the recording of the lower repetition frequency, the system was made almost compatible. The servo system of the recorder was required to handle as a reference frequency the pulse repetition frequency of 910, which was synchronously recorded by three transverse recording heads on the scanning wheel. This gave a once-around scanning wheel speed of 303.3 rps. To accommodate a frequency of 285, only one of the three heads was used, with the head wheel slowed down from its 303.3 to 285 rps. The attendant poor utilization of the tape (one tape scan utilized, two tape scans left bank) was a small price to pay for the compatibility between two pulse-rate frequencies. The crystal-controlled reference oscillator for both the recorder and the radar has a dual-channel output reference, one at 910 cps and the other at 285 cps. For control of the head wheel and the capstan of the tape recorder, the 910 figure was divided by three to give a 303.3 reference standard for the servos. The 285 reference was used directly. A simple switch between the two tape-recorder servo reference standards constituted the only servo modification needed. A tape-tension idler was added to ensure constant tension, a necessary requirement for high reliability.

As in the commercial video recorder, the control, timing, and audio tracks were placed longitudinally along the tape edges (Fig. 1). The timing track, required for the reduction of the recorded information, was multiplex with the pulse repetition frequency. The audio log track has proven valuable for orientation during analysis, and for correlation between the output displays.

OPERATION

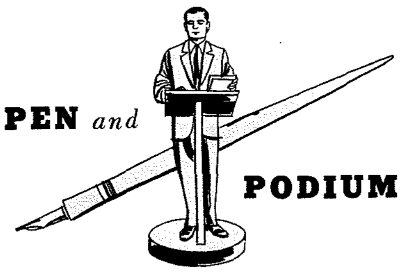
The DAMP version of the recorder has been used in down-range tracking of missiles and their re-entry into the atmosphere. In these operations, the characteristics of the radar and of the missiles are fully known, and opportunity is afforded for a complete calibration of the reflected radar signal. With this calibration, a meaningful study can be made of the effects of the unknowns on the reflected signal. The availability of video information for such study gives several orders of new detail with which to work. As yet, this great mass of information has not been completely assimilated. The fine structure detail has not yet been fully interpreted. However, some information is beginning to shape up concerning ion sheath, shock wave, and vehicle attitude. The capability of the system is presently limited by the ability to interpret.

The recording of radar video has given a new tool for a more-precise reconstruction of the complete radar picture from targets both inside and outside the world's atmosphere. At the moment, the recording equipment — the data collection — is ahead of data reduction. This may be the condition for some time to come. The present equipment is the first of more-sophisticated collection devices that can be built employing the art of video recording. Another such device is a helical-scan recorder for simultaneously recording six continuous channels of radar video to give a more-complete coverage of the radar spectrum. The value of this technique has been demonstrated by a preliminary development program at RCA. This technique recently came into the news through its use, also, in Japan for commercial video.

A large measure of credit for this program is due R. C. Wilcox and J. R. Hall. Others making significant technical contributions include J. Heizer, C. Lauxen, and F. Lee of DEP Applied Research; and K. Solomon of ASD. Special appreciation is extended to M. Fink and J. N. Niewenhouse of M & SR for coordination and to the TV Terminal Equipment Group of IEP for information on the commercial recorder.

F. E. SHASHOUA, Leader, Recording Systems, received his BSEE from Faraday House College, England, in 1952 and his MSEE from Newark College of Engineering in 1954. Since joining RCA in 1956, he has developed a variety of high-speed precision servomechanisms used on the Quadruplex Video Tape Recorder and on military magnetic-drum systems. He has also developed a multi-loop wideband servo system with a response beyond 120 cps. He participated in the systems study of the DAMP recorder. He has prime responsibility for the video record and playback amplifiers and for all the servomechanisms. More recently, he has been active in the systems development of a miniaturized wideband video recorder and a companion processing unit. He is a member of the IRE, an Associate of AIEE, and a graduate of the IEE (England), and has a patent pending.

W. R. ISOM received his BS from Butler University in 1931, and taught there from 1937 to 1944, when he joined RCA at Indianapolis. He developed the first commercially available TV film projector and many special mechanisms for kinescope recording equipment for advancing film during the vertical blanking time of a TV system, and for sound-recording equipment for both films and magnetic tape. His most recent work has been the development of precise, high-velocity, large-capacity magnetic-recording systems using tape, drums and disks. He has pioneered the use of air bearings, air suspensions, and air-floated heads for video recording, tape and drum memories, and military tape and drum systems for broadband recording and radar data processing. He was instrumental in expanding the advanced environmental-test facilities of RCA. His group also has been responsible for heat-transfer and temperature-control developments in electronic equipment, and advanced mechanical devices, including stabilized platforms and gyroscopes. Mr. Isom is a fellow of SMPTE and a Senior Member of the IRE.



Based On Reports Received Over a Period of About Two Months

INDUSTRIAL ELECTRONIC PRODUCTS

Camden, N. J.

Television Tape Recording: Principles and Present Practice

A. H. Lind. New York City SMPTE Conf. Feb. 10, 1960. Principles, highlights, and future considerations involved in television tape recording.

A Tunnel Diode Tenth Microsecond Memory

M. M. Kaufman. IRE Nat'l Convention, Waldorf-Astoria Hotel, New York City, March 24, 1960. A type of tunnel diode memory cell believed to be practical for a large (approx. 10^5 bits) memory has been developed. This memory cell is a baseband destructive "read" type with a resistor loaded tunnel diode and a transformer coupled output.

Improving TV Picture Quality Through Phase Equalization

R. S. Jose. Nat'l Assn. of Broadcasters Convention, Chicago, Illinois, March 7, 1960. The factors causing phase or time delay distortion are reviewed and the effects on picture quality are illustrated.

New 5000 Watts High Efficiency AM Transmitter Type BTA-5T

I. R. Skarbek. *Broadcast News*, March, 1960. A third harmonic resonant circuit of the final amplifier modifies the instantaneous plate-current plate-voltage waveform of the conventional class C amplifier permitting 90-92% stage efficiency.

The Micromodule Program

J. Wentworth and D. Mackey. IRE Micro-Circuits Symposium, Univ. of Pa., Jan. 20, 1960. Progress and status are reviewed, and the relationship of micromodules to "solid-state" approaches is realistically evaluated and found compatible.

Description of the Tunnel Diode and Its Applications

J. W. Wentworth. *Field Engineers' Electronics Digest*, Vol. 8-1, April, 1960. A comprehensive discussion on tunnel diodes, with a minimum of mathematics, and includes materials used in the construction, typical application and the performance characteristics under various applications.

TV Automation

F. R. McNicol. NAB Convention, April 6, 1960. Important steps in the development of automation of the program assembly function as a promising approach to cost reduction in operation of a TV station.

Improvements in Television Cameras

J. H. Roe. NAB Convention April 6, 1960. Significant improvements in TV camera performance.

HOME INSTRUMENTS

Cherry Hill, N. J.

Lamp and Receptacle Provide Standby Power and Appliance Checker

J. B. Powell. *Electronic Design*, Vol. 8, No. 1, pg. 112. An accessory for bench work used to check for short circuits and continuity.

DEFENSE ELECTRONIC PRODUCTS

Camden, N. J.

Communications in High Intensity Noise

W. Meeker. IRE Professional Group on Audio, WCAU Studios, Philadelphia, Pa., Feb. 17, 1960. Problems of communicating in high-intensity acoustical noise and methods of calculating speech intelligibility.

Weapons System Support

D. B. Dobson. NAECON, Dayton, Ohio. May, 1960. Responsibilities of Weapons System Support and their effect on a hypothetical system.

Study to Determine Critical Environments Encountered by High Altitude Vehicles

B. V. Wacholder and E. Fayer. Effects of the environments on vehicles and equipment operating on the fringes of the earth's atmosphere and beyond to the surface of the moon. April 6-8, 1960 Meeting of the Institute of Environmental Sciences, Los Angeles, California.

Reliability Prediction . . . Its Validity and Application as a Design Tool

T. C. Reeves. 5th Design Engineering Conference, New York City, May 24, 1960. A survey of predictive techniques for the designer of complex equipment and systems where procedures for reliability prediction are not in common use.

Resistor Reliability-Capability Analysis

B. R. Schwartz. 6th Nat'l Symposium on Reliability and Quality Control, Washington, D. C., Jan. 11-13, 1960. A new concept in obtaining specific reliability data based on test results developed during vendor quality assurance test programs.

Practical Maintainability Numerics

M. P. Feyerherm and H. W. Kennedy, Jr. 6th Nat'l Symposium on Reliability and Quality Control, Washington, D. C., Jan. 11-13, 1960. Maintainability indices and numerics which the electronic design engineer can use in improving the maintainability of his equipment.

Design Reliability Analysis—A Proven Technique for Production Control and Enhancement

H. L. Wuerffel and D. I. Troxel. 6th Nat'l Symposium on Reliability and Quality Control, Washington, D. C., Jan. 11-13, 1960. Modern weapon systems and equipments have achieved reliability gains as high as 50 to 1 over W. W. II equipment and 10 to 1 over 1950 equipments.

The Operational Support of Space Vehicle Missions

H. S. Dordick. American Astronautic Society—6th Annual Meeting in New York City Jan. 21, 1960. Support requirements and factors for space vehicle systems such as logistics, test equipment training devices and preventive maintenance routines are analyzed.

Applied Systems Support Concepts

J. S. Williams. NAECON, Dayton, Ohio, May 2-4, 1960. A basic electronic systems support concept and its application to specific types of ground, airborne, satellite, and space systems.

Servomechanism Fundamentals

H. Lauer, R. Lesnick, and L. E. Matson. A revised edition published by McGraw-Hill Book Co. of New York includes a greatly expanded portion on transfer-function methods as applied to linear servos, following a basic introductory study of their transient behavior.

Dry Circuit Evaluation of Mechanical Connections

J. W. Kaufman, H. R. Sutton, A. V. Balchaitis, and W. R. Matthias. April issue of the *Electrical Manufacturing* Magazine. Identification, definition and development of instrumentation to reliably evaluate electrical contacts used in connectors on BMEWS.

Moorestown, N. J.

Design Review

G. J. Armbruster. 6th Nat'l Symposium on Reliability and Quality Control, Washington, D. C. Jan. 11-13, 1960. Reviews the working relationships between design and review personnel and its effectiveness.

Reliability Models

P. R. Gyllenhaal. IRE-PGRQC, Presidential Apartments Feb. 2, 1960. A procedure for developing a septum reliability model.

Organization of a Parts, Materials and Process Operation

L. Jacobs. IRE Prof. Group on Components, Jan. 11, 1960, Los Angeles. An activity to investigate, test, standardize and review the application of parts, materials and processes for military electronic equipment.

Quality Control and Reliability on a Major System Project

R. H. Baker. Standards Engineers Society, Engineers Club, Philadelphia, Pa., Jan. 25, 1960. Operation of a reliability and quality control group on a large systems project and discussion regarding standardization actions which are being accomplished.

Charts Ease Amplifier Calculations

Roy. A. Henderson. *Electronic Industries*, December, 1959. Graphs of plate efficiency and plate voltage swing, pulse duration (Theta), pulse shape (Alpha), and plate current ratios are presented for class C amplifiers, doublers and triplers.

The Use of FM in Correlation Radar

W. Blau. BMEWS Systems Conference, RCA Moorestown, N. J., Jan. 11, 1960. Long pulse sinusoidal FM is employed in a radar system exhibiting high combined range-velocity resolution. The correlation output has a bandwidth which is compressed to the AM pulse spectrum for a target in the range gate.

A Practical Parametric Amplifier Design and Its Application to Monopulse Radar

J. A. Luksch. Masters Thesis submitted January, 1960 to the Moore School of Engineering, Univ. of Pa. Theoretical considerations and experimental results are presented concerning the design of a uhf parametric amplifier and its operation in a monopulse radar.

Patents Granted TO RCA ENGINEERS

Based on Summaries Received over a period of about two months

INDUSTRIAL ELECTRONIC PRODUCTS

Printing Mechanism
2,919,641—Jan. 5, 1960; F. W. Pfleger

Signal Detecting Circuit
2,920,239—Jan. 5, 1960; W. Saeger

Semi-Conductor Trigger Circuits
2,921,206—Jan. 12, 1960; M. C. Kidd

Simplified Two-Channel Multiplex System
2,921,981—Jan. 19, 1960; M. C. Kidd

Phonograph Apparatus
2,921,992—Jan. 19, 1960; J. D. Bick

Information Handling Device
2,920,313—Jan. 5, 1960; D. L. Nettleton and L. Bensky

Method of and System for Storing Data Magnetically
2,926,338—Feb. 23, 1960; D. L. Nettleton, A. Beard (DEP), and L. Bensky

Synchronizing Signal Separation
2,923,766—Feb. 2, 1960; R. W. Sonnenfeldt

Color Television Matrix Amplifier
2,924,648—Feb. 9, 1960; A. C. Luther, Jr.

Modulation System for Transmitters
2,924,791—Feb. 9, 1960; C. J. Starner

Sawtooth Wave Generator
2,926,284—Feb. 23, 1960; M. B. Finkelstein, and H. C. Goodrich (Home Instruments)

Film-Television Editing System and Method
2,927,154—March 1, 1960; W. V. Wolfe and T. C. Sharp (Hollywood)

Motion Picture Film Editing System
2,927,153—March 1, 1960; J. J. Askins and H. A. Young (Hollywood)

DEFENSE ELECTRONIC PRODUCTS

Memory Reading System
2,925,588—Feb. 16, 1960; I. H. Sublette and L. S. Bensky (Camden)

Information Handling Device
2,925,589—Feb. 16, 1960; E. J. Schmitt (Moorestown)

Voice Coil Structure
2,925,541—Feb. 16, 1960; W. R. Koch (Moorestown)

HOME INSTRUMENTS

Automatic Gain Control with Variable Resistance Device in Antenna Circuit
2,923,816—Feb. 2, 1960; J. B. Schultz

Notch Filter in Brightness Channel of Color Television Transmitter
2,921,121—Jan. 12, 1960; G. L. Grundmann and R. W. Sonnenfeldt (IEP)

ASTRO-ELECTRONIC PRODUCTS

Tachometer
2,927,268—March 1, 1960; F. F. Shoup and T. E. Haggai

ELECTRON TUBE DIVISION

Servo-Motor Hoisting and Handling Apparatus
2,924,429—Feb. 9, 1960; M. R. Weingarten and R. M. Hollinger (Lancaster)

Electron Tube Mount
2,921,209—Jan. 12, 1960; A. W. Bloom and R. K. Wolke (Harrison)

RCA RECORD DIVISION

Coated Phosphor Particles
2,920,003—Jan. 5, 1960; J. A. Davis, (Marion, Ind.)

RCA LABORATORIES

Magnetic Switching Systems
2,927,307—March 1, 1960; J. A. Rajchman

Burlington, Mass.

An Error Minimization Technique For Sampled-Data Systems
C. W. Steeg, Jr. and A. F. Engelbrecht. IRE 7th Region Conf. and Electronics Exhibit, Seattle, Wn., May, 1960. The increased significance of sampled-data in control systems has emphasized the desirability of transferring well-known techniques for continuous systems into methods applicable to discrete systems.

ELECTRON TUBE DIVISION

Harrison, N. J.

Hi-Fi Applications of New Triode-Pentode
W. M. Austin, *Electonics World*, Jan. 1960. Applications of the RCA-7199, a miniature medium-mu triode — sharp-cutoff pentode specially designed for use in high-fidelity audio equipment.

Versatile Modulator
P. Koustas. *Radiotronics*, Jan. 1960. A modulator which furnishes audio power between 25 and 100 watts and can modulate 100% any r-f input power up to 200 watts. The modulator uses RCA-6146 vhf beam-power tubes in the output stage.

Nomographs for Modification of Electron-Tube Dimensions
R. D. Reichert. *Electronic Industries*, Jan. and Feb., 1960. Present nomographs to determine physical tube dimensions, provided dimensions and electrical characteristics of a tube of the same general class are already known.

A New, Rugged, Ceramic Penecil Tube for Class-C Service
C. J. Gurwacz. AIEE Winter General Meetings, New York City, Feb. 1-5, 1960. Mechanical and electrical design features of the RCA-7554, intended for class-C amplifiers and frequency-multipliers up to and above 1000 megacycles, and for c-w oscillators up to and above 3000 megacycles.

Design Considerations for Modulators and Converters Using a New Miniature Beam-Deflection Tube
M. B. Knight and J. T. Maguire. AIEE Winter General Meetings, New York City, Feb. 1-5, 1960. Unique design features of the RCA-7360—a new beam-deflection tube providing output currents which are a function of the mathematical product of two input signal voltages.

Lancaster, Pa.

Luminescence
G. E. Crosby. Roddy Science Society at Millersville State Teacher's College, Jan. 12, 1960. Differentiates the several kinds of luminescence and describes the emitting characteristics of various types of phosphors.

Chemistry in Color Television
D. T. Copenhafer, Jr. *WGAL-TV*, Lancaster, Pa. Feb. 7, 1960. The role of the chemist in the design, manufacture, and quality control of color-television equipment.

SEMICONDUCTOR AND MATERIALS DIVISION

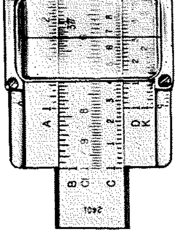
Somerville, N. J.

New Semiconductor Materials and Tunnel Diodes
E. O. Johnson. Main Line Cleveland, Inc., Cleveland, Ohio, Jan. 13, 1960. Relative merits of various semiconductor materials with respect to their use in tunnel diodes, including electrical characteristics and possible applications of tunnel diodes.

Tunnel Diodes
D. J. Donahue. N. N. J. IRE Section Meeting, Montclair, N. J., Jan. 13, 1960. The theory of operation, design features, and possible applications of newly developed RCA tunnel diodes.

Determination of Dislocation Densities in Silicon Crystals by an Optical Method
G. Eckhardt and S. Lederhandler. American Physical Society Mtg., New York City, Jan. 27-30, 1960. A photometric method for the determination of dislocation densities in silicon crystals prompted by an observed correlation between dislocation density and crystal residual stress.

A Two-Transistor Regenerative Receiver for 80 and 40 Meters
E. M. Washburn. *RCA Ham Tip*, Jan.-Feb. 1960. A miniature "Ham" receiver using two RCA-2N247 p-n-p "drift" transistors.

Engineering  NEWS *and* HIGHLIGHTS

RCA LABORATORIES ANNOUNCES 1959 ACHIEVEMENT AWARDS

The RCA Laboratories has announced the following recipients of its Achievement Awards for 1959:

Rubin Braunstein: *for contributions to the understanding of energy-band structures of semiconductors through optical studies.*

David Kleitman: *for development of means for preparing high-efficiency evaporated phosphor films.*

Murray A. Lampert: *for theoretical studies leading to greater understanding of the behavior of charge carriers in solids and gases.*

Herbert Nelson: *for the development of techniques for fabricating semiconductor devices with high performance and uniformity.*

Kerns H. Powers: *for contributions to the theory and practice of error-correction, coding, and modulation techniques.*

Leonhard F. Reinhold: *for the development of practical processes related to magnetic tape.*

Benjamin Abeles and **George D. Cody:** *for team performance in the development of a superior technique for measuring the thermal conductivity of semi-conductors at high temperatures.*

Richard W. Ahrons, William L. Behrend, Walter G. Gibson, and **Edwin M. Hinsdale, Jr.:** *for team performance in developing apparatus for improved tape-recording of color television.*

William H. Fonger and **Michael Kestigian:** *for team performance in research leading to a substantial improvement of the efficiency of vacuum-tube heaters.*

Imre J. Hegyi and **Egon E. Loebner:** *for team performance in synthesis of high-energy-gap III-V semiconductors.*

Paul G. Herkart and **Leonard R. Weisberg:** *for team performance in research leading to greater understanding and significant improvements in the synthesis of gallium arsenide crystals.*

Gerald B. Herzog, Morton H. Lewin, Henry S. Miller and **James C. Miller:** *for team performance in research on ultra-fast computer circuits.*

Hendrik J. Gerritsen and **Henry R. Lewis:** *for team performance in research leading to new maser materials and high-frequency masers.*

David F. Martin, Arthur Miller, and **Arthur I. Stoller:** *for team performance in research on new materials for magnetic tape.*

John Bruce Rankin and **Oakley M. Woodward, Jr.:** *for team performance in developing an electronically steerable radial-waveguide antenna.*

SARNOFF FELLOWSHIPS AWARDED TO TEN RCA MEN

Ten RCA men have been awarded David Sarnoff Fellowships for graduate study in 1960-61. These grants, which include full academic fees, a stipend of $2500 to $4000 depending on marital status, and a $1000 gift to the school, are for one academic year, with the recipient eligible for reappointment.

Three of the current awards are for the second year, and went to: **I. Bernal,** RCA Laboratories, Princeton (Ph.D., Physical Chemistry, Columbia University); **S. M. Marcus,** DEP, Camden (Ph.D., Physics, University of Pennsylvania); and **C. W. Rector,** Electron Tube Division, Lancaster (Ph.D., Physics, Johns Hopkins University)

The seven new appointees are: **C. L. Becker,** DEP, Tucson, Arizona (Ph.D., E.E., University of Arizona); **I. J. Fredman,** RCA Service Company, Riverton (Ph.D., Mathematics, Princeton University); **J. C. Miller,** RCA Laboratories, Princeton (Ph.D., E.E., Yale University); **S. Skalski,** Semiconductor and Materials Division, Somerville (Ph.D., Physics, Rutgers University); **H. Anderson,** Electron Tube Division, Harrison (M.B.A., Management, University of Pennsylvania); **A. B. Cerderman,** DEP, Burlington, Mass. (M.B.A., Harvard Business School); and **S. J. Corpora,** National Broadcasting Company, New York (Master of Fine Arts, Yale University).

RCA 501 INSTALLED AT AEP

An RCA 501 computing system has been installed at the Astro-Electronic Products Division, Princeton, N. J. It will be used in processing of bulk data from satellites, information in natural languages, scientific calculations, and to study test devices to supplement computing system capabilities.

The installation at AEP is the first one to be used for scientific calculations. AEP, in a joint effort with the Advanced Program Activity of the Electronic Data Processing Division, IEP, is developing subroutines and scientific speed-codes which will have universal applicability wherever an RCA-501 system is used. A staff of fifteen engineers and a crew of five professionally trained computer operators are available to aid AEP engineers in the steps necessary in the solution of problems.

CORRECTING OUR ERRORS . . .

In Vol. 5, No. 4, in "Dielectric Ceramics in Electron Tubes," by W. J. Koch and T. F. Berry: on pp. 38-39 the photomicrographs for Figs. 5 and 7 should be transposed, as should those for Figs. 8 and 10, and 11 and 12. Also, in the captions for Figs. 2 through 12, the magnification powers should be 2/3 the values listed. Our thanks to E. C. Hughes, Jr., Mgr., Commercial Engineering, Electron Tube Division, Harrison, N. J., for bringing these to our attention.—*The Editors.*

BEST PAPER AWARD TO GUERBER

H. P. Guerber, of the Electronic Data Processing Division, IEP, recently won a *Best Paper Presentation Award* at the 1960 Winter Convention on Military Electronics, sponsored by the IRE Professional Group on Military Electronics. Mr. Guerber's paper, entitled "AutoData—RCA's Automatic Message Switching System," describes RCA's step into digital data communication systems.

HOLLYWOOD IEP ACTIVITY EXPANDS

The Film Recording Section (IEP) has become a part of the Closed Circuit Television and Film Recording Department, Broadcast and Television Equipment Division, IEP. The Film Recording and West Coast Closed Circuit Television Systems Engineering facilities will remain in Hollywood. Approximately 4000 square feet of additional space has been acquired in the same building from NBC for a model shop, Class A manufacturing, and warehousing. The engineering staff has already been augmented by the addition of one systems engineer, **H. E. Jury;** plans call for the addition of two more during the year.

COMMITTEE APPOINTMENTS

J. L. Pettus, Mgr., West Coast Closed Circuit TV Systems Engineering and Film Recording, IEP, has been appointed Chairman of the Sound Engineering Committee of the Society of Motion Picture and Television Engineers. He has been active in the SMPTE for 21 years and during the last several years has held several positions in the Hollywood Chapter.—*C. E. Hittle*

E. J. Byrum, of Receiving Tube Manufacturing Engineering, Electron Tube Division, Harrison, N. J., has been appointed Managing Editor of the Northern New Jersey IRE Newsletter.—*T. M. Cunningham*

Within Surface Communications, DEP, Camden, N. J.: **P. J. Riley** has been elected Chairman of the IRE Professional Group on Product Engineering and Production, Philadelphia Chapter. He has also been elected to the National Administrative Committee of the PGPEP. **J. Knoll** has been appointed Program Chairman and **W. J. Welsh** (of Missile and Surface Radar, Moorestown) has been elected Secretary of the Philadelphia PGPEP Chapter.—*R. E. Patterson.*

F. J. Hermann, Mgr., Scientific Instruments, IEP, has been elected President of the Philadelphia Chapter of Eta Kappa Nu.

REGISTERED PROFESSIONAL ENGINEERS

W. R. Percivale, Electron Tube Division................Prof. Eng., 11018, N.J.

J. W. O'Neill, Missile and Surface Radar Division.........Prof. Eng., 11044, N.J.

MEETINGS, COURSES AND SEMINARS

IEP ENGINEERING DINNER MEETINGS

IEP has inaugurated a series of Engineering Dinner Meetings, of which two have already been held. The first, on November 4, 1959, included an address by **T. A. Smith,** Executive Vice President, IEP, who discussed "Goals for IEP and the Engineer's Contribution." The second, on January 26, 1960, had as the main speaker **D. H. Ewing,** Vice President, Research and Engineering who discussed the growing problem of foreign competition. All IEP Engineering managers and members of the professional staff were invited. The purposes of the dinners are to provide an opportunity for IEP Engineering personnel to become better acquainted across divisional lines and to present speakers of interest to IEP Engineers.
G. A. Kiessling

PERSONNEL IN RCA

At the invitation of Professor T. C. Helmreich, **John Hirlinger,** RCA ENGINEER Editorial Board Chairman for the Electron Tube Division and Semiconductor and Materials Division, delivered a well-received talk on "The Place and Function of Personnel in RCA" to a class in Industrial Management at Purdue University on March 11, 1960.—*C. A. Meyer*

TELEVISION SEMINAR AT NAB CONVENTION

At the conclusion of the recent National Association of Broadcasters Convention in Chicago, IEP Broadcast Engineers held a two-day seminar, April 7-8, 1960. Lecture topics covered included Transistorized Switching Equipment, Special Effects, New TV Cameras, TV Automation, Film Cameras, Microwave Equipment, VHF Directional Antennas, Audio Tape Recording, Video Tape Recording, Servo Systems, and new FM Transmitters. IEP engineer-lecturers were: **J. W. Wentworth, J. H. Roe, H. N. Kozanowski, H. E. Gihring, A. H. Lind, R. B. Marye,** and **L. E. Anderson.** A similar seminar was scheduled for the SMPTE Convention, Los Angeles, May 6-7.
—*E. T. Griffith*

COLOR AND MONOCHROME TV

L. Whitcomb, Mgr., Electrical Equipment Development Engineering, Marion, was guest speaker at the March 9th meeting of the Marion Subsection of the AIEE. His discussion described transmitted signals, receiver changes, and picture tube differences for color TV systems as compared to black-and-white systems.—*Jan DeGraad*

ENGINEERING LECTURE SERIES AT HARRISON

D. H. Ewing, Vice-President, Research and Engineering, presented the first in a series of lectures of general interest to engineers, sponsored by the Harrison Engineering Education Committee to 300 Electron Tube Division engineers on February 9, 1960. He reviewed the status of research and development in the Far East in general and in Japan in particular. The second lecture April 20, 1960, featured **M. Staton** from Astro-Electronic Products Division speaking on "RCA's Plans for the Electronics Associated with Men in Space."

A special series, to present timely subjects for engineers was inaugurated with a lecture on "Applications at High-Frequency Induction Heating" by Dr. J. F. Libsch of Lehigh University, on March 10, 1960.—*T. M. Cunningham*

ENGINEERS IN NEW POSTS

In the Electron Tube Division, **W. E. Breen,** Mgr., Microwave Manufacturing, announces the appointment of **H. M. Learner** as Superintendent of the new Microwave Special Tube Manufacturing activity, which will produce sample quantities of newly-developed microwave tubes. **J. Gale** has been promoted to Mgr., Methods and Estimates for Microwave Operations. **G. D. Hanchett** has been named Coordinator, Technical Planning for the Electron Tube Division. In Kinescope Operations, **W. J. Harrington** has been appointed Mgr., Development Shop. **J. B. Lovecchio** has been named Mgr., Administrative Planning. At Cincinnati Receiving Tube Operations, **R. G. Ashton** has been named Administrator, Work Simplification and Materials Handling. In Entertainment Tube Products, Lancaster, Pa., **J. D. Ashworth** has been named Administrator, Engineering Administration, Kinescope Engineering, replacing **D. G. Garvin,** who becomes Mgr., Institutional and Laboratory Sales, Government, Industrial Tube Products.

In the Semiconductor and Materials Division, **J. M. Spooner,** Plant Manager, Findlay Plant, announces the following members of his staff: **R. J. Hall,** Mgr., Manufacturing, **R. H. Kramer,** Mgr., Manufacturing Standards, **K. D. Lawson,** Mgr., Plant Engineering, **J. W. Ritcey,** Mgr., Production Engineering, and **H. A. Uhl,** Mgr., Plant Quality Control. For the new Mountaintop, Pa., plant now under construction, **A. E. Mohr** has been named Mgr., Production Engineering by **G. H. Ritter,** Plant Mgr.

In the RCA International Division, **M. E. Karns,** Director, Licensing Operations, announces his staff as follows: **S. S. Barone,** Mgr., Licensing; **R. F. Holtz,** Gen. Mgr., Laboratories RCA, Ltd. (Zurich); **H. W. Johnson,** Mgr., Patent Services; **P. A. Richards,** Managing Director, American Electronics Enterprises Ltd. (Tokyo); **L. A. Shotliffe,** Mgr., Technical Aid Development; **H. A. Strauss,** Special Representative, Licensing; and **E. F. Sutherland,** Mgr., Administrative Services.

In the RCA Victor Record Division, **A. J. Viere** has been named Mgr., Quality Control, for the new Tape Manufauturing Plant in Indianapolis. In the Record Operations Department, **R. A. Boas** is Mgr., Management Engineering and **A. L. McClay** is General Plant Mgr., Manufacturing.

Within Industrial Electronic Products, **F. J. Dunleavy,** General Mgr., Industrial and Automation Division, announces his organization to include: **N. M. Brooks,** Chief Engineer; **S. K. Magee,** Mgr., Food Machinery and Scientific Instruments Department; **I. C. Maust,** Mgr., Detroit Automation Products Dept.; and **M. J. Yahr,** Mgr., Audio Products Dept. Under Mr. Magee, **H. C. Gillespie** is Mgr., Engineering. In Broadcast and Television Equipment Division, **V. E. Trouant,** Chief Engineer, Engineering Dept., announces his organization: **F. C. Blancha,** Coordinator, Mechanical Design; **A. E. Garrod,** Mgr., Drafting; **T. M. Gluyas,** Mgr., Broadcast Studio Engineering; **W. R. Johnson,** Mgr., Engineering Services; **H. N. Kozanowski,** Mgr., TV Product Advanced Development. In the Electronic Data Processing Division, **J. W. Leas,** Chief Engineer, Engineering Dept., announces his organization as: **H. H. Asmussen,** Staff Engineer; **C. M. Breder,** Mgr., Data Processing Engineering Administration; **J. A. Brustman,** Mgr., Engineering Programs and Planning; **H. M. Elliot,** Mgr., Computer Product Line Engineering; **D. L. Nettleton,** Mgr., High-Speed Computer Engineering; and **R. A. Wallace,** Mgr., Mechanical Design and Peripheral Devices Engineering. Also within EDP, **J. N. Marshall** is Mgr., Advanced Systems Engineering and **R. E. Wallace** is Mgr., ComLogNet Project, within the Data Communications and Advance Systems Department. **R. E. Wilson** has been appointed Mgr. of the new industrial electronics plant to be built in Washington County, Pa. He will report to **N. Caplan,** Mgr., RCA Communications Dept., who heads industrial electronics activities in that area.

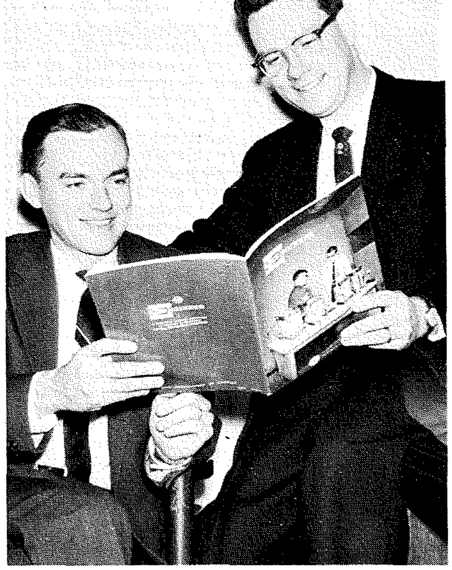
In RCA Victor Home Instruments, **J. J. Toyzer** has been appointed Mgr., Manufacturing Engineering Administration.

In the National Broadcasting Company, Inc., **C. W. Slaybaugh** has taken the position of Director, International Enterprises, and will also serve as Vice Chairman of the Board, NBC International, Ltd.

In Defense Electronic Products, **R. Stalemark** has been appointed a senior member of the staff of the Surface Communications Systems Laboratory. In the Missile Electronic and Control Engineering Department at Burlington, **C. E. Leete** has been named Mgr., Product Assurance, and **Dr. R. C. Seamans** has been appointed to the Scientific Advisory Board of the U.S. Air Force. In the Missile and Surface Radar Division, **C. J. Foskett** has been named Mgr. of the new BMEWS Operations Liaison Office at Hanscome Field in Bedford, Mass. Succeeding him as Mgr. of BMEWS Programming and Manufacturing Coordination is **H. M. Emlein,** formerly Operations Mgr. of the IEP Industrial and Automation Division. In DEP Staff appointments, **L. H. Orpin** has been named Mgr., Planning, and **R. V. Miraldi** Mgr., Management Engineering.

Dr. Victor E. Buhrke leads a seminar of RCA crystallographers from Marion, Lancaster, Harrison, Somerville, Princeton, and Camden, the first of its kind specifically keyed to X-ray applications within RCA. This seminar was under the auspices of the Applications Laboratory, Scientific Instruments, IEP, Camden, N. J., of which Dr. Buhrke is Director. Similar seminars are planned for the future. (See Vol. 5, No. 5, "Why an X-ray Laboratory in Camden," by Dr. Buhrke.)

George Kiessling (left) and RCA ENGINEER Editor Bill Hadlock (right) welcome Sig Dierk as Chairman of the IEP Editorial Board.



Don Garvin (right) discusses an Entertainment Tube Products Dept. article with John Ashworth, new Ed Rep.

RCA VICTOR COMPANY, LTD. JOINS "RCA ENGINEER" ACTIVITIES, NAMES RUSSELL ED REP

The Editors and Advisory Board are particularly pleased to announce that engineers and scientists of RCA Victor, Ltd., Montreal, Canada, are now full-fledged participants in the RCA ENGINEER. Planning is now under way for articles from that area. **Dr. J. R. Whitehead,** Director of Research, RCA Victor Company, Ltd., has named **H. J. Russell** of their Research Laboratories as Editorial Representative.

ENGINEERING MEETINGS AND CONVENTIONS

June 8-11
National Society of Professional Engineers, Annual Meeting, Statler-Hilton Hotel, Boston, Mass.

June 13-15
Radio Frequency Interference Symposium, IRE, Washington, D.C.

June 15-17
American Physical Society, McGill University, Montreal, Canada

June 20-21
Chicago Spring Conference on Broadcast & TV Receivers, PGBTR and Chicago Section of IRE, Graemere Hotel, Chicago, Ill.

June 20-24
American Institute of Electrical Engineers, Summer General Meeting, Chalfont-Haddon Hall Hotel, Atlantic City, N.J.

June 22-24
Electronic Standards & Measurements Conference, PGI of IRE, NBS, AIEE, NBS Boulder Labs, Boulder, Colo.

June 25-July 9
1st Congress International Federation of Automatic Control, PGAC et al, Moscow State University, Moscow, USSR

June 26-July 1
American Society for Quality Control, Chalfont-Haddon Hall, Atlantic City, N. J.

June 27-29
National Convention on Military Electronics, PGMIL of IRE, Sheraton Park Hotel, Washington, D.C.

DIERK NAMED TO HEAD "RCA ENGINEER" ACTIVITIES FOR IEP; ASHWORTH REPLACES GARVIN AS LANCASTER ED REP

In Industrial Electronic Products, Camden, N. J., **Siegried F. Dierk** has been named Chairman of the RCA ENGINEER Editorial Board, made up of seven Editorial Representatives throughout IEP. Concurrently, he was appointed as an Engineering Editor on the RCA ENGINEER staff. These duties form an important part of his new position as Technical Publications Administrator for IEP, to which he was recently named by **G. A. Kiessling,** Mgr., Engineering Standards and Services, who had performed these functions since the transfer of **C. W. Sall** to the RCA Laboratories. (See *News and Highlights*, Vol. 5, No. 5). Mr. Dierk's new responsibilities are well described in this issue on Pp. 2-4.

In the Entertainment Tube Products Department, Electron Tube Division, Lancaster, Pa., **John D. Ashworth** has replaced **Don Garvin** as RCA ENGINEER Editorial Representative. He will serve as a member of the Electron Tube and Semiconductor Division's Editorial Board, whose Chairman is **John Hirlinger.** The Editors extend their best wishes to Don Garvin, who has done a particularly fine job for the RCA ENGINEER.

Siegfried F. Dierk attended the Ohio State University and Drexel Institute of Technology. Upon discharge from the U.S. Air Force, where he worked on airborne radar and navigational equipment, Mr. Dierk joined RCA's commercial digital computer section in 1955. During the following year he assisted in the operational check-out and installation of the System Central of the BIZMAC system. In 1956 and 1957 he participated in the design and development of a digital data processing equipment for a missile program and a military ground-to-air data-link system. Late in 1957, Mr. Dierk entered the technical publications field in the EDP Engineering Publications Group. Here he was responsible for the compilation, writing, editing and production of periodic research reports to the Government. His functions also included the preparation of engineering reports, specifications and proposals as well as visual aids for technical papers and sales presentations. Mr. Dierk is currently attending the Evening College of the Drexel Institute of Technology. He has now assumed the post of Technical Publications Administrator for IEP, with responsibilities for professional papers, activities and Engineering Reports and Memorandums.

John D. Ashworth received an AB degree from Franklin & Marshall College in 1953 and came to RCA in Lancaster the same year. After a short stint as a Factory Supervisory Trainee, he joined the Lancaster Personnel Dept. as Suggestion Administrator. In 1954, he assumed the position of Administrator, Salaried Employment at Lancaster, and in 1956 was named Administrator, Organization Development. He now succeeds Mr. Garvin as Administrator, Engineering Administration, Kinescope Engineering, Entertainment Tube Products.

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RCA ENGINEER

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RCA ENGINEER EDITORIAL REPRESENTATIVES