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RCA ENGINEER

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JOHN D. ASHWORTH

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 with the company by stressing the interrelated nature of all technical contributions.

●

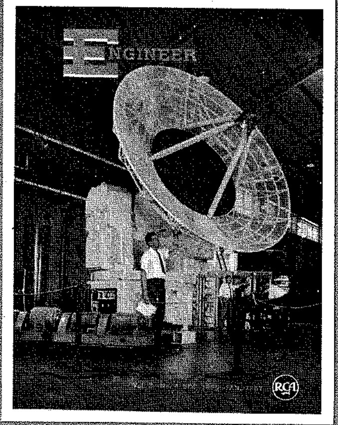
To help publicize engineering achievements in a manner that will promote the interests and reputation of RCA in the engineering field.

●

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 Antenna Pedestal of Instrumentation Radar AN/FPS-16 (XN-2) featured on the cover, is being tested in "DEP's" Heavy Equipment Lab, Missile and Surface Radar Eng., Moorestown, N. J. Standing under Antenna is Paul Levi, one of the Design Engineers. Power drive motor generator system is in left foreground. Azimuth drive motors are in open compartment of pedestal. Oscar Wilsker, a Servo System Design Engineer, is (at left) in front of racks containing azimuth and elevation servo amplifiers. Richard Wood, Jr. (Engineer at right) also participated in this development. For description of Instrumentation Radar, see article by Irving Stokes and David Barton.

DEFENSE ENGINEERING

It has been said that no war is ever fought with the weapons of the last war. It is the job of those who do military planning to decide what weapons to use if our country should be attacked. But while the weapon plans themselves may be shrouded in national security, the trend which defense measures are taking is quite evident. It is in the direction of increasing mobility, range and weapon effectiveness.

As the time factor for action is lessened, as speed of movement is increased, as the range of operation becomes greater, it no longer becomes feasible to depend upon a human brain or a group of brains to control the detailed operation. While human brains will direct broad plans, we must, so to speak, assign to electronics the task of directing and controlling specific parts of the defense action. The tools used for these purposes are sensing devices, communications, data handling systems and computers. Through these means weapons can be assigned, located properly, and made to function with greatest effectiveness. The detailed systems are visible in terms of fire control systems, missile guidance systems, bombing and navigation systems and the like.

The success of electronic control systems is measured in terms of Effectiveness, Cost, Reliability and Operability. Not only must the system do the job in terms of the highest performance to assure superiority, but it must do so at costs which are reasonable, it must be dependable and be capable of being operated by ordinary human beings.

The responsibility for the conception of defense control systems and for their design and implementation falls upon the electronics engineer. This is a grave responsibility indeed, since the defense of our country to a high degree depends upon the kind of job done by electronics engineers. This is a relatively new responsibility also, because the role of electronics was formerly as a component in the defense chain rather than as the directing agency.

Since we in RCA have pledged ourselves to aid in national defense, our role has become more important, more complex and, at the same time more challenging. Our objective, established a number of years ago, was to prepare ourselves for the greater responsibility. We believe that we have done so. Some of the programs we have undertaken have been of long duration and have required a great deal of planning in terms of manpower, facilities and financial requirements. We feel that we have attained the status we have sought and we are currently undertaking programs which are of vital importance for national defense.

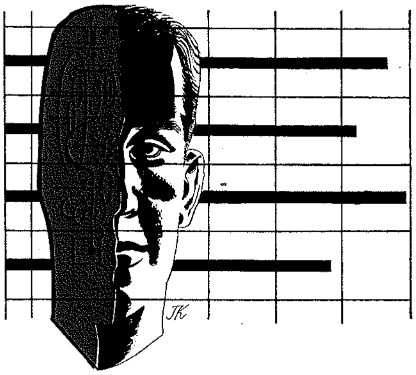
Measured by the results already achieved, of which we are proud, we are confident that RCA engineers will make even greater contributions in the future for the protection of our country and of the American way of life.

T A Smith

Executive Vice President
Defense Electronic Products
Radio Corporation of America

AN INTERROGATORY EVALUATION OF THE CREATIVE MIND

Editor's Note: This article deals with a subject on which many people have expressed opinions. Dr. Pessel, a research and development engineer of predominantly chemical and metallurgical background, has written his conclusions on one aspect of creativity. It is our thought that you would find them as interesting and thought-provoking as we did. We present this article as the personal views of a creative engineer on creativity.



by

DR. LEOPOLD PESSEL

Chemical and Physical Laboratories
Components Division
Camden, N. J.

IF YOU WERE to interview a man for the sole and specific purpose of determining the creative ability of his mind, how would you go about it? What are the components that make up such a mind? What technique of questioning can be applied to evaluate them? And is there a possibility of reassembling them into a composite picture and finding a yardstick to measure it with? All of these are challenging and as yet not entirely solved problems. It may appear presumptuous and hazardous to place the shackles of systematics upon something as evasive and volatile as creativity. However, in order to obtain some sort of frame support for the vague and fluid mental webbing resulting from an interview, it is proposed to assume four basic aspects or components of the creative mind.

1. **Quality.** Is the mind *factual* or *expansive?*
2. **Resources.** What is the stock of mental associations?
3. **Potential.** What is the nature and force of drive?
4. **Direction.** Which guideposts is the mind setting for itself?

QUALITY

It is obvious that such a mind must be active, intense and acquisitive. However, we can distinguish two types of mental acquisitiveness. The factual mind is bent upon acquisition of facts and knowledge, upon deepening them to the utmost, and upon their effective utilization. The expansive mind does not have the urge to acquire knowledge by penetrating into all the depth there is. It will tend to spread horizontally, eager to engulf as many divergent fields as possible and to build associating links as it roams about. Although there are very few wholly creative minds, the expansive mind is usually predominant in the creator of the new. Any origination comes from association of things so diverse that it does not become obvious until pointed out. And the man who does the pointing out is the originator, creator, or inventor. Consequently, and by instinct, his mind seeks more and more objects of association. Hence, the roaming about. This type of mind may go into depth, too, apparently emulating the factual mind, but for a different motive. The factual mind does it for the sake of acquiring more knowledge, the expansive mind in order to possess more nuclei for interassociation. This type of mind will stop harvesting the field when the remaining facts seem no longer interesting from the point of view of new associations. The factual mind will go on collecting facts for the sake of facts and for their usefulness as such.

In the case of the factual mind, acquisitiveness is combined with concentration, logical judgment, definiteness, and a desire for numerical and quantitative information. In the case of the expansive mind, acquisitiveness is tinted by imagination, curiosity, deviation, questioning, doubt, and a desire for qualitative information. As a result, the expansive mind acquires associations between phenomena and observations rather than factual data. Typical characteristics are doubt and questioning. If the associations were firm and definite, they would not be those of the inventor. They have to be loose and multifold, capable of being rapidly broken and re-assembled into new patterns to produce the new and original. This particular "scanning" ability of associating links is probably the keynote quality of the expansive mind.

In the case of an applicant for a professional position, there may be an instinctive desire to stress the factual aspects of his mind at the expense of the expansive ones. For this reason it may be advantageous to explore the quality component of his mind by conversing about topics having no connection with his professional activity.

For example, if a man of factual mind has traveled, he will discuss the important sights he has seen, being proud to point out that there is little of importance he has missed. The man of expansive mind, however, may confess that he has missed many of the important sights, but the trip has become memorable to him by many vague impressions gained on off-the-beaten-path excursions. He will display the elements of curiosity and imagination and will talk about the adventurous and exploratory aspects of traveling rather than about the fact-and-sight-gathering ones.

You may lay before your man a menu from some foreign restaurant, listing both familiar dishes with tempting, well-known names and strange, nondescript items in a foreign language. The factual mind tends to play it safe and select something he knows and is sure of. The expansive mind tends to pick something entirely unknown and having a strange name, "just for the heck of it."

You may have on hand reproductions of art, possibly of the controversial modern type. The factual mind will be quick to express a like or dislike. The expansive mind will tend to be uncertain, will see both good and bad, or may even venture to discuss how he would have approached the subject.

The conversation may turn to personalities, people that may have been unsuccessful in their task. The factual mind will be quick and decisive in pointing out the salient causes of the failure. The expansive mind will be much less sure. He will try to uncover some of the more hidden facts and connections behind the case and he is bound to express his belief that the matter may not be entirely closed.

Finally, you may wish to discuss the approach to a difficult and challenging research problem—again unconnected with the applicant's proposed field of activity. The factual mind will stress the acquisition of facts and basic knowledge. To the expansive mind, the need for a radically new approach and for invention will be instinctively more important and he will stress this aspect more than any other.

The elements of imagination, curiosity, urge for exploration of and mental engagement in strange and unfamiliar fields should reveal themselves in a conversation of the indicated character. The supply of topics usable for this purpose should be unlimited.

RESOURCES

Expansiveness of mind results in the accumulation of a fund of mental contacts, experiences, integrations, and associations, as well as factual knowledge. This fund constitutes the mind's resources. In the factual mind, which tends towards specialization and depth, factual knowledge will constitute the bulk of these resources. In the expansive mind, which tends towards versatility and breadth, the other factors just indicated will predominate. The individual having such a mind will be inclined to be a man of many hobbies, a man of diverse interests or of many skills, a perpetual student of many, sometimes only remotely connected, subjects. Like a butterfly fluttering from bloom to bloom and just sipping the easily obtainable nectar, the expansive mind will reach for the treasures of association predominantly concentrated at the surface of any subject, leaving the underlying bulk of solid facts to the specialist, the factual mind. This trait accounts at least partly for the well-known fact that a genius shows eminence in several, sometimes unrelated, fields. His vast fund of associations leaves its mark of imagination and originality on whatever he undertakes.

Part of the resource component of the expansive mind is the accumulation of factual knowledge of the experience type as distinguished from the book-study type for which it often constitutes a replacement. Factual-experience knowledge, coupled with the other components, is one of the most powerful tools of the successful creative mind. It is an important component and fountain for Direction to be discussed later.

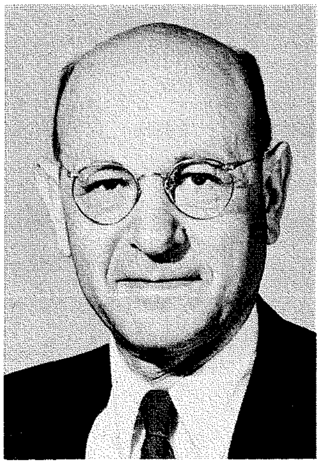
It is a relatively simple matter to uncover the extent of the resource component in an individual, and little needs to be said about the conversational technique. However, it is suggested that an attempt be made to link at least two entirely unrelated subjects out of the store of the man's interests and to observe his ability and tendency to form linking associations spontaneously and on the spur of the moment.

POTENTIAL

Potential indicates the driving force and the motives propelling the mind into productive action. For the factual mind, the predominant goal is success of the undertaking. The expansive mind is primarily interested in the synthesis of something new and not previously attained. The factual mind will not be satisfied until his work is perfect—or, if it is not, he will have some valid reason for it. In the expansive mind, there is often a saturation of interest when the novelty of a principle or of a creation or an invention has been demonstrated. Completion and refinement are often looked upon as burdensome chores. The motives of the factual mind are interest, professional pride, satisfaction of accomplishment, or just a sense of duty. They are always well under control and readily diverted to something else,

LEOPOLD PESSEL received his PhD degree in Physical Chemistry at the University of Vienna and also has a diploma in E. E. from the Drexel Institute Evening School.

Dr. Pessel was formerly Technical Director for the Metals Coating Co. of America and has been connected with the Chemical and Physical Labs, RCA, Camden, for the past 16 years, engaged in chemical and metallurgical research and development. Dr. Pessel has 45 patents to his credit. He is a registered professional engineer in Pennsylvania and a member of RETMA Committees on Solderability of Components and on Printed Wiring, the American Chemical Society, the American Inst. of Mining and Metallurgical Engineers, the National Association of Corrosion Engineers, the Philadelphia Mineralogical Society, and the Aircraft Owners and Pilots Association.



if deemed desirable. The expansive mind is driven primarily by the thrill of creation and by enthusiasm, motives which are not easily controlled and may carry him further and longer along an unsuccessful or impractical path than is desirable. The factual mind experiences few failures, the creative mind many—but the expansive mind always comes back for more.

The factual mind will be somewhat embarrassed by failures, the expansive mind will be almost proud of them. This difference in mental attitude is so distinct that it may well serve as a keystone in interrogation. Ask the man to tell you about those undertakings of his which have failed! Watch for the element of enthusiasm. Watch for his ability to bounce back in the face of disappointment! These mental traits are mainsprings of an expansive mind. They are evident in early life and are never lost, no matter how old the individual. They account for the apparent agelessness of a genius and his ability to create up to the most advanced age. While there is no yardstick to measure potential or drive of the creative individual, its presence and degree of intensity will quickly reveal itself in a discussion of the man's motives, past and present, and of his ambitions for the future.

DIRECTION

While Quality, Resources, and Potential give substance and life to our chimerical Creativity, it would grow wildly, uselessly, or even destructively like a cancer unless there is present a fourth component termed Direction. It encompasses all controlling and regulating factors and guideposts which direct the creative mind into constructive, useful, and successful completion of a creation. Direction may not be an intrinsic component of creativity, but it is here given this rank because it is inseparably linked with creative effectiveness. Direction is composed of background factors such as factual experience knowledge, responsibility, maturity, judgment.

Some measure of a man's direction component is obtained by a conversational slant towards realism, responsibility, and a sense of completion and fulfilment. If the man has been professionally active in the past, a review of his reports, publications, patents, and the like should be solicited, but added to this should be all accomplishments of record, no matter how distant or unrelated to his proposed field of work. The man should be encouraged to speak freely of his accomplishments, staying within the boundaries of truth, of course. By being urged to talk, without any inhibition, about anything he feels has been an accomplishment, irrespective of whether it has been acknowledged as such by others, he will reveal the realistic guide posts of his direction component.

FORMATION OF THE COMPOSITE PICTURE

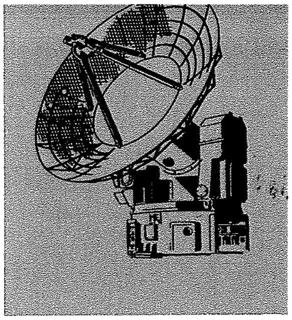
While the questioning may be planned to explore each of the four components separately, all of them will reveal themselves, to a certain extent, at all phases of the interview. The interrogator will have to devise his own method of keeping score. There is, of course, no possibility of rendering the results of the analysis in quantitative or numerical terms. It might be feasible for the interviewer to assemble a composite picture and to present it in some qualitative terms appropriate for a concept such as creativity. However, this would place excessive weight upon the individual opinion of one man. In addition, it would deprive the analysis of the element of flexibility with respect to interpretation and adaptation by others. For this reason, it is desirable not to report a qualitative composite as such, but to render the components separately in qualitative terms, suggesting interpretation and formation of the composite picture to the recipient of the report.

Such an evaluation might be worded along the following lines: Case A.: "Mr. A. possesses an exceptionally expansive and imaginative mind. However, due to his youth and inexperience, his resources are rather limited. His mind shows a potential of considerable drive and enthusiasm. There is moderate evidence of direction by judgment. Factual-experience knowledge is slight. Under proper guidance, he shows promise of developing a mind of considerable creativity." Case B.: "Mr. B. possesses a decidedly expansive and imaginative mind with exceptionally extensive association resources. His potential of drive and enthusiasm is only moderate. There is ample evidence of direction by judgment and factual experience knowledge. This mind should have considerable and mature creativity, but means should be found to bolster its lagging enthusiasm." Case C.: "Mr C. possesses a definitely factual mind with only limited imagination. There is strong interest in factual knowledge but little drive or enthusiasm for horizontal expansion. His direction by judgment and sense of duty is sound. While this mind reveals very valuable and important characteristics, it does not appear outstanding from the point of view of creativity."

It will be noted that these analyses are restricted to evaluation of creativity and do not concern themselves with technical or professional knowledge or with the numerous personality traits which may be decisive in the acceptance or rejection of an applicant for some specific position. Such decisions will be based upon additional interviews by technical supervisors, personnel managers, and the like, but they will be aided by the availability of analyses of the type described.

Successful evaluation greatly depends on the interrogator's mind, personality and ability to attune himself to the mind he seeks to evaluate. Most individuals harbor simultaneously both factual and creative elements, and detection, separation, and weighing of the creative components is, to a certain degree, a matter of resonance. In other words, it takes a creative mind to understand fully the components of creativity and their inter-action.

Although some of the views set forth above may seem unorthodox, it must be realized that we are dealing with a quality which is, to a large measure, appraised and valued for its very unorthodoxy. Also, the routine and orthodox methods of evaluation have not proven too successful in the past. The above presented approach to the problem may not be perfect, but at least it should yield a type of information which, although urgently needed, has been too often neglected in the past.



A BRIEF HISTORY OF THE MISSILE AND SURFACE RADAR DEPARTMENT

by

H. R. WEGE, Mgr.

Missile & Surface Radar Department
Defense Electronic Products
Moorestown, New Jersey

THE MISSILE & Surface Radar Department is responsible for the engineering and production of radars and guided missile systems for shipboard, ground or vehicular installations. This department is unique in that its organization and facilities have been custom-built to fit the needs of its particular products. This did not happen overnight, but rather is the result of a planned program of evolution and expansion over the past ten years.

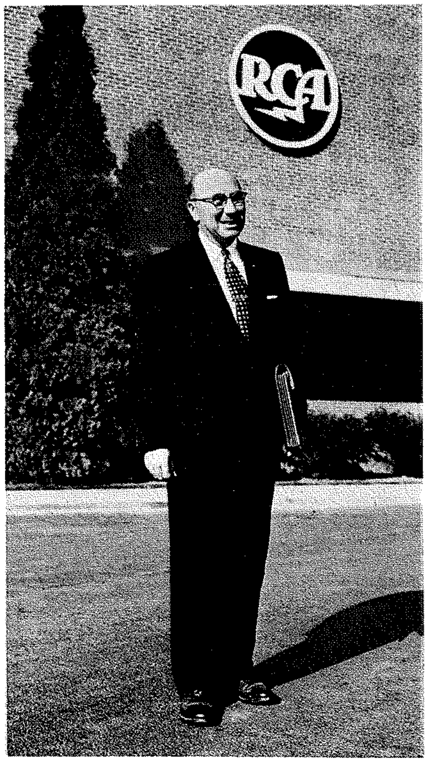
"WAR-END" STATUS

When the war in the Pacific suddenly ended in August of 1945, our production contracts, almost entirely for shipboard radars, were immediately terminated or drastically cut back. After reassignment of personnel to commercial activities, what was then known as the Marine & Ground Radar Engineering Group, located in Building 53, consisted of approximately 25 engineers. This group had little or no work and, since it had been concentrating on low-frequency production equipments developed either before or during the early phase of the war, our competitive position was not yet established in the high-frequency radar application fields.

POST-WAR DEVELOPMENT

RCA's post-war planning resulted in the establishment of an engineering activity called the Government Radiation Engineering Section located in Building 10-7, Camden, to which this radar group, along with other similar engineering groups, was transferred and integrated. Utilizing the best abilities of this reorganization, various types of developmental and study contracts were negotiated with all three of the Armed Services, aimed at re-establishing our competitive radar position and acquiring the necessary background of experience in the higher frequency ranges. Of particular significance was a study contract on radar techniques with the Bureau of Ordnance under the cognizance of the Applied Physics Laboratory of the Johns Hopkins University, in connection with the Navy's Bumblebee Guided Missile Program. This contract, negotiated in 1946, is still active today. Not only have numerous studies in the radar and guided missile field been made but various items of hardware, including a prototype of a very precise monopulse tracking radar, have been supplied to the Applied Physics Laboratory.

As a result of this broad development program, our "know how" and organization increased to a point where, by 1950, we were able to compete successfully for production business, even those systems on which we had not done the basic development. One of the important production contracts obtained at that time was for TPS-10D Height Finders for the Air Force. Several hundred of these equipments were produced during the next five years and are presently giving excellent service in air defense nets throughout the world. As a matter of fact, this procurement was probably the second largest for a single type of ground based radar that the Air Force has made to date.



Having successfully and firmly re-established our position as a capable radar supplier, we realized that we could now expand our position in this highly competitive field. Because of the heavy equipment involved and the need for ground floor space to accommodate trailers and field testing, a portion of Building 53 was rehabilitated. The radar group was separated from the Government Radiation Engineering Section and moved there in the summer of 1950.

BUILDING 53 OUTGROWN

Largely as a result of our work with the Applied Physics Laboratory in connection with the Bumblebee family

H. R. WEGE, Manager, Missile and Surface Radar Department, joined the General Electric Company in Radio Receiver Engineering in 1925, after completing his studies at Kansas State College, where he received his BSEE.

He transferred to RCA Victor in 1929, and subsequently devoted ten years to the engineering of special receivers and related equipment for both commercial and Government use. In 1940 he was appointed Supervisor of a newly formed Radar Engineering Group. By 1950, the group was designated as a separate Engineering Section with Mr. Wege as Manager. The growing importance and expansion of the Radar Engineering Section soon necessitated its relocation from Building 53 in Camden to a new site. This resulted in the establishment of the RCA Moorestown Engineering Plant, which was dedicated in December of 1953.

Mr. Wege received the RCA Award of Merit in 1954 in recognition for his contribution to the completion of a five-year program to advance RCA in Guided Missile work.

Mr. Wege is a member of the American Society of Naval Engineers, Senior Member of I.R.E., a member of the RCA 25 Year Club, a Licensed Professional Engineer in the State of New Jersey, and a member of Armed Forces Communication and Electronics Association. In 1955 Mr. Wege was elected to Sigma Tau, National Engineering Honor Fraternity, at Kansas State College.

of guided missile systems, we received a contract from the Army early in 1951 for a Land-Based Terrier Fire Control System for use with the Terrier Missile, a member of the Bumblebee family of missiles. This program, in addition to major radar development and production programs, resulted in further rapid expansion to the point where the facilities in Building 53 were no longer adequate for this fast-growing engineering organization.

This resulted in the acquisition of 420 acres of land on the outskirts of Moorestown, New Jersey, early in 1952, and the building of an engineering plant specifically designed for the engineering and assembly production of radar and guided missile systems for shipboard, vehicular or ground installations.

THE WEAPONS SYSTEM CONCEPT

About this same time, we revised our engineering organization in preparation for the handling of major weapons systems by dividing it into four basic groupings—Systems Engineering, Project Management, Engineering Services and Equipment Development and Design—the latter being subdivided into Electronic Engineering and Mechanical Engineering. This organization can be more easily understood by the use of a simple analogy, that of the building industry, where Systems Engineering represents the Architect; Project Management, the General Contractor; and the Development and Design Groups represent the various craftsmen or specialists. While all four of the basic groups are essential, the Project Management Group must assume the initiative in the overall direction of any program based upon the weapons system concept.

By weapons system concept, we mean the capability of initiating the concept of a weapons system, starting with an idea or requirement and carrying the job to completion through many difficult steps, including feasibility studies, development and design, field evaluation, production, installation, training and maintenance—up to the point of transfer to the Military Services, as a complete operating system. This is sometimes referred to as a "turn-key" job.

The weapons system concept per se is not new. However, since conclusion of World War II, weapons systems have become larger and much more complex. The Military Services have therefore asked industry to assume more and more responsibility in the engineering, production and overall management of this effort. This is particularly true in the case of ground based missile weapon systems. Where previously a contractor might have been asked to build a radar to rather detailed specifications, today he is asked to devise and produce the overall system where the radar, a small system in itself, is only a part of the weapon system.

To do this effectively, he must first understand the threat and be as ingenious in visualizing all possible enemy systems as he is in devising a system to counter them. He must take into account all of the factors outlined above in the definition of a weapons system. Naturally, this type of effort requires many skills and talents, many of which are not often found in a single contractor organization no matter how large. This, then, is where weapons systems management plays such an important role. The weapons systems management organization need not have all of these special skills but it must have a broad technical grasp and understanding of them in order to subcontract for them and direct the efforts of these supporting organizations effectively.

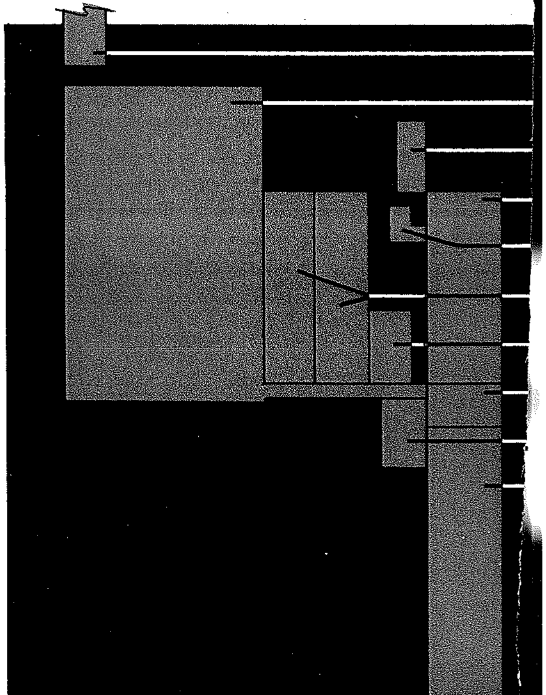
THE TALOS SYSTEM

The Talos Land-Based System is a typical example of what is meant by a weapons system. This system is a fixed installation, ground-to-air guided missile system, for defense of Military bases and industrial centers against enemy air attack. It consists of many elements of electronic and electromechanical equipment, such as radars, computers, launchers and communication equipment, all integrated into one large weapons system. It can detect approaching enemy aircraft at long range. This information is automatically processed through its electronic brain and nerve center to permit the launching and controlling of missiles which will seek out and destroy the enemy aircraft. The system includes special buildings to meet tactical conditions and safety requirements. It represents what we believe to be the most advanced system concept for an automatic guided missile system being developed today.

DECENTRALIZATION

In November of 1955 with the separation of the Engineering Products Division into two activities—Commercial Electronic Products and Defense Electronic Products—four operating departments were established under Defense Electronic Products. The Airborne Systems Department and the Surface Communications Department were established in Camden, while the West Coast Electronic Products Department was established in Los Angeles. Moorestown was established as the Missile & Surface Radar Department facility.

With the establishment of the Missile & Surface Radar Department, the major portion of the Shoran and Specialities Engineering Section, which had specialized in information handling and data processing techniques among other things, was transferred to Moorestown and integrated with the Missile & Radar Engineering Section. These two organizations complemented each other in skills needed in the handling of overall weapons systems. Likewise, a new marketing organization was formed out of personnel representing these two engineering sections by the transfer of these people to Moorestown. Transfers from other activities were also made to round out the new department organization and provide for such functions as production, personnel and financial.



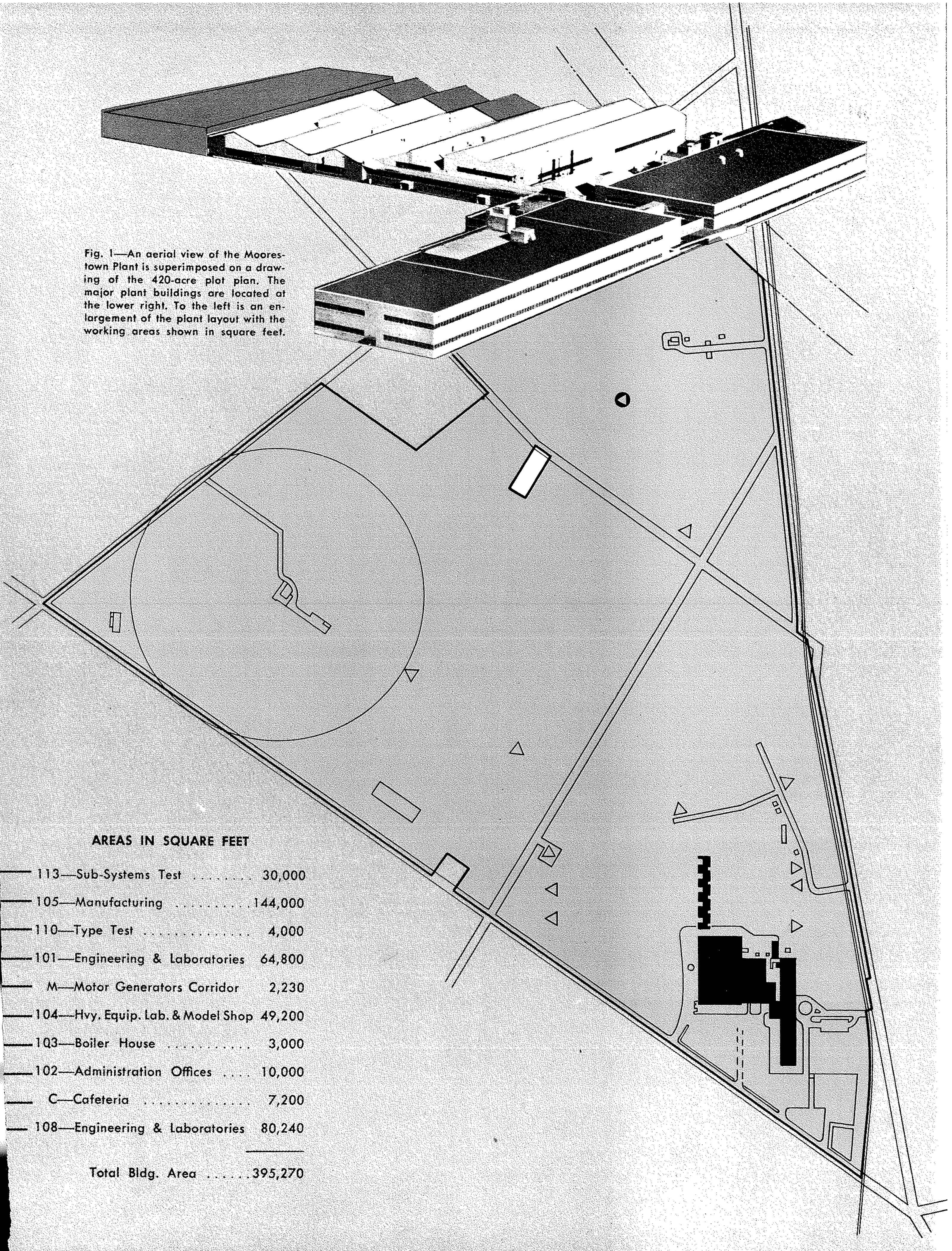


Fig. 1—An aerial view of the Moorestown Plant is superimposed on a drawing of the 420-acre plot plan. The major plant buildings are located at the lower right. To the left is an enlargement of the plant layout with the working areas shown in square feet.

AREAS IN SQUARE FEET

113—Sub-Systems Test	30,000
105—Manufacturing	144,000
110—Type Test	4,000
101—Engineering & Laboratories	64,800
M—Motor Generators Corridor	2,230
104—Hvy. Equip. Lab. & Model Shop	49,200
103—Boiler House	3,000
102—Administration Offices	10,000
C—Cafeteria	7,200
108—Engineering & Laboratories	80,240
Total Bldg. Area	395,270

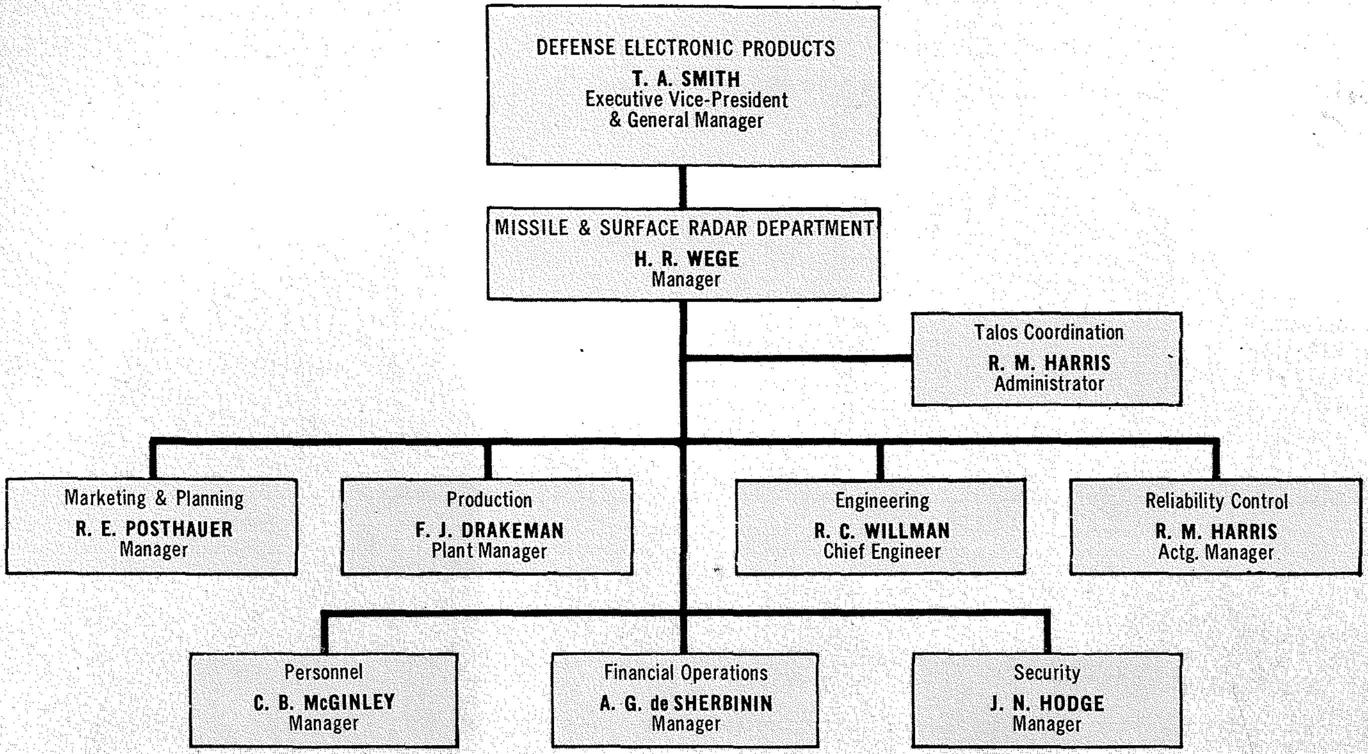


Fig. 2—Staff meeting of the Missile and Surface Radar Department. Reading from left to right: A. G. deSherbinin, F. J. Drakeman, C. B. McGinley, J. N. Hodge, R. C. Willman, R. E. Posthauer, R. M. Harris, and H. R. Wege.

MISSILE & SURFACE RADAR DEPARTMENT ORGANIZATION

The Missile & Surface Radar Department resulting from this decentralization and reorganization is essentially an autonomous operation, as can be seen from Fig. 2. In other words, it is really a small company within a larger company. We have the full responsibility and authority to manage our business and to carry out our commitments. Naturally, we work very closely with the overall Defense Electronic Products activity and also avail ourselves of assistance from other parts of the RCA organization.

While the engineering activity plays the dominant role in the direction of any major weapons system program, it is very important that it be properly supported by the other functions which make up a complete operating entity.

Because of the magnitude of the overall effort required for handling the Talos Land-Based Weapon System, a *Coordinator* was established, reporting directly to the Department Manager. His function is to mesh all activities, to expedite the program, to break bottlenecks, to determine priorities and to coordinate many tasks which cross functional lines.

The *Marketing & Planning* function is in essence the business agent for the Missile & Surface Radar Department. This function, in a team effort with associated activities — Engineering, Production, Financial, etc.—serves as "Chairman" in the planning and direction of the overall Missile & Surface Radar Department activity from a business standpoint. It consists of four main sub-divisions—a Contracting Section supported by an Administration Section, an Office Service Group and a Planning activity, plus field representatives stationed at Washington, D. C., and Dayton, Ohio. The Contracting Section has prime responsibility for dealing with the customer.

Our *Production* organization, headed by the Moorestown Plant Manager, is quite conventional with one exception. In addition to the normal functions of procurement, processing, production control, manufacturing, inspection, quality control, cost estimating and plant engineering, we have established a Production Programming Group reporting directly to the Plant Manager. As the name implies, this group is responsible for the planning, coordination and direction of overall Missile & Surface Radar Department's production Programs. This includes work allocated to Moorestown, as well as other RCA Plants and outside subcontractors. Our Production Programming function was established specifically to handle major programs of weapons system magnitude, such as Talos, where more than one RCA Plant and numerous outside subcontractors are required on the overall production program.

The Engineering organization is being covered under a separate article in this issue by our Chief Engineer, Mr. R. C. Willman.

The *Reliability Control* function has been established to coordinate our overall reliability program and to control the quality of the end product. The basic responsibility for designing reliability into the equipment, of course, rests with Engineering. The Reliability Control function assists in the evaluation and determination of

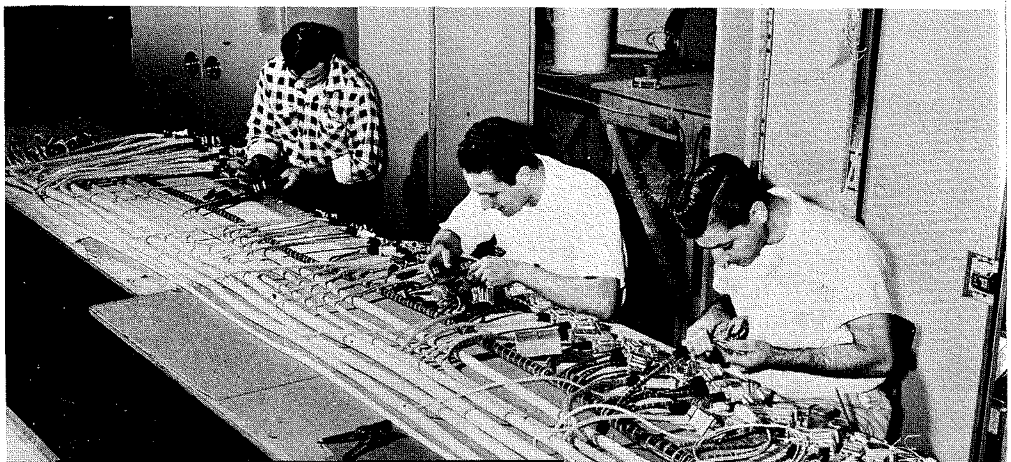


Fig. 3—An example of the intricate cable-lacing techniques in use in Moorestown. (L to R) Messrs. DeChurches, Pantaloni and Martinelli are shown inserting pins in plugs on an overhead harness.

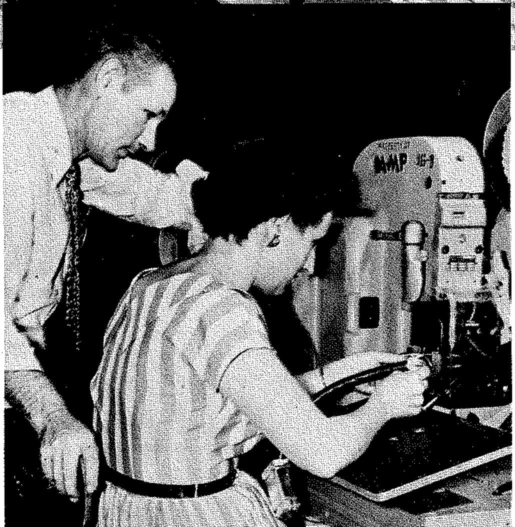


Fig. 4—A. Wallen, Supervisor, watches while N. Riccardi operates an AMP machine. This machine, one of the most modern innovations, strips wire and crimps taper pins to the leads in one mechanical operation.

Fig. 5—Miss Lorraine Sylvester, Receptionist (photo taken in the Main Entrance Lobby) is busy with Mrs. Mary Shinn of Moorestown Missile and Surface Radar Engineering. Lobby serves as a central point of contact between Plant Personnel and visitors from all parts of the country.

the degree of reliability actually attained, the establishment of standards for production and the checking of the product against these standards.

The *Personnel* activity of the Missile & Surface Radar Department organizationally equipped to provide full and complete personnel services for the kind of business engaged in by the Missile & Surface Radar Department. The general services provided include Services and Benefits; Training; Wage/Salary and Labor Relations; Employment, Records and Testing; and the operation of a modern, complete, Company-owned Cafeteria and waitress-service dining room.

The *Financial Operations* of the Missile & Surface Radar Department follows a conventional organizational pattern similar to the Financial Department of Defense Electronic Products. The operations consist of five major groups—General Accounting, Cost Accounting, Budgeting, Contract Accounting and Tabulating, Timekeeping and Payroll. Over the past six months, this organization has been developed from a limited plant accounting operation into an integrated financial unit capable of handling all the financial operations of the Department. Extensive training of new personnel is under way to assure the availability of adequate financial management for future expansion of the department.

The *Security* activity has the basic responsibility of interpreting and administering the security regulations of the Department of Defense's Industrial Security Manual Safeguarding Classified Information. This activity controls the access to the plant by visitors; provides instructions for the storage; transmission, reproduction and destruction of classified material; and provides control of the various areas by directing the Plant Guard Force. In addition, it services the various activities of the plant by requesting necessary personnel clearances and arranging visits to other Government installations and Department of Defense contractors' facilities.

A MODERN WEAPONS SYSTEMS FACILITY

Fig. 1 is a composite showing the Moorestown plant. Its facilities include 420 acres of land which provide ample room for systems tests and field evaluation. The land which is not used for field testing is leased to farmers in the vicinity. The original buildings, totalling 165,000 square feet of floor space, were completed in 1953. This space was practically doubled in 1955. The buildings shown in the background are presently under construction. They are additions to our present manufacturing space for the production of Talos radar equipments. These buildings are scheduled for completion the latter part of this year and will bring the total floor space to approximately 400,000 square feet. Approximately one-half of this is for engineering purposes. The plant is equipped with specialized laboratories, a model shop, type testing facilities and many other necessary facilities for a weapons system activity.

TWO THOUSAND EMPLOYEES

The Missile & Surface Radar Department, here at Moorestown, presently includes a total of approximately 2,000 people. The Engineering Department alone consists of approximately 1,200. Of this number, about 600 are Engineers. The remainder in Engineering are Draftsmen, Model Makers, Laboratory Technicians and other supporting personnel. The total work force will exceed 3,000 by the end of 1957.

CONCLUSION

As one reads this brief history of the growth of the Missile & Surface Radar Department and walks through its large modern weapons systems engineering and production facility, one might well wonder how did this all come about in the relatively short span of ten years. It came about because of the RCA Management policy of delegating responsibility to the working level and backing their recommendations with capital when satisfied that their recommendations were sound. This is still the policy of the Corporation and the fact that the Missile & Surface Radar Department continues to grow in importance at a rapid pace is evidence that this policy pays off, both for individuals within the organization and the Corporation. The initiative, however, rests with the individual.

While the Missile & Surface Radar Department already has substantial weapons systems responsibilities, it is our objective to increase our capabilities to such an extent that the Military Services and other potential customers will beat a path to our door in ever increasing numbers. As a group, we are dedicated not only to our individual and organizational responsibilities, but to the service of our Nation, as inscribed upon the plaque presented to us by Brig. General David Sarnoff on May 4th at our dedication exercises.

Fig. 6—Sidewalk Superintendents take note: Construction of the new wing is well underway. This view shows part of the building (No. 112) which will add about 100,000 square feet of manufacturing space to the existing plant's 44,000 square feet. In addition to this, Sub-Systems Test Building 113 will provide another 30,000 square feet. Connection to the main building will be by way of a canopy.

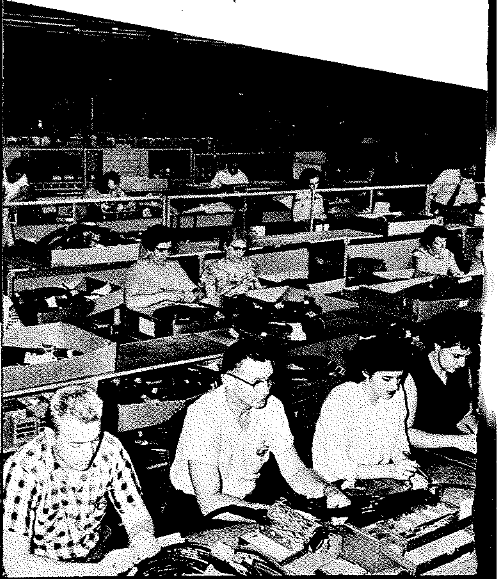
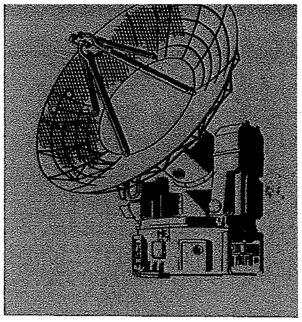


Fig. 7—A view of a portion of the modern Moorestown manufacturing section. Here operators are assembling complex electronic equipment. In the foreground, L to R, T. Carr, B. Podgorski, E. Watkins, J. Hatcher and R. Janice.



MISSILE & SURFACE RADAR ENGINEERING

by

R. C. WILLMAN
Chief Engineer
Missile & Surface Radar Department
Defense Electronic Products
Moorestown, New Jersey

IT IS THE purpose of this article to touch upon a few of the factors that characterize our Missile and Surface Radar Engineering operations and what is being done to meet the changing needs in this field.

Never before in the history of our country has there been the demand for engineering services that exists today. This results from a tremendous increase in the number of technical problems needing solution, together with a growing comprehension of the engineer's ability to solve these problems. The increasing size and complexity of scientific weapons for our national defense is a major contributing factor to this need. It therefore behooves us to assure the most effective use of the talent that is available.

THE ENGINEERING APPROACH

The power and effectiveness of the engineering approach in the solution of problems has always been understood by a relatively small group of people. It has only been during the past decade that this understanding has extended to countless others who have been faced with technical and economic problems beyond their comprehension or solution. The effectiveness demonstrated by the engineering approach during this period has made an impact on industry and, to some extent, on the general public.

Most impressive to engineers, scientists and laymen alike, has been the continued growth of basic technical knowledge and the addition to our fund of scientific know-how. Skills, abilities and techniques are increasing at a staggering rate. As recently as 1941 it was estimated that our national annual expenditure for research was under one billion dollars; whereas today it is something over $6 billions.

To date, we have not been too effective in using the solution of past problems as stepping stones and foundations for the handling of more extensive and complex problems. This is a situation existing throughout industry and the military. However, there has been an encouraging increase in the awareness of this problem area, which is providing the environment that assures continued rapid advance.

SYSTEMS CONCEPT

Climaxing the above consideration is the concept of the systems approach. This is the approach frequently referred to in limited business and industrial problems as "operations research." It is the application of the scientific method to handling an entire problem area encompassing purpose, techniques, economics, strategy, and human engineering. The number of variables in this approach is exceedingly large, and simultaneous handling of these to optimize the overall results is the essence of the systems approach.

In Missile and Surface Radar Engineering, we have been keenly aware that the key to a successful operation is the effective combination of highly specialized skills on the one hand and the "systems" approach to general problem-solving on the other. The combining of these in a manner which stimulates the development and growth of individuals in both areas equally alike is the key to an effective and strong organization. We believe that in our Missile and Surface Radar engineering organization we have made a significant step in the solution to this problem. The *Systems Concept* is a subject which is described in this issue in greater detail by N. I. Korman.

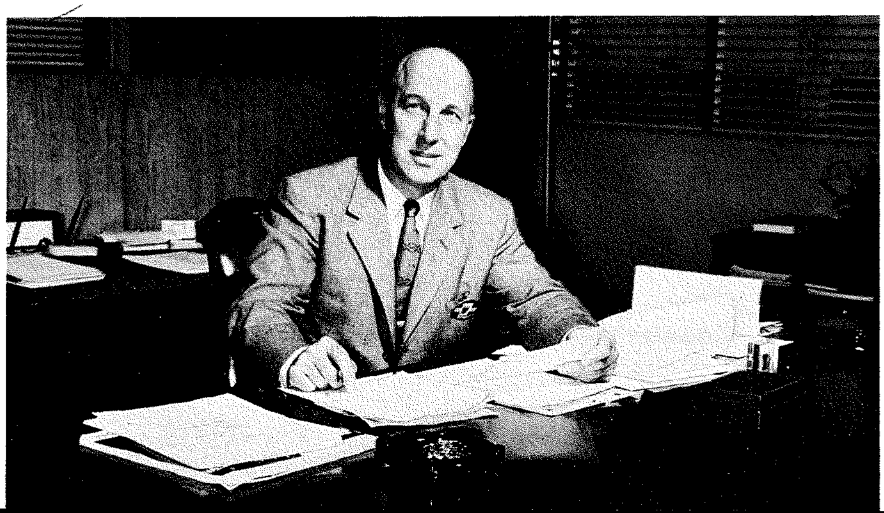
WEAPONS SYSTEMS

The most recent step in our growth is the undertaking of "weapons systems" responsibilities. We are in the process of developing this type of business at Moorestown and are therefore relying more and more on those projects for which we can obtain "weapon system" responsibility for the major part of our activity. This comparatively new responsibility extends the systems con-

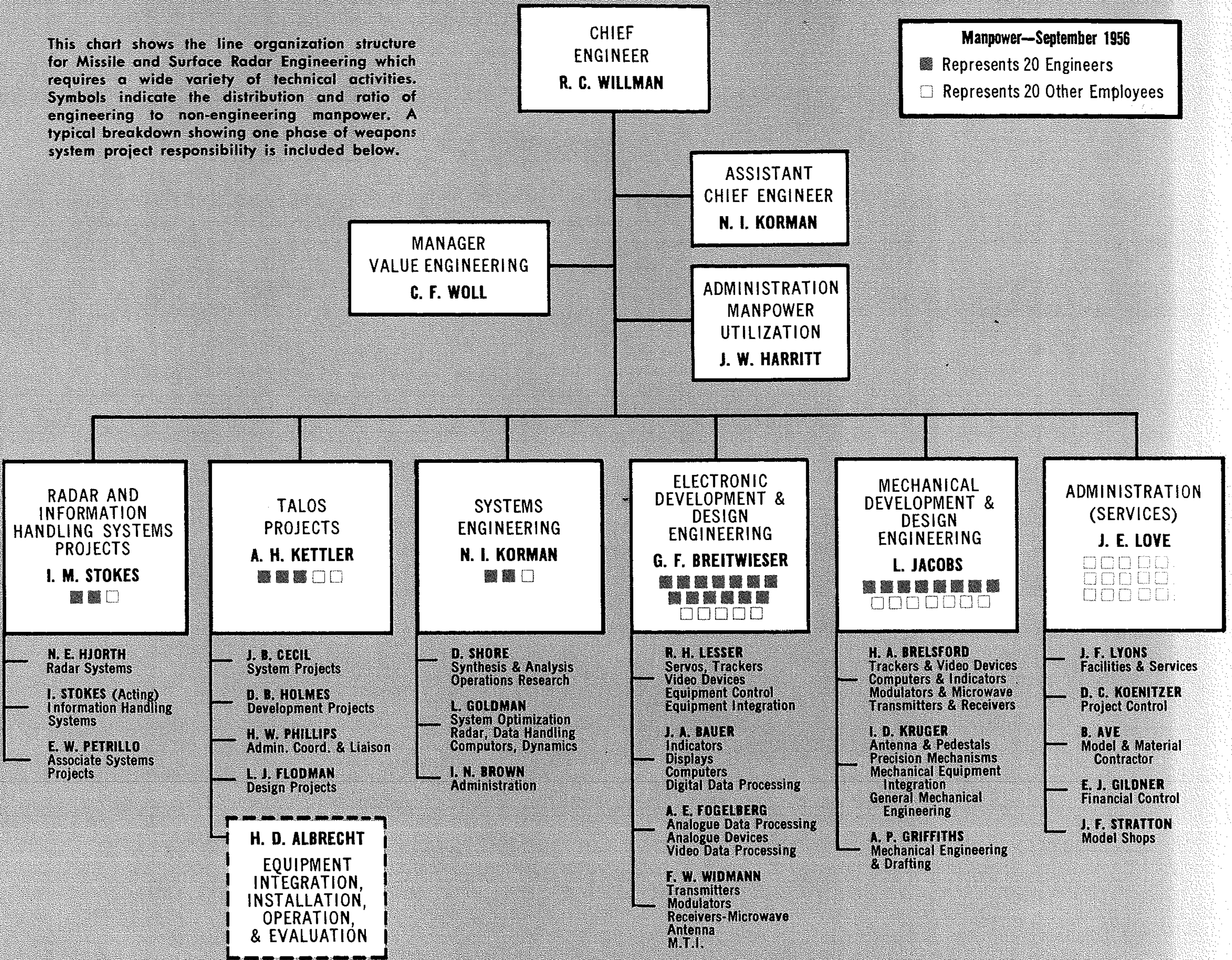
RICHARD C. WILLMAN, Chief Engineer, Missile and Surface Radar Engineering, holds a B.S. in E.E. degree from the University of Washington. He was first employed by General Electric, where he worked with Radio and Photophone. In 1929, he transferred to RCA Photophone and was later assigned to the RCA International Division. From 1933 to 1935, Mr. Willman was in charge of RCA Film Recording in Hollywood. Moving to Camden, he designed many advanced sound recording items for the motion picture industry. He then became associated with the RCA International Sales, serving as Manager of the London Recording Department.

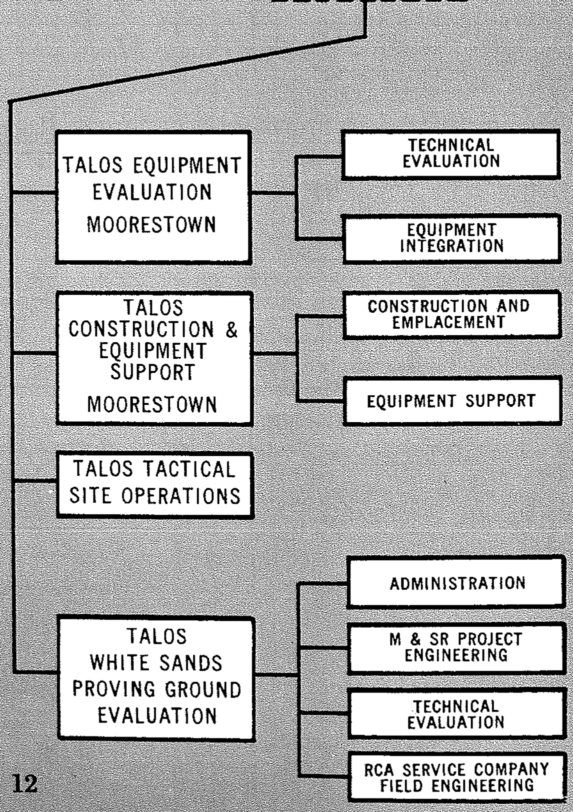
Mr. Willman was associated with RCA's Government Sound Engineering during World War II, and was recognized by the Navy through a Certificate of Commendation for his work on Naval Fire-Control Equipment. In 1948 he became Manager of Government Sound Engineering and in 1951 was appointed Chief Design Engineer of Custom Products. In 1955 he was made Manager of Government Engineering Administration, holding this position until accepting his present post.

Mr. Willman is a member of IRE, American Society of Naval Engineers, the Advanced Management Association of Harvard and the American Institute of Management.



This chart shows the line organization structure for Missile and Surface Radar Engineering which requires a wide variety of technical activities. Symbols indicate the distribution and ratio of engineering to non-engineering manpower. A typical breakdown showing one phase of weapons system project responsibility is included below.





This photo shows DEP's Missile and Surface Radar Engineers during a Staff planning meeting at Moorestown plant. From left to right: A. H. Kettler, Mgr. Talos Projects, G. F. Breitweiser, Mgr. Electronic Development and Design, I. M. Stokes, Mgr., Radar and Information Handling Systems Projects, R. C. Willman, Chief Engineer, Missile and Surface Radar, J. E. Love, Mgr. Administration Services, N. I. Korman, Assistant Chief Engineer, Missile and Surface Radar Engineering and L. Jacobs, Mgr. Mechanical Development and Design.

cept to embrace the skills necessary for operation, maintenance, and supporting facilities and services to make the system a single unit of striking power in its operational environment.

REQUIRES NEW METHODS

Many new problems accompany these broadening responsibilities that require fresh approaches and pioneering in engineering management methods and procedures. Practices established over the years with experience in the direction of product organizations and developing consumer products have had to be modified in keeping with the needs for supplying custom products to the Military. There are a number of reasons why this is so, but it stems primarily from two broad considerations:

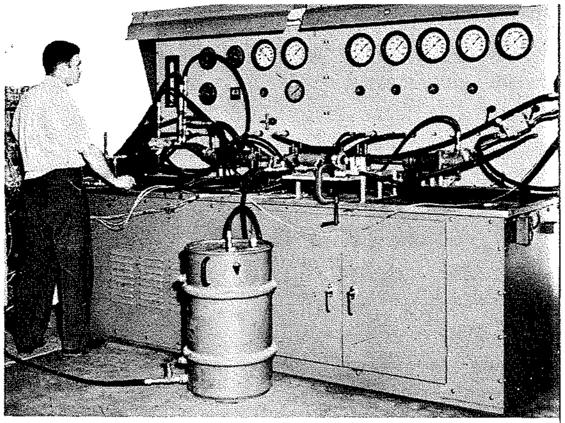
First, the size and complexity of today's scientific weapons call for the closely coordinated effort of several hundreds of engineers involving a wide variety of skills on a single program. This is quite a different problem from that presented by the same number of engineers working on several diversified products not interdependent nor requiring similar specialized skills.

Second, the complex character of our government business requires unusual timing, frequent changes, and a different emphasis of effort than that required in commercial fields. This is not to say that it is any more difficult, or less so, but to point out that it is a considerably different type of business. These considerations demand a much closer integration of engineering with the marketing and production functions than that normally required in the past.

THE ENGINEERING ORGANIZATION

Expanding on the first consideration, a brief description of our Missile and Surface Radar Engineering organizational thinking is in order. When we consider it has only been in the last 30 years that industry has acquired large engineering departments, we realize that the art of directing a large number of engineers is comparatively new. The "giant" corporations, as they were known in the 1920's, had comparatively few engineers to support their products; but since that time, the engineering content of products has increased to the point where large engineering forces are not unusual.

The art of managing large engineering departments in industry over this period has been fairly well developed according to product needs. With the introduction of the "systems" and the "weapons systems" concepts, however, where hundreds of engineers are required on a single program, the need has arisen for better methods for assuring coordinated team effort and yet providing for the professional growth and recognition of individuals within the organization. It is interesting to observe other companies undertaking this broadening scope of work and their methods used to solve this problem. The most successful of these appear to gravitate toward similar solutions and we believe that the approach we have been following in Moorestown embraces the most desirable features of these methods.



Harold Perkel shown in a Mechanical Engineering lab performing engineering tests with a typical hydraulic power drive setup.

LINE ORGANIZATION

Based on the concept that management is getting things done through people, and that the proper concern of management is the development of those people, our line organization is designed to provide the right niche for each person—with a proper atmosphere for training him, supplying the technical facilities, and, the support to help him determine the answers for the project to which he may be assigned.

The pooling of like skills has many advantages; therefore our line organization is functional. The five major functions of the line organization are Projects, Systems, Electronic Development and Design, Mechanical Development and Design, and Administration or Services, (see chart on opposite page.) At present there are some 42 functional groups established under these headings. Specialists are grouped together to provide for maximum communication and guidance on similar problems. The state of the art is advanced by continuous challenging contacts among specialists seeking together to find "best answers" to their common problems. Recognition and optimum utilization of special talents are secured by consistently reporting to the same line leadership, regardless of changing product activity. Mechanical engineers report to mechanical engineering supervision, electricals to electricals, systems to systems, etc.

PROJECT ORGANIZATION

The line organization is supplemented by a project organization which is set up for each of the principal projects or jobs to be done. The project engineer is charged with the responsibility of project management. He is responsible for managing the program within Engineering and insuring that the Engineering Department responsibilities are fulfilled. This includes, in addition to coordinating the systems and development and design effort, many other facets of Engineering's responsibilities to Marketing, Production, and the customer. Among these are instruction books*, training*, test equipment, building construction and site preparation, logistics, installation* and maintenance*, spare parts, field evaluation*, and continuous reporting and customer liaison. The extent of these functions is illustrated in the chart of the previous page where a phase of the Talos weapon system responsibilities is listed. There are many more. Each project has assigned to it engineering specialists from each of the functional groups, to form the project team responsible for getting the project on the road and keeping it there. The project managers are relieved of administrative responsibilities of the personnel assigned to work with them from the line organization, thus affording them the maximum of attention to the project direction.

As we continue to grow it becomes increasingly important to emphasize the recognition of the project team organization and operation, in order that an element of measurement and recognition of good performance of individuals is provided. Project organization charts are issued at frequent intervals showing the people comprising these teams, just as religiously as line organization charts are issued. To the uninitiated the coexistence of a project organization with a line or supervisory organization is not always clearly understood. Recognizing that the product organization has the advantage of providing good team spirit and affords a close association of each individual with the end product, this virtue can be retained by the proper combining of these two forms of engineering organizations. While a great deal can be said about the working relationships that exist within this type of organization, this article is limited to a few observations about contacts that exist between the members of these project teams.

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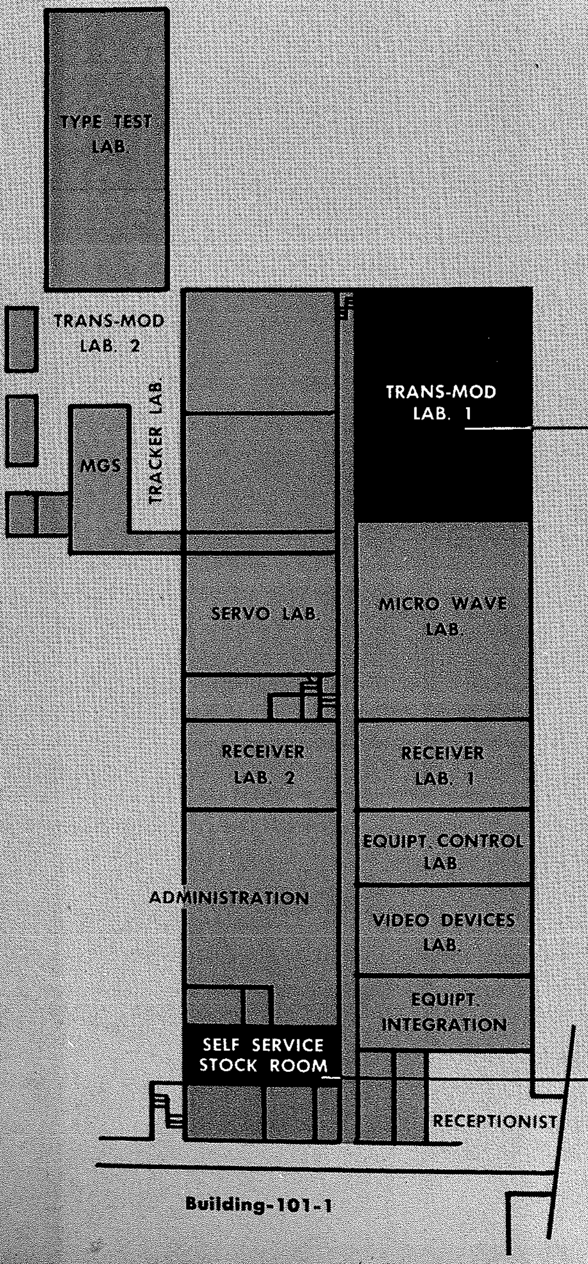
*A separate article in this issue explains how the RCA Service Company is a vital factor in supporting these items of our "weapons systems" effort.



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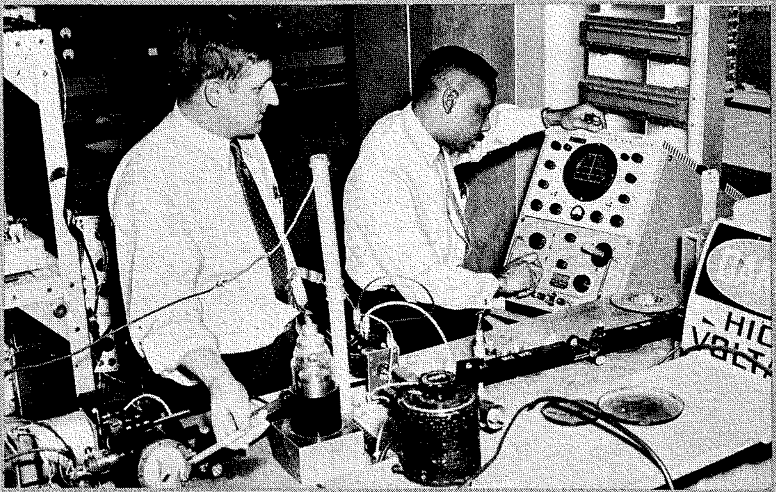


Engineers Al Gorski (left) and Jim Smith are shown working on a breadboard setup using a Klystron for a huge power Radar application.

Al Miller (foreground) and Herb Hollering (also facing camera) are busy selecting component parts from the "M&R" Engineering Stock Room.

Since the requirements of each job are widely different, and since the skills of people assigned to each team will vary greatly, it is not practical to try to define the beginning and end of each funtional group's responsibility. It is recognized that in some cases people are being formed into teams who have had no previous working relationships. There is, therefore, a getting-acquainted period at the start of projects which necessitates meetings coördinated by the project engineer between team members. At this time the work to be done is mutually agreed upon and assignment schedules established for doing it. On some teams and some jobs, it is conceivable that the systems engineer may carry the program well into the design phase, while on other teams the design man may reach far into the systems area, in taking hold of the work. In most cases the project engineer is very active technically but in all cases, he exerts careful control of costs and schedules. In this he is aided by personnel assigned from the Administration group.

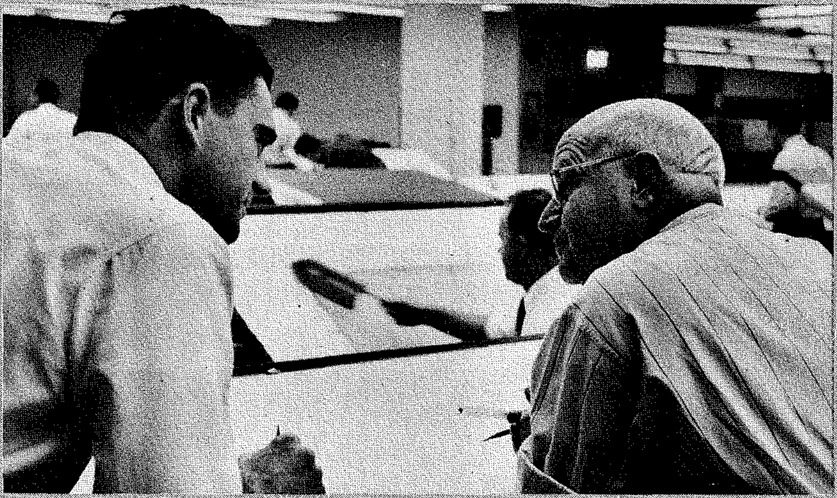
It is the line organization management job to see that the proper skills are included in each team, to watch closely the performance of their representatives on each team, and to see that the work is being properly handled.

CHIEF ENGINEER AND STAFF

The Chief Engineer and members of his staff, who are the heads of these functional groups, review the performance of the project teams with respect to schedules and are in position to evaluate and recognize individual as well as team performance.

While organization is important, it is recognized that it is the competence and attitudes of the people comprising these project teams that assures a high standard of performance. The organization as described has served well in helping to build up the current Missile and Surface Radar Engineering organization to over 1100 people responsible for over $24 millions of requisition engineering in this current year. The steady growth and the changing character of our operations necessitates almost continuous organizational changes coupled with the development and advancement of individuals within it.

In support of the second consideration cited earlier, a high order of inte-



Shown in one of Moorestown Plant drafting rooms B. Dancyuer, engineer (left) is getting a job started by W. R. Robson, Mechanical Design Draftsman.

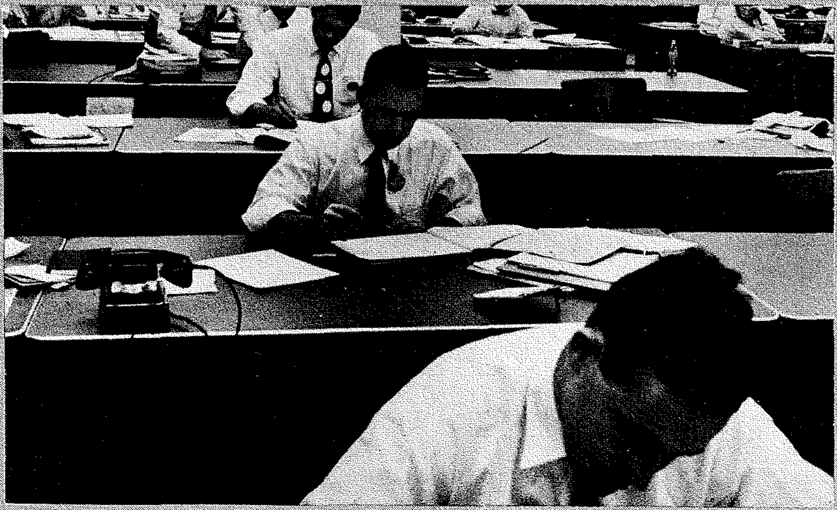
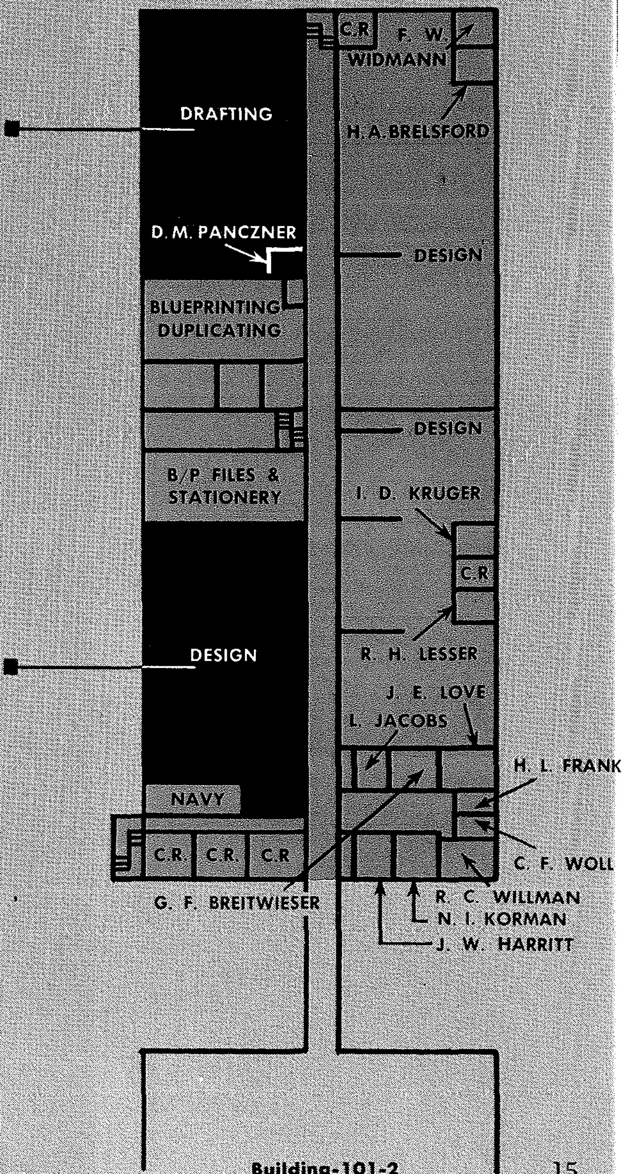
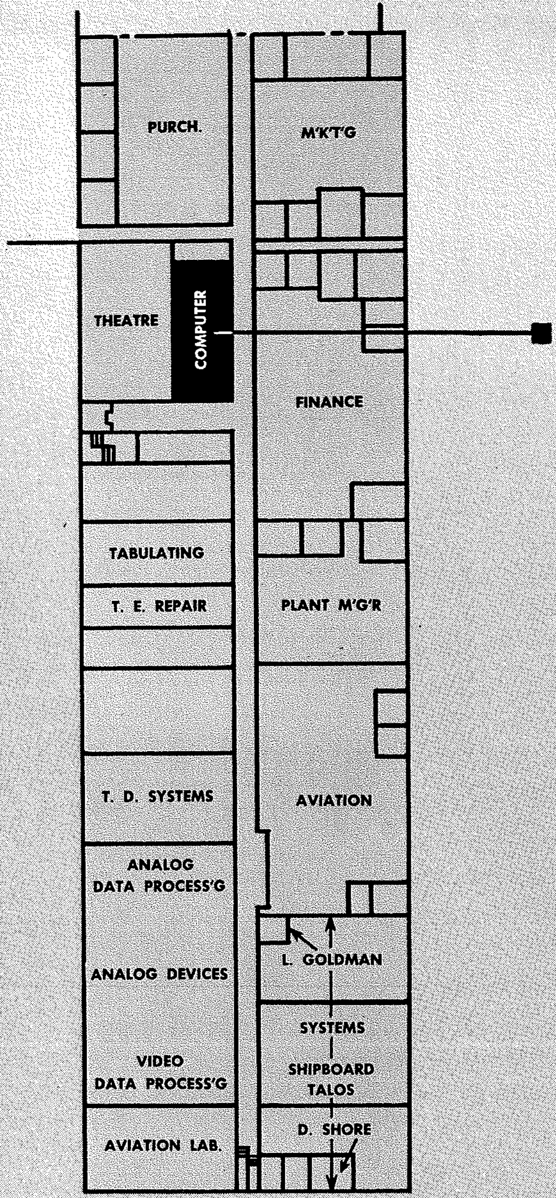


Photo showing a typical Design Engineering Office Area.





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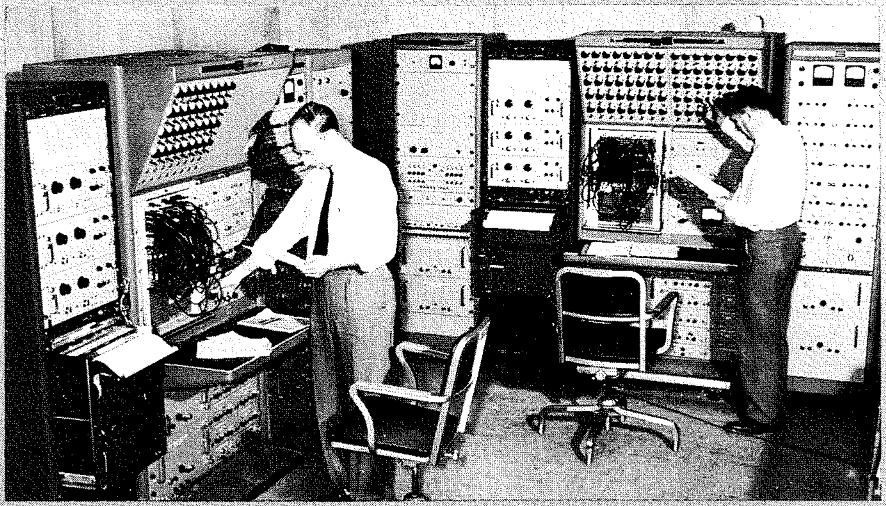
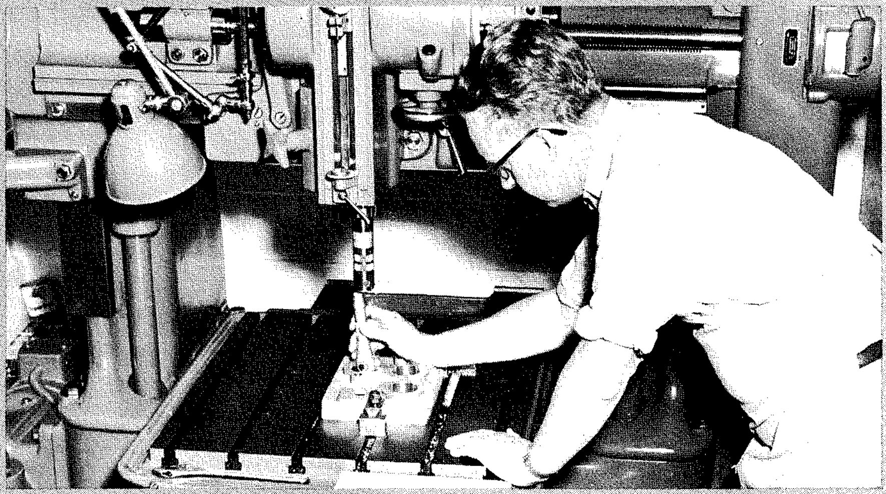


Systems Engineers, A. M. Issacson (left) and D. E. Rosner are shown in the Computer room where complex problems are solved easily and quickly.



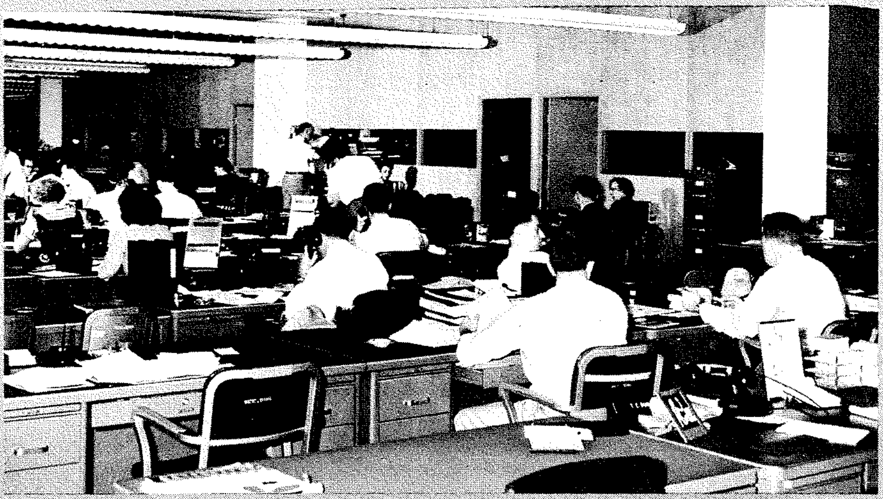
In this typical Model Shop scene, Ernie Polk is getting ready for a precision boring job on a Jig Borer.

gration has been developing between Engineering and Marketing, also between Engineering and Production. This is being encouraged in order to meet the timing and to insure the proper direction of effort required so that we function as an integrated operation capable of carrying weapon systems responsibility. While close teamwork has always been desirable between these departments, the character of our Missile and Surface Radar business makes teamwork essential. The establishment of the Moorestown operation as a complete operating department of DEP provided the environment for this relationship to flourish.

INTEGRATED OPERATION ESSENTIAL

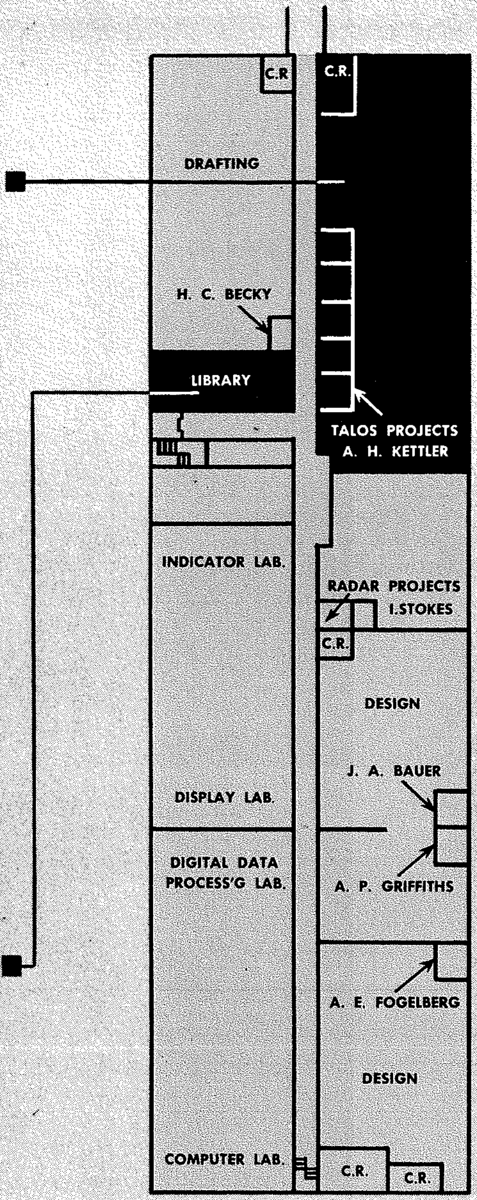
To stress the degree of integration required, a couple of recent examples will serve to indicate the many departures that have been made from the accepted procedures followed for many years. In both the Target Designator and Talos programs, the government needed first equipments on a very urgent basis. Schedules were developed allowing for the normal periods of development, design, preparation of complete drawings, release, ordering and production. These resulted in unacceptable time cycles. In both of these contracts, Engineering undertook the building of the first systems in the model shop, even though they represented two of the four largest equipment systems ever built by RCA for the government. This was necessary in order that equipment construction could proceed as promptly as information could be made available. In other words, the integration of engineering and the construction effort that resulted by doing this work in the model shop out-weighed the inexperience of Engineering in the fields of production control, processing, etc.

In taking on this responsibility, Engineering became more cognizant of production problems and therefore timed their design effort in such a way as to concentrate on items requiring long lead times and in keeping with the construction effort required. As a result, long time procurement items were ordered first, and those components requiring a great deal of fabrication and direct labor efforts were released early. Many formalities were dispensed with. Construction started



View of the Talos Projects Engineering Office.

Engineers Sheldon Novick (left) and Paul Frawley are being assisted by Mrs. Campbell, Librarian in selecting reference books from the Moorestown Engineering Library.



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and proceeded prior to completion of all design and drawing work. Wiring diagrams and complete assembly drawings were "phased in" when needed, toward the end of the equipment construction stage. The relationships that developed between the engineers and the model shop set a pattern which must be maintained between Engineering and Production for an increasingly large proportion of our type of equipment where quantity is comparatively small and the size of the systems large.

TALOS DEMANDS INTEGRATION

This type of integrated effort is currently developing in the release of the Talos* production items. This method of operation, while not entirely new, is becoming more and more the accepted practice. It is not to be construed that this method of operation is proposed where large-volume production is involved, although there are some features that have been, and should be applied. These examples serve to show that on the initial release of systems never before produced and where time is important, Engineering must have a fuller appreciation of production problems. In turn, Production must be geared to reach far into the engineering operations to extract advance information that will permit them to proceed on the most important items first. The demarcation between Engineering and Production under such an operation becomes obscure, because the two functions are so thoroughly integrated. Engineering release dates are less meaningful because release of information is continuous. Similar analogies can be cited with regard to the relationship between Engineering and Marketing. Both of these functions in this type of business are so interdependent that there must exist at all times complete integration of action and planning.

Just as the systems approach considers all the variables simultaneously in the technical development of equipment, it is equally necessary that management extend this consideration to the simultaneous treatment of the functioning of the operating departments of our business. We believe we are making definite strides in this direction at Moorestown.

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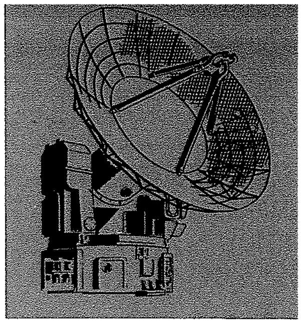
*See article by H. R. Wege this issue in which Talos is briefly described.



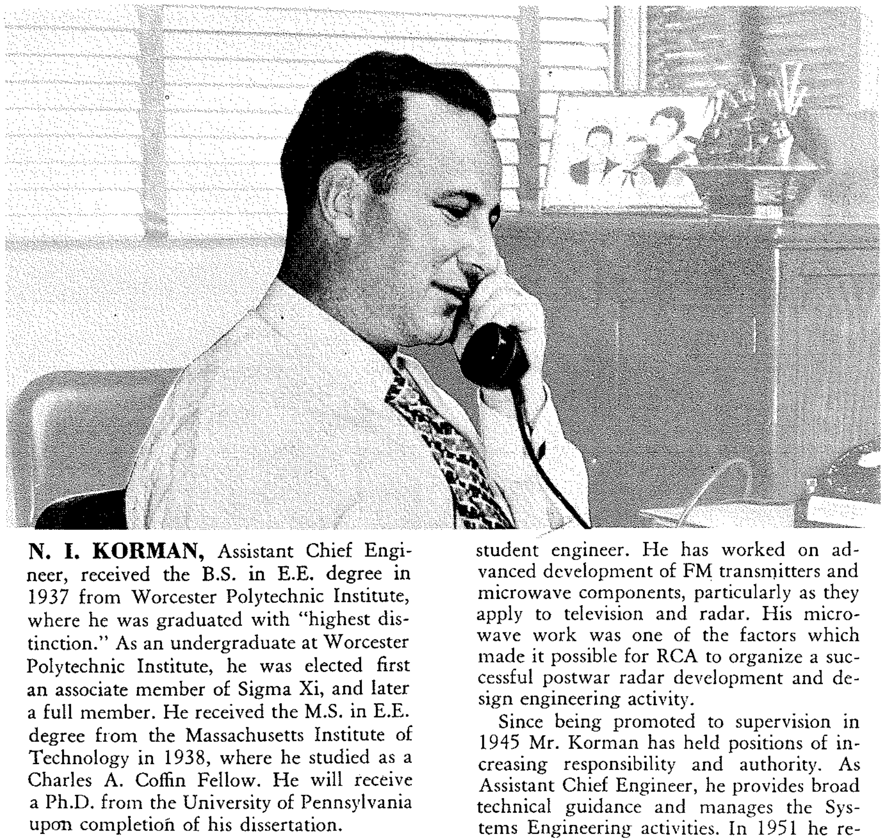
SYSTEMS ENGINEERING IN THE MISSILE AND SURFACE RADAR DEPARTMENT

by **N. I. KORMAN**
Ass't Chief Engineer
Missile and Surface Radar Engineering
Defense Electronic Products
Moorestown, N. J.

During world war II, customers for radar equipment found it impractical to buy radar components such as receivers, indicators and transmitters as individual items, and weld them into an effective system. The attempts which were made to assemble radar systems from purchased components generally led to unsatisfactory results. This was not only because the customer did not have sufficient numbers of properly qualified personnel, but also because the give-and-take in component performance specifications (necessary for obtaining an efficient system) could not be implemented. This was due to a cumbersome contracting system, and difficulties in communication between the various isolated groups. As a result, in the years immediately following World War II, radar equipments were generally produced as entire systems from single suppliers.

The Radar Engineering Section of the Engineering Products Department, which was organized in the closing days of World War II, was comprised of groups which specialized in the components constituting the radar system. In addition, it recognized project engineers who were responsible in all respects for each of the radar systems being developed. These project engineers not only saw that their job was properly scheduled and budgeted, but also insured the technical compatibility of the components to make for an efficient radar system. In the beginning, this project responsibility was vested in the most responsible individuals in the Section, namely the leaders and managers of the various component groups.

After some years of experience with this type of operation, project engineering became a more and more specialized job. As this became evident, project engineers were relieved of all other duties so that they could concentrate and specialize in the techniques for effective project engineering. Further experience, however, soon showed a distinct tendency for some individuals in the project engineering activity to emphasize the technical or systems work at the expense of the project management duties. This tendency was accentuated by the fact that completely new systems being placed with industry for development were becoming more and more sophisticated, encompassing electronic, mechanical and aeronautical equipments. These systems were being designed to perform certain comprehensive military functions and came to be known as "Weapons Systems." With the greater complexity of these systems and with the requirement that they be highly efficient and highly integrated, it appeared desirable to separate from the project groups those individuals who had shown the greatest aptitude for handling technical or systems work, and set them apart in a separate systems group. Here, they would be much more effective in devising powerful techniques for systems engineering and for training newcomers in the techniques of systems engineering. This pioneer attempt in RCA to recognize the systems engineering function and to organize properly for it has met with great success.



N. I. KORMAN, Assistant Chief Engineer, received the B.S. in E.E. degree in 1937 from Worcester Polytechnic Institute, where he was graduated with "highest distinction." As an undergraduate at Worcester Polytechnic Institute, he was elected first an associate member of Sigma Xi, and later a full member. He received the M.S. in E.E. degree from the Massachusetts Institute of Technology in 1938, where he studied as a Charles A. Coffin Fellow. He will receive a Ph.D. from the University of Pennsylvania upon completion of his dissertation.

Mr. Korman joined RCA in 1938 as a student engineer. He has worked on advanced development of FM transmitters and microwave components, particularly as they apply to television and radar. His microwave work was one of the factors which made it possible for RCA to organize a successful postwar radar development and design engineering activity.

Since being promoted to supervision in 1945 Mr. Korman has held positions of increasing responsibility and authority. As Assistant Chief Engineer, he provides broad technical guidance and manages the Systems Engineering activities. In 1951 he received the RCA Victor Award of Merit.

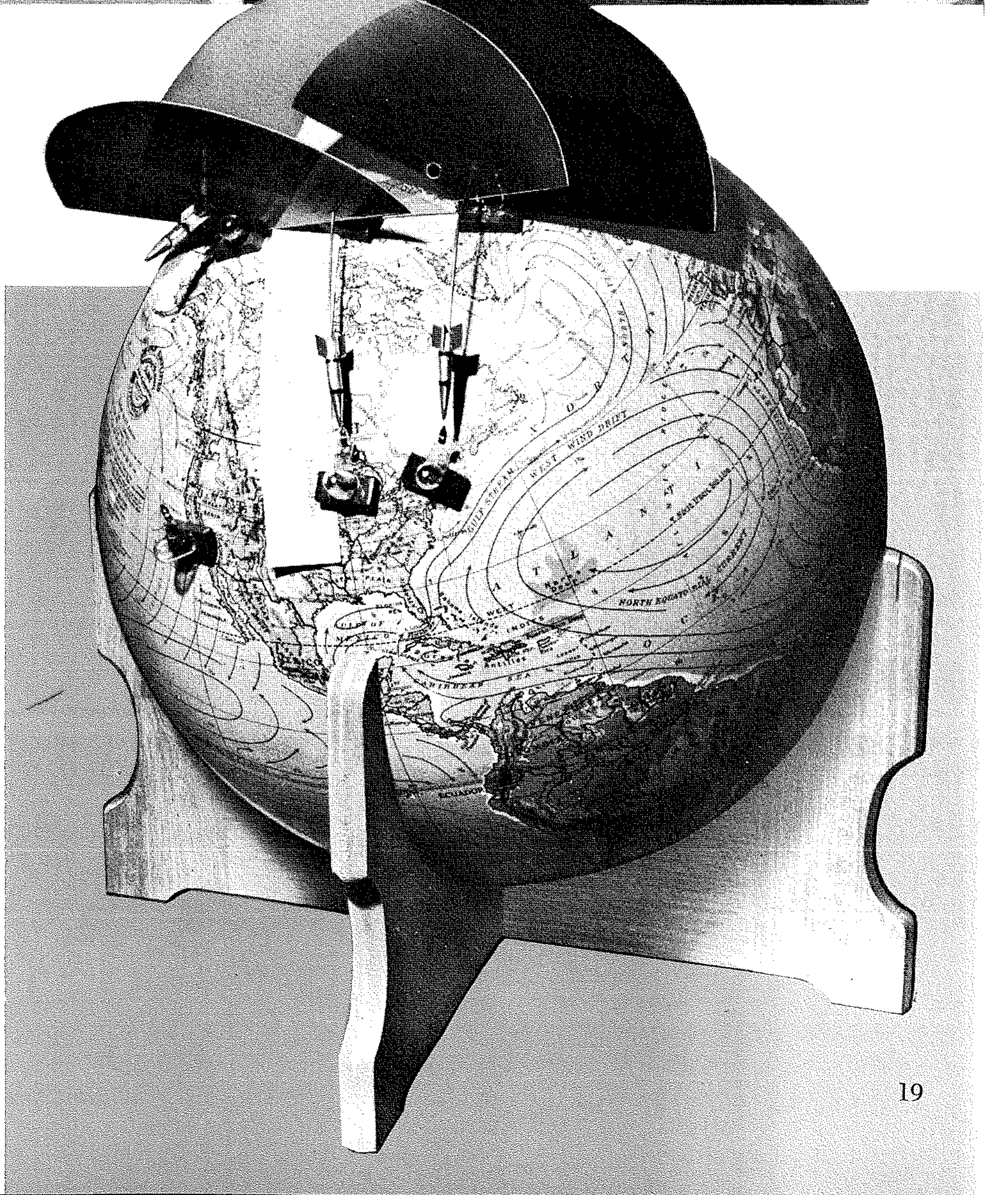
FUNCTIONS OF SYSTEMS ENGINEERING

The Systems Engineering work in the Missile & Surface Radar Department falls into two broad categories: Systems Synthesis and Analysis, and Systems Optimization. In the synthesis of systems, the work is concerned with questions as to what military operations will be like five and ten years hence, and what characteristics systems should possess to be effective at that time. To do this work effectively, the state of the art as it will probably exist at the future period must be assessed. Developments must be initiated and stimulated which will advance the state of the art in the proper directions to cope with the future problems. The requirements for future systems must be set forth and many trial systems must be assembled (figuratively speak-

Systems Engineers must know the threat in its most fundamental terms to devise an effective defense. Systems Engineering now encompasses planning on a global scale. Engineers in this photograph are L to R, O. L. Patterson, E. Mechler, D. Shore, Manager, Systems Engineering, C. Carlson, S. Spauling, Dr. H. Benecke, P. J. Caruso.

ing) and tried to determine how best to meet these future requirements. In the evaluation of alternative systems for meeting these future requirements, the systems must be evaluated not only for their technical adequacy and effectiveness, but many questions relating to cost, firepower, logistics, manpower, achievability, reliability, maintainability and the like must be investigated for each of the possible systems. This evaluation activity makes use of many techniques of Operations Research. Therefore, in devising future systems, our Systems Engineering activity utilizes engineers who specialize in operations research, as well as highly creative and imaginative engineers who possess broad and comprehensive knowledge of what can probably be done with electronic, mechanical and aeronautical equipment in the future. Systems Engineering must not only find the most feasible system configuration to satisfy a given operational requirement, but must also follow through by recommending a development program to achieve it.

Once the major parameters of a system have been delineated, evaluated and accepted, it becomes necessary to define the system in much greater detail so that development and design of the actual equipment can proceed. The system must be carefully reviewed to assure that it will operate efficiently under all conditions. All portions of the system must be scrutinized closely to assure that the system can be built with available compo-



nents and that the system has been optimized to the greatest extent possible. As the specialists in the design activities work out the detailed equipment design, the results of their efforts may require or permit modification in the relations between various units of the system. In extreme cases the attainment of basic system objectives may even be affected. Thus, the way in which the detailed characteristics of the equipment combine to shape the overall performance of the system must be brought into sharper focus as the design progresses, in order to optimize the system to the greatest extent possible.

All of the above work is known as "Systems Optimization." To carry out this system optimization requires mature engineers. These men must not only have had much design and development experience and a broad knowledge of the engineering involved in developing and designing equipment, but also an extensive knowledge of all kinds of equipment within their field. The engineers who specialize in the optimization work are familiar with radar, information handling and fire control, computers—both analogue and digital—and the flight dynamics of missile systems. They combine with this knowledge excellent theoretical backgrounds and analytical abilities.

SCOPE OF WORK

The scope of systems engineering duties is rather broad. It includes analytical studies of such subjects as missile system dynamics, radar range considerations, noise filter theory, statistics and the like. It includes delineation of the detailed interrelations of the various components making up a system; that is, specifications must be prepared to insure the compatibility of many of the system components such as receivers, transmitters, servos, etc. As the design and development work proceeds on the system components, system engineers must examine these developments to determine whether they are in accordance with the system objectives and to evaluate their effect on the system performance. Systems engineers delineate and examine in detail the system and subsystem tests to determine whether system requirements will be met and to evaluate what the system performance will be.

RELATIONSHIPS WITH OTHERS

In carrying out their work, systems engineers have close relations with other groups both inside the Engineering Department and outside. Systems engineers act as consultants to project engineers. They advise the project engineers as to how and whether the technical system requirements can be met within the broad budgetary, time and specification limits imposed by project considerations. This advice is invaluable in determining the approach which is taken to satisfy the customers' requirements.

Systems engineering must be thoroughly conversant with military operations, problems, and equipment systems requirements. Systems engineers, therefore, have frequent contacts with the many types of specialists in these matters in the employ of the Armed Services. These contacts serve not only to keep systems engineers aware of changing requirements but also to educate those in the Armed Services as to the possibilities inherent in systems and equipment developments being carried on in our organization.

Systems engineers work closely with design and development engineers in evaluating the adequacy of the component performance being achieved to satisfy the system requirements. Systems engineering also reviews all the development work being carried on to determine whether it is adequate to establish and maintain aggressive leadership in the product line of the department. On the other hand, these contacts with the design and development engineers serve a vital function in constantly refreshing and enlarging the system engineers' knowledge of the state of the art.

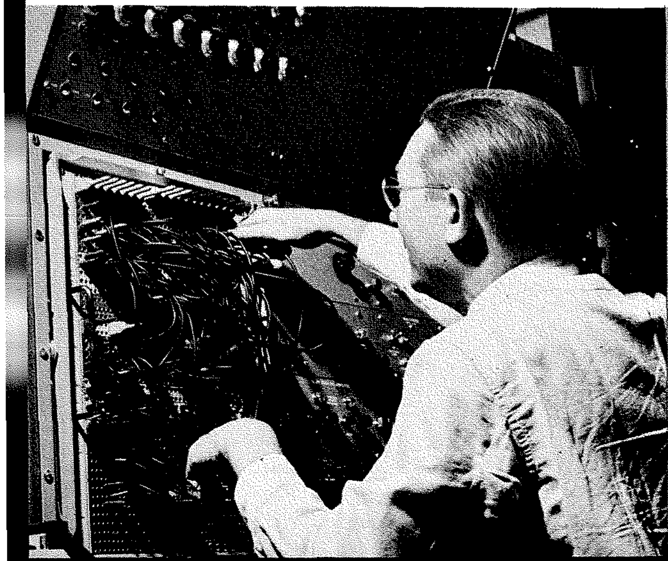
FACILITIES

The Systems Engineering Group possesses no laboratory of its own. Instead, it keeps in close contact with the design and development activity in order to maintain its knowledge of the present state of the art and make more accurate predictions as to the future state of the art. Where it recognizes that development is necessary to advance the state of the art in order to make possible desirable systems, it stimulates the design and development activities to carry on such development.

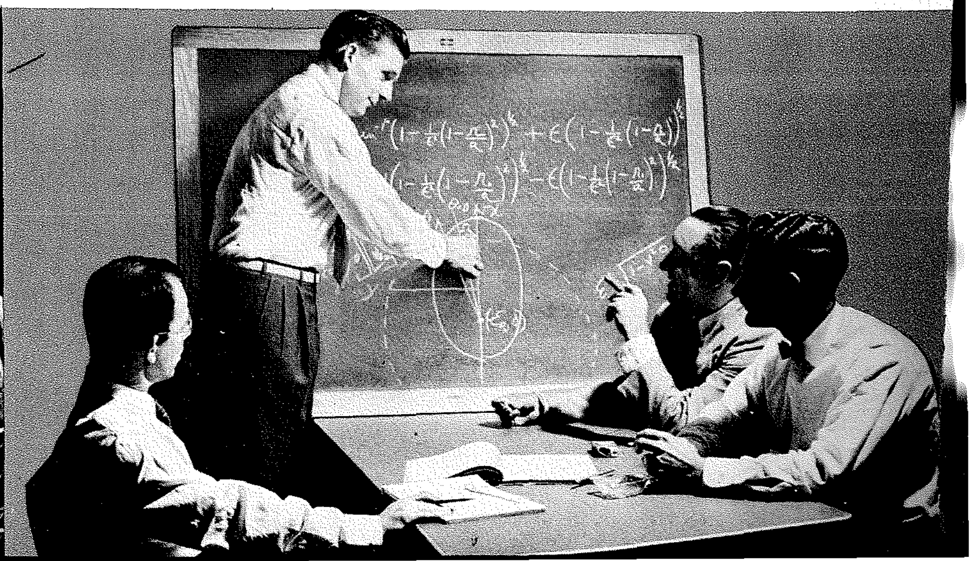
There is a considerable amount of mathematical calculation necessary to support systems engineering work. In order to facilitate these computations without burdening the highly experienced systems engineers with what would be to them routine, a numerical analysis group is available. This group uses desk calculators, digital computers and analogue computers to carry out their work. They also give advice to systems engineers on methods of solving dynamic systems equations by approximation methods where this might be advisable because of the magnitude or complexity of the problem.

CONCLUSIONS

Recognition of the importance of the systems engineering concept and the need to create an atmosphere in which it could prosper has resulted in an organization with advanced notions of how to operate effectively. The engineering activity of which it is a part owes a great deal of its success to the vigor of its systems group.



O. E. Rosner, Engineer, shown at the master control panel of the Computer Console, which is a part of the Engineering facilities located at the Moorestown plant.



Today's systems frontiers involve celestial mechanics as illustrated by this group of Engineers. From L to R: O. L. Patterson, S. Spaulding, Dr. H. O. Benecke, P. J. Caruso.

MINIMIZING LOCAL OSCILLATOR DRIFT

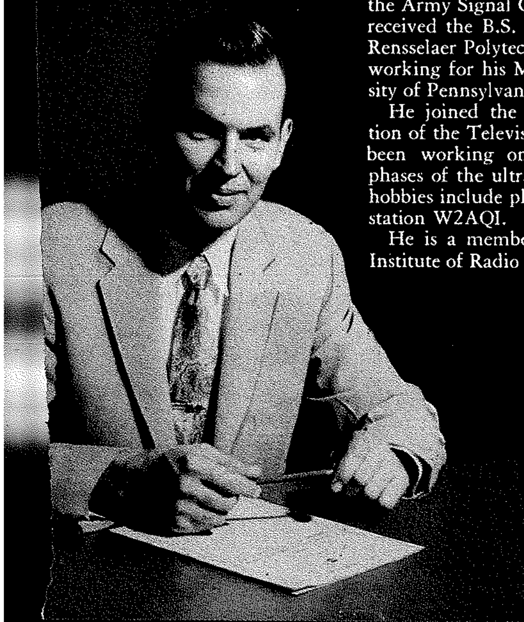
by **W. Y. PAN and D. J. CARLSON**
Advanced Development Engineering
RCA Victor Television Division
Cherry Hill, N. J.

WITH THE INCREASING complexity of most receivers for governmental services and the advent of color television at UHF and VHF, the requirement for local oscillator stability is beyond the conventional trial-and-error method of frequency compensation. In view of the emphasis being placed on stability and reliability (particularly in defense engineering) conventional methods of measuring frequency drift are similarly inadequate. Analytical approaches are desired in measuring incremental frequency deviations and in providing means to minimize the local oscillator drift.

WHY DO LOCAL OSCILLATORS DRIFT?

Virtually every parameter of a local oscillator system has some effect on the operating frequency. The profound factors affecting the parameters, and hence the oscillator frequency, are:

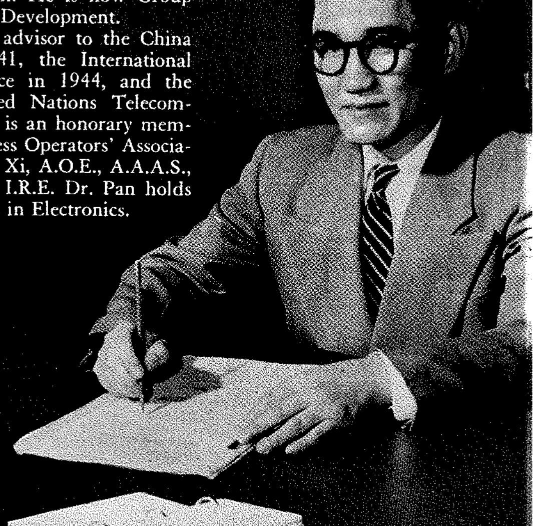
1. *Harmonics* — Harmonics generated in a local oscillator cross modulate each other and the fundamental to produce currents at the fundamental frequency that are not necessarily in phase with the fundamental-frequency currents from the normal mode of operation. The phase of the resultant fundamental-frequency current changes the frequency of operation which, accordingly, becomes sensitive to the amount and distribution of harmonics in the circuit. The effect of harmonic voltages on frequency stability can be minimized by employing a tuned circuit having a high effective Q.
2. *Input-Power Fluctuations*— Fluctuations in line voltage, for instance, change the amount of power being supplied to the oscillator tube, thus affecting the temperature rise of the tube electrodes as well as the tuned-circuit elements. In addition, any input-power fluctuation alters the phase relationship between electrodes owing to the variation in the position and density of the space charge which deviates the oscillator frequency. This factor of frequency instability can be reduced by proper selection of oscillator tubes.
3. *Secular Effect* — In most tuned circuits, the operating frequency changes with the passage of time, even if the temperature and other conditions are maintained constant. This secular effect is often referred to as "aging." It is present to a greater or lesser extent in all known tuned circuits and tubes but may be held to a minimum by a choice of materials which are inherently stable, such as ceramics and most metals.
4. *Humidity* — The conductivity, dielectric constant and dielectric strength of air are affected by its pressure and humidity. Therefore, the frequency of a tuned circuit with air dielectric components is a function of these variables. Moreover, the mechanical dimensions of coil forms and support often change with humidity. Precise control of frequency is, accordingly, possible only if suitable precautions are taken in the construction of the circuit elements.
5. *Ambient Temperature Rise* — The frequency deviation of an oscillator resulting from ambient temperature rises is commonly known as "warm-up drift." It is the principal and unavoidable cause of frequency instability in practically all receivers. For this reason an analytical approach to combat this temperature problem will be discussed.



DAVID J. CARLSON served 2½ years with the Army Signal Corps during the last War and received the B.S. Degree in E.E. in 1950 from Rensselaer Polytechnic Institute and is currently working for his Master's Degree at the University of Pennsylvania.

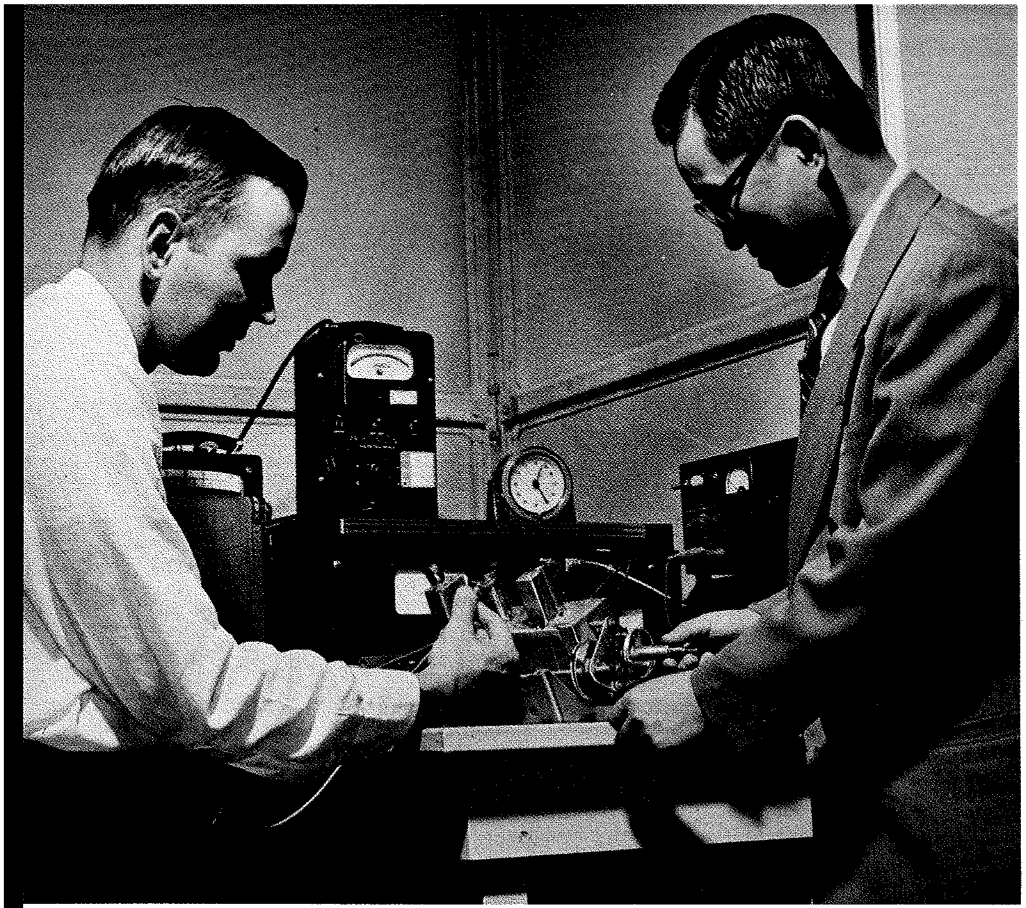
He joined the Advanced Development Section of the Television Division in 1950, and has been working on projects related to various phases of the ultra-high frequencies (uhf). His hobbies include photography and amateur radio station W2AQI.

He is a member of Eta Kappa Nu and the Institute of Radio Engineers.



WEN YUAN PAN received the E.E. Degree in 1939 and Ph.D. in 1940 from Stanford University. He was a research associate at the Radio Research Lab. at Harvard U. during the last war. Since 1945, he has been with the RCA Victor Television Division. He is now Group Manager of R-F Circuits Development.

Dr. Pan served as an advisor to the China Defense Supplies in 1941, the International Civil Aviation Conference in 1944, and the Committee of the United Nations Telecommunications in 1946. He is an honorary member of the Veteran Wireless Operators' Association, a member of Sigma Xi, A.O.E., A.A.A.S., and a senior member of I.R.E. Dr. Pan holds more than twenty patents in Electronics.



The authors (D. J. Carlson, left and W. Y. Pan at right) are shown in their laboratory during engineering performance measurements of oscillator stability.

To aid this analytical approach, equipment for the automatic and continuous recording of frequency deviations has been developed.

HOW TO RECORD FREQUENCY DEVIATIONS?

Heretofore, the method of measuring oscillator warm-up drift was done by tracking the oscillator signal manually. In doing so, an operator was required during the entire drift run and sudden changes in oscillator frequency were often missed.

The operating principles of the automatic and continuous recording equipment are shown by the block diagram in Fig. 1. By using broadband networks in the "r-f unit," dependence on the tuner local oscillator of the recording equipment is eliminated and only the detected sine-wave difference-signal is utilized in the "video unit." The sine wave is shaped into a square wave and subsequently rectified. The d-c output is directly proportional to the frequency deviation of the local oscillator under test.

A recording made by this equipment is indicated in Fig. 2 on the 1.0 mc full-scale range. The frequency of the oscillator under test was 525 mc, typical for some aviation radar and UHF television receivers. In this sample oscillator, all circuit elements external to the oscillator tube are not temperature-sensitive. Therefore, the oscillator frequency drift is caused only by the variations of tube capacitances.

ANALYTICAL REPRESENTATION OF LOCAL OSCILLATOR DRIFT

1. *Oscillator-Tube Drift*

The heat flow in an oscillator tube depends upon the instantaneous temperature of the hot bodies, the geometry of the tube elements, and other factors of a complex nature. The instantaneous cathode-to-grid radiation, for instance, has been found to be

$$Q = \alpha\,(1 - e^{-\beta t}) \qquad (1)$$

where

t = time

α = total radiated power

β = a time constant, determining the rate of heat flow from the cathode to the grid

The cathode-to-grid radiation raises the grid temperature which transforms the grid configuration and geometry. The resultant physical changes taking place in the grid structure cause deviations in interelectrode capacitances and hence the oscillator frequency. For small frequency deviation (Δf) as compared to the local oscillator frequency (f), the expression for Δf takes the same form as Equation (1), except that α = the maximum oscillator-frequency deviation and β = the rate of change of oscillator frequency.

The frequency characteristics of the 525 mc sample oscillator recorded in Fig. 2 can be represented analytically

$$\Delta f = -0.750\,(1 - e^{-0.4t}) \qquad (2)$$

where

$\alpha = -0.750$ mc

$\beta = 0.4$

and the time,

$t = 0$ when the local oscillator has been energized exactly one-half minute to enable the receiver to attain operable conditions

To determine the value for β, a point corresponding to 0.632α is located on the curve in Fig. 2. The time required at that point is the reciprocal of β. The dots drawn along the recorded curve are calculated from Equation (2), and the accuracy of the analytical representation is believed to be good enough for all practical purposes.

2. *Circuit-Element Drift*

The general analytical expression of Equation (1) applies also to any circuit element that is temperature-sensitive when it is subject to the flow of heat. When several such elements form parts of a local oscillator circuit, the frequency drift caused by each element must be expressed by an exponential equation; thus the overall frequency deviation Δf_o becomes

$$\Delta f_o = \alpha_1\,(1 - e^{-\beta_1 t}) + \alpha_2\,(1 - e^{-\beta_2 t}) + \ldots \qquad (3)$$

However, when the relative magnitudes of $\alpha_1, \alpha_2 \ldots$ vary substantially, or the values of $\beta_1, \beta_2 \ldots$ do not differ too much, the overall frequency deviations for all the circuit elements can be approximately given by

$$\Delta f_o = \alpha_o\,(1 - e^{-\beta_o t}) \qquad (4)$$

OSCILLATOR FREQUENCY STABILIZATION

To illustrate the application of this analysis to practice, a "step-by-step" stabilization of a local oscillator commonly used in VHF commercial television receivers will be described. It is believed that the same approach may be followed to stabilize local oscillators in receivers for other services at frequencies up to and including the UHF band.

1. *The Original Oscillator Circuit* The original or uncompensated VHF television oscillator circuit is indicated in Fig. 3, the frequency of which varies from 101 mc at channel 2 to 257 mc at channel 13. The inductances L_2 and L_3, at channel 13, are short-circuited; under these conditions the inductance L_1 and the circuit capacitances constitute the frequency-determining elements. At channel 7 however, only L_3 is short-circuited. Consequently, L_2 tunes from channels 7 to 13 inclusive, whereas L_3 tunes from channels 2 to 6 inclusive. All capacitances external to the oscillator tube are not temperature-sensitive.

2. *Analysis of the Original Frequency Characteristics* When installed in a VHF commercial color television receiver, the frequency characteristics of the original local oscillator at channel 6 are illustrated by the Δf (overall) curve in Fig. 4 which exhibits two distinct changes in slopes. Accordingly, there are at least two major components of frequency deviations.

a. The fast-acting component,

$$\Delta f_1 = \alpha_1 \, (1—e^{-\beta_1 t})$$

The fast-acting component is caused by the changes of tube capacitances during the early minutes of operation. To evaluate this component, all associated circuit elements of the original oscillator were replaced with a single inductance L_o made of "milvar" wire having an extremely low coefficient of thermal expansion. L_o and the tube capacitances then constituted the frequency determining elements. The corresponding frequency deviations are

$$\Delta f_1 = -0.00475 \, f \, (1—e^{-0.55t}) \quad (5)$$

It is evident that the frequency deviation, Δf_1, is directly proportional to the oscillator frequency. At channel 6, the oscillator frequency is 126 mc; so $\alpha_1 = -0.610$ mc and $\beta_1 = 0.55$ which is independent of the oscillator frequency.

b. The slow-acting component,

$$\Delta f_2 = \alpha_2 \, (1—e^{-\beta_2 t})$$

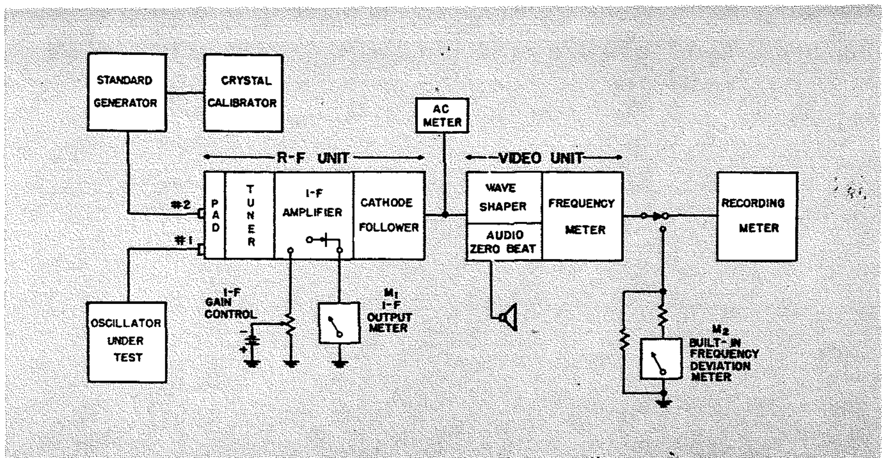
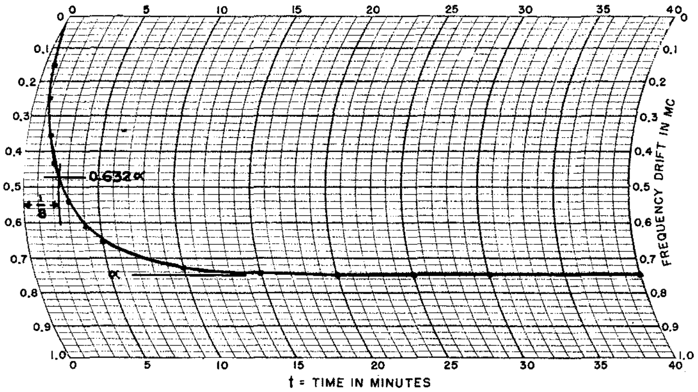


Fig. 1. Automatic frequency deviation recording meter.



$\Delta f = -0.750 \left[1-\epsilon^{-0.4t}\right]$

Local Oscillator Frequency— 525 MC

Fig. 2. Sample recording.

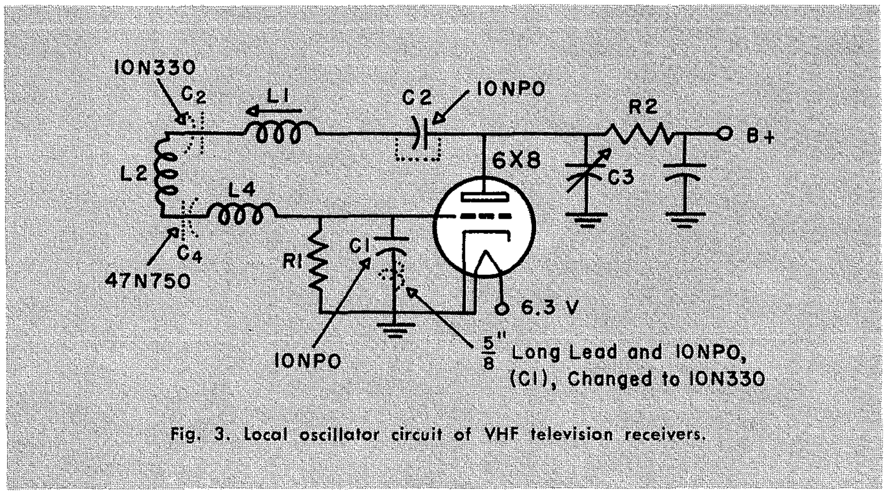


Fig. 3. Local oscillator circuit of VHF television receivers.

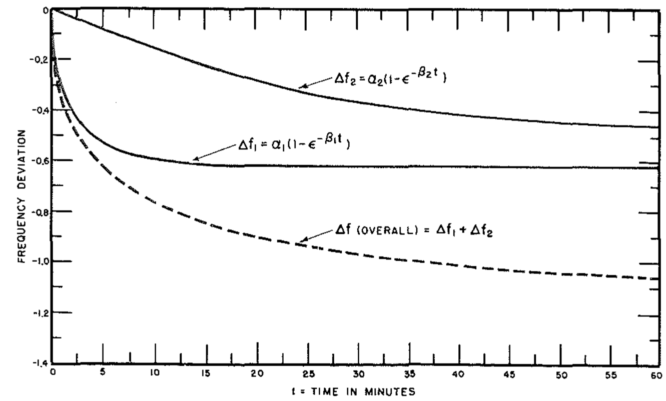


Fig. 4. Original frequency characteristics.

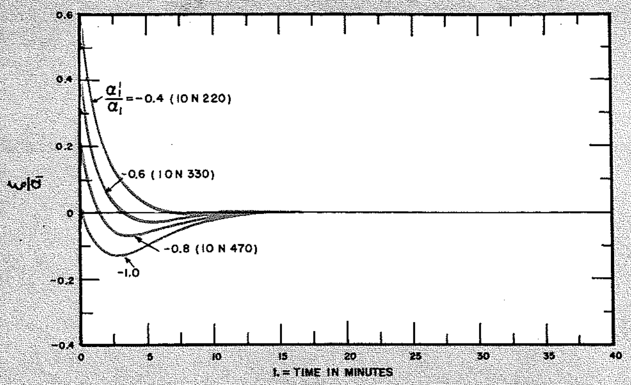


Fig. 5. Compensation error $\xi = \alpha_1 (1 - e^{-.29t}) + \alpha_1 (1 - e^{-.55t})$

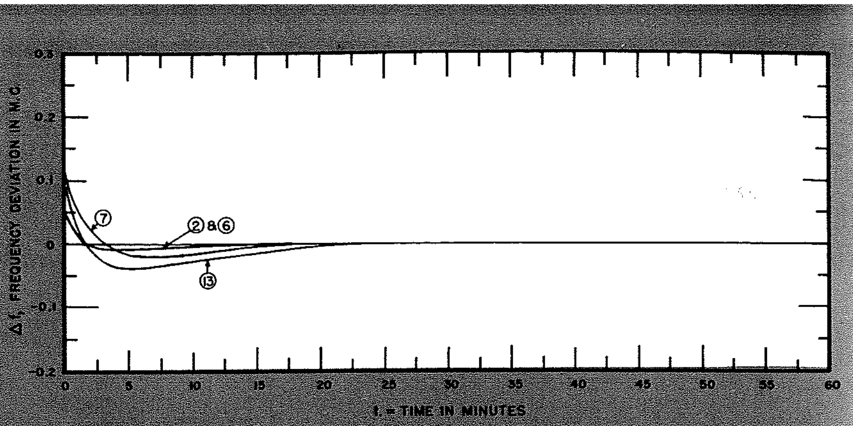


Fig. 6. Frequency characteristics of a stabilized VHF television local oscillator.

The difference between the instantaneous overall frequency deviation Δf and the fast-acting component Δf_1 gives the slow-acting component Δf_2. At channel 6,

$$\Delta f_2 = -0.500 \ (1 - e^{-0.04t}) \qquad (6)$$

3. *Requirements for Frequency Stabilization*

To obtain good frequency stabilization of the original local oscillator, the following requirements must be fulfilled.

a. At least two compensating elements, *A* and *B*, are needed—*A* to compensate for the fast-acting component Δf_1, and *B* to compensate for the slow-acting component Δf_2. The expressions for *A* and *B* are, respectively

$$\Delta f'_1 = \alpha'_1 \ (1 - e^{-\beta'_1 t}) \text{ and}$$

$$\Delta f'_2 = \alpha'_2 \ (1 - e^{-\beta'_2 t})$$

b. These two compensating elements must be so situated in the oscillator circuit that β'_1 of *A* approaches the value of β_1 of Δf_1, and β'_2 of *B* approaches the value of β_2 of Δf_2.

c. The compensating elements must exhibit negative temperature sensitivities, in this case, to raise the oscillator frequency with temperature rise.

d. The magnitudes of α'_1 of *A* and α'_2 of *B* must approach those of α_1 of Δf_1 and α_2 of Δf_2.

4. *Stabilization Procedures*

The stabilized oscillator circuit is again shown in Fig. 3; the modifications are indicated by the dotted components.

a. The capacitance C_1 (replaced with 10N330 and a lead of 5/8″)—The capacitance C_1 compensates for Δf_1, the fast-acting component of the oscillator-frequency deviation. For perfect compensation

$$\Delta f'_1 = -\alpha_1 \ (1 - e^{-\beta_1 t}) \qquad (7)$$

To make $\beta'_1 = \beta_1$, the capacitance C_1 must be located as close as possible to the source of heat flow. It is therefore placed at the grid pin of the oscillator tube. The resultant β'_1 value is 0.29 as compared to β_1 of 0.55 for the fast-acting component. The discrepancy between β'_1 and β_1 unavoidably introduces a compensation error, ε, where

$$\xi = \Delta f_1 + \Delta f'_1 \qquad (8)$$

The compensation error expressed in Equation (8) is evaluated in Fig. 5 with values for α'_1 to be -0.4, -0.6, -0.8 and -1.0 of the α_1 value. The error is minimum when $\alpha'_1 = -0.6\ \alpha_1$. At channel 6, $\alpha_1 = -0.610$ mc according to Equation (5); the corresponding compensating error, after two minutes of operation, is $-0.04\ \alpha_1$ or -0.025 mc, and $\alpha'_1 = -0.6\ \alpha_1$ or 0.360 mc. A compensating capacitance of 10N330 produces these results approximately.

The added inductance, consisting of a 5/8″ lead of C_1, makes α'_1 proportional to the oscillator frequency, as α_1 does, at all channels.

b. The capacitance C_2 (replaced with 10N330)—The capacitance C_2 compensates for the slow-acting component for channels 7 to 13 inclusive. At these upper VHF television channels, the inductance L_3 and capacitance C_4 are short-circuited. Again for perfect compensation,

$$\Delta f'_2 = -\alpha_2 \ (1 - e^{-\beta_2 t}) \qquad (9)$$

C_2 is situated among the associated circuit elements of the local oscillator where the rate of temperature rise is relatively low. Hence the value of β'_2 is approximately equal to β_2. The capacitance and temperature sensitivity of C_2 are determined in a manner analogous to that for C_1 and the corresponding $\alpha'_2 = \alpha_2$ at all upper VHF television channels.

c. The added capacitance C_4 (47N750)—At the lower VHF television channels, both C_2 and C_4 are effective in frequency stabilization. Owing to the difference in L/C ratios at the lower oscillator frequencies, C_2 is not sufficient to compensate for the frequency deviation. The addition of C_4 makes α'_2 (at lower channels) $= \alpha_2$. The β'_2 value of C_4 is about equal to the β'_2 value of C_2 because the locations of these two elements are equally distant from the heat source.

5. *Residual Frequency Deviations*

A typical production VHF television receiver incorporating these compensating elements behaves as shown in Fig. 6 at channels 2, 6, 7, and 13. The maximum residual frequency deviation is less than ± 50 kc after a period of two minutes, and all channels become almost completely stabilized within 30 minutes. This residual frequency deviation during the early minutes of operation is principally caused by the discrepancy between the β'_1 value of the compensating element and the β_1 value of the fast-acting component.

To further minimize the local oscillator drift, oscillator tubes other than the minature type must be used or the compensating element C_1 must be built inside the oscillator tube to produce a

β'_1 value about the same as β_1. Due to constructional differences, the β_1 of the RCA pencil triode tube, for instance, is 0.32 which is so close to the β'_1 value of 0.29 that any local oscillator using a pencil triode tube can be compensated more exactly than the results shown by Fig. 6.

CONSIDERATIONS PERTAINING TO UHF LOCAL OSCILLATORS

The same approach utilized to stabilize a VHF television local oscillator applies equally well to the stabilization of UHF local oscillators for all services. Appropriate compensating elements can again be secured by analyzing the original frequency characteristics of the oscillator with the aid of the analytical representation expressed in Equation (1).

1. *Dimensional Resonances*

The stabilization procedures at UHF, however, are further complicated by the fact that some of the associated circuit elements of the local oscillator may have electrical lengths comparable to $\frac{1}{4}\lambda$ of the local oscillator frequency. To illustrate this complication, a typical UHF commercial television local oscillator is shown schematically in Fig. 7a. This oscillator covers a continuous frequency range from 517 mc at channel 14 to 931 mc at channel 83 by means of a variable gang capacitor. This is coupled to the 6AF4A oscillator tube by a transmission line having a characteristic impedance of approximately 150 ohms.

At the socket pins of the 6AF4A tube, the oscillator voltage between the grid and plate falls to a minimum value at approximately 1000 mc. Any temperature sensitive element placed across these two points would affect the oscillator frequencies either above or below that frequency. At 1000 mc the effect is theoretically zero. Since the oscillator line is 1-9/16″ long, the voltage minimum or null point at the other end of the line corresponds to 500 mc.

Let the distance at the junction between the oscillator line and the stator assembly of the gang capacitor be zero, then the null points along the line are illustrated in Fig. 7b. For instance, the 725 mc null point occurs at ⅞″.

2. *Relative Effectiveness of Compensating Elements*

By placing an appropriate temperature-sensitive capacitor at any point "x" along the oscillator line, the relative effectiveness of frequency compensation (P_x) at an oscillator frequency (f) is determined by

$$P_x = 1 - |\operatorname{Sin}\theta|$$

where

$\theta = \frac{1}{2}\pi\, f/f_x$

and

f_x = null frequency corresponding to point x

3. *Three-Point Compensation*

One compensating element, when properly placed in the UHF oscillator circuit, is sufficient only in receivers designed for a single-frequency or very narrow frequency range operation. To cover an extended band of frequencies, three compensating elements are required for good stabilization. Let compensating capacitances C_1, C_2, and C_3 be connected at points along the oscillator line corresponding to null frequencies of 1000, 500, and 725 mc respectively. The relative compensations of C_1 ($f_{x1} = 1000$ mc) and C_2 ($f_{x2} = 500$ mc) on the oscillator frequency are given by the K_1P_1 and K_2P_2 curves respectively in Fig. 8. The $K_1P_1 + K_2P_2$ curve shows the combined effect of C_1 and C_2.

It must be stressed that the temperature sensitivities and capacitances of these compensating elements depend upon the α values needed at these frequencies. The constants K_1, K_2, and K_3 take into account the differences in temperature sensitivities and capacitances of these three compensating elements. Furthermore, since the oscillator line is a good heat conductor, the β values at these three locations do not differ too much.

The contribution of C_3 ($f_{x3} = 725$ mc having a positive temperature sensitivity) is represented by the dashed curve K_3P_3 which leads to an overall compensation marked $K_1P_1 + K_2P_2 + K_3P_3$. Several commercial UHF television receivers have been stabilized with three-point compensations. The residual frequency deviations are less than ± 100 kc at any UHF television channels.

CONCLUSIONS

With the aid of the automatic recording equipment, the analytical expression for frequency deviations greatly simplifies the problem of local oscillator stabilization. The procedures described to stabilize a VHF television local oscillator may be followed to combat the warm-up drift of local oscillators for practically all services at frequencies up to and including the UHF band.

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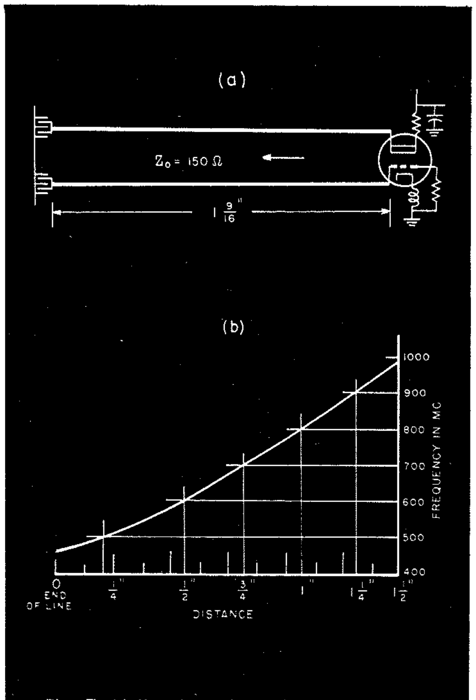


Fig. 7. Null points along the oscillator line.

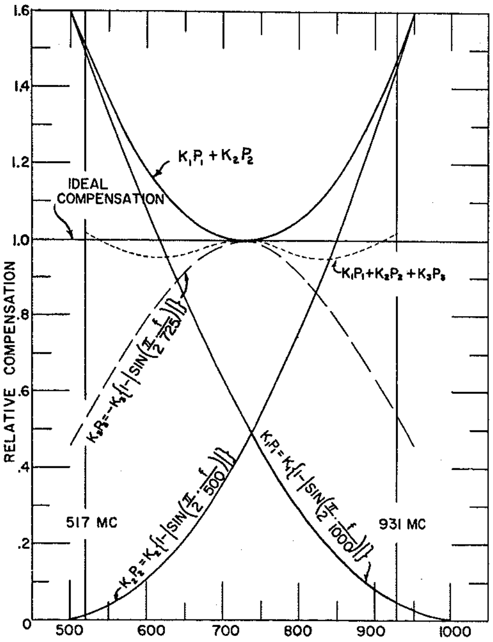
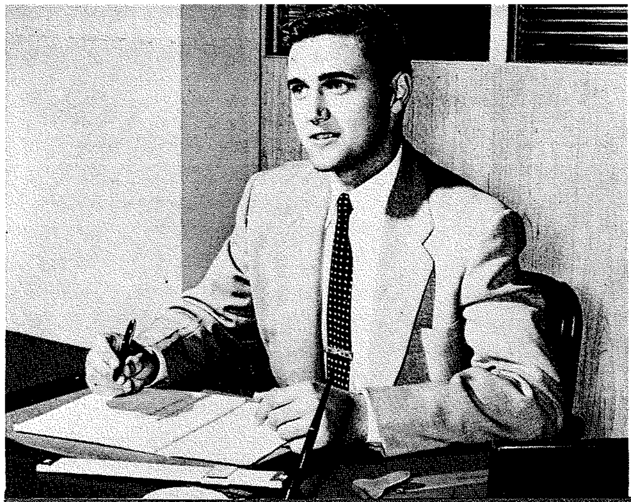
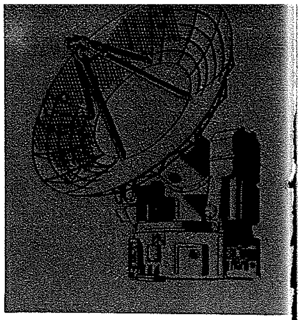


Fig. 8. 3-Point compensation.



DAVID K. BARTON received his A.B. Degree in Physics from Harvard University in June 1949. Upon graduation he returned to White Sands Proving Ground, New Mexico, to resume, under Civil Service, the development work on guided missiles range instrumentation started during his Army service in 1947-48. Four years' experience in tracking radar and computer system engineering at White Sands was followed by two years in the Radar Division of the Signal Corps Engineering Laboratories at Fort Monmouth. Mr. Barton joined the Missile and Surface Radar Section at Moorestown, New Jersey early in 1955 and has since worked in the Systems Engineering Group on Instrumentation Radar and advanced systems problems.



IRVING STOKES, Manager of Information Handling and Radar Projects Engineering, received a BS in EE degree in 1938 from Newark College of Engineering. In 1939 he completed the graduate course in Thermionic Tube Theory at the Stevens Institute of Technology. He has also successfully completed courses in Management and Application of Statistical Analysis to Design of Experiments.

In 1938 Mr. Stokes joined Tung Sol Lamp Works, where he was connected with analysis and control of radio tube quality. He joined the U. S. Army Signal Corps as a civilian design and development engineer in 1940. Mr. Stokes was engaged in the design and development of radar applications for searchlight and anti-aircraft control; recognition and identification; paratrooper and advance airport homing beacons; ground navigation systems; electronic surveying and missile trajectory determination and guidance. During this period he was awarded four patents.

Prior to joining RCA in 1955, as Manager of the Precision Tracking Radar Systems Projects Group, Missile and Surface Radar Engineering, Mr. Stokes was Deputy Director of the Radar Division of the Signal Corps Engineering Laboratories. Mr. Stokes is a member of Tau Beta Pi and a former member of industry panels and committees in the field of radar and guided missiles.

GUIDED MISSILE INSTRUMENTATION RADAR

By

I. STOKES and D. K. BARTON
Missile and Surface Radar Engineering
Defense Electronic Products
Moorestown, N. J.

IN 1946 THE FIRST German V-2 rocket to be fired in this country sat on the launcher at White Sands Proving Ground. After final count-down began, the men at the radar desert site, 1 mile south of the launcher tensely awaited the rocket launcher signal. The historical significance of the imminent event was of secondary importance in the minds of the participants to the desire to achieve a successful conclusion to nine or more months of intensive design, development and planning effort. At zero time, a cloud of smoke, flame and sand rose beneath the missile as it slowly lifted itself from the base and hovered precariously a few feet off the ground, seeming to drop back a little just prior to the start of a determined acceleration skyward. At launch a strong radar reply from the missile beacon appeared on the radar scope and automatic tracking began soon thereafter. At approximately 9,000 feet above the desert floor, the V-2 began to wobble noticeably so that observers at all points of the compass received the illusion that the rocket was about to fall in his direction. At this point, one of the fins tore off and fluttered towards the ground as the missile laid over on its side and headed for Texas. The fuel cut-off device was activated and impact 18,000 yards from the launcher resulted in a crater 30 feet deep and 30 feet across. The radar had tracked and plotted the complete trajectory, in spite of the fact that the lost fin had contained the beacon receiving antenna. This rather gratifying radar performance established the radar as a key device for guided missile instrumentation.

EARLY U.S. SYSTEMS

The development of high-altitude research rockets and guided missiles in the United States brought together instrumentation methods from many fields. From the aircraft test field came internal instrumentation, radio telemetry and recording devices. Anti-aircraft artillery evaluation has made extensive use of theodolites, and these were brought to bear on missiles in the earliest stages of development. Various fixed camera methods were derived from other ordnance projects, as well as from the field of Astronomy, which also contributed the long focal length telescope. Electronic instrumentation came from the fields of navigation, direction finding, fire control, close-support bombing, and from specialized methods such as the doppler radio techniques used by the Germans in the V-2 program. Since the program got under way toward the end of World War II, it was logical that military equipment, surplus and captured, would play a significant role, and this was certainly true in the case of radar equipment.

THE SCR-584 RADAR

One radar in particular, the SCR-584, proved particularly valuable to the test ranges, and has maintained its usefulness to this day. The primary reasons for this were its availability (some fifteen hundred sets had been built by the end of the war), reliability (a tremendous production and field engineering effort had followed the original MIT Radiation Laboratory development work), and flexibility. Designed for control of 90mm AA guns and similar weapons, the SCR-584 was equipped with alternate forms of data output, an oversized modulator and power supply, and ample space for additions and modifications that proved necessary. Furthermore, development of instantaneous electronic plotting boards (operating in rectangular coordinates) had already been carried out for use in close-support bombing and in mortar location. Transponder beacons were also available from the close-support bombing program, as was a standard radar modification for long-range tracking of beacons. Thus, the SCR-584 was ready for the earliest V-2 and Wac Corporal firings at White Sands Proving Ground, and was in use at other rocket ranges. Along with the radar, of course, there were used the famous German Askania theodolite, Bowen-

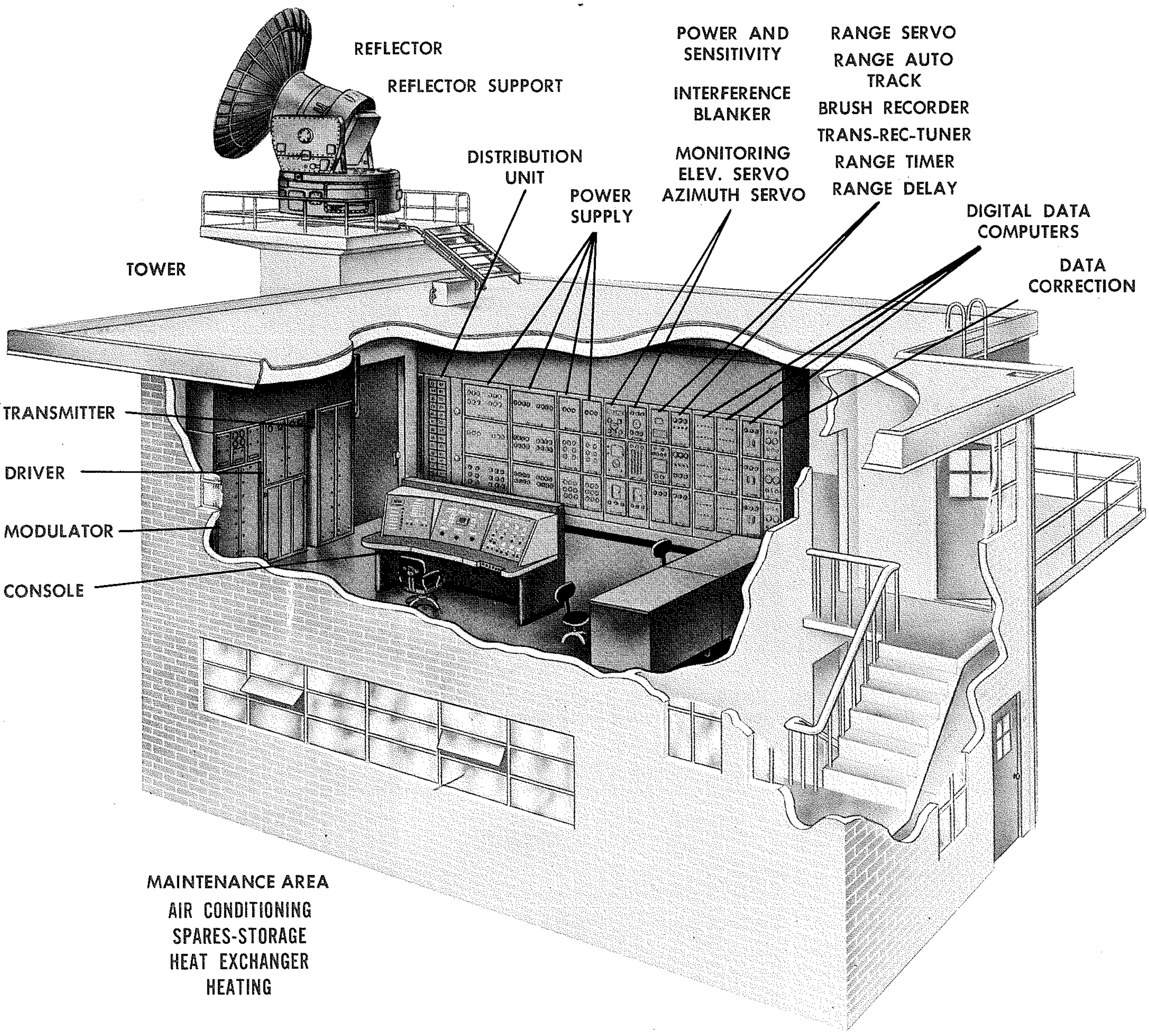


Fig. 1—Artist's conception of typical Instrumentation Radar equipment setup.

Knapp fixed cameras, and doppler radio system.

MODIFICATIONS AND REFINEMENTS

The flexibility of the original SCR-584 has already been mentioned. Dozens of important field modifications were made in order to incorporate design advances to this radar at various times in the range instrumentation programs. These were concerned primarily with extending range of tracking and range rates, synchronizing adjacent radars for reliability of operation without interference, recording of position and signal strength data, and providing control links to the missile through modulation of radar pulse rate or pulse code. Ultimately these and other improvements were incorporated through factory modification in the AN/MPQ-12 radar, which first became available in 1949, and in the improved AN/MPQ-18, which followed the MPQ-12 in design and has been operational since late 1954. These radars have been used primarily at WSPG, but similar modifications have been applied to the SCR-584 for use at NAMTC (Pt. Mugu), NOTS (China Lake), AFMTC (Cocoa), Edwards Air Force Base, and Eglin Field. Other nomenclature applied to modified SCR-584 radars includes AN/MPG-2 (refers to X-band set using MC607 kit on standard SCR-584), AFMTC tracking radar Mod II (similar to the MPQ-18) and AFMTC tracking radar Mod III (C-band version of Mod II). Some of these sets are still in the process of factory modification, with delivery extending through 1956. In each case, the basic SCR-584 pedestal, modulator and power supply, and 30-cycle conical scan is employed, while most other major components have been replaced or extensively modified. In some cases, the cost of modification has run to two or three times the original cost of the radar.

Parallel to evolution of improved radars has been a great effort in system design, involving chain radar operation, real-time computing, plotting and data transmission, precision data recorders, communications systems, transponder beacons, control and telemetry equipment. The effect of this effort, which will not be described in detail here, has been to provide further uses for radar data, and to keep a continuing pressure towards development of radars with greater precision and range, so that significant data can be supplied to the instrumentation system as a whole.

PRECISION RADARS

The inherent advantages of the use of radar for military purposes have encouraged great efforts in development of precision radars, which have proceeded continuously at RCA since the end of World War II. The chief results of this effort have been four major radar equipments culminating in the Instrumentation Radar, AN/FPS-16 (See Cover Illustration and Fig. 1).

The first of these major radar programs is known as the Bumblebee radar which was developed by RCA as an associate contractor of the Applied Physics Lab., Johns Hopkins University. The Bumblebee radar has been tested extensively and has been in continuous operation at Applied Physics Lab. since May 1953.

The second precision radar built by RCA is known as the Terrier radar, and was designed for use in the Army Application of the Navy Terrier Guided Missile System. This radar has been in continuous operation since early 1954, at the Naval Ordnance Test Station, Inyokern, California, where it was tested extensively by the Marine Corps.

The third member of this family of precision radars is the Instrumentation Radar AN/FPS-16 (XN-1) which was developed for the Navy Bureau of Aeronautics. The radar has been completed and has been evaluated by the Naval Research Laboratory. The results achieved with this radar have shown that its tracking performance is superior to any radar tested to date.

Two AN/FPS-16 (XN-2) radars are presently being built at RCA's Moorestown Plant. These radars are production prototypes and are expected to exceed the performance results achieved with the XN-1 model. (See equipment photos of Figs. 2, 3, 4 and 5.) A production contract for twenty-two AN/FPS-16 radars has been awarded to RCA with delivery commencing in December 1957. The proven high accuracy of the AN/FPS-16 design has resulted in the adoption of this precision instrumentation radar for use at the Navy, Army and Air Force guided missile test ranges at Pt. Mugu, California; White Sands Proving Ground; and Patrick Air Force Base, Florida.

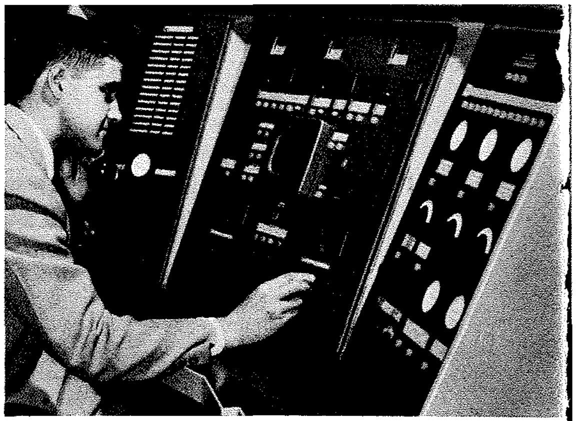


Fig. 2—David K. Barton, one of the authors, is shown at the control console of the Instrumentation Radar.

The net result of these developments, occurring over the last twelve years has been to make available a radar capable of precision and instrumental accuracy to a factor of ten greater than that obtained with modified SCR-584's.

BRIEF DESCRIPTION OF THE AN/FPS-16 INSTRUMENTATION RADAR

The Military Performance or operational characteristics of the AN/FPS-16 are classified and cannot be discussed here.

The radar is designed for installation as a fixed station and will be housed in a building similar to the artist's conception shown in Fig. 1. The antenna pedestal is mounted on a tower which is isolated from the building proper in order to minimize vibrations transmitted to the tower. The electronic equipment is housed in specially designed rack-type cabinets with ease of maintenance as a primary consideration. (See Figs. 3 and 5.) The equipment is cooled by a closed circulating air-conditioning system. A regulator is provided at the bottom of each cabinet to control the amount of cold air entering, with the return through a duct at the top of the cabinet. The operating console of modern design was "human engineered" for optimum operator efficiency. Only one operator is required even though the radar is one of the most complex built to date.

The obvious importance of reliable performance during operations involving the expenditure of thousands of dollars has dictated the use of the latest reliability techniques in the equipment design. In addition built-in checkout equipment has been included to insure adequate monitoring of component performance.

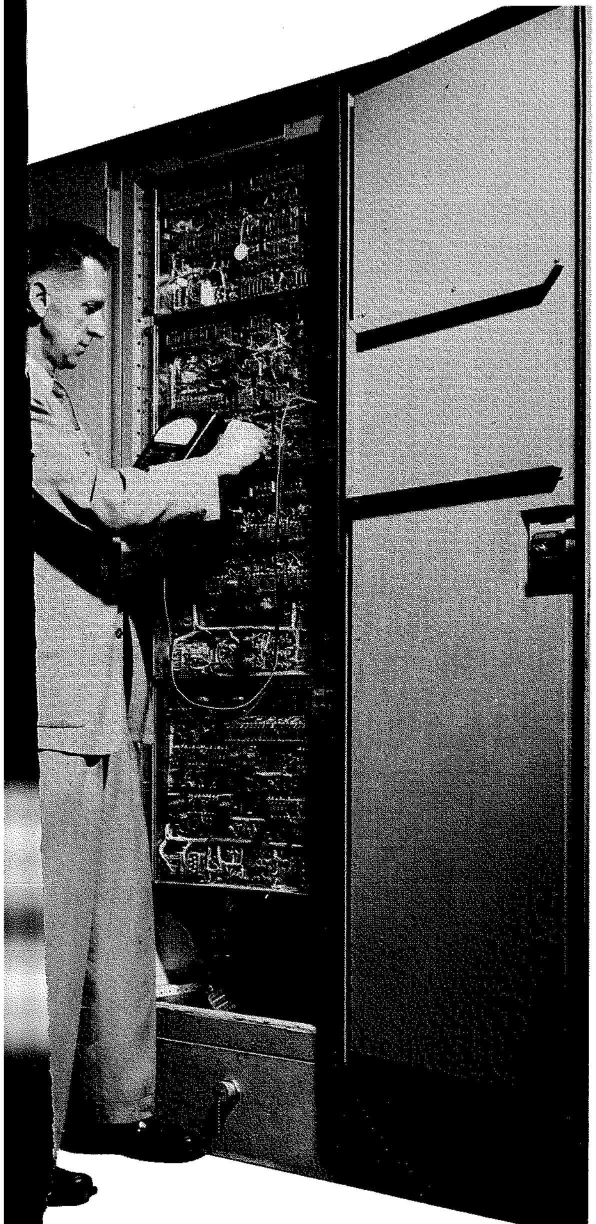
The antenna pedestal shown on the front cover was built to give high mechanical accuracy and smooth tracking, and was made rugged to give reliable operation under severe environmental conditions. Its performance has been such that it represents a major advancement in the state of the art.

Since Instrumentation Radar installations represent a considerable investment of money, effort and training, a high degree of flexibility has been achieved. This makes feasible the later inclusion of new advances in radar and thus forestalls early system obsolescence. In addition, the flexibility provides an instrument adaptable to a multiplicity of missions required by the guided missile test ranges. Some examples of this flexibility include the ability to:

a. Change frequency readily.
b. Provide synchro, potentiometer and digital data individually or simultaneously.
c. Track skin reflections or beacons.
d. Accept two or three coordinate designation data.
e. Be readily modified by substitution of chassis or racks in a generously spaced equipment layout.

In spite of all the sterling characteristics achieved in this radar design, RCA is currently engaged in the development of some significant improvements to enhance the system usefulness and maintain the enviable lead over competitive equipments.

Fig. 3—Merritt Sheeder, Project Engineer, is making a circuit check at the readily accessible underside of an Instrumentation Radar Chassis.



THE RADAR AND ITS TASK

A tracking radar is essentially a device whereby a highly directive antenna is positioned by a servomechanism onto the selected target, from which range and angular error signals are derived by reflection of the radar's transmitted wave or by use of a transponder in the missile or aircraft being tracked. The Instrumentation Radar operates in the microwave frequency. region and uses pulse transmission. The position of the target is given by two angles of the antenna (azimuth and elevation) and by slant range from the radar. The principal advantages of employing the radar for guided missile instrumentation, as compared with the best of competitive systems, are its ability to track with high accuracy in darkness and through clouds, as well as atmospherically clear conditions to long ranges, and to yield data which can be readily and instantaneously reduced to its final form. These advantages are possessed by no other means of range instrumentation. The Instrumentation Radar will therefore be used to track missile and aircraft targets (with or without beacon transponders) and to produce spherical coordinate data outputs of high accuracy from which an instantaneous record of the target trajectory can be obtained.

REAL-TIME PLOTTING AND RANGE CONTROL

Test ranges have for some time exploited the obvious advantages of the radar method where high accuracy has not been required. One such application has been instantaneous display of target data on plotting boards, for quick evaluation of flight operations and for range control and safety. In this application, the presence of all data in electrical form at one station, with reduction to rectangular form within the capability of simple analog computers, has hastened the growth of large installations for plotting of multiple targets in various projections, using data from several radars simultaneously. The ability of radars to track aircraft by reflection, as well as the abilities to conduct several tracks from a single station without interference, and to transmit commands to the target through special beacons, have made radar a primary means of control for drone aircraft and a potential means of guidance for various missile tests.

Existing modifications of the SCR-584 have proven sufficiently accurate for real-time plotting of position on a full-scale basis, but difficulties arise when small regions in space are expanded for detailed plots, or where velocity data is required. Limitations of these radars have prevented full exploitation of the radar-plotting system for impact prediction of high altitude missiles and similar tasks. With the availability of radars such as the AN/FPS-16, the limiting errors will be shifted back to the computing or plotting equipment in most cases, and predictions from velocity data will be greatly improved.

CHAIN RADAR SYSTEMS

As long as missile tests were conducted at short range or on near-vertical trajectories, a single radar station sufficed for tracking. However, as soon as long range horizontal flights or other trajectories of military interest were undertaken, the need for two or more coordinated tracking stations became apparent, and "chain radar" systems were developed. To this day radar systems with the ready availability of electrical data in a form for simple reduction, have been essentially the only source of real-time data for exchange between stations. Once available for transmission, radar data is used to position other types of instrument as well as succeeding radars in the chain. Accuracy of modified SCR-584 radars has proved barely sufficient for applications involving transmission of real-time data, and considerable system work has been done to preserve even this accuracy through the various conversions of coordinates and electrical form required. Present systems use analog data outputs from the radar to feed coordinate conversion analog computers located at each radar site. Analog data in rectangular form is then converted to digital form for transmission over communication links, and the reverse process followed after reception at the remote point. With the high accuracy of the AN/FPS-16 radar, the analog processes used in chain operation can be eliminated entirely. Designation of a target, remote plotting of position on an expanded scale, or recording of data for trajectory analysis purposes will thus be possible to the full accuracy of the radar instrument.

RADAR DATA PROCESSING

In addition to real-time use of analog data from the radar, most test ranges require some more accurate permanent record of radar tracking data. With the arrival of precise instrumentation radars such as the AN/FPS-16, this facet of radar instrumentation will assume increased importance. There is presented the prospect of precise tracking data, available under all-weather operations, with negligible reduction time required, and limited in accuracy chiefly by uncertainties of tropospheric refraction. Where most present installations depend upon photographic recording of synchro data, range scopes, mechanical scales and (when possible) boresight telescopes (Fig. 4), the new radars will provide direct digital read-out of angle and range data, as precise as (or more precise than) present theodolite data and requiring only solution of two simple triangles for reduction to rectangular form. Refraction correction-to-elevation angle data will also be needed to obtain highest accuracies, and in general some modification from rectangular coordinates is needed to put the data in form for final use. None of these processes need take longer than a few seconds per data point reduced, even in such machines as present card-programmed calculators, and in many cases real-time reduction should be possible. Direct electrical transfer (possibly through magnetic tape recording) will eliminate all manual reading operations. The method has already been demonstrated at the White Sands Proving Ground and elsewhere, limited by the accuracy of modified SCR-584 radars. Of particular importance in the new radar, is the elimination or correction within the radar of the several sources of significant error which have formerly required calibration and correction in the reduction process. In the AN/FPS-16, for instance, these errors will not merely be calibrated and known, but will be reduced below the threshold of significance for data reduction. Means of applying the refractive correction for average atmospheric conditions automatically have also been investigated and are feasible within the confines of the radar. Output data to the computers will thus be capable of immediate reduction by simple processes, without manual operations of any sort, and without any film processing.

COMMUNICATIONS FOR RADAR INSTRUMENTATION SYSTEMS

One of the major advantages of the radar method is that each station is self-sufficient as far as trajectory measurement is concerned. Communications channels are used for data transmission in the chain radar system assuring target acquisition both for radars and for optical and other instrumentation remote from the launcher. Other than this, communications requirements for a radar instrumentation system are chiefly for voice communications, signalling and control circuits, and timing. Even in the timing circuits there do not exist the extreme requirements for precision that apply to baseline instrumentation systems—it is only necessary to match the complete trajectory data obtained at the radar to some range time reference within a few tenths of a millisecond to achieve full system accuracy. Present digital data transmission equipment (such as AN/TSQ-1) is designed to operate reliably within the poorest voice channels, and thus an entire radar instrumentation sys-

Fig. 4—Defense Electronic Product engineers (left to right: Merritt Sheeder, Lawrence Carapellotti, and Simpson Adler) are examining an Instrumentation Radar schematic with the radar boresite tower in the background.

tem can be operated using standard voice communications links.

RADAR BEACONS

Transponder beacons developed for navigation and close-support bombing were used in the first V-2 and Wac Corporal in 1946. In the succeeding ten years, intensive development has made available a series of radar beacons expressly designed for range instrumentation. Small size, light weight and low-power drain are the distinguishing characteristics of most of these, and ruggedized construction far beyond that required in guided missiles has been achieved.

The use of a beacon improves radar tracking in three respects, as compared to reflection tracking. First it extends the range by an amount depending chiefly on the ability of the beacon receiver to sense the radar interrogation. Secondly, a beacon provides a point source for the radar to track, eliminating target scintillation. A comparison of reflection and beacon tracking results for similar flight paths shows that improvement is obtained at relatively short ranges. Thirdly, use of a beacon provides positive identification of the desired target and rejection of ground clutter. With the beacon transmitter offset several megacycles (or any desired amount within the radar band) reflective targets and clutter are attenuated 30 to 40 db. Special codings in the beacon receiver or transmitter can distinguish one beacon from another when several are used at once in the same area.

A further advantage of using a beacon is that it provides a two-way communication path between the target and the ground radar. Equipment is available to utilize this channel for guidance commands, emergency cut-off or detonation commands, and for telemetry from the target. The high gain and reliability in the radar-beacon path is available for these functions, while frequency selectivity, pulse coding, and the narrow radar beam provide protection from interference. Channel bandwidth is limited, of course, since the radar repetition rate provides the "carrier" for all information exchanged. Depending on the method of modulation, bandwidths in the order of a hundred cycles are available for each pulse in a code group used for information. Five or more such pulses may be used simultaneously in each direction of transmission, meeting most requirements for simple telemetry.

CONCLUSIONS

The Instrumentation Radar AN/FPS-16, based on extensive research and development effort carried on continuously since the last war, has been demonstrated to be capable of instrumental accuracy and precision well beyond the known uncertainties of tropospheric propagation. Combined results of field tracking tests, mechanical and electrical lab tests, and error analysis indicates extremely high overall accuracy.

The radar can maintain the above accuracy and precision under all normal weather conditions, target maneuvers and target locations (within the observed hemisphere of coverage) except at zenith and below 2 to 3 degrees in elevation angle.

Systems for using radar data in real-time and for later analysis are far advanced, and can provide complete trajectory data without appreciable time lags.

No other instrumentation system can attain higher accuracy over extended paths (10 miles or greater) under average weather conditions. Only plate camera systems (against a star field at night) offer any substantial margin of accuracy at any time.

ACKNOWLEDGEMENT

The list of technical contributors to the ten-year program leading to this major advance in the radar field would be too extensive to reproduce here. The authors have merely recorded the biographical sketch of the growth of an important new equipment. The credit for engineering advances of the system belong to the Missile and Surface Radar Department collectively and to greater and lesser degrees with individual engineers in the organization.

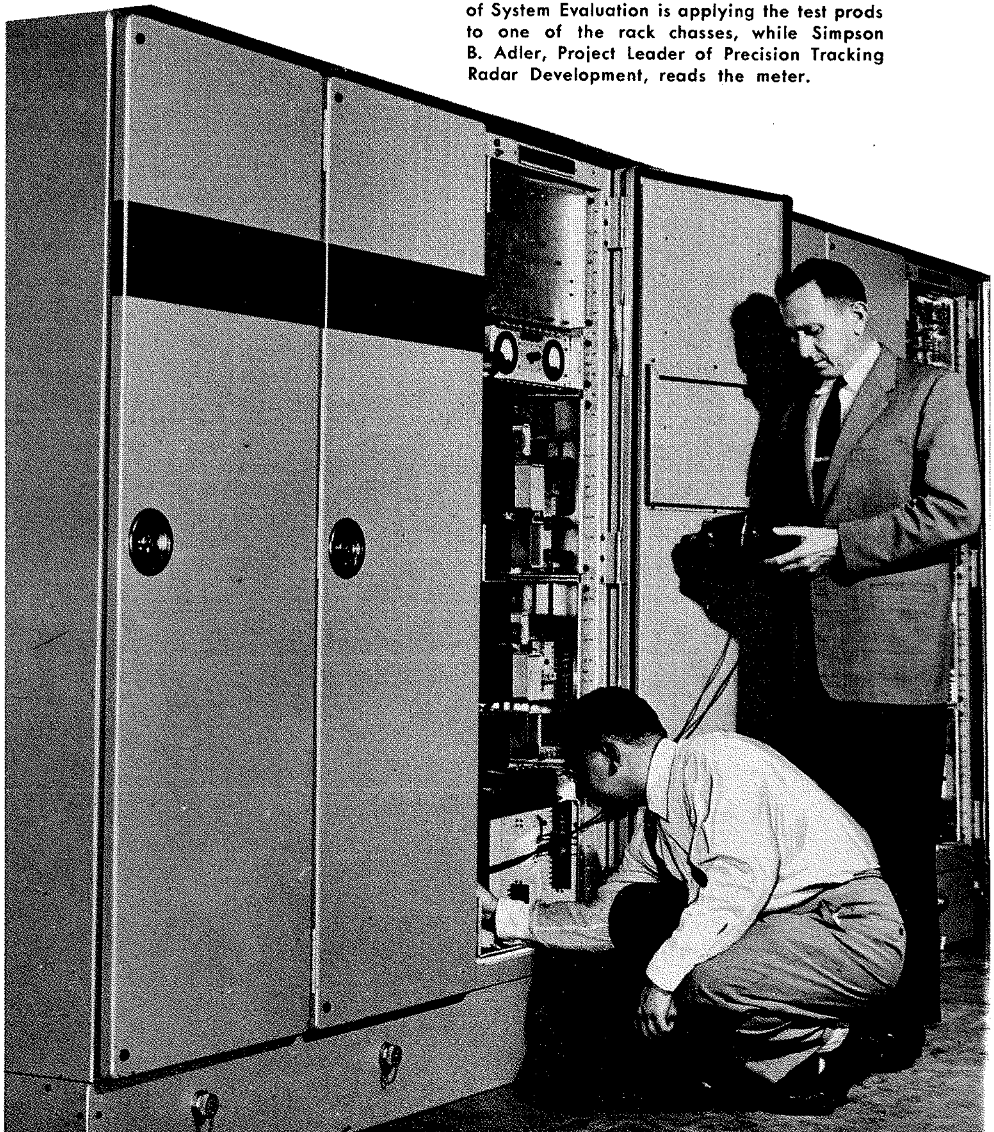


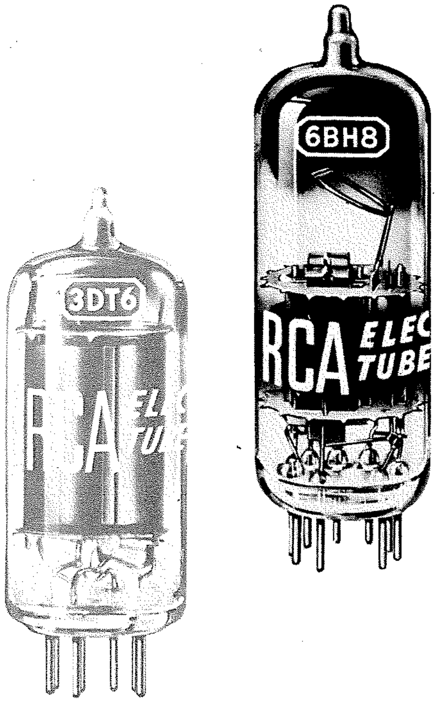
Fig. 5—Lawrence T. Carapellotti, Project Leader of System Evaluation is applying the test prods to one of the rack chasses, while Simpson B. Adler, Project Leader of Precision Tracking Radar Development, reads the meter.

SERIES-STRING APPLICATIONS OF ELECTRON TUBES (COMMERCIAL AND MILITARY)

by

R. G. RAUTH

Receiving-Tube Applications Laboratory
Tube Division
Harrison, N. J.



THE MANUFACTURERS of electron tubes and components are engaged in a never-ending search for improvements in quality which will result in greater reliability. A basic ingredient of quality, not only in development and design, but also in manufacturing is a constant attention to detail. In most formulations of the reliability of specific equipments, it is agreed that "reliability is predictable only if adequate information is available on the quality of components and the conditions to which they will be subjected."[1]

In the consideration of the reliability of electron tubes in series-string applications, it is of primary importance to consider first the conditions or factors peculiar to electron tubes operating in series strings.

HEATER SURGE VOLTAGES

When the decision was made in the television industry to use electron tubes with heaters connected in a single string, a program was undertaken to determine the probable maximum surge voltages to which individual electron-tube heaters might be subjected. The data obtained from tests conducted in the course of this program have formed the basis for a universal curve from which general conclusions can be drawn concerning possible surge voltages to be expected in series-string applications. These data have also made possible the formulation of heater-warmup-time ratings and limits which are commensurate with tube life and equipment reliability.

To obtain information applicable to the numerous combinations of tubes which might be used in series-string applications, it was necessary to design a test that would impose more stringent conditions on the tube than would be encountered in most commercial or military applications. These conditions were achieved in a nineteen-tube string having a "string warm-up time" of fourteen seconds. The "string warm-up time" is defined as the sum of the products of the rated heater voltage and warm-up time of the individual tubes in the string divided by the line voltage. The string was considered to be uniform because none of the tube warm-up times varied by more than 0.3 seconds from the string warm-up time of 14 seconds. This uniformity prevented individual tubes in the string from absorbing any initial surge voltage from the tube under test. Tubes having warm-up times ranging from 7 to 16 seconds were successively inserted into the test circuit to obtain a surge-voltage reading. The string warm-up time was recalculated for each tube. Final data compiled for tubes in the 2-, 3-, 5-, 6-, 12-, and 25-volt classes are shown graphically in Fig. 1.

FEATURES OF SURGE-VOLTAGE CURVE

The ordinate in Fig. 1 is the ratio of tube surge voltage to rated heater voltage, and the abscissa is the ratio of tube warm-up time to string warm-up time. The use of these ratios makes the vertical and horizontal axes unitless, thereby allowing the curves to be used universally in the determination of surge voltage to be expected in series-string applications regardless of variables such as number of tubes and combinations of heater-voltage ratings in the string. The warm-up time of any tube in the string and the string warm-up time are the only two factors which must be known to determine the probable surge voltage that a tube will be subjected to in a particular string. Sufficient experimental data indicate that the curves are applicable to all strings having warm-up times in the range from 8 to 14 seconds. Analysis of the curves in Fig. 1 confirms the assumption that no surge voltage will occur when the ratio of tube warm-up time to string warm-up time is equal to unity.

All points on the curve were obtained experimentally except those at zero warm-up time. These points which were calculated, served to prove the experimental trend that a separate and distinct curve exists for each voltage group. These end points have also been verified experimentally, within reasonable limits, by the insertion into the test circuit of tubes which were previously heated at 80 per cent of their rated heater voltage. The circuit shown in Fig. 2 was used to determine these end points. In this circuit, r_1, r_2 . . . r_{17}, r_{18} represent the resistances of the 14 second tubes in the test circuit, and R represents the resistance of the tube under test.

At time t_0, or when switch s_1 is initially closed,

$$Vt=\frac{E}{\Sigma r_1 \ldots r_{18}+R} X R$$

where V_t = initial surge voltage of the tube under test
E = line voltage
r = individual cold resistances of the 14-second tubes
R = resistance of a tube under test having zero-second warm-up time at t_0

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[1] G. R. Herd—"Estimation of Equipment Reliability" ARINC, Washington, D. C., May 26, 1955

It was assumed in these calculations that the cold resistance of a heater is equal to 1/7 of its hot resistance. This value was confirmed by measurement and found to vary less than 10 per cent.

In the standard test circuit used in the determination of the warm-up time of electron tubes shown in Fig. 3, the cold resistance of the tube under test is always equal to 0.75 of its hot resistance.

The warm-up time of an electron tube is defined as the time required in this circuit for a tube to reach 80 per cent of its rated heater voltage, E_f, after switch S_1 is closed. The series limiting resistor R_s is equal to three times the hot resistance of the tube, or 3.0 R_h. The resistance, R, of the tube under test at the 80-per-cent-E_f point is given by

$$R = \frac{0.8\ E_f}{3.2\ E_f/3.0\ R_h} = 0.75\ R_h$$

USE OF CURVES

The practical significance of the surge-voltage curves in the design of reliable series-string circuits may be demonstrated by discussion of a typical application. Table I shows a popular heater string for television receivers. In this string, it is not possible to utilize a series limiting resistor because the tube voltages add up to approximately the nominal line voltage of 117 volts. This string is typical of the most severe designs from the standpoint of heater surge voltages. Although the use of a series limiting resistor could reduce possible heater surge voltages by approximately 15 to 20 per cent, changes would have to be made in the selection of tube types. The heater warm-up time indicated in Table I for each tube type is an average reading for a large number of tubes. These average times vary between 10 and 14 seconds depending upon tube type. The range of values is primarily due to differences in structural design and heater-cathode breakdown considerations between tube types. Experience has shown that heater warm-up time varies in proportion to the mass of the heater, including the insulating coating. Consequently, tubes having large heaters, such as the 25CD6-GA, have average warm-up times in the order of 13 seconds, and tubes having small heaters, such as the 3CB6, have average warm-up times in the order of 10 seconds. On this basis, it is almost impossible in practice to obtain a string warm-up time of 14 seconds. In most applications, the string warm-up time will probably range between 11 and 13 seconds. The warm-up time for the string shown in Table I was calculated to be 12.4 seconds, which is a reasonable value to be expected for most applications. For series-string tube types utilizing 600-milliampere heaters, heater surge voltages of no more than 1.5 times the rated heater voltage are considered to be safe. Table I shows that in no case does this surge voltage exceed 140 per cent. Because these tubes are controlled so that a random selection of tubes will provide samples having a narrow range of heater warm-up times in a particular application, it is reasonable from the standpoint of design and reliability that the heater string in Table I would be satisfactory.

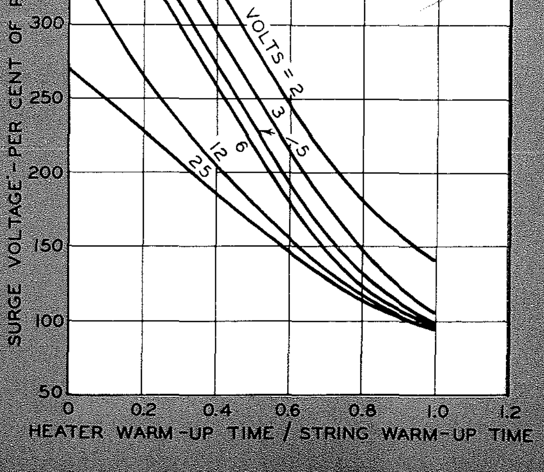

Fig. 1—Universal surge voltage curve

HEATER-CATHODE LEAKAGE

When electron tubes are operated in series strings, particular importance must be attached to the problem of heater-cathode leakage and the significance of heater-cathode ratings. Heater-cathode leakage is caused primarily by the conduction or emission of electrons between the heater and the cathode. A recent paper[2] has described this phenomena as a collection of positive ions in the heater coating which can be reduced by the use of high-purity alundum coating and high-temperature processing during tube manufacture. The use of this technique reduced heater-cathode leakage levels by a whole order of magnitude. Closely allied with the problem of actual leakage currents is the problem of hum, which may be caused by magnetic coupling between the heater and the free electrons near the cathode surface or capacitive coupling between the heater and grid or between the heater and cathode.

Although many of the problems related to heater-cathode leakage can be overcome through good tube design, high levels of quality control, and proper manufacturing techniques, it becomes increasingly important in series-string applications to avoid situations which tend to aggravate leakage problems. The reliability and life of tubes can be seriously affected by slight changes in environmental and usage conditions.

In general, most electron tubes for series-string applications have a maximum heater-cathode-voltage rating of 200 volts. (Damper diodes and tubes which are quite frequently used in "stacked B+" systems have consid-

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[2] "Some New Developments Which Have Improved Subminiature Tube Quality" by Irving E. Levy, *Proceedings* of Second National Symposium on Quality Control & Reliability in Electronics (Washington, D. C., Jan. 9-10, 1956)

erably higher ratings.) This value is a peak voltage rating, i.e., the sum of the d-c and peak a-c voltages existing between the heater and cathode including signal voltages. The heater-cathode-voltage rating usually specifies polarity and is generally lower for applications in which the heater is positive with respect to the cathode. It has been shown that heater-cathode breakdown and heater burnouts are a function of the rate of tungsten transfer from the heater to the cathode. This rate is significantly influenced by bombardment of the heater by electrons from the cathode. These electrons form positive tungsten ions in the heater which migrate to the cathode at a rate dependent upon the polarity of the heater-cathode voltage and the temperature of the heater. The higher the positive heater-cathode voltage, the higher the rate of tungsten transfer.[3]

Although exceeding an electron-tube rating will rarely cause instantaneous failure, the effect will surely be to increase the magnitude of the failure rate of the tube and, therefore, to increase the chances for unsuccessful operation of a specific piece of equipment. The operation of electron tubes under conditions somewhat more conservative than their ratings will, in general, increase their reliability by reducing their rate of failure, and will thereby improve the chances for successful operation.

FULL-WAVE VOLTAGE DOUBLER

Fig. 4 shows one type of application, the full-wave voltage doubler, which should normally be avoided when series strings are used. The main disadvantage of this circuit, as compared to the half-wave voltage doubler, is the lack of a common input and output terminal. This design necessitates the operation of heaters at a comparatively high positive d-c potential.

Normally, series-string tubes are rated so that no more than 100 volts d-c may be applied between heater and cathode when the heater is positive with respect to the cathode. The operation of electron tubes below this value will of course, increase reliability and decrease the rate of failure.

In the analysis of a circuit for proper heater-cathode operating conditions and possible sources of heater-cathode-leakage problems, there are five basic considerations:

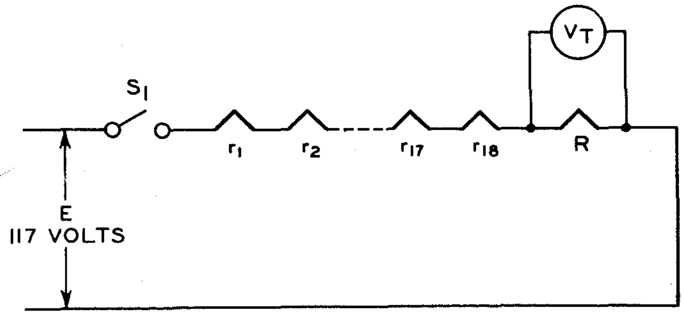
(1) The magnitude of the *a-c surge voltage* across the heaters,
(2) The magnitude of the *a-c steady-state* voltage across the heaters,
(3) The magnitude of the *d-c surge voltage* between heater and cathode.
(4) The effects of the *combination of the a-c and d-c surge voltages* between heater and cathode, and
(5) The effects of the *combination of the a-c and d-c steady-state voltages* between heater and cathode.

Analysis and actual measurements of the full-wave voltage doubler shown in Fig. 4 indicate that the a-c surge voltage across each heater is very low, and probably would not exceed 125 per cent in any random selection of tubes. The main reason for this moderate a-c surge voltage is the comparatively large series dropping resistor used to maintain the tubes near the high side of the string within their maximum heater-cathode-voltage ratings. The a-c steady-state voltage across each heater is well within limits because the measured line current is 597 milliamperes.

In full-wave voltage doublers, the combination of the surge a-c and d-c heater-cathode voltages is particularly excessive. At the moment when S_1 is closed, d-c heater-cathode voltages are applied which are equal in magnitude to the peak value of the line voltage, or 165 volts. This value is sustained for about 5 seconds, or longer in some applications, until other tubes in the circuit gradually reach operating temperature and begin to draw load current. At this point, the voltage decreases gradually to slightly more than half of the peak line voltage, or about 90 volts steady-state. This steady-state value is dependent upon the size of the filter capacitors and filter resistor. At the same time, peak a-c voltages in the order of 70 to 100 volts exist between the heater and cathode of tubes near the high side of the string.

The effect of the combination of excessive a-c and d-c surge voltages between heater and cathode on the life of series-string tubes was evaluated by means of the following test. The string shown in Fig. 4 was placed in series with an interval timer set for a cycle of 11 seconds on and 9 minutes 49 seconds off across a 117-volt line. A d-c heater-cathode voltage of +250 volts was applied with the heater positive to determine the upper limit of heater-cathode breakdown. Under this condition, one 5T8 developed a heater-cathode short after two cycles. Another 5T8 inserted

Fig. 2—Circuit used to determine zero warm-up time points for the curves in Fig. 1



$$V_T = \frac{E}{\Sigma r_1 \ldots r_{18} + R} \times R$$

where

E = nominal line voltage
V_T = initial surge voltage of tube under test
r = individual cold resistances
R = resistance of a tube under test having zero-second warm-up time at t_0 or at the 80%-rated-E_f point in the standard test for warm-up time.

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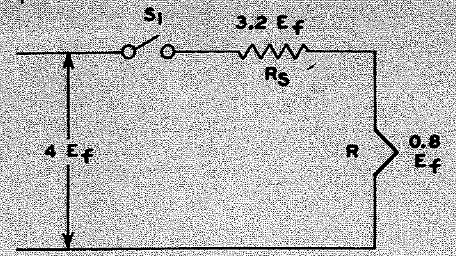
[3] G. H. Metson, E. F. Richard, F. M. Hewlett—"Some Experiments On The Breakdown of Heater-Cathode insulation in Oxide Cathode Receiving Valves" Proceedings I.E.E., Vol. 102, Sept. 1955, Page 678.

Fig. 3—Standard test circuit used in the determination of the warm-up time of series string tubes



$$R = \frac{0.8E_f}{3.2E_f/3.0R_h} = 0.75R_h$$

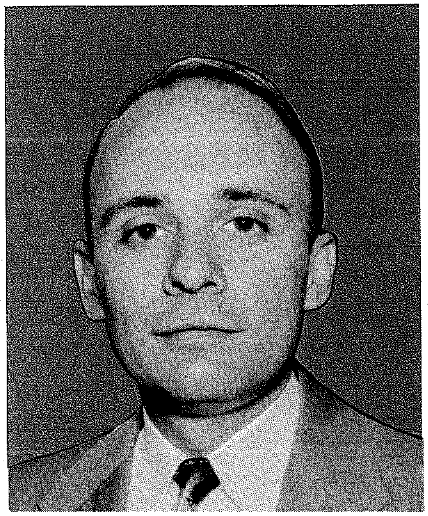
where E_f = rated heater voltage
R = resistance of tube under test at the 80%-E_f point in the standard test for warm-up time.
R_h = hot resistance of tube at rated E_f and I_f.

in the same position developed a heater-cathode short after three cycles. A third 5T8 was then placed in the circuit, and the heater-cathode voltage was reduced to +225 volts. Under these conditions, the circuit was cycled successfully more than 2200 times without experiencing either a burnout or a heater-cathode short. The 225-volt test conditions were then duplicated on 50 production tubes. During a period of 2000 cycles, one tube, or 2 per cent of the sample, developed a heater-cathode short.

This value of 2 per cent is equivalent to a part failure rate of 0.235 per cent per 1000 hours in a specific piece of equipment using all of the various tube types tested. This part failure rate is about twice as good as the normal design-goal reliability level required for commercial equipment, but about seven times poorer than that required for military equipments. However, as more tubes of the type which failed in the above test are used in a particular equipment, the part failure rate would approach 24 per cent per 1000 hours. The operation of series-string tubes in the full-wave voltage doubler, therefore, places some tube types very close to the threshold of catastrophic failure. Other life-test data indicate that the operation of tubes with excessive steady-state positive d-c voltages between heater and cathode results in failure rates about 5 times greater than those experienced with intermittent negative heater-cathode operation and 12 times greater than those with continuous negative heater-cathode operation.

STEADY-STATE VOLTAGE

The third important consideration in series-string applications is the steady-state voltage condition across each tube in a string. Because the current is common to all tubes in a series string, the voltage drop across individual tubes will vary according to the steady-state value of heater resistance. In series-string tubes, this factor has been controlled by tightening the heater-current limits to ±4% at rated voltage, and controlling the average of all production to ±2.5%. However, even with narrow limits on heater current, wide variations in steady-state heater voltage, and resultant abnormal heater input power and abnormal cathode operating temperatures, are found in equipments which allow too wide a spread in line voltage. An analysis of commercial television receivers has shown that the average spread in line current as the voltage ranges between 105 and 130 volts, or ±10%, is between 550 and 650 milliamperes, or ±8.5%. Receivers which do not use series dropping resistors have a narrower spread, between 570 and 645 ma. The wider spread in receivers having series dropping resistors may be attributed to either too high a resistance value or an increase in resistance value with life. For fifty tubes measured in these receivers at the line voltage of 117 volts and a current of 600 ma., and at a low line voltage of 105 volts and a current of 550 ma., the average spread in steady-state heater voltage was between 12% and 20% below rated heater voltage. "Bogie" tubes for heater current, which tested 600 ma. at rated voltage, average 12% below rated voltage, and tubes 4% on the high side, which tested 625 ma. at rated voltage, averaged 20% low. The tubes which averaged 20% below rated heater voltage were operating 30% below normal heater input power. *Corresponding* conditions were found to occur at high-line-voltage conditions. Cathode temperature measurements on tubes having similar spreads in heater input power vary between 1000° K and 1300° K. The best tube life for most tube types has been found to occur when cathode temperatures are about 1050° K. Operation below this value results in an inability of the cathode material to reactive itself, usually called "cathode poisoning," and tube life is shortened by the loss of emission. Operation above this value results in cathode sublimation and accelerated rates of emission, and tube life is shortened by the deposition of free barium on other tube elements which



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Mr. Rauth is a member of the Institute of Radio Engineers and Eta Kappa Nu.

causes emission from electrodes which should not emit and produces leakage currents across insulating surfaces.

TEST RESULTS

Numerous investigations have been made into the operation of military series-string equipments. A 500-hour life test was conducted on ten harmonic generators, 5 of which were wired for 6.3-volt parallel heater operation and 5 for 28-volt series-string operation. Results revealed close correlation between the number of tube failures and the percentage of excess heater voltage applied to the series-string tubes. With a line voltage of 28 volts across the series-string units, the average heater voltage was 6.75 volts, or 7% above the rated value. In some cases, the heater voltage was as high as 7.35 volts, or almost 17% above rated value. The rate of failure for the series-string tubes over the life-test period was 3 times greater than that of the tubes used in parallel operation. All but one of the defects were due to excessive leakage and loss of emission, as discussed previously in the theoretical tube considerations.

Another reliability life test, conducted on the AN/ARC-27, consisted of 40 receivers including 2200 tubes.[4] This test strikingly pointed up the necessity of operating electron tubes at their rated heater voltages and of keeping spreads in line voltage within closer limits if greater reliability and lower equipment failure rates are to be expected. In this test, 20 receivers were unmodified, and 20 receivers were modified to reduce the heater voltage from 6.9 volts to 6.3 volts at the line voltage. As a result of this change, the failure rate for receiving-tube types was reduced by a factor of 4 to 1, and the mean time between malfunctions, which is the total number of operational hours divided by the number of malfunctions, was increased by approximately 57%. The major tube defects in the unmodified equipments were due primarily to shorts and leakage.

CONCLUSION

In conclusion, the following general recommendations should be followed to increase reliability in series-string applications:

(1) As shown by the curves in Fig. 1, tube types having lower heater voltage are subject to higher surge voltages in any series string. If these tubes must be used, they should be placed as close as possible to the low side of the heater string.

(2) The use of series limiting resistors is recommended in series strings to reduce possible heater surge voltages by approximately 15 to 20%.

(3) Electron tubes should not be subjected to heater surge voltages greater than 1.5 times their rated heater voltage. In applications where this value is exceeded, it may be possible to reduce its magnitude by a change in the selection of tube types.

(4) If a choice of tube types exists for a specific application, the types with the larger cathodes should be used because tubes with small cathode structures are likely to produce poorer reliability.

(5) Applications, which operate electron tubes near or in excess of their rated heater cathode voltages, such as the full-wave voltage doubler and "stacked B+" systems, should be avoided. Reliability and tube life will decrease exponentially as the positive heater-cathode voltage is increased. Operation of tubes with positive heater-cathode voltage results in tube failure rates 5 times greater than *intermittent* negative heater-cathode operation and 12 times greater than *continuous* negative heater-cathode operation.

(6) Supplies which cause unbalanced spreads in line voltage across the string and which cause individual heaters to operate considerably above rated voltages at nominal line voltage should be avoided, or regulators should be added to maintain the supplies within closer limits.

References

(1) "Filament and Heater Characteristics". Cecil E. Haller; Electronics; July, 1944.

(2) "Designing Trouble-Free Series Tube Heater Strings". M. B. Knight; Tele-Tech; April, 1953.

(3) "Series Heater and Filament Strings in Military Equipment". Advisory Group on Electron Tubes; Tele-Tech; Jan. 1955.

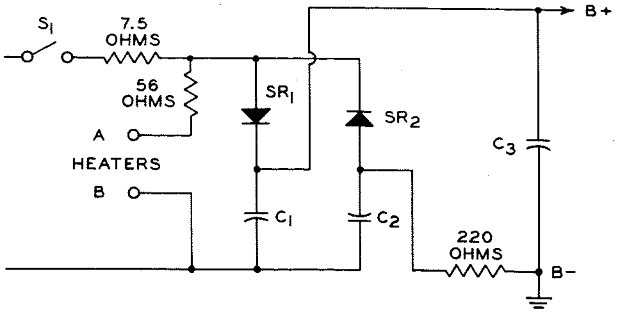

Fig. 4—Full-wave voltage doubler in series-string application

TUBE HEATERS CONNECTED IN SERIES BETWEEN A AND B IN FOLLOWING ORDER: (A), 12AX4-GTA, 12BQ6-GTB/12CU6, 5AQ5, 5AM8, 12BH7-A, 5J6, 3BC5, 3CF6, 3CF6, 3AU6, 5AN8, Kinescope, 5T8, 5U8, 6SN7-GTB, (B)

TABLE I

Tube Type	Heater Warm-Up Time	Heater Warm-Up Time String Warm-Up Time	Tube Voltage Surge — Percent
25CD6-GA	13	1.05	80
12XA4-GTA	12	.97	90
12L6-GT	12	.97	90
12W6-GT	14	1.13	80
6SN7-GTB	10	.81	122
6SN7-GTB	10	.81	122
12BY7-A	11	.89	105
5U8	11	.89	115
5T8	12	.97	102
5U8	11	.89	115
3CB6	10	.81	140
3CB6	10	.81	140
4BQ7-A	10	.81	137
5U8	11	.89	115
Kinescope	10	.81	122

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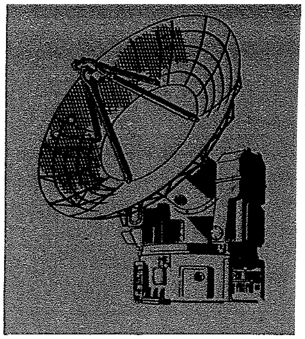
[4] Aeronautical Radio Inc., Special Report, Nov. 4, 1955 "Effect of Heater Voltage Modification on Reliability of AN/ARC-27 Receiver-Transmitter"



DEVELOPMENT OF AIRBORNE SYSTEMS

by

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THE EVER-INCREASING scope of automatic control has generated the requirements for a unified technical approach to problems spanning many specialized areas of the physical sciences. The collection of devices required in automatizing an activity has come to be called a "system". The procedure followed to incorporate control requirements into practical equipment capable of performing the desired task is usually referred to as "system development".

AIRBORNE SYSTEMS AND SUB-SYSTEMS

The generality of the term "system" in its currently accepted meaning conveys little indication of the magnitude of the task the system is intended to perform. For example, an interceptor aircraft may be considered a system comprising the air-frame, its electronic and control sub-system, its armament and its communication equipment. However, the interceptor may also be considered as a subsystem of the larger air defense system comprised of ground radars, computation centers, communication networks and the interceptors. A similar parallel exists in the field of commercial aviation. Here, the aircraft and its equipment may be considered a system itself, or as a subsystem of an automatic traffic control system.

The intent here is to deal with airborne systems only—in particular, electronic airborne systems. These can be defined as technically complex equipments utilized in inhabited or uninhabited aircraft. Inhabited airborne systems such as interceptors, strategic bombers, fighter bombers, strategic and tactical reconnaissance aircraft and transport aircraft fall under this definition. Uninhabited aircraft may be surface- or air-launched at surface or airborne targets giving rise to the need for air-to-air, air-to-surface, surface-to-air and surface-to-surface missiles.

DEVELOPMENT

An overall process resulting in the production of a new system is shown in Fig. 1. The military or civil situation initially indicates that a new system is needed. Detailed requirements specify the objectives to be satisfied by the system's performance. The development phase results in a proven experimental system model which eventually provides the basis for a production prototype system with complete plans for production. The manufacturing process utilizes the production plans in assembling, testing and delivering production models of the final system for use in the field. Early production models must be evaluated under field conditions to be certain the system satisfies the original need. Successful completion of this operational evaluation removes the last barrier to full scale production of satisfactory systems. Closely allied with production throughout the life of the equipment is the field service activity.* This provides close contact between ultimate users of the system and the producing organization.

Although the diagram of Fig. 1 indicates sequentially independent activities, there are in fact backward-acting effects of each stage. As an example, it is conceivable that evaluation results may well dictate new effort on the product design or even development type. As a result, continuous systems engineering is required throughout the complete process.

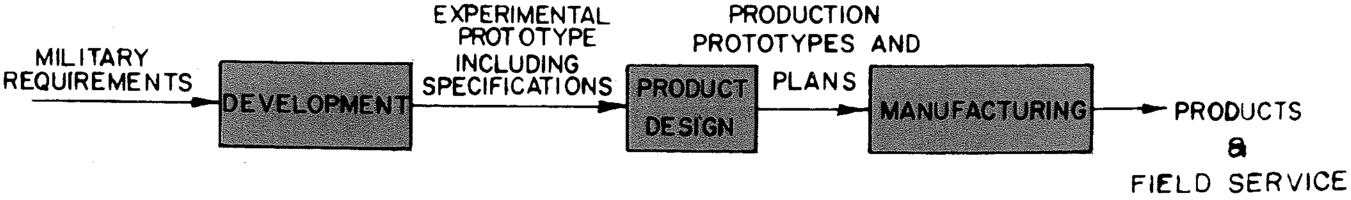
DEVELOPMENT PROCEDURE

The procedure involved in the development phase in Fig. 1 encompasses a diverse group of technical activities. These include operational analysis, preliminary design based on analysis and simulation, component and subsystem design, system "mock-up" and laboratory test, and finally flight tests.

Initially, operational analyses are required to convert the overall system requirements into specific performance features. These analyses are concerned with various limitations put upon the tactical usefulness of the airborne system. Errors encountered in ground-supplied information, time required for various elemental functions to be performed in the air, and maneuverability of the airborne vehicle itself are factors to be considered.

With specific overall system performance requirements reasonably well defined, it is possible to start the preliminary design phase of development. This phase is concerned with determining the best functional layout and tentative system and subsystem specifications. Types of analyses involved in this phase range from

Fig. 1—An overall process resulting in the production of a new system



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*See "The Field Engineer in Support of DEP Weapons Systems" by T. G. Whitney this issue.

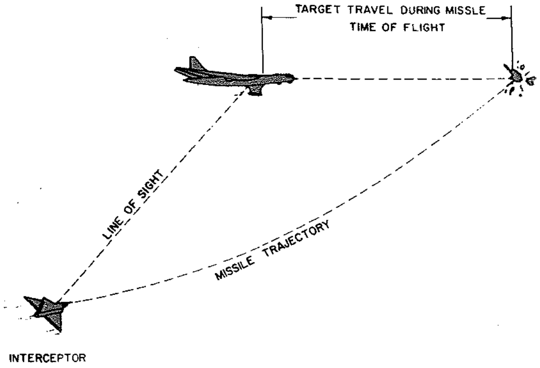
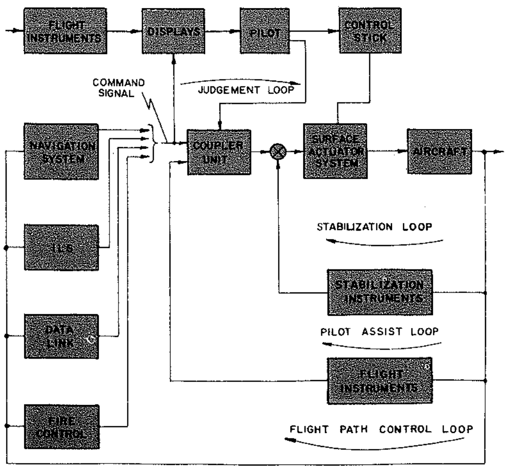


Fig. 2—Pictorial representation of attack phase of interceptor mission

dynamic analyses (evaluation of system stability under dynamic input conditions), through error and statistical studies (system performance deviations caused by instrument inaccuracies and limitations) to overall system reliability analyses.

The third basic phase of the developmental procedure consists of development of subsystems and/or components required for satisfactory system performance. Subsystems may be electronic, hydraulic, mechanical or a combination of these. In most cases, subsystems utilizing a large percentage of existing components can be obtained, but almost invariably some new equipment or sub-subsystems are required. Such a development program involves analysis, construction and test, and hence parallels the phases of the complete system development.

Fig. 3—Functional diagram of interceptor electronic and control system



Having developed equipment to perform the subsystem functions, the next step is to assemble the complete system in the laboratory, evaluate the performance, and investigate the unexpected interactions between subsystems. This process is the often underestimated fourth phase of a development procedure and culminates in successful laboratory demonstration of desired performance.

However, final proof of the ability of the system prototype to perform its intended function is only found under end use conditions. Hence, extensive flight testing of the experimental prototype is required before development can be considered complete.

TIMING OF ACTIVITIES

Up to this point no mention has been made of the timing of the various developmental activities although it might be incorrectly assumed that they occur in consecutive order. In reality, most activities are active throughout the whole process. This overlapping is required not as an expedient to meet deadlines but because of the interrelated nature of the work. For example, continuing analyses are required at the outset of development to evaluate data coming back from subsystem developments, system laboratory tests, and from developmental flight tests. In general, it is more realistic to consider that all activities exist throughout the development with emphasis shifting from activity to activity sequentially, as the development progresses.

In summary, the basic tools which are brought to bear upon a system development problem range from mathematical analyses, through "simulators," to partial and complete flight tests. It is through such analysis that basic problems are "pinpointed" to permit a choice of the most likely solutions. Simulators augment this analysis effort by representing actual system behavior under realistic conditions. They also provide a simple means of changing either the system parameters or the functional form itself. However, analysis and simulation will only yield system information that is based upon the characteristic behavior of the operator. Flight tests—partial and complete—are needed to be assured that all pertinent characteristics have been considered. The concurrency of the several phases of a development effort is again shown by the desirability of matching simulator performance to flight test results during and subsequent to a flight test program. Here, the causes of any major deviations can be "pinpointed" quickly, allowing modifications to be made to the subsystems and the system itself, if necessary.

A TYPICAL "SYSTEM" DEVELOPMENT —INTERCEPTOR AIRCRAFT

The development of an electronic and control system for a modern interceptor aircraft provides a typical example of the application of the process just described.

By definition, the basic function of such aircraft is the interception and destruction of attacking bombers. Hence the interceptor system must have capabilities (a) to navigate from its base to the vicinity of the target either under control of ground-based information centers or its own navigation system, (b) to locate and attack the target, and (c) to return to its base safely under all weather conditions. The second of these is usually attained by the electronic and control system carried entirely within the interceptor. Fig. 2 is a pictorial representation of this attack phase.

FUNCTIONAL DESIGN OF INTERCEPTOR SYSTEM

A functional diagram for the interceptor electronic and control system is shown in Fig. 3. This diagram is quite general and does not contain all the detailed information resulting from a preliminary study. For example, the functional box labelled "Surface actuator system" encompasses, in a conventional aircraft, three control actuators for the aileron, rudder and elevator. However, the diagram does show the various types of stabilization and control loops required for the interceptor mission.

The innermost feedback loop—the stabilization loop—has become necessary in modern aircraft by virtue of the reduction in aerodynamic damping that is a property of aircraft configurations required for higher and higher speed flight. The stabilization loop adds "artificial" damping to make the combination of aircraft and stabilization system a more readily controllable unit. The stabilization loop is directly associated with airframe stability and is of prime concern to the airframe manufacturer. It is also the tightest—or fastest acting—loop of the overall interceptor system.

The next loop—the pilot assist loop—exists, as the name implies, to relieve the pilot of the tiring effort of controlling the vehicle. This loop provides coordination of maneuvers and automatic maintenance of constant altitude, speed, and angular orientation in azimuth and elevation without regard to the overall interceptor flight path being followed. Switching and synchronizing functions accomplished within the coupler unit allow smooth transition from mode to mode, command limiting required by safety, and provide necessary signal filtering.

The third feedback loop provides flight path control as required in several modes of interceptor operation. The possible modes are indicated in Fig. 3. The flight path may be controlled (1) in earth coordinates by a ground environment and data link, (2) in relation to the target as required under fire control operation, (3) in geographic coordinates of latitude and longitude in the navigation mode, or (4) in relation to the landing strip as in the ILS mode. This loop is the slowest acting one of the system since changes in the flight path necessarily occur more slowly than changes in either airframe orientation or angular velocity.

The pilot's function in the system of Fig. 3 is predominantly that of exercising judgement as to mode selection and proper operation of the automatic system. However, provision must be included to allow him to override the system in event of failure or other emergency. To carry out this function it is necessary that the display subsystem present the pilot with a sufficient quantity of readily understandable information to allow him to evaluate the automatic system performance. The pilot can exercise his control either by change of operating mode through the coupler unit or by overriding the system in the present mode by use of his control stick.

To summarize, an interceptor system may be broken down into several feedback loops, each differing in function. The various functions require separate loops operating upon different measured quantities and with different speeds. This is true of airborne systems in general. Inner loops are faster and generally utilize rate information while outer loops are slower and usually involve position information as the actuating quantities. Interceptor system design has progressed to the point where the pilot is no longer required to perform as an integral part of the several control loops. Today the pilot is carried with the system solely for his superior powers of judgement and decision-making.

EXAMPLES OF SHORT- AND LONG-PERIOD EFFECTS

In general, the short-period system performance characteristics are most closely associated with the subsystems. On the other hand, the long-period characteristics are more associated with the various modes of overall system operation. The flight control subsystem provides an example of the short-period effect. Aircraft motions are controlled by deflections of the aircraft control surfaces. Such deflections generate forces and moments upon the aircraft which are resisted by vehicle inertia by damping forces generated by rolling, pitching or yawing of the airframe. The airframe displacement, rates, and accelerations may be measured and used to modify the control surface motions so that the final airframe and control system is superior to the performance of the airframe alone. Fig. 4 presents the response to a step command of such a system for roll control of an aircraft. The solid curve represents short-period optimum system response at a particular aircraft speed and altitude. The dotted curve represents variations that occur as speed and/or altitude changes. If such variations are too great, then the parameters of the flight control subsystem must be changed with flight condition. This is usually the case with modern aircraft.

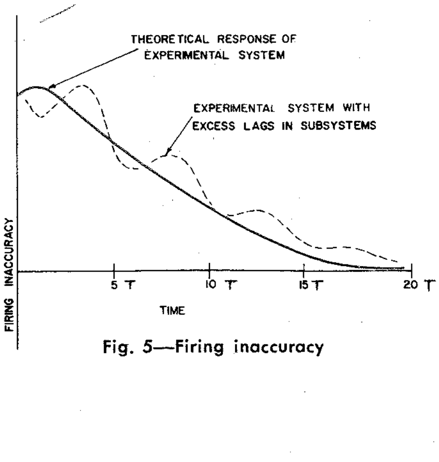


Fig. 5—Firing inaccuracy

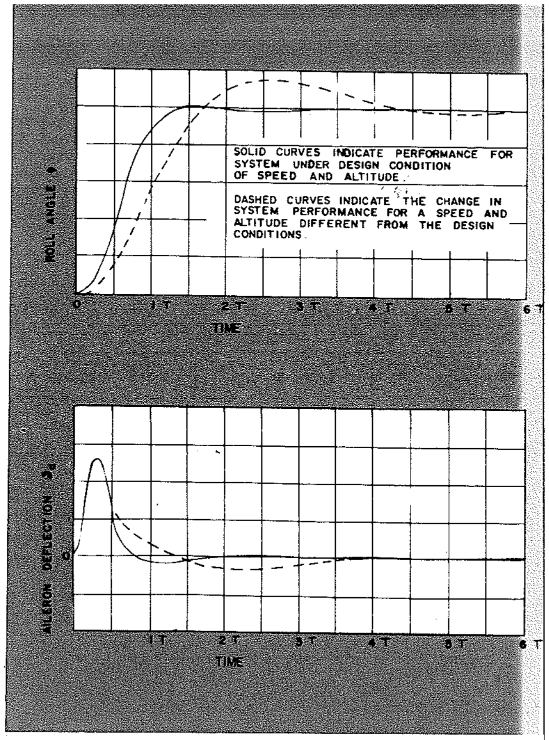


Fig. 4—Step response of flight control subsystem about roll axis for a one degree command signal

Fig. 5 shows the time variation of the firing inaccuracy during an attack of an interceptor against a bomber. The solid curve represents performance of the overall system with near-ideal subsystems, i.e., subsystems with acceptable dynamic lags. Note that the time for the inaccuracy to settle toward zero is large, compared with response time of the roll control performance of Fig. 4. As the subsystem dynamic performance degenerates and excessive lags enter the system, the overall performance becomes oscillatory over an ever-increasing percentage of the attack run. One criterion for system design is that tolerances on subsystem performance be a maximum.

The complexity of the system is such that the responses of Figs. 4 and 5 could not be conveniently obtained without the use of extensive analog computing equipment, especially since many variations must be investigated. The computing facility of Fig. 6 was purchased from Electronic Associates for use at the Airborne Systems Laboratory in Waltham. This installation is capable of solving three-dimensional interception problems and has provision for a tie-in with a cockpit simulator.

PILOT EVALUATION

Since the interceptor carries a pilot and possibly a radar operator, it is necessary to evaluate the capability of

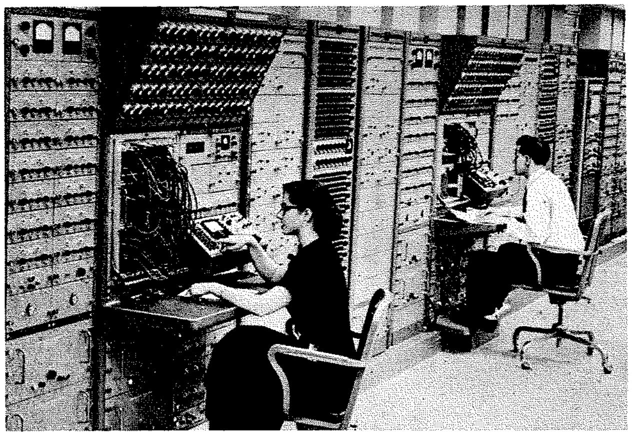


Fig. 6—Computing facility at the Airborne Systems Laboratory in Waltham

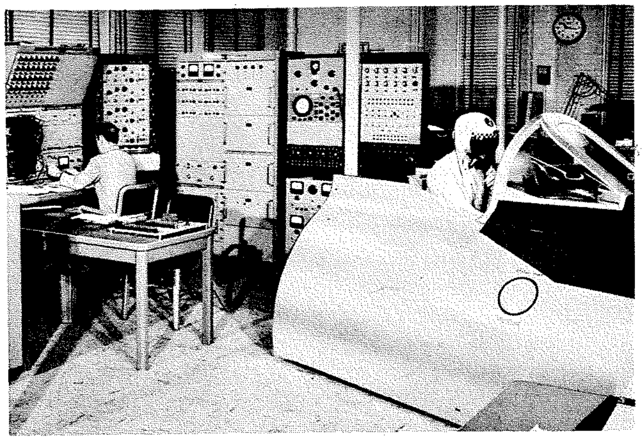


Fig. 7—Pilot environment simulation facility

personnel to accomplish the desired functions. Interrelations between the human operators and the automatic equipment are investigated, and display and control equipment suitable for these tasks are devised.

Here again the analog computer facility is used in conjunction with cockpit and flight environment simulation to perform evaluations. The pilot environment simulation facility at Waltham, shown in Fig. 7, consists basically of an instrumented cockpit mounted in a spherical enclosure (not shown). Visual indications are projected on the inner surface of the enclosure which portrays the aircraft attitude relative to earth. Incorporated in the cockpit are an electro-hydraulic stick-force generating system and an electro-hydraulic device for simulating airframe normal accelerations by tightening the pilot's shoulder harness. The analog computer is used to solve the kinematic, geometric and dynamic problems involved in an overall interception. The computer and associated equipment generate the proper signals for the cockpit instrumentation. With this facility, it is possible to evaluate pilot action over a complete interception from take-off to target kill.

INTERCEPTOR SUBSYSTEM DEVELOPMENT

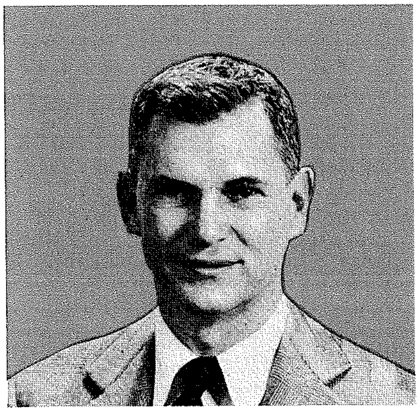
For an interceptor electronic and control system, separate subsystems requiring development consist of such items as a radar, a computer, a flight control system and communication equipment. An example of an early stage of such a subsystem development is the single axis stable reference system of Fig. 8 which consists of an integrating rate gyroscope, a platform capable of rotation about one axis, i.e., a turntable, and the necessary electronic equipment and motors to drive the platform in response to gyro-detected motions and command signals. This stage of the subsystem development determines the adequacy of the chosen electro-mechanical components and pinpoints the characteristics of the electronic equipment required to meet demands of the system design.

Subsequent development may incorporate three such proven single axis systems into a single three-axis stable reference for use in an experimental model of the overall system.

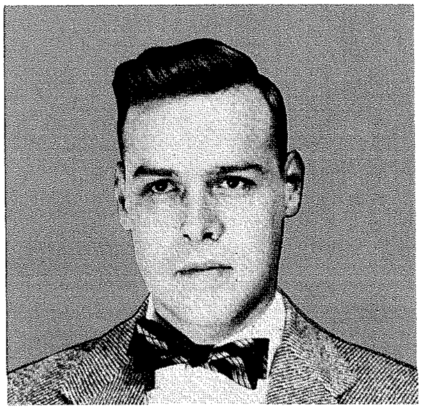
SYSTEM LABORATORY EVALUATION

It is in Laboratory System testing that unexpected interference between subsystems first becomes apparent. This may take the form of power supply interactions, impedance mismatches, unwanted signal transfer between adjacent equipments, or the cumulative effects of second-order dynamic characteristics of several subsystems in series.

It is desirable to attack these unexpected problems at the earliest possible time during development work with preliminary models of the separate subsystems. In any event, all parts of the system must be accessible when undergoing this laboratory evaluation. An example is shown by Fig. 9.



DR. R. C. SEAMANS, JR., Manager of Airborne Systems Laboratory, Airborne Systems Department, was appointed to that position in 1955. He received a B.S. in Engineering Science from Harvard University in 1939 and an M.S. in Aeronautical Engineering from M.I.T. in 1942. He was Instructor, Assistant Professor and Associate Professor in Aeronautical Engineering at MIT from 1941 to 1955. His doctorate degree in Instrumentation was granted in 1951, and in 1953 he was made Director of the Flight Control Laboratory, MIT. Dr. Seamans is the author of numerous technical papers and has served as a consultant to the military services and industry in the field of aircraft and missile control. He is now a member of the Subcommittee on Automatic Stabilization and Control of the National Advisory Committee for Aeronautics.



HENRY W. PICKFORD received his B.S. degree in Aeronautical Engineering from MIT in 1946. The following four months were spent at the Naval Aircraft Factory. Two subsequent years with the Structures Department of Chance Vought Aircraft Company. In 1948 he was employed by MIT as a Staff Member concerned with operational evaluation of guided missile systems. Four additional years were spent in the development of an experimental guided missile—during the last two of which he was in charge of a system development group effort. He was awarded his Master's Degree in Aeronautical Engineering from MIT in 1955. He joined the Airborne Systems Laboratory of RCA in June 1955 and is presently a member of the engineering staff reporting to Dr. R. C. Seamans, Jr.

A radar antenna is mounted upon a table capable of moving the radar base. Fixed horn antennas are used to provide the radar with a fixed target. With this arrangement, it is possible to examine the performance of the radar antenna stabilization system in the presence of programmed motion inputs. The same basic installation can be used to evaluate radar performance by tracking live targets through the window shown.

FLIGHT TEST

Developmental flight testing begins with installation of the system in total or in sections in a representative aircraft of the type for which the system is intended. A period of time and a substantial effort must be devoted for check-out of the separate subsystems to assure satisfactory ground operation. Then, in the case of complex interceptor systems, a series of tests in flight are required to evaluate the several modes of operation. Finally, the complete system data obtained from these tests are compared to the expected design performance (see Figs. 4 and 5). Data must also be obtained on the overall flight path of the interceptor relative either to earth or to the target for comparison with predicted results. A typical comparison of an interceptor flight test path during attack with a predicted flight path determined by simulation of the problem is shown in Fig. 10. The several paths determined by simulation are noticeably distinct and any differences are due to the pilot not responding to the same commands identically. Hence, several runs by simulation are necessary in order to determine the range of trajectories expected in flight. Examination of the flight test result of Fig. 10 with such a series of simulator solutions indicates good agreement. Finally, in the case of an interceptor fire control system, flight test data regarding the aiming errors at firing—and hence the armament miss distance—are required.

Fig. 10—Comparison between trajectories obtained with simulator and actual trajectory from flight test.

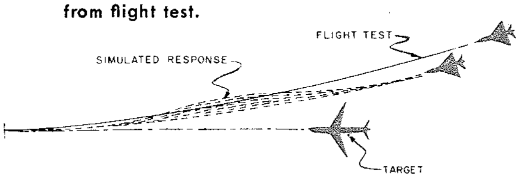


Fig. 8—Single-axis stable reference system

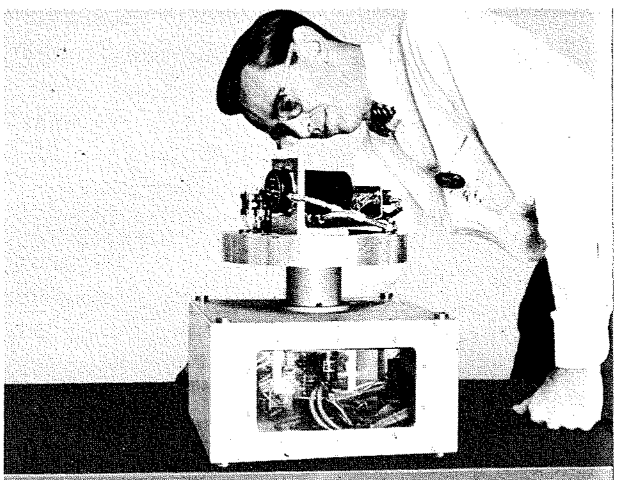
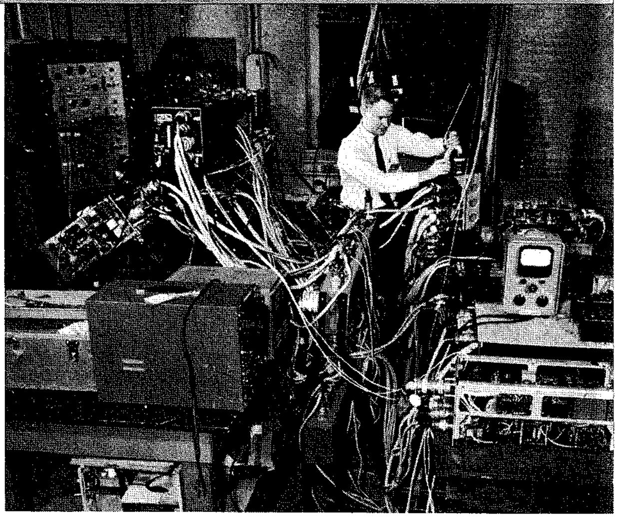


Fig. 9—Interceptor electronic system "mock-up" for laboratory testing



DEVELOPMENT ORGANIZATIONS

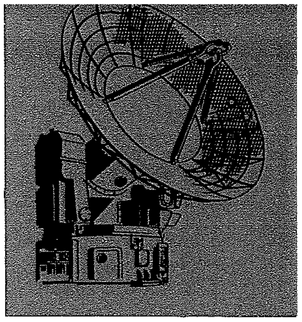
The organization most suitable for development effort is dictated by a combination of conflicting forces. On the one hand, it is desirable to organize the activity with a common goal, namely the completion of a particular project. On the other hand, the specialized talents or facilities are equally in demand and are applicable to several projects within an organization. The presence or absence of subcontractors, the character or subsystem development involved, the availability of manpower, and the effects of simultaneous projects within a given laboratory must all be considered.

These are, however, basic factors felt to be necessary qualities of adequate organizations. Of prime importance is the ability of the people making up the organization. Secondly, the organization must be such that communication occurs on a day-to-day basis between key individuals and groups working on a common project. Reports and memoranda assist in conveying information and recording activities, but frequent contacts between engineers, draftsmen and technicians are necessary.

SUMMARY

The development leading to the completion of a new airborne system is one which requires efforts in a wide variety of technical areas, efforts which must continuously feed information forward and backward until the system is proven to be successful in accomplishing its task. The processes required to attain this end are similar whether or not the system involves the human element—whether the system being considered is a manned interceptor, a commercial transport aircraft, a guided missile or a satellite vehicle. The systems in guiding and controlling these objects have in common the existence of several feedback loops differing predominantly in the function they perform and in the speed with which they must act. Hence, the analysis techniques as well as the overall development processes are applicable to all.

Since the basic characteristic of the development process is its continuous feedback of information from one phase to another, the organization chosen to carry out this process must encourage communication between participating engineers.



EXTENDED RANGE TIMING TECHNIQUES

by **A. I. MINTZER**

Missile and Surface Radar Engineering
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PRESENT AND FUTURE requirements of range timing equipment used in pulsed tracking radars and navigational systems are in the direction of extending the presently achieved precision of time measurement to greater ranges. Among the techniques capable of providing this precision, the use of mechanical phase modulation of a sinusoidal time base has been the most widespread in field equipment. Other techniques using gated counters with vernier pulse discrimination[1] to obviate the resolution limitations imposed by the clock frequency period have been used in range measurements. However, considerable development might be necessary to use all digital techniques[2] to provide the precision time modulation required in closing automatic tracking loops and providing suitable range data in analog form.

The present paper will discuss the limitations and difficulties experienced with conventional two-scale mechanical time modulators, especially at long ranges. System configurations and circuit techniques found to be helpful in improving precision, flexibility and reliability will also be described. Since some of these techniques have been incorporated into classified equipment, exact performance details cannot be given.

DESCRIPTION OF THE PROBLEM

Mechanical timing systems have been used extensively to provide precise time variable range markers with the following features.

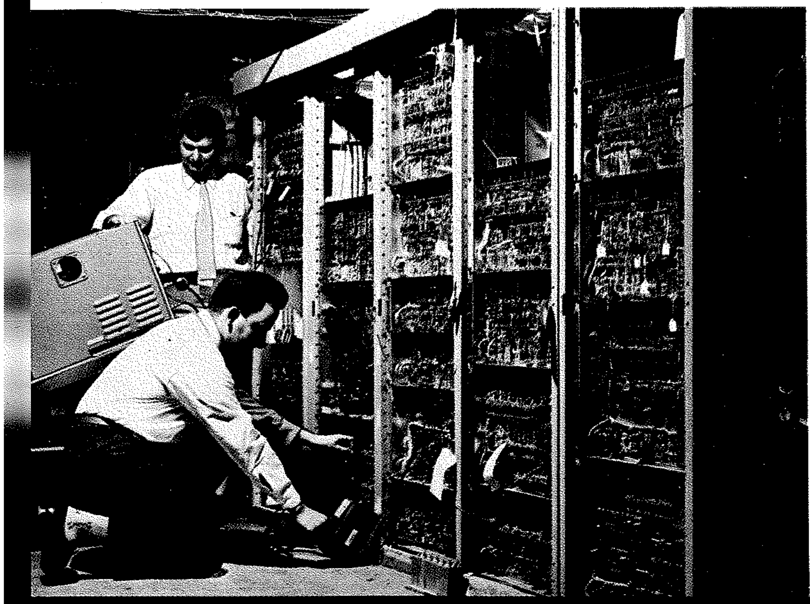
1. The basic accuracy and stability can be the function of a crystal controlled oscillator.
2. The major components of error are cyclic in nature. They result from non-linearities in mechanical components such as gears, bearings, couplings, etc. and electrical non-linearities in mechanical phase modulators.
3. With multiple timing scales, the overall precision, in theory, may be extended indefinitely.
4. Range information is available in a wide variety of forms. These include: precisely-defined time-modulated pulses; linear and non-linear analog a-c or d-c voltages from potentiometers and synchros, direct-reading dials and counters; parallel digital coded pulses from shaft-to-digital encoders.
5. The basic circuits are well known and have been field tested innumerable times.
6. Although mechanical systems present servo bandwidth limitations in tracking loops, the present state of the instrument servo art can readily cope with present and foreseeable future target inputs.

For these reasons possibly, the development of all electronic timing systems has not progressed to the point where they supersede mechanical time modulators.

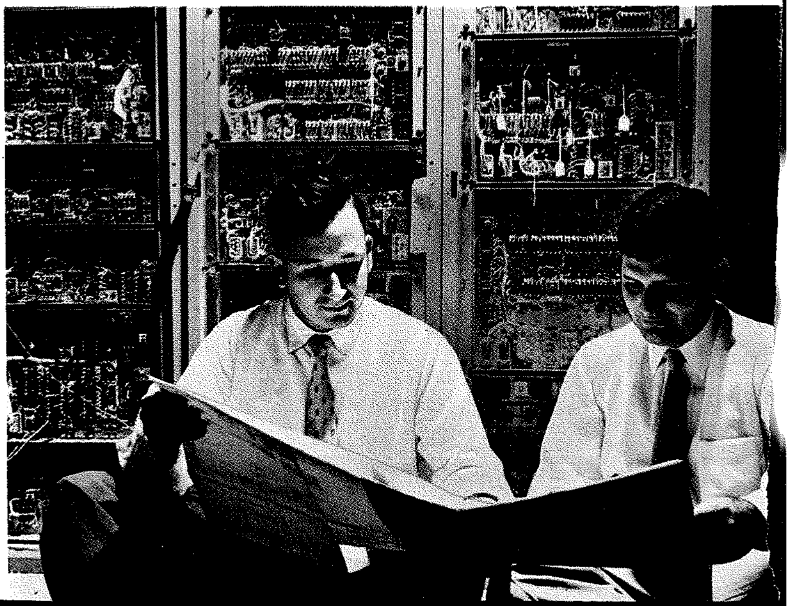
However, in double-scale mechanical time modulators, difficulties arise in the interpolation process. That is, a coarse range marker must select one precision pulse out of many throughout the entire range interval to eliminate ambiguity of information. If the coarse range marker selects the wrong range pulse, the range data can be in error in discrete multiples of the basic timing period.

These factors can be better illustrated by considering a typical two-scale mechanical timing system as shown in Figs. 1 and 2. In this system the basic timing period is controlled by a c-w crystal oscillator. Long term stability of the order of one part per million at normal room temperatures is readily obtainable, using an oven-temperature-controlled crystal in a Meacham bridge circuit, for example. The frequency stability would provide the only source of cumulative error in ranging. Errors caused by propagation anomalies resulting from unpredictable atmospheric effects of course cannot be eliminated. However, adequate accuracy may be obtained by pulling the frequency of the crystal

A. G. Chressanthis and A. I. Mintzer taking alignment measurements on the laboratory setup of precision range timing and tracking equipment.



Time out for consultation concerning circuit schematic of range timer chassis



oscillator such that the error is minimized for a given timing period over most normal atmospheric conditions.

The amplitude comparator or pipper shown in Fig. 1 generates pulses *T* units apart, precisely set to one phase angle of the reference sinusoid. This can be done with a stability of up to .01% of *T*, provided certain techniques, to be described later, are employed. The train of pulses, also known as pips, are used to provide the synchronizing pre-trigger and the zero range trigger, both at a repetition period corresponding to *n T* units. This is accomplished by generating a pulse from an *n*:1 scaler. The scaled-down pulse initiates a gate which selects and regenerates the next reference pip to form the pre-trigger. This essentially eliminates the effect any small variation caused by the inertia of the scaling process may have in shifting the phase of the pre-trigger relative to the reference sinusoid. The zero range trigger is formed by a similar process by a gate delayed in time from the pre-trigger. Using this technique, the synchronizing triggers have, for all practical purposes, no uncontrolled time jitter, which is necessary for accurate range data.

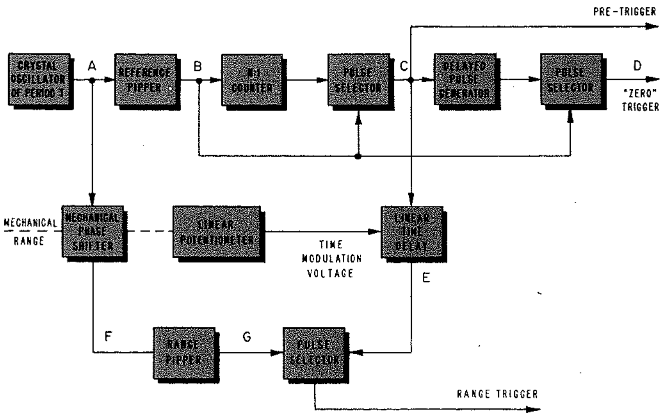


Fig. 1—Simplified block diagram of double scale electromechanical timing system

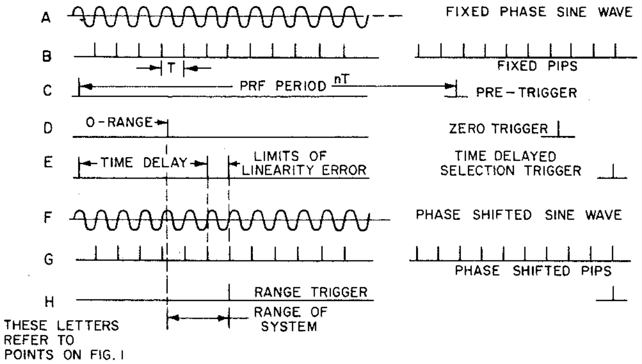


Fig. 2—Timing diagram corresponding to system of Fig. 1

The pre-trigger is necessary to start the linear time delay before zero range to minimize the non-linearities caused by the starting transients. The linear time delay can be of either the bootstrap or Miller runup or rundown types. These circuits are thoroughly discussed in the literature[3] and can easily achieve about .25% accuracy under laboratory conditions. However, in field usage, accuracy greater than 1% is maintained with difficulty. Factors affecting stability and accuracy are:

1. The maintenance of the same RC time constant under different environmental conditions for present day components.
2. Slope errors as a function of tube and supply voltage variations.
3. Zero errors as a function of uncontrolled contact potential and cut-off bias variations, as well as tube emission and supply voltage variations.
4. The slope and zero adjustments for accurate range calibration are critical at long ranges. This may not be done properly by relatively untrained personnel.
5. Fast time jitter can be controlled to within .01% of the maximum range in field equipment. This effect becomes more serious as ranges are increased.

Since the time delay circuit provides the means for interpolation, its defects, previously enumerated, provide a definite limitation to the reliable extension of ranges greater than 50*T* for the double-scale system shown in Fig. 1. Other limitations, although minor, are the finite recovery time required and the non-linearity present at low ranges. The latter necessitates the use of a pre-trigger while the former limits the usable range obtainable for a given *Pulse Repetition Frequency* (P. R. F.).

The mechanical phase modulator represents the major source of cyclic non-linear range error. These devices can be developed from functional potentiometers, split plate capacitors, or resolvers. They are excited by the reference sinusoid and provide, in theory, a constant amplitude sinusoid, whose phase shift relative to its excitation is a linear function of its mechanical position or range. The best phase modulators available so far are phase shift resolvers which can yield about .05% linearity errors at reference frequencies up to 100 kc. To achieve this, considerable care must be taken in

GLOSSARY OF TERMS

PIPPER—An amplitude comparison circuit that produces a train of pulses or "pips" corresponding in time to one precisely determined phase angle of a reference sinusoid. This phase angle is preferably at $2n\pi$ radians, where n is any integer, since the slope of the sinusoid is maximum at this angle.

AMPLITUDE COMPARISON—The process of determining the abscissa of a waveform given its ordinate by indicating the instant of equality of the amplitude of one voltage to another (usually called a reference).

TIME MODULATION—The process of producing a marker pulse delayed from a reference pulse in accordance with any suitable electrical or mechanical intelligence.

TIME MEASUREMENT—The process of determining to a desired degree of precision the time interval between corresponding points of the reference and time modulated pulses. Time modulation often implies time measurement.

driving these resolvers to assure proper excitation phase relationships, amplitude tracking, and absence of transients and harmonics in the reference crystal-controlled sinusoid. Amplitude distortion, for example, should be held to within 1%. It has been observed that for an undistorted sinusoid excitation, linearity error can be correlated to the modulation seen on the output, as a function of range. That is, minimum linearity error corresponds to minimum amplitude modulation. The linearity error of the phase shifter is mechanically scaled to repeat itself every revolution and is therefore cyclic in nature.

It may be noted that in range tracking systems, the cyclic error creates a dynamic tracking error which increases with target speed. For example, while tracking a constant velocity target, the cyclic error introduces a range disturbance whose spectrum is greater than the servo bandwidth. This would create undue range errors and especially affect range rate data.

Returning to Figs. 1 and 2, the phase shifted sine wave in most cases is greatly attenuated from the reference excitation. Thus further amplification must be provided before amplitude comparison pipping is applied.

For range data stability, the train of pips generated from the phase-shifted sinusoid must maintain exact coherence. When the mechanical range is fixed, the phase-shifted sinusoid must maintain under all external conditions the same phase relationship with the excitation sinusoid. It may be noted that the P. R. F. may be varied in discrete steps of T units without affecting the range data. However, the P. R. F. variation should not increase beyond the mechanical range limitations. Otherwise, an ambiguous pulse is present (second time around pulse) and the duty cycle limitation is exceeded. These effects can be circumvented only at the expense of a great deal of circuit complexity.

There are many variations of the two-scale timing system. However, Fig. 1 represents a system combining the best design techniques. Other systems, for example, generate a P. R. F. trigger externally and gate an oscillator. For crystal-controlled oscillators[4] this is extermely difficult to do without creating large range errors due to the gating transient. In addition, crystal oscillator circuit configurations best for gating are not optimum for frequency stability. To provide for suitable quenching, the dead time must be inordinately large. Transients due to phase shifting a pulsed sinusoid also create range errors.

To summarize, precision of ranging is readily obtainable in a two-scale mechanical time modulator because of the stability inherent in the crystal oscillator and the linearity achieved by mechanical phase modulators. However, ambiguity resolution of the range pulses is limited by the linearity and stability of the coarse-time-delayed pulse. This means that such timing systems when used for maximum ranges $R > 50T$ are marginal in field usage.

CORRECTIVE SYSTEM TECHNIQUES

One method to ease the ambiguity resolution problem is to select one of the scaled down range pulses and use the latter to start a gate which selects the original precision range pulse. This implies using a triple scale system. For example, if the scaling ratio is 8:1, the range linearity and precision required by the time delay circuit is proportionately reduced 8:1. However, several serious limitations present themselves if continuous scaling alone is used:

1. The P. R. F. period must be restricted to an integral multiple of 8 T units if range coherence is to be provided. This severely limits the flexibility of the timing system in accepting changes of P. R. F. Since certain guidance systems use P. R. F. modulation, this would be a serious blow indeed.

2. If the scaler should momentarily fail, provisions must be made, preferably automatically, to restore the scaler to its original phase with respect to the reference sine wave.

3. A minor limitation is that the dead space must be greater than $8T$ if the range pulse can be brought to zero range.

Figs. 3, 4, 5 and 6 show two systems employing triple-scale time-modulation methods, but avoiding the limitations imposed by the P. R. F. constraints. That is, each system recycles itself each repetition period, and is thus capable of operating during P. R. F. changes at discrete multiples of T units.

The system shown in Fig. 3 provides the 8:1 scaling in a step counter. The latter is recycled by a gate initiated by the pre-trigger and reset by one of two dual cyclic triggers. The latter are pulses $8T$ apart in time selected by

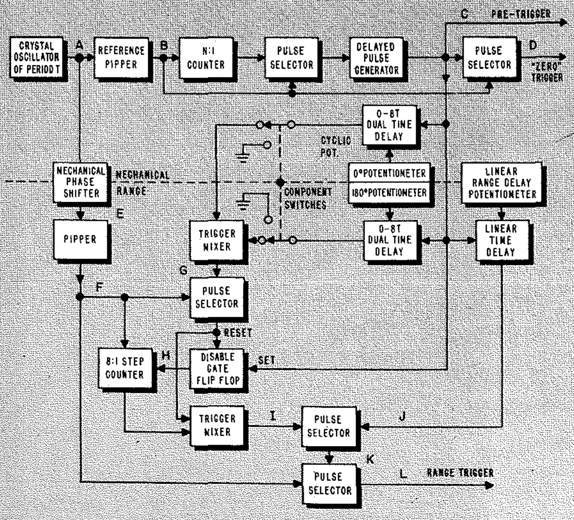


Fig. 3—Simplified block diagram of cyclic triple scale electromechanical timing system

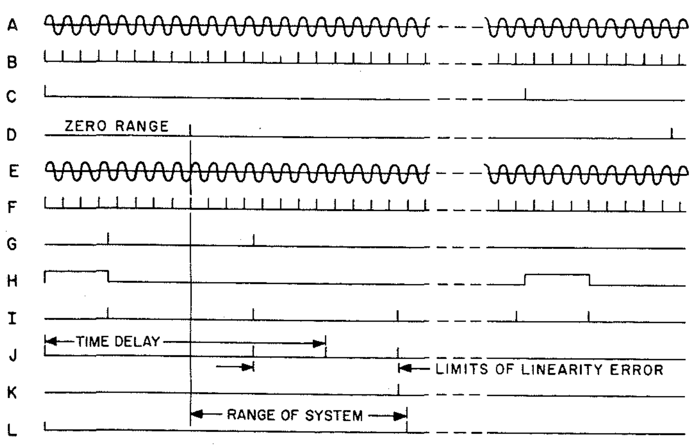


Fig. 4—Simplified timing diagram corresponding to system of Fig. 3

dual time-delay circuits from the range pips. Thus, each time delay circuit acts as a two-scale timer over a range comprising 16*T* units from the pre-trigger. Dual single-turn continuous potentiometers phased 180° apart provide the time-modulation voltage for their respective time-delay circuits. These time delay circuits are required to correct the discontinuity occurring when the slider arm of one potentiometer traverses the region of maximum to minimum range voltage. That is, two pulses were available 90% of the time and during the flyback time of one, the other is available about 8*T* units from the pre-trigger. The ambiguous pulse is disconnected by a cam-operated micro-switch and the effective pulses are mixed to provide the reset trigger for the disable gate. Thus, the first selected intermediate trigger acts as the reset pulse. The cyclic nature of the triggers would be obvious by observing the output of the trigger mixer as the range is varied.

The disable gate clamps the step counter to its initial state while it is present. Subsequently, when the gate is reset, the counters operate. In this fashion, range coherence is maintained. This system, designated "cyclic," requires careful adjustment of the phasing of the cam-operated microswitches and dual time circuits and potentiometers. However, it has proved stable in maintaining alignment. Difficulties were experienced in maintaining the adjustment of the step counters. The latter are quite susceptible to supply voltage, input pulse and tube variations.

The system shown in Figs. 5 and 6 is somewhat more elegant and is easier to adjust and maintain. Scaling down is provided by a locked oscillator frequency divider[5] which is recycled by a disable gate initiated by the first selected range trigger and reset by the pre-trigger. This circuit helps to assure that the 8:1 pulsed sine wave starts off in the same phase for each P. R. F. This circuit will be discussed in more detail later.

The 8:1 pulsed sinusoid is phase shifted one revolution every increment of range corresponding to 8*T* units. Pips generated from this 8:1 phase-shifted output are tracked by the coarse time delayed pulse which selects one of the pips. The selected range trigger, as mentioned before, is used to set the disable gate and also to set a selection gate for the next precision pip. The selected precision pip represents the mechanical range.

It may be noted that the scale number can be increased several-fold by using additional re-cycled frequency dividers. By this technique, precision may be obtained out to ranges greater than 1000T. The discussion will now be limited to the circuit techniques necessary to optimize the dual phase shifter triple scale timing system shown in Fig. 5.

LOCKED OSCILLATOR FREQUENCY DIVIDER WITH RE-CYCLING

Figs. 7 and 8 show a simplified circuit and waveform diagram of the locked oscillator frequency divider with re-cycling. The locked oscillator frequency divider[4] resembles a cathode coupled multivibrator with tank circuit synchronization. That is, the input source at frequency Nf_o synchronizes the cathode coupled oscillator with output frequency of f_o because of the intermodulation of the input and the harmonics of f_o. To improve synchronization the tank circuit is loaded down by a suitable value of series resistance. This enhances the harmonic content of the output provided care is taken to prevent loss of synchronization or possible astability. In the timing system described above, the tank circuit is tuned to ⅛ the input crystal oscillator frequency. This circuit can provide excellent frequency stability and phase lock provided the tuning of the tank circuit is adjusted to the middle of the lock-in range. However, since phase stability to within only ± 12.5% is required, this circuit is more than adequate for the scaling requirements of the system shown in Fig. 5.

To re-cycle the frequency divider, a positive gate pulse is applied to the disable cathode follower. The latter is normally biased to cutoff until the gate is applied. When the cathode follower conducts, it presents a low impedance across the tank circuit, and oscillations are effectively squelched except for a small residual output. The latter is due to the regenerative connection of the cathode coupled circuit. The level of the residual output is such that no effective spurious timing pulses are produced. In effect, the circuit described above is the marriage of the locked phase frequency divider and the pulsed cathode coupled ringing or marker circuit.

In the circuit shown, the gate is initiated by the first selected pulse

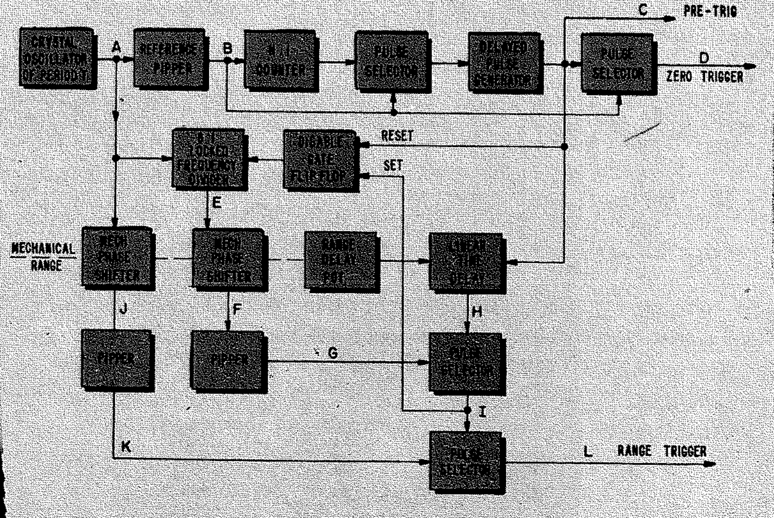


Fig. 5—Simplified block diagram of double phase shifter triple scale electromechanical timing system

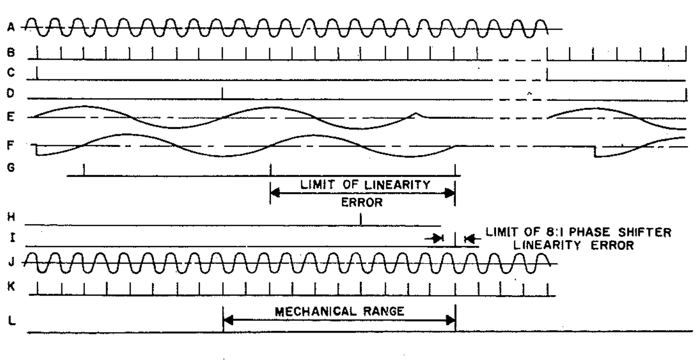


Fig. 6—Simplified timing diagram corresponding to system of Fig. 5

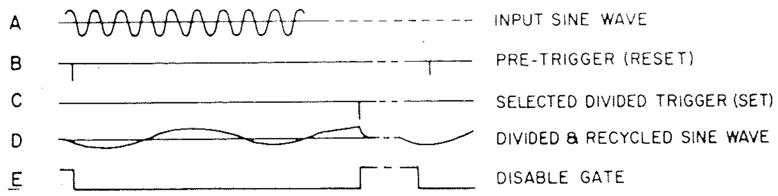


Fig. 7—Simplified circuit of the locked oscillator frequency divider with recycling

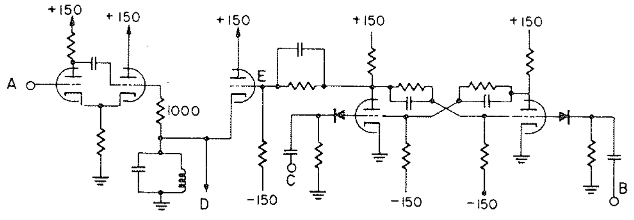


Fig. 8—Waveforms associated with circuit of Fig. 7

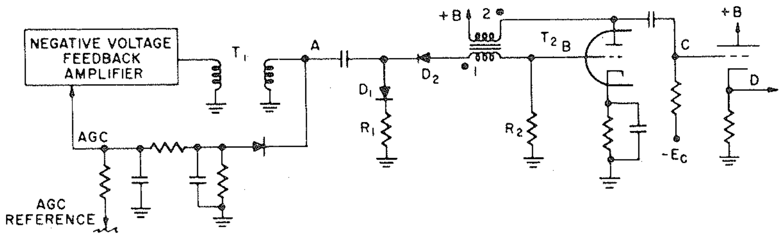


Fig. 9—Simplified circuit diagram of precision multiar pipper

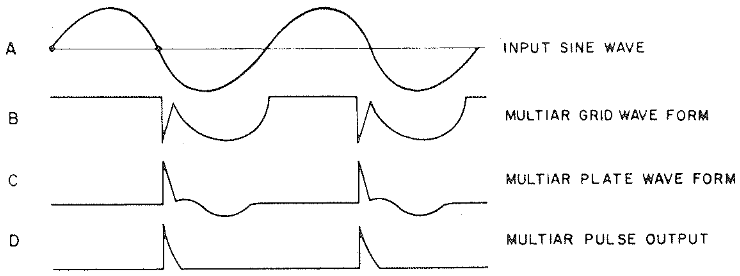


Fig. 10—Waveforms corresponding to circuit of Fig. 9

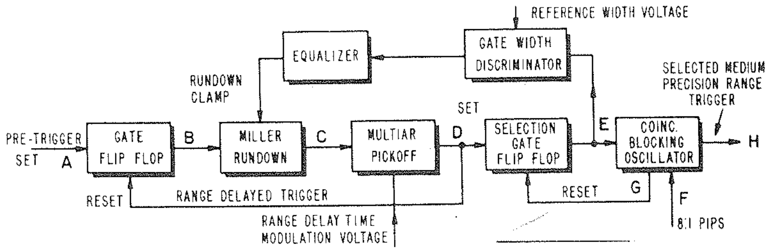


Fig. 11—Simplified block diagram of pulse tracking time delay

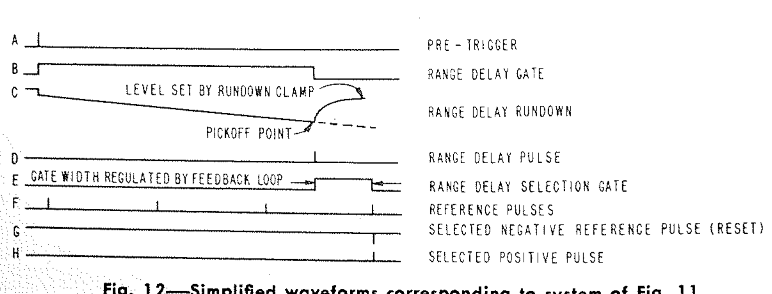


Fig. 12—Simplified waveforms corresponding to system of Fig. 11

derived from the phase shifted output of the locked phase frequency divider. Since the gate is reset by the pre-trigger, which is phase coherent to the input reference sinusoid, the locked oscillator output starts out with the same phase each repetition period. The starting transient is minimized because of the natural ringing effects and the coherence of the disabling gate. However, if the P. R. F. is changed over a wide range, care must be taken in standardizing the disabling impedance characteristics. Clamping and direct coupling the disable gate minimizes transient variations caused by P. R. F. changes. The harmonic distortion caused by the synchronization process can be minimized by driving the output through selective buffers.

MULTIAR PIPPER

As discussed previously, the phase stability and precision of the fixed phase and variable phase pips to their respective driving sinusoids is a severely critical requirement. Generally, pips have been produced by amplitude comparison of a sinusoid at a fixed phase point and generating a pulse from the comparison signal. This has been accomplished by amplifying, squaring, and differentiating the sinusoid. For reliable precision, this technique is not suitable since reliance is placed on the uncontrolled cutoff and grid current characteristics of triodes and pentodes. In addition, the amplitude comparison point is rarely controlled at the optimum zero crossover point. This results from the difficulties in maintaining phase stability in overdriven amplifiers or trigger circuits.

Fig. 9 shows a simplified schematic of a multiar type of amplitude comparator where reliance is placed on the reasonably stable transition characteristics of the crystal diode, and regenerative feedback is used to minimize the delay time in generating a marker pulse. In this circuit, while the sinusoid goes positive, the diodes, D_1 and D_2 prevent the grid of V_1 from going positive. The latter is essentially at quiescent bias during this condition, with the current limited by the dissipation rating of the tube. As the sinusoid goes through zero in a negative direction, diode D_2 conducts, dropping the grid voltage at V_1. This negative drop is reinforced by the regenerative connection of the pulse transformer T_1, which produces a rapid negative going pulse superimposed on the negative going grid waveform. This is accomplished by a type of reverse blocking oscillator action. The plate winding of the pulse transformer supplies the desired positive pulse to a cathode follower which rejects any negative going residue and produces clean, high current positive pulses accurately referenced to the driving sinusoid. Transition times of less than .1 microseconds and amplitudes of more than 30 volts at 100 ohms load have been readily obtained at frequencies up to 100kc.

For optimum stability, the sine wave driving the multiar should have its amplitude at its maximum value consistent with the requirement for an amplitude distortion of less than 5%. Another limitation to the amplitude requirement is the peak inverse voltage ratings of diodes D_1 and D_2. Coupling transformer T_1 permits a step up of voltage to this value (up to 200 volts peak-to-peak) while not exceeding the linear dynamic range of the negative voltage feed-back amplifier. The latter should enhance phase stability and low impedance drive to the multiar, minimizing reaction of the multiar pulse back through the amplifier. Diodes D_1, D_2, R_1, R_2 are needed to provide a symmetrical load to the sinusoid so that the zero level crossover point is maintained.

Since phase reference of the multiar pulse is a function of the amplitude of the reference sinusoid, an AGC system should prove helpful in maintaining extreme stability of phase. This is readily accomplished by "peak-detecting" the continuous sinusoid drive to the multiar and filtering the result. The AGC voltage is derived from this output which is compared to a reference potential. Since the dynamic range of the input sinusoid is quite limited in most cases, the design requirements for the AGC loop are quite straight-forward.

REFERENCE PULSE TRACKING TIME DELAY

Performance limitations of the coarse time delay circuits discussed previously may be minimized by utilizing a simple feedback tracking loop. Since, in all the previously described systems, the objective of the time delay circuit is to track and select one range pulse out of many as a function of mechanical range setting, the selected range pulse could be used to correct for the time delay errors. For example, in an ideal negative-going sawtooth and multiar pickoff-time delay circuit, we represent

T_d=time delay of output pulse
T_p=time delay of reference pulse
V_o=voltage of sawtooth at time t=o
V_p=pickoff voltage

Assume that V_p is fixed. Then

$$T_d = K_1 (V_o - V_p) \qquad (1)$$

the incremental component $t_d = K_1 (v_o)$

$$\text{if } v_o = K_2 (t_p - t_d) \qquad (2)$$

$$\frac{t_d}{t_p} = \frac{K_1 K_2}{K_1 K_2 + 1} \qquad (3)$$

where K_1=slope scale factor
K_2=feedback scale factor

Equation 3 represents the usual servo loop relation which can be implemented by the system shown in Figs. 11 and 12.

Essentially, a multiar comparator produces a negative pulse delayed from the pre-trigger as a function of both the range pickoff voltage and the voltage applied to the rundown clamp. The negative pulse sets a gate generator which selects the next precision range pip among a train of range pips. The selected range pulse resets the gate. This has the desirable effect of eliminating the possibility of selecting more than range pip and the need for gate width calibration adjustments. In addition, the width of the gate is a measure of how well the range delayed trigger tracks the selected range pulse. For example, the nominal width of the selection gate should correspond to 4T units if the range pulses occur 8T units apart. This width can be measured by integrating the gate, clamping the resultant output and comparing it to a reference value. This output can be used as the initial level set of the rundown and the feedback loop is thus closed to regulate the width of the selection gate.

In practice, the time delay would be adjusted with the loop open at a desired range. The loop would then be closed and adjustments would be made to maintain the same time delay as for the open loop case. By this technique considerable improvement may be obtained in minimizing the effect of time jitter and non-linearities in the delay circuit. Fail-safe provisions of a sort may be provided by including position memory in the loop by means of suitable equalizers.

CONCLUSIONS

The techniques discussed in this paper are refinements introduced in timing systems which are at present in an enviable state of the art. However, there is always room for improvement in designing better performing, more reliable components, and simpler, more economical circuitry. The need for such improvements will probably continue to tax the ingenuity and skill of future designers of long range timing systems.

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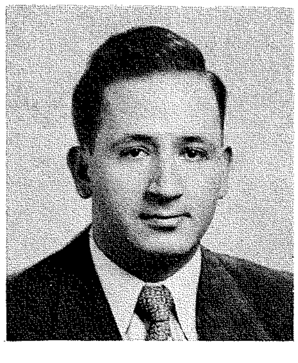

ALFRED I. MINTZER graduated from the City College of New York in 1949 with the degree of B.S. in E.E. After graduation he was employed by Evans Signal Laboratories where he carried on field work on tracking radars and designation equipment. From 1951 to 1952, he developed instrumentation equipment for guided missile fuze components at Diamond Ordnance Fuze Laboratories.

Mr. Mintzer joined the RCA Missile and Surface Radar Engineering (section 596) in 1952. Since that time, he has concentrated on the development of precision range timing and tracking systems for instrumentation and fire control radars. He is now a member of the Systems Optimization Group of Section 596.

THE 8BT8-A FOUR TRANSISTOR POCKET RECEIVER

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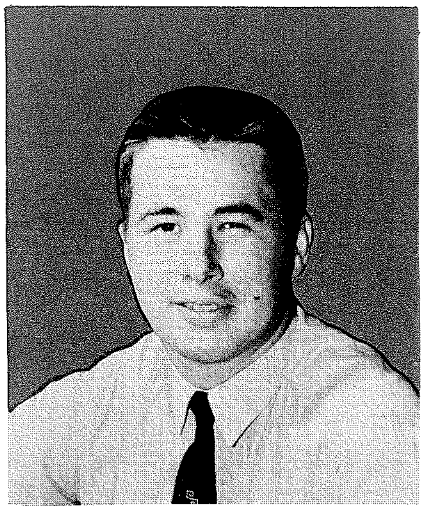
WITH THE ANNOUNCEMENT of the transistor several years ago, the possibility of a miniature pocket size receiver became a technical reality. However, until recently, the cost of such a receiver would have made it an economic misfit. Fortunately, this condition no longer exists. The increased availability and lower price of the transistor now makes it commercially feasible for miniature receiver applications. These events prompted the development of the Four-Transistor Pocket Receiver, model 8BT8. The object was to design a minimum cost receiver that would be small enough to be carried in one's pocket, and yet maintain acceptable performance characteristics. Some of the compromises involved in achieving this end will be discussed in this article.

BRIEF DESCRIPTION

The 8BT8 is a four transistor pocket receiver designed to cover the standard broadcast band. The superheterodyne circuit includes a converter, an i-f stage, a diode detector, an audio driver, and a class A power output stage. A second diode is used to prevent strong signal overload. Tracking is accomplished by the use of a cut plate oscillator gang. An RCA 2⅛-inch miniature speaker and printed circuit construction are used. The receiver uses a 9-volt mercury battery which provides more than 55 hours of operation with a 17 ma current drain. The circuits are designed to operate over a temperature range of from −10°C to +70°C. The receiver is enclosed in a case molded from unbreakable "Impac" material and measures 5½″ x 3⁵⁄₁₆″ x 1⅝″ A schematic diagram is shown in Fig. 1. Any mention of components in the following pages will refer to this schematic.

AUDIO OUTPUT

The audio output stage uses an RCA 2N109 transistor operate as class A in a grounded-emitter configuration. In order to obtain an output of 25 mw, a d-c power input of about 75 mw is necessary. The efficiency of the output stage including the output transformer is approximately 35%. This value of collector dissipation for the 2N109 presents somewhat of a problem. First, a heat sink must be used. Secondly, enough battery power must be used for stabilization, so that the collector dissipation is held within limits throughout the required temperature range, and for a production spread of transistors. This stabilization is accomplished by the proper choice of R_{12}, R_{13}, and R_{14}. With a nominal transistor, the collector current and collector-to-emitter voltage are approximately 11 ma and 6.5 volts, respectively. Under these operating conditions, simultaneous voltage clipping and current limiting, or maximum power output, occurs with an output load impedance of 800 ohms. Considering the nominal 2N109 to have a β (common emitter current gain) of 70, the average power gain of the output stage at 1000 cps is 35 db. The input impedance at 1000 cps is about 800 ohms. Due to the rigid size limitations on the by-pass capacitor C_{12}, and the output transformer T-5, the frequency response is down 3 db at 300 cps. This response is quite adequate for the audio performance of the receiver because the low-frequency response of the speaker and case falls off very rapidly below 300 cps.



JOHN B. SCHULTZ joined RCA as a cooperative student in June 1953. He was assigned to the Advanced Development Section of the Home Instruments Division, and later was transferred to the Advanced Development Section of the Radio and "Victrola" Division. He received his Bachelor of Science Degree in Physics in 1955 from St. Joseph's College, Philadelphia. Since that time he has remained with the Radio and "Victrola" Division as a design engineer and has been engaged in work on transistors and associated circuitry.

AUDIO DRIVER

The audio driver stage also uses an RCA 2N109 transistor operated as class A in a grounded-emitter configuration. Temperature stability and interchangeability are accomplished by the resistors R_8, R_{10}, and R_{11}. By drawing enough current through the network of R_8 and R_{10} so that any change in base current will not affect the base voltage, the operating point tends to remain constant. The stability of the circuit is increased by the use of higher bleeder currents. The limit of this current is determined by the maximum permissible battery drain. R_{11} provides d-c degeneration and this also tends to stabilize the operating point. Since the input impedance of the output stage is relatively low (compared with the output impedance of the driver stage) a transformer is used to more nearly match the impedances of the two stages. The zero-signal collector current of the driver stage is 2 ma. At this current the power gain with a nominal β transistor is 40 db. This is about 8 db more than could be obtained if an r-c coupling network were used in place of the driver transformer. The volume control is connected to the secondary of the driver transformer, and the tap is connected so that decreasing the volume control setting tends to present a lower impedance to the collector of the driver. By reducing the output load impedance of the driver stage as the signal increases, strong signal voltage clipping in the output of the driver stage is avoided. This action also improves the frequency response of the driver transformer. At 2 ma collector current, the input impedance of the driver stage is approximately 1000 ohms at 1000 cps.

DETECTOR

The 8BT8 uses a single crystal diode as an audio and AGC detector. The diode is effectively connected between the base and emitter electrodes of the driver transistor, and is poled so that the forward conduction is opposite in direction to the normal base emitter current flow. The resistor R_7 is added in series with the diode so that the proper forward bias may be applied to the diode detector. The capacitors C_5, C_6, and C_7 act as audio and i-f by passes. Since there is approximately 75 db of power gain following the detector, a detector output of 8×10^{-10} W will drive the audio system to full output. Operating the diode detector at these low-power levels presents somewhat of a problem. When the input impedance of the detector is low (less than 3000 ohms) the i-f voltage at the input of the detector must be correspondingly low. In the 8BT8 receiver the input impedance to the detector is 2500 ohms at 455 kc. Thus, to drive the audio system to full output, an i-f voltage of about 40 mv is required at the input of the detector. Since the forward resistance is high and also very non-linear at these voltage levels, the efficiency of the detector is low. The power loss in the detector with 30% modulation is 27 db. Also, distortion due to high modulation becomes apparent at these low voltage levels. When operating the diode detector in this non-linear region, the amount of distortion for a given percentage modulation is governed primarily by the voltage level.[1] The ratio of the a-c load impedance to the d-c load impedance is a secondary consideration. Although the performance of the diode detector is not as good as might be desired, it is a necessary compromise between the considerations of cost and size of the 8BT8. Another reason for operating the diode at such low-power levels, is to avoid the problems associated with i-f harmonic "tweets."

AUTOMATIC GAIN CONTROL

The cathode of the diode detector is connected through R_7 to the base of Q-3, and the anode is connected directly to the emitter. In this configuration the base of Q-3 is driven positive as the i-f signal input to the detector is increased. By effectively connecting the diode directly between the base and the emitter of Q-3, there is no d-c degeneration due to resistive elements in the collector-emitter circuit.

As the base of Q-3 is driven positive, the collector current decreases. This decreases the voltage drop across R_{11}, and the emitter of Q-3 is driven positive. The bases of the i-f and converter stages are connected to the emitter of Q-3 through the filter networks of R_2C_3, and R_3C_4, respectively. When the input signal to the detector increases, the bases of the i-f and converter stages are driven positive and their collector currents decrease. This decrease in collector current provides the necessary gain control. The emitter of the i-f stage is returned to the junction of R_4 and R_6, while the emitter of the converter is returned to the junction of R_4, and R_5 through R_1. The combination of R_4, R_5, and R_6 comprise a bleeder network which

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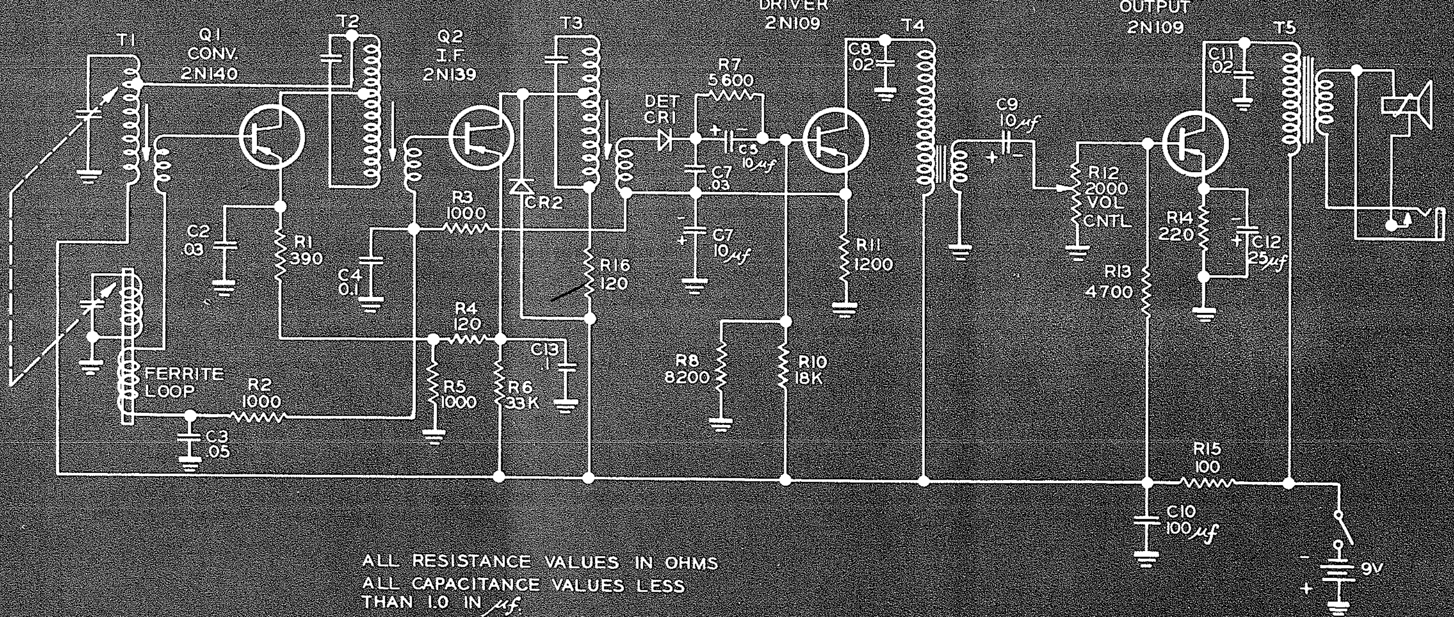
[1] EM-5096 "The Diode Detector At Low Voltages," J. B. Schultz



ALL RESISTANCE VALUES IN OHMS
ALL CAPACITANCE VALUES LESS
THAN 1.0 IN μf.

Fig. 1—Schematic diagram of the model 8BT8, Four-Transistor Pocket Receiver.

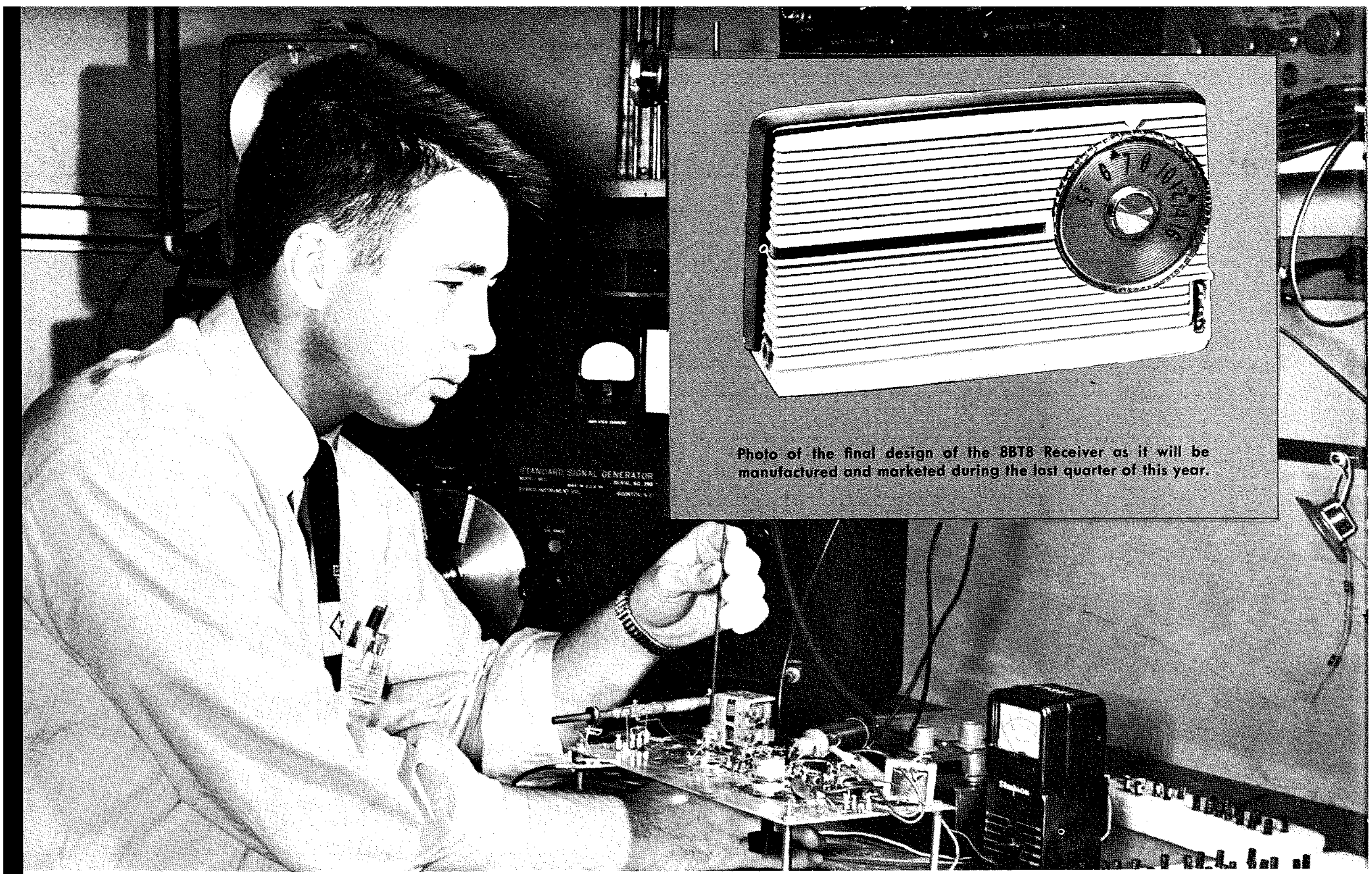


Photo of the final design of the 8BT8 Receiver as it will be manufactured and marketed during the last quarter of this year.

Photo showing the author making adjustments on the first developmental circuit of the 8BT8 Receiver.

tends to keep the emitters of the controlled stages at a constant d-c voltage despite variations of their collector current. Since the collector current depends upon the base-to-emitter voltage, a more nearly constant emitter voltage will make any change in base voltage more effective in changing the collector current.

It is possible under very strong conditions to reduce the collector current in the i-f stage below .2 ma. If the current in the converter is allowed to fall below this value, there is a possibility that the oscillator would cut out. This condition would produce a "motorboating" effect on strong signals. To prevent this, a resistor R_1, is placed in the emitter circuit of the converter stage. In order to maintain a correct zero signal bias, R_1 cannot be returned to the same voltage as the emitter of the i-f stage, but must be connected to some potential closer to ground. This is accomplished by the use of R_4.

I-F AMPLIFIER

The i-f amplifier of this receiver uses an RCA 2N139 transistor. The zero-signal collector current is about 1 ma. while strong signal current is below 0.1 ma. The input and output of the transistor is connected through single tuned transformers to the converter and detector circuits respectively. Because of the severe size requirements, single tuned i-f transformers must be used. With these single tuned transformers the maximum adjacent channel attenuation is limited by the bandwidth necessary for acceptable audio performance. Since broader bandwidths result in poorer adjacent channel selectivity, a compromise was made between these two factors. With an operating Q of 50 the two i-f transformers provide a 10 kc adjacent channel attenuation of 16 db and a 6 db bandwidth of about 9 kc.

Since the 2N139 has certain inherent[2] feedback networks connecting the output with the input, the maximum gain of the transistor can only be utilized as stable gain if the transistor is accurately unilateralized by an external network. This of course is not readily accomplished in production since variations in transistors, transformers, and components would make it impractical to maintain perfect unilateralization. Thus, in a practical design, enough gain must be deliberately thrown away in mismatch and insertion losses to provide stable gain for all normal variations of circuit elements. The maximum useful gain is, therefore, lower than the maximum gain of the transistor, and is governed by the amount of stability desired, and the degree of variation that is encountered in the circuit elements. Ordinarily, when designing an i-f system the operating Q and the maximum useful gain are known. From this data the unloaded Q and turns ratio of the i-f transformer can be determined.[3] In the case of the

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[2] "Study of PNP Alloy Junction Transistor from D.C. Through Medium Frequencies," L. J. Giacoletto
RCA Review—Dec. 1954 Vol. XV No. 4

[3] Stability Considerations In Transistor I-F Amplifiers, D. D. Holmes and T. O. Stanley Transistors 1 Pages 403 to 421.

8BT8, obtaining the maximum useful gain would require an unloaded Q higher than that of present miniature i-f transformers. The highest unloaded Q that is possible is about 150. With this unloaded Q, and with a loaded Q in the order of 50 the i-f stage, including both transformers, provides 30 db of power gain.

CONVERTER

The converter stage uses an RCA 2N140 transistor which performs the function of both oscillator and mixer. The zero signal collector current is about 1 ma. This current decreases to about .2 ma at very strong signals. The oscillator is operated as class A, and the oscillator feedback is applied between the collector and base. For optimum performance, a base to emitter oscillator voltage of about .16 volts is desired. Under this condition, the conversion gain of the converter is about 25 db. The collector of Q1 is returned to a tap on the oscillator coil through the first i-f transformer. Since the impedance of the i-f transformer is comparatively low at oscillator frequencies, it does not affect the oscillator performance. The output impedance of the converter at the intermediate frequency is about 50k-ohms. This is matched to the first i-f transformer. R-f signals are applied to the base of the converter in series with the secondary of the oscillator coil. The impedance of this winding is small at radio frequencies, so there is very little r-f degeneration across it. A 4⅝″ x ½″ x ⅛″ ferrite rod antenna is used for signal pickup. The operating Q of the antenna circuit (about 60) represents a compromise between image and i-f rejection, selectivity, and sensitivity.

STRONG SIGNAL LIMITER

As the r-f signal increases, the AGC circuits begin to operate, and the gain of the converter and i-f stages is reduced. This gain will decrease when input signal is increased, and will continue to do so until the diode detector has utilized its maximum possible control over the collector current of the driver stage. At this point, the gain of the converter and i-f stages no longer continues to decrease with increasing signal. If under these conditions the input signal continues to increase, overload distortion will occur in the driver stage. In order to prevent this, a diode CR-2 is connected between the collector of the i-f stage and the negative side of the power supply. The diode is connected so that the voltage drop across R_{16} provides a reverse bias of about .12 volts. Under small signal conditions, the impedance of the reversed bias diode is high (compared with the other circuit impedances) and therefore has no effect upon the circuit. However, when the signal excursions become very large, the diode is driven into its forward conduction region and thus appears as a shunting impedance across the output of the i-f stage. This action permits satisfactory operation at any signal strength up to 1-volt per meter.

OVERALL PERFORMANCE

Figs. 2, 3, 4 and 5 show the overall performance of the receiver. Other performance measurements are given below.

Stage	**Current Drain**
Converter	1 ma
I-F	1 ma
Driver	2 ma
Output	11 ma
Bleeder Networks	2 ma

2nd harmonic i-f tweet (910 kc) = 2% at 5000 μv/m

I-F Rejection (600 kc) = 40X

Image Rejection (600 kc) = 80X

Noise 20 db signal to noise ratio at 500 μv/m

CONCLUSION

The performance of this type of receiver will be greatly enhanced when improved types of transistors become commercially available. Present indications are that the rapid advances in the semiconductor field will soon provide the circuit design engineer with transistors that will vastly improve the flexibility and widen the scope of transistor applications.

ACKNOWLEDGEMENT

The author would like to acknowledge the cooperation of Mr. P. Gallo, engineer, Product Design Group, Radio & "Victrola" Division, whose performance measurements of the 8BT8 appear in this article.

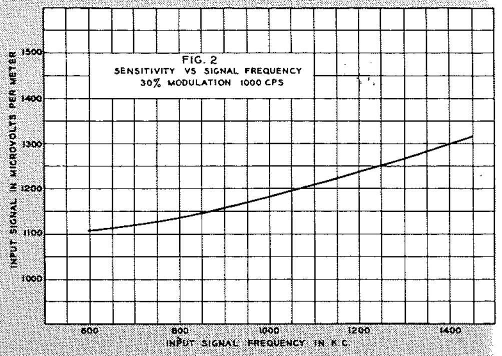


FIG. 2

SENSITIVITY VS SIGNAL FREQUENCY
30% MODULATION 1000 CPS

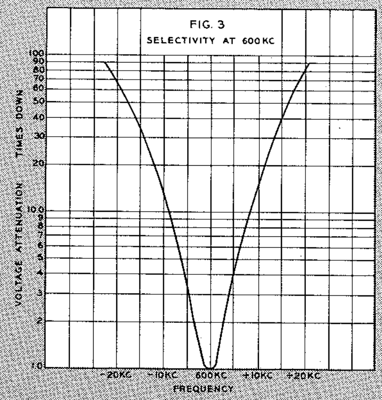


FIG. 3

SELECTIVITY AT 600KC

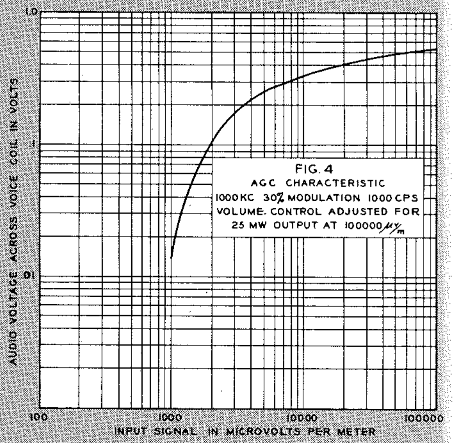


FIG. 4

AGC CHARACTERISTIC
1000KC 30% MODULATION 1000 CPS
VOLUME CONTROL ADJUSTED FOR
25 MW OUTPUT AT 100000 μv/m

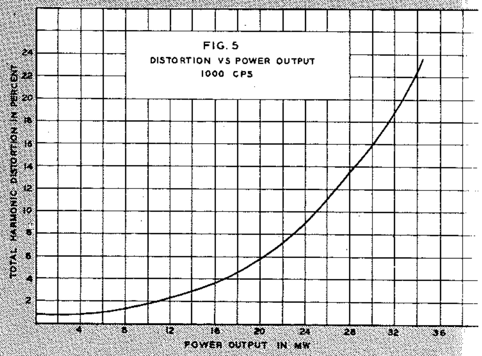
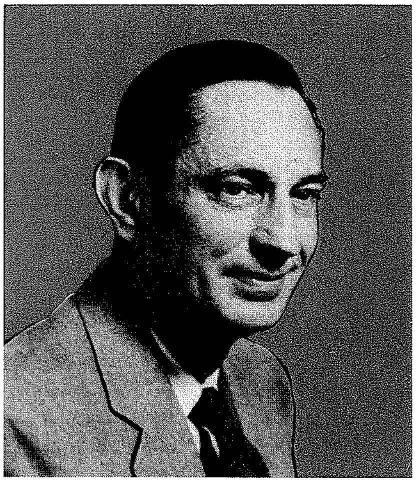


FIG. 5

DISTORTION VS POWER OUTPUT
1000 CPS

PROPERTIES AND APPLICATIONS OF CERAMIC PERMANENT MAGNETS

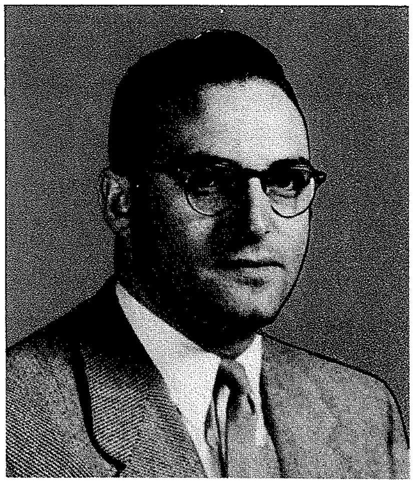
by
Dr. H. L. DONLEY and Dr. I. GORDON
RCA Laboratories, Inc.
Princeton, N. J.



DR. HUGH L. DONLEY graduated from Hobart College with a BS degree in 1930, and received the MS and PhD degrees in Physics at Brown University in 1932 and 1935 respectively. In 1935 he joined RCA as a research engineer in the Research Division of RCA Manufacturing Co. He came to RCA Laboratories in 1941.

Dr. Donley has researched in the fields of crystal filters, silicon diodes, dielectrics, TV development and ferrites.

He is a member of the Phi Beta Kappa, Sigma Xi, the American Physical Society, and the IRE.



DR. IRWIN GORDON received the BS degree in ceramics at Rutgers University in 1948, and the PhD in 1952. Since joining RCA Laboratories in 1952 he has worked on magnetic materials.

Dr. Gordon is a member of the American Ceramics Society, Keramos (Ceramic Honor Society) and Sigma Xi.

A CERAMIC PERMANENT magnet is comprised of materials that possess properties uniquely different from previously known permanent magnets.

Values of remanence as low as 2600 gauss, a coercive force as high as 2200 oersteds, as well as an energy product of 1.5×10^6 gauss-oersteds, have been obtained with these oxidic permanent magnet materials. Magnets made from it for use in loudspeakers and focus units for kinescopes and traveling wave tubes are economical and simple to manufacture.

INTRODUCTION

The mineral magneto-plumbite of composition $PbFe_{12}O_{19}$ was first described crystallographically by Adelskold.[1] By replacing the lead ion with barium or strontium the same structure is maintained. Other workers,[2] upon examining the $BaCO_3$-Fe_2O_3 system, have shown that certain compositions are ferromagnetic, and still others have prepared permanent magnets from these ferrimagnetic oxide compounds.[3,4] These permanent magnets are characterized by a high coercive force (H_c of about 1500 oersteds), and low remanence (B_r of about 2000 gauss), yielding energy products, $(BH)_{max}$, of the order of 10^6 gauss-oersteds.

In these laboratories it has been found that a better permanent magnet materials can be made using the composition $PbFe_8O_{13}$. Fig. 1a shows the demagnetization curve for this composition prepared in the manner presently outlined; Fig. 1b shows the demagnetization curve for $BaFe_{12}O_{19}$ from previously published work. For comparison, the demagnetization curve for Alnico V is included as Fig. 1c.

These oxide permanent magnets are of interest because they are economical and simple to manufacture. In addition, unlike the Alnico magnets, they contain no nickel or cobalt, two scarce and expensive elements.

The present paper describes the magnetic properties of this oxide composition, together with its application in permanent magnets for loudspeakers and focus magnets for both kinescopes and traveling wave tubes.

PREPARATION

These permanent magnet oxides are synthesized by essentially the same ceramic techniques as generally used in the preparation of "ferrite" materials[5] except for more strict control over particle size. After the material is fabricated, it is then magnetized in a field of at least 8000 oersteds, and for optimum properties the magnetization should be parallel to the direction in which the piece was pressed.

TEST METHODS, THE DEMAGNETIZATION CURVE

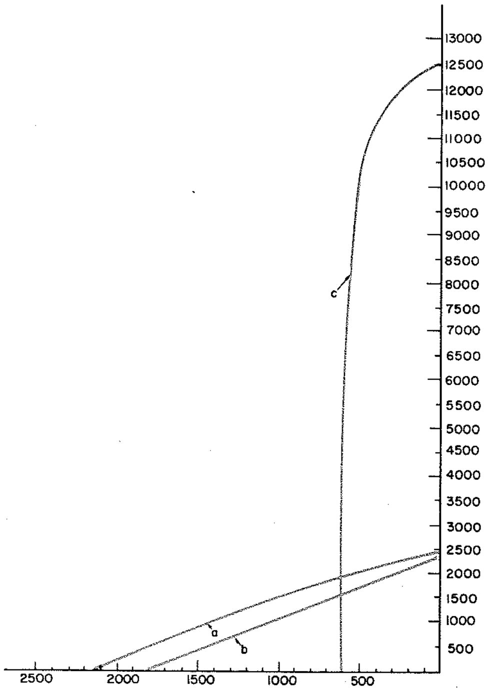
In general, all magnetic circuits of which a permanent magnet forms a part contain air gaps. Hence, the permanent magnet is always subject to a demagnetizing field and must operate at some induction lower than its residual induction (B_r) which prevails if the circuit is completely closed. For example, let Fig. 2 represent the hysteresis loop for a perfect magnetic circuit of the material whose residual induction is B_r and coercive force is H_c. The magnetic circuit then has an intrinsic magnetomotive force *(M.M.F.)* sufficient to maintain the induction B_r which is measured by H_c oersteds for every centimeter length of the circuit. An air gap introduced in the circuit will reduce the remanence to some value, B (Fig. 2). Associated with this B is some magnetic force, H, from which may be calculated the *M.M.F.* necessary to maintain this B across the air gap of known dimensions. Thus, the important curve to know for a permanent magnet is that part of the hysteresis loop which lies in the second quadrant (the demagnetization curve). Consequently, to obtain this curve which is characteristic of the material itself, tests must be made on specimens in a virtually closed magnetic circuit. A recording d-c hysteresis loop tracer of laboratory design was used to obtain the hysteresis loop or demagnetization curve of a particular specimen.

For the measurement of B, the specimen was wound about its center portion with a few turns of fine wire. The coil placed at the center of, and contiguous with, the sample insured a more accurate estimate of the true induction in the sample.

The magnetizing field, H, was determined with an air-core solenoid coil placed adjacent to as the sample. The output from each coil was integrated by the loop tracer and fed to an x-y recorder.

The flux density in the gap of the loudspeaker structures or along the axis of a large ring for focusing was measured by using the ballistic galvanometer as a flux meter with a search coil whose dimensions were small with respect to the gap dimensions. Since the dimension of such a small search coil could not be determined with accuracy, the search coil and ballistic galvanometer were calibrated by observing the galvanometer deflection when the search coil was withdrawn from a known magnetic field.

Fig. 1—Demagnetization curve for (a) $PbFe_8O_{13}$, (b) $BaFe_{12}O_{19}$, (c) Alnico V.



MAGNETIC PROPERTIES

Coercive Force and Remanence in the Ceramic Permanent Magnets

One of the distinguishing characteristics of the oxidic permanent magnets is a high coercive force which can be explained theoretically in two ways.[7] On the one hand is the high crystal anisotropy of this structure; on the other hand, the fine-particle theory may also be used to explain the high coercive force. For this reason, it is necessary to keep the particle size small; values of H_c of 2200 oersteds have been measured.

Coupled with the high coercive force in this oxide magnet is the relatively low (for permanent magnets) value of saturation magnetization. The $PbFe_8O_{13}$ has been prepared to have a remanence (B_r) as high as 2600 gauss; the saturation (B_s) is about 4400 gauss. Acting to affect the B_r is the density of the sample; the higher the density, the greater the remanence tends to be. In sintered bodies, the density (porosity) can be controlled directly by means of firing time and temperature. That is, the more heat-work applied to the sample, the greater the B_r tends to be. However, this increase in B_r (i.e. density) is obtained at the expense of the coercive force, increasing the grain size to above the optimum grain (i.e. domain) size. It has been calculated and experimentally verified that the grain size for optimum H_c is approximately one micron. It is therefore necessary to effect a compromise between density (i.e. B_r) and particle size (i.e. H_c).

These variables can be controlled by grinding time, firing temperature, and time at firing temperature. In laboratory experiments, energy product values of $(BH)_{max}$ equal to 1.56×10^6 gauss-oersteds are attained.

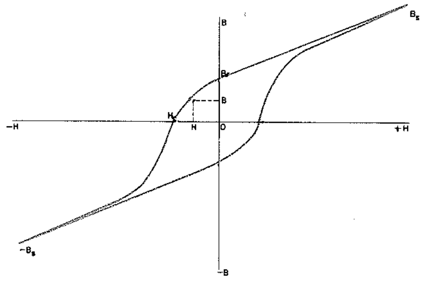
Curie Temperature

The Curie temperature has been reported for $BaFe_{12}O_{19}$.[3] The average of several trials in a simple experiment placed the Curie temperature for both $BaFe_{12}O_{19}$ and $PbFe_8O_{13}$ in the neighborhood of 455°C.

THE ENERGY PRODUCT

It has already been pointed out previously, that an air gap introduced in an otherwise closed magnetic circuit will reduce the induction from the remanent value, B_r, to some value B corresponding to some value H (Fig. 2). Now, consider a simple magnetic circuit which contains a permanent magnet of length L_s and cross-sectional area A_s. A highly permeable material of sufficiently large cross-section to produce no magnetic potential drop throughout its length transfers all the flux lines from the permanent magnet to a gap of length L_g and cross-sectional area A_g. (Areas are taken perpendicular to the lengths which are parallel to the lines of flux.) If the area, A_g, of the gap is taken as its geometrical area, and all flux lines are assumed normal to the soft iron pole faces, then the flux (ϕ_g) in the gap is the same as the flux in the magnet (ϕ_s). If the flux density, B, is uniform over the area A,

Fig. 2—Hysteresis loop showing that the remanence is reduced to some value B when an air gap is introduced in the magnetic circuit.



$$\phi = BA \qquad (1)$$

and hence

$$\phi_s = \phi_g \text{ or} \qquad (2)$$

$$BA_s = B_g A_g \qquad (3)$$

where B and B_g refer to the flux density in the magnet and gap respectively.

Equation (3) simply expresses the fact that the lines of magnetic flux are continuous. A further condition of the magnetic circuit can be expressed if one recalls that the air gap sets up a field in a direction opposite to the internal field, H, in the magnet, and the externally applied $M.M.F.$ is zero. The second condition may be written as

$$HL_s + H_g L_g = 0, \text{ or}$$

since in air $H_g = B_g$, this becomes

$$HL_s = -B_g L_g \qquad (4)$$

Equations (3) and (4) combine to give the following

$$(BH) L_s A_s = -Bg^2 L_g A_g, \text{ or}$$

$$V_s = \frac{B_g^2}{(BH)} V_g \qquad (5)$$

This last equation then says that the volume of the magnet (V_s) required to maintain the flux density B_g in the gap volume V_g will be a minimum when the product of B and H is a maximum for the material. This (BH) product is called the energy product because it is proportional to the magnetic energy of unit volume of the material $BH/8\pi$ and also to the energy stored in a unit volume of the gap, $B_g^2/8\pi$. The maximum value of BH or $(BH)_{max}$, the maximum energy product, is thus the quality factor for the magnetic material in question.

PERMANENT MAGNET DESIGN

A particular permanent magnet material will be used most efficiently when the dimensions of the magnet formed from this material are such that a minimum volume is required to maintain a given field in a given volume of space. The determination of these dimensions by equations (3) and (4) and the minimum volume by equation (5) in accord with the $(BH)_{max}$ for the material would be simple if leakage could be neglected. Unfortunately, this is never the case, because a gap of even small dimensions will introduce considerable fringing about the gap itself. In addition, the assumption of uniform flux density in the derivation of equations (3), (4), and (5) is no longer valid when an air gap is inserted in the circuit because leakage from surfaces will occur. The magnitude of this surface leakage flux will depend both upon the geometry of the structure and the distance from the pole faces at which it is considered.

However, one still desires to predetermine the dimensions of the magnet such that the operating point for $(BH)_{max}$ is realized to give a minimum volume of magnet in spite of the leakage. The final design of the magnet dimensions is still largely based upon experiment.

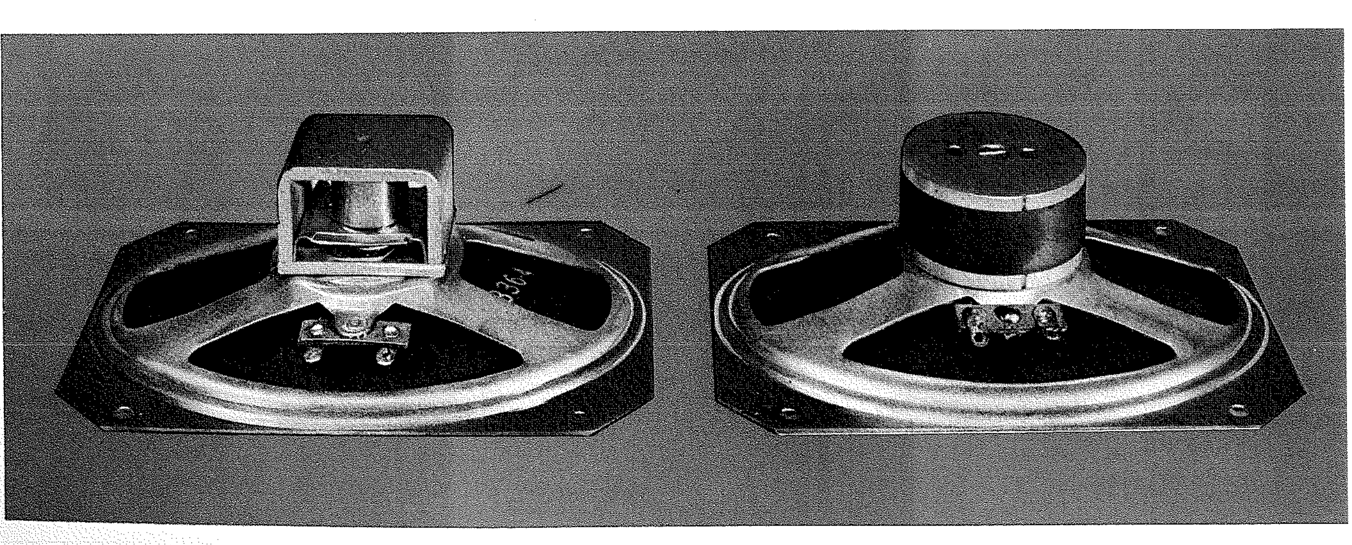
The generally accepted procedure used in design is to modify equations (3), (4), and (5) above to take account of leakage. Moreover, the magnet volume must then be increased by the amount of the total leakage as compared to that without leakage in order to obtain, in both cases, the same field in a gap of given dimensions.

The general shape of the ceramic magnet to produce the same field in a given gap as, for example, an Alnico V magnet generally used can be compared by means of the equations. The optimum H and B are approximately 1100 and 1400, respectively, for the oxide material and about 500 and 10,000, respectively, for Alnico V. By equation (4) then, the ceramic magnet is only one half as high as the Alnico V magnet. Therefore, surfaces have only one half the separation in the ceramic magnet speaker which increases the leakage in by at least a factor of two over the Alnico V speaker when the magnet area A_s is calculated for optimum B. In addition, about seven times the cross-sectional area is required in the oxide magnet over the Alnico V type because the flux-carrying capabilities are seven times greater for the latter material. In other words, the oxide magnet must, for optimum shape, be a large flat disc or ring causing high external surface leakage as compared to a rod type structure of lower leakage for the Alnico V magnet when used in a loudspeaker.

APPLICATIONS

Samples of the oxide magnets have been fabricated for use in several applications. The more important uses include replacing the Alnico V mag-

Fig. 3—A design of a loudspeaker using $PbFe_8O_{13}$ in the magnet assembly (right) compared with a production Alnico V type.



net in a loudspeaker, being used as a focus magnet for a black and white kinescope, and as a periodic field beam focusing magnet in traveling wave tubes.

Fig. 3 shows a design of a loudspeaker using $PbFe_8O_{13}$ in the magnet assembly alongside a production Alnico V type loudspeaker. Data for the $PbFe_8O_{13}$ magnet as well as for the Alnico V magnet are shown in Table 1. For some loudspeaker applications the higher stray flux field from the oxide magnet may be objectionable.

TABLE 1

	$PbFe_8O_{13}$	Alnico V
O.D. (inches)	2.07	0.84
I.D. (inches)	1.0	—
Height (inches)	0.7	0.625
Volume (in^3)	1.82	0.347
Weight (grams)	158	41
Gap flux (B_g)	8000	9000
Flux per gram	50.6	220
Total leakage	3.0	2.1

A second application for $PbFe_8O_{13}$ is a focus magnet on a 21-inch black and white kinescope. A preliminary design for a focus unit is shown in Fig. 4 beside an Alnico V production unit. The structure consists of (a), a threaded soft iron shunt which fits the tube neck quite closely, (b) soft iron top and bottom plates and (c), the oxide magnet ring. The threaded shunt acts to short circuit the flux; when the shunt is at its outermost position, the field acting on the kinescope beam is at its strongest. Focusing action, then, is accomplished by varying the amount of "short-circuited" magnetic flux via the shunt.

Still another application ideally suited to this oxide permanent magnet material employs the unusual coercive force available therein. In the development of periodic field beam focusing in traveling wave tubes, it has been found to be most convenient to assemble a series of axially magnetized rings. Opposite polarities of adjacent rings provide the alternating magnetic field which brings about the desired focusing action. The magnetic field along the axis of this structure is determined by the dimensions and the magnetic characteristics of the ring. The field is such that the magnitude of the demagnetizing effect precludes the use of the Alnico-type magnets. Further, the ring-type structure strongly favors the ceramic methods of fabrication and magnetic nature of $PbFe_8O_{13}$. In a preliminary design, the structure consisted of a number of rings alternately polarized and separated by iron shims as in Fig. 5. This compares to an alternate structure employing a water-cooled electromagnet and the consequent awkwardness inherent to such a design.

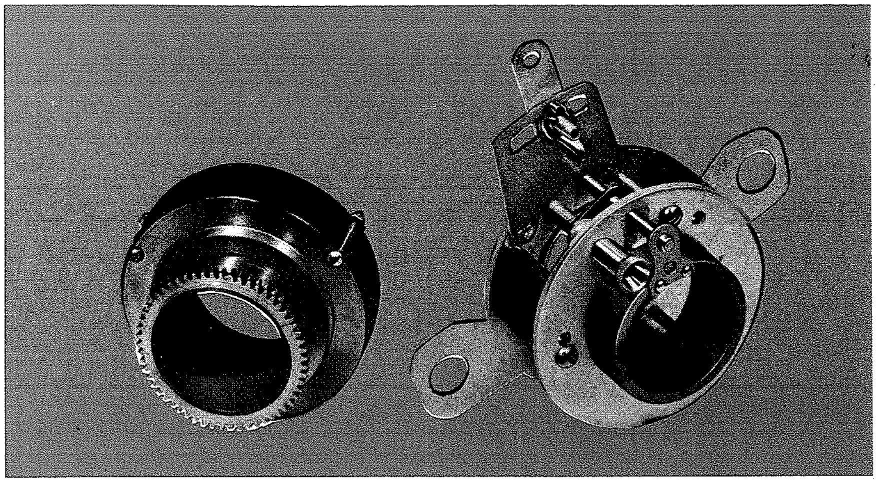
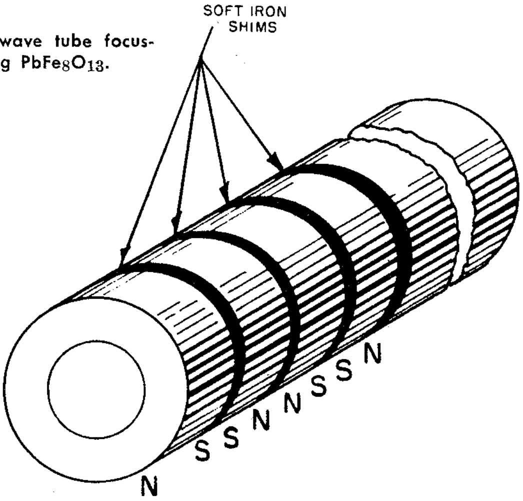


Fig. 4—A preliminary design for a kinescope focus unit using a ceramic magnet (left) alongside a production Alnico V unit.

Fig. 5—Traveling-wave tube focusing unit using $PbFe_8O_{13}$.



CONCLUSIONS

Ceramic magnets inherently have high internal reluctance. Therefore, they are best suited for such open magnetic circuit applications as focusing magnets for TV kinescopes and traveling wave tubes.

The low cost and availability of the raw materials holds out an attractive advantage. Beside the cost advantage, the magnets can be shipped to the assembler in any magnetic state.

Furthermore, the methods and equipment used in processing are quite common and little difficulty should be encountered in manufacture.

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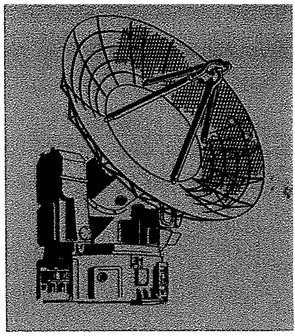
THE FIELD ENGINEER IN SUPPORT OF DEP WEAPONS SYSTEMS



by **T. G. WHITNEY, Mgr.**
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A NEW BREED OF engineer has developed in the electronic industry as a direct result of the many advancements and the stepped-up production of military equipment and systems. This is the Military Electronics Engineer or Field Engineer, as he is better known. Unlike the Design Engineer who specializes in specific circuit or equipment design, the Military Electronics Engineer must have a special type of know-how in the installation, service and maintenance of military electronics equipment, and the related instruction of military personnel. His knowledge must be acquired through experience in the application of the various equipments to fit individual military requirements. He must know how to deal with every level of military personnel from the maintenance man to staff officers, and he must fill the gap that exists between the Design Engineer and the Maintenance Technician.

OBJECTIVES

The prime objective of the Field Engineer is to keep equipment in top-notch working order — obtaining maximum performance on a round-the-clock schedule in most instances. By working with equipment under various environmental conditions, and, by teaching military personnel operation and maintenance he is in an ideal position to assist engineering and manufacturing. Pertinent information regarding equipment operation, reliability, military acceptance, and recommendations for modification result in improved equipment performance and maintainability.

WEAPONS SYSTEM CONCEPT

As part of the "Weapons System" program of RCA-DEP, the Government Service Department has been providing field engineering and associated services to DEP. This extends RCA assistance from product or system design to installation and maintenance at the military site. These services also include training, field evaluation, and other special services requiring the assistance of the Field Engineer. This cooperative effort between DEP and GSD enables the RCA Weapons System concept to operate smoothly and effectively toward the common goals of both engineering and the military customer.

During the past six years, GSD has, in effect, been providing the services required in the "Weapons System" concept to DEP on many of its products. Products which are usually preceded by a prototype, or evaluation model, require many of the field services during its evaluation, or trial period.

TARGET DESIGNATION EQUIPMENT

The Monochrome and Color Target Designation Equipment, which was designed and manufactured by RCA for the Bureau of Ordnance, is a good example of the cooperative efforts of DEP and GSD in carrying the product from initial design through complete installation, evaluation and acceptance by the military. The Target Designation Equipment, perhaps, represents one of RCA's first efforts toward the new "Weapons System" concept and has illustrated the basic need for such a program when system complexity reaches this point.

TYPICAL FUNCTIONS OF FIELD ENGINEERS

The RCA Field Engineer found his place in many facets of the Target Designation Equipment (TDE) program. While engineering was fabricating development models of the monochrome and color TDE, he received training on the equipment. When the developmental models were completed, he supervised the installation of the equipment in shipyards and aboard ship and trained personnel in the operation and maintenance. During government evaluation of the TDE, he maintained the equipment and made recommendations to Engineering for improvements and modifications. After evaluation he remained aboard the vessel to give "On-The-Job" Training and maintenance asistance.

Complete reports by Field Engineers on equipment operation, field changes, modifications, system operating changes, spare parts requirements, reliability, military comments, degree of acceptance and general recommendations were provided DEP for use by both engineering and manufacturing.

A special quality control program was established by GSD under DEP sub-contract for the preparation of

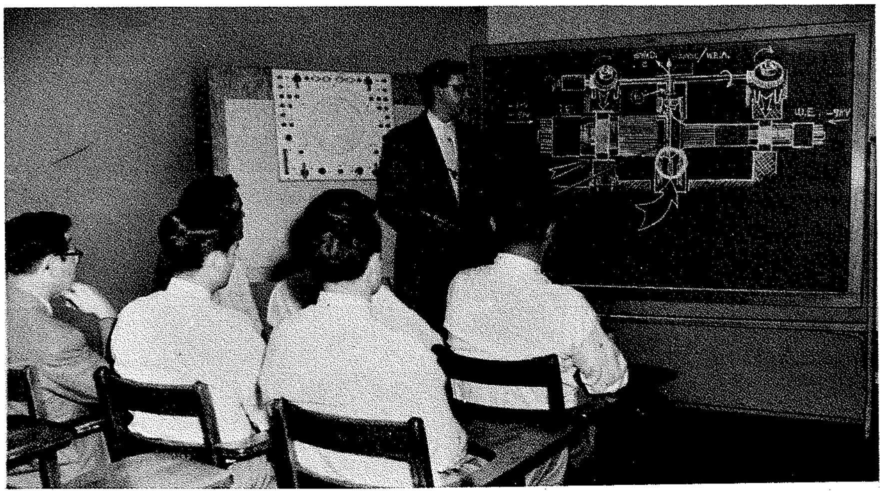


Fig. 1—Training courses on Target Designation. Equipment enabled yard and shipboard personnel to do a more effective job in installation and maintenance.

Acceptance Inspection Instructions for use by BuOrd inspectors. This program covered the entire TDE program from individual components to major units of the system.

After production models of the MK-4 and MK-6 Target Designation Equipments began to enter the field, GSD inaugurated a "shipboard assist" program, implemented by RCA Field Engineers, to train shipboard personnel in the operation and maintenance of the production equipment. Again, the feedback system of field reporting enabled DEP to incorporate modifications so that the equipment would perform its intended function more satisfactorily.

The experience gained on the TDE program was instrumental in the establishment of the present "Weapons System" concept. This program proved beyond a doubt that both DEP and the military customer would benefit by the packaged program, or "Turnkey" type of service, offered in this new concept of system design.

Many other similar programs have been, or currently are being carried out by both DEP and GSD. Some of these are briefly outlined below:

TALOS

The new Talos project represents one of the largest Weapons Systems that has been undertaken by a single contractor. The Missile and Surface Radar Department, as prime contractor, is responsible for delivering the system as a unit capable of being operated by Military personnel trained in all phases of its initial operation and maintenance.

FIELD ENGINEERING

Trained Field Engineers who have been working on field projects for many years were assigned to the Talos project. Their experience on other weapons systems in the preparation and fulfillment of the types of service required on the Talos project has given them an insight to logistic, installation, training and maintenance problems.

Under sub-contract to the Missile and Surface Radar Department, the GSD Engineers follow the system into the field after extensive training on the system and sub-systems in the factory. They must train military officers and men in the operation and maintenance of the Talos system. During the evaluation period they will provide assistance to the military in installation, training and maintenance, and then augment the Air Force maintenance program on all Tactical Talos installations.

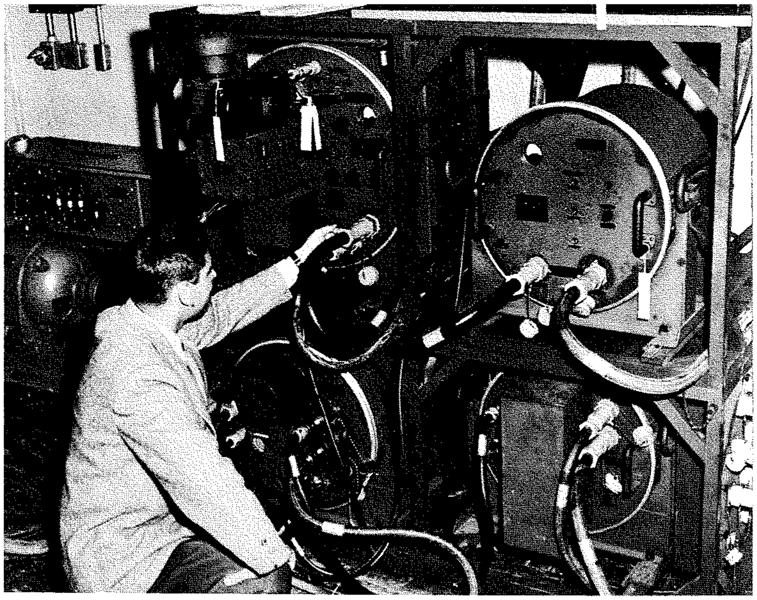


Fig. 2—RCA Field Engineer Rod Stevens inspects cabling connections on TPS-10D equipment.

SYSTEMS ENGINEERING SUPPORT

Complete military logistic studies are being prepared which will formulate logistic support of the entire system. The goal of this study is to present optimized solutions to inherent problems in maintenance, supply, training, reliability and associated problems concerning manpower, technical equipment, spares, transportation and packaging methods.

THOMAS G. WHITNEY graduated from Union College with a BS in 1925. He worked for Western Electric and Electrical Research Products, Inc. for 13 years successively as a field engineer, District Service Manager and Staff Engineer in Theatre-Sound systems. Mr. Whitney came to RCA in 1941 as a Staff Engineer in Photophone. He worked on shipborne radar before and during the war years. In 1949 he became Manager of Commercial Service, RCA Service Company, and transferred to the Government Service Department in 1950 as Field Operations Manager. He assumed his present post in 1955.

Liaison Field Engineers are stationed at key military locations for maximum effectiveness in accomplishing or interpreting military requirements.

FSR PROGRAM

The Factory Service Representatives act as technical liaison representatives on all products produced by DEP. These Engineers periodically visit military installations to check and discuss installation and maintenance of DEP products. They maintain repair depots for trouble shooting and modification of early production for DEP products.

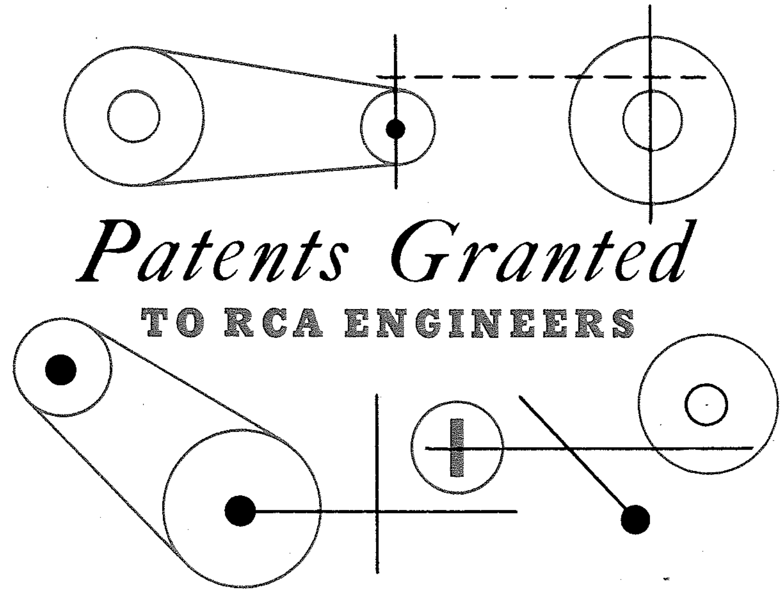
FIELD SUPPORT

Every GSD Field Service Engineer is backed up by a comprehensive field support program that enables him to draw on the vast resources of RCA. The Field Support Activity keeps him alerted and up-to-date on the latest developments in DEP products and in the general field of electronics.

CONCLUSION

This article touches only a few of the many projects that are currently in process through the joint efforts of DEP and GSD. Future planning indicates that the trend in military and Engineering thinking is toward utilization of the "Weapons System" concept as a standard procedure on all future contracts involving complex electronic systems.

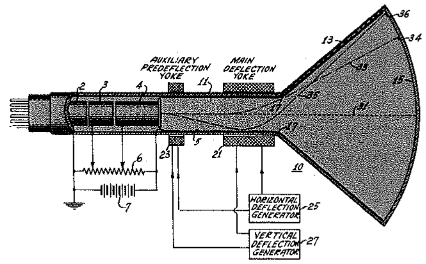
The Government Service Department, operating as an experienced and seasoned service "arm" of DEP, can provide the services required in the "Weapons System" concept to fulfill RCA's obligations for the "Turnkey" type of installation.



Patents Granted
TO RCA ENGINEERS

Based on Summaries Received over a period of about two months

LUMINESCENT COMPOSITION (Patent No. 2,728,027)—granted Dec. 20, 1955, to William E. Scull, Jr., RCA Victor Television Division, Cherry Hill, N. J. Reverse sense preliminary deflection imparted by auxiliary yoke spaced on tube neck ahead of main deflection yoke, continually displaces entry point of beam into main deflection region in direction opposite to the direction of deflection imparted by main scanning yoke. This substantially increases effective neck aperture width and permits exceptionally wide angles of deflection without the striking of tube neck "corners" by the beam; it also permits use of longer, more efficient yokes without the "corner" masking problem.

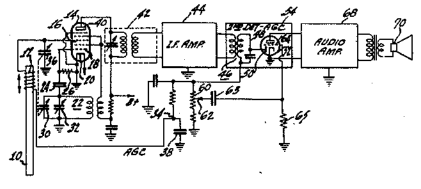


Pat. No. 2,728,027

METHOD OF COATING A MICA BASE WITH MAGNESIUM HYDROXIDE (Patent No. 2,715,586)—granted August 16, 1955 to W. F. Lawrence, Tube Division, Harrison, N. J. In a method of coating a mica base with magnesium hydroxide, the coating after application in a conventional way, is heated to the reaction temperature of magnesium hydroxide (at least 325°C), and then wetting the coating in water.

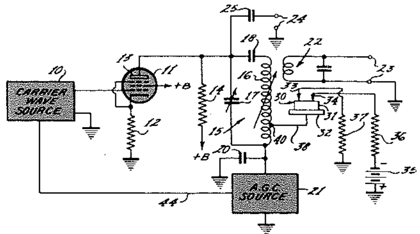
COMPOSITIONS INCLUDING POLYSTYRENE AND TERPHENYL (Patent No. 2,750,349)—granted June 12, 1956 to David H. O'Herren, RCA Victor Record Division, Indianapolis, Ind. Polystyrene is preferred for injection molding of phonograph records, but polystyrene unmodified is undesirably stiff and sticky for proper mixing. The composition of this invention include a terphenyl mixed with the polystyrene to impart better mixing and molding properties.

RECEIVER WITH ADJUSTABLE FERRO-MAGNETIC ROD LOOP ANTENNA (Patent No. 2,750,497)—granted June 12, 1956 to Harold B. Stott, RCA Victor Radio & "Victrola" Division, Cherry Hill, N. J. The ferrite loop antenna is used with a superheterodyne receiver and forms part of the signal selection circuit. Means are provided for simultaneously tuning the signal selection and oscillator circuits. The ferrite loop antenna includes an antenna coil asymmetrically supported on an elongated ferromagnetic rod. At least a portion of the winding near one end of the rod is longitudinally adjustable along the rod to change the inductance thereof and provide a tracking adjustment in the pickup circuit at the low frequency end of the band.



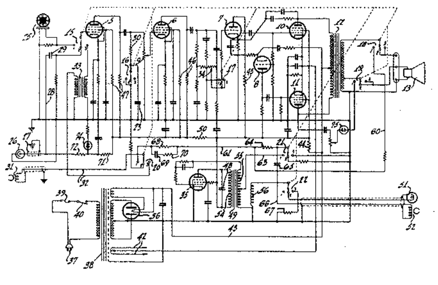
Pat. No. 2,750,497

SELECTIVITY CONTROL CIRCUIT (Patent No. 2,750,452)—granted June 12, 1956 to Hunter C. Goodrich, RCA Victor Television Division, Cherry Hill, N. J. To provide a variable selective amplifier, a resonant circuit and a source of control voltage (i.e., AGC source or potentiometer) are connected between the base and emitter of a transistor. Input signals are applied to the base. By adjusting the control voltage the effective resistance of the transistor is varied to vary the Q of the resonant circuit.



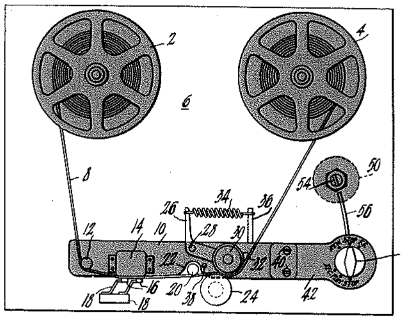
Pat. No. 2,750,452

SOUND RECORDING AND REPRODUCING CIRCUIT FOR PICTURES (Patent No. 2,756,277)—granted July 24, 1956 to Lowell H. Good and Frank L. Putzrath, Defense Electronic Products, Camden, N. J. A single amplifier unit includes a high frequency oscillator, a record-reproduce head, a photoelectric cell, an exciter lamp, and an erase head, together with a plurality of mechanically interconnected switches for connecting the above units into the amplifier circuit, depending on how the amplifier is being used, the switches also connecting and disconnecting various coupling elements between amplifier stages, depending on the particular use of the amplifier at the time. By the use of a special two secondary winding transformer, magnetic record-reproduce head, bias and erase head energy are supplied from one of the secondary windings. When the amplifier is used for photographic reproducing, the other secondary of the transformer is connected to the exciter lamp, and the output of the amplifier is connected to a speaker.



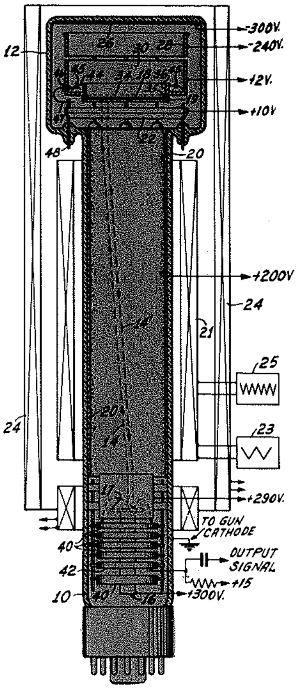
Pat. No. 2,756,277

MAGNETIC RECORDING APPARATUS (Patent No. 2,751,438)—granted June 19, 1956 to John S. Baer, Commercial Electronic Products, Camden, N. J. In a magnetic recording-reproducing machine, a single control instrumentality 44 is arranged to control all operations involving the magnetic record transport mechanism, the engagement and disengagement of the recording-reproducing transducer 14 with the tape 8 and the electrical connections to the recording and reproducing amplifiers.



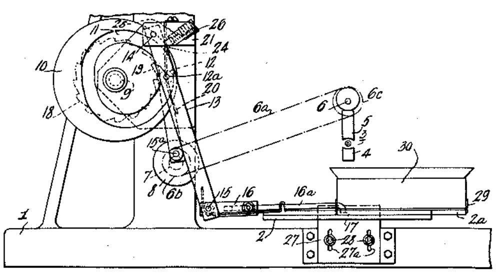
Pat. No. 2,751,438

GLASS TARGETS FOR IMAGE ORTHICONS (Patent No. 2,743,150)—granted April 24, to William G. Rudy, Tube Division, Lancaster, Pa. The specific nature of the invention is that of providing a target electrode for a t.v. pickup tube formed of a thin film of glass 18 whose surface is treated in several ways to form a bloom or mat on the surface thereof, whereby the effects of nonuniformity inherent in the glass or deposits of foreign matter on the glass are eliminated. Specifically, one operable method of treating the glass target is to expose the surface of the target to a mild sulfur dioxide atmosphere to provide a bloom, or chemical deposit, or formation on the glass surface.



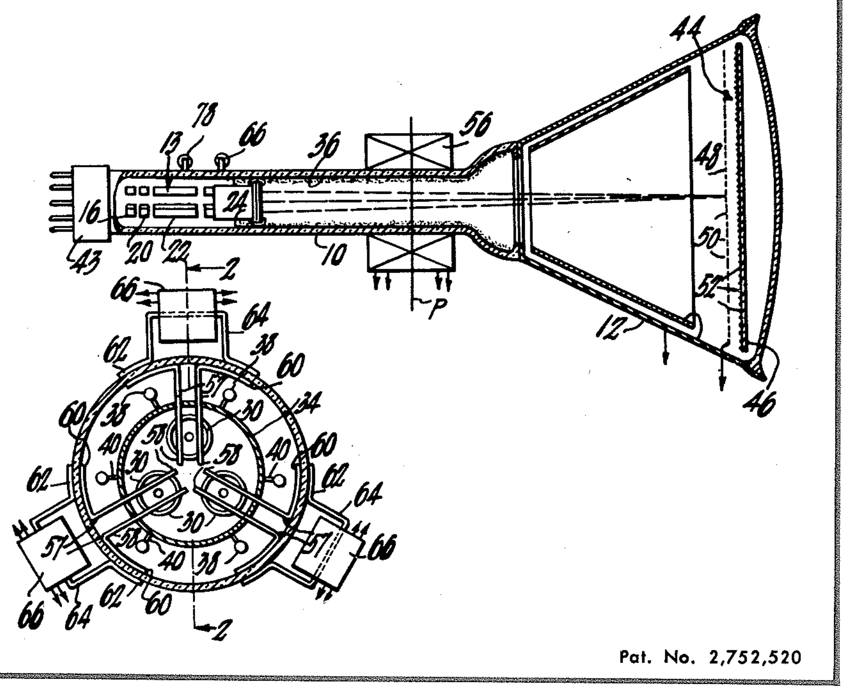
Pat. No. 2,743,150

POSITIONING AND STACKING DEVICE FOR ELONGATED ARTICLES (Patent No. 2,752,743)—granted July 3, 1956 to Robert Friedli, Jr., Tube Division, Harrison, N. J. In a machine for making cathode sleeves with integral tabs, a packaging device is provided for stacking the sleeves in compartments after ejection from the machine, with the tabs oriented in a common direction. The device includes a plurality of compartments and is movable across an ejection point on the machine for receiving cathode sleeves. Aligners swingably mounted across the compartments align the sleeves in stacks with the tabs disposed at one side of the stacks.



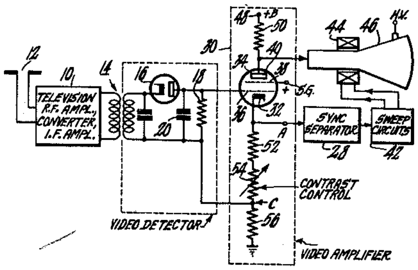
Pat. No. 2,752,743

TRI-COLOR KINESCOPE (Patent No. 2,752,520)—granted June 26, 1956 to Albert M. Morrell, Tube Division, Lancaster, N. J. The invention is in providing magnetic converging plates 57 mounted in the path of each electron beam of a plural beam gun structure used in a color television tube. Plates 57 are used to sustain a magnetic field therebetween which is established in each case by a magnetic coil 66 whose armature 64 is positioned adjacent to extensions 60 of the plates 57. Each magnetic field is of a polarity to direct its respective electron beam toward the gun axis. By adjusting the current through each coil 66, it is possible to bring all of the beams to a common point of convergence on the target 44.



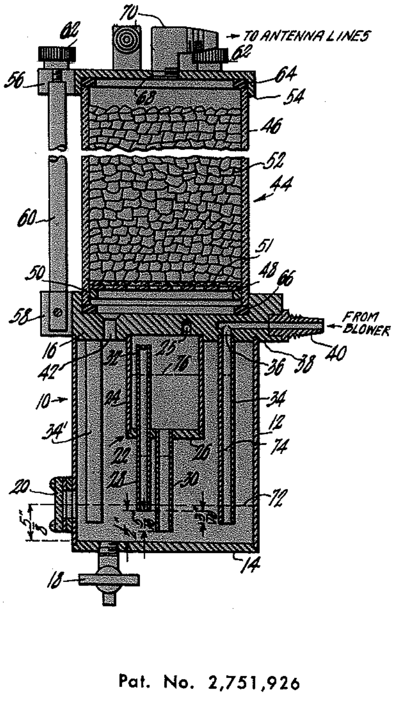
Pat. No. 2,752,520

AMPLIFIER GAIN CONTROL (Patent No. 2,752,431)—granted June 26, 1956 to Hunter C. Goodrich, RCA Victor Television Division, Cherry Hill, N. J. In order to feed a utilization circuit from the cathode of a video amplifier which has a cathode-resistor contrast control, invention includes an additional resistor connected between the variable resistor and ground. Signals are applied between the grid of the amplifier and the junction of the variable resistor and the added resistor. As the contrast control is varied, the signal at the cathode does not vary, since voltage changes across the variable resistor are compensated for by voltage across the added resistor.

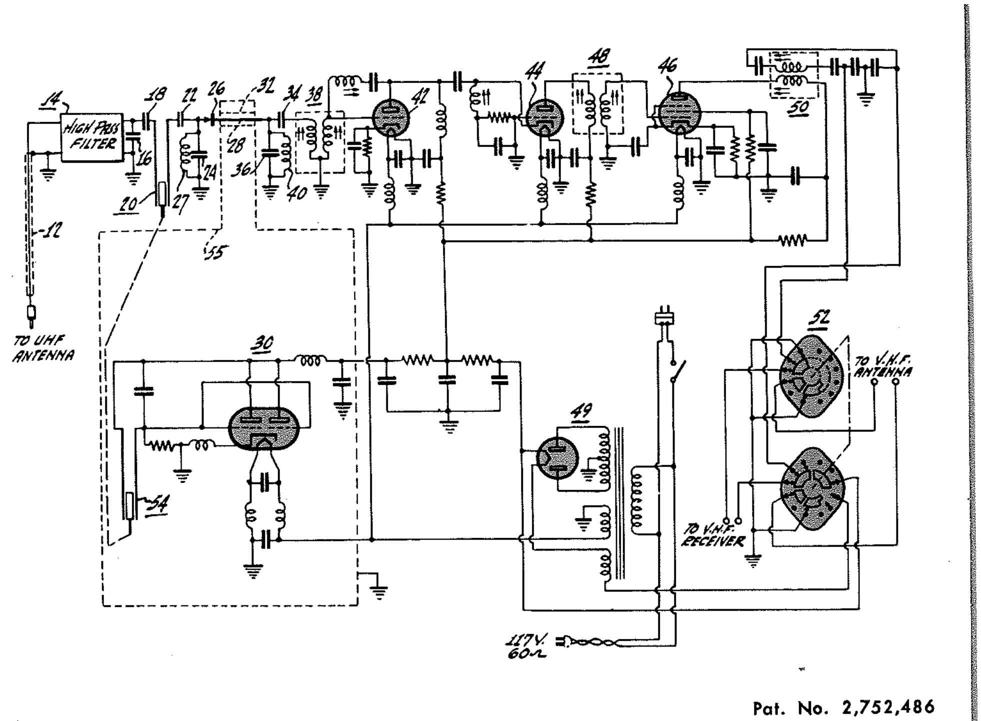


Pat. No. 2,752,431

LIQUID SEAL (Patent No. 2,751,926)—granted June 26, 1956 to John A. Liggett, Commercial Electronic Products, Camden, N. J. A primary chamber 10 has inlet passageways 34 and 34′, a relief passageway 28, and a reservoir passageway 30. The latter two passageways communicate with a reservoir chamber 22 having a vent 25. These passageways are liquid sealed, with the lower opening to the relief passageway 28 above the lower openings of the other. An outlet passageway 42 leads to the transmission lines to be pressurized through a desiccant. The small liquid head on the inlet passageways is readily overcome by low-pressure blowers. Excess pressure is relieved through relief passageways 28 without breaking seal. Whether none, or one or more, blowers is used, the inlet passageways remain sealed.



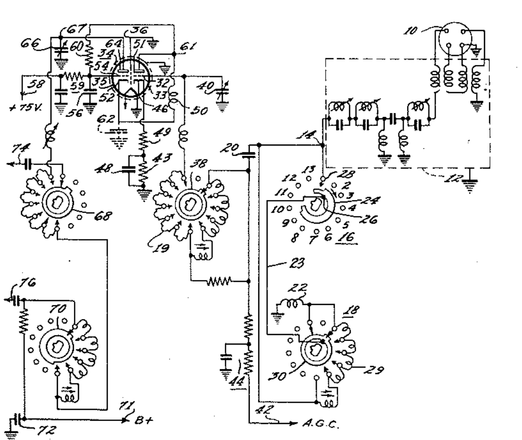
Pat. No. 2,751,926



Pat. No. 2,752,486

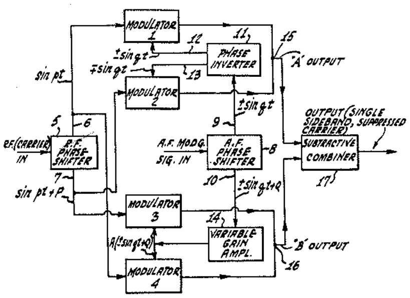
ULTRA HIGH FREQUENCY OSCILLATION INJECTION EQUALIZER (Patent No. 2,752,486)—granted June 26, 1956 to WEN Y. PAN and ROBERT D. FLOOD, RCA VICTOR TELEVISION DIVISION, Cherry Hill, N. J. The UHF converter includes a conductor positioned to intercept oscillator radiation. The coupling of the oscillator signal to the conductor is characterized by a sloping amplitude-frequency characteristic. To equalize the coupling of the oscillator signal to the conductor over a band of frequencies, a second coupling member is provided which partially surrounds the conductor. The second coupling member which has a cut away portion parallel to its longitudinal axis and a plurality of slots perpendicular to the axis has an amplitude frequency characteristic that is complementary to the first mentioned characteristic.

SERIES CONNECTED TOTEM-TRIODE AMPLIFIERS (Patent No. 2,750,450)—granted June 12, 1956 to JOHN C. ACHENBACH, and SIMEON I. TOURSHOU, RCA VICTOR TELEVISION DIVISION, Cherry Hill, N. J. For providing modified remote cut-off characteristics for optimum r-f amplifier operation of series-connected tubes without necessitating high AGC voltage or providing cross-modulation, a fixed bias circuit is arranged for the high voltage series tube comprising a voltage dividing network from B+ and including the low voltage series tube. Accordingly, tube impedance balance is maintained substantially constant and the remote cut-off characteristic is chosen by the proper voltage divider ratio.



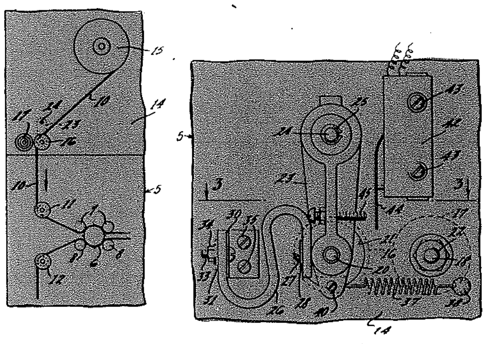
Pat. No. 2,750,450

SINGLE SIDEBAND GENERATOR (Patent No. 2,752,570)—granted June 26, 1956 to JAMES R. HALL, DEFENSE ELECTRONIC PRODUCTS, Camden, N. J. SSB generator of phase rotation type. Outputs of 4 modulators are added by pairs to provide 2 "paired" outputs. RF energy of zero phase applied to one modulator of each of 2 pairs, and quadrature RF energy applied to other modulator of each pair. AF of certain phase is applied in push-pull to first pair of modulators, and AF shifted in phase 90° applied through variable gain amplifier to second pair of modulators. First and second "paired" outputs combined subtractively to provide SSB signal.



Pat. No. 2,752,570

MECHANICAL FILTER (Patent No. 2,750,128)—granted June 12, 1956 to CARL E. HITTLE, COMMERCIAL ELECTRONIC PRODUCTS, Hollywood, Calif. In film transport systems, mechanical filters are used between film advancing sprockets and the supply and take-up reels to prevent load irregularities from being transferred to sound translation points and produce speed fluctuations at these points. This invention is such a mechanical filter having a spring attached to one side of an arm on which a film roller is mounted, and an "S"-shaped "Viscoloid" strip attached to the other side of said arm. The other end of the spring and the other end of the strip are anchored. The spring provides the resiliency of the filter and the strip the damping element thereof.



Pat. No. 2,750,128

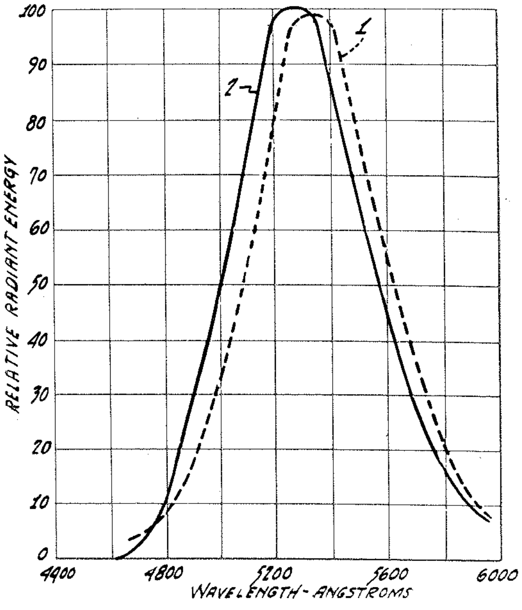
FLUORIDE PHOSPHORS (Patent No. 2,746,933)—granted May 22, 1956 to ARTHUR L. SMITH, TUBE DIVISION, Lancaster, Pa.

$x\text{CaF}_2 \cdot y\text{AlF}_2 : Z\text{Mn}$

$x + y = 1$ mole

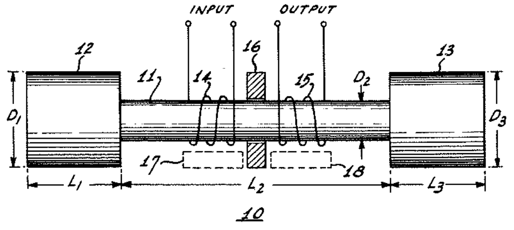
where: x is between 0.99 and 0.10 mole

z is between .001 and 0.1 mole



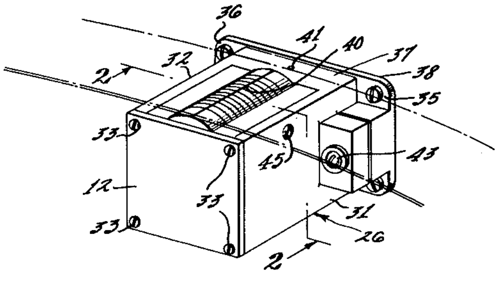
Pat. No. 2,746,933

ELECTROMECHANICAL RESONATOR (Patent No. 2,753,529)—granted July 3, 1956 to IRVING MARON and LESTER M. GLICKMAN, DEFENSE ELECTRONICS PRODUCTS, Camden, N. J. Conventional low frequency electromechanical resonators are of relatively large physical size. For example, a conventional resonator designed to operate in the torsional mode and to have a mid-band resonant frequency of 10 kilocycles, would be approximately 6 inches long. The invention provides a dumbbell-shaped resonator having dimensions determined by the desired frequency of operation. Input and output signals are applied and derived from the center or neck portion of the resonator. The dumbbell-shape permits the resonator to vibrate at relatively low frequencies and still have small dimensions. For example, a resonator having a mid band frequency of 10 kilocycles need be only 1 inch long.



Pat. No. 2,753,529

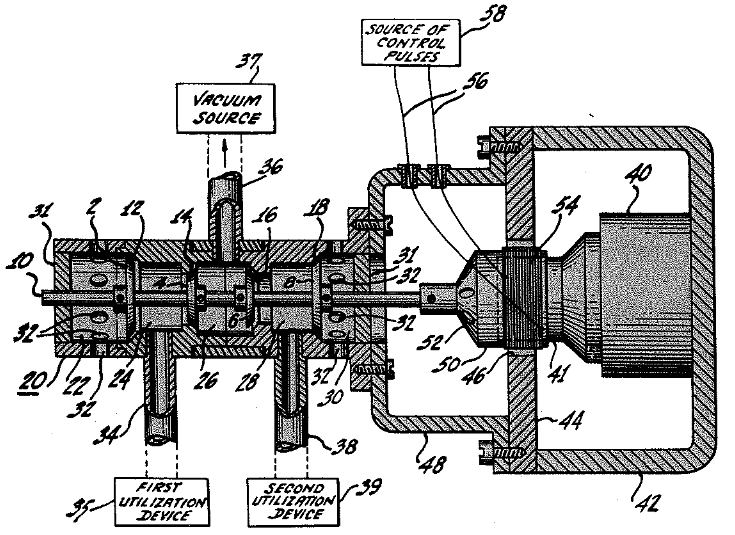
MULTIPLE MAGNETIC HEAD CONSTRUCTION (Patent No. 2,756,280)—granted July 24, 1956 to Michael Rettinger, Commercial Electronic Products, Hollywood, Calif. To provide a magnetic head assembly having several head units, a group of half head unit sections are aligned in a rack or frame and then plasticized with partitions between the half head sections to form a cluster. The pole faces of the half sections are simultaneously lapped to insure that the pole faces are in the same plane. Two opposing clusters are then positioned in an open-faced casting with spacers between the pole faces and then plasticized to provide a complete assembly.



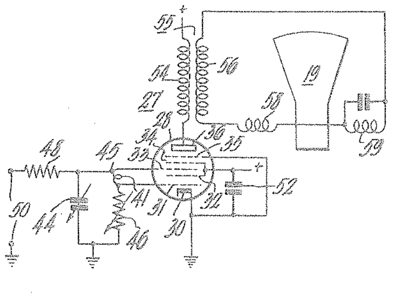
Pat. No. 2,756,280

SYNCHRONIZED SAWTOOTH WAVE GENERATING CIRCUITS (Patent No. 2,753,485)—granted July 3, 1956 to Richard W. Sonnenfeldt, RCA Victor Television Division, Cherry Hill, N. J. A blocking oscillator is constituted by a pentagrid converter tube having an inductor 41 connected between the control and injection electrodes to form a tuned circuit resonant at a high frequency of the order of 300 mc. A variable resistor and a variable capacitor have values at which the time constant is long compared to the resonant frequency of the tuned circuit. The oscillator will block in two modes of operation. In the first mode of operation the oscillations build up slowly and die out for a short time. In the other mode of operation the oscillations build up very rapidly to a given level, remain at that level for a short time and then die out for a relatively long interval. The mode of oscillation is controlled by the value of the resistor and the repetition rate is controlled by the capacity.

VALVE ACTUATING MECHANISM (Patent No. 2,750,961)—granted June 19, 1956 to Joseph M. Uritis, Defense Electronic Products, Camden, N. J. To provide a valve actuating mechanism for fast acting start-stop film or tape drive mechanism using vacuum film holding techniques, there is provided a valve assembly which is driven by an electrodynamic motor unit.



Pat. No. 2,750,961

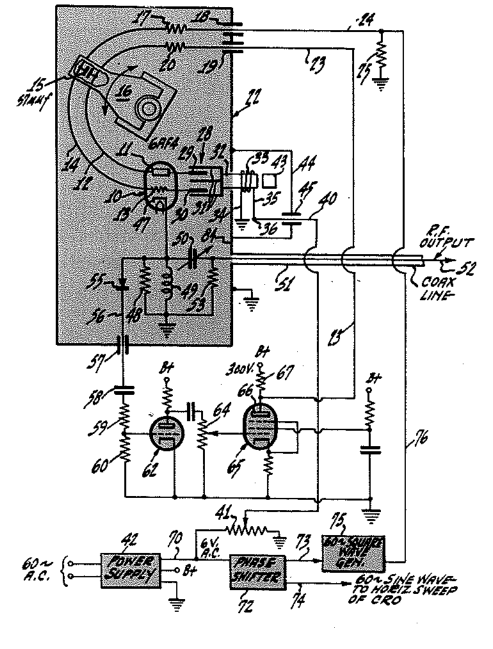


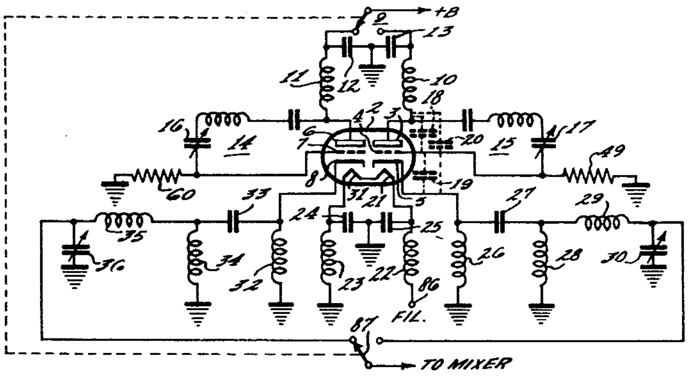
Pat. No. 2,753,485

METHOD OF MAKING NICKEL CARBON ALLOY SLEEVES (Patent No. 2,753,283)—granted July 3, 1956 to Stanton Umbreit, Tube Division, Harrison, N. J. After a nickel workpiece is shaped to sleeve form, it is heated in the presence of a carbon bearing atmosphere at a critical temperature and for a critical time to cause carbon from the atmosphere aforementioned to diffuse into the nickel without producing an objectionable outer coating of carbon. This method avoids loss of carbon during the shaping step.

ULTRAHIGH FREQUENCY SWEEP GENERATOR (Patent No. 2,752,499)—granted June 26, 1956 to Horace F. Hanthorn, Electronic Components, Camden, N. J. An ultra-high frequency sweep generator which may be tuned to a center frequency anywhere in the range between 300 and 1000 mc. by means of a sliding shorting capacitor 15. A vibrator actuates a capacitor 28 to cause the oscillator frequency to sweep sinusoidally about the center frequency. A leveler circuit including tubes 62 and 65 maintains the output at a substantially constant amplitude.

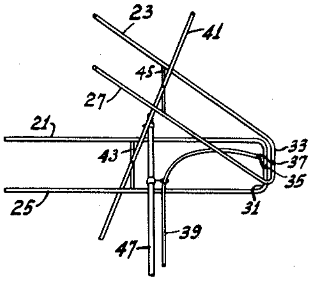
Pat. No. 2,752,499





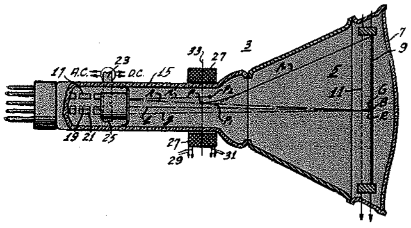
Pat. No. 2,753,456

TUNABLE OSCILLATOR CIRCUITS (Patent No. 2,753,456)—granted July 3, 1956 to Wen Y. Pan and David J. Carlson, RCA Victor Television Division, Cherry Hill, N. J. In UHF oscillators it has been found to be impractical to switch high impedance oscillator tuning circuits due to the shunt capacity variations of the switches. The oscillator of the invention includes a cathode output circuit which is at a low impedance level so that the shunt capacity variations of the switch are less significant. The cathode output circuit is tuned to a harmonic of the oscillator fundamental frequency and thus permitting the oscillator to operate at a lower fundamental frequency.



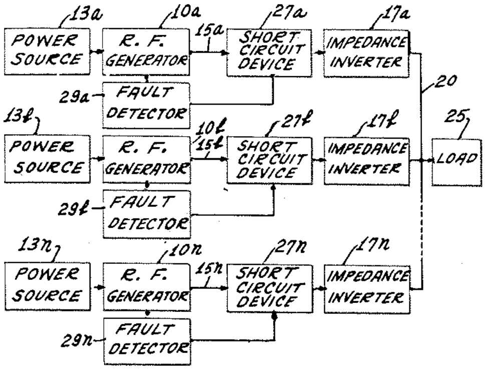
Pat. No. 2,756,420

MULTI-BAND ANTENNA (Patent No. 2,756,420)—granted on July 24, 1956 to Robert F. Kolar, RCA Victor Television Division, and John D. Callaghan, RCA Service Company, Cherry Hill, N. J. An antenna in accordance with the invention comprises two vertically stacked long wire V antennas with a dipole located between the two V's and electrically connected thereto by conductive connecting elements. An antenna in accordance with the invention is compact, simple, and mechanically stable, and may be used for receiving very high and ultra-high frequency signals.



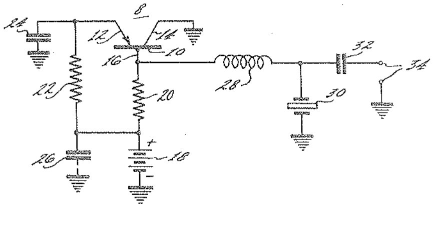
Pat. No. 2,755,402

COLOR KINESCOPES OF THE MASKED TARGET DOT-SCREEN VARIETY (Patent No. 2,755,402)—granted July 17, 1956 to Albert M. Morrell, Tube Division, Lancaster, Pa. In this screen-unit the dot-like apertures in the mask decrease in diameter as measured outwardly from the center of the screen-unit. Thus, the relatively small electron-jets near the edge of the unit can strike the relatively larger phosphor-dots off-center without infringing upon a dot of a different color.



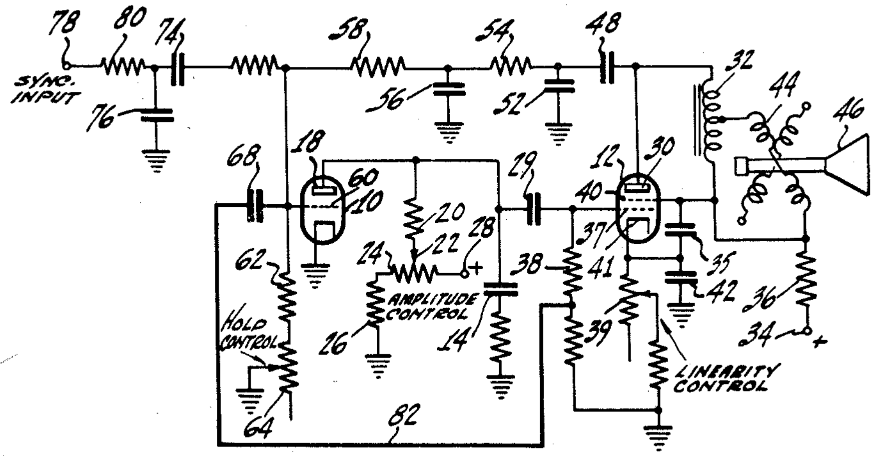
Pat. No. 2,753,454

ELECTRONIC CIRCUIT PROTECTION SYSTEMS (Patent No. 2,753,454)—granted July 3, 1956 to William N. Parker, Tube Division, Lancaster, Pa. The invention provides a protective system for a plurality of RF power sources which supply energy to a common load over a transmission line. A short circuiting device is connected across the transmission line between the power sources and the load, and is located in an odd number of quarter wavelengths from the load. The short circuiting device is operated in response to a fault in any one of the power sources, thereby preventing power in the load from flowing back thru the transmission line to the faulty power source. The impedance inverting characteristic of the quarter wavelengths spacing transforms the short circuit into an open circuit at the load, thus minimizing the effect of the short circuit on the load.



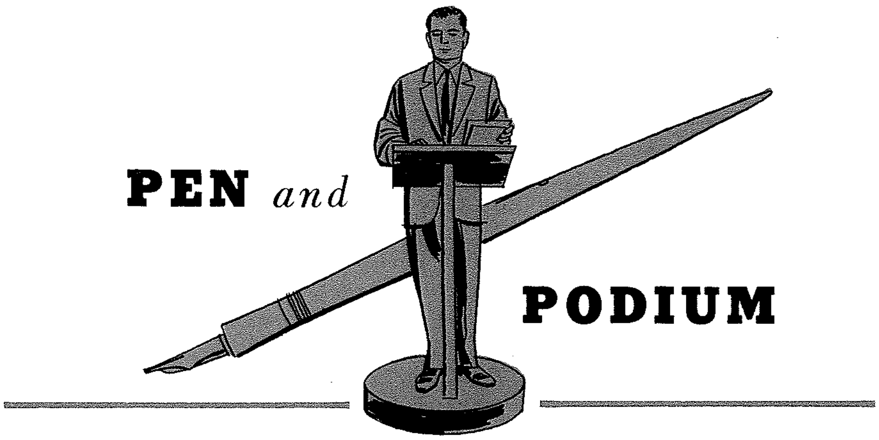
Pat. No. 2,751,498

CRYSTAL CONTROLLED OSCILLATOR CIRCUIT (Patent No. 2,751,498)—granted June 19, 1956 to Max E. Malchow, Commercial Electronic Products, Camden, N. J. In conventional transistor crystal controlled oscillators there is a tendency for the crystal to lose control of the oscillations. This drawback is overcome by this invention by connecting an impedance element (inductor) and the crystal between the base and ground of a current multiplication type transistor.



Pat. No. 2,729,766

ELECTRONIC OSCILLATOR CIRCUITS (Patent No. 2,729,766)—granted January 3, 1956 to B. Vilkomerson, RCA Victor Television, Division, Cherry Hill, N. J. In the vertical deflection circuit of television receivers, a controllable frequency multivibrator or blocking oscillator is used as a source of deflection signal. In prior art, rapid change of vertical "Hold" control causes oscillation to collapse. By using a degenerative feedback loop around oscillator, the tendency for collapse is greatly reduced.



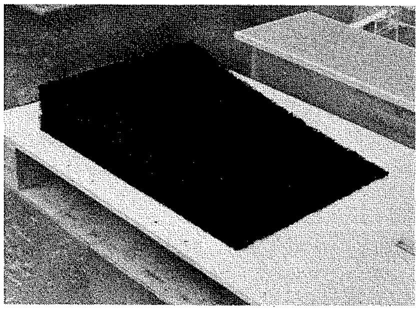
PEN *and* PODIUM

Based On Reports Received Over a Period of About Two Months

APPLICATION OF HF DRIFT TRANSISTORS IN RADIO RECEIVERS . . . By L. M. Krugman, RCA Radio and Victrola Division, Cherry Hill, N. J. Presented on October 23, 1956 in Washington, Pa. for the Canonsburg test and production engineers. The paper outlined the development of the transistor from the basic junction to the present RCA 2N247 drift unit. The characteristics and theory of operation of the conventional junction were reviewed and extended to cover tetrode, surface barrier, intrinsic, and drift types. Equivalent circuits and typical values of the hybrid pi parameters were discussed. The transistor figure of merit, the maximum frequency of oscillation was related to the geometrical and electrical device properties in terms of the base lead resistance, collector capacitance, and transit time. Intrinsic and extrinsic factors effecting transistor stability in typical high frequency circuits were also considered.

A BISTABLE SYMMETRICAL SWITCHING CIRCUIT . . . By T. P. Bothwell and L. Kolodin, Defense Electronic Products, Camden, N. J. Presented on October 2 at the National Electronics Conference, Chicago. The principal shortcomings of high-speed bistable transistor circuits have been their limited power output relative to standby power, unsymmetrical rise and fall times, and design complexity. The availability of high-speed complementary transistors has made possible a circuit employing two complementary pairs of transistors which are capable of delivering a load power greater than standby power. Since minimum requirements are placed on the transistor, practically any available high-frequency transistor can be used. An Analysis of the transient and static circuit characteristics are given and a design for computer application is carried out.

MINIMIZING THE EFFECTS OF AMBIENT LIGHT ON IMAGE REPRODUCTION . . . By G. L. Beers, Product Engineering, Camden, N. J. Presented at SMPTE Convention, October 7-12, Los Angeles, California. One of the important factors in determining the quality of either a television or motion-picture image is the ambient light to which the image is subjected and the effect of this light on the reproduced picture. Some of the means which have been employed to minimize the effects of ambient light on picture reproduction are discussed. A method has been developed which under favorable conditions has produced startling results in permitting the reproduction of both television and motion-picture images under adverse ambient-light conditions. The paper describes this method and gives experimental data illustrating its effectiveness under typical conditions. Some of its limitations are indicated. A demonstration was given showing the application of the method to the reproduction of motion pictures.



Radio Frequency Absorber—Kolar

RADIO FREQUENCY ABSORBER FOR FREQUENCIES ABOVE 50 MC. . . . By R. F. Kolar, RCA Victor Television Division, Cherry Hill, N. J. Presented on October 1, 1956 at the National Electronics Conference held in Chicago. The need for an anechoic chamber which is useful at radio frequencies as low as 50 mc has become acute. To design such a room, it was necessary to develop a wall-lining material which is effective at all frequencies above 50 mc. Methods for evaluating the material and the sources of error which were encountered are discussed.

MEASUREMENT OF ELECTRON-TUBE CHARACTERISTICS . . . By John M. Lowery, Tube Division, Camden, N. J. Presented at National Electronics Conference, Chicago, Ill., October 1-3, 1956. Because the characteristics of individual tubes differ to some degree from average published values, the circuit-design engineer must determine the effect upon equipment performance. The tube-performance factor of continued equipment reliability can only be established when tube characteristics are measured with an instrument similar to that used by the original design engineer. This paper reviews tube parameters of voltage amplifiers, power amplifiers, and diodes, and describes an instrument which has sufficient versatility to obtain the required information.

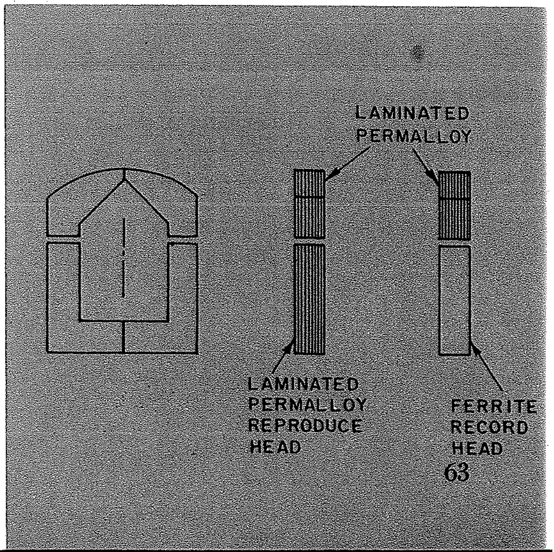
TECHNIQUES FOR MAKING DEVELOPMENTAL RECEIVING-TUBE PARTS . . . By H. J. Ackerman, L. J. Caprarola, and G. C. Walther, Tube Division, Harrison, N. J. Presented at the 3rd National Conference on Tube Techniques, New York City, September 12-14, 1956. The fabrication of developmental receiving tubes requires an engineering activity which devises techniques applicable to the rapid production of small quantities of quality parts. This paper describes how tube components such as mica spacers, grids, heaters, and other metal parts are produced by means of simple and flexible tooling and techniques.

MAGNETIZING CURRENT IN PULSE TRANSFORMERS . . . By T. Douma, Defense Electronic Products, Moorestown, N. J. Presented on October 3 at the National Electronics Conference, Chicago, Ill. This paper discusses the effect of magnetizing current in pulse transformers both during the pulse and in the interpulse interval. During the pulse the magnetizing current causes finite rise time and droop. A circuit is described which eliminates the droop. In the interpulse interval the magnetizing current may cause the switch tube (in line type pulsers) to go into continuous conduction especially at high duty cycles. A circuit is described which prevents this trouble.

SURFACES FOR HIGH-VOLTAGE VACUUM-TUBE RECTIFIERS . . . By J. J. Carrona, Tube Division, Harrison, N. J. Presented at the 3rd National Conference on Tube Techniques, New York City, September 12-14, 1956. This paper compares the arcing and reverse-emission characteristics of various surfaces commonly found in electron tubes, specifically rectifiers. In the evaluation of these surfaces, field-emission curves were recorded at increasing potential, and the breakdown voltage was observed. The performance of several of these surface finishes was further evaluated by actual production use in type 3B2 half-wave vacuum rectifier.

REPLACEABLE POLE TIP CAPS FOR CINEMASCOPE MAGNETIC REPRODUCE HEADS . . . By M. Rettinger, Commercial Electronic Products, Hollywood, Calif. Presented on October 8-12 at the SMPTE Fall Convention, Los Angeles, Calif. Ring-type magnetic recording and reproducing heads are contacted by the abrasive medium, and hence their useful life is shortened by a wear process. The subject replaceable pole tip cap consists of a pair of brass holders in which the laminated tips of the cores are

Replaceable Pole Tips—Rettinger



plasticized. The cap is fastened to the main housing assembly by means of two 1-72 screws, and locating pins are employed to assure correct azimuth on the part of the precision-aligned pole cap. When the cores of a cap are worn, the cap is removed by unfastening the two mounting screws and detaching the cap, after which a new cap may be substituted. For reproduce heads, the tips as well as the cores are made of laminated Permalloy. For recording heads, in order to lower bias current requirements, the tips are made of laminated Permalloy and the cores of solid Ferrite.

APPLICATIONS OF POWER TRANSISTORS TO AUDIO OUTPUT STAGES . . . By Robert Minton, Semiconductor Division, Somerville, N. J. Presented at the IRE/RETMA Radio Fall Meeting, Syracuse, N. Y., October 17, 1956. This paper presents design considerations for the application of alloy-junction p-n-p power transistors to audio-frequency output stages. Optimum transistor operating conditions are given for practical circuit designs. Both class A single-ended and class B push-pull power-output stages are evaluated, and the effects of variations in source and load impedances are discussed. Methods of obtaining the desired stability of dc bias with variation in ambient temperature are described. Over-all performance is evaluated with respect to power gain, distortion, efficiency, and frequency response. The variety of circuit aspects described should be useful to engineers engaged in the design of transistor audio systems requiring relatively high power output.

HIGH-RESOLUTION FLYING-SPOT SCANNER FOR GRAPHIC ARTS COLOR APPLICATIONS . . . By L. Shapiro and H. E. Haynes, Commercial Electronic Products, Camden, N. J. Published in the RCA REVIEW, September, 1956. There is described a high-resolution, slow-speed scanning and reproducing system developed to serve as input and output devices for an electronic computer which provides color correction in the production of half-tone plates for color printing. In addition to its extremely high resolving power, this system is notable for low image distortion, extreme time stability both geometrically and sensitometrically, uniformity of characteristics in different parts of the field, and precise control of tone rendition. Employing a special 10-inch kinescope, the scanner portion derives input information for the computer by simultaneously scanning three precisely registered color separation plates, requiring 12 minutes for a frame scan. Four images representing the required printing ink tone values (cyan, magenta, yellow, and black) are sequentially recorded photographically from a second identical kinescope. Over-all performance is such that on full-page pictures, prevailing requirements in high-quality magazine printing applications are satisfied. This paper deals with the scanner and recorder, and includes a description of the equipment and some of the development problems encountered. The system as a whole, and particularly the computer, has been reported elsewhere.

A TRANSISTORIZED SEVEN - POSITION PORTABLE MIXER . . . By Kurt Singer, Commercial Electronic Products, Hollywood, Calif. Presented at SMPTE Convention, October 7-12, Los Angeles, Cal. This paper deals with the description of a seven-position portable mixer, which has been transitorized throughout. Its electrical facilities and mechanical construction were described fully. A detailed circuit description of the individual transitorized amplifiers, together with explanation of constructional features, were also given. Excellent stability, low distortion and a very good signal-to-noise ratio have been obtained in this equipment.

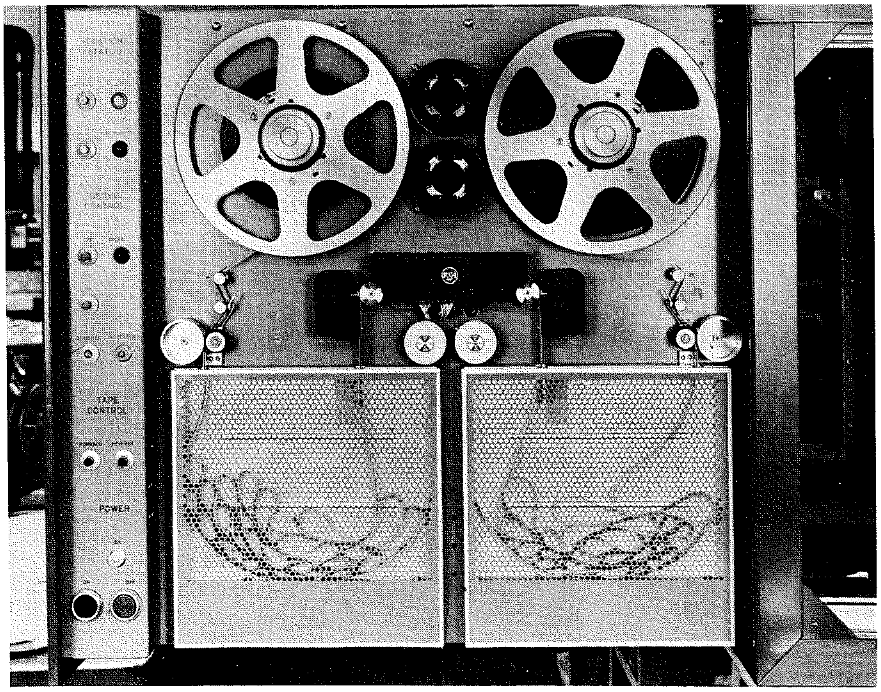
TROPOSPHERIC SCATTER PROPAGATION—A MODERN METHOD OF RADIO TRANSMISSION . . . By E. A. Laport, Administrative Engineer, Communications, Radio Corp. of America, New York. Presented at the Armed Forces Communication & Electronics Association on September 27, 1956. The prevailing theory of tropospheric forward scatter propagation is described and its recent uses in practical systems outlined. The results of recent systematic measurements to determine scatter losses as dependent on frequency, distance, climate, antenna size and bandwidth were presented. The basic differences in frequency modulation and single-sideband techniques for communication systems using this mode of propagation were discussed.

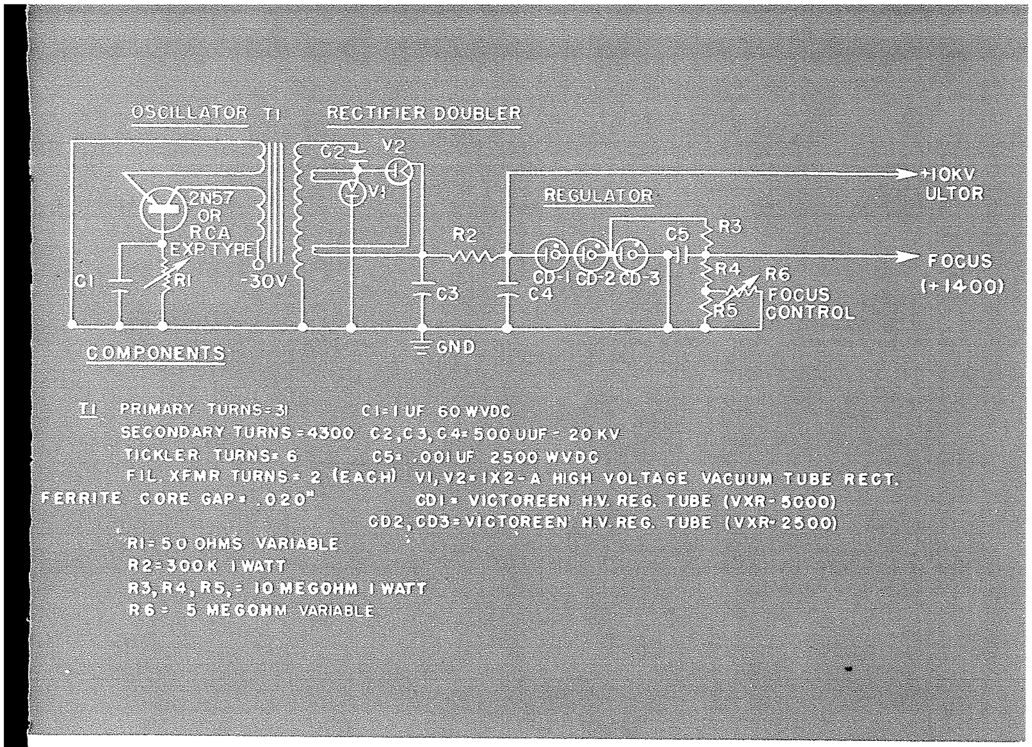
CONTROL PHILOSOPHY IN THE DESIGN OF THE RCA BIZMAC TAPEFILE . . . By R. E. Montijo, Commercial Electronic Products, Camden, N. J. Presented at the National Electronics Conference on October 1, 1956. In the RCA Bizmac System, the Tapefile is the basic data storage unit. The Tapefile is utilized as external storage in computing and sorting operations, in high-speed input and output operations where required, and for long-term reference storage. The RCA Bizmac System concept provides for the use of a large number of Tape Stations in a flexible, integrated system. These Tape Stations are semi-automatically switched between the various using equipments from a remote control point in accordance with a system schedule. It is obvious, then, that function control and accuracy of the Tapefile is an important feature of such a system. This paper presented the control philosophy of the Tapefile together with the operating procedures necessary in the remote operation of this data storage equipment. In addition, the need for various accuracy control features was discussed.

FIELDS IN IMPERFECT ELECTROMAGNETIC ANECHOIC CHAMBERS . . . By Robert F. Kolar, RCA Victor Television Division, Cherry Hill, N. J. Published in the RCA REVIEW, September 1956. The performance of an electromagnetic anechoic chamber can be predicted from the results of transmission line measurements on small samples of the wall absorbing material. Since the calculation of the field within a room is a near-field problem the customary Fraunhofer or Fresnel approximations of Kirchhoff's equation cannot be used. However, the problem can be solved fairly accurately if the room is sufficiently large. The calculations have been checked by measurements made in front of a twelve-foot-square wall covered with the absorbing material and with an aluminum sheet.

IMAGE ORTHICON FOR PICKUP AT LOW LIGHT LEVELS . . . By A. A. Rotow, RCA Tube Division, Lancaster, Pa. Published in the RCA REVIEW, September, 1956. The performance of standard image orthicons at low light levels is limited by noise and time lag. It is shown that signal-to-noise ratio is a direct function, and time lag an inverse function, of the beam modulation, i.e., the ratio of signal current to beam current. It is also shown that the beam modulation may be increased by an increase in the spacing between the glass target and mesh screen. An image orthicon incorporating relatively large target-to-mesh spacing has been designed. In this tube, which is usable at light levels as low at 10^{-4} foot-lambert, noise and time lag have been substantially reduced

Control Philosophy—Montijo





CRT Power Supply—Toscano & Heffner

by the use of a target-to-mesh-screen spacing of 0.150 inch.

A NEW DEVICE FOR TRANSISTOR STABIBILIZATION . . . By C. F. Wheatley and R. E. Kleppinger, Semiconductor Division, Somerville, New Jersey. Presented at the IRE/RETMA Radio Fall Meeting, Syracuse, N. Y., October 17, 1956. This paper describes a biasing network which can be used to stabilize transistor operating currents under conditions of varying ambient temperatures and supply voltages. In class B and high-power class A applications, this instability results in distortion at low temperatures or decreased supply voltages. It may cause permanent transistor damage due to "thermal runaway" at high temperatures or increased supply voltages. Experience indicates that current variations are due primarily to the transistor voltage-current transfer characteristic and that collector current at zero emitter voltage contributes a secondary effect. Methods of controlling variations by means of a biasing network (sensitive to temperature but insensitive to voltage) are discussed. When diode biasing is used instead of conventional resistive biasing, the stability is improved a hundredfold with respect to temperature variations and tenfold with respect to voltage variations. Circuits using diode biasing are considered.

EFFECTS OF THE EARTH'S MAGNETIC FIELD ON COLOR PURITY IN THE SHADOW-MASK COLOR KINESCOPE . . . By H. N. Hillegass and J. L. Hudson, Tube Division, Lancaster, Pa. Presented at the IRE/RETMA Radio Fall Meeting, Syracuse, N. Y., October 17, 1956. The nature and extent of misregister due to the action of the earth's magnetic field depends upon the nature of the field within the vicinity of the tube, the orientation of the field with respect to the tube, and the mode of tube operation. If this field is uniform (less than approximately 1 gauss), and oriented in a known direction, the misregister patterns produced on the screen may be predicted with reasonable accuracy. The observation of various effects of the earth's magnetic field on the operation of the RCA-21AXP22 color kinescope are discussed. A purity magnet and a magnetic-field equalizer which are used with the 21AXP22 to compensate for misregister caused by the earth's magnetic field are described.

ON OPTIMUM NONLINEAR EXTRACTION AND CODING FILTERS . . . By A. V. Balakrishnan and R. F. Drenick, Defense Electronic Products, Camden, N. J. Presented at the Information Theory Symposium, Boston, in September, 1956. Also published in the Proceedings of the Symposium. The paper consists of two parts. In the first part, optimal methods are established for the extraction of a certain non-Gaussian signal from another, or from noise. It is shown that the resulting extraction filter is nonlinear and it is obtained in a form in which its realization in terms of passive devices is apparent. The second part of the paper deals with the problem of how to impart a desired non-Gaussian characteristic to a signal. The ideas are illustrated by a hypothetical application, namely, the simultaneous transmission of two signals of the same frequency band.

TELECOMMUNICATIONS GROWTH IN VARIOUS COUNTRIES OF THE WORLD . . . By E. A. Laport, Administrative Engineer, Communications, Radio Corp. of America, New York. Presented on September 13-14 at the IRE Mid-West Conference on Communications, Cedar Rapids, Iowa. The status of telecommunications varies greatly from country to country depending on the state of economic development. Typical situations were discussed by regions from the least developed to the most advanced, and their needs outlined. The increasingly important role of radio in telecommunications within various countries was emphasized for various classes of service. The work of the International Radio Consultative Committee and the International Telephone Consultative Committee of the International Telecommunications Union was mentioned together with their influence on equipment characteristics and cooperative regional projects.

CAMERA TUBES USED IN COLOR-TELEVISION BROADCAST SERVICE . . . By R. G. Neuhauser, Tube Division, Lancaster, Pa. Presented at the SMPTE Convention, Los Angeles, Calif., October 8-12, 1956. A brief review was given of tubes currently used in television camera systems and of those found basically unsuitable for color camera work. General requirements of tubes for color-television pickup were discussed, and basic performance characteristics that limit the pickup field to several tubes for color television were evaluated. The performance characteristics of vidicons and image orthicons now used are compared with the required characteristics. Quality problems in color pickup and answers to these problems were discussed.

CRT POWER SUPPLY USES TRANSISTOR OSCILLATOR . . . By P. M. Toscano and J. B. Heffner, Defense Electronic Products, Camden, New Jersey. Published in the September issue of ELECTRONICS. High-voltage power supply uses 12.5-kc oscillator with positive-feedback tickler. Output voltage is doubled, rectified and held to 10 kv by three series corona-discharge tubes. Filament voltage for two electron-tube rectifiers is obtained from transistor oscillator coil. Only external power required is negative 30-v collector supply. Unit supplies high voltage for monitor picture tube in a television repeater.

VACUUM MELTING OF FILAMENTARY-CATHODE ALLOYS FOR ELECTRON-TUBE USE . . . By C. W. Horsting, Tube Division, Harrison, New Jersey. Presented at the 3rd National Conference on Tube Techniques, New York City, September 12-14, 1956. Composition of the base metal of an oxide-coated cathode is a major factor which determines quality and behavior of an electron tube during its manufacture and life. A vacuum-melting procedure contributing greatly to the composition control of alloys used for filamentary-type oxide-coated cathodes is described.

TRANSISTORIZED MARKER BEACON RECEIVER . . . By R. G. Erdmann, Defense Electronic Products, Camden, N. J. Presented on October 27-29, 1956 at the East Coast Conference for Aeronautical Electronics, Baltimore, Maryland. This paper describes the development of an all transistorized marker beacon receiver for use as an airborne navigational aid. It gives performance equal to or superior than most preceding tube models. A three-light adapter unit has been developed for use with the one light system and is described in the paper. A complete three light system (receiver plus adapter unit which consumes only about 1½ watts of power) is also discussed.

THE PRESENT STATUS OF TRANSISTOR APPLICATIONS . . . By D. B. Kret, Defense Electronic Products, Camden, N. J. Presented at the Radio Fall Meeting of RETMA/IRE, Syracuse, New York, on October 15, 1956. This paper serves as a review of the present application of Semiconductor devices with respect to many related factors. Economy, reliability, size and weight, ruggedness, availability and suitability are discussed and comparisons are made between tubes and transistors.

SPECIFIC COOLING RATES OF PLATE MATERIALS IN VACUUM . . . By C. W. Horsting, I. S. Solet, and T. A. Sternberg, Tube Division, Harrison, New Jersey, and P. Avakian, Massachusetts Institute of Technology, Cambridge, Mass. Presented at the 3rd National Conference on Tube Techniques, New York City, September 12-14, 1956. This paper describes a cooling-curve method which has been developed for the determination of the specific cooling rates of several materials used for anodes or plates in electron tubes. In this method, a cylindrical sample of the material is permitted to cool in vacuum while the temperature is automatically recorded as a function of time. Materials tested include iron, steel, nickel, and both clear and carbonized nickel-coated steel.

PROPAGATION TEST ON 955.5 MC, 1956 MC and 6700 MC . . . By H. R. Mathwich, Commercial Electronic Products, Camden, N. J., E. D. Nuttall and A. M. Randolph, United Gas Corp., J. E. Pitman, Philco Corp. Presented on October 4, 1956 at the Fall General Meeting of the AIEE, Chicago, Ill. This paper gives the results of a microwave propagation test run in the Gulf South area. Propagatino at three frequencies as mentioned in the title was measured for 16 months over a 20 mile path. The results include the basic loss statistics of the three frequencies, seasonal and divisional propagation patterns and outage time distribution curves. The test shows the effect upon propagation of grazing clearance in a microwave path.

PRODUCTION TESTING IN THE AUTOMATIC FACTORY . . . By H. S. Dordick, Defense Electronic Products, Camden, N. J. Presented on September 24, 1956 at the Fifth Annual Industrial Electronics Symposium, Cleveland, Ohio. Progress in the mechanization of production testing of electronic products is reviewed. Several test equipments are described and evaluated. The necessity for considering the quality monitoring function of production as a continuous and integrated system is emphasized. This approach enables the test process planner to utilize the powerful tools of operations research in determining the nature of the test equipment and procedures required for optimum operation. A test system for the automatic factory is described. This system calls for the more efficient use of statistical sampling techniques as well as the more efficient feedback of test data. Within the framework of this system, new requirements on test equipment have been developed and several equipments are described which fit into this new concept. In addition, product design for automatic testing and the specification of product reliability as an aid in preparing test procedures are discussed. Finally the activities of an industry-wide RETMA Test Group on Standards for Product Testing in Mechanized Production is described.

ENGINEERS AND MUSIC . . . By C. H. Chandler, Defense Electronic Products, Camden, N. J. Published in the September-October, 1956 IRE Transactions on Audio, Vol. AU 4, No. 5. Engineers working in the field of audio may find themselves at a serious disadvantage because of a lack of musical knowledge. The acquisition of such knowledge can increase their professional prestige, improve the quality of their work, and open new horizons for personal enjoyment. The author of this paper, a musician of varied experience as well as an engineer, tells how a background in music is useful and not very hard to obtain.

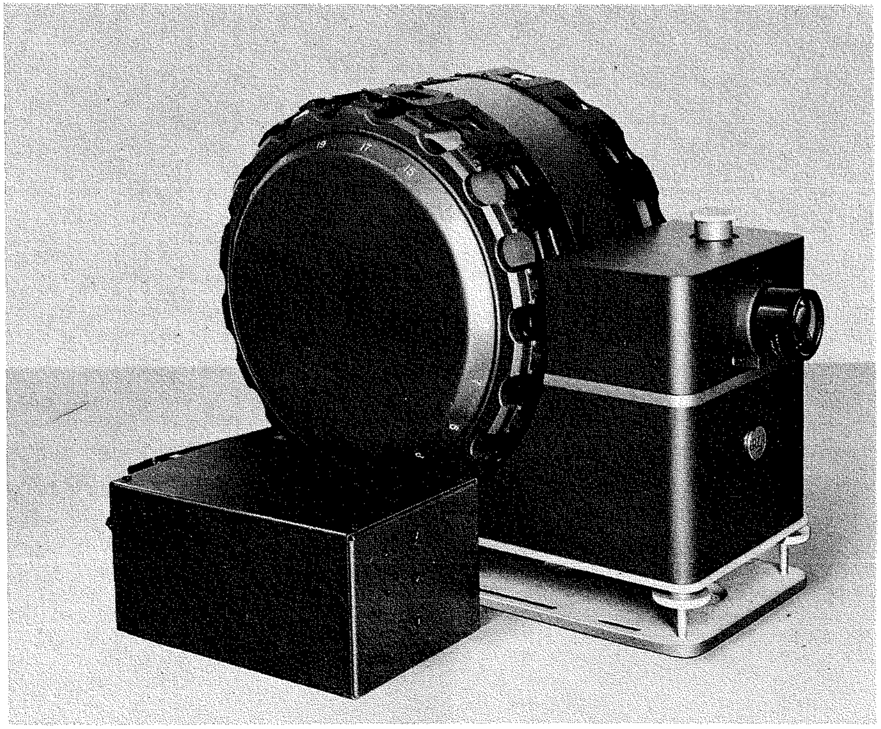
DETERMINATION OF TRANSISTOR PERFORMANCE CHARACTERISTICS AT VHF . . . by G. E. Theriault and H. M. Wasson, RCA Victor Television Division, Cherry Hill, N. J. Presented on October 16, 1956 at the RETMA Radio Fall Meeting, Syracuse, N. Y. Useful power gain, noise factor, and other important performance characteristics of an electronic device can be secured only with measuring equipment properly employed. At present, it is difficult to evaluate characteristics of transistors in the VHF band, and this paper describes how special impedance matching transformers are utilized to advantage in evaluating VHF transistors. It is found that the essential performance characteristics of the later types of transistors used as i-f and r-f amplifiers in TV Receivers are nearly comparable to those of conventional vacuum tubes.

PULSE RESPONSE COMPUTATION . . . By D. R. Crosby, Commercial Electronic Products, Camden, N. J. Presented on October 3rd at the National Electronic Conference, Chicago. The numerical computation of the pulse response of a linear network of some 14 elements is performed using three methods: Fourier Series, Cesaro Sum, Fourier Transform. When the pulse rise time is of major interest, the superiority of the finite Fourier Series is shown, while the superiority of the Cesaro Sum is demonstrated when the shape of the pulse top is of central concern. For comparable networks, when the services of a programmed digital computer are available, such numerical computations appear much simpler than a completely analytic approach.

TRANSISTORS IN MOTION PICTURE & TV By H. J. Woll, Defense Electronic Products, Camden, N. J. Presented on October 12, 1956 at the SMPTE Convention in Los Angeles. The present status of transistor audio and video equipment is outlined. Advantages are cited of transistor equipment over its vacuum tube counterpart. Features of low power drain, small size and weight, portability, better reliability, and circuit simplicity are illustrated, and trends in the transistorization of motion picture and television equipment are explored.

A 2" X 2" SLIDE PROJECTOR FOR COLOR TELEVISION FILM SYSTEMS . . . By R. D. Houck and A. E. Jackson, Commercial Electronic Products, Camden, N. J. Presented by Mr. Jackson on October 11, 1956 at the 80th SMPTE Convention, Los Angeles, Calif. Color television film system requirements for a slide projector are more rigid than those of a monochrome television film system. The slide projector described in this paper was designed to fulfill all color requirements and satisfy monochrome needs as defined by a survey of representative television stations. Slide capacity is more than doubled. Easily loaded drum type slide holders are used with dual slide channels. Internal optical multiplexing permits continuous slide programming. Color balance problems between slide channels are eliminated by the unique optical and multiplex systems. Evenness of slide illumination exceeds that of present projectors and light output meets all requirements for vidicon film camera systems.

2x2 Slide Projector for Color TV—Houck & Jackson



Engineering NEWS *and* HIGHLIGHTS

BARTON KREUZER ELECTED SMPTE PRESIDENT

Barton Kreuzer, Director of Product Planning, RCA, Camden, New Jersey, has been elected President of the Society of Motion Picture and Television Engineers for 1957-58. The results of the national SMPTE elections were revealed to those attending the 80th semiannual convention of the Society at the Hotel Ambassador in Los Angeles. Mr. Kreuzer will succeed John G. Frayne of Westrex Corporation.

Mr. Kreuzer joined RCA in 1928 and was concerned with electronic development work, film recording engineering, theatre field engineering and film recording licensee contacts. In 1935 he entered the commercial phase of RCA activities as head of film recording equipment sales for RCA's Eastern industrial licensees, and in 1937 conducted similar activities for Hollywood film recording sales, becoming National Sales Manager in 1941.

In 1943 Mr. Kreuzer was appointed Manager of RCA Theatre Equipment activities with headquarters at Camden. He also served as General Product Manager of the Engineering Product Division and Marketing Manager of the Theatre and Industrial Equipment Department before assuming his present position in 1954.

Mr. Kreuzer is a Fellow of the SMPTE. He is also a member of the IRE.

WYNKOOP ELECTED HEAD OF PROPELLER CLUB . . . Rear Admiral Thomas P. Wynkoop, Jr., U.S.N. (ret.), Vice President, Commercial Marine Distribution, RCA, was elected President of The Propeller Club of the United States at the organization's annual convention in New York October 12.

Admiral Wynkoop succeeds Colonel Raymond M. Hicks, Executive Vice-President of the United States Lines, who had served as President for the past two years.

The Propeller Club is an organization designed to promote, further and support an American Merchant Marine, and aid the development of river, Great Lakes and harbor improvements. The Club has a membership of some 12,000, organized in 126 local units throughout the United States and in foreign countries.

SMPTE HONORS DR. SCHADE . . . Dr. Otto H. Schade, Sr., Staff Engineer, Receiving Tube Engineering, Harrison, received an honorable mention from the SMPTE award committee for his paper "Image Analysis in Photographic & TV Systems" which appeared in the November 1955 issue of the Journal of the SMPTE.

NEW SCREEN PERMITS VIEWING OF TV AND MOTION PICTURES IN WELL-LIGHTED AREAS . . . Experimental development of a radically new type of picture screen that makes possible the viewing of television and motion pictures in artificially or naturally lighted areas was disclosed at the SMPTE Convention recently.

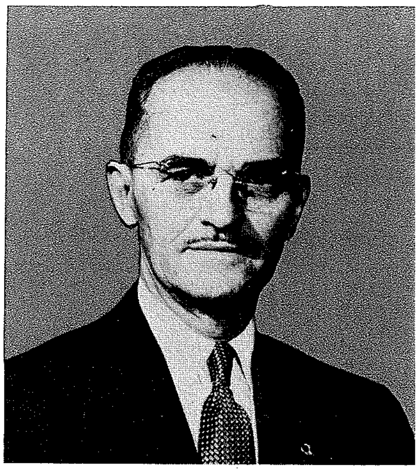
Dr. George L. Beers, Administrative Engineer, RCA Product Engineering, who developed the screen, described and demonstrated the development before the convention at Los Angeles.

This experimental RCA screen makes possible increases of up to 20-to-1 in picture contrast under adverse ambient light conditions, and has produced, in tests, startling results in the reproduction of both television and motion pictures.

RCA has not as yet established any commercial plans for the experimental screen, but numerous tests conducted in various locations under a variety of ambient light conditions indicate the screen's potential for presentation of TV and motion pictures in lighted schoolrooms, homes, showrooms, and theatres, and for special applications, such as observation of airborne and ground-based radarscopes.

The RCA development, known as a directional viewing device, is similar in structure to a honeycomb, consisting of a network of tiny, interconnecting cells. The device is fabricated with aluminum foil, .001-inch thin, and cell width, length, and depth can be varied to produce a range of viewing angles.

R. H. HEACOCK NAMED TO SMPTE POST

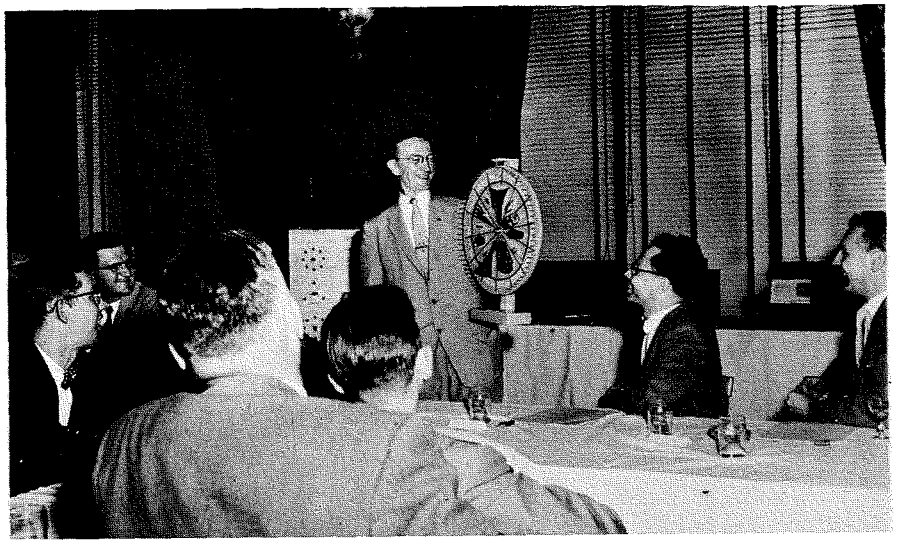


. . . Ralph H. Heacock, Product Manager of Theater Equipment, Radio Corporation of America, has been named chairman of the Projectionists Information Committee of the Society of Motion Picture and Television Engineers, it was announced by Dr. John G. Frayne, President of the Society. The Committee was organized to increase the information available to projectionists on motion picture projection techniques and to keep them abreast of new developments in the industry, Dr. Frayne stated at the 80th semiannual convention of the SMPTE at the Los Angeles Ambassador.

Mr. Heacock, who joined RCA in 1922, has been actively engaged in the development, design and manufacture of sound heads and theater projection equipment. He was chairman of the Film Projection Practice Committee of the SMPTE from 1952-55 and is still an active member of that group.

Dr. G. L. Beers demonstrating his screen in comparison with a standard movie screen.

WALLY JAMES HONORED AT HARRISON



Wallace M. James was honored for his long and intimate association with Receiving Tube Engineering at a dinner held at the Robert Treat Hotel in Newark, on August 28, 1956. Wally was formerly Manager of Receiving Tube Engineering, and has recently assumed new duties as Administrator of Product Engineering and Advanced Development on the Staff of the Tube Division's Chief Engineer, Dr. G. R. Shaw.

The dinner was attended by about 85 engineers from Receiving Tube Engineering, and featured a program of humorous gift presentations and skits, which was enthusiastically received by the group.

Mr. James received a B.S. degree in Electrical Engineering from the University of Kansas in 1925. He worked as a radio engineer with the General Electric Company at Schenectady from 1925 to 1930. He then came to RCA at Camden, and supervised a group working on vacuum tube application problems. In 1933 he transferred to the Tube Division in Harrison, and has held various administrative or managerial positions in the Engineering Department since that time. He is a Senior Member of the IRE, and in 1953 received the RCA Award of Merit.—*R. L. Klem*

LANCASTER ENGINEER WINS ARRL PRIZE

G. S. Gadbois, of the Chemical and Physical Laboratory at Lancaster was awarded the First Place Prize by the American Radio Relay League for having obtained the highest score in a recent national contest sponsored by the League. Points were accumulated on the basis of number of contacts achieved by a single radio operator in the maximum number of areas and in the maximum number of frequency bands. Mr. Gadbois set up his station atop Mt. Equinox in Vermont and obtained 301 total contacts in 44 areas and in the following four bands; 50 mc, 144 mc, 220 mc, and 432 mc.—*D. G. Garvin*

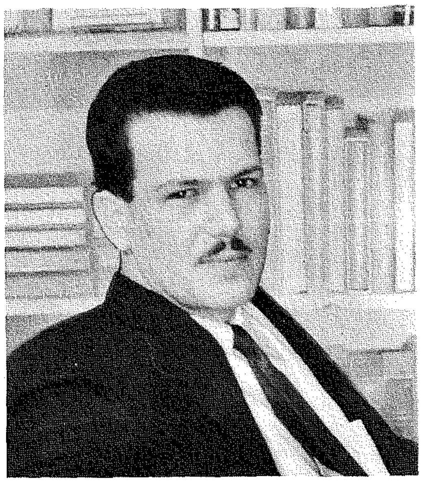
DR. BERG TOURS EUROPE

Dr. Morris Berg, Chemical and Physical Laboratory of Color Kinescope Operations of the Tube Division at Lancaster combined business with pleasure this summer while touring Europe on his honeymoon. He visited:

A. RCA Laboratories—Zurich, Switzerland
B. Brown Boveri & Co., Ltd.—Baden, Switzerland
C. Sudplastik und Keramik—Plochingen, Germany
D. English Electric Valve Co., Ltd., Research Labs., Stratford, England
E. British Thomson Houston Co., Ltd.—Rugby, England

During the visits Dr. Berg reviewed the latest techniques in glass-metal and ceramic-metal seals. On his return he presented a talk on the trip as part of the Engineering Lecture Series at Lancaster on August 30, 1956.—*D. G. Garvin*

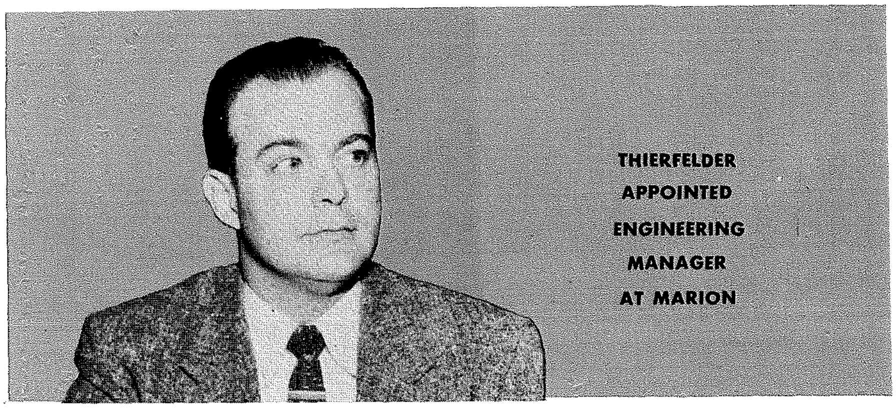
ENGINEER PUBLISHES BOOK OF POETRY



D. L. Roberts, Color Kinescope Development, Tube Division, Lancaster, is the author of a new book of verse titled TREMELO which was recently published by Exposition Press in New York.

TREMELO is a collection of verses with illustrations by the author and is a statement of 20 meditations. It is a first book for the author.

Mr. Roberts is a graduate of Millersville State Teachers College where he received his B.S. degree in 1950. He joined RCA at Lancaster in 1952.—*D. G. Garvin*



THIERFELDER APPOINTED ENGINEERING MANAGER AT MARION

C. W. Thierfelder, who was formerly Manager, Black and White Kinescope Design and Standardizing, has been named Manager, Black and White Kinescope Engineering.

Mr. Thierfelder received the degree of Bachelor of Science in Electrical Engineering from Oklahoma University in June, 1946. He started with the RCA at Lancaster in September, 1946, as a Design Engineer. In September, 1951, he received his M.S. degree in Physics from Franklin and Marshall College. He was recalled to active duty in the Navy from November, 1951 to December, 1953 after which he returned to RCA and was appointed Manager, Black and White Kinescope Design and Standardizing at Marion. He is a member of JETEC 6 (Joint Electron Tube Engineering Council Committee on Cathode Ray Tube Standardizing) and also the following honorary fraternities: Tau Beta Pi, Sigma Tau, Eta Kappa Nu, and Sigma Pi Sigma.

D. C. Ballard has been appointed Manager, Black and White Kinescope Design and Standardizing, replacing Mr. Thierfelder. He was formerly Supervisor of Standard Black and White Kinescope Design.

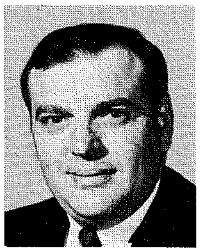
Mr. Ballard received his B.S. degree in Electrical Engineering in 1947 and his M.S. degree in 1948, both from the University of Kansas.

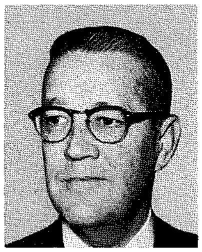
In December, 1948 he joined RCA in Lancaster as a Cathode Ray Tube Design Engineer. He was transferred to Marion in January, 1954 as a B. & W. Kinescope Design Engineer. He is a senior member of the IRE and a member of the SAM (Society for the Advancement of Management). He is also a member of Tau Beta Pi and Sigma Tau. —*J. deGraad.*

NEW EDITORIAL REPRESENTATIVES APPOINTED

W. W. Wagner has replaced Harry Polish as a member of the DEP Editorial Board. Mr. Polish has assumed the duties of Manager, Camden Plant Personnel.

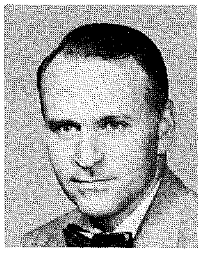
Mr. Wagner joined RCA upon graduation from New York University in June 1947, with a BSME degree. He was employed as a Manufacturing Student Engineer and upon completion of his training program, was assigned as a supervisor in the Fabrication Plant. In October 1948, he was transferred to Personnel as an employment interviewer. In April 1953, he was appointed Manager, General and Home Office Wage and Salary Administration. He was transferred to Engineering Personnel on August 15, 1953, as Manager, Engineering Employment. Mr. Wagner was appointed Manager, Camden Engineering Personnel in September, 1956.

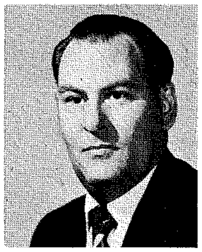

W. W. Wagner


C. D. Kentner

C. Dale Kentner has been appointed a member of the DEP/CEP Editorial Board. Mr. Kentner is Manager, Advanced Development and Measuring Equipment, Broadcast Transmitter Engineering, CEP, and will represent this activity for the RCA ENGINEER.

Mr. Kentner received the BSEE degree at Kansas University. After two years at GE, he started with RCA in 1930. Mr. Kentner has been associated with television engineering since 1933, with the exception of the war years, when he worked on radar design. He is a member of the IRE and has five patents to his credit.


M. Hollander


E. G. Lurcott

Matthias Hollander has been appointed co-member with Dr. D. C. Beaumariage to represent DEP Airborne Systems, Moorestown, on the Editorial Board.

Mr. Hollander is Engineering Editor, Airborne Systems. He received his A.B. degree in English from Harvard University and is working towards an M.S. degree in Physics at Temple University. From 1946-52 he was a technical writer and editor, the U. S. Air Force and Navy, and contributing editor to Funk and Wagnalls 1948-52. He spent three years as Research Reports Supervisor at Philco Corporation before joining RCA in 1955.

Mr. Hollander is a Member of IRE.

ASSISTANTS APPOINTED TO DEP-CEP EDITORIAL BOARD MEMBERS


J. A. Bauer discusses plans with assistants at Moorestown. Left to right: H. A. Brelsford, J. A. Bauer, E. F. Poole, F. W. Widmann, I. Brown, I. N. Brown, G. S. Paul and G. W. K. King (inset).

Assistants to the members of the DEP-CEP Editorial Board have been appointed by the Engineering Managers to represent their respective areas. Assistants to J. A. Bauer, Missile and Surface Radar Engineering, are H. A. Brelsford, I. N. Brown, Irving Brown, G. W. K. King, G. Paul, E. F. Poole, and F. W. Widmann.

Harlin Brelsford received a B.S. degree in M.E. from Newark College of Engineering and has credits in electrical engineering from Drexel Institute. He is Manager, R-F, Video and Computer Mechanical Engineering. Mr. Brelsford is a registered Professional Engineer in New Jersey and has three U. S. Patents to his credit.

Irmel N. Brown, Manager, Systems Engineering, received his B.S. in M.E. degree from the University of Kentucky and has done graduate work there. He is a member of Tau Beta Pi and a Senior Member of IRE.

Irving Brown holds the degrees of B.S.E.E., with high honors, from the University of Iowa and M.S.E.E. from the University of Pennsylvania. He is a Leader in Talos Design Projects. Mr. Brown has been appointed Adjunct Professor of Electrical Engineering at Drexel Evening College, and is a member of Tau Beta Pi, Eta Kappa Nu, and IRE.

George W. K. King received the degree of B.S.M.E. from Michigan State University. He was recently responsible for the design and integration of instrumentation into the Talos Dummy Weapon. He is a member of ASME; the Society of Experimental Stress Analysis; the Association of Professional Consultants; IRE, and Chairman of the Organizing Committee of the Professional Group on Reliability and Quality Control; and Chairman of the Reliability Committee on Environment. Mr. King is a licensed Professional Engineer in the states of Pennsylvania and Michigan, and the author of a number of published papers.

Gerald Paul is a mechanical engineer, engaged in working on antenna pedestals. He received the degree of B.Sc. in M.E. from the University of Pennsylvania, and is a member of ASME.

Edward F. Poole, 3rd, holds the degrees of B.S. from the U. S. Coast Guard Academy and M.S. in Physics from Drexel Institute of Technology. He is presently working on radar projects.

Frank W. Widmann received the degree of B.S.E.E. from Drexel Institute and has completed course requirements for an M.S.E.E. degree. He is Manager, Transmitters, Modulators, Microwave Antennas and Receivers. Mr. Widmann is a registered Professional Engineer in the state of New Jersey and is a member of IRE, Tau Beta Pi, and Eta Kappa Nu.

General Engineering Development

Eugene G. Lurcott, Jr., (see cut, column 1) has been appointed as assistant to L. M. Seeberger, DEP General Engineering Development. Mr. Lurcott attended Drexel Institute and during the war was in charge of theory instruction at the U. S. Navy Airborne Radio Materiel school. He is presently Project Engineer in Visual Data Handling, engaged in system studies on air traffic control problems and displays using direct view storage tubes.

ASSISTANT EDITORIAL REPRESENTATIVE APPOINTED AT LANCASTER

Max Petrisek, has been appointed Assistant Editorial Representative by W. G. Fahnestock at Lancaster, covering the Cathode Ray and Power Tube Engineering activity at Lancaster.

Mr. Petrisek served with the Army Air Force as a Captain. He graduated from Washington and Jefferson College in 1949 with a B.S. degree in Physics. In 1949 he joined RCA as a Manufacturing Engineer until 1952, when he became Manager, Small Power Tube Production Engineering. In May 1956, he was appointed Manager, Production Engineering-Power Tube at Lancaster, Pennsylvania. He is a member of Sigma Pi Sigma and the IRE.

MEETINGS, COURSES AND SEMINARS

COLOR TELEVISION . . . AUSTIN E. HARDY of the Chemical and Physical Laboratory at Lancaster, presented a lecture on September 27, 1956 on the "Colorimetry of Black and White and Color Television Kinescopes." The lecture was in connection with a week long Color Measurements Symposium sponsored annually by the General Electric Company for the benefit of workers in the textile, paint, dye, and graphic arts industries. The meeting was held at Portsmouth, New Hampshire at the Wentworth-by-the-sea. Mr. Hardy was presented with an engraved pen desk set in appreciation of his contribution. *—D. G. Garvin*

ENGINEERING COURSE OFFERED AT MARION PLANT . . . Graduate work in Electromagnetic concepts is currently being offered to Marion Engineers, through the auspices of the Purdue University Graduate School. The scope of this course includes the theory of dielectrics and conduction, thermodynamics and photo-electric phenomena, Maxwells equations, and electromagnetic effects due to steady and changing currents.

Dr. Robert T. Watson of the Marion Advanced Development Group is conducting the course. Dr. Watson received his B.A. degree in Physics from DePauw University in 1943, and a Ph.D. in physics from the Massachusetts Institute of Technology in 1951. While at M.I.T., he conducted research work at the Research Laboratory of Electronics. Before joining RCA in October of 1955, Dr. Watson was associated with the DuPont Company as a plant Physicist and later as a senior Research Project Physicist. He is a member of Sigma Xi, The American Physical Society, and the Society of Motion Picture and Television Engineers.

The course is being taken by the following Marion engineers for graduate credit. W. G. Hartzell, F. E. Fisk, T. E. Sisneros, J. W. Hart, A. C. Porath, D. C. Collins, T. P. Warne, L. D. Fraser, R. Stafford. R. L. Thompson, L. E. Weullner, R. J. Konrad, and S. P. Meir.*—J. deGraad*

RCA MOORESTOWN AND CAMDEN ENGINEERS ATTEND AMERICAN GEAR MANUFACTURERS' ASSOCIATION PANEL . . . The Radar and Interception Device Control Gear Committee, and the Rocket and Missile Gear Task Committee of the AGMA met at Cleveland, Ohio, on September 25 and 26 to discuss problems pertaining to these special groups. Of vital interest to RCA were such subjects as high-speed gear design, the effect of high-frequency vibration, interchangeability of parts, relationship of error in master gear to composite check and other items. H. J. Mackway of Missile and Surface Radar, Moorestown, and M. J. Walker of DEP Standards participated in the discussion. Mr. Mackway's topic covered "Relationship of Error in Master Gear to Composite Check" and Mr. Walker covered "Low Temperature Problems in Power and Control Gearing—Dimensional Stability."*—J. A. Bauer*

EFFECTIVE WRITING COURSE . . . A 16 hour course on effective writing was started October 23, sponsored by Television Broadcast Equipment Engineering. This course is intended particularly for engineers and engineering supervisors and is based on the "learn by doing" approach coupled with group critiques. The course is conducted one night a week and instructors are C. R. Monro and J. W. Wentworth. *—J. H. Roe*

TV TRAINING COURSE . . . An intensive survey course was started the tenth of October by Broadcast Studio Engineering, CEP. This course is limited to members of the Broadcast Studio Engineering group and is intended to emphasize newer ideas in network analysis and synthesis. 15 members of the group are attending. The course meets two nights a week and is of 15 weeks duration.

J. W. Wentworth and A. F. Inglis, Broadcast Studio Engineering, CEP, addressed a meeting of the Society of TV Engineers (a local Los Angeles group) on October 18, 1956. The subject of their talk was "Trends in Color TV."*—J. H. Roe*

FUNDAMENTALS OF ELECTRONIC SYSTEMS

. . . An after hours course in the Fundamentals of Electronic Systems for Mechanical Engineers is being conducted this fall, aimed at increasing the newly-hired mechanical engineer's understanding of, and identity with, the end products of DEP-CEP.

The course comprises a survey of the functions, gross operation and application of characteristic DEP-CEP electronic systems, preceded by a cursory treatment of electronic fundamentals. Fourteen weekly sessions are scheduled on, respectively, Linear Circuit Parts, Tubes and other Non-Linear Circuit Parts, Basic Circuits, RF Propagation, Voice Transmission and Reception, Introduction to Systems Engineering, Radar Fundamentals, Television Fundamentals, Analog Computers, Digital Computers, Airborne Fire Control, Control and Guidance, Airborne Communication and Navigation, and Integrated Military Applications.

Each of these subjects is presented by an RCA engineer having authoritative project experience in the particular subject area. The course has been sponsored and organized under the auspices of the Mechanical Coordinators Committee. The course schedule is given below.*—H. E. Coston*

Session No.	*Tuesday*	*Subject*	*Lecturer*
1	Oct. 16	Introduction & Linear Components	D. Troxel
2	Oct. 23	Tubes & Non Linear Components	M. Feyerherm
3	Oct. 30	Basic Circuits	F. Hartshorne
4	Nov. 6	R. F. Propagation	I. Munson
5	Nov. 13	Voice Transmission & Reception	F. Hartshorne
6	Nov. 20	Introduction To Systems Engineering	H. Wuerffel
7	Nov. 27	Radar Fundamentals	T. Greene
8	Dec. 4	Television Fundamentals	H. Wuerffel
9	Dec. 11	Analog Computers	E. Masterson
10	Dec. 18	Digital Computers	E. Schlain
11	Jan. 7	Airborne Fire Control	J. Vick Roy
12	Jan. 14	Control and Guidance	D. Shore
13	Jan. 21	Airborne Communication & Navigation	K. Law
14	Jan. 28	Integrated Military Applications	Optional—Instructors not selected

COLOR TV SEMINAR . . . A Color Seminar for Industrial Television and Broadcast Engineers was held at the Roosevelt Hotel, Hollywood, Calif., October 15 and 16 and October 18-19, 1956. Approximately 450 engineers attended. Speakers were N. J. Oman, J. W. Wentworth, W. J. Derenbecker, A. H. Lind and A. F. Inglis from Broadcast Equipment Engineering, Commercial Electronic Products.*—J. H. Roe*

DESIGN FOR MANUFACTURE . . . An in-hours course in Design for Manufacture is being presented this fall to a group of thirty-eight junior mechanical and electrical engineers from DEP and CEP (in the Camden, Moorestown area). This course, consisting of sixteen weekly, three-hour sessions, is designed to introduce the fundamentals of production design and includes sessions on dimensioning, materials selection, casting, forming and machining processes, welding, sheet metal construction, circuit packaging, fasteners, plastics and finishing systems. Instructors for the individual sessions are for the most part, consultants from the Materials and Mechanical Standards group or Product Engineers with extensive RCA manufacturing experience. In addition to lectures and simple case studies, many of the sessions include on-the-spot observation of RCA processes, arranged with the active cooperation of DEP Fabrication Plant. The course is presented under the auspices of the Mechanical Coordinators Committee of DEP-CEP and will be offered again in February 1957.*—H. E. Coston*

AIEE-IRE CREATIVE ENGINEERING SYMPOSIUM . . . A Creative Engineering Symposium, sponsored by the Philadelphia Chapters of AIEE and IRE, was held one evening each week from October 11th to November 13th at the University Museum Auditorium, the University of Pennsylvania, Philadelphia. The purpose of the six sessions was to provide thought-provoking lectures by outstanding speakers in the fields of research, design, product development, psychology, and public relations, to stimulate engineering imagination and thinking.

RICHARD L. ROCAMORA, AIEE, CEP Communications Engineering, served as Chairman of the Symposium, and H. J. Laiming, IRE, DEP Surface Communications Engineering, served as Secretary.

C. M. SINNETT, Manager, Advanced Development Engineering, RCA Victor Television Division, was the speaker at the second session. His talk was titled, "The Creative Person—Can He Be Spotted?"

DR. ALFRED N. GOLDSMITH, Consulting Engineer for RCA, was the speaker at the fourth session, speaking on "Creative Methods and Techniques."

G. L. DIMMICK, Chief Development Engineer, DEP General Engineering Development, spoke on the panel on Management of Creative Engineers, the subject of the November 8th session.

JAY J. NEWMAN, Manager, New Product Planning and Research, Components Division, conducted the summary of the Symposium.

SES HOLDS FIFTH ANNUAL MEETING . . . The Fifth Annual Meeting of the Standards Engineering Society was held October 3, 4 and 5 at the Willard Hotel, Washington, D. C. The meeting was opened with a keynote address by Madhu S. Gokhale, Society president, and Administrator, Mechanical Standards, RCA Corporate Standardizing. Mr. Gokhale spoke on the subject of "Standards—Guides for Tomorrow."

MEETINGS, COURSES AND SEMINARS

SIAM NATIONAL MEETING . . . The Society for Industrial and Applied Mathematics (SIAM) held a meeting in conjunction with the 527th meeting of the American Mathematical Society at the Massachusetts Institute of Technology, Cambridge, Mass. Those meetings were held on Saturday, October 27.

Dr. Rudolph Drenick, of the Radio Corporation of America, presided at this one and one-half hour session. The program consisted of two invited papers. Dr. H. H. Goldstine, of the Institute for Advanced Study, spoke on "Remarks on Von Neumann's Probabilistic Logics," and Dr. R. J. Nelson, of Case Institute of Technology, presented the paper "Increasing Reliability by Duplication of Components and Systems."

SYMPOSIUM ON THERMAL DESIGN

A Symposium on Thermal Design in Electronic Equipment was held in Camden on August 23rd and 30th. It was specifically concerned with designing electronic equipment for thermal environment. Experience in recent typical equipments revealed the quantitative relationships between thermal environment and reliability and the need for better control of thermal environment.

At the first session of the symposium, the following papers were presented on the state of the art:

- "The Effects of Temperature on Electron Tubes"—M. P. Feyerherm, DEP Components Application Review.
- "The Influence of Thermal Environment on Component Parts Failure"—D. I. Troxel, DEP Components Application Review
- "A Reliability Approach to Thermal Design" and "Thermal Testing and the Evaluation of Reliability"—T. C. Reeves, DEP Components Application Review
- "State of the Art and Future Trends in Forced Air Cooling Systems"—G. Auth, DEP Airborne Communications and Navigation
- "Fundamentals of Unconventional Cooling System Design"—R. B. Dyson, DEP General Engineering Development

At the second session, papers dealing with case studies in thermal design, drawn from recent RCA experience, were presented:

- "Prediction of the Thermal Environment within a High Performance Aircraft"—A. Scalzo, DEP Airborne Fire Control Engineering
- "Design and Test Procedures for Cooling the MA-10 Fire Control Radar"—J. Furnstahl and J. Currier, DEP Airborne Fire Control Engineering
- "Thermal Design in High Power Transmitters"—G. J. Rogers, CEP Broadcast Transmitter Engineering
- "Thermal Design in Surface Radar"—A. P. Moll, DEP Missile and Surface Radar Engineering
- "Thermal Design in Surface Communications"—G. V. Bradshaw, DEP Surface Communications Engineering
- "Thermal Design in Miniaturized Equipment"—G. W. King, DEP Missile and Surface Radar Engineering.

The Reliability Committee on Environment, G. W. King, Chairman, sponsored the Symposium. T. C. Reeves served as Program Chairman.

The Proceedings of the Symposium are available in the Engineering Library, Camden.—*H. E. Coston*

Engineers undergoing training at RCA Service Company's Missile Test Project in Florida

B. F. Wheeler of CEP Communications Engineering attended a meeting of RETMA Committee TR 14.1, Microwave Systems, at Syracuse, N. Y. on September 27 and 28. New standards for Antenna System patterns and Baseboard Gain Stability prepared by Mr. Wheeler were adopted. A list of 68 definitions and standards in the microwave radio field are being circulated for comment prior to submission for final industry approval.

Dr. D. Joseph Donahue of the Chemical and Physical Laboratory at Lancaster is Chairman of the Radio Publicity Committee of the Southeastern Pennsylvania Section of the American Chemical Society. DR. DAVID T. COPENHAFER and Mr. THEODORE A. SAULNIER of the same activity also are committee members. The Committee produces weekly radio programs over many of the radio stations in southeastern Pennsylvania. The programs are primarily news broadcasts of chemical advancements and research. (WLAN-Lancaster, WGET-Gettysburg.) — *D. G. Garvin*

ENGINEERING TRAINING PROGRAM STARTED AT MTP . . . Realizing the need for a continuous source of "Range Qualified" young professional engineers, RCA recently started an Engineering Training Program at the RCA Service Co. Missile Test Project, Patrick Air Force Base, Fla., to help solve the problem of recruiting qualified professional people for engineering positions.

The purpose of the Engineering Training Program is to provide training at the Missile Test Project that will enable recent engineering college graduates to qualify for careers in missile test instrumentation.

Engineering Trainees are assigned to Training and Services for administrative purposes, and training is supervised by Technical Training. After orientation and 8 weeks of classroom instruction in all phases of instrumentation, the trainee is assigned Down Range for 4 weeks. Then he spends time in Data Reduction, Shops, Installation Support, Instrumentation Control, and 9 weeks at the Cape.—*J. F. Hollabaugh*

CHERRY HILL ADVANCED ENGINEERING TRAINING PROGRAM—RADIO RECEIVERS

The portion of the advanced engineering training program* dealing with specific Radio and "Victrola" design and development applications accounts for 20% of the total program. However, over 60% of the electrical engineers in the Division are participating in the preparation and presentation of the lecture series. The subject matter which is based on over 130 years of engineering experience will require hundreds of man-hours of preparation.

The vigorous impact of semi-conductor devices on the Radio and "Victrola" product line is indicated by the following schedule, 40% of which is devoted to transistor circuitry.—*W. S. Skidmore*

Subject	*Instructor*	*Presentation Date*
Tube Mixers & Converters	E. Cornet	2-19-57
Transistor Mixers & Converters	L. M. Krugman	2-26-57
Tube IF Amplifiers	E. Cornet	3-5-57
Transistor IF Amplifier	L. M. Krugman	3-12-57
Detectors—AM	M. J. Nowlan	3-19-57
Detectors—FM	J. M. Link	3-19-57
Small Signal Transistor Audio Circuits	W. Hasenberg	3-26-57
Preamplifiers—Tubes and Transistors	J. J. Davidson	4-2-57
Transistor Power Amplifiers	W. Hasenberg	4-9-57
Tube Power Amplifiers	J. J. Davidson	4-16-57
Power Systems		
Part 1	W. S. Skidmore	4-23-57
Part 2	J. R. Shoaf, II	4-23-57
Acoustics	S. V. Perry	4-30-57
Overall Integration	H. N. Hoffer	5-7-57

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*See C. M. Sinnett, *Cherry Hill Advanced Engineering Training Program—TV Receivers*, RCA ENGINEER, Vol. 2, No. 2, pp. 34 & 35, August-Sept. 1956.

COMMITTEE APPOINTMENTS

Surface Communications, DEP

N. C. Colby, Surface Communications Engineering, DEP, has been elected Chairman of the joint Professional Groups on Microwave Theory and Techniques, and Antennas and Propagation, of the Philadelphia section of IRE.—*T. T. N. Bucher.*

T. H. Story, Surface Communications Engineering, DEP, has been appointed to the Radio and TV Committee, and to the Award Committee, to choose the Engineer of the Year. Appointment was made by the Chairman of the Engineers Week Committee, sponsored by the Philadelphia Chapter, National Society of Professional Engineers. —*T. T. N. Bucher*

Radio and Victrola Division

L. M. Krugman, Leader, Advanced Development Group, Radio and "Victrola" Division has been appointed to serve with the RETMA Radio Receiver Committee R-6, which is to work on the standardization of transistors.—*W. S. Skidmore.*

BIZMAC, CEP

Glenn Poorte, BIZMAC Engineering, CEP, was appointed a member of the IRE Subcommittee for Digital Computer Logical and Block Diagram Symbols.—*T. T. Patterson*
H. G. Reuter recently was appointed the RCA representative on the AIEE Committee on Electrostatic Charge Standards.—*T. T. Patterson*

DEP Standards and Engineering Services

M. P. Feyerherm has been appointed as a member of the AIA (Aircraft Industry Association) Power and Gas Tube Subcommittee of the Armed Services Electron Tube Committee.

J. A. Connor has been appointed Chairman of the RETMA Ad Hoc Committee on Environmental Requirements of the N-1 Military Components Engineering Coordination Committee.

D. I. Troxel is a member of Mr. Connor's Ad Hoc Committee.
R. H. Baker was elected Chairman of the IRE Professional Group on Military Electronics for the 1956-57 year.—*H. E. Coston*

NEW CHAPTER OF RADIO PIONEERS FORMED

E. H. Felix has received a charter from the national executive committee to set up a *Delaware Valley Chapter of the Radio Pioneers.* A. R. Hopkins, Manager, Commercial Electronic Marketing Department, CEP, is a member of the temporary organizing committee. The first meeting took place in Philadelphia Oct. 4, 1956 and was attended by the president and other leading national officers of the organization. E. T. Griffith was in charge of meeting arrangements. The Radio Pioneers is nationwide in scope, with local chapters in the principal cities. The several hundred members include the early leaders of radio who organized the first broadcasting stations, the nationwide networks and entertained the first radio audiences in the twenties and early thirties. Interested Pioneers are invited to contact members of the organizing committee.

HUMAN ENGINEERING TEAM FORMED AT MOORESTOWN

Representing a new trend in engineering organizations, a Human Engineering Group has been organized to work in close contact with the various missile and surface radar projects at RCA Moorestown. The group, headed by Dr. Fred H. Ireland and staffed by Dr. Robert A. Coyer and Mr. William C. MacPherson, act as consultants on human factors during the systems design and equipment development phases. Doctors Ireland and Coyer are both Experimental Psychologists and combine their training and industrial background with the experience of Mr. MacPherson, an Industrial Design Engineer.

Fred H. Ireland, Human Engineering Administrator, RCA Missile and Surface Radar Department, received his B.S. from Fordham College in 1948. He continued his graduate studies in psychology at Fordham University and was granted an M.A. in 1949 and a Ph.D. degree in 1955.

Dr. Ireland has held various positions in experimental and applied psychology. He joined RCA in July 1955 as an experimental psychologist, serving as human engineering consultant during the developmental phases of a land-based missile system, shipboard fire control equipment, and several radar sets. In May 1956 he was appointed to the position of Administrator, Human Engineering. He is an associate member of the American Psychological Association, the Eastern Psychological Association, and a senior member of the IRE.

Robert A. Coyer received his B.A. from the University of Buffalo in 1949. He continued at the same university as a graduate research assistant and teaching fellow, receiving his Ph.D. in June 1953. Dr. Coyer has worked in the field of human engineering with the Stanley Aviation Corporation and the Bell Aircraft Corporation.

Dr. Coyer joined RCA in June 1956. Since then he has acted as consultant during the design of information handling equipment for a Naval missile weapons control center, and during an analysis of human factors in a proposed Naval missilry system. He has also participated in an improvement study of an existing weapons control facility. Dr. Coyer is a member of Sigma Xi and The American Psychological Association.

William C. MacPherson graduated from Georgia Institute of Technology with the degree of B.S. in Industrial Design. From 1951 to 1953 he was design director for Michaux Enterprises where the principal products were manufactured under his patent.

Mr. MacPherson joined the RCA Missile and Surface Radar Department in June 1956. He was assigned as human engineer to a developmental program for a land-based missile system, and participated in the design of communications facilities, operator consoles, and a lighting system for a fire control room. He also acted as consultant on land-based and shipboard radar equipment. Mr. MacPherson is a member of The Society of Plastic Engineers.

REGISTERED PROFESSIONAL ENGINEERS

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

Name	*Section*	*State*	*Licensed As*	*License No.*
CEP Communications Engineering				
J. J. Liggett	584	N. J.	Prof. Eng.	9325
RCA Service Co.				
E. L. Klein		Wash. D. C.	Prof. Eng.	3563
Tube Division, Harrison				
Edwin Nickl	690	N. J.	Mech. Eng.	9376
Radio & "Victrola" Division, Cherry Hill				
A. J. Mannino		Del.	Prof. Eng.	1317

ENGINEERING MEETINGS AND CONVENTIONS

December 1956 - February 1957

DECEMBER 10-12
Eastern Joint Computer Conference, IRE, AIEE, ACM, Hotel New Yorker, New York, N. Y.

JANUARY 14-15
Symposium on Reliability & Quality Control in Electronics, IRE, NBS, ASQC, Statler Hotel, Washington, D. C.

JANUARY 23-25
IRE, Symposium On Very Low Frequency Waves, NBS, Boulder Labs, Boulder, Colo.

JANUARY 28-29
Symposium on Microwave Ferrite Devices & Applications, IRE, Engineering Societies Bldg., New York, N. Y.

Electronics in Aviation Day, IRE, IAS, RTCA, Sheraton Astor Hotel, New York, N. Y.

FEBRUARY 7
Annual Mid-Winter Symposium Aircraft Instrumentation, New York ISA, Garden City Hotel, New York

FEBRUARY 14
Symposium on Recording of Heart Sounds, IRE University of Buffalo Medical School, Buffalo, N. Y.

FEBRUARY 14-15
Conference on Transistor Circuits, IRE, AIEE, Philadelphia, Pa.

FEBRUARY 26-28
Western Joint Computer Conference, IRE, AIEE, ACM, Statler Hotel, Los Angeles, Calif.

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The Editorial Representative in your group is the one you should contact in scheduling technical papers and arranging for the announcement of your professional activities. He will be glad to tell you how you can participate.

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