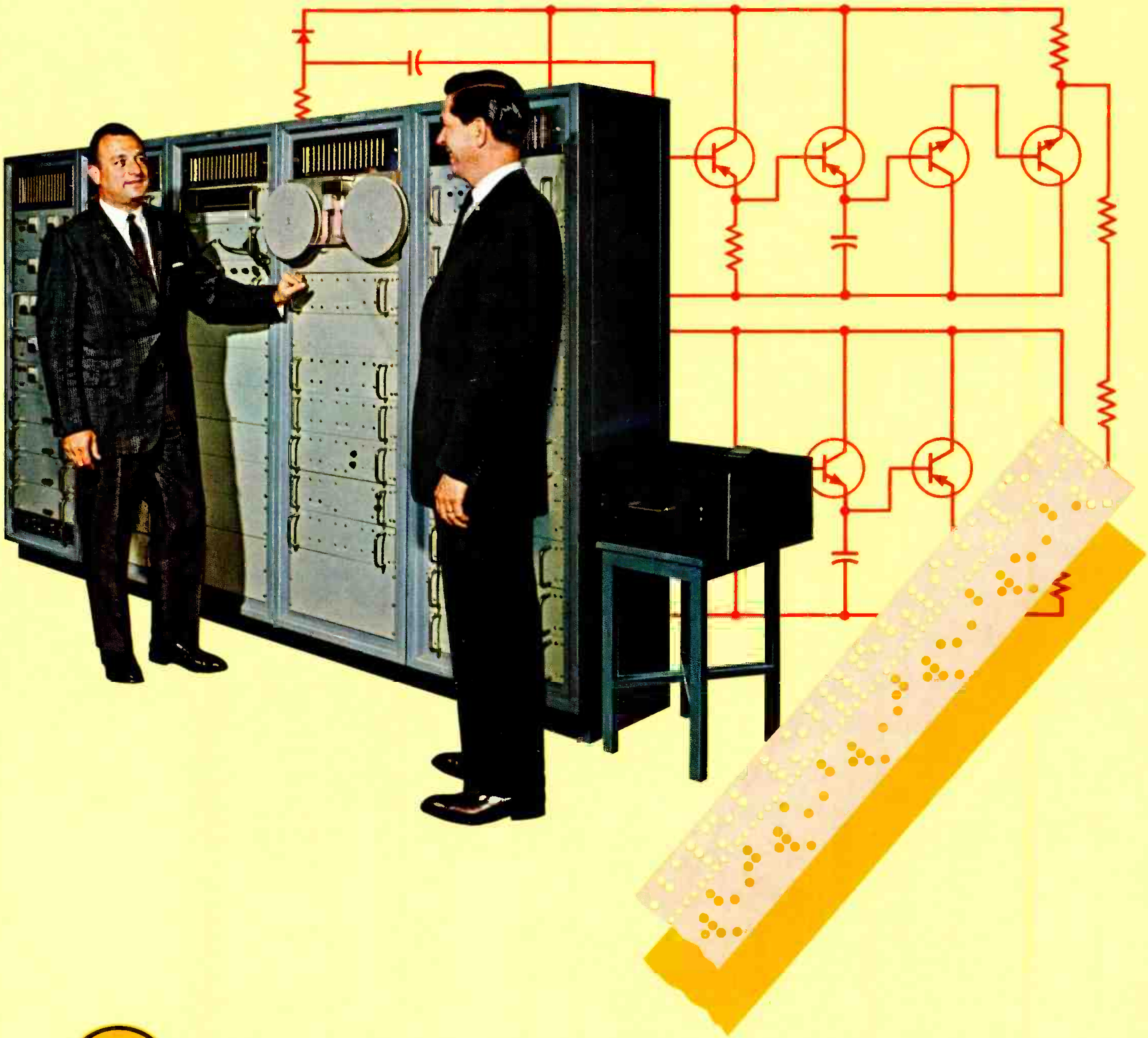
RCA ENGINEER



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OUR COVER

. . . illustrates the philosophy of programmed automatic checkout equipment, the theme of this issue. Pictured is the FATE (Factory Automatic Test Equipment), with (left) I. K. Kessler, Division Vice President and General Manager, DEP Aerospace Communications and Controls Division, and E. C. Kalkman, Manager, Systems Support Engineering, DEP-ACCD.

DEFENSE SYSTEMS SUPPORT

Emphasis in this issue focuses, deservedly, on the vital role of DEP support equipment in the successful operation of modern major defense systems—and on sophisticated systems support and logistics problems which must be solved by the engineer.

Recent technical advances in defense electronic systems and marked changes in our national defense and space programs have made the customer (the military) realize increasingly that no system can function without adequate support in both standard and specialized test, checkout, and maintenance systems; this checkout phase is essential to the final, successful utilization and operation of the prime defense system.

Today, advance planning takes cognizance of important areas in which system operation must be verified. Characteristically, the support equipment itself has changed markedly; the novelty and complexity involve challenging new engineering problems to be solved. Automation, the application of digital techniques, the trend toward system checkout of man himself, and other related developments present stimulating goals—paralleling those of the most sophisticated prime defense systems.

It is interesting to note that in the Air Force budget alone for the fiscal year 1963, *more than a billion and a half dollars* are earmarked for support of installations and facilities. This somewhat surprising volume of dollars is indicative of the major stature today of logistics and support business. I believe that it is important that RCA be even more extensively involved in the future in this most important endeavor in defense electronics.

Walter G. Bain

Walter G. Bain
Vice President
Defense Electronic Products
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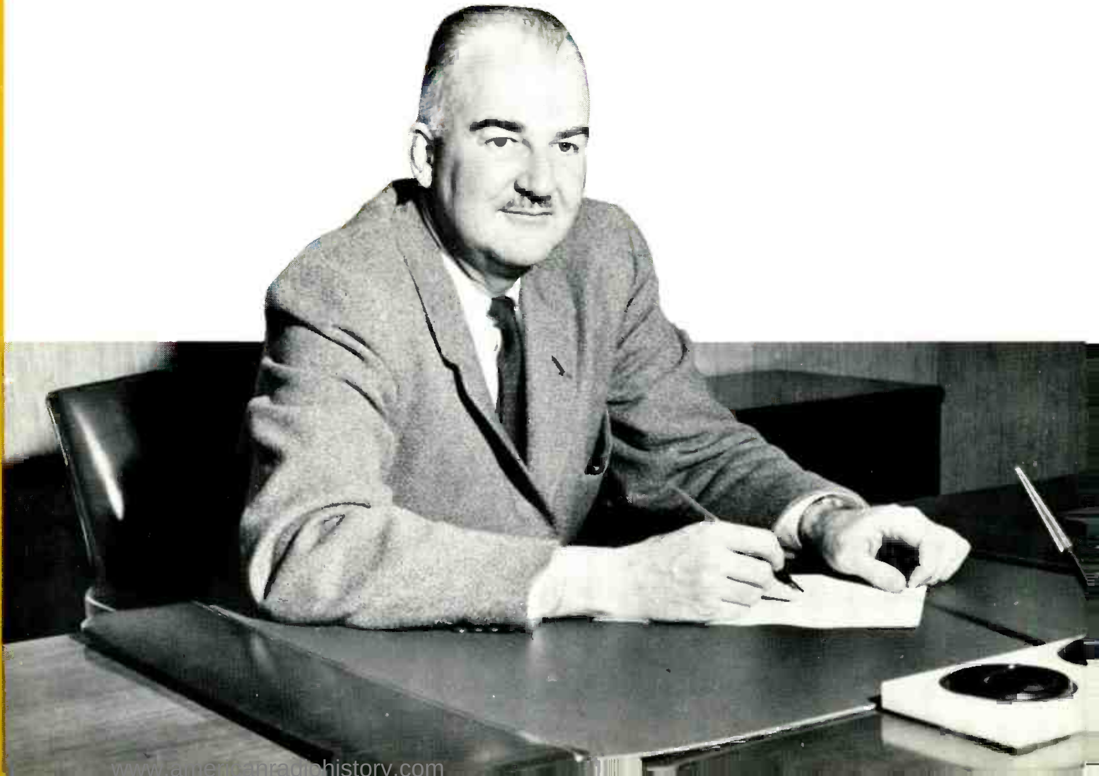

RCA ENGINEER
VOL. 8, NO. 2
AUG.-SEPT. 1962

CONTENTS

PAPERS

NOTES

DEPARTMENTS

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

● To disseminate to RCA engineers technical information of professional value. ● To publish in an appropriate manner important technical developments at RCA, and the role of the engineer. ● To serve as a medium of interchange of technical information between various groups at RCA. ● To create a community of engineering interest within the company by stressing the interrelated nature of all technical contributions. ● To help publicize engineering achievements in a manner that will promote the interests and reputation of RCA in the engineering field. ● To provide a convenient means by which the RCA engineer may review his professional work before associates and engineering management. ● To announce outstanding and unusual achievements of RCA engineers in a manner most likely to enhance their prestige and professional status.

With literally hundreds of technical journals and magazines in print today, it is especially important for the engineer or scientist to select the most appropriate one for his technical paper. Answers to the question of how best to go about this are presented herein. Three major categories of publications related to electronics are described: 1) the professional society journals; 2) company publications of a professional caliber, and 3) commercial technical magazines. Differences among the publications in these three categories are discussed. Also covered are editorial review and technical evaluation procedures, manuscript submission requirements, general publication practices, payment policies, and availability of reprints.

The Engineer and the Publication

EFFECTIVE PLACEMENT OF ENGINEERING PAPERS

CHARLES A. MEYER, Mgr.
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THE ENGINEER who spends many hours writing a technical paper wants to and deserves to reach a large group of readers. The readers, however, must be a "knowledgeable" group so that the information will not only be of benefit to them but will also bring credit to the author and his sponsoring company.

With the hundreds of technical publications and dozens of professional society meetings each year, the engineer-author often has a problem in selecting the right publication or platform for his material. For best results, the many factors leading to a suitable selection should be considered *before* the paper is written. In this way, the special requirements of a particular publication and its readership, or of a meeting and its audience, can influence the way the subject matter is treated. An understanding of these requirements will make the choice an easier and more profitable one.

TYPES OF PUBLICATIONS

On a broad basis, the technical publications that electronics engineers read and write for can be divided into three categories: professional, company, and commercial.

Professional publications are those issued by the professional societies and include the *Proceedings of the IRE*, the many *Convention Records*, the AIEE *Electrical Engineering*, the IRE Professional Group *Transactions*, and the like. The second group includes publications of a professional nature issued by industrial companies. Examples in this group are the *RCA Review*, RCA ENGINEER, *Bell System Technical Journal*, and *IBM Journal*. The third group, publications issued by commercial publishing organizations, is the largest and includes publications like *Electronics*, *Electronic Design*, *Electronic Equipment Engineering*, *Electronics World*, *Audio*, and many others.

There are several major differences among these groups of magazines. They differ in readership, emphasis, editorial review procedure, submission requirements, and payment practices. In addition, there are substantial differences among the magazines within the groups. With a knowledge of these differences, the engineer-author will be better able to select the right publication for his writing efforts.

PROFESSIONAL SOCIETY PUBLICATIONS

Among the aristocrats of the technical publications field are the professional societies' major publications, such as the *Proceedings of the IRE* or the AIEE *Electrical Engineering*. These publications are considered by many to be essentially publications of record. Papers are accepted and published with the expectation that they will be of permanent value as reference material.

Papers submitted to a publication in this group are usually reviewed by volunteers from the society membership who are experts in the particular field of the paper under consideration. The review cycle may be fairly long (several months and occasionally much longer) and may include several reviewers. If changes or additions are suggested, the author is asked to provide them. To facilitate the review procedure, the author is asked to submit three to six copies of his paper. Upon its acceptance, he is also asked to submit reproducible copies (including inked master drawings) of his illustrations. The professional societies do not remunerate the author; in fact some of them, such as the Physics societies, make a publication charge of up to $40 a page. The publication of a manuscript by a professional society journal provides the author and his company or university with prestige, a readership of high technical level, and, of course, a substantial amount of professional satisfaction.

A number of other professional societies besides the IRE and the AIEE publish papers related to the electronics field. Information about publications of some of these societies is shown in Table I.

Apart from its *Proceedings*, the IRE is a very prolific publisher of a wide variety of technical material. It sponsors the *Transactions* of 28 different professional groups, the *Records* of its major international meetings, and the publications resulting from a host of regional or specialized meetings. In addition, it is responsible for the Pro-

Table I—Some Professional Society Publications Covering the Electronics Field.

Name	*Society*	*Issued*	*Circulation**
Proceedings of the IRE	IRE	Monthly	76,000
PG Transactions	IRE	Varies	Varies
Electrical Engineering	AIEE	Monthly	53,000
AIEE Transactions	AIEE	Varies	Varies
Physics Today	AIP	Monthly	32,000
Journal of Applied Physics	AIP	Monthly	9,000
Review of Scientific Instruments	AIP	Monthly	9,000
ISA Journal	ISA	Monthly	21,000
Science	AAAS	Weekly	68,000
Astronautics	ARS	Monthly	22,000
Journal of the SMPTE	SMPTE	Monthly	
Journal of the AES	AES	Quarterly	3,000
Aerospace Engineering	IAS	Monthly	20,000

* Circulation figures are based on average circulation in first half of 1961 as obtained from *Standard Rate & Data.*

HOW TO SUBMIT

The mechanics of submitting an article to a commercial publication are relatively simple. Required are one fully approved,[1] clean, *double-spaced* typewritten copy of the paper, a complete set of illustrations (not necessarily reproducible masters) and a letter of transmittal stating that the article has not been published before and has not been accepted by another publication.[2] If a security or proprietary clearance is involved, it is the author's responsibility to obtain it prior to submission.[1]

Submission to a professional society for publication in its major periodical usually involves multiple copies and sets of illustrations. The IRE, for example, requires three sets of each to facilitate its review procedure. In addition, master copies of illustrations suitable for reproduction are also required. These master copies, which should be inked, drawn, and lettered professionally, may be submitted after the paper has been reviewed and accepted.

The receipt of the article or paper will be acknowledged by the publication, often with a form postal card, and then the wait begins. The professional societies may take several months. The commercial magazines will vary considerably. Among the prompt reviewers are *Electronics*, *Electronic Design*, and *Electronics World*. Such publications will accept or reject a paper in a matter of a few weeks and, if the editors have changes or additions to suggest, they will communicate with the author promptly. After an article is accepted, publication may take several months or longer depending on the frequency of the publication. Weeklies, of course, can publish much more rapidly than monthlies.

Table III—Commercial Technical Publications Listed by Major Field.

Name	*Issued*	*Circulation**
GENERAL		
Electronic Design	Biweekly	38,000[c]
Electronic Equipment Engineering	Monthly	41,000[c]
Electronic Industries	Monthly	58,000[c]
Electronic Products	Monthly	57,000[c]
Electronics	Weekly	54,000[a]
Western Electronic News	Monthly	19,000[c]
MILITARY-SPACE		
Military Systems Design	Bimonthly	38,000[c]
Missiles & Space	Monthly	24,000[c]
Space/Aeronautics	Monthly	58,000[c]
INDUSTRIAL		
Electronic Packaging & Production	Bimonthly	15,000[c]
Electro-Technology	Monthly	32,000[c]
Industrial Research	Monthly	41,000[c]
Product Engineering	Biweekly	51,000[a]
Research/Development	Monthly	34,000[c]
CONTROLS, AUTOMATION, DATA PROCESSING		
Automatic Control	Monthly	37,000[c]
Automation	Monthly	33,000[c]
Computers & Automation	Monthly	4,000[c]
Control Engineering	Monthly	32,000[a]
Datamation	Monthly	31,000[c]
Instruments & Control Systems	Monthly	32,000[c]
SERVICE TECHNICIAN		
Electronic Technician	Monthly	82,000[a]
Electronics World	Monthly	240,000[a]
PF Reporter	Monthly	74,000[a]
Radio-Electronics	Monthly	156,000[a]
HOBBY, EXPERIMENTER, POPULAR		
CQ	Monthly	92,000[a]
Electronics Illustrated	Bimonthly	187,000[a]
Electronics World	Monthly	240,000[a]
Popular Electronics	Monthly	388,000[a]
Popular Science	Monthly	1,260,000[a]
QST	Monthly	105,000[a]
Radio-Electronics	Monthly	156,000[a]
Scientific American	Monthly	300,000[a]
73	Monthly	34,000[a]
OTHER		
Audio	Monthly	25,000[a]
Broadcast Engineering	Monthly	8,000[c]
Microwave Journal	Monthly	22,000[c]
Nucleonics	Monthly	20,000[a]
Semiconductor Products	Monthly	13,000[b]
Solid State Design	Monthly	20,000[c]

* Circulation figures are based on average circulation in first half of 1961 as obtained from *Standard Rate & Data*.
[a] Paid circulation.
[b] Paid circulation about 75%.
[c] Controlled circulation.

Once the article is accepted, the author may not see it until it is in print. Usually, however, he will receive a galley proof and an opportunity to evaluate any editorial changes. He will probably not see page proofs or engraver's proofs of the illustrations.

The professional society publications move more deliberately. After the review, the interchange of comments, and eventual acceptance, the society will submit galley proofs, proofs of the illustrations, and often page proofs. The *Transactions* of the Professional Groups of the IRE, however, do not all follow the same procedure as the *Proceedings of the IRE*. The *Transactions* are edited by volunteers, and their practices vary considerably. Some of the Professional Groups will, like the *Convention Record* and other meeting records, require the authors to submit their manuscripts typed on prepared master sheets which are then photographed and reproduced directly by a photo-offset process. In such cases, no further editing can be done and final results are entirely the author's responsibility.

REPRINTS

Once an article or paper is in print, the author may receive many requests for reprints. The professional societies may solicit a reprint order when they send the author proofs to review. The commercial publications usually do not solicit reprints, but will arrange to supply them if requested. Reprints are not expensive, varying in price from about $5.00 a hundred copies and up, depending upon the number of pages and the quality of the reprinting method. Reprints ordered from the printer of a professional society journal *prior to publication* are usually the lowest priced. Reprints may also be obtained from RCA company publications at reasonable rates by arrangements with the editors (See Table II).

The average engineer-author is stimulated and encouraged by requests for his article and will want reprints to fill these requests. In many cases, the marketing or engineering activities will arrange to pay for a quantity of reprints, supply a number of them to the author to take care of requests, and distribute the bulk of them where they can contribute to the company's prestige or commercial interests.

CONCLUSION

RCA's well-established policy of encouraging engineering papers is a recognition of the benefits, both to the company and to the authors, of getting good articles published in the technical periodicals. The appearance of a well-written article or paper in an appropriate publication is by far the most effective way of reaching a large group of readers eager for knowledge of technical advances in their special fields of interest.

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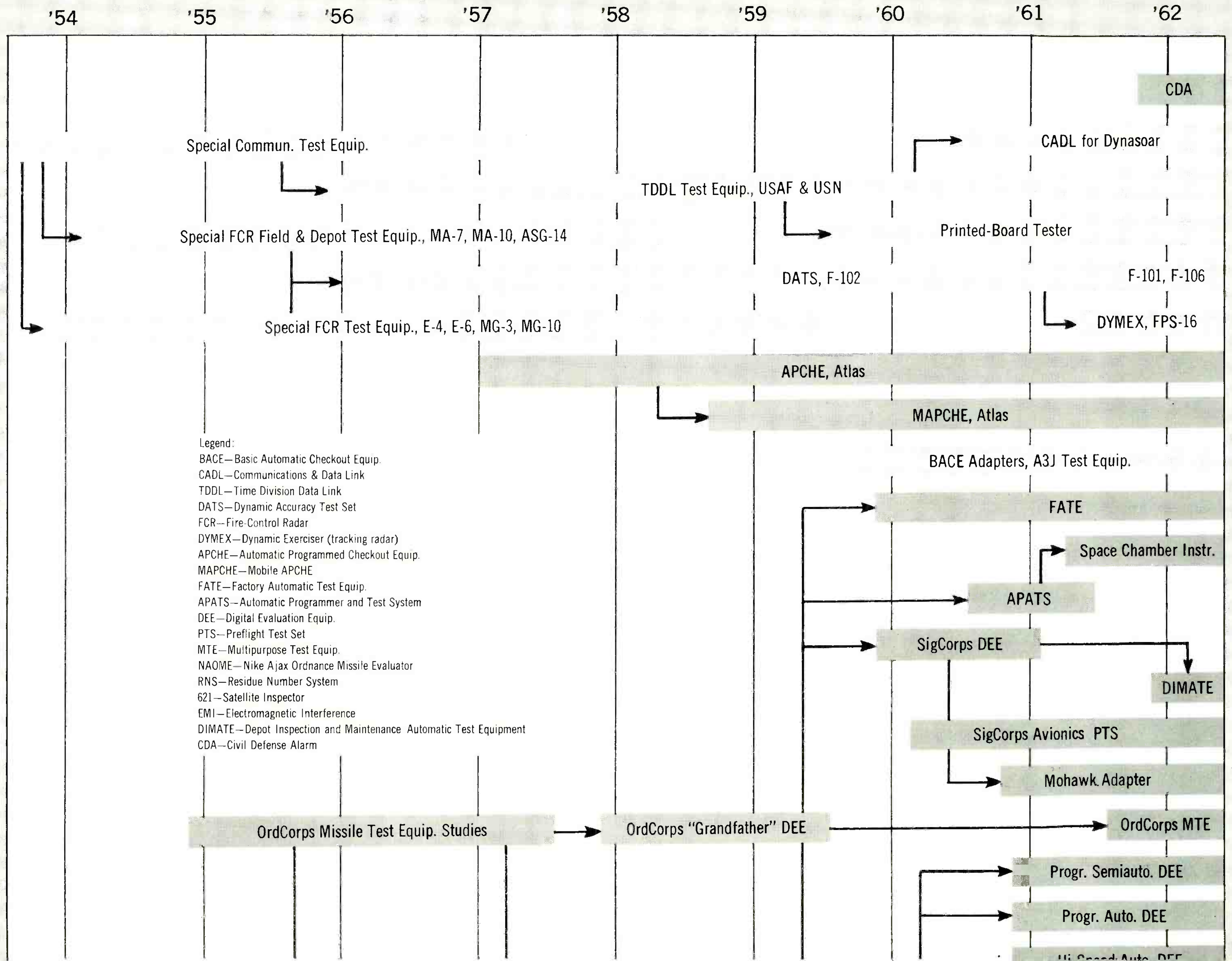
[1] For information on the required approval procedure for RCA-authored papers, contact the Technical Publications Administrator, or his representative, for your operating area.

[2] Because the RCA ENGINEER is available only to the RCA technical staff, it is practical (and often desirable) to submit a paper concurrently to a commercial or professional journal and to the RCA ENGINEER. The fact that the paper may appear in the RCA ENGINEER should not affect consideration by the commercial or professional journal. Again, contact your Editorial Representative or Technical Publications Administrator for details.



Legend:
BACE—Basic Automatic Checkout Equip.
CADL—Communications & Data Link
TDDL—Time Division Data Link
DATS—Dynamic Accuracy Test Set
FCR—Fire-Control Radar
DYMEX—Dynamic Exerciser (tracking radar)
APCHE—Automatic Programmed Checkout Equip.
MAPCHE—Mobile APCHE
FATE—Factory Automatic Test Equip.
APATS—Automatic Programmer and Test System
DEE—Digital Evaluation Equip.
PTS—Preflight Test Set
MTE—Multipurpose Test Equip.
NAOME—Nike Ajax Ordnance Missile Evaluator
RNS—Residue Number System
621—Satellite Inspector
EMI—Electromagnetic Interference
DIMATE—Depot Inspection and Maintenance Automatic Test Equipment
CDA—Civil Defense Alarm

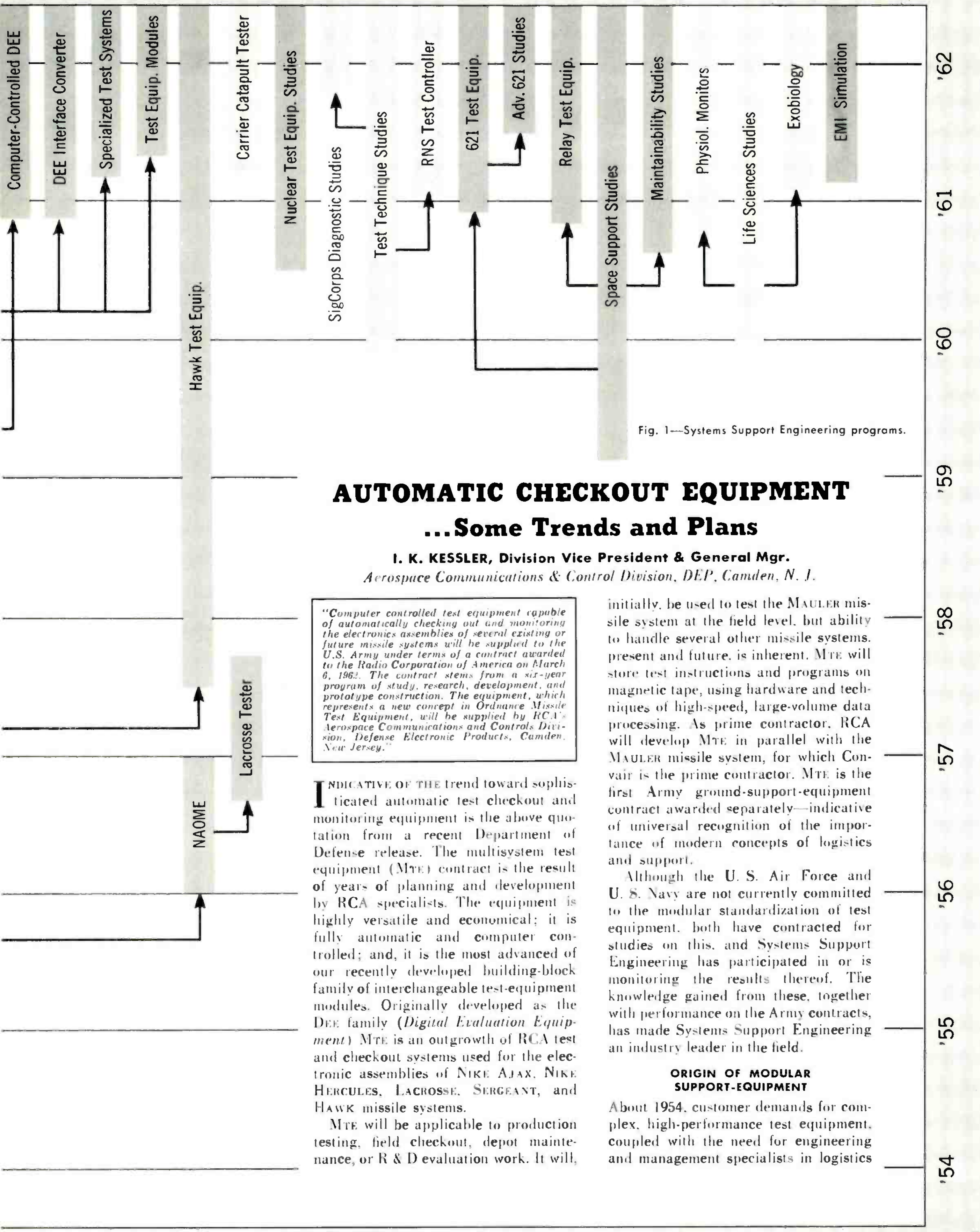


Fig. 1—Systems Support Engineering programs.

AUTOMATIC CHECKOUT EQUIPMENT

...Some Trends and Plans

I. K. KESSLER, Division Vice President & General Mgr.
Aerospace Communications & Control Division, DEP, Camden, N. J.

> *"Computer controlled test equipment capable of automatically checking out and monitoring the electronics assemblies of several existing or future missile systems will be supplied to the U.S. Army under terms of a contract awarded to the Radio Corporation of America on March 6, 1962. The contract stems from a six-year program of study, research, development, and prototype construction. The equipment, which represents a new concept in Ordnance Missile Test Equipment, will be supplied by RCA's Aerospace Communications and Controls Division, Defense Electronic Products, Camden, New Jersey."*

INDICATIVE OF THE trend toward sophisticated automatic test checkout and monitoring equipment is the above quotation from a recent Department of Defense release. The multisystem test equipment (MTE) contract is the result of years of planning and development by RCA specialists. The equipment is highly versatile and economical; it is fully automatic and computer controlled; and, it is the most advanced of our recently developed building-block family of interchangeable test-equipment modules. Originally developed as the DEE family (*Digital Evaluation Equipment*) MTE is an outgrowth of RCA test and checkout systems used for the electronic assemblies of NIKE AJAX, NIKE HERCULES, LACROSSE, SERGEANT, and HAWK missile systems.

MTE will be applicable to production testing, field checkout, depot maintenance, or R & D evaluation work. It will, initially, be used to test the MAULER missile system at the field level, but ability to handle several other missile systems, present and future, is inherent. MTE will store test instructions and programs on magnetic tape, using hardware and techniques of high-speed, large-volume data processing. As prime contractor, RCA will develop MTE in parallel with the MAULER missile system, for which Convair is the prime contractor. MTE is the first Army ground-support-equipment contract awarded separately—indicative of universal recognition of the importance of modern concepts of logistics and support.

Although the U. S. Air Force and U. S. Navy are not currently committed to the modular standardization of test equipment, both have contracted for studies on this, and Systems Support Engineering has participated in or is monitoring the results thereof. The knowledge gained from these, together with performance on the Army contracts, has made Systems Support Engineering an industry leader in the field.

ORIGIN OF MODULAR SUPPORT-EQUIPMENT

About 1954, customer demands for complex, high-performance test equipment, coupled with the need for engineering and management specialists in logistics and support, were instrumental in the formation of a separate group in DEP.

Modularly constructed test equipment originated in the RCA Service Company, as the result of an Army Ordnance study contract. Upon completion of studies and following prototype hardware-design initiation, responsibility was transferred to the DEP Aerospace Communications and Controls Division (then Airborne Systems Division) in Camden, New Jersey. The program was phased into the existing test-equipment design groups for the Dynamic Accuracy Test System (DATS), the ATLAS Launch and Countdown Equipment (under subcontract from the DEP West Coast Missile and Surface Radar Division), and the Data Link Test Equipment. These engineering groups, prior to the transfer, had also been supporting the fire-control and communication systems built by DEP.

In parallel with the Ordnance contract, the RCA Service Company completed the preproduction HAWK Field Maintenance Test Equipment at its Alexandria, Virginia facility. Subsequent production orders were built in the Camden defense plant.

SYSTEMS SUPPORT ENGINEERING TODAY

The design group that originally consisted of four engineers has now grown into a team of over 150 engineers and scientists. The growth and spread of the product line (Fig. 1) is based on several major technical strengths: the established building-block family of test equipment, continuous research in advanced test techniques, in-space maintenance studies, an established life-sciences program, automatic teaching, and environmental stimulation.

The Systems Support Engineering sections report to the Chief Engineer, Aerospace Communications and Controls Division, Burlington, Mass. Major programs (such as MTE, with a Program Manager) report to the Division Vice-President and General Manager.

Systems Support has four engineering areas that contribute to the product line:

Preliminary Design consists of senior engineers, responsible for the determination of future trends in the field of support, the development of new ideas and products, and public-relations activities.

Project Management personnel are responsible for the successful completion of specific contract projects.

Systems personnel are responsible for outlining specific support parameters for any given system and for the parameters of a complete support system. They also integrate specific customer desires into systems requirements, and generate the systems specifications for design group guidance.

Design personnel are responsible for electrical and mechanical hardware design, packaging, production follow, documentation, and related tasks.

PLANNING OF TEST EQUIPMENT PRODUCT LINE

Systems Support supplies an integrated product line of equipment and logistics services in support of weapon or space system development, production, operation, and/or maintenance. Prime system *integration* depends heavily on the success of such support equipment, which must be compatible with the prime system's original electrical and mechanical requirements—and its potential for future development and expansion as well. These factors necessitate close liaison with all facets of the prime system. We do not supply one particular item of automatic test equipment modified for each customer, but rather an integrated line of equipment adaptable to specific applications.

For example, the DEE system has provided a library of designs for many types of test-equipment "building blocks." Blocks built from these designs have been used in various delivered equipments as well as for Camden defense plant (for example, FATE, Factory Automatic Test Equipment, illustrated on the front-cover photo, is being used for production testing of electronic assemblies).

THE FUTURE TRENDS

There is now increasing emphasis on space systems, and the separation of support procurements and prime-equipment procurements. Automatic test equipment is no longer a novelty. Feasibility has been demonstrated and future sales will be based on performance innovations in the art of testing and on technical competence.

Strategy being followed for future product line expansions calls for the development of more building-block designs, as an outgrowth of the MTE program. The philosophy of complete end-to-end system testing, typified by DATS. is being expanded and extended. Automatic mechanical test and evaluation equipment (MEE) is being added to the MTE program to insure coverage of the hydraulic and pneumatic test requirements areas. Electro-hydraulic test-equipment based on the concept of combined circuit and hydraulic or pneumatic checkout (e.g., a servo loop) is being developed. Investigations must continue into non-classic test techniques; for example, use of transfer-function analysis to indicate condition, rather than measurement of individual circuit values such as voltage. There are also exotic test concepts based on use of infrared, ultraviolet, or x-ray detection of out-of-ordinary conditions in equipment in equipment in order to *foretell* changes in operation.

CONCLUSION

In summary, the trends in systems support are toward more automation to simplify personnel participation; exotic test methodology, especially in space simulation and in-flight space support; and standardization and modular solid-state circuitry in the test equipment itself.

More centralized DOD procurement for support equipment coupled with the newer method of allocating budgeted funds for a given system not just to the prime system (with support equipment tacked on) but separately as individual system-support contracts, should increase the demand for the special capabilities that our Systems Support Engineering can provide.

IRVING K. KESSLER, Division Vice President and General Manager, DEP Aerospace Communications and Controls Division, received his BS from Temple University and has done graduate work in Psychology at the University of Pennsylvania. From 1941 to 1946, he was with the RCA Victor Division as Wage and Salary Administrator. From 1946 through 1957, he was with the John B. Stetson Co. as Vice President. In 1959, he rejoined RCA as Manager, Management Engineering, and in August 1960 was named to his present executive position. Mr. Kessler has taught, lectured, and written widely on various phases of scientific management and industrial relations. His teaching activities, in addition to those within RCA, have included Temple University, Junto, and Princeton University—the latter in the graduate school Industrial Relations Conference Faculty. Among his many professional and civic organizational activities, he has been President of the Industrial Relations Association of Philadelphia, on the National Panel of Arbitrators of the American Arbitration Assoc., and is a member of the Industrial Relations Committee of the NAM and the American Society of Naval Engineers.

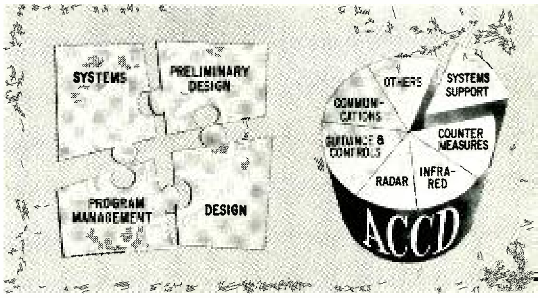


Fig. 1—In the photo, APATS equipment is shown as installed at Lockheed-Sunnyvale, with E. McDowell, RCA Service Company Installation Engineering, (center) and two representatives from Lockheed.

The increasing number of space missions and types of vehicles has led to a multitude of highly complex test instrumentations. To provide an accurate, reliable, and automatic evaluation equipment for prototype spacecraft, RCA designed and built the Automatic Programmer and Test System (APATS). It is used with the Lockheed High-Vacuum Orbital Simulator (HIVOS) installed during the latter half of 1961 at Lockheed's Missile and Space Company plant at Sunnyvale, California. An outgrowth of the DEE family (see Dobson and Wolff, this issue), APATS provides an easily maintained and expandable instrumentation system. Although requirements for the marriage of HIVOS and APATS were extremely complex, the test system was completed and installation started within 9 months.

AUTOMATIC EVALUATION OF SPACE VEHICLES DURING ENVIRONMENTAL TESTS

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Testing space-vehicle electronic equipment under simulated environmental conditions can be a complicated and time consuming procedure. In the conventional approach, each vehicle undergoing such evaluation requires specialized test apparatus in conjunction with a test chamber and its associated equipment. Several technicians are needed to perform a sample test and to calibrate the equipment, thus requiring an extra amount of time before the actual environmental testing can proceed. Also, the use of several types of separate, specialized test equipment increases the problem of test-equipment malfunctions, and can thus further delay the environmental testing of complex electronic specimens.

APATS—A SIMPLIFIED TEST PROCEDURE

The APATS design has eliminated the need for such special-purpose test equipments, since it is an integrated, general-purpose, automatic system capable of performing a multitude of tests for all specimens to be evaluated in the simulator. Test-equipment calibration, maintenance, and operation are automated so that operating personnel can be kept to a minimum.

The APATS system employs solid-state circuit design previously proven extremely reliable and efficient in Army Signal Corps test systems. Circuits which make up the digital control logic elements—gates, registers, counters, power amplifiers, relay drivers, comparators, program controllers, and tape controls—all have proven records of operational reliability.

APATS automatically performs preprogrammed tests on vehicle and satellite specimens while they are contained in the simulator. Tests include: 1) generating stimulus, 2) programming the exact destination to which the stimulus will be sent, and 3) evaluating the specimen's response to each stimulus, using comparison techniques. Results of the tests are decoded, stored, displayed, and/or printed out on hard copy.

In the case of the RF data-link interface subsystem, stimuli are in the form of an RF interrogation of the specimen under test. Specimen return to APATS is stored on video tape and simultaneously translated by pulse-amplitude-modulated telemetry apparatus into analog voltages representing the data being transmitted.

THE APATS EQUIPMENT

APATS consists of five major subsystems: a system test control unit, an RF data-link interface system, a tape-recorder console, a power-distribution console, and a mobile unit containing the peripheral equipment. The APATS equipment is mounted in 12 racks and uses standardized modules (Figs. 1 and 2).

The system test control unit is comprised of a main junction box, specimen power supplies, signal distribution console, and a system programmer. The sys-

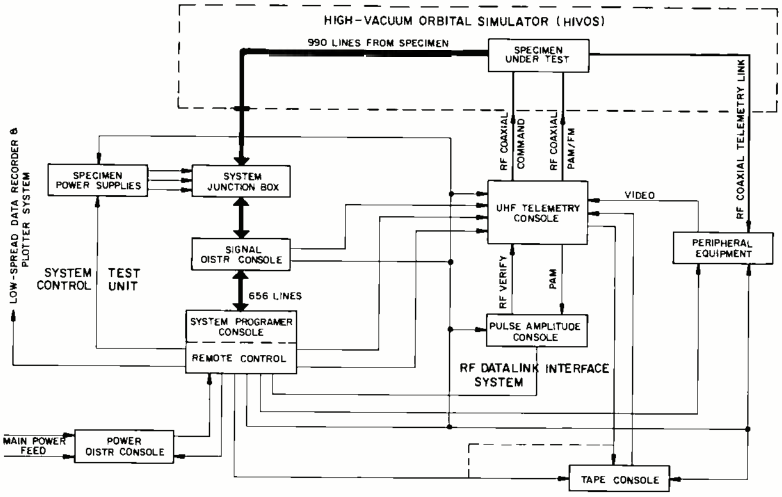

Fig. 2—The APATS system.

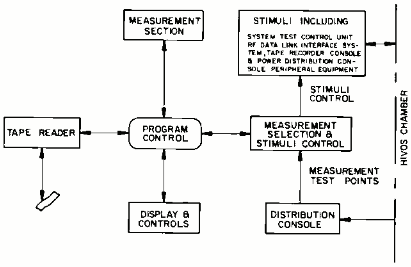

Fig. 3—APATS programmer.

tem junction box receives voltage-monitoring stimuli and sensor lines from the specimen. These lines are routed to the signal distribution console. Outputs from the lines are available at a patch panel on the distribution console where they can be monitored, recorded and, as necessary, controlled. Monitoring, recording, and evaluation of specimen-activation events and specimen malfunctions are performed by this console.

PROGRAM CONSOLE INTERPRETS TEST ROUTINE

The program console performs the function of a central programmer-comparator. In addition to remote control of the other APATS consoles, the console automatically performs all of the comparison and evaluation measurements of the specimen function. The programmer controls the selections of stimuli, selects test points to be monitored, and determines program continuation in accordance with the measurement and evaluation results.

The RF data-link interface system consists of a UHF telemetry console and a pulse-amplitude-modulation (PAM) console. The UHF telemetry console transmits self-contained, preprogrammed command messages to the specimen through coaxial cables. It is also capable of performing wide-band and narrow-band evaluation of power, frequency, and frequency deviation of the PAM telemetry wave train received from the specimen. The PAM video is recovered and sent to the tape reader console for storage, and to a discriminator for demodulation. The resulting pulse amplitude signal is fed to the telemetry console, where it is processed for main frame and subframe separation. The peripheral equipment cart contains a VHF telemetry receiver and provisions for six discriminators. The output of the receiver can be fed into the UHF telemetry console discriminator for VHF-PAM telemetry processing.

The programmer (Fig. 3) automatically interprets programmed test routines from the tape reader, and then carries out the orders as directed. In performing test routines, the programmer: 1) provides stimuli and peripheral equipment control to the other consoles of the APATS system; 2) selects the desired measurement test point, function and range; 3) performs evaluations to determine if the measured parameter is within acceptable limits; and 4) based on the results of each test, makes decisions—such as deciding the test routine to perform next or when to stop testing.

PROGRAMMER OPERATION

The programmer unit is operated as a bit-serial, character-serial device, which minimizes the circuitry required, and increases over-all reliability. The bit-serial operation does not increase the over-all testing time of the system, since each character from the tape reader is processed in a fraction of the time that it takes for the tape reader to move from one character to the next. This is because the tape reader performs conversions at the rate of 200 characters or frames/sec. (Actual character read time is approximately 1.7 msec, while the time required to process the character is less than 0.16 msec.) Thus, a factor of greater than 10 to 1 exists between programmer processing time and the tape-reader conversion rate.

In the normal mode of operation, data pertaining to a particular test sequence are searched for and, when located, read into the programmer. Tests on the tape are preceded by tape address instructions and addresses, enabling the programmer to locate desired data and to sense when to read data into the programmer. After completing the tape search operation, the programmer performs the test sequences stored on the tape.

Over-all operation is controlled by instructions obtained for either the test sequences, manual commands, or remote inputs. During testing, the program control elements obtains instructions from tape, interprets them, and issues appropriate commands to other units. Instructions may also contain *display* or *print* commands, or they may select a particular measurement range and measurement function. These instructions may be: 1) commands selecting particular stimuli, 2) commands setting up other console functions, 3) measurement test-point selection commands, 4) a comparison command, or 5) commands to branch to a new series of tests.

At all times, the program control (along with the instructions) controls the flow of data to and from the various units of the system. Provisions for remote control of the program control unit are included in the system for interrupting programmer operation until a particular subsystem operation is complete.

A TYPICAL TEST SEQUENCE

A typical test sequence might require data to be routed to the stimuli control unit, which would then select the desired stimuli for the specimen under test in the HIVOS chamber. Next, the measurement test-point selector would be commanded to route the proper monitoring point from the distribution console to the measurement section. The instructions would then select the range and type of measurement, followed by a setting of the upper and lower limits of the parameter to be measured.

After a comparison command, the programmer would be instructed to either branch to a new test sequence or continue on to the next test in the original sequence. This process of performing tests from tape would be continued until testing was completed or stopped, or a defective unit was detected.

The system junction box provides terminal points for 990 incoming specimen lines. In addition, it accepts DC power from the specimen power supplies for routing to the unit under test. Incoming specimen lines are routed to the distribution console, where any information from the specimen can be monitored, recorded, or controlled. Of the 990 lines, 656 lines are routed from the distribution consoles to other APATS consoles. Specimen power supplies are controlled both locally and remotely from the programmer console.

Signal Distribution

The signal distribution console receives signals of the specimen function that are routed through its interface connectors. Signals from the specimen umbilical and test plugs are routed via a patch system to their respective connectors. These and other signals generated by the system programmer and the system test control unit may be monitored on the input-test-point panel with a digital voltmeter and an oscilloscope. In addition the distribution console provides a means for automatically monitoring the squib lines of the HIVOS Specimen.

RF Data-Link Interface System

Upon command of the programmer console, a message generator converts and clocks the 39-bit parallel message information from the punched-paper tape reader to 37 bits of message. These are fed serially to a voltage-controlled oscillator. The remaining 2 bits are used to recognize one of four different types of message formats. Message-type information is used to gate the 37 circuits that select the bit-time slots to be blocked for each message.

Output of the voltage-controlled oscillator (VCO) is one of three frequencies: 43 kc for a logical *1*, 37 kc for a logical *0*, and 40 kc for no information. The VCO output is mixed with a 1-kc sine wave generated by a 1-kc clock in the message generator. The resultant signal is used to frequency-modulate a 1700-to-1850-MC signal generator. This FM command signal is transmitted to the specimen unit under test via a coaxial cable.

The signal generator output also can be routed to a spectrum analyzer and a frequency counter, where its deviation and frequency are monitored during initial adjustments of signal-generator characteristics.

Upon receipt of a valid message, the specimen generates a 10-msec message-acceptance pulse (MAP) which is sent back to the console on one of four lines. Two lines are RF telemetry and two lines are umbilical information. It is from these sources that continuation of messages into the specimen are governed. If the MAP is present on the proper line at the time when the message generator generates a MAP interrogation pulse, a *tape reader advance* pulse is generated. If a MAP is not generated or is not on the proper line, an *error* signal is generated and the tape is prevented from advancing.

The Telemetry Console

The telemetry console also accepts a PAM-FM-FM signal from the specimen. This signal, at a frequency between 2200 and 2300 Mc, is coupled to a wideband preselector and a narrowband preselector through a power divider. The wideband preselector selects a 24-kc spectrum which is fed to the frequency counter and spectrum analyzer for evaluation of frequency accuracy and deviation. The narrowband preselector, with a bandwidth of 800 kc, selects only the desired signal spectrum. The selected signal is then coupled to another crystal detector for power monitoring and to a superheterodyne receiver where the video signal is extracted.

The video is then fed to a high-speed magnetic-tape recorder and stored for later and thorough evaluation. The video signal is coupled also to a heterodyne discriminator, where the PAM is extracted. The PAM signal is routed to the PAM console, where channel separation and monitoring is performed.

The PAM Console

The PAM console accepts PAM pulse-train signals from the specimen through the telemetry console and demultiplexes them for measurement. Operation of this console is controlled by a programmer which is part of the console. The console has visual digital display and simultaneously records the measurement results of the channel selected by the programmer on punched paper tape and on a decimal printer. This operation is performed sequentially for each channel selected by the programmer.

The PAM console also continuously monitors 11 manually preselected channels simultaneously. Each output of 10 of these channels is displayed on an individual DC voltmeter. The remaining channel monitors the RF data-link PAM *verify* MAP signal which is routed to the telemetry console. Eleven of the possible 2048 channels are montored continuously. All preselceted channels are processed sequentially and fed into a tape punch and to a digital printer for display. Outputs from the tape-punch are used to store telemetry data on punch cards for subsequent data analysis.

The only external commands required by the PAM console are those for *start* and *stop*. These commands can originate either from the programmer console or from an associated remote-control unit. A portable unit containing a receiver is used to further enhance the reliability of data acquisition from the payload by providing an alternate channel for the reception of VHF telemetered data.

Power Distribution Console

The power distribution console accepts two feeders from commercial power lines: 208/120 volt AC, 3-phase, 60-cycle, 4-wire, *Y*-connected. Each feeder is capable of transmitting a maximum of 100 amperes to the console, and each phase is monitored for voltage and current.

Power is routed to a circuit breaker panel and then to the running-time meter panel. The accumulative running-time meters monitor *on* time of the twelve 30-ampere, 3-phase power lines. The power is then distributed to the test consoles and to a low-speed data and plotting system. Metering and controls are provided to monitor and control power to the consoles and the 120-volt-AC single-phase outlets.

CONCLUSION

APATS is designed to fulfill the need for automatically performing the complex testing routines necessary to assure the proper operation of aerospace electronic equipment. A significant feature is that it is comprised of proven, field-tested equipment.

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TECHNIQUES FOR INFLIGHT SUPPORT OF FUTURE SPACE SYSTEMS

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Because future space missions will be complex and the "payloads" will involve more-sophisticated equipment (and often be manned), considerable effort must now be directed to maintenance and support of the space vehicle while in flight. This article briefly describes some of the problems confronting the space systems support engineer and a few of the solutions proposed.

In early space vehicles, little or no thought was given to problems of maintaining or supporting the prime vehicle. The "support" problem was only a detailed checkout of the booster and whenever possible, a one-shot check of the simple payload prior to launch.

Now, we are operating and planning spacecraft systems to perform extremely complex missions. Multi-function payloads have reached a level of complexity requiring a checkout procedures equal to those of the boosters; additionally, space vehicle checkout may become necessary while in orbit.

For manned payloads, for example lunar missions of extended duration, inflight maintenance is highly significant because of heavy emphasis placed understandably on crew survival. The longer the mission duration, the greater the difficulty in meeting reliability requirements; consequently, the need arises for additional modes of achieving mission success—such as redundancy and maintenance.

SPACE MISSION ANALYSIS

The vehicle mission and its reliability profile must be examined first in specifying a space maintenance system. The vehicle mission indicates payload weight limitations and flight duration. Reliability data provides an estimate of system survival probability for a given mission duration. These factors influence the degree of redundancy, the choice of in-space maintenance, the repair techniques and tools necessary to maintain vehicle subsystems at the desired reliability level.

Four basic mission profiles for manned vehicles are presently being considered:

Mission 1 is primarily for research and reconnaissance, with durations of 1 to 17 orbits, and altitudes in the vicinity of 80 to 200 miles. The present Mercury capsule and DynaSoar vehicles constitute space missions of this nature.

Mission 2 would be a surveillance, reconnaissance, satellite inspection, maintenance, rescue or ferry-type system. It would use heavier and more advanced versions of the Mercury-Gemini and DynaSoar vehicles, maneuverable and multi-manned. Orbital altitudes up to 1,000 miles and mission durations of 3 weeks are being considered.

Mission 3 represents a permanent orbital station at altitudes up to 1,000 miles to serve as a platform for extensive astronautical and biological observations, as well as an assembly point for lunar and other planetary missions. Construction would be undertaken by docking techniques of substages ferried into space by the methods of Missions 1 and 2.

Mission 4 represents lunar and other planetary missions, probably assembled in either earth or lunar orbit with the aid of techniques developed for Missions 1, 2, and 3. It would contain various mission modules such as booster, mission, command, lunar landing, and earth-return re-entry vehicles.

The penalty of putting these vehicles into space in respect to *launch weight* (combined booster and payload at take-off) is shown in Fig. 1. Small unmanned scientific payloads and communication satellites of 100 pounds require launch weights of 36,000 pounds for low orbits and up to 100,000 pounds for lunar probes. Larger manned payloads for lunar or military surveillance missions of the 10,000- to 20,000-pound class may require launch weight up to 1 million pounds. For lunar landings and return, launch weights may approach 8 million pounds, requiring 12 million pounds of thrust.

When the cost of launch facilities, ground tracking, and the family of boosters are considered, the importance of a successful mission is evident. Fig. 2 examines the survival probability of each of the four space missions mentioned. The exponential failure rate $P_s=\exp(-t/\text{MTBF})$ is assumed.

The relative equipment simplicity of the unmanned communications satellite, for example, requires no post launch maintenance. The *manned* surveillance and lunar missions present a more serious picture. Equipment complexity plus mission length lower the reliability considerably. Figs. 3a and 3b show improvements with equipment redundancy, spares, and maintenance added. Periodic checkout of the extended surveillance mission system will raise the confidence level to near 100 percent each time a successful test and needed repair is made. Test interval is chosen at 10 hours; confidence level decays exponentially to 93.5% at the end of this period when the next test is performed, and so on. Failures occurring during the mission will be picked up at each test interval and repairs made from spares carried aboard. This cycle continues until all spares are exhausted (1,008 hours, or six weeks) at which time the complete exponential decay begins.

For a lunar mission, only a limited amount of spares may be carried, usually as built-in redundancy. Because of weight limitations, redundancy must be highly selective and applied only to those equipments that have relatively lower reliabilities. The improvement is made only to the degree necessary to give a 90-percent probability of survival for 336 hours, or 14 days.

MAINTENANCE AND REPAIR TASKS

As shown in the reliability profiles of the space missions, *inflight* maintenance can make up the difference between the actual and desired probabilities of success in complex, especially manned, missions. Vehicle weight limitations impose restrictions on the amount of spares and test equipment that may be carried. Crew tasks and work loads affect the amount of testing that can be done manually and impose requirements for some automation when limitations in human reaction and mobility can jeopardize crew safety during emergencies. Fig. 4 illustrates a flow of possible maintenance actions. The levels of maintenance action can be defined as follows:

1) *Overt fault recognition (monitoring).* The operator can quickly and easily detect that his equipment is not functioning properly. The operator can be in a vehicle, in a ground station, in an orbiting repair vehicle or in an orbiting repair base.
2) *Straight-through dynamic testing* which can localize faults to major subsystems and detect calibration requirements with minimum signal inputs.
3) *First-level fault diagnosis* which can detect faults in major assem-

blies and subassemblies of the subsystems.

4) *Second-level fault diagnosis* which can detect faults to the module or major-component level.
5) *Third-level fault diagnosis* which can detect faults to the part level.

Specific repair techniques can be classified as:

1) Direct replacement using parts from the logistic store.
2) Direct replacement using cannibalized standard part from nonpriority equipments.
3) Rebuilding by means of simple construction techniques.
4) Self-repair or self-healing wherein the failed unit or part can adapt itself to a new condition or can cause inherent changes in its structure that can be construed to be repair.
5) Redundancy by automatic and manual switchover to new unit.

In addition, the essentials for effective maintenance include adequate inventory of spares and materials for repairs, sufficient repair kits and tools, technical instruction and prepared diagnostic maintenance routines for malfunction analysis, and prime-system design specifications that enhance maintainability.

In general, the weight and cost for inflight maintenance of a composite mechanical-electronic vehicle system depends on the level of repair. Fig. 5 shows parametrically the relationship between weights of onboard checkout equipment and level of replacement made. It is apparent that for repair at the lowest level (piece, part, or component) considerable numbers of test points, cabling, and instrumentation is required to isolate each failure, though the weight of spares is relatively low. Conversely, little instrumentation is required if failures are to be isolated to major subsystems or assemblies, but the weight of spares would be high, approaching that of the total system. Disregarding other considerations, the optimum selection in this case might be at the intersection of the two curves.

CHECKOUT TECHNIQUES

Checkout techniques may be initiated manually, automatically, or a combination of both. On the more complicated vehicle missions, the crew may not be able to perform all of the maintenance tasks manually, because of the work load from other duty assignments. As an example, the equipment complexity in an extended surveillance mission could require 300 separate tests for an adequate checkout — manually, requiring $2\frac{1}{2}$ hours to perform. With some automation, this same test requirement could be accomplished in 15 minutes.

Preliminary space-vehicle analyses have emphasized the use of the central control and guidance computer on a time-share basis to provide the framework for automating the test functions. Since the computer load is cyclic (being most active during launch, orbital transfer and reentry), the other periods are available for use in fault diagnosis and control of checkout routines.

Dynamic straight-through system testing lends itself readily to computer-controlled test routines. A considerable amount of test information may be gained from this technique with a minimum of input stimuli. This is based on the premise that a dynamic exercise of the system under realistic operating conditions provides more-precise indication of performance than does successive monitoring of static signals such as power-supply voltages and current. The insertion of simulated radar returns into the front end of a surveillance radar system is an example of this technique. The performance may be evaluated at the output of a data correllator end, along with discrete measurements at selective points of the system, provide a measure of receiver sensitivity, dynamic range, frequency stability, and resolution, with a very limited number of input stimuli. The onboard computer can initiate the test at selective intervals and perform readout comparisons with its memory and, additionally, perform fault isolation to the module level.

Consideration has also been given to the use of telemetry testing whereby programming and data analysis for fault isolation is accomplished on the ground. Telemetry has become a standard subsystem for all space missions and has a high availability on a time-share basis.

Fig. 6 illustrates an application of this technique. A periodically transmitted test message from a ground S-band system is received by the space vehicle, and by its proper address through the command and control initiates commands to guidance and surveillance subsystems. The response of this exercise will be subsequently retransmitted back by return telemetry on the control subcarriers. Comparison and analysis of the returned data with the initial instruction on the ground determines loop performance. Appropriate signal pick-offs in the vehicle subsystem provides fault isolation to a replaceable module or black-box level. The space crew would perform necessary repair based on instruction from ground as to location of failure.

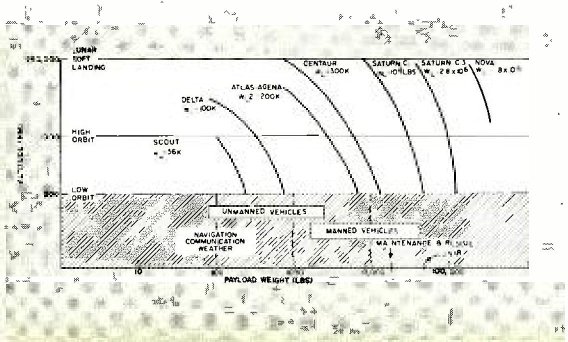


Fig. 1—Launch weight, W_L, and payload weight of various space missions.

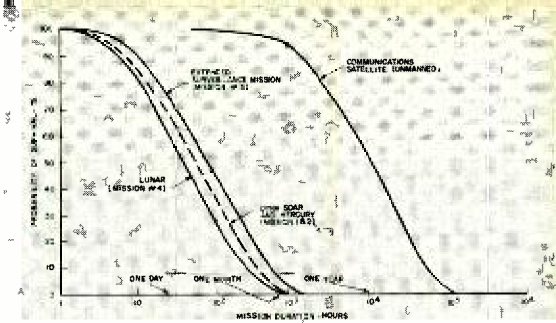


Fig. 2—Survival probability, P_S, of four types of space missions, where $P_S = \exp(-\lambda t)$, with $\lambda = 1/\text{MTBF}$

AUTOMATIC TEST EQUIPMENT

An automatic checkout system can be used to perform the calibration and dynamic-testing function, first-level diagnostic testing, and in several cases, the final diagnostic testing. Certain assemblies may require this technique at the assembly level only. Further isolation would then be accomplished manually. A proper assignment or allocation of maintenance tasks between automatic and manual test equipment would be accomplished based on crew work loads and criticality of equipment to failure rate.

An automatic test system that might be used on a permanent satellite or a lunar mission may contain:

1) *Programming equipment* that provides coordinated and precise control of the test equipment and the unit under test by using prepunched or magnetic tape.
2) A *switching unit* that selects test points determined by the programmer and routes signals to the test evaluator.
3) A *comparator* that accepts the information from the test points as ordered by the programmer and determines if the selected test results are within permitted tolerance.
4) An *operator's console*, including control and display devices to present the evaluation of the tests to the operation.
5) An *adaptor unit* that is the link between the tester and the unit under test.
6) A *stimulation unit* that provides signals to be injected into the unit under test.
7) A *measurement unit* which provides a standard for the comparator.

The final design and program storage

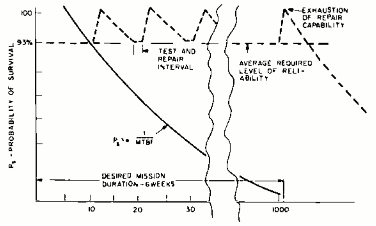


Fig. 3a—Extended surveillance system reliability profile, MTBF=127 hours.

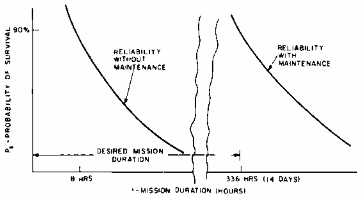


Fig. 3b—Lunar mission reliability profile.

capacity of the system is defined by the number of items to be tested and the number of replaceable or repairable items within each subsystem.

Although an automatic tester reduces such problems as test time and personnel skill requirements, it creates new problems of weight and space requirements. This problem is partly alleviated by using the primary guidance computer in place of the programmer-comparator on a time share basis and, wherever possible, functions "borrowed" from the prime equipment.

Manual test equipment might well be used by the maintenance man to perform diagnostic testing and fault location in areas not covered by the automatic test system.

UNMANNED SATELLITE SYSTEMS

For relatively simple, unmanned satellites, inflight maintenance only becomes a factor if a *system* of several satellites must be in orbit for a desired mission and if such a system is worth maintaining. Thus, in the case of a single-function vehicle, one of perhaps twenty in the system, if the controlling agency is satisfied with less than perfect operation, either no maintenance or "maintenance" by direct replacement is adequate. However, if the satellite is multi-function and of considerable weight and cost, and if its proper operation is of great strategic or tactical importance, then destruction and direct replacement may well be too expensive and perhaps impossible for a variety of reasons—not the least of which is the possibility of no readily available launch capability. In this case, there may be an economic and technical necessity to send a manned or unmanned vehicle to rendezvous with the malfunctioning satellite in order to make repairs.

For the unmanned vehicle transmitting data to monitored ground stations, a common form of fault recognition is by overt means, i.e., the ground station detects system failure through data analysis. If the ground station is unmanned for extended periods of time, the use of programmed and periodic checks of the parity of the data received will uncover the overt failures.

During reduced periods of operation where time is not at a premium, a certain amount of first- and even second-level fault diagnosis can be performed utilizing a fairly wideband data-link system as previously shown in Fig. 6. Greater depth of isolation than this, though, is unlikely, since the bandwidth requirements and the normal noise arising in space communications systems reduces the accuracy of this method.

MAINTENANCE SUPPORT VEHICLES

The discussion up to this point has concentrated on those space vehicle missions where maintenance can be accomplished from resources within the vehicle or in combination with resources available on the ground. For extensive orbital operations dealing with large payloads and indefinite mission durations, it appears that a shuttle or a support space vehicle must be created to satisfy logistic demands in the way of periodic exchange and replacement of personnel and supplies. Vehicles weighing in the vicinity of 10,000 pounds or higher fall into this category. With current launch costs running $2500 per payload pound, it becomes more economical to service large vehicles in space as opposed to returning them to the ground and re-launching each time maintenance and supply is required.

The separate support vehicle also satisfies the rescue requirement. Docking and rendezvous must become a routine function if rescue is to be accomplished. Maintenance and logistics will merely exploit it. A typical conceptual design of a space rescue and logistics vehicle using the DynaSoar, or glide, re-entry configuration is shown in Fig. 7. This vehicle might weigh in the vicinity of 40,000 pounds and have fuel capacity for servicing seven or eight satellite systems in 150-mile-high orbits. The combined payload weight of the system it would be servicing could be as high as 200,000 pounds.

ALLOCATION OF MAINTENANCE AND REPAIR FUNCTIONS

There are numerous ways in which the test and repair functions can be allocated with a support vehicle. Table I illustrates seven of these, called *configurations A* through *G*.

In a self-contained support vehicle like *configuration A*, using present-day miniaturization, the entire test and repair unit may weigh over 2000 pounds and occupy a space of more than 300 cubic inches. By 1965-68, using presently conceived miniaturization techniques, this could reduce to about a quarter of that size and weight. By 1975, thin-film-circuits with (by then) demonstrated reliability may allow a weight of about 200 pounds and a size of about 30 cubic inches.

Configuration B is a manned support vehicle which contains only the man and his tools. The vehicle under test contains its entire self-test equipment, and houses its own spares. This is *not* a too-far-fetched approach if one considers the possibility that this manned support vehicle may be on an extended maintenance tour of many vehicles in a large system. Conceivable is a system design wherein the visiting maintenance man can make use of the prime equipment so that, in effect, it tests itself. Spares are obtained either from the vehicle storage or by cannibalizing other less important parts of the prime system.

Configuration C is a middle-ground system which makes use of the fact that much of the stimuli requirements can be found among the functions of the prime vehicle.

Configuration D is another approach that makes use of either a ground station or an orbiting station. This system depends upon the communication link between the repair vehicle and home base. Since this link will always be available but may not always be in use, it can be adapted to this purpose.

Summarizing, then, from the point of view of size and weight of the test and repair portions of the *manned* support vehicle, one can rank from the highest

Fig. 4—Maintenance action flow analysis.

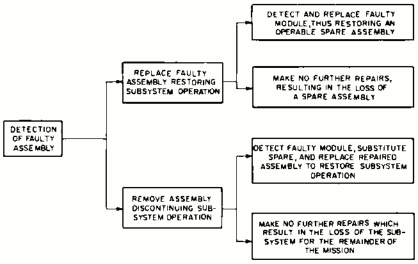
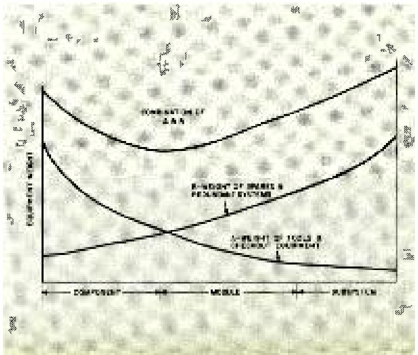


Fig. 5—Level of replacement.



weight to the lowest as follows: Configuration *A*, largest; *C*, next largest; *D*, third largest; and *B*, least size and weight. It might be expected that in the 1965-68 period, the size and weight of configuration *C* would be 300 pounds and 50 cubic inches; and of configuration *D*, 180 pounds and 30 cubic inches. Additional reductions for the 1968-75 period can only be guessed.

TABLE I—Allocation of Maintenance and Repair Functions

Basic Support Equipment	*Function Allocation* *Ground or Orbiting Base Station*	*Support Vehicle*	*Prime Space System*
.........MANNED SUPPORT VEHICLE.........			
Configuration A:			
Programmer—Comparator		X	
Switching		X	
Display		X	
Adapter and Manipulators		X	
Stimuli		X	
Measurement		X	
Spares		X	
Tools		X	
Configuration B:			
Programmer—Comparator			X
Switching			X
Display			X
Adapter and Manipulators			X
Stimuli			X
Measurement			X
Spares			X
Tools		X	
Configuration C:			
Programmer—Comparator		X	
Switching		X	
Display		X	
Adapter and Manipulators		in part	in part
Stimuli			X
Measurement		X	
Spares		in part	in part
Tools		X	
Configuration D:			
Programmer—Comparator	X		
Switching		X	
Display		X	
Adapter and Manipulators		in part	in part
Stimuli			X
Measurement	X		
Spares		in part	in part
Tools		X	
.........UNMANNED SUPPORT VEHICLE.........			
Configuration E:			
Programmer—Comparator	Programmer	Comparator	
Switching		X	
Display	X		
Adapter and Manipulators		X	
Stimuli		X	
Measurement	X		
Spares		X	
Tools		X	
Configuration F:			
Programmer—Comparator	X		
Switching	X		
Display	X		
Adapter and Manipulators		in part	in part
Stimuli	X		
Measurement	X		
Spares			X
Tools			(redundancy)
Configuration G:			
Programmer—Comparator	Comparator	Programmer	
Switching		X	
Display	X		
Adapter and Manipulators		in part	in part
Stimuli			X
Measurement	X		
Spares		X	
Tools		X	

The *unmanned* support vehicle (configurations *E*, *F*, and *G*) makes more use of the ground or orbiting base facility.

In *configuration E*, the vehicle under under test and repair is entirely passive. This system depends upon a very broad communication capability. Indeed, while for the manned vehicles size and weight were the controlling factors, in this case. communication capability is more important. For this extreme case, all of the testing is essentially controlled from the base station.

Configuration F clearly requires an extensive communication system and keeps test and repair load weight to a very minimum. If the manipulative devices are large, complex and heavy, this may well be a required procedure.

Configuration G reduces the information-transfer requirements by placing the programmer in the support vehicle. Thus, a fixed program can be used. A reduction in flexibility results but this loss must be weighed against the need for more communication facilities.

SUMMARY

Much progress in space technology is needed before the details of support problems are identified. It must be remembered that where the mission has limited alternatives. the requirement for checkout and repair is reduced. Similarly, if the crew is limited in its modes of action. as for example. having only to decide whether to continue to the next phase of the mission or abort, the degree to which checkout is performed is limited to that necessary only for making this decision.

ACKNOWLEDGEMENTS

Credit is due W. A. Rose, of ACCD Camden, for data shown in Fig. 1.

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T. Taylor

H. S. Dordick

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H. S. DORDICK received his BS from Swarthmore College and MSEE from the University of Pennsylvania, and will receive a Ph.D upon completion of his thesis. He has also completed the course work for an MS in Operations Research and Systems Engineering at the University of Pennsylvania. Before joining RCA, he was employed by Leeds and Northrup as a development and applications engineer. With RCA since 1954, he is Leader of a group performing operations research studies on system-support for advanced space vehicles. In addition, his group is also responsible for Life Sciences and Bio-Satellite work within DEP. He is on the staffs of the Graduate Hospital of the Graduate School of Medicine of the University of Pennsylvania, and the Pennsylvania Hospital, where he is engaged in research on the determination of Ovarian Function by means of electronic sensing devices. The work is being done on a National Institute of Health grant. Mr. Dordick is an author & co-author of numerous papers on Life Science, Systems Support, and Automation.

Fig. 6—Checkout of space vehicle using telemetry, with programming-and fault-analysis

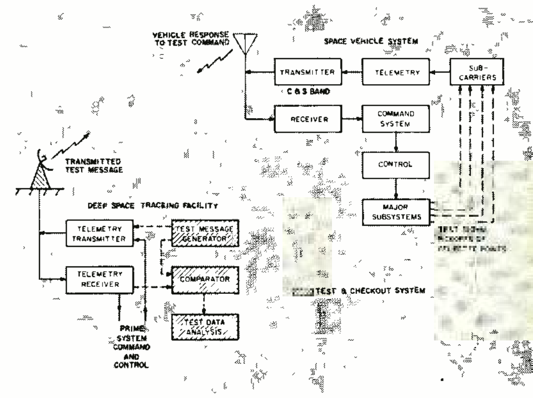
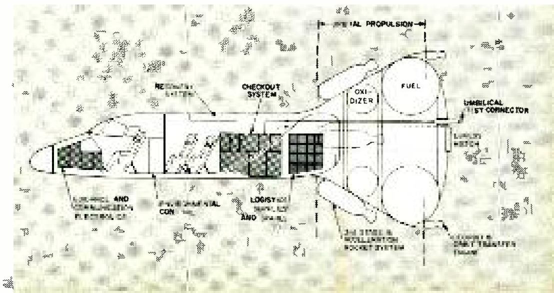
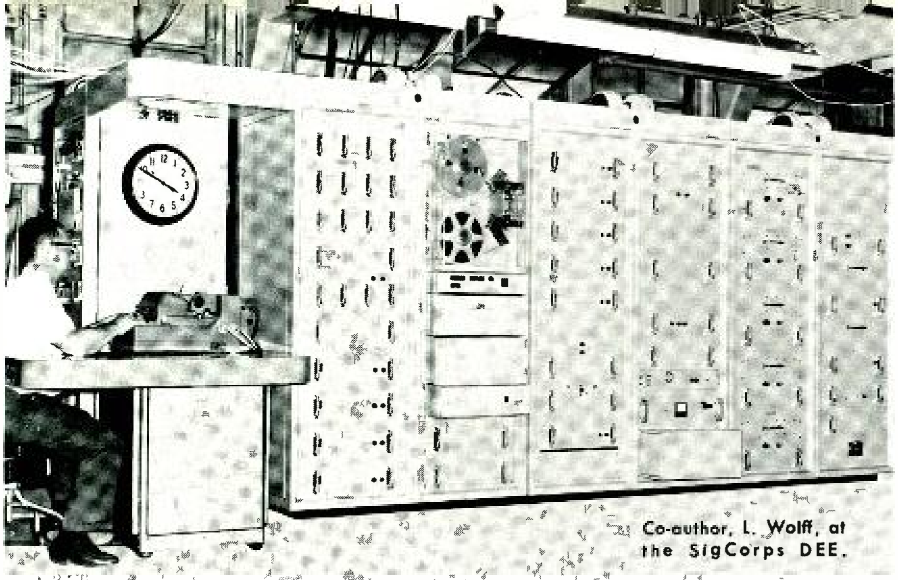


Fig. 7—Logistics and rescue support vehicle. subsystem on ground.





Co-author, L. Wolff, at the SigCorps DEE.

THE SIGNAL CORPS DEE
...Advanced Digital Evaluation Equipment

D. B. DOBSON and **L. L. WOLFF**
Systems Support Engineering
Aerospace Communication and Controls Division
DEP, Burlington, Mass.

The Signal Corps DEE is an advanced, general-purpose, self-checking, readily expandable test system installed at the Tobyhanna Signal Depot, Tobyhanna, Pennsylvania. It incorporates all-transistor logic and continues the modular construction developed on the Ordnance DEE Programs to attain the highest performance level with the lowest possible equipment and maintenance costs.

GENERAL DESCRIPTION

The new Signal Corps DEE is a complete test system, capable of handling alphanumeric data, that uses magnetic-tape storage and punched-paper-tape input-output, and provides a printed tape output. In addition, an internal high-speed core memory provides bulk storage for fast random access to data and programs.

The computer is a general-purpose, digital, sequentially controlled, random-access, transistorized machine. It consists of a number of integrated units (and attendant power supplies): a high-speed memory, program control, tape selecting and buffer unit, and control rack with an associated paper-tape punch and reader, automatic typewriter, and electronic printer.

PROLOGUE: A PROGRESSION OF CHECKOUT EQUIPMENT DESIGN

The advanced Signal Corps DEE equipment evolved from digital evaluation equipment[8] designed by DEP-ACCD Systems Support engineers, which proved to be the forerunner of the several related and modern equipments. In 1961, RCA received a contract to completely refurbish and update the "Grandfather DEE." This modernized equipment, the "Letterkenny DEE," was installed during 1961 at the Letterkenny Ordnance Depot, Letterkenny, Pennsylvania; it is being used to test and evaluate ordnance missile component assemblies at the depot level.

Next was the successful development of a family of integrated, automatic, all-purpose test systems.[9] The DEE concept at this stage included these versions: programmed semi-automatic; programmed automatic, high-speed automatic, and computer-controlled DEE.

An offshoot of the programmed automatic version of DEE during the same period is the Factory Automatic Test Equipment (FATE), featured on the front cover of this issue. FATE uses a disk memory rather than an aperature plate memory, as test requirements dictated repetitive test of a relatively low number of units on a production-line basis. Stimuli generators were selected to fulfill test requirements as specified by manufacturing personnel. Operation is essentially identical to the Letterkenny DEE and the Signal Corps DEE described in this article. Another related test equipment based on building blocks similar to those used in the Signal Corps DEE is the Automatic Preflight Avionics Test Set, described elsewhere this issue.

The Signal Corps DEE described in this article is a still more advanced DEE equipment. This latest version, and in fact the whole DEE family, has resulted from Systems Support Engineering's success in tackling the U.S. Army Ordnance study programs launched in early 1960. That program had called for long-range planning of advanced building-block test equipment design. Each system has conclusively proved that the building block concept can be most efficiently reduced to specific hardware, economical to obtain and use. The outstanding advantage of this equipment is that the family of test equipment designs, on a modular basis, reduces the need for new design of the building blocks themselves for each new test system required.

The high-speed memory is a random-access regenerative aperture-plate device which provides storage and work area for programs and data. The size was chosen after careful analysis of the maximum test requirements. The memory has a capacity of 1000 characters (8000 bits). Each location is individually addressable and can store any one FIELDATA character. (FIELDATA was chosen as the machine language, since it is now the military standard.) The FIELDATA characters include all the letters of the alphabet, the ten decimal digits, control symbols, and special marks.

One character can be brought into the memory register and then regenerated in its original location in one 50-μsec cycle.

The program control is the arithmetic and logical control element. It interprets and executes the instructions of the program stored in the high-speed memory. The computer and the on-line peripheral devices operate in accordance with a stored program of single-address instructions. The instructions that can be executed by the program control include all the categories necessary for processing of data: input-output, data handling, arithmetic, and decision and control. Each instruction is made up of either six characters or one character. The instruction consists of three parts for the six-character instruction: 1) an *operation code* (read, multiply, transfer, etc.); 2) an *index* that determines the number of characters in the operand; and 3) an *address*, a four-character address of the addend, subtrahend, destination location of an item, etc. The single-character instruction consists of one part, an operation code stating that a particular operation must be performed.

The central-control equipment provides for complete monitoring of the operation of the DEE and the on-line devices, with panel display of test results and status-level action. Automatic or manual operation, maintenance, program insertion, and program testing can be accomplished from the central control.

The paper-tape reader accepts 8 holes

(bits)/frame on punched paper tape and operates at the rate of 10 frames/sec. It is used for initial program insertion, program testing, "one-shot" test programs, and insertion of periodically changing constants.

The electronic printer accepts data directly from the high-speed memory or the comparator-evaluator and operates at the direction of the stored program. The printer has a recording and indicating capacity of 12 digits, and prints out at a rate of 4 lines/sec. Higher-speed printers can be utilized, but capacity would be unused because of unit-under-test limitations.

The typewriter and tape punch are used for the original preparation and verification of punched-paper-tape programs and for subsequent input to the Dee storage media via the paper-tape reader. These devices are keyboard-operated and simultaneously print on paper stock the same information that is being punched on tape. The typewriter operates at a speed of 10 characters/sec. in the *read* or *print* mode. The *print* mode is used to give the operator necessary instructions.

The random-access file is an aperture-plate memory which provides fast random access, storage for data and programs. It operates under automatic program control. The memory has a capacity of 1000 eight-bit characters. The memory is capable of transferring from *read* to *write*, or *write* to *read*, and from *store* to *withdraw* of a character in 10 μsec.

The tape station contains the tape transport, used by the Dee for bulk storage of program information. The tape mechanism operates at 150 inches/sec forward and backward. Because of the great variety and number of units that can be tested by the Dee, together with the number of tests required by each unit, only magnetic tape affords the storage density required together with ease of access, cost, and space required.

TEST ROUTINES

The Signal Corps Dee automatically interprets test routines derived from a high-density storage device and performs the functions dictated by the instructions within the routines. In performing the test routines, the Dee: 1) provides stimuli to the unit under test; 2) selects the desired measurement test point, function, and range; 3) performs evaluations to determine if the measured parameter is within acceptable limits; and 4) makes decisions such as which test routine to perform next or when to stop testing, based on the result of each test.

By utilizing an internal random-access high-speed core memory and the circuitry of the Dee instructions, the Dee system has the following capabilities:

1) Measurement of circuit parameters may be stored and later recalled for additional computation.
2) Decision making and revision, or creation of new limits for subsequent tests.
3) Iterative test routines can be executed, such as simulating frequency sweep generation, searching for an unknown incoming frequency or voltage, or performing a series of continuity tests.
4) Common subroutines may be used repeatedly, thus reducing programming time and conserving storage space.

Random access capability is incorporated in the computer control logic, which makes it possible to gain rapid access to any portion of a test within a program on the magnetic tape, thereby extending the use of common subroutines. Bi-directional tape search capability is incorporated in the tape control circuitry. Search is possible in both the forward and the reverse directions, thereby reducing the average tape search time. This capability permits tape "jump" operations in either direction.

A typical test sequence, as determined by the instructions, might require data to be routed to the stimuli control unit, which would select the desired stimuli for the unit under test. The instructions would then select the type of measurement and the proper range. The *monitor* switch is then instructed to move to a particular position so that the desired function is routed into the measuring section. The digital output of the measurement section, representing the value of the measured parameter, is then compared against predetermined limit. After the results of the comparison are obtained, the Dee is instructed to continue into the next test or in the case of a faulty result it is instructed to branch to a new test routine in order to isolate the cause of the faulty reading. Whenever additional test routines are required, the magnetic tape unit is commanded to start a search for the desired block of data. When the desired data is located, it is transferred into the high-speed memory and the operations resulting from the new data are automatically performed by the Dee.

The procedure outlined above continues until the test program has been completed or a fault has been located which must be corrected before testing on that UUT can be resumed.

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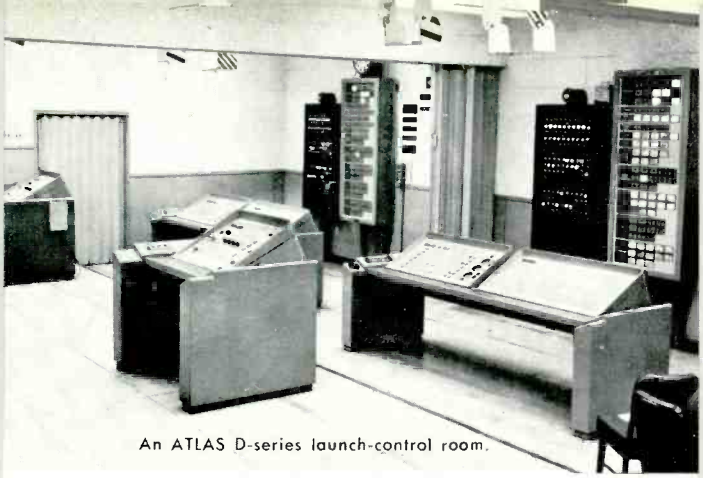
DAVID B. DOBSON received the BEE from Rensselaer Polytechnic Institute. At the Signal Corps Engineering Laboratories, Ft. Monmouth, N. J., he participated in the development of high-powered audio amplifying systems. Subsequently he was appointed the Electronics Member of the Army Psychological Warfare Board, where he engaged in the application of electronic equipment to psychological warfare. Upon joining RCA, he was first engaged in the production follow of fire-control radars. Later, he was assigned as Project Engineer for the maintenance engineering aspects of the MA-10 (AN/ASG-14) radar for the F-104, and was responsible for the design, construction, and delivery of two complete sets of USAF Depot Test Equipment for the radar. He next was responsible for the ASTRA Production and Depot Test Equipment design and development. With the formation of Systems Support Engineering, he became engaged in the application engineering of RCA systems-support products to new areas, with responsibilities for successful contract performance. He is a member of the IRE, the AIEE, and the Society of American Military Engineers, and has presented and published papers on many aspects of systems support.

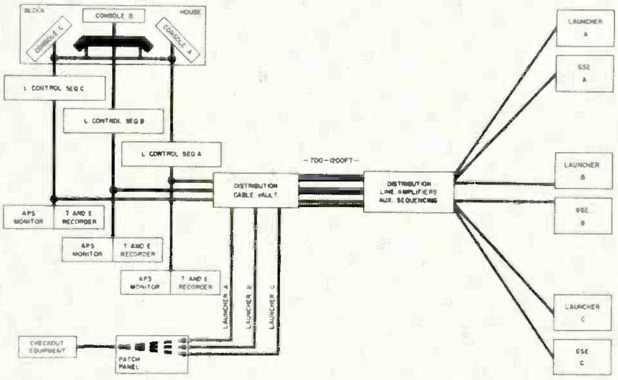
LARRY L. WOLFF received his BSME degree in 1939 from Prague University, and spent the following three years as a junior engineer designing heavy machinery. He served in World War II as an Engineer and Intelligence Officer in Europe and the Pacific theatres of war. After the war, he was a technical advisor and interrogator at the Nuremberg Trials. After serving again in the Korean War, he joined the Burroughs Corporation Research Center in 1955 and became supervisor of technical publications. With RCA since 1959, he has been assigned as publications engineer to the Systems Support Area of the Aerospace Communications and Controls Division in Camden, New Jersey.

AUTOMATIC PROGRAMMED CHECKOUT AND LAUNCH CONTROL FOR THE ATLAS MISSILE

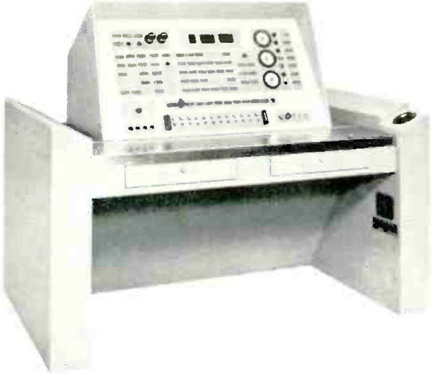
Missile and Space Projects Group
*Data Systems Division**
DEP, Van Nuys, California



An ATLAS D-series launch-control room.

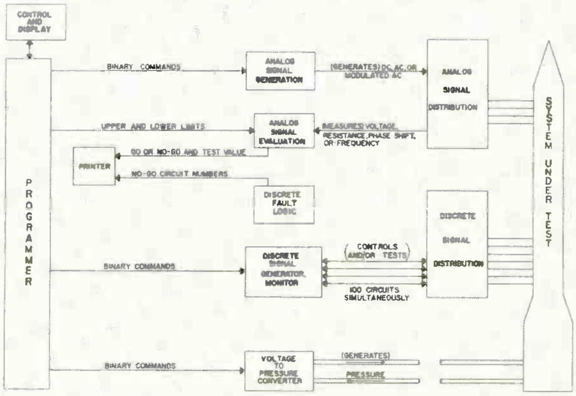


System diagram, ATLAS launch-control, and APCHE checkout equipment.

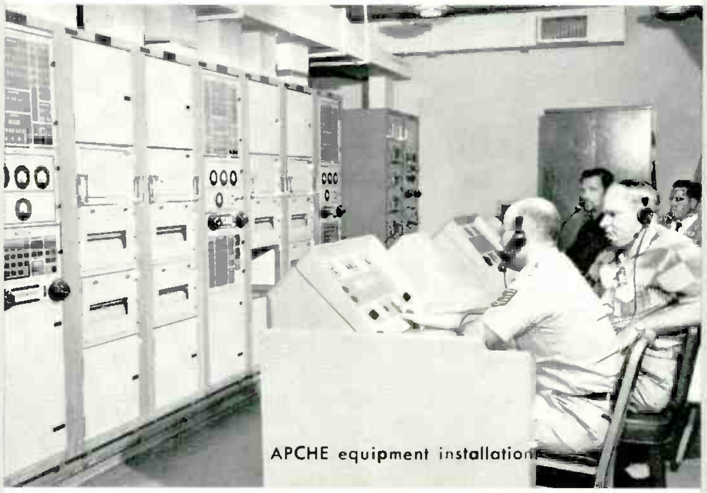


An ATLAS E-series unitary launch-control console.

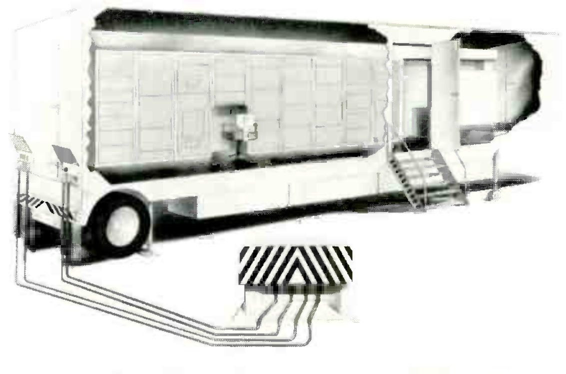
The Missile and Space Projects organization, which is managed by **W. M. McCord,** (photo, below) consists of the following activities: Product Support, managed by **E. B. Levinson**; Programming and Program Control, managed by **W. M. McCord** (Acting); Saturn Projects, managed by **W. Adams**; Advanced Projects, managed by **J. T. Underhill**; Design Projects, managed by **E. Green**, and Display Projects, managed by **B. G. Lewis.** This organization had its origin at the DEP Missile and Surface Radar Division in Moorestown, N. J., where one of its major functions was management of the ATLAS Program initiated in mid-1957 with award of a study contract from General Dynamics-Astronautics. In March 1959, the organization and the ATLAS Program (initiated in mid-1957 with award of a study contract) formed DEP West Coast Missile and Surface Radar Division (now called the DEP Data Systems Division, Van Nuys, Calif.). In early 1961, this project activity assumed responsibility of a contract awarded to RCA by NASA to produce a prototype 110 computer system for the SATURN automatic checkout and launch control. The initial order for the SATURN prototype 110 computer system was followed in February 1962 with an order for three follow-on systems plus associated equipment. In addition to the NASA work, the Missile and Space Projects Activity is actively engaged in displays, solid propellant booster checkout, and the redesign and production of the 110 industrial-control computer.



APCHE checkout system diagram.



APCHE equipment installation.



MAPCHE, mobile version of the APCHE system.

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*Formerly the West Coast Missile & Surface Radar Division during the course of the APCHE and Launch Control engineering work.

PROLOGUE

An Engineering Success Story

APCHE, Automatic Programmed Checkout Equipment for the ATLAS missile, and the ATLAS Launch Control Equipment are excellent examples of major RCA defense-engineering successes. From the early studies conducted in 1957 to the delivery of the advanced design Mobile APCHE in 1961, RCA combined its wide-spread defense talents and production skills efficiently. The result: a significant engineering accomplishment in the field of sophisticated automatic test and checkout equipment.

The DEP Divisions involved in the ATLAS engineering program included the Missile and Surface Radar Division at Moorestown, the Missile Electronics and Controls Division at Burlington, Mass. (now part of the Aerospace Communications and Controls Division) and the West Coast Missile and Surface Radar Division, Van Nuys, California (now the Data System Division).

Moorestown M&SR was the lead division for the ATLAS launch control project and handled the project management and system-concept work on APCHE. Detailed APCHE design and manufacturing was handled by the ME&C Division on a subcontract from M&SR. After the establishment of a separate West Coast Division, project management was transferred from Moorestown M&SR to West Coast M&SR. In addition, West Coast M&SR handled the final assembly, installation, and support.

What APCHE and Mobile APCHE have achieved for the operational ATLAS weapon system is best indicated by the following quotation from an Air Force Memorandum by Major Simms M. Spears:

> ". . . a comparison of an APCHE check to one accomplished by manual means, (personnel using standard test equipment) shows that APCHE can run a complete missile system test, including time to set up for tests and time to run decks, in an estimated 8 hours down-time for the missile. The same test performed manually would take at least 40 hours down-time—a factor of 5 to 1. An even more impressive comparison is that the APCHE test of the missile takes approximately 48 man-hours using six men, whereas the manual test has by actual experience, taken 600 man-hours with 15 men being required during the test—with most of the personnel required being highly skilled."

Credit for the successful fruition of the ATLAS program belongs to RCA design and development engineers too numerous to mention. Initially, the engineering program was under **G. F. Breitwieser,** then Chief Engineer of M&SR and now Chief Engineer of Data Systems Division. **S. L. Simon,** Chief Engineer of ACC in Burlington and **W. M. McCord,** Mgr. of the Missile and Space Projects activity in DSD Van Nuys headed up other contributing engineering groups.

Editor's Note: This prologue and article were made available through the cooperation of RCA ENGINEER Editorial Representatives, **D. B. Dobson,** ACC Systems Support Group, Burlington, Mass., and **D. J. Oda,** Data Systems Division, Van Nuys, Calif. The accompanying article is based largely on a paper written by **G. L. Seelig,** formerly with the Data Systems Division, Van Nuys, Calif. The Editors sincerely acknowledge his work in preparing this material.

THE ATLAS weapons system is this nation's first operational intercontinental ballistic missile. Its development covers more than a decade of intensive research, engineering, and test evaluation by numerous industrial contractors. The diverse efforts of this industrial team have been integrated by the General Dynamics–Astronautics Corporation under the direction of the Air Force Ballistic Systems Division.

PROGRAM HISTORY

For ATLAS, studies of the operational requirements for ground support equipment (GSE) were initiated in mid-1957. During July 1957, the RCA Missile and Surface Radar Division at Moorestown was awarded a six-month study contract by General Dynamics–Astronautics to establish the operational requirements and design criteria for a tactical launch control and automatic checkout system for the ATLAS.

Toward the end of 1957, the RCA study team had completed the major study program objectives for the Initial Operational Capability (IOC) weapon.

In December 1957, RCA was awarded a contract for the design, fabrication, and field installation at Vandenberg Air Force Base, California, of the first operational ATLAS Launch Control Equipment and the APCHE (Automatic Programmed Checkout Equipment). The program required equipment to be delivered to the field site during the fourth quarter of 1958 (9 to 12 months after contract authorization). *This stringent schedule was met.* The first hardware items left RCA Moorestown, New Jersey, in September 1958, and the last major electronic assembly was shipped to Vandenberg early in January 1959.

The equipment comprising this first operational installation (designated 65-1) included close to 200 major electronic units (cabinets, consoles, TV cameras, etc.) and 2500 interconnecting cable assemblies. The crash nature of the program is evident in that all equipment *was air-lifted* from RCA in New Jersey to Vandenberg by Military Air Transport aircraft.

During the first four months of 1959, the RCA equipments were interconnected and integrated as a complete system (more than 30,000 electrical interconnections) and formally delivered to General Dynamics for over-all site integration with the missile and other GSE. The weapon system was transferred to the Strategic Air Command and declared operational in August 1959. On 9 September 1959, approximately twenty months after the award of the development contract to RCA, the first ATLAS operational firing was successfully made by Strategic Air Command personnel at Vandenberg employing the RCA launch-control equipment.

During the latter part of 1958 and early 1959, RCA was awarded additional engineering, production, field installation, and site activation contracts for a total of 10 ATLAS-IOC complexes (comprising 30 launch installations) plus equipment for two R&D pads employing the ATLAS as a boost vehicle.

Overlapping the production and activation of the IOC squadrons, a second generation of operational ATLAS weapons was being developed. This advanced configuration, intended to provide greater security against nuclear bombardment, is designated the *Unitary System.* It is characterized by widely dispersed and hardened missile launching pads, each pad being separately controlled by its own autonomous launch control center. The Unitary System employs a later ATLAS missile series, with more powerful engines, an all-inertial guidance system, and considerably simplified airborne subsystems.

In May 1959, the West Coast Missile and Surface Radar Division negotiated contracts with General Dynamics to provide prototype launch control and checkout systems for this advanced ATLAS weapon. The first Unitary Launch Control equipment, consisting of one console and four assemblies (totaling the equivalent of 16 standard electronic cabinets) was delivered in December 1959 and early 1960. Because launching sites were dispersed, it was necessary that new missile checkout equipment be mobile. As such, a trailerized configuration of the checkout system known as the MAPCHE (Mobile APCHE) was designed. This equipment was designed, fabricated, and extensively tested under stringent environmental conditions prior to its delivery in early August 1960. Both systems were phased into production at an accelerated rate. By the end of January 1962, a total of 49 MAPCHE systems and 30 Unitary Launch Control systems had been delivered to General Dynamics.

OPERATIONAL LAUNCH CONTROL SYSTEM

To launch an R&D ATLAS missile, literally dozens of highly trained engineers and technicians labored ten, twenty, or more hours to complete the necessary manual countdown sequences. The imperative military requirement for a rapid retaliatory capability renders this manual approach totally inadequate.

Based on a review of R&D launching techniques and analysis of military doctrine, the following fundamental operational requirements were established for the tactical launch-control system:

1) The system must provide continuous, round-the-clock monitoring of

the state-of-readiness of the missile and GSE.

2) The system must permit rapid response to a *Strategic Alert*. Specifically, operating personnel must be able to transfer the weapon immediately from the standby condition to one of *ready-for-launch*.
3) The countdown sequencing must be automated, yet must provide for manual intervention to hold or abort the mission until the last possible moment prior to launch.
4) The system must feature maximum simplicity in data display and controls to assure error-proof operation by a minimum military crew.
5) The system must provide automatically for all necessary interlocks to assure maximum safety.
6) The system must provide for maximum reliability.

The tactical launch control system is based on the principle of *permissive sequencing*. In this system, an operator must initiate the countdown for the main missile and GSE subsystems. The sequence then proceeds automatically until a major check point is reached. The operator then must determine whether to "hold" or continue the sequence. If the countdown is to continue, he must manually initiate (depress an illuminated pushbutton) the next cycle. This allows for flexible control of a large system, but does not require the operator to have a detailed understanding of the complex system relationships. The knowledge that a check point has been reached in the countdown will usually provide sufficient information for the operator to proceed. Successful application of this method has reduced the launch crew requirements for the IOC system to two operators and one supervisor.

Launch operators man a dual-panel console called the *operator/analyst* console. From the *launch display and control* panel, the launch operator initiates, monitors, and controls the countdown of the missile and GSE through the permissive sequence cycle until the "final-commit" point is reached. A total of 12 manual pushbutton actions are required. The second operator, seated to the right of the first and in front of *launch analyst* panel, monitors in greater detail the various missile and GSE subsystems, determines causes of malfunctions, and recommends a course of action when faults arise. Information on the launch analyst panel is displayed by an illuminated, animated flow diagram of the propellant loading system, as well as by indicators depicting missile status. The displays are in sufficient detail to enable the launch analyst operator to recommend a decision whether to continue the countdown in spite of a malfunction, hold and repair, attempt manual override, or abort the launch.

The third crew member, the launch supervisor, commands and directs the overall countdown. He performs this vital function from a *launch officer* console which contains summary displays of all missile and GSE subsystems, plus an automatic digital countdown clock. Immediately prior to launch, the direct control of the countdown is transferred from the launch operator to the launch officer. It is his responsibility to activate the "final-commit" sequence leading to the ignition of the ATLAS engines and lift-off. Also located on the launch officer console is the "abort" button enabling the launch supervisor to prevent missile launch for functional or tactical reasons at any time unil the retraction of the missile umbilical cables.

In addition to the two operational countdown consoles described above, various other status, fault location, and facility panels are located in the blockhouse control center to provide specific types of detailed data. These are used during the 24-hour-per-day standby condition.

Extensive human engineering studies preceded the development of all consoles and display panels. The result of these efforts determined not only the panel layout and location of indicators and controls but influenced the launch philosophy and system concept. In describing the launch-control system, emphasis has been placed on the control consoles, because it is from these locations that the initial commands are generated and the system responses displayed. The ATLAS launch-control system, however, additionally includes dozens of electronic equipment cabinets for selectively enabling and/or inhibiting countdown sequencing commands, and for processing hundreds of response signals from the missile and its launch equipment. These responses, both analog and discrete types, are displayed in summarized form on the operating consoles and auxiliary status display panels. The heart of the countdown control logic is contained in the *master sequencer*. This unit, consisting of five cabinets, includes over a thousand relays, and processes all control and response signals between the operational consoles, the missile, and GSE. Hard-wire conductors connect the output of the master sequencer to the launch pad, located approximately 700 to 1000 feet from the blockhouse. All electronic equipments (cabinets, consoles, power distribution and display panels) are interconnected through terminal distribution vaults. An indication of the size and complexity of the tactical system, may be obtained from the fact that over 36,000 interconnections are required for three launch pads.

AUTOMATIC CHECKOUT SYSTEM —THE APCHE

Part of RCA's responsibility for the ATLAS ground-support equipment was the requirement to develop an integrated Weapon Checkout System for tactical installations. The fundamental system objectives were defined as follows:

1) to test the airborne subsystems and critical components to determine missile flight readiness;
2) to test GSE to determine its operational readiness for achieving a successful countdown;
3) to localize faults to replaceable units;
4) to perform these tests automatically in accordance with predetermined test procedures, thereby reducing human variability.

From these basic system requirements, the RCA study program established certain specific design criteria. These defined a machine which could be programmed to:

1) generate a family of precise stimuli for interrogating the system under test (SUT);
2) automatically switch these stimuli to input test points of the system under test and connect the output response terminals to the checkout equipment for evaluation;
3) quantitatively compare the SUT responses with the predetermined upper and lower limits and display the resultant evaluation on a simple *go* and *no-go* indicator;
4) incorporate means for self-check of the checkout machine to assure its proper performance.

Based on these criteria, RCA developed the Automatic Programmed Checkout Equipment (APCHE), a versatile automatic general-purpose tester.

APCHE is designed to perform two basic types of tests: 1) generation and evaluation of analog functions, and 2) generation and evaluation of discrete signals. Analog functions are those which convey intelligence by their amplitude, polarity, frequency and/or phase. Stimuli representing the precise quantitive values of these analogs are programmed to the system under test, and the systems' responses (also in analog form) are detected and converted to their digital equivalent and compared by APCHE to preprogrammed limit values. By these techniques, APCHE checks amplifier responses, gyro outputs (amplitude and phase), power supplies, resistance networks, etc. Discrete signals, on the other hand, can be defined as those signals which convey intelligence by their presence or absence. Precise voltages are not necessary when used to make discrete measurements. Examples of discrete tests made by APCHE are to; 1) command and confirm the opening and closing of valves, 2) check continuity of cables and wiring, and 3) test relay logic networks. As many as 100 discrete stimuli/response combinations can be programmed simultaneously.

By the addition of a synchronized time base and counters, APCHE also is able to evaluate system reaction time, make frequency measurements, and determine response characteristics as a function of time. For example, APCHE can and does check settling times of amplifiers, engine response lags to pitch and yaw commands, valve operating time, and the performance of flight control timers.

Additionally, APCHE incorporates a servo analyzer known as the *transfer function analyzer*. This circuit enables APCHE to measure the steady-state response of a 400-cps servo, used by the ATLAS for controlling engine gimbal movement.

Through the incorporation of these testing capabilities, APCHE is able to check out the following missile-borne and ground stationed-subsystems: 1) propellant loading (fuel and liquid oxygen), 2) autopilot, 3) hydraulic system, 4) hold-down and release mechanism, 5) gaseous transfer systems (liquid nitrogen and helium), 6) ground power system, 7) emergency pressurization system, 8) pneumatic system, 9) propellant utilization system, 10) guidance test set, and 11) over-all guidance loop.

The APCHE may be defined broadly as a program/comparator type of machine using punched cards for external programming and storage. These cards, containing 540 hole positions, are prepunched in accordance with a detailed step by step test sequence. Depending on the length and complexity of the test operation, as few as 12 and as many as 400 cards are required to complete the checkout of a given ATLAS subsystem. Information punched onto the cards includes the card deck number (identifying a specific subsystem test), the card number (serialized for each card deck), the stimuli characteristics (AC or DC and magnitude), the switching commands to select the proper test point (both for stimuli and response), the upper and lower limit values, and other miscellaneous data such as delay time before measuring response, indication to perform a manual adjustment, selection of internal or external references, etc.

To test a subsystem, a deck of punched cards, programmed to perform an automatically sequenced test, is inserted in the card magazine of the programmer. The test operation begins when a *start* button on a control panel is depressed. The programmed card is interpreted by electromechanical card-hole-sensing contacts which select digital-to-analog converters (DACONS), analog-to-digital converters (ADCONS) counter registers, digital comparators, switching matrices, etc. In an analog test, such as measuring amplifier gain, the desired input stimuli is developed by the DACON which converts the digital card-hole data to a precisely scaled analog voltage, supplied from an internal reference source. This analog voltage is fed to the proper test point through a switching unit also controlled by card-hole locations. The resulting analog response voltage appearing at the output test point of the system under test is routed through relay trees to scaling network detectors, and an ADCON. The ADCON, which operates in a manner similar to a digital voltmeter, converts the analog voltage into its digital equivalent. The ADCON output is transferred to a digital comparator where the response signal is compared with preestablished upper and lower limits programmed onto the punched card. The result of this evaluation is displayed on a *go* and *no-go* indicator on the APCHE control panel and also permanently recorded on a paper tape upon which is printed both the test value and the upper and lower limits. Discrete testing is accomplished in a similar manner. The system under test is commanded by the card programmer to operate a device such as a relay or valve. The response indicating the state of the device is fed to a discrete comparator where it is compared with the expected response. The resulting *go* or *no-go* data is sent to the printer and control panel indicators.

The fixed-installation APCHE employed at the tactical sites is operated from a console which contains the card programmer, printer, and a control and display panel. An operator may select either an automatic or a manual mode of operation. In the automatic mode, the cards of the deck are continuously processed through the programmer at a maximum rate of two cards per second until a *no-go* condition occurs. The machine then stops and the operator must replace or repair the malfunctioning unit. He is assisted in isolating the specific fault and in the repair procedure by a detailed *no-go* instruction book provided for each card deck. In the manual mode, each card is advanced singly at the command of the operator, which permits performance of detail test analysis and/or manual adjustments.

One significant feature incorporated in APCHE is the ability to perform a complete self-check. A special card deck (self-test deck) is inserted into the machine, and through preprogrammed instructions APCHE stimuli-generating circuits (DACON) are routed through the switching matrix back to the response lines, the ADCON, and digital comparator. In this mode, all APCHE circuits are checked since the programmed limits allow only for the calculated tolerances of the components in the closed-loop network.

APCHE is employed both for checking the flight readiness of the ATLAS missile at the launch pad and for periodic maintenance checks of missiles returned to the Squadron Maintenance Area for repair and overhaul. A total of about 6000 cards arranged into approximately 25 card decks are employed to test the ATLAS-IOC and its associated GSE.

With the development of dispersed Unitary Launch sites, a new checkout and maintenance doctrine was established. Instead of fixed checkout facilities at each of the nine blockhouse control centers of a Unitary ATLAS squadron, a mobile checkout system was desired which could be periodically rotated to each launch pad.

In accordance with this new operational requirement, RCA developed a trailerized checkout station called Mobile APCHE or MAPCHE. This latter system is functionally similar to its fixed-site predecessor. It is housed in a specially designed semitrailer for transport over rugged terrain and for operation under extreme environmental conditions. MAPCHE is a self-contained and completely self-validating mobile checkout station capable of functioning without support (other than site power) for extended periods. It consists of 36 electronic chassis contained in 9 equipment racks. In addition to a major mechanical repackaging necessitated by the stringent transport and environmental operating conditions, MAPCHE incorporates some new circuits for testing the more powerful ATLAS engines and to check out an electropneumatic missile propellant utilization system. Owing to simplification of the missile subsystems and a modification of checkout philosophy, only about 2000 cards are required to test the latest ATLAS missile.

SUMMARY

The ATLAS intercontinental ballistic missile and its associated GSE is one of the most advanced strategic weapons in the hands of the United States military forces. The effectiveness of this weapon to respond quickly and reliably to a *strike* order is in no small way due to the RCA-designed checkout and launch control equipment.

AUTOMATIC PREFLIGHT TEST SET FOR ARMY AIRCRAFT

The multipurpose automatic checkout equipment described herein is designed to replace the need for the many small, separate test equipments that have been used in the field for U.S. Army aircraft. It is of modular design and self-checking, and provides flexibility to handle future changes in test requirements or entirely new equipment.

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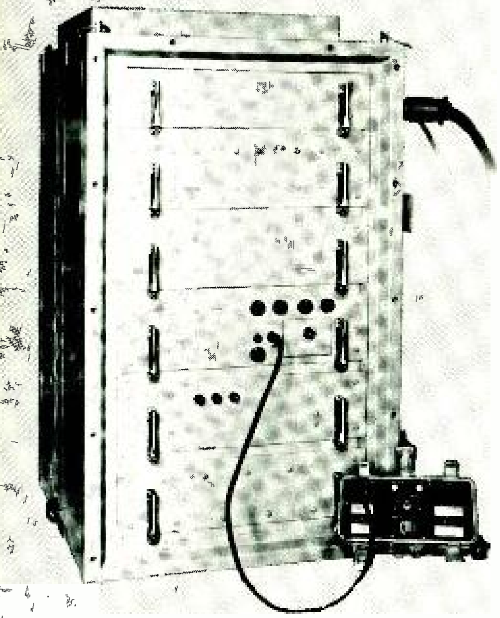


Fig. 1—Prototype model of the Preflight Test Set, which would be vehicle-mounted in operational use. Facing here is the digital rack, with the Remote Control Unit (Fig. 2) at lower right. Back-to-back behind the digital rack is the stimulus rack.

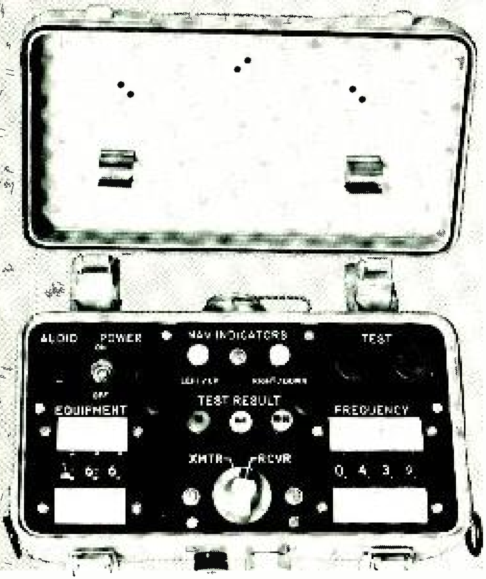


Fig. 2—Remote Control Unit.

THE RAPIDLY GROWING Army Aviation program is generating more and more aircraft requiring a wide variety of Signal Corps electronic equipment. This communication, navigation, and identification (IFF) equipment must undergo a rapid and accurate preflight test and checkout. Nearly 100 different types of such electronic gear are now in use. In addition, equipment use is dictated by geographical area assignment and/or mission. Thus, the complexity and range of equipment places stringent demands on the skills of mechanics who must perform the preflight tests.

These demands, plus the present test problems described below, have created an urgent need for a simple, reliable, and accurate preflight test set—a need that is met by the RCA prototype equipment described herein.

OPERATIONAL TEST PROBLEMS

Tests must presently be performed by checking with a nearby control tower; this uses air time and adds to the overworked air traffic centers. Also, such checks do not evaluate the power output, timing accuracy and stability, percent of modulation, receiver sensitivity, receiver tuning accuracy, or distortion. Although a rough indication of speech intelligibility is provided, no critical operational characteristics are checked. Sufficient tests must be made over a representative band to make sure that dead spots will not suddenly appear when the pilot shifts channels.

Separate test sets are currently used for each electronic equipment. These test sets are dissimilar in function, operation and appearance. Although each set is small, the total number required for one aircraft *often exceeds* the size, weight, and cost of a single multipurpose tester. Furthermore, operators must become familiar with the individual circuits of many test sets.

THE RCA AUTOMATIC TEST SET

To meet the requirements of *modern* flight-line testing, RCA has built for U.S. Army Signal Corps a prototype of a multi-use *Preflight Test Set* (Fig. 1). It performs a closed loop, dynamic checkout of aircraft electronic equipment on an operational system basis. Validity of the operational approach, as opposed to lengthy box-by-box system tests is based upon failure—phenomena characteristics of airborne electronic equipment. Experience indicates that after operational status has been satisfactorily verified, in-flight failures that occur are generally due to a complete loss of operability and not equipment deterioration. Thus, preflight checks may be qualitative in character; such qualitative functional tests assure that calibration is correct and that the system is indeed operational. Threshold measurement techniques are used; results of each test are compared against two limits: one, to detect marginal operation, the other, to detect *go, no-go* operation.

DESCRIPTION OF FUNCTIONS

The vehicle-mounted Preflight Test Set is driven to the proximity of the aircraft. The operator, after checking that test equipment is *on* and the self-test switch is *off*, takes the cable-connected remote-control-and-display unit (Fig. 2) into the cockpit. A cable is then connected from the audio jack on the control box to the audio-output jack of the aircraft.

To perform any test, the operator first applies primary power to the Test Set. Then, a series of reset pulses are generated to de-energize all logic relays within 1 second. Reset circuitry is then returned to the normal operating conditions, and *power on* and *start* buttons are illuminated on the control box.

The operator next "dials" the nomenclature of the unit to be tested (example, ARC-44). With the *transmitter-receiver* switch in the applicable position, the desired frequency of operation is dialed (available in 100-kc steps from 000.1 to 399.9 Mc). When APX-44 IFF equipment) is dialed, the frequency synthesizer automatically receives tuning information for the proper frequency regardless of the frequency selectors.

When the *start* button is pushed, start lights are extinguished and the automatic tests are initiated. This includes a time delay, a setup of internal circuitry, and readying the comparator measurement section for operation. A *ready to measure* signal is then generated and actual testing begins. The complete testing of IFF and navigational units-under-test (UUT) involves more than one step and up to three steps maximum.

When the UUT is a communications set or an automatic direction finder, testing is accomplished by the audio measurement portion of the comparator-measurement unit. Two quantities are measured: the amplitude of the audio, and the noise content of the audio. A *go*, *no-go*, or *marginal* light is energized, depending on the results of these measurements.

In testing identification equipment, the IFF-comparator portion of the measurement-comparator unit is used. Only *go* or *no-go* results will be given, since marginal operation of IFF gear is not allowable. Three steps are required to test the three IFF modes.

If the UUT is an ARN-30A VOR or an R746/ARN Glide Scope Indicator, testing is accomplished by comparing the movement of a cockpit instrument with information obtained by energized lights on the remote-control-and-display unit. For instance, in testing the R746/ARN Glide Scope Indicator, the *up* indicator illuminates 5 seconds after pushing the *start* button; at the same time, the Glide Scope Indicator needle in the cockpit should move up.

The operator, after noting the *go* test result (correlation between the display unit light and the cockpit indicator) will notice that the proceed button is lighted. Pushing the *proceed* button will not cause the *start* light to come on, indicating that there is a step 2 to the test, which was initiated when the *proceed* button was pushed. After 5 seconds, a *down* button will light and the cockpit indicator needle should also move down. At this point, the *proceed* button again energizes; when it is pushed, the *start* button lights, indicating "end of test." A *general reset* function is also generated, readying the Test Set for the next test.

LOGIC

Seven timing pulses, with an amplitude of 28 volts and a duration of 23 msec are generated in the timing-and-switching unit; these pulses are parallel-fed to the seven selector switches on the remote-control-and-display unit. Each of the switches has four wafers. The wafers are wired in a 1-2-4-8 binary-coded-decimal system with one separate input line to each of the seven switches and four output lines from each switch (one line from each wafer). The four outputs are connected through diode *or* gates and routed back to the timing-and-switching unit through the control cable.

The four lines that bring the information back from the remote-control-and-display unit connect to seven storage relay drivers. The input to each relay driver is gated with an original timing pulse. Coincidence between these two signals at the input to a relay driver causes the relay to energize. A holding bias is then applied to the relay driver input to keep the relay energized until the end of the test when a *general reset* function is generated.

The outputs of these relays now contain decimal information as to what UUT is being tested, what frequency is to be generated, and (when applicable) whether the UUT is a transmitter or a receiver.

RF ATTENUATOR SETTING

The UUT nomenclature and frequency data are supplied to a diode matrix board within the programmer; the output of the matrix board appears in digital decimal form on 33 parallel lines, 20 of which carry *db attenuation due to UUT* and 13 of which carry *db attenuation due to frequency.*

The two numerical outputs of the matrix board are applied to a logical net consisting of diodes and gates which automatically adds the two quantities and converts the sum to the code needed for controlling the attenuators located in the synthesizer.

CONTROL FUNCTIONS

The programmer also selects the appropriate modulating frequency, the total number of steps in the test, and, in the case of an IFF test, the proper mode. These relays are activated by UUT information. The modulating frequency and the IFF mode change with each step for tests of more than one step and this information is supplied to the relay network by means of a modified four-stage ring counter.

At the beginning of a test sequence, a *storage completed* signal advances the ring counter to step one. When the UUT stabilizes in operation, a *ready* signal from the synthesizer unit sets a flip-flop which causes a *measurement enable* signal to be generated in synchronism with the next timing pulse from the timing-and-switching unit. At completion of the measurement, a *measurement complete* signal arrives, setting a flip-flop. This flip-flop illuminates the *proceed* light on the remote-control-and-display unit and enables an *and* gate. When the *proceed* button on the RC&D unit is depressed, this *and* gate will pass the resulting proceed signal to the input of a flip-flop, which extinguishes the *proceed* light and advances the ring counter by one position. If this is the last step, the general reset function will be generated at this time readying the programmer for the next test. Otherwise, the programmer will continue with the second step using the same sequence as before.

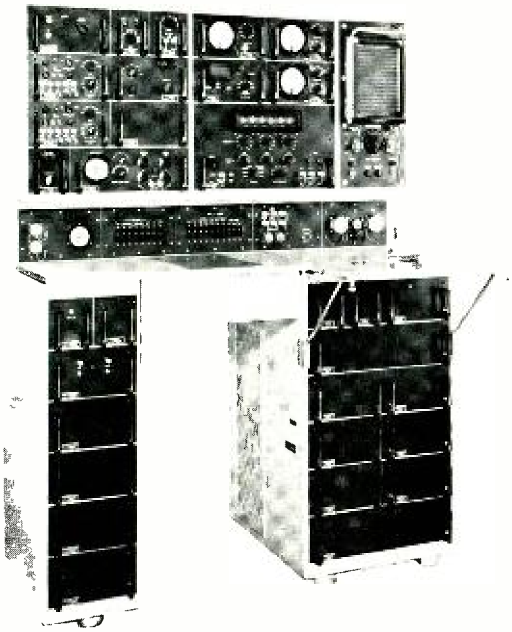
Each step will be performed in succession until the last step is completed. At this time, operation of the *proceed* button will cause the *general reset* function to be generated. At the beginning of each new step, a pulse is generated which ends the *measurement enable* signal until a new *ready* signal is supplied by the timing-and-switching unit. When an IFF test is performed, the *measurement enable* signal is also used to command the synthesizer to generate an *IFF interrogating* signal.

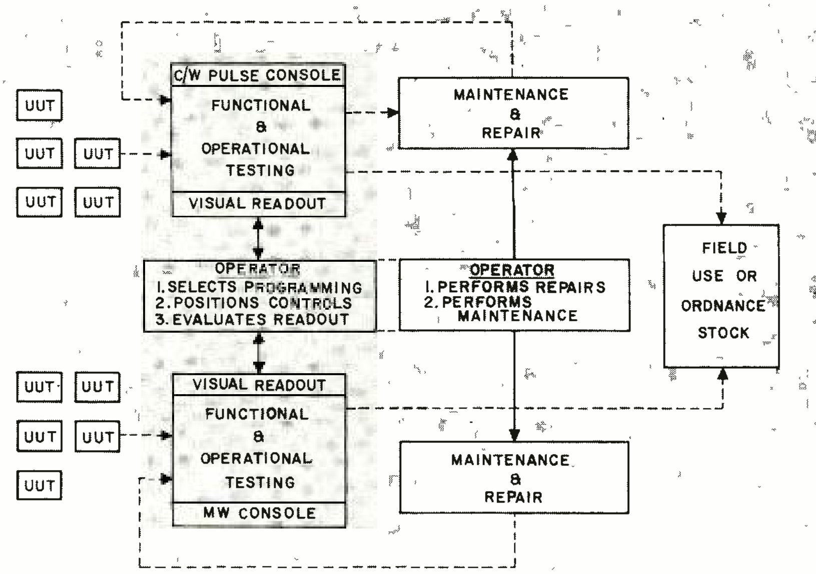
CONCLUSION

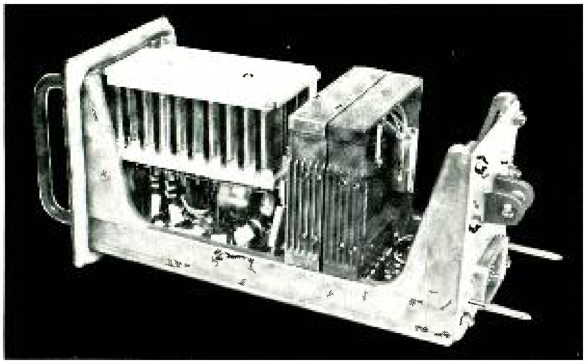
The RCA prototype Preflight Test Set fulfills the need for test equipment to quickly and automatically evaluate aircraft electronic equipment. Additional features of the test set include complete self-testing capability and modular construction. This provides greater flexibility during major changes in testing requirements or when additional equipment of a new design are introduced.

RCA is currently negotiating a follow-on production contract for this equipment, which is currently undergoing field testing by the Army.

WALTER MERGNER served as an Electronics Technician in the US Navy between 1951-1954. He was graduated from the University of South Carolina in 1958, receiving a BSEE. Upon graduation he joined RCA where he engaged in the design of the Time Division Data Link series of test sets. He then became the engineer responsible for the electrical design of the Data Link Module Board Analyzer. Following this, he engaged in the electrical design of the Signal Corps Preflight Test Set. He is a member of Tau Beta Pi.







INTEGRATED TEST EQUIPMENT FOR THE HAWK

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The HAWK missile support equipment described here is a reliable and simple test-system that can be reprogrammed or changed as needed to handle future revisions to test requirements or to the design of the prime system. Now in operational use, it fulfills the field-maintenance requirements for the missile electronics and its launch and control system.

MISSILE SYSTEMS require complicated and sophisticated support equipments during all phases of their operations and maintenance. The mission of these equipments is to assure the successful operation of the systems in the field and, thus, maximize the probable success of every launching.

To accomplish this mission for the HAWK Missile System, RCA designed, developed, and produced the electronic repair and maintenance equipments of the HAWK electronic repair shops for use by the U. S. Army Ordnance Corps. These equipments are completely integrated, semiautomatically controlled, and modularized — providing 3rd- and 4th-echelon field maintenance and testing for both the missile and its associated launching and control system.

Fig. 1 illustrates the HAWK equipment, large numbers of which are now operational in both the U. S. Army and U. S. Marine Corps.

CONSOLES

Two types of test consoles utilizing only 26 different modularized units provide for all the necessary electronic tests for the HAWK system. One console is used primarily to test microwave units, and the other on CW and pulse units. Both consoles provide for tests and checks of common parameters such as voltage, current, and impedance. In addition, each console provides all the necessary power supplies for the units to be tested.

MODULES

Multiple application is the keynote in module design. Of the twenty-six different modules referred to above, eleven have multiple applications in both consoles. Eight of the eleven are used twice, one is used four times, one is used seven times and one is used eight times. This reduces the over-all cost per module and maximizes the advantages of standardization in the system.

Programming of functions and ranges of all controlled modules is accomplished automatically for each particular test setup selected by the console operator provided that the console programmer has been set to *automatic*. The switching is then done by solenoid-operated rotary switches located in the controlled modules.

Deviations from any specific preset programming sequences may be introduced by the operator at his discretion by setting the programmer to *manual* and simple manipulations of the respective module manual controls. After such "deviation testing" is completed, a simple switch operation returns the programmer to *automatic* and the modules are all automatically reset to the program previously selected by the operator.

All modules are removable for service or replacement from the front of the console and are supported, aligned, and positioned by guide rails to preclude connector misalignment problems. Module retention and extraction are accomplished by locking cam type handles on the front of the modules.

INDICATORS

All indicators, except for the electronic

SOME KEY DESIGN FEATURES

- Modularized console construction.
- Semiautomatic or manual programming of multiple-range instruments.
- Direct-reading, analog-type indicators.
- A modularized, direct-reading counter.
- Programmable stimulus generators.
- Programmable power supplies.
- Maximized test capabilities with respect to limited space.
- Expandable test capabilities.
- Complete self-checking capability.
- Standardization of parts, components, etc.
- Human-engineering factors.

Fig. 1—A HAWK test console, a typical console module, a unit-under-test flow chart, and some key design features.

counter, are direct-reading, multiple-range, automatically-programmed analog-type units. Analog units are used, primarily because nearly all of the missile components to be tested are analog. Other reasons include: 1) versatility of equipment without extensive and costly programming changes; 2) minimization of the number of instruments required for system testing; 3) minimization of training program time for technical field personnel; and 4) reduction of equipment complexity by elimination of requirements for ADCONS, DACONS, computer modules, peripheral read-in and read-out devices, etc.

The sole exception to the analog approach is the electronic counter. Digital means, in this case, were employed as the simplest method of satisfying the wide range of counting and timing functions required by the HAWK units.

STIMULUS GENERATORS

All the stimulus requirements of the HAWK units under test are provided by the test consoles. Power supplies are programmable over wide ranges of values as also are most of the other stimulus generators.

The unmodulated CW generators cover wide bands of frequencies ranging from 1 cycle to 500 kc, and a large portion of the radar intermediate frequency band. Included in these ranges are several fixed-frequency outputs for special purposes.

Modulated CW generators provide for AM, FM, and noise modulations, either separately or together. In addition, modulating signals are provided by the console for the external x-band microwave generator.

Two pulse generators provide outputs which are variable in repetition rate (40 to 1000 pulses/sec), pulse width (1 to 2500 μsec), and amplitude (0 to 100 volts). In addition, one of the pulse generators may be slaved to the other to provide for two pulse presentations and other pulse delays.

EXPANDABILITY

The original equipment provided for economical expansion and extension of testing capabilities. The soundness of this important feature has been demonstrated on several occasions. For instance, four different modules had additional capabilities added to them and two entirely new modules were added to the console configurations over a year after the original design was sold.

Only relatively minor changes were required in the console wiring and the modular construction of the console permitted field modification of the older configuration of the consoles with only a minimum of down-time. The new modules were then simply inserted and the equipment was operable again with greatly expanded capabilities and improved performance.

SELF-CHECK

All consoles have had self-checking capabilities incorporated into them in order to check out their own circuitry using only appropriate self-check programs. Of course, provisions have also been made to make periodic calibration against known standards as well. However, the self-check capability of each console provides for calibrations of its equipments in relation to its own internal standards at any time in the field. Thus, the shop equipment is completely self-sufficient.

STANDARDIZATION

In line with the general concepts of standardization programs for equipments built by DEP at RCA, the various aspects of the Hawk project were thoroughly scrutinized and a suitable program of standardization was established. The rule was that standardization was to be carried as far as practical without limiting the capability of the end product, the console. Some of the areas to which standardization concepts were applied are:

1) *Module sizes*
2) *Common hardware*
3) *Connectors*, modules, two types; printed-circuit cards, one type
4) *Basic common mechanical parts*, side-frames, rear panels, etc.
5) *Electronic hardware*, shield terminations, taper pins, terminals, etc.
6) *Militarized components*
7) *Mil-Spec materials*
8) *Common special parts*, transformers, etc.

HUMAN ENGINEERING FACTORS

Location and arrangement of modules and controls have been assigned to provide for maximum utility and convenience of the operator. All indicating devices are located above the work table; power supplies are located in the pedestals below the work table, and modules with frequently used controls are located in the center and toward the right side of the upper console.

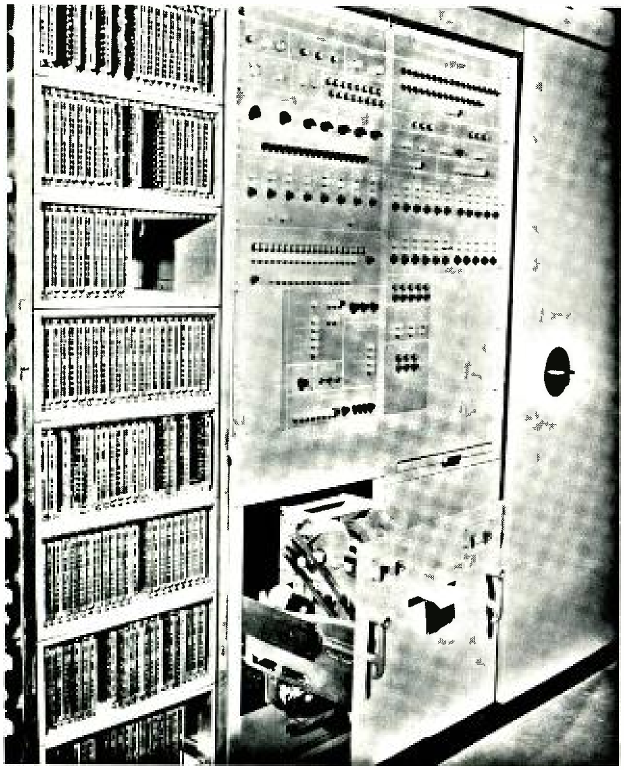
Five front panels in the recessed intermediate section of the console contain all the circuit breakers and fuses for the various AC and DC power supplies. In addition, convenience outlets, an elapsed time meter, and most of the connector receptacles for the test cables are provided on these panels.

IN SUMMARY

The field maintenance equipment built by RCA for the HAWK Missile System electronic repair shops has been successfully meeting its objectives in field usage since the early part of 1960. It has been proven to be a reliable, simple, and efficient test equipment system which can be readily changed and/or reprogrammed as necessary, to account for changes and new capabilities of the prime equipment as they arise. Thus, the degree of obsolescence attributable to the equipment has been minimized, and the utility of the equipment has been maximized.

Large numbers of the HAWK consoles have already been produced by RCA; additional consoles having the latest configuration are presently in production—thus, continuing to contribute to the operational success of the HAWK system.

WILLIAM J. PERREAULT received his BSEE from the University of Minnesota in 1958, and joined RCA as a specialized trainee the same year. Subsequently, he was assigned to the DEP Airborne Systems Division in Camden, where he worked on the design of transistorized circuits and with the Systems Integration Group for the ASTRA Project. He was then assigned to a production release and follow-up group on the MG-10-FME program. He then joined the Systems Support Equipment Engineering, where he was responsible for the electrical design, development, and system integration for the HAWK-FME program. Recently he was transferred to the Burlington, Mass. facility of ACCD, where he is currently responsible for the design of several stimulus units of the MTE program. He has been pursuing graduate work towards an MSEE and is a member of the IRE and the AIEE.



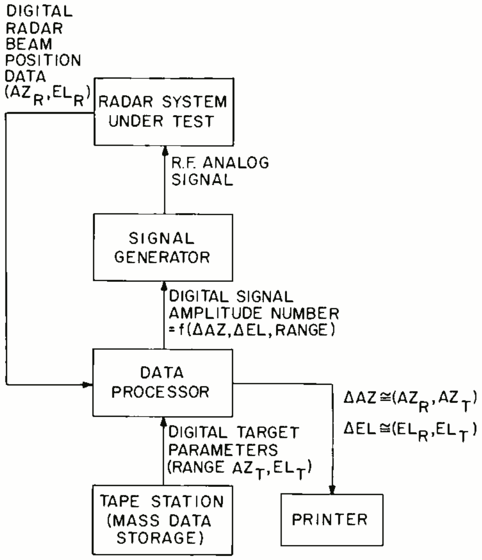


Fig. 1b — Illustration of functions of Fig. 1a.

Fig. 1a — Special-purpose data processor for target simulation.

INTEGRATED, ADAPTABLE, AUTOMATIC CHECKOUT AND SIMULATION CONCEPTS

This paper discusses the methodology of checkout and simulation when developed for a particular system application, as opposed to universal test equipment. Covered are techniques of information processing, signal generation, automatic measurement, and data display.

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CHANGES IN modern day electronic systems have brought forth the great need to incorporate confidence-giving devices to determine, continuously or on command, the operability of the system. Key to the operating success of these new systems is competent design meeting extremely high reliability goals. To assure that these high-reliability system goals are met, efficient and reliable checkout and simulation techniques are invaluable. The use of checkout and simulation concepts provides these advantages: 1) a means for reliability analysis, 2) a training tool for personnel, 3) integration and acceptance facilities, and 4) an over-all confidence factor in the tactical electronic system.

Additionally, a well-conceived checkout and simulation system provides dollar savings by reducing the quantity and quality of maintenance personnel, avoiding redundant equipment, and reducing the need for high-quantity spares.

PHILOSOPHY

Factors influencing the sophistication or automaticity of checkout and simulation systems include: 1) the mission of the tactical equipment, 2) intermittent or continuous operation of the tactical equipment, 3) manned or unmanned operation, 4) mean time between failures of the system, 5) spare parts consideration, and 6) the over-all size of the system.

Checkout and simulation systems described here are designed *for a particular application as opposed to universal test equipment.* For large systems where similar multi-element blocks are used, as in electronically steerable arrays, low-cost common transducers should be used in the checkout and simulation system. Logic elements or other analog or digital circuits should be of the same design and configuration as similar elements in the tactical system. This simplifies logistics and increases cross-usage.

Most importantly, checkout and simulation equipment should be even more reliable than the tactical system under test so that final test results are beyond question. Along with the high reliability, the measuring elements of checkout and simulation subsystems should have accuracies greater than those being measured. Generally, a five-to-one factor in accuracy is a good compromise between cost and proper operation. In rare cases, it is sufficient for the accuracy of the measuring element to be equal to the accuracy of the equipment being measured—providing at least a 50-percent chance of alerting to a failure in the tactical subsystem.

The control and observation of checkout and simulation subsystem results are generally accomplished from a console. Layout of the console controls and displays are of great importance to assure rapid, proper operator reaction to tactical situations; as a training device, the console uses simulation techniques to generate a tactical environment.

Information processors available in the tactical system are utilized whenever possible for economy. When existing processors are utilized to maximum capacity or when the checkout and simulation routines are specialized, separate machines are warranted.

METHODS FOR CHECKOUT SYSTEM DESIGN

Several primary methods have been used successfully in system checkout applications. Some of the methods to be discussed have been mixed; others have taken the form of separate equipments:

1) *Dynamic Simulation and Performance Evaluation.* Dynamic realistic inputs are inserted into the system; the resultant answer data extracted from the system output terminals is analyzed automatically. This method establishes overall performance and accuracy of the system. Additionally, it indicates where faults may be in small systems; in large systems, very little fault-area information is obtained.

2) *Automatic Monitoring.* Usually passive sensors that threshold or measure relatively static quantities from many test points within the system. Fault locations are pinpointed but system accuracy may not be indicated.

3) *Automatic Signal Tracing.* Signal generators insert static and dynamic signals at intermediate points in the system. This approach is effective where intermediate monitoring levels are low, rendering it impractical to monitor at these points but possible to insert signals. Measurement is subsequently performed at a single higher level output point.

Combinations of the above methods have been implemented successfully. APCHE (ATLAS Programmed Checkout system) uses a combination of techniques 2 and 3. The BMEWS CAM (Continuous Automatic Monitoring) system uses methods 1 and 2 as two separate systems. Method 1 can be used effectively when the equipment has a well defined set of input and output terminals (as in a radar or communication system). Where there are many inputs and outputs, as in a missile launch checkout system, Method 3 is useful. Method 2 is used for rapid fault isolation in large defense systems operating continuously.

CHECKOUT SYSTEM MAKEUP

The basic functions of a checkout system can be described in four general categories: 1) information processing and control, 2) signal-generation devices, 3) automatic measurement techniques, and 4) displays.

Information Processing and Control

Usually, the heart of any checkout system is the central control and data-processing equipment. The central control and information processing equipment generally functions in one or more of the following ways:

1) Controls remote signal-generating devices for signal insertion and processes answer data.

2) Sequences sensing and measuring devices for automatic monitoring and processes answer data for fault determination.

Signal-generation control may take the form of simply closing a switch to connect a signal generator to an appropriate point in the system. A more complicated function would be to vary amplitude, frequency, pulse width, etc. of the generating device after connection has been made. Variation is preprogrammed and not usually dependent on system response. A more complex simulation technique would be to preprogram the signal generator, measure the response of the system, and alter the signal generator according to system response. This technique may be found in the realistic simulation of dynamically varying targets for insertion into a radar system.

Target information is usually prerecorded in digital form on a mass storage media such as magnetic tape. Data stored on tape represents varying spatial positions of a simulated target. Since a radar beam normally moves to track a target or scan an area, its position changes. The amplitude of the generated signal will then be made to vary according to the radial displacement of the simulated target with respect to the radar beam axis, i.e., the output of the generating device will depend on the response (position) of the radar beam as well as the preprogrammed information.

Thus, to accurately and realistically control the generator, the radar beam equation is solved each time a simulated return is generated. Because of the complexity of solving the beam equation and the necessity for repeated solutions at a high rate, a programmable data processor is utilized; it may be a general purpose computer or a special purpose machine developed for the particular application. Fig. 1 illustrates a special purpose data processor used for target simulation for the BMEWS system. An additional function of the data processor is to format answer data for display. The display device most commonly used is a printer.

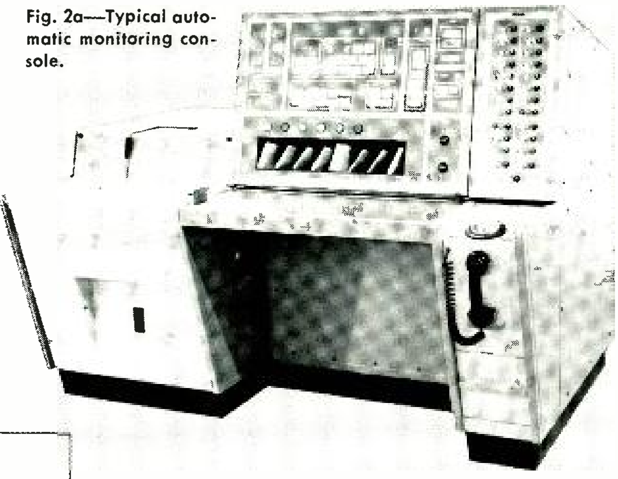
Sequencing and controlling remote measuring and sensing devices, and processing of answer data can be accomplished by special-purpose data-processing equipment or by a general-purpose computer. Since sequencing requires a large number of instructions (usually one for each monitored point) and the time required for each point is relatively long, media such as punched cards or punched tape are frequently utilized. Data-processing equipment simply interprets stored instructions and connects the proper sensing device to a particular point in the system (Fig. 1b). The sensing device is usually an analog-to-digital converter, located remotely; answer data is transmitted back to the central data-processing equipment where comparison and analysis take place automatically. Typical equipment utilizing a special-purpose data processor with instructions stored on punched cards and answer data received from remote analog to digital converters can be found in BMEWS-CAM.

Signal Generation Devices

Signal-generation devices can have provisions for control by digital means from central information processing equipment. The output level of these devices is dependent on the point of signal insertion and the type of signal required.

In radar checkout applications, the output is usually a pulsed RF signal with controllable amplitude and range. If the radar system is coherent, precise variation of the carrier frequency to produce simulated doppler shift is required. The frequency must be varied according to a prescribed simulated target range rate. The range rate is supplied in digital form and controls the frequency of a voltage controlled oscillator (VCO) by utilizing a counter and digital-to-analog converter in a closed-loop configuration. The VCO may then be multiplied to the appropriate frequency for insertion into the system. Range is generated by inserting the complement of a digital range number, each pulse-repetition frequency, into a counter and counting to zero. A pulse with range equal to the digital number is then produced and is shaped into a simulated video return. In general, the type of generation technique must be tailored to the system requirements.

Fig. 2a—Typical automatic monitoring console.



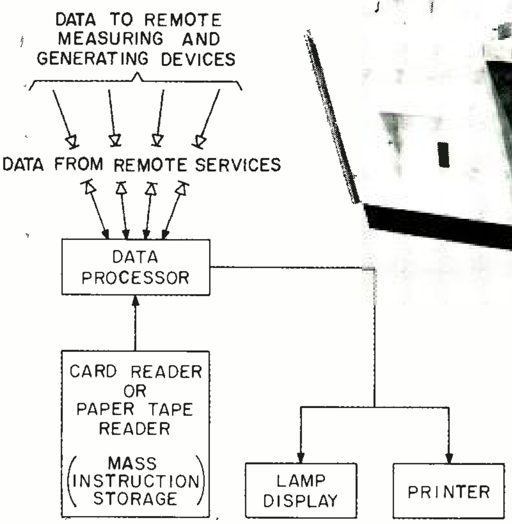


Fig. 2b — Illustration of functions of Fig. 2a.

Automatic Measurement Techniques

The most common automatic measuring technique is to convert the quantity to be monitored to a DC voltage such that an analog-to-digital converter can readily handle it. With the advent of higher-speed converter, the pulse signals in certain cases can be handled without conversion to DC. Where pulses of very short duration are present, *sample* and *hold* circuits are used to stretch the pulse to a duration compatible with the converter. An alternate method of monitoring is to utilize an analog comparator supplied with a reference voltage. The reference voltage may be derived from a centrally generated digital number applied to the comparator via a digital-to-analog converter. The disadvantage of the comparator is that no numerical answer is available for processing.

In BMEWS-CAM, a combination of the two methods are implemented. The majority of points are handled sequentially by analog-to-digital converters with relatively few, but key points being handled in a continuous manner by preset analog comparators.

Displays

Displays for automatic checkout and simulation systems should be relatively simple in nature. Where over-all dynamic simulation is performed, the main display device is usually a medium-speed printer. A printer is necessary because of the large amount of data points required to display. Automatic monitoring for a large-point system usually requires a printer for the sequential monitoring portion (where many points are switched into the system) and lamp displays for certain key-points which are continuously monitored. A typical console for an automatic monitoring system is illustrated in Fig. 2: the console contains a printer, card-reader for sequentially monitored points, and a lamp display for continuously monitored points. Note that the lamp display is arranged as a block diagram of the system.

SUMMARY

Fundamental considerations in conceiving checkout and simulation systems dictate that for most efficient operation and design, the checkout hardware should be designed as an integral part of the tactical system. This, however, does not negate the possibility of including simulation and checkout equipment as ancillary gear to a previously designed system, since this has occurred many times in the past due to limitations on the original contract costs. In addition, the checkout technique utilized should be tailored to the particular system it services. These principles apply only where the tactical system is of such complexity to warrant an automatic checkout system. Adherence to the above principles result in the most efficient and economical system.

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SELF-VERIFICATION OF SYSTEM STATUS

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Self-verification (SV) is a method of continuously providing positive information as to the operational status of a complex system. This paper introduces the SV concepts, which are being successfully applied by DEP-SurfCom to Minuteman.

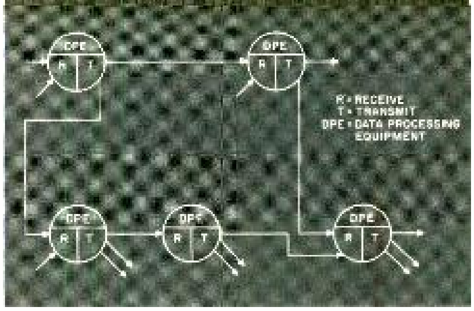

Fig. 1—A typical segment of a multi-link system.

THE TREND in modern-day communications systems is toward *maximum availability*—i.e., constant operational readiness. The desired availability can be sought through meticulous design and the use of highly reliable components, while periodic system testing offers some additional assurance. However, both methods leave much to be desired. For example, despite the use of highly reliable components, the large number of parts in a complex system reduces over-all reliability, thus lessening the availability assurance. Moreover, periodic testing is valid only for an indeterminate period immediately following the test. And, in systems requiring *100-percent availability*, periodic tests and/or rigid maintenance routines are time-consuming and costly.

A more-effective approach is the *self-verification* (SV) technique, which satisfies reliability criteria and supplants many of the maintenance requirements. Ideally, SV achieves continuous system surveillance, immediately detects any malfunction, and then reports the fault by a *go* or *no-go* signal. The SV techniques are applicable to both analog and digital systems; however, discrete *go–no-go* displays suggest digital equipment, to which SV is particularly amenable.

RCA developed the SV techniques described here and applied them to an existing missile communication system. However, SV is applicable to any large complex system comprising a number of "independent" links or nodes. Fig. 1 shows a typical segment of such a multi-link system. Each link comprises essentially similar *receive*, *transmit*, and *data processing* nodes. The interconnection between the receive and transmit nodes can be as complex as required. Additionally, some nodes can be manned or remotely controlled and unmanned.

SYSTEM FIGURE OF MERIT

To evaluate the impact of SV in terms of system reliability improvement, the degree of assurance must be determined. Such a measuring stick should: 1) weigh all modes of operation and determine contributions to the over-all system merit rating, and 2) respond proportionately to the failure rates of critical components so that it reflects the impact of these failures on the system capability. Unfortunately, the usual measuring sticks, availability and reliability, are not applicable to complex multi-link systems generally.

The availability A of a system is equal to the portion of time that the system will perform satisfactorily:

$$A = \frac{\text{MTBF}}{\text{MTBF} + \text{MDT}} \tag{1}$$

Where: MTBF = mean time between failures, and MDT = mean down time

Before Eq. 1 can have any significance, either of the following conditions must exist:

Condition 1. If a specific mode of operation could be defined as *minimum acceptable* (with any further degradation being unacceptable), then the percentage "up" time could be determined. Although this condition is not usually present in most large complex systems, it may exist in some particular portions of the system; percentage up time in these portions can be evaluated. But, these parts cannot be combined in the usual manner to yield an over-all system availability.

Condition 2. If each part of a system were separate and independent, and no component or group of component failures would affect any other part, then the system availability could be determined by combining the availabilities of single parts. If all availabilities were equal, then each would also be the availability of the system; the availability of a single part would then become the percentage of the part available at any time (long-term average). But, generally, systems are considerably more complicated. Some component failures affect one part only; others have a considerably broader effect on system performance. Similarly, the reliability concept is not applicable to the system in its entirety. Thus, a new figure of merit, termed *relative system capability* (RSC) was devised.

RELATIVE SYSTEM CAPABILITY

This new figure of merit, RSC, has the following properties:

1) It is derived from statistical data on component failure rates, and accurate reliability models of the system.

2) It gives a measure of the long-term average number of system links that will be functional.

3) It incorporates suitable weighting factors, equivalent to the effects of failures on the system capability, for all critical elements.

4) It weighs proportionately all possible modes of system operation caused by the varying degrees of degradation.

5) It can be calculated by available mathematical techniques.

The RSC is calculated as follows:

Step 1) Using Eq. 1, determine the availabilities of the system step-wise by removing each independent link in a discrete manner.

Step 2) Multiply each of the availabilities of step 1 by the total number of system links remaining operable and sum the products.

Step 3) Divide the sum of step 2 by the total number of links.

Step 3 gives a measure of the number of operable links and is the RSC. All critical components are suitably weighed since impact on the system is immediately reflected in the suitable availability term and gauged by the number of units which remain operable. All other modes of operation due to varying degrees of degradation are included so that a true long-term average is obtained without defining the "acceptable" modes. The methods of calculation are based on a simple averaging and weighing technique, readily derived and performed. However, because of cost and other critical functions, very few systems can or will be 100-percent "self-verified." Thus, each system must be considered as consisting of a verified portion and unverified portion.

The verified portion is the system complex whose RSC is determined (as indicated above) by reference to the system reliability model. This yields

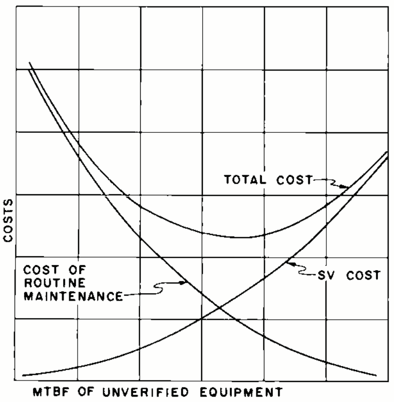

Fig. 2—Cost trade-off optimization.

the percentage of individual system links that will be operable (verified).

The unverified portion's impact on RSC is determined by the particular portions of the system left unverified. The availability A of an unverified portion, for high availabilities, is given by:

$$A = \frac{\text{MTBF}}{\text{MTBE} + T/2} = \text{RSC}_u = 1 - \frac{T/2}{\text{MTBF}_u} \quad (2)$$

Where: T = time over which availability is determined, RSC_u = relative system capability (unverified), and MTBF_u = mean time between failures of the unverified portion of a single link, defined by:

$$\text{MTBF}_u = \frac{2}{2 + L_u T} \quad (3)$$

Where: L_u = failure rate of unverified portion of a single link.

Therefore, availability of the unverified equipment in a single link is dependent only upon the failure rate of the unverified portion and the time between routine maintenance checks. This availability of the single link is numerically equal to the RSC of the unverified portion of the system. Over-all RSC is equal to the product of the capabilities of the verified and unverified portions of the system. Thus, even with restrictions of routine maintenance operations, the unverified portion becomes the controlling factor in the over-all RSC.

COST TRADE-OFF RELATIONSHIPS

To minimize costs, determine the optimum combination of frequency of maintenance and degree of SV; to do this, the exact costs of verification equipment and routine maintenance must be known.

With such information available, a suitable plot of the cost trade-off could be made (Fig. 2). The abscissa (MTBF of unverified equipment) is a measure of the degree of SV. As the degree of SV becomes greater, the MTBF for the unverified equipment becomes greater.

The over-all cost of routine maintenance is determined by the individual costs of manpower, materials, equipment, and facilities required for each link to maintain the equipment at the required availability level. Actual frequency of maintenance per year, F, is

$$F = \frac{AT}{2} \text{MTBF} (1 - A) \quad (4)$$

Where: A = availability requirement for unverified equipment, T = period of time considered (usually one year) in hours, and MTBF = mean time between failures of the unverified equipment of a single link in hours.

When repairs are necessary in the unverified equipment, the amount saved by having each repair crew perform the checkout on the unverified equipment at each link is P_f (the failure probability):

$$P_f = 1 - P_s \quad (5)$$

Where: $P_s = \exp(-T/\text{MTBF})$ = probability of survival of a link.

Since P_f determines the average number of times a link must be maintained in the period T, the curve of annual *cost of routine maintenance* (Fig. 2) approaches a minimum.

The second curve, SV *cost*, is determined by both the design and production costs of the extra equipment annually allocated at each site, plus the cost of maintaining this equipment; cost increases rapidly for each additional increment of verification. Thus, in attempting to achieve complete SV, the 100-percent point is approached. The third, or *total cost*, curve is simply the arithmetic total of the first two curves.

The complete *cost trade-off*, then, is composed of three steps:

1) To achieve any particular availability, the various combinations of degree of verification (MTBF of unverified equipment) versus the associated maintenance program (time between maintenance checks) must be determined.
2) The cost of the verification and associated maintenance program (knowing that P_f percent of sites are visited annually for repairs) must be determined.
3) The minimum point on the summation curve of the two costs involved must be located.

Table 1—Limiting Conditions for SV

SV Scheme	*Frequency of SV*	*Percentage of Equipment Self-Verified*
1	→ ∞	100
2	→ ∞	0
3	→ 0	100
4	→ 0	0

Since exact figures for these calculations are generally unavailable, the extent of SV providing the greatest return in equipment verified (without compromising system MTBF) is based on an engineering design approach. The over-all design of a system may be considered from two aspects: 1) the level of reliability achieved, and 2) the simplest functional requirements.

Further, in any system, optimum design is achieved by a perturbation and iteration process of these two factors. To appraise the effects of SV, this process is evaluated on the basis of 1) maximization of the time between routine maintenance checks; 2) maximization of RSC; and 3) assurance of compliance with the system MTBF requirements.

The over-all system MTBF and the MTBF of the unverified portions are then used to calculate the RSC. The availabilities curves of T (time between maintenance) vs MTBF, and of T vs A can then be plotted to determine a first approximation to the degree of SV required.

Finally, using the design criteria for the types of SV possible, the final amount of SV incorporated into a system can be determined. The problem then reduces to selecting a given type of SV and designing equipment for it.

SYSTEM REQUIREMENTS

Considering any link of a system as a two-port, traditional "black box," the link will give a known output when stimulated by a known input. This form of test is ideally suited to give a *go* or *no-go* indication of operational capabilities. Such a system is basically a gross-fault locating method, useful for determining the over-all operation of the equipments. If additional nodes are available, it is possible to treat each module of the system as a smaller two-port black box and, thus, localize a fault to a module or circuit.

The time and frequency of testing must also be considered in any SV scheme. Ideally, verification of vital functions should occur 100 percent of the time, for 100 percent of the equipment. Although in practice these goals are seldom realized, close approximations can be accomplished (Table I). The figures indicated in Table I are limiting conditions only; e.g., *Frequency of SV* approaches 0 in Scheme 3, but does not actually reach it. Schemes 2 and 4 are obviously impractical. Scheme 3 is feasible, but not as desirable as Scheme 1. Thus, if SV is to be achieved, the closest possible ap-

Table II — SV Implementation Criteria

1) sv should be a dynamic test in preference to static type.
2) sv circuits should monitor the functions of the operational circuits, but never participate in their action.
3) sv circuits should be able to "report" their own failure.
4) sv circuits should not cause operation of a system in any critical mode.
5) sv circuits should monitor the system during normal system up time for catastrophic failure and out-of-tolerance drifts.
6) sv should indicate the effect of the failure upon system performance as a *go* or *no-go* status signal.
7) sv should make as much use as possible of the inherent system verification concepts.
8) sv should not be achieved by the use of functional or spare redundancy. (Functional redundancy is equipment duplication which contributes to the system capacity as well as reliability. Spare redundancy is duplication that does not increase system capacity, but is intended only to improve reliability.)
9) sv should be considered an integral system design parameter.
10) sv test should exercise circuits through modes the circuits must actually perform.
11) sv should be continuous so that the frequency of testing is compatible with the statistical aspects of reliability.
12) sv should monitor the system logic switching rules and check all logic paradoxes.
13) sv operation should be completely automatic, or sv should be so designed that required operating manpower is minimized.
14) sv must cease immediately, and the system revert to the normal state, upon the initiation of operational use of the system.

proximation to Scheme 1 should be adopted. Failing this, Scheme 3 or the best engineering compromise will have to be used.

TYPES OF SV

On the basis of the above requirements, the implementation of sv can be divided into four groups: 1) automatic (ASV), 2) nonautomatic (MSV), 3) dynamic (DSV), 4) static (SSV). Each of these categories can exist in two forms, *marginal* and *nonmarginal*.

A marginal test program is a fault-detection scheme in which different parameters are varied within prescribed tolerance limits to determine the operating capabilities of the system. The method is useful primarily to detect imminent failures and is intended to check a class of malfunctions not considered in the sv criteria.

A nonmarginal test program is essentially a fault-detection scheme wherein the system parameters are considered as operating at their nominal values. All types of sv are basically of this form, the important fact is that all existing failures, catastrophic or out-of-tolerance, are detected by this scheme.

Automatic self-verification is a diagnostic approach that periodically tests, on a program basis, the entire system by exercising every function through its normal states. Generally, sv to this extent is not possible. In lieu of this and satisfying the concept of ASV, a process can be adopted to check all critical functions; however, this may introduce too many extra components. So, while ASV appears in general to fulfill the needs of verification, its disadvantage is that implementation is extremely complex and may lower the system MTBF and the Availablity; also, the testing process may tie up the system.

Nonautomatic self-verification, MSV, is similar to ASV, with one major difference: the test program is operator initiated. The MSV has all of the disadvantages of ASV and one more—it requires complex manual technical procedures and coordination.

Dynamic self-verification uses pseudo-valid operational procedures to exercise the links of the system. Procedures are used to check the operation of most functions (certain critical functions can be left quiesent as required). This DSV method eliminates many problems of ASV and MSV, but falls short of achieving a 100-percent functional checkout.

Special operational procedures initiated to excite the system into a dynamic operating condition are monitored to ascertain the correct response of the various functions. Despite the fact that DSV does not check 100 percent of the system, it has sufficient merit to be the most usable sv method.

Static self-verification is a test procedure normally used when the system is quiescent. In contrast to the DSV, this test performs verification without using the system operationally. Instead, the principles of logical deduction and the monitoring of logical paradoxes form the underlying basis of this form of sv. The SSV is never a complete test, but is a worthy adjunct (in combination with DSV, for example) to enhance the over-all degree of system verification.

Table II lists implementation criteria for sv methods.

CONCLUSIONS

For the MINUTEMAN complex, the application of this technique has resulted in an optimum sv design that has increased the over-all amount of equipment by a modest percent, to achieve performance verification of approximately 99 percent of the system.

The sv technique can be applied to any system, but particularly digital systems. Many methods of implementation are possible; however, given the reliability requirements for a system, and the constraints predicated by its operational use, an optimum method of sv can be selected. Using the techniques herein presented, the selected method of sv can be designed *to minimize additional equipment and cost*, and *to maximize system availability*.

Thus, sv provides an ideal solution to an ever present problem. *What is the status of this system now?*

ACKNOWLEDGEMENT

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H. J. KISHI (left) received his BEE from Rensselaer Polytechnic Institute in 1951 and his MEE from the City College of New York in 1954. Upon graduation from Rensselaer, Mr. Kishi joined RCA Laboratories Terminal Facilities Group, New York. He immediately became active in the development of electronic circuitry for time division multiplex/automatic error correction terminals then under development for RCA Communications, Inc. He has become a specialist in digital signaling code applications, modular digital circuitry, magnetic cores, and transistor circuitry applications. Starting in 1959, he was a member of an RCA Laboratories team active on the PANGLOSS Project, working on statistical detection techniques concerning binary and non-binary signaling methods, and theoretical and experimental work on enhancing reliable communications by nonlinear predetection schemes. In 1960-61, he handled systems engineering assignments on the MINUTEMAN Project. Since 61, at RCA Labs he has concentrated on high-speed data communications. He is a Member of the IRE and has received an RCA Laboratories Achievement Award for outstanding research. He has five patents issued and several pending.

M. P. ROSENTHAL (center) received his B.S. in Physics from Brooklyn College in 1959. He joined the SurfCom Systems Laboratories, New York in 1960, preparing technical reports for a large weapon system. He is now a Member of the Technical Staff; among his current duties are proposal preparation, technical paper coordination, and reports. From 1955-1960 he held supervisory technical publications positions at Renner, Inc., Renwar, Inc., and the Electric Boat Div. He is a Member of the IRE and STWP. He is co-author of Basics of Fractional Horsepower Motors and Repair, J. F. Rider Publisher Co., 1959; and Basic Air Conditioning, J. F. Rider Publisher Co., 1961.

JACK COHEN (right) received his BEE from City College of New York in 1950 and his MEE from New York University in 1957. Since 1952, he has been in digital data processing, systems, and equipment, starting with Burroughs Corp. and then with Bendix. He joined the DEP-SurfCom Systems Labs in 1959 as Senior Project Member, Technical Staff, leading a group on MINUTEMAN Systems Design. He recently left RCA to join the Sperry Gyroscope Div. of Sperry-Rand Corp.

The determination of trace impurities is important in understanding the behavior of materials in solid-state devices. Spark-source mass spectrometry provides a versatile analytic tool of great sensitivity that is playing a valuable role in basic research on new materials at the RCA Laboratories.

Dr. J. KURSHAN, Mgr.

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On February 23, 1961, J. R. Woolston, a Member of the Technical Staff at RCA Laboratories, along with a senior engineer from Associated Electrical Industries in Manchester, England, waited anxiously at New York International Airport. As they searched the early morning sky, they were rewarded by the appearance of a large cargo-carrying plane which landed smoothly and taxied up to the unloading area where they were standing. The plane was carrying an MS7 spark-source mass spectrometer destined for the David Sarnoff Research Center. This was only the sixth instrument of its type to be produced and the *first* one shipped to the Western Hemisphere. Over four years had elapsed since action was initiated to acquire such an instrument, and 20 months had passed since a firm order had been placed. The two men were there to see that nothing went wrong at this stage of the operation. As Figs. 1a-b show, the MS7 is a large, integrated instrument with complex electronic controls. The anxiety shown at the airport is readily understood and, happily, it was rewarded by a successful installation.

Trace impurity analysis by mass spectrometry is now available as one of the activities of the Research Services Laboratory and illustrates well many facets of the role played by this Laboratory in research and engineering. As work progresses in the preparation of materials for electronic applications, more information is needed about the basic constitution of these materials. Often, this analysis is conducted as an integral part of the materials-research program, especially when new analytical methods are required. Occasionally, the analytical needs become large enough and sufficiently well-defined that it is advantageous to provide the analyses as a centralized service which can be requested or requisitioned by the scientist or engineer whose primary interest is improvement of the material rather than analysis. The advantages gained by providing mass spectrometry in the organizational framework of a research service include the following: *ready availability* to other groups of the expertness and skill developed by the operator; *experience* acquired from a variety of different sources and problems; *capability* for developing special methods to handle novel situations; *a sustaining program* to improve techniques, to understand the existing limitations, and to provide for new needs; a *service* available to other divisions of the company; and, therefore, justification of the cost of expensive instrumentation on the basis of its broad utilization.

ROLE OF TRACE IMPURITIES

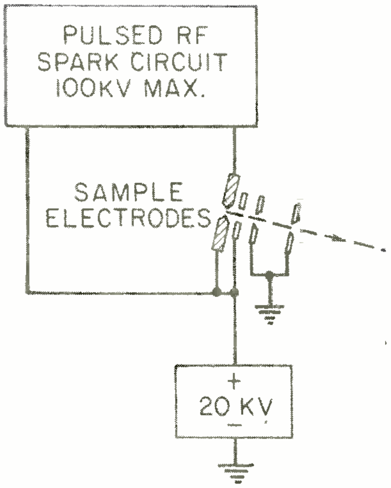
Technological advances in materials often outstrip our understanding and control of the phenomena involved. The semiconductor field provides a good example of the significance of trace impurities and furnishes an outstanding area of application for spark-source mass spectrometry. Progress in the semi-conductors utilized for transistors has been a see-saw between the control of chemical impurities and of other crystal imperfections. The first point-contact transistors were made with polycrystalline germanium intentionally doped with an impurity such as phosphorus to establish the desired conductivity type according to existing crystal-rectifier art. The reproducibility and reliability of transistors were improved substantially when large single crystals could be grown from starting material that had less than one part per million (ppm) of impurity before the desired doping material was added. Today's transistors, and related semiconductor devices, have several important parameters at least partially determined by trace impurities present in concentrations which are completely insignificant in non-electronic products.

One phenomenon, the Hall effect, produces a voltage that varies inversely with electronic carrier concentration; the Hall effect is thus an indirect measure of the impurity concentration which produces the carriers.[1] Because of the relatively high Hall voltages obtainable from semiconductors, the Hall effect itself is now being utilized in a variety of practical devices (e. g. magnetic field measurement). Electrical conductivity (or resistivity) is determined by both carrier concentration and mobility and, thus, combined with information obtained by Hall measurements, provides another indirect measure of impurity concentration. Resistivity in turn is used as a design criterion for various device parameters such as junction capacitance, breakdown voltage, emitter efficiency, etc. Impurities may also deter-

Fig. 1a—The MS7 mass spectrograp
modified source. The author is obs
while J. R. Woolston adjusts the ion

Fig.

SPARK-SOU
TRACE



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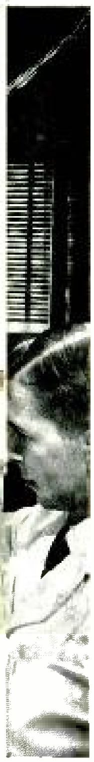
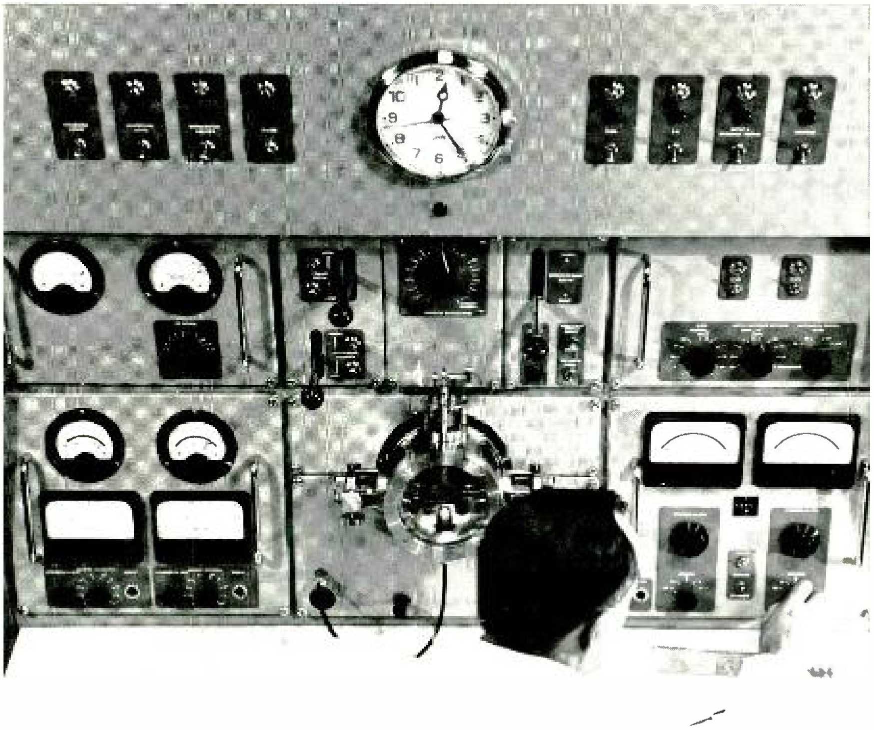


Fig. 1b—Front panel of the MS7 Mass Spectrometer showing ion source chamber in the center. All operating controls are within easy reach.



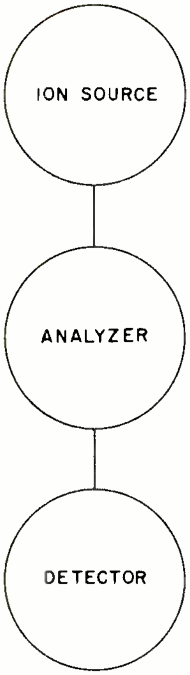
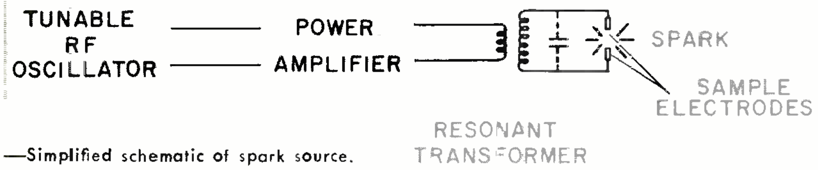


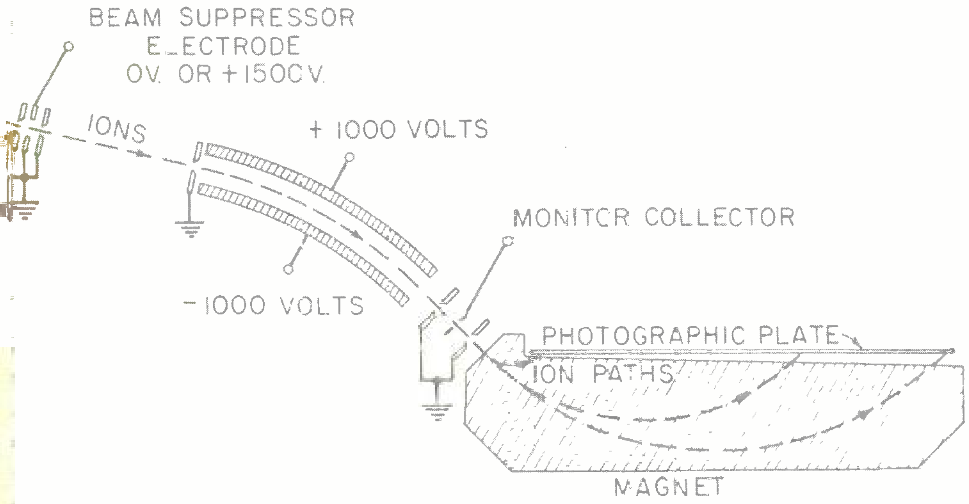
Fig. 2—Block diagram of typical mass spectrometer.



—Simplified schematic of spark source.

RCE MASS SPECTROMETRY FOR THE IMPURITY ANALYSIS OF SOLIDS

Fig. 4—180° direction focussing analyzer.



DR. JEROME KURSHAN received his AB (with honors) in Mathematics and Physics from Columbia University in 1939 and his PhD in Physics from Cornell University in 1943. He was an Assistant in Physics at Columbia University in 1939 and held the same position at Cornell University from 1939 to 1943. He received a government citation for wartime contributions to the Office of Scientific Research and Development. Dr. Kurshan joined the RCA Laboratories as a Member of the Technical Staff in 1943. During World War II, he also taught evening courses for Rutgers University under sponsorship of the Emergency Science and Management War Training Program. At RCA Laboratories, he conducted research in the fields of electron tubes and semiconductor devices and helped to administer the latter research program. Dr. Kurshan was named Mgr., Graduate Recruiting in January 1956; Mgr., Technical Recruiting and Training in June 1956; and Mgr., Employment and Training in January 1958. He was appointed to his present position, Mgr., Research Services Laboratory, in March 1959. This activity provides RCA Laboratories with technological skills in nuclear radiation, physical and chemical analysis, applied mathematics and computation, materials synthesis, electronic devices, and information services. Dr. Kurshan is a Senior Member of the IRE, of which he is a Member of the Professional Group on Engineering Management, a past member of the Education Committee, and of the Subcommittee on Solid State Devices, and a past Chairman of the Princeton Section. He is also a member of the American Physical Society, Phi Beta Kappa, Sigma Xi, Phi Kappa Phi, and Pi Mu Epsilon.

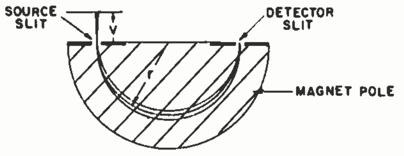


Fig. 5—Schematic diagram of spark-source, double-focussing mass spectrograph.

mine the trapping of minority carriers and hence affect the carrier lifetime. Intrinsic germanium at room temperature has a free electron concentration of 2.3×10^{13} per cubic centimeter or 5×10^{-10} free electrons per atom of germanium. One ohm-centimeter n-type germanium has a free electron concentration of 1.7×10^{15} per cubic centimeter or 4×10^{-8} carriers per atom. Such resistivities are of practical interest, although some devices (such as tunnel diodes) involve much higher carrier levels. Since these carrier concentrations can be produced by comparable concentrations of impurities, it is seen that impurity analysis at the level of ten parts per billion (ppb) atomic or better is significant in the study and production of semiconductor devices. Spark-source mass spectrometry can provide this information with significant advantages over most other analytical methods.

A REVIEW OF MASS SPECTROMETRY

Any mass spectrometer has three basic parts: *ion source*, *analyzer*, and *detector* (Fig. 2). A number of choices are possible for each of these building blocks, and the designer tries to optimize the combination of choices for the particular application. A review of some of the major schemes utilized will contribute to an understanding of the principles involved.

In principle, we wish to measure the presence of certain atoms or molecules in a sample. In practice, the analyzer is designed to utilize the properties of charged particles which have been freed from the original matrix, and so the front end of the instrument is invariably an ion source. We find ourselves actually determining mass-to-charge ratio rather than mass itself. Ambiguities, however, can usually be resolved, and the extra variable (number of electronic charges) can sometimes be usefully employed in confirming an identification.

The characteristics desired in an ion source for the trace analysis of solids are: high efficiency of ion production, uniform ionization efficiency, and freedom from contaminating ions. There are a number of other requirements that are less general and whose importance depend on the design of the rest of the system. For example, if sensitive electrical detection is to be used at the output, the ion source should not introduce electrical noise. A mono-energetic source of ions eases the requirements on the analyzer section. Duckworth,[2] in his review of mass spectrometry, lists the following major sources of positive ions: gas discharge, surface ionization, electron impact, vacuum spark, low voltage arc, Philips ionization gage, field emission, ion bombardment, and electron bombardment. Negative ions may also be generated, but in general they are harder to produce and are used primarily for more specialized or restricted investigations.

The ionization methods most useful in the trace analysis of solids are surface (or thermal), electron impact, and vacuum spark. In addition, ion bombardment (sputtering) has been very valuable in the analysis of adsorbed surface layers on solids. Surface ionization sources are invaluable in certain applications, for example in working with microgram samples using the technique of isotopic dilution. They are, however, unsuited for a broad-spectrum analysis because both the evaporation rate and the ion-to-neutral ratio vary widely among the elements. Electron impact is the most commonly used ionization mechanism in mass spectrometry. Honig[3] has used this method for solids analysis. Here a heated crucible is used to vaporize the sample whose vapor is then ionized by an electron beam. This source can provide ions with a very small energy spread and has merit where an analyzer employing only simple direction focussing is to be used. It also produces stable, low noise ion current, permitting the use of sensitive electrical detection. While the ionization efficiency varies for different elements, relative values can be calculated adequately for semi-quantitative accuracy from ionization cross-section data. An important limitation arises in the analysis of refractory materials which require very high temperatures for vaporizing the sample.

The ion source used in the MS7 mass spectrometer utilizes a pulsed vacuum spark to perform the dual role of releasing and ionizing atoms and molecules from the sample. As developed by A. J. Dempster in 1936, this source took the form of a high-frequency, high-voltage discharge between two electrodes in vacuum. The present instrument uses the arrangement shown schematically in Fig. 3. The oscillator frequency is about 0.5 Mc and the spark voltage can be adjusted up to values of the order of 100 kv. The RF pulse length and repetition rate are adjustable, but are typically of the order of 100 μsec and 1 kc, respectively. The self-resonant output transformer is a variation of the well-known Tesla coil. Since the discharge occurs between electrodes formed of the sample itself, ions are produced which are chemically representative of the sample being analyzed. The major advantages of this ion source are: All elements present in the sample are ionized with comparable efficiency, the variation being within a factor of three; contamination is minimized by avoidance of a crucible and by keeping the sample holders away from the active spark region; surface impurities can be detected by careful control of the sparking conditions and by observation of the ions as a function of time. The chief disadvantages of the vacuum spark ion source are: The energy-spread among the ions formed is relatively large (several thousand volts); the spark is unsteady and electrically noisy; the ion patterns at the output are complicated by an abundance of multiply-charged and polyatomic ions. While these disadvantages are formidable, they were overcome successfully by N. B. Hannay[4] in a double-focussing mass spectrometer employing photographic plate detection. This work paved the way for the several successful commercial instruments which have recently appeared.

The analyzer portion of a mass spectrometer (second block in Fig. 2) can follow one of several basic principles, although once the ion source is determined, there may be less freedom in the choice of analyzer design. Historically, some of the earliest applications of mass spectrometry used a single-focussing or deflection type analyzer. A charged particle moving with constant energy at right angles to a uniform magnetic field describes a circular path

Fig. 6—Mass spectrum of GaAs sample recorded photographically.

given by: $m/e = k\,H^2 r^2/V$ (1)
Where: m = mass in atomic mass units, e = number of electronic charges, H = magnetic field strength in gauss, r = radius of the path in centimeters, V = energy in electron volts, and $k = 4.826 \times 10^{-5}$. As employed by Dempster in 1918, ions enter the magnetic field region through a narrow slit at the boundary as shown in Fig. 5. After 180° deflection, they emerge at distances determined by Eq. 1. Ions of the same energy, but entering the magnetic field with slightly different directions, are brought to a focus at the same point. Often single-focussing mass spectrometers are made with deflection angles of 60° and 90°. These utilize smaller magnets which comprise a circular sector of the same angle and provide convenient field-free regions for the source and detector since the slits are then located at a distance from the boundaries of the magnetic field.

Single-focussing analyzers require either a source of mono-energetic ions or else an energy filter ahead of the analyzer. Double-focussing analyzers have been devised which simultaneously focus ions having a significant spread in both initial energy and direction, the position of focus being dependent only on m/e for given operating conditions. Most of these arrangements require the ions to traverse successively radial electrostatic and homogeneous magnetostatic fields. The MS7 mass spectrometer uses a double-focussing analyzer and thus is enabled to take advantage of the spark source which produces ions with uniform sensitivity for different elements but with a large range of initial ion energies.

Fig. 4 illustrates how the MS7 gets simultaneous focus for both velocity (energy) and direction. The electrostatic analyzer forms the arc of a circle subtending an angle of $\pi/4\sqrt{2}$ radians (31°50′) at a radius of 15 inches. The deflection in the magnetic field is $\pi/2$ radians (90°) regardless of the ion mass, the path radii varying from 1.3 to 8.0 inches. Ions of different m/e are brought to individual foci in a plane near the boundary of the magnetic field despite a spread of several hundred volts in energy.

The third function diagrammed in Fig. 2, ion detection, can also be performed in a variety of ways. It is seen in Fig. 5 that the MS7 utilizes a photographic plate which has the advantage of recording simultaneously a spectrum of masses, thus preserving relative abundance information, despite a fluctuating source such as the vacuum spark. The photographic plate is an integrating device which requires about 10^4 ions for a barely detectable trace in the MS7. The photographic plate also has a number of drawbacks. It is a source of adsorbed gas; the latent image must be developed chemically; its sensitivity varies somewhat for different ions and is also dependent on ion energy; it is sensitive to light.

Electrical detection using an electrometer tube and a DC amplifier can be employed with a suitable exit slit to limit the mass range being detected. The mass observed can be varied by changing the magnetic field strength. It is practical to measure currents as small as 10^{-16} amperes. Vibrating reed electrometers are favored over DC-feedback amplifiers for the most sensitive detectors. In the MS7, an electrometer tube is used, but only as a nonselective detector in conjunction with the monitor collector (Fig. 4). By integrating the monitored current, an electrical measure is obtained of the total number of ions transmitted.

Individual ions can be detected by means of an electron multiplier, whose first stage is exposed to the ion beam. The conversion yield (ratio of secondary electrons to incident ions, varies with the ion energy and the ion mass. Gain instability occurs due to the variation of the secondary emission ratio with time. The high sensitivity and fast response are especially valuable in shortening the time to determine a particular mass or where the amount of sample is limited. Where a more complete spectrum is to be determined, the total time for successive determinations of different masses becomes comparable to the exposure times required by photographic plates which, however, record the spectrum simultaneously.

TECHNIQUE OF SPARK-SOURCE MASS SPECTROMETRY

An appreciation of the problems in trace analysis as well as the results achievable can be obtained by considering the MS7 instrument specifically, whose essential electrical features are diagrammed in Fig. 4. The source, analyzer, and detector regions are physically distinct and are pumped differentially by separate diffusion pumps. In addition, these regions can be isolated by vacuum valves so that either the source or the photo-plate chamber can be opened to air without deteriorating vacuum conditions in the analyzer.

Samples should be in the form of pairs of bars about 1/16 inch square and 1/2 inch long. They are held in spring-loaded tantalum clips to minimize breakage of brittle material and to reduce interference of the holder material with the analysis. Tantalum has a single major isotope (mass 181), and its multiply-charged ions fall on noncritical points in typical mass spectra. The sample bars comprise the spark electrodes. Metals and semiconductors usually perform very well, whereas higher resistivity materials make it difficult to provide sufficient spark current. Samples are normally etched to remove surface contamination and then handled with plastic-tipped tweezers since metal tweezers will leave "fingerprints" that can be readily detected by the mass spectrometer. The source region is normally baked at 250°C by means of external heaters after the sample has been inserted and a vacuum obtained. The extent of baking is determined somewhat by the sensitivity of analysis desired, but several hours are often needed. Pressures of the order of 10^{-8} torr are typical for the ion source and analyzer parts of the system. The photographic plates cannot be baked, but the magazine holds eight plates so that they can be thoroughly outgassed by prolonged stay in vacuum.

The voltage, repetition rate and RF frequency of the spark are adjusted to give maximum beam current without excessive heating of the sample electrodes. The photographic plate can be remotely manipulated to expose 15 separate strips and successive exposures are normally increased by a factor of approximately $\sqrt{10}$ in total charge transmitted. This is measured by the monitor collector which intercepts a fixed fraction of the beam. Exposures can be timed by switching the spark voltage itself, or by permitting continuous sparking and deflecting the beam by a voltage on the suppressor electrode. The instrument can cover a mass ratio of 35:1, the m/e range normally employed running from 7 to 240.

TYPICAL ANALYSIS

The method of obtaining information from the photographic plate can best be understood by a discussion of a specific analysis. Fig. 6 is a reproduction of a typical 2-by-10-inch glass negative plate exposed in the analysis of a gallium arsenide sample. The numbers on the right indicate the relative exposures (in units of 10^{-9} coulombs), each number corresponding to the horizontal exposed strip to its left. For accurate interpolation between exposures a microdensitometer recording is taken on the individual lines. For a semiquantitative analysis or a quick survey, a simpler visual procedure is utilized. The graded series of exposures enables the analyst to pick the one at which a particular line just appears. The shorter the exposure for this appearance, the more abundant the corresponding constituent. While a number of corrections need to be made for a quantitative determination, to a first approximation the concentration C of an atom in the sample in parts per million is given by:

$$C = B/EA$$

Where E = "exposure," or charge collected, on the monitor electrode in nanocoulombs, A = fractional abundance of the isotope observed, and B = a factor determined by the efficiency of ion production, the plate sensitivity, the ratio of multiply-charged and polyatomic ions, and the fraction of the beam intercepted by the monitor. The factor B can be taken as 3 for the normal operating conditions currently employed with our instrument.

The shortest exposures are made to establish a reference point in terms of the major constituents and serves as a calibration check on the plate sensitivity. The strongest lines in any exposure in Fig. 6 are due to $^{69}Ga^+$, $^{71}Ga^+$ and $^{75}As^+$. The scale at the bottom of the plate gives m/e values. Since all impurities are present in very low concentration and since the abundance ratio of the two gallium isotopes is approximately 3:2, these lines nominally represent 30, 20, and 50 percent, respectively, of the sample atoms. The triad of gallium and arsenic lines reappear at ½, ⅓, ¼ . . . of the actual mass numbers due to mono-atomic ions charged 2+, 3+, 4+. . . . In addition, lines appear between mass numbers 138 and 150 due to various combinations of the three isotopes taken two at a time. Lines due to three-atom clusters are also visible. There is a line at mass number 112½ attributed to $^{75}As_3^{++}$, although such polyatomic ions do not usually appear with more than one electronic charge.

Silicon appears as an impurity in this sample at mass number 28, 29 and 30 with respective isotope abundances of 92, 5 and 3 percent. While in principle, any of the lines could serve for identification, CO could also be present at mass 28 and C_2H_5 at mass 29. Mass 30 is thus the clincher in the identification, and although silicon is present in a concentration of about 1.5 ppm, the $^{30}Si^+$ line does not appear until the last few exposures because of its low abundance.

Aluminum (present at about 0.3 ppm) has a single isotope at mass 27 and can be masked by a hydrocarbon fragment of the same mass number. On the present plate the two lines can actually be resolved, since the mass defect of the hydrocarbon exceeds the resolving power of the instrument (about 1:1500). Identification is verifiable (on the original plate) by a faint line at mass 13½ due to $^{27}Al^{++}$ only.

The carbon and oxygen background in a mass spectrometer is normally high due to pump oil vapors, adsorbed gases and water vapor. Effective outgassing procedures have been recently developed for reducing the background gas concentration to less than 100 ppb and the $^{12}C^+$ and $^{16}O^+$ lines seen on this plate represent bulk impurities in the sample.

It may be noted that the lines due to ^{55}Mn, ^{58}Ni, ^{63}Cu and ^{65}Cu show a nonlinearity as a function of exposure. That is, they are stronger on the "100" exposure than on the "300." This is attributed to segregation of these impurities in the sample. As the sample is consumed in the spark, an impurity-rich region is exposed and there is an increase in ions of this impurity. Similar nonlinearities can occur due to adsorbed atoms on the sample surface. The interpretation is dependent on the sample preparation, outgassing treatment and the exposures at which the lines are observed.

The $^{75}As^+$ line begins to appear at the shortest exposure (requiring only milliseconds) although this may not be apparent in the reproduction. Because the beam current is limited by the characteristics of the instrument to less than a nanoampere, the longest exposures used may take several hours. The general blackening at the longest exposures of the matrix elements is believed due to secondary and tertiary ions from the photoplate and the magnet pole faces. It is a function of adsorbed gas and vacuum conditions and limits the detection of very weak lines adjacent to the major constituent lines. This blackening can be reduced by prolonged baking and pumping and the plate shown is a very good example of minimum interference. In the region between mass 40 and 60, a number of unsharp lines appear which are actually the heads of bands rather than individually distinct traces. These are due to a charge exchange effect where collisions between ions and residual gas atoms in the analyzers result in one losing and the other gaining a charge. Relatively sharp lines are formed, since there is discrimination against ions which exchange charge at locations other than the region between the two analyzers.

FUTURE

Spark-source mass spectrometry for the trace analysis of solids is still in its infancy. It has already established itself, however, as one of the important analytical techniques in furthering materials research because of its combination of sensitivity, broad coverage and speed. Work by J. R. Woolston at RCA Laboratories has already greatly reduced one of the serious limitations, poor detection limits for H, C, N, and O. These elements can now be detected at levels down to 0.1 ppm before they are masked by background gases. This has been very valuable in a better understanding of compound semiconductors where oxygen, for example, appears to play a more significant role than in germanium. Further progress will undoubtedly be made in pushing back detection limits of all elements.

The MS7 is basically a mass analyzer and such an instrument in a research laboratory is bound to be used unconventionally in solving problems. Fig. 1a shows an adaptation made so that the spark source could be replaced by a source of ions in the form of a phosphor subjected to electron bombardment simulating normal operating conditions.

Many refinements are still needed in the basic utilization of spark-source mass spectrometry for accurate quantitative determinations. Plate sensitivity needs better control and more study as a function of operating parameters. Better methods are needed for reading the plates. The ionization mechanism and the variations in ionization efficiency require a better understanding. Methods are needed for increasing the beam current without reducing mass resolution. Techniques must be developed for using small samples, for analyzing small regions of samples and for sparking "difficult" samples such as powders, insulators, or even liquids. Progress is actually being made on all these problems, yet their existence makes this branch of materials analysis a very stimulating field of activity.

ACKNOWLEDGMENT

Grateful acknowledgment is made to J. R. Woolston for many helpful discussions and to both him and R. E. Honig for critical reading of this paper.

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NEW FIBER-OPTICS TECHNIQUES
. . . For Precision Measuring Devices, Transducers, and Automatic Control Systems

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Initial RCA work with fiber optics concentrated on optical systems—for example, in high-resolution TV systems. Now, as described herein, fiber optics is being applied to transducers, distance and angle measuring devices, automatic position-control systems, card and tape readers, light-operated relays, function generators, and other similar devices.

The author, E. D. Grim, Jr. The insets show fiber-optic shaft encoder (ADCON) with case (top) and without (bottom). See Fig. 4 for ADCON details.

Applied research in fiber-optic techniques has been in progress at RCA for a number of years.[1-6] Initial efforts were primarily concerned with the application of fiber optics to improve optical-system performance. Included in these have been high-resolution TV systems with fiber-optic line-to-raster converters, fiber-optic bundles for flexible links in optical systems, and other applications of coherent fiber-optic arrays.

Another area of investigation has been that of scanners using fiber-optic coherent lines and bundles to transform lines to arcs so that linear arrays can be scanned by a rotating sensor. This technique is obviously not limited to the conversion of linear-input to arc-output arrangements, but can convert from any input array to any other convenient output array so that coherent scanning may be accomplished.

NEW FIBER-OPTIC APPLICATIONS

In this paper, RCA applications of fiber optics to transducers, distance and angle measuring devices, automatic position-control systems, card and tape readers, light operated relays, function generators, and other similar devices are described. Applications in this area have stressed the use of single or multiple noncoherent bundles, since in many cases this arrangement leads to the simplest and most inexpensive fabrication. The following attributes of fiber optics admirably suit them for application in these fields:

1) The ability to transmit light from one point to another through flexible glass filaments that permit bending and twisting the fibers to any conceivable configuration.
2) The capability to arrange any aperture shape at one end of a bundle, and change it to any other aperture arrangement at the other end. This is particularly useful when a narrow coding pattern for high-resolution position sensing is illuminated by a source whose dimensions are not compatible with the pattern width. This capability is also advantageous for optimally coupling to a photosensitive element whose dimensions are not matched to the pattern. Maximum utilization is made of available light with a minimum of complexity of the optical components.
3) The ease of fabricating devices made from the fiber-optic elements. Ordinary epoxy resins form a suitable matrix for embedding the fiber elements, and simple glass-grinding techniques suffice for finishing the faces of the elements.
4) The high light-utilization efficiency and small size of fiber-optic configurations complement each other. That is, a comparable reduction in wattage dissipation accompanies a reduction in size over ordinary, or conventional optical systems; cooling requirements in small units can be met effectively.

The basis for the new developments is the fiber-optic element, a fine filament

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of glass of circular cross-section and high index of refraction surrounded by a thin jacket of lower-index glass. The net result of this configuration is that a light ray entering one end of the bundle is reflected internally from wall to wall with low loss, and finally emerges from the opposite end of the bundle. Thus, the fiber acts as a "waveguide" for the incident light. Since the fibers can be fabricated with diameters of less than 0.001 inch, a high degree of resolution and accuracy can be obtained with the applications described in this article.

FIBER-OPTIC VERNIER PICKOFF

The fiber-optic vernier pickoff has application to a class of servomechanisms used to position a load in accordance with a sequentially switched prerecorded input command. The preprogrammed star tracker with a clock-driven input tape as a navigation system reference is a military application of this type of servomechanism; a machine tool with a programmed tape input for an automatic work cycle is a commercial application. The component determining the resolution and accuracy of this system is the pickoff, or the sensor. The pickoff yields the voltage or current analog of the output load position; examples are: synchros, microsyns, resolvers, linear potentiometers, and resistive potentiometers.

The configuration of a new vernier fiber-optic pickoff system is shown in Fig. 1; its operation and its advantages over the conventional pickoffs are described below:

The *A converter* consists of circular bundles arranged in a matrix array at the input, or light-source end of the converter. Each round bundle consists of many fibers which are reconfigured at the opposite end of the converter into a column one-fiber wide. All fibers in the bundle labeled *1* are arrayed in the column labeled *1*, and the same is true of bundles *2*, *3* and so on. When the input end of bundle *1* is illuminated, a column of light appears in column *1* at the opposite end of the converter, and so on for the remaining columns.

The *B converter*, or rotor, consists of a number of adjacent columns of fibers similar to those at the output end of converter *A*, but less in number. Fibers in each column form a circular bundle on the top or side of converter *B*. A photodiode is then placed with its sensitive area against the circular array formed by each fiber bundle. The light or dark input to each column on the *B* converter will be sensed by the photodiode in this configuration.

The system operation is explained below. Fibers of 0.003 inch diameter are used in the *A* stator converter and fibers of 0.002-inch diameter are used in the rotor *B*. To obtain each discrete position of rotor *B*, an opaque tape with cutouts is positioned over the matrix array of fibers in converter *A* at the input end. The cutouts allow light from the source to illuminate portions of the matrix, and thus produce a precise light-to-dark transition in the column array of fibers at the *B* converter end of converter *A*.

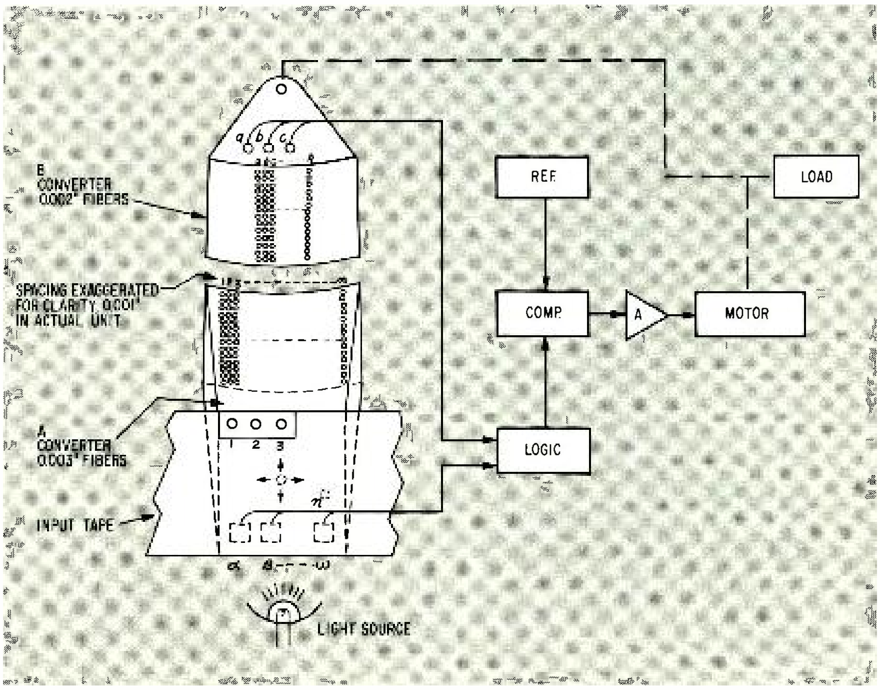
For example, if the light-to-dark transition is desired between columns *3* and *4*, then the cutout area on the tape includes *1*, *2*, and *3* positions at the matrix end of the converter, and the rest of the matrix is not illuminated. Thus, columns *1*, *2*, and *3* will be lighted and *4* to *N* will be dark.

This precise light-to-dark transition may be established in general between the q'th and $q + 1$ element by a tape cutout from *1* to q position. This is the first part of the positioning scheme. The servo is set up so that a phase-sensitive error signal is developed which will drive the load shaft and the *B* converter pickoff to the light-to-dark transition at the circular arc end of the *A* converter. The photodiode associated with one column in the *B* rotor converter, labeled *a* or *b* or *c* or . . ., is selected by the logic circuit to produce the error signal to position the output-shaft reference point precisely to the light-to-dark edge in the *A* stator converter. This selection is done automatically with each new position of the input tape by providing holes in the tape so that the holes labeled α, β, γ, . . ., will be illuminated in some pattern. There will be enough of these holes to provide selection of the K different outputs of the *B* converter. The illumination through these tape holes could directly illuminate photodiodes or could be guided by fiber-optic bundles to photodiodes, which will operate relays or other logic circuits to connect the proper input to the servo. The use of the multiple columns in the *B* converter for the vernier operation is explained below. Consider the situations portrayed in Fig. 2a, which is a top view of the rotor and stator interface shown in Fig. 1. The numbered lines represent the edges of the columns in the converters. The *0* position on each converter is taken as the reference mark, and the converter rotor *B* is rotated with respect to converter stator *A*.

Now, it is desired to position converter *B* with respect to *A* such that 0.001-inch tangential displacement between the reference marks is accomplished. Note that this is ⅓ of a division of the elements on converter *A*, and ½ of a division on converter *B*. Note first that the *0* positions on *A* and *B* are lined up by the servo when the light-to-dark transition occurs at the *0* position on the *A* converter, and when column *1* is selected in the *B* converter.

Now, to obtain the relation depicted in Fig. 2b, the cutouts in the tape are changed so that the light-to-dark transition occurs at position *1* on the *A* converter, and the logic selection illumination is arranged so that column *2* on the

Fig. 1—Configuration of the fiber-optic vernier pickoff system.



B converter is selected. This aligns the *1* markers on each converter, and it may be seen that this vernier action positions the reference markers 0.001 inch apart as was desired.

The position of the references, 0.002 inch apart, is accomplished by changing the mask so that the light-to-dark transition occurs at position *2* on the *A* converter and by selecting column *3* on the *B* converter. The resultant alignment of the marks labeled *2* on Fig. 2c produces the desired result of an 0.002-inch separation of the reference marks. Positioning the *0* reference on the *B* converter 0.003 inch to the right of the *0* reference on the *A* converter is accomplished by moving the light-to-dark transition on the *A* converter back to position *1* and selecting the *1* column on the *B* converter by suitable changes in the light mask. Thus, all the possible unique positions of the system between two reference points on the *A* converter have been covered. Since these may be general positions, it may be seen that the positioning capability is possible over the complete converter range. Note also that, with different ratios between the relative sizes of the fibers, greatly increased resolution may be obtained; for example, a ratio of fiber diameters of 9:10 may be used, which would allow positioning to 1/10 of the larger fiber diameter. Also, it is possible to use smaller diameter fibers with this higher order vernier system to obtain doubly enhanced resolution.

A summary of the advantages of the new vernier fiber optic pickoff are:

1) There are no wiping contacts to wear out. Once the fiber converters have been formed and potted, they are practically indestructible.

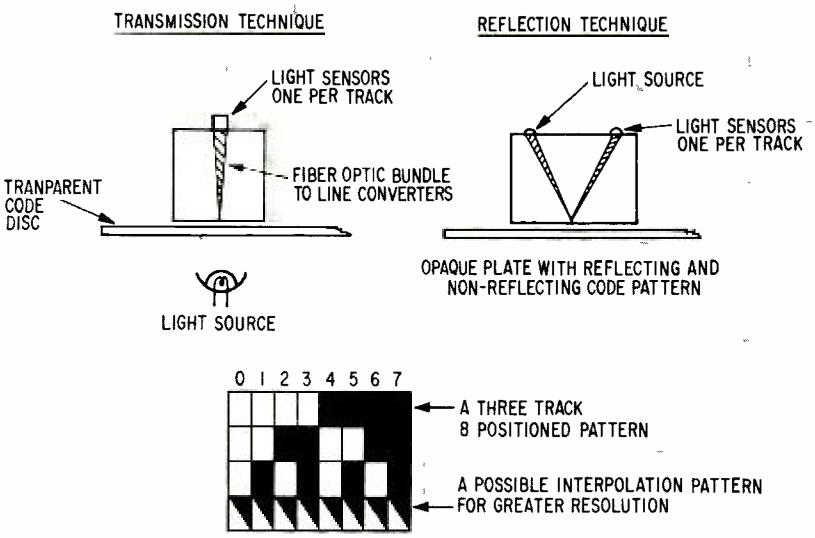


Fig. 3—Positioning systems using fiber optics and binary patterns.

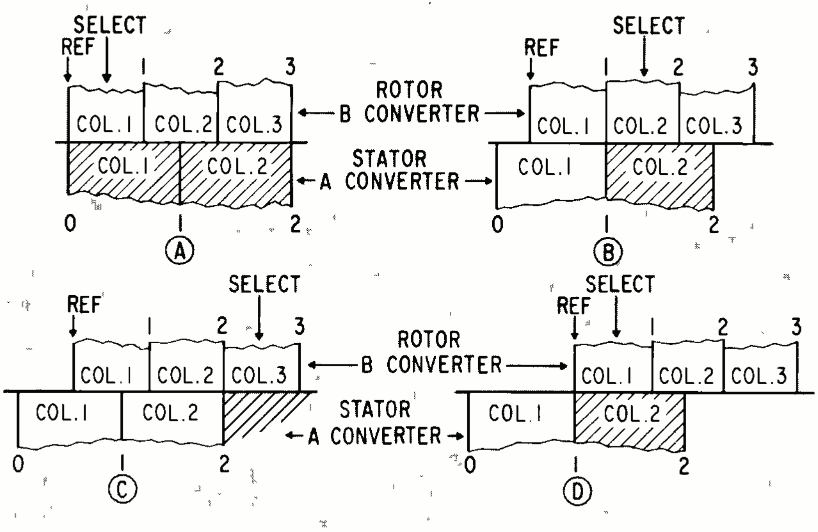
2) There is no hunting between wires as occurs in high-gain servos using wire-wound pots.

3) There is no quadrature null voltage as occurs in synchros, resolvers, differentials, and other pickoffs of a similar nature.

4) The resolution and accuracy may be increased by decreasing the fiber element size or increasing the radius of the circular arc on which the fibers are arrayed, since the pickoff scheme is incremental in nature.

5) The fiber-optics converter may be designed for special codings from the input to output end to accomplish special functions. Initially, complete flexibility in matrix input to circular arc output is possible.

Fig. 2—Vernier relationships between A and B converters.



6) Many types of input systems can be used, such as tape or card masks, or the basic fiber-optic converter may be designed to convert from more conventional coded arrays such as the punch card to the required matrix array for the proposed converter input.

7) The fiber elements may be arrayed in a circular arc, in a linear array to control linear motion, or in any conceivable array of curves or lines where motion and accurate positioning are desired. This is one of the most remarkable advantages of this technique.

FIBER OPTIC POSITIONING SYSTEMS USING REFLECTED OR TRANSMITTED LIGHT FROM THE WORKPIECE OR PATTERN

The heart of this positioning system concept is again a fiber-optic sensor which accurately determines the worktable position for automatic control. In concept, it is quite similar to the vernier pickoff described above, except that the stator reference consists of a binary pattern array of opaque and clear areas to establish the precise reference. A single line of fibers senses the pattern and may be programmed to a desired position by balancing a binary input command against the pattern output as sensed by the fiber-optic line.

The binary pattern will consist of separate tracks which represent the bits of a binary code. If there are *N* tracks, in general 2^N discrete positions may be represented in a given length with a single fiber-optic line used as a sensor. If further resolution is desired, more than one fiber-optic sensing line may be used. These may be spaced so as to obtain in-

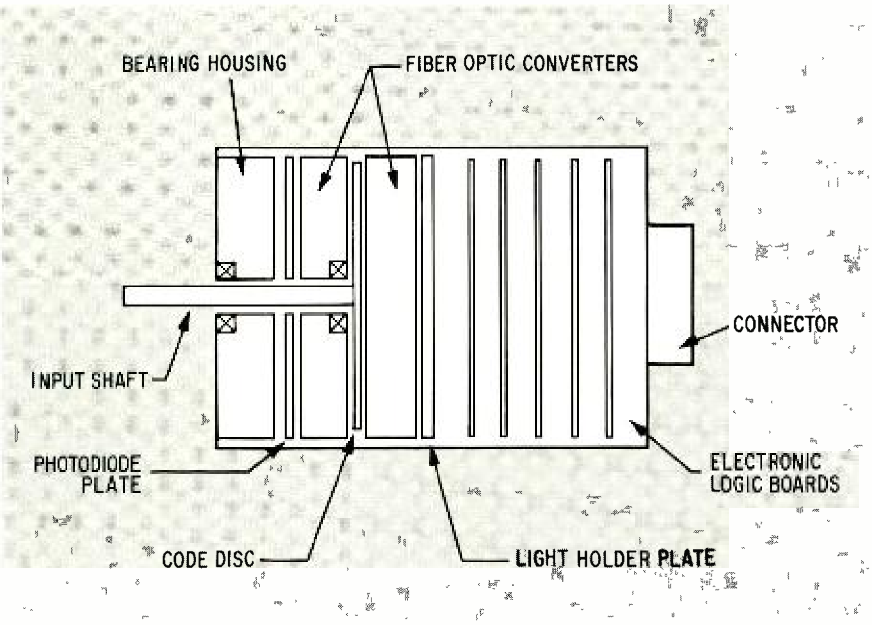


Fig. 4—Layout diagram for the fiber optic ADCON

terpolation on the finest bit, or fibers of a different diameter than the binary pattern width may be used to obtain a vernier effect, similar to that described above in the vernier pickoff.

Two principles may be used for pattern sensing. The first is the use of back lighting on a transparent pattern and sensing the transmitted light. The second method uses an opaque pattern, where the binary pattern consists of reflecting surfaces. The fiber-optic sensor then consists of two fiber-optic lines, adjacent to each other and above the pattern. A light source illuminates one bundle and the light from the line output of this bundle reflects from the pattern surface and enters the line entrance face of the pickup bundle. In this fashion, the binary pattern may be illuminated and sensed from the same side of the pattern. The possibility also exists for provision of an analog pattern in the final bit place of the positioner. This would correspond to the slidewire techniques used in precision bridge measuring devices. This would provide interpolated positioning capability between the discrete positions in the least significant bit and increase the resolution and precision of the overall device. A diagram of the fiber-optic positioners is shown in Fig. 3.

THE FIBER-OPTIC SHAFT ENCODER

The concept for the ADCON developed from techniques conceived during the applied research studies in the fiber-optic transducer area, coupled with the knowledge of the shortcomings of the present state-of-the-art in ADCON design. The fiber-optic ADCON will be superior to both the mechanical and optical units which are now available for the following reasons:

1) Elimination of sliding contacts, providing noise-free output signals coupled with greatly increased mean time before failure.
2) Elimination of stiction and viscous friction due to brush pressures on the code disk.
3) Equal or better resolution than the mechanical ADCON in the same diameter.
4) Minimum wattage requirement for the light source in the ADCON, because of the greatly enhanced light utilization with the fiber-optic design.
5) The accomplishment of a natural binary output with an optical ADCON design.
6) A reduction in weight and complexity over the conventional optical ADCON because of the elimination of the requirement for conventional optics and special light source power supplies.
7) A competitive sales price per unit when compared to the present optical and mechanical units.

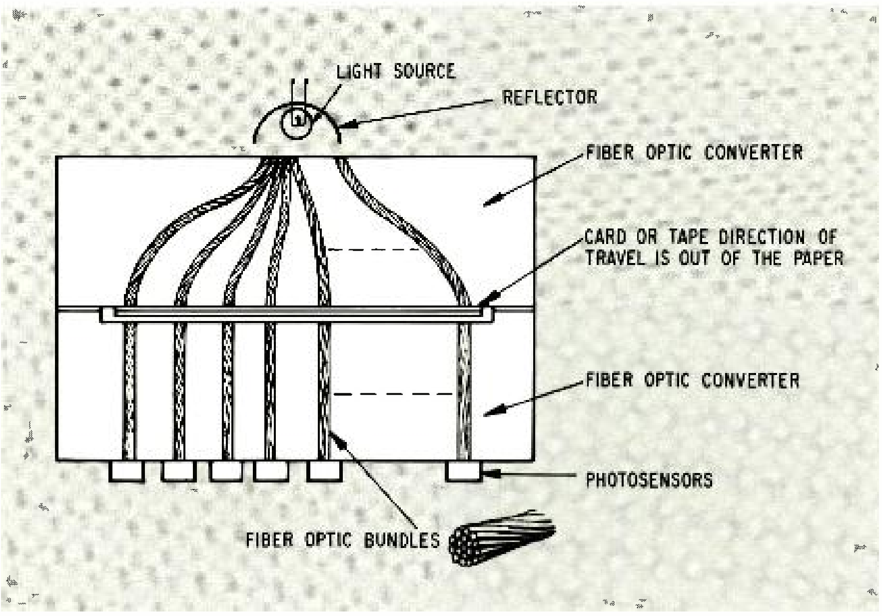
A feasibility model of the fiber-optic ADCON is now operating successfully in the laboratory; this unit has the following specifications:

1) Diameter: 2.5 inches
2) Length: 3.25 inches
3) Weight: 9 ounces
4) Resolution: 7, 8, or 9 bits in one revolution
5) Output: Natural binary, bit and complement
6) Logic Levels, bit: + 6V →*1*; + 0.5V →*0*
7) Maximum rotational rates: 20 rpm
8) Power dissipation of logic circuits and light sources: 0.5 watt

Parameters were chosen to fulfill the needs of a specific application in a tactical aircraft, and may be modified for other applications. Specifically, higher resolution in a single or multiturn design could be accomplished in the same diameter as the present feasibility models; and, it would also be possible to fabricate a grey-code design if that type were desirable.

The fiber-optic ADCON design includes a light assembly coupled to a fiber-optic converter. This converter optimally

Fig. 5—Fiber-optic card reading system.



couples to the light filament at one end, and converts to a shape optimally matched to the code disk pattern at the other end. The light passes through the transparent code disk and then through another similar fiber-optic converter, which is coupled to a photodiode assembly that senses the binary pattern on the code disk. The physical arrangement of the bundles and sensors is such that the *V*-scan logic may be accomplished for a non-ambiguous natural binary output. A layout diagram of the fiber-optic ADCON is shown in Fig. 4.

THE FIBER OPTIC TAPE OR CARD READER

Photoelectric sensing systems for reading punched cards and tapes have been used for many years. They have the following distinct advantages over mechanical readers:

1) Higher reading speed
2) No contact wear or bounce
3) No card or tape damage
4) Longer system life
5) Lower system maintenance

However, there are two problems arising in the design of conventional optical systems:

First, a heat problem arises in the reading head, because of the high wattage requirements for the light sources. This is due to the inefficient utilization of the light in the conventional optical system.

Second, washout, or the inability of the system to discriminate two adjacent holes in the tape or card due to lack of response in the photosensing element. Both of these problems can be solved by the use of the techniques of fiber optics (consider the system shown in Fig. 5).

This system consists of a light source with a reflector which illuminates a circular bundle of fiber optics. This bundle is split into many separate smaller bundles positioned so as to illuminate the tape or card holes individually as they pass under the fiber-optic array. In considering the details of this optical system several points become evident.

With the use of the reflector, a high percentage of the light energy may be focused on the input end of the fiber-optic converter. This light energy emerges from the multiple output ends of the bundle with essentially the same intensity as the input. Thus, each tape hole location will be illuminated as if the light source were located at the output end of the bundle. This may be compared with the usual optical system where light is located some distance from the tape or card to obtain the coverage area desired; a higher wattage requirement and a poor area utilization of light result.

The fiber-optic array solves this problem by producing essentially cold light of high intensity at the tape or card-hole location. This bundle may also be shaped to the precise size and configuration of the tape or card hole. After the illumination passes thru the card hole it must be directed to the photosensor. Since, in general, the dimensions of the photosensors are not compatible with the spacing of the tape or card holes, a fiber-optic converter may be used on this side of the card or tape. The fiber-optic bundles are laid out from the tape or card-hole array to the photosensor array, and potted to form a permanent converter. The ends of the bundles may be shaped to match the tape or card hole at the input end and reformed at the opposite end to match optimally to the surface of the photosensor.

Since the light intensity of the source is utilized in a much more efficient fashion, very-high-illumination intensities with small wattage sources may be obtained. This leads to the solution of the two problems which were outlined above. Since the light source is removed from the photosensing elements, the heat dissipation problem is minimized by using a low-wattage source. The increase in light intensity means that more drive will be accomplished on the photosensors, and thus a higher threshold level established for the presence of light. In this fashion a greater difference in output signal will exist between light and no-light conditions, and at high data rates a greater difference will exist between pulses from adjacent tape holes. In this fashion, the problem of washout may be minimized.

OTHER APPLICATION AREAS

Continual improvement in light sources and photosensitive elements coupled with the advanced techniques of fiber optics allow replacement of many mechanical devices with superior optical ones.

Switching

For example, mechanical devices with switch contacts such as relays, choppers, stepping switches, etc., have a limited life due to the deterioration of these contacts. Contacts may be replaced by photosensitive elements coupled to light sources thru fiber-optic converters to form efficient, compact, and reliable long-lasting units. At the present time these contacts are limited to low-powered switching applications because of the voltage and current limitations of the photosensing elements. However, with the continued improvement of photosensitive materials and devices in the future, light-operated, single-stage, high-power switching will be possible. At present, power handling capabilities of photosensors are in the 10-to-1000-mw range, and a perfect switch may only be approximated by these devices.

Light Gradations

Fiber-optic converters can also be used to advantage in applications where gradations in light are to be measured rather than the simple presence or absence of light. Such things as function generators and rotation indicators where a pattern on a rotating wheel is sensed can be built efficiently with the new fiber-optic techniques. In these applications the fiber optics may be used to convert the source illumination from a point to a narrow radial line illuminating the pattern on the rotating disk. A similar pickup line is arrayed on the opposite side of the pattern disk and senses the light which passes thru the pattern. This light is piped down the fiber-optic elements which are arrayed at the opposite end of the pickup converter in a shape that matches optimally the sensitive area of a photoelement. The photo-element output is proportional to the amount of light passed by the pattern and thus produces a voltage or current representation of the pattern.

CONCLUSION

In conclusion, the basic techniques of fiber optics assure the greatest efficiency possible in light utilization. Fiber optics will also have application in areas other than scanning and coherent picture transmission; for example, possible applications are in the process control field and in data-position sensing elements. Fiber optics allow improvements in light utilization and the accomplishment of light distributions difficult or impossible with conventional optical methods. For these reasons, technological advances using the techniques of fiber optics seem assured during the next five years.

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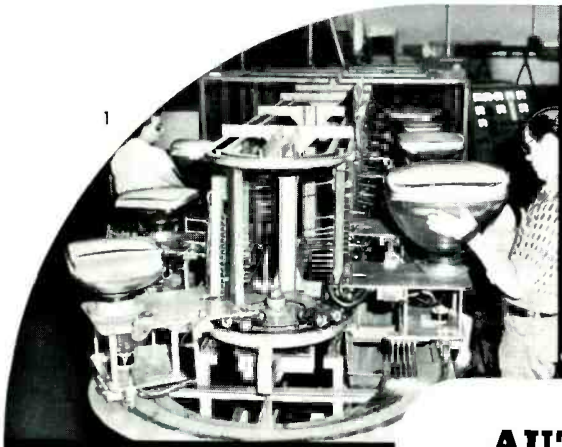
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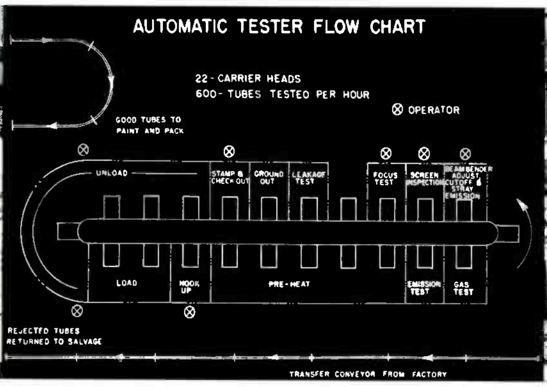

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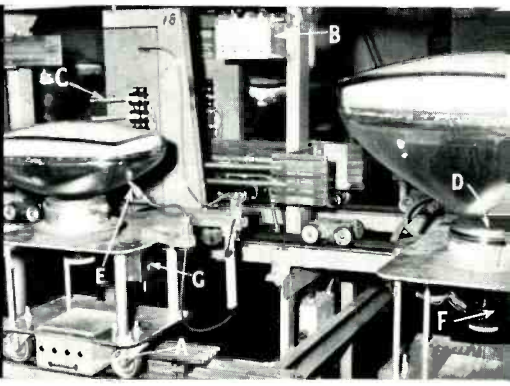

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AUTOMATIC TESTING OF PICTURE TUBES


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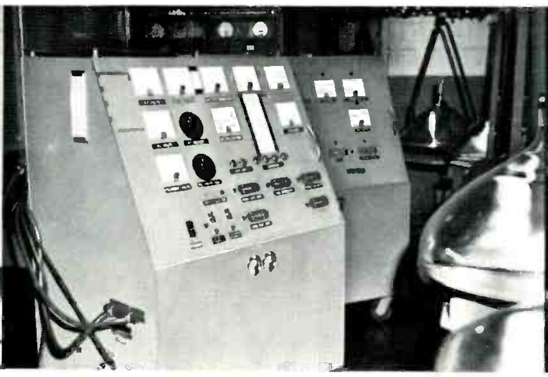
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The new automatic test equipment described here is now in use for the production-line testing of picture tubes at the Marion, Indiana plant of the Electron Tube Division. The equipment, developed and designed by ETD engineers of that plant, can handle 650 picture tubes per hour, and has provided an important solution to the testing problems inherent in increasing production rates and number of picture-tube types.

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Manufacturing Engineering

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Marion, Indiana

Before the installation of automatic test equipment, all picture tubes produced in RCA's Marion plant were tested on manual test sets little different from those designed more than two decades earlier for testing cathode-ray tubes. Then, as production increased and the number of tube types mounted, it became apparent that automatic testing was badly needed.

Fifteen months of intensive research were required for the development of an automatic device which was compatible with the existing standards of production rate, test parameters, and tube quality. Within six months after the completion of the design, the equipment had been installed and was in operation. The new equipment, which exceeded all expectations, proved capable of completely testing more than 650 tubes per hour and required only seven operators. Some fifteen test sets and operators would be required for a comparable rate with manual testing.

NEW AUTOMATIC TEST SET

The new equipment, designated the M2707J Automatic Test Set (Figs. 1, 2), consists of an oval-shaped nonindexing table conveyor having 22 carriers which convey the tubes to various test consoles and cabinets. Each carrier (Fig. 3) has a deflecting yoke, a dual socket (capable of connecting operating voltages to either the standard-based or wafer-based tubes), an anode contactor, an encoder system for test selection, a reject flag system, and a spring contactor to supply the various test voltages from a stationary bus bar.

The first operator loads each tube face up on the carrier by placing the neck through the universal deflecting yoke (Fig. 4). The second operator attaches the socket, inserts the anode contact, and programs the test sequence by depressing a pattern of buttons on the encoder system. As the carrier advances, contact is made with the bus bar which supplies heater voltage for preheating the tube. The tube then proceeds through a series of six test sections (each having a time interval of 6 seconds) in which the following automatic tests are performed (Figs. 5 and 6): 1) a cathode quality test, 2) a gas test, 3) a cutoff test, 4) a screen-check test, 5) a focus-condition test, and 6) a leakage test. A third operator, located at the cutoff test section, makes a visual test for stray emission on certain types and positions and adjusts a beam-bender magnet on ion-trap types. The fourth and fifth operators check screen condition and focus condition, respectively. Immediately after the leakage-test position, there is a "ground out" position to remove high-voltage charges from the conductive ex-

Fig. 1—Automatic picture-tube tester, Marion Indiana plant, capable of testing over 650 tubes per hour. At the right, operator loads tube on tester. Tubes at left have completed test and are ready to be removed from automatic test set. The room that houses this automatic test equipment is environment (temperature and humidity) controlled for maximum efficiency of test equipment. All test sections are located in the background.

Fig. 2—Automatic picture-tube tester flow chart.

Fig. 3—Close-up view of test set carrier heads showing detail: (a) encoder box for operator test code selection; (b) encoder check lights to check operator test code selection; (c) tube carrier buss contacts for test voltages; (d) universal yoke and tube support; (e) anode voltage contact and lead; (f) base socket for pin connection; (g) automatic reject flag indicator.

Fig. 4—Operator at left loads tube through universal yoke on carrier test head and removes pin protector. Operator at right positions socket, P2 lead and depresses the proper buttons on the encoder box to establish the test sequence at each test position for that particular tube type.

Fig. 5—Test consoles for the automatic cathode quality test and the automatic gas test. Each console, connected to the test conveyor through bus bars, performs a series of automatic tests in less than 6 seconds.

Fig. 6—Four of the six-second test positions. From left to right: the automatic high-voltage cutoff test, the screen-check test, the focus-condition test, and the automatic-leakage test.

ternal paint and the anode contact button. The sixth operator verifies that the type under test was properly coded for its required test sequence, checks out the reject flag on the carrier head against the reject tape on tube, places a test stamp identification on good tubes. and disconnects the socket and the anode contact. The seventh operator unloads all tubes. Good tubes are placed on a conveyor for painting and packing; rejected tubes are conveyed to the salvage-analysis department.

ENCODER-DECODER TEST SEQUENCE SELECTION SYSTEM

Originally, it was felt that all standard-product reject limits for all types, could be consolidated into one set of specifications including cathode quality factor. cutoff, gas, and high-voltage leakage. However, with the advent of custom-made types tested to individual specifications, it became evident that more flexibility was necessary in the equipment. As a result, a new sequence selection system was developed which permits the loading operator to code each tube carrier with the information necessary for automatic adjustment of the testing parameters throughout the test sequence. Complete flexibility of testing and loading is obtained because each carrier is electrically independent in each test position. Tests on all tube types were standardized to fall within one of fifteen classes of testing specifications. The carrier coding system selected consists of four constant-contact push-button switches mounted on the face of the tube carrier. The four buttons with their sixteen operating combinations allow the operator to select the correct test class for the tube to be tested. For example, the operator takes a tube to be tested from the factory conveyor, determines its type number, and assigns the test class by referring to a type-class chart. After determining the correct test class, the operator loads the tube on a carrier and programs the test sequency by pushing buttons corresponding to the test-class numbers. The button maintain their setting throughout the succeeding test; wipers on the carrier and stationary bus bar at each test position operate the test circuits to adjust the test conditions. After the tube has been tested, the push-buttons are released automatically before another tube is loaded. A manual code release is provided on the face of the push-button panel, and light boxes placed on the test conveyor permit visual checking of the carrier code information.

AUTOMATIC CATHODE-QUALITY TEST

The cathode-quality tester makes the following series of six tests automatically in a period of less than 6 seconds: tests for opens, shorts, emission warmup, internal continuity, cutoff, and quality factor θ (emission compared to cutoff). The initial test coding selects one of two *G2* voltages (Grid No. 2) and one of two limits of the cathode-quality factor, depending on whether the tube is a grid-driven or cathode-driven type. If a tube is rejected, automatic circuit or lock-in limit meters energize the reject system.

AUTOMATIC GAS TEST

After the tube leaves the cathode-quality test, it enters a gas-test section. The gas-test equipment contains a difference amplifier which is automatically adjusted to balance out the leakage of the tube under test. Operating voltages are applied, and the tube is then automatically adjusted to a cathode current of 500 μamp. A small negative potential applied at the ultor collects any ionized gas present and results in a very small current which is fed to the difference amplifier. The amount of imbalance is in direct relationship to the amount of gas in the tube. A limit meter measures the imbalance and, if necessary, energizes the reject systems.

By selecting one of two limits, the control-test coding system can check bent-gun (ion-trap) types against one specification and straight-gun types against another.

AUTOMATIC CUTOFF TEST

At the next 6-second test position, an operator positions and adjusts a beam-bender magnet, the test for one-microampere cathode-current cutoff at 16-kv anode voltage is performed, and visual stray emission is checked on tri-potential focus-lens types. This test section was initially planned only as an operator position at which a beam-bender magnet is positioned on the neck of bent-gun (ion-trap) types prior to screen check. (A beam bender is used to center the beam through the top aperture for maximum screen illumination during the screen-condition check.)

However, soon after the automatic testing equipment was placed into operation, a problem in checking cutoff on straight-gun types at the cathode-quality tester developed as a result of the variety of designs of straight-gun-mount types. It was found that the drop in cutoff voltage from the 16-kv anode voltage to the lower 300-volt anode voltage used at the cathode-quality test was not uniform among the various straight-gun-mount types. Because the drop in emission was found to be proportional to the drop in cutoff voltage on individual-mount types, the test for cutoff compared to emission in the cathode-quality factor test was satisfactory. However, an additional test for cutoff limits at a 16-kv anode voltage was necessary.

Because no test was made on straight-gun-mount types at the beam-bender adjust position, and high voltage was available for screen illumination, automatic equipment was designed and installed at that position to perform a 16-kv anode voltage cutoff test.

Each straight-gun-mount type coming into this position is checked for cutoff. Segregating straight-gun from bent-gun mounts is predetermined by the initial test-coding selection. As the tube comes into position, a 16-kv anode voltage is applied. The *G2* voltage is applied as required for the mount type, i.e., 50, 300, or 500 volts, as predetermined by initial test coding. The cathode current is limited to 100 μamp. The *G1* voltage is adjusted negative until bridge balancing at 1-μamp cathode current is maintained. (Cathode voltage is adjusted positive in the case of cathode-drive types.) At the point of bridge balancing, the cutoff voltage necessary to achieve 1-μamp cathode current can be read directly on a panel meter. At the point of balance, preset limit contacts for both the high and low limits are energized. If the free-moving pointer rests against either the high- or the low-limit contacts, it is electromagnetically locked to that contact. The respective reject is automatically counted on the low- or high-cutoff reject counter. For reject identification, two differently colored lights mounted at the following screen-check position are used to indicate the high or low reject; the screen-check operator marks the reject information on the faceplate of rejected tube. The selection of one of the four sets of cutoff limits used at this position depends on the requirements of the particular mount being tested; the limit is predetermined by the initial test-code selection.

Immediately after the cutoff test, tri-potential focus lens tubes are biased past cutoff and the anode voltage for the tube type under test is applied. The operator visually checks for stray emission in the same overhead mirror used for observing maximum light output during adjustment of the beam-bender magnet on ion-trap-mount types. Any rejects observed at this position are counted, and *reject* is noted on the faceplate by the screen-check operator.

SCREEN-CHECK TEST

The tube then moves into the next six-second section, which is the screen-condition test position. At this test position, an operator visually checks screen condition, open-focus-grid element, and discontinuity of aluminum. Three anode voltages are available for checking the variously rated tubes. The lower voltage rating of the tube is used for the test because screen check is more critical at the lower anode voltage. The correct anode voltage is predetermined by the initial test-coding selection. The light output of each tube is controlled by a phototube in a circuit which automatically adjusts the grid bias to control the light output to 30 foot-lamberts. The operator at this position checks over all screen condition for color, color uniformity, spots, holes, and stains; rejects are counted and marked on the faceplate.

As the tubes come into the screen-check position, the focus grid is at ground potential which, in effect, provides visual focused raster lines across the screen. Halfway through this test position the focus-grid potential is switched to −1200 volts (+1500 volts is used for the tri-potential focus-lens types). The tube is then defocused, and the focused raster lines are washed out; the operator rejects the tube for open-focus grid if the change does not occur.

The last test made at this test position, for continuity of aluminum, is made during the last three quarters of a second of the test position. The raster size is automatically reduced (under-scanned) to approximately one-third size. The operator checks the raster for keystoning, flutter, or black lines through the raster. If any of these effects is noted, the tube is rejected for discontinuity of aluminum.

FOCUS-CONDITION TEST

At the focus-condition test position an operator checks for overall focus condition as follows. As the tube enters the test position, the operator throws a selector switch to establish the proper raster size for 90° to 92°, or 110° to 114°. The operator also utilizes a second selector switch while the tube is under test to move through three voltage positions: low focus-voltage limit, bogie focus-voltage, and high focus-voltage limit. The four focus-voltage ranges available for the various tube or mount types are predetermined by the initial test-coding selection. These four sets of voltages are supplied by a unique switching system coupled to a voltage divider. If the operator cannot obtain good overall focus at one of the three focus-voltages, the tube is rejected for poor focus.

AUTOMATIC LEAKAGE TEST

The automatic leakage-test section is divided into two equal periods: the low-voltage leakage tests and the higher-voltage leakage test. As the tube moves into the first half of the test position, it is automatically checked for leakage on *G1*, *G2*, and *G4*, and for positive and negative heater-to-cathode leakage. A meter for each of these tests uses a lock-in limit contact to energize the counters and reject systems.

The tube then moves into the second half of the test position where, as predetermined by the initial test coding, one of four high voltages is applied to the anode while one of two reject meters is energized, depending on the tube rating and leakage limit.

In previous manual testing, visual stray emission tests and measured *G4* leakage tests were made. In automatic testing, it was found that the visual stray-emission test could be dropped; a combined anode leakage was measured through *G4* and *G2* to ground at lower limits than had been used previously for the *G4* leakage test (except on the tri-potential focus-lens types). At this test position, the lock-in limit meter operates another counter and reject system.

AUTOMATIC REJECT MARKERS

Automatic reject markers are located at the cathode quality, gas, and leakage test positions; six such markers are used on the automatic tester. The markers place colored identification tape on the cone of a rejected tube. The marker arm rides against the cone of each tube as it passes by the test position. If the tube is a reject, a piece of colored pressure-sensitive tape is fed out at the end of the arm, and brushed on the cone of the tube. Differently colored tapes are used at each of the markers to identify specific types of rejects.

Three of the markers are used at the cathode quality test: one to identify opens, shorts, emission warmup, and cathode-quality factor; one to identify poor internal continuity; and one to identify poor cutoff. A fourth marker is used at the gas test position to identify gas rejects. The fifth and sixth markers are used at the leakage test to identify rejects for low-voltage leakage and high-voltage leakage.

Although the automatic reject tape-marker system worked well, if the marker ran out of tape or the feed system malfunctioned, the rejects would not be detected. Therefore, a second automatic reject system was incorporated as a double check on the automatic reject tape markers. This system was an automatic reject flag indicator on each of the carrier heads. As the reject system of the test position is energized, a white flag is dropped on that particular head. Because the operator checks the white reject flag against the reject tape on the bulb, reject tape-marker malfunctions are caught immediately and corrected. The reject flag is then reset automatically before the carrier head reaches the load position again.

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M. I. Jefferson

LEO M. WHITCOMB joined RCA in Marion in 1949. His experience includes 5 years on instrumentation with the Victor Chemical Works and 7 years as an Equipment Test Designer with Farnsworth Radio. He is presently Manager of Electrical Design, Equipment Development and Engineering Section, and is responsible for the electrical design of kinescope manufacturing equipment, kinescope testing equipment, and the design of specialized laboratory equipment. He is Vice President of the Marion Industrial Management Club and a member of the Marion Engineers' Club.

MILLARD I. JEFFERSON received his BSEE degree in 1952 from West Virginia University. He was employed in 1952 by the Electron Tube Division, Marion, Indiana as a Manufacturing Engineer and has since worked in the finishing area of kinescope manufacture. He was instrumental in setting up and placing the automatic kinescope tester into production use at the Marion plant.

SPECIAL TEST EQUIPMENT FOR A HIGH-CAPACITY MICROWAVE RELAY SYSTEM

The need for special communications test equipment of a quality not commercially available was apparent during the design of the high-performance MM-600 microwave relay system. Thus, to perform the precise measurements required for such high-channel-capacity systems meeting CCIR recommendations, a wide range of test instruments was designed: first as laboratory development tools, and later packaged as compact and portable units intended for field installation and maintenance work.

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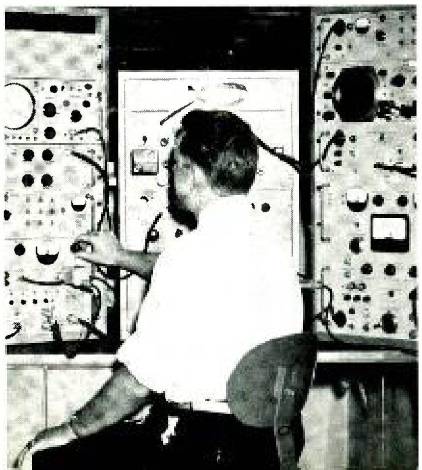
THE SPECIAL test equipment for the MM-600 microwave relay system[1] is designed for three required measurement ranges: 1) baseband, 2) intermediate, and 3) radio-frequency (Fig. 1a). Although developed for the MM-600-2 system, which is capable of carrying 600 channels of telephony or one color video channel, the special test equipment described in this paper may be of considerable interest for use on other communication systems or in similar applications.

GROUP DELAY AND LINEARITY

Intermodulation distortion is one of the main limitations of telephony signal-to-noise ratios ($S:N$) in high-capacity radio-relay systems. A major portion of this distortion is caused by group delay variations of the IF and RF circuits and nonlinearity of the modulation-demodulation transfer characteristic. Video system performance factors such as differential phase and gain are also a function of these two parameters. A *Delay and Linearity Test Set*, comprised of a transmitter and a receiver unit, was designed for the simultaneous measurement of delay distortion and linearity (Fig. 1b).

Fig. 1a—Combined measurement setup for RF, IF, and baseband measurements, illustrating the special test equipment for the MM-600. As can be seen, the various test sets are contained in "pull-out" packages.

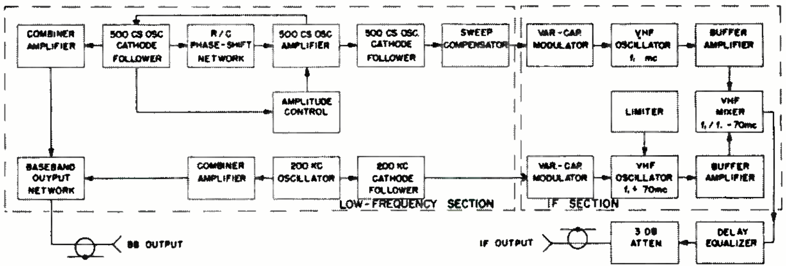


Group delay variations, caused by changes in the slope of the phase-versus-frequency characteristic, must be measured on individual units. Delay variations must also be measured on complete operating systems and equalized with considerable accuracy to minimize distortion. The linearity of the modulators and demodulators must be measured to permit correct alignment for optimum performance. One of the main features of the delay and linearity test set is that group delay measurements do not require an external reference path and can be made from station to station in a microwave relay system installation.

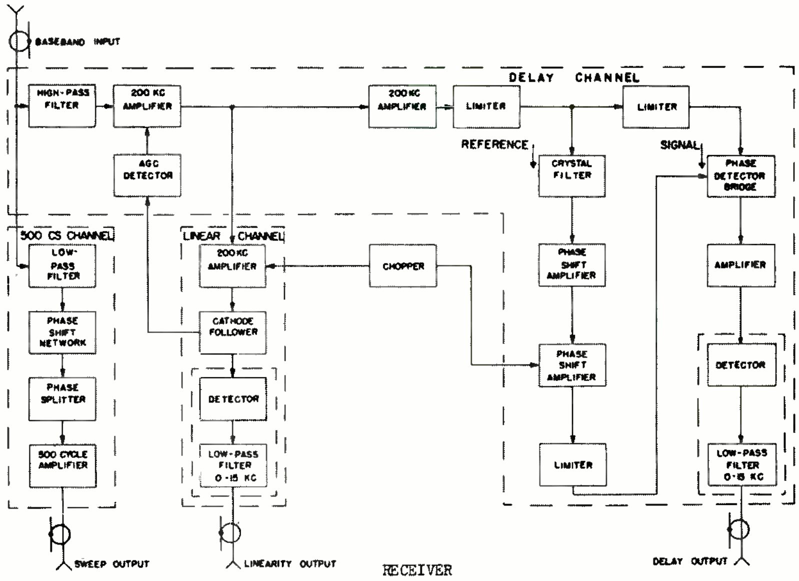
The measurement technique (Fig. 1b) is to apply a swept FM-modulated IF carrier to the input of the circuit under test and analyze the phase and amplitude variations of the FM signal after demodulation. The transmitter unit provides a 70-Mc output signal swept over the band 70 ±8 Mc at a 500-cycle rate. This signal is also frequency modulated with 200 kc at a low deviation.

In applications where the circuit under test includes a modulator unit, a baseband output is available which contains the 500-cycle sweep signal and the 200-kc information signal. At the demodulated output of the system being measured, the receiver unit analyzes the changes that have occurred to the transmitted 200-kc signal. These changes are translated into voltages for oscilloscope display which can be calibrated in terms of group delay and linearity variation. The receiver divides the demodulated signal into what may be considered as being three separate channels. The sweep channel amplifies the recovered 500-cycle signal: this is used to drive

Fig. 1b—Delay and linearity test set.



TRANSMITTER



RECEIVER

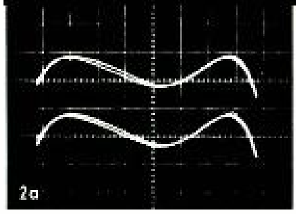


Fig. 2a—Demodulator linearity measurement using Delay and Linearity Test Set. Automatic calibration is by a switch that separates traces by 2%. Horizontal sweep, 2 Mc/division.

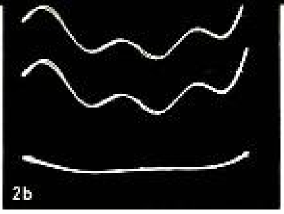


Fig. 2b—Group delay measurement using Delay and Linearity Test Set. Automatic Calibration is by switch that separates traces by 10 nsec. Lower trace is resultant system delay after equalization and correction of poor feeder reflection. Horizontal Sweep, 2 Mc/division.

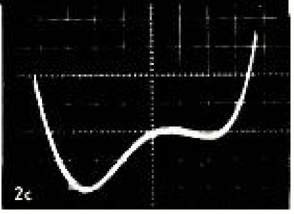


Fig. 2c—Residual group delay of equalized system shown in Fig. 2b has been expanded to show resolution of the instrument. Each vertical division, 1 nsec.

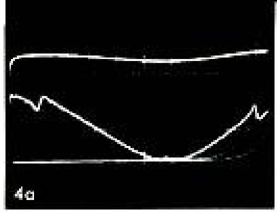


Fig. 4a—Input impedance of an IF amplifier measured with the IF Reflectometer. Upper trace is the automatic calibration facility here set to a return loss of 26 db. The Frequency Marker has been included in the circuit to illustrate marking at 62, 70, and 78 Mc.

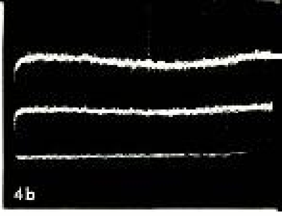


Fig. 4b—Lower trace is measurement of VSWR of a standard termination. Upper trace is 40-db return loss calibration curve indicating that the termination is of the order of 46 db or 1.01 VSWR. Horizontal sweep, 4 Mc/division.

the horizontal deflection axis of the oscilloscope. The linearity channel detects the amplitude of the 200-kc signal and displays a pattern on the vertical axis of an oscilloscope. The scope can be directly calibrated in percentage change by internally inserting an attenuator switched in and out of the channel at a 60-cycle rate. This gives a very convenient calibration (Fig. 2a).

The group delay channel detects the phase changes of the 200-kc signal by means of a phase comparison bridge. A reference signal for this phase detector is obtained by passing some of the 200-kc signal through a 100-cycle bandpass, crystal filter. The filter removes the phase modulation sidebands on the 200-kc signal at ±500 cycles and multiples thereof; such sidebands were created while sweeping across the nonlinear phase-frequency characteristic of the system under test. A built-in calibrated phase shift may be switched in and out of the reference path at a 60-cycle rate to give a 10-nsec calibration on the oscilloscope display (Fig. 2b). The resolution of the instrument is 0.5 µsec of delay change and 0.25-percent linearity over the 62-to-78-Mc bandwidth. As a delay of 0.5 µsec is equivalent to only 0.036° at 200 kc, the design of the 200-kc crystal oscillator in the transmitter unit and the 200-kc narrowband crystal filter in the receiver unit had to be extremely stable. A special crystal cut is used for temperature stability; the crystal is placed in a large shock-mounted heat sink for good short-term stability to prevent oscilloscope trace jitter.

The lower trace of Fig. 2b illustrates how delay of the system has been corrected by delay equalization networks to reduce the intermodulation distortion. The ripples of the initial measurement shown in the upper curves are a result of mismatch in the feeder system connecting the system radio equipment under test to the antennas. The amplitude and period of the reflections may be analyzed to locate the source of reflection; e.g., poor joints, damaged feeders or high antenna VSWR.

TELEPHONY PERFORMANCE EVALUATION

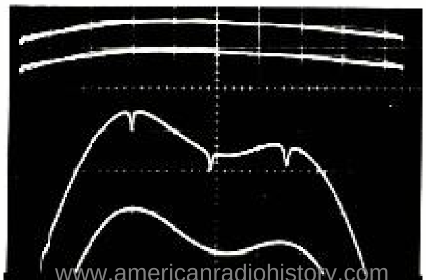
A method of evaluating over-all system telephony performance has been defined by CCIR recommendations. The technique is to employ white noise to simulate voice traffic upon a fully loaded system. Narrowband-stop filters are inserted in the input noise spectrum loading a system; the noise falling into unloaded channels at the system output is then analyzed to determine the extent of the thermal and intermodulation noise components created in the circuit under test. The figure of merit of performance is the *noise power ratio*—the ratio of the noise power in a loaded channel (slot *out*) to the noise power in an unloaded channel (slot *in*).

An *Intermodulation Test Set* was developed to evaluate performance of any system having 24 to 960 voice-channel capacity. The transmitter noise generator uses very flat video amplifiers to amplify resistor thermal noise up to a —10-dbm level; the desired system input level is set by an accurate attenuator.

A switch on the test set transmitter and receiver selects the desired slot frequency to be inserted in the noise-loading spectrum. The test set receiver employs straight-through tuning—using wideband amplifiers between two highly-selective band-pass filters. Thus, problems of self-generated intermodulation are reduced, and spurious responses encountered in superheterodyne-receiver measuring techniques are eliminated. Self-generated intermodulation is very low, and thermal noise is limited only by the extremely low thermal-noise power level in the 3-kc bandwidth of the special low-noise amplifiers. The noise power ratio of the test set measured back-to-back is better than 75 db.

A measurement of noise power ratio at various levels of noise loading can be plotted for different baseband channel frequencies to evaluate system performance; such curves can be analyzed to determine optimum channel deviation, the contributions of intermodulation, and the thermal noise at different frequencies in the baseband. This type of analysis allows comparison of the unit or system performance with that predicted by calculations.

Fig. 3—Lower curves show gain frequency response of an IF amplifier measured with the IF Sweep Generator. Vertical calibration is achieved as shown in upper traces by a 1-db step generator built into the IF detector. Marker pips have been inserted on one trace at 62, 70, and 78 Mc by the Frequency Marker. Horizontal deflection, about 4 Mc/division.



IF CIRCUIT MEASUREMENTS

Several test sets were developed to aid in the design, production alignment, and field maintenance of IF circuits; typical measurements required are frequency response, gain, input and output VSWR, and AGC action.

IF Sweep Generator

An extremely level *IF Sweep Generator* was designed to sweep a frequency range up to 70 ±14 Mc with output levels of 0.3 to 1.5 volts and an amplitude flatness of ±0.05 db. The generator uses a saturable reactor to sweep the resonant frequency of a Colpitts oscillator. A unique levelling circuit contains a starvation amplifier with 90-db gain in a single-stage feedback loop; this system prevents the generator from becoming unstable at any error-signal frequency. Particular attention was paid to the harmonic content of the output which is more than 46 db below carrier and which otherwise would prevent accurate amplitude flatness measurements through IF band pass circuits. Fig. 3 shows a typical IF amplifier sweep display with the upper trace showing the flatness of the sweep generator alone.

IF Detector

An *IF Detector* was developed for use with the sweep generator, the detector has a frequency-response variation of less than 0.05 db and a 75-ohm input VSWR of 1.02 or less over the frequency band 70 ±15 Mc. A 0.1-db pushbutton attenuator facilitates calibration of the oscilloscope display shown in the upper traces of Fig. 3. A full-wave detector minimizes the possibility of a nonsymmetrical input waveform giving erroneous results.

Frequency Marker

Frequency indications on the detected IF sweep display may be inserted by use of a *Frequency Marker* unit. High-Q absorption filters are coupled in at 62, 70. and 78 Mc to produce 0.1-db notches in the displayed response. These markers are illustrated in Figs. 3 and 4. The high-Q notches are produced by a series resonant circuit consisting of a series capacitor—and a parallel resonant circuit tuned slightly above the marker frequency. At series resonance. the inductive reactance of the parallel resonant circuit is varying rapidly, thus giving a Q-multiplication effect. At the same time, the series shunt resistance is limited to that of the parallel resonant circuit which is adjusted to give a 0.1-db drop in level across a 75-ohm line.

IF Reflectometer

An *IF Reflectometer* to give a swept display of the reflection coefficient versus frequency of an IF impedance match was designed and developed. The reflectometer assists in alignment of IF-amplifier input and output circuits. delay equalizer tuning. and in checks of impedance termination on any 75-ohm impedance circuit operating with a center frequency in the 70-Mc region. The IF Reflectometer gives a direct-reading measurement of reflection coefficient in the range 20 to 40 db (1.2 to 1.02 VSWR) over the 55-to-85-Mc range.

The Reflectometer consists essentially of a precision high-directivity directional coupler with two bidirectional pick-up probes. One is oriented to receive the forward wave from an external IF sweep test signal, and the other to receive the wave reflected from the circuit under test (Fig. 5). Outputs from the pick-up probes are fed through a coaxial switch, an internal IF amplifier, and a detector which is connected to an oscilloscope. The relative amplitude of the incident and reflected signals may be compared on the oscilloscope when the coaxial switch is actuated. The amplitude of the forward wave is adjusted by a built-in calibrated step attenuator, until the forward and reflected signals appear at the same amplitude on the oscilloscope. The value of attenuation inserted in the forward-wave path provides a direct reading in decibels. of the reflection coefficient of the terminating circuit. Fig. 4a shows a typical IF amplifier input impedance with a calibration trace at 26 db (1.1 VSWR). A frequency marker has been inserted between the reflectometer and the IF amplifier load during calibration to indicate how the markers may be used to calibrate the frequency sweep of the VSWR display.

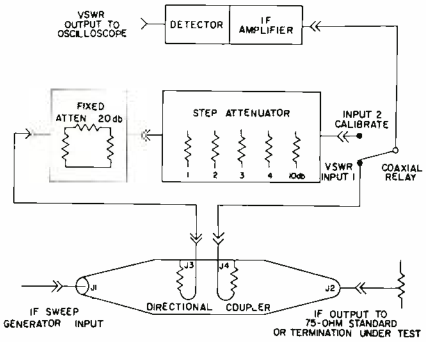


Fig. 5—IF Reflectometer.

RF MEASUREMENTS

Precise measurements in the RF band are made by employing an *RF Sweep Generator* capable of sweeping 1 Gc in the 1.6-to-2.6-Gc range. Output levels up to 200 mw and an amplitude flatness of better than ±0.1 db in any 50-Mc band, or ±1 db in the full 1-Gc sweep range. are provided. The high output level and wide sweep range are obtained by employing a *Carcinotron* backward-wave oscillator with a closed-loop levelling action derived from a special combination of a flat directional-coupler and RF output detector. High-gain DC amplifiers give the required operational control and allow a 1-kc internal, or 0-to-25-kc external, amplitude modulation.

A wide band coaxial isolator is included on the backward-wave oscillator output to prevent high load reflections from damaging the tube or upsetting the levelling action. A high-pass, low-pass strip-line filter absorbs the second and third harmonic power output of the tube in a dummy load and allows the fundamental signal to pass unattenuated. Experience with precise measurements showed that unless the sweep-signal harmonics are absorbed, rather than reflected back to the backward wave oscillator as with normal lowpass filters, the generator levelling action can be upset and cause erroneous RF frequency response and VSWR measurements.

To perform precise VSWR measurements upon RF cavities. branching networks. and transmission lines, a waveguide *Directional Coupler*, with an extremely high directivity of 50 db over the band of 1.7 to 2.3 Gc was developed for use with the RF Sweep Generator. This coupler measures reflections to 1.005 VSWR: a precision waveguide termination with a VSWR of 1.005 was designed for use in conjunction with the coupler.

SUMMARY

The availability of these special test and measurement instruments has greatly simplified the design. production and field maintenance of the MM-600 radio relay equipment. Some of the success in the high performance achieved by existing MM-600 systems is in no doubt due to the advantage of having suitable test equipment for the precise analysis of all factors affecting performance. With this in mind. other instruments of advanced design are being made available. One employs an FM swept-frequency technique for measuring waveguide reflections or multipath echoes in the 1.7-to-2.3-Gc microwave band.

ACKNOWLEDGMENTS

The author would like to acknowledge that the development of these instruments was the combined effort of several design engineers and wishes to express his appreciation for contributions of all those who participated in the various development programs.

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D. F. RUSSELL graduated with honors in Electrical Engineering from McGill University in 1955. He joined RCA Victor Company Ltd. upon graduation and spent two years upon the development program of the doppler radar for the Mid-Canada Line. In 1957 he was associated with the newly formed development team for the MM-600 microwave relay equipment and became a group supervisor in the Communications Equipment Design group in 1959. He is a member of the Corporation of Professional Engineers of Quebec and the Institute of Radio Engineers.

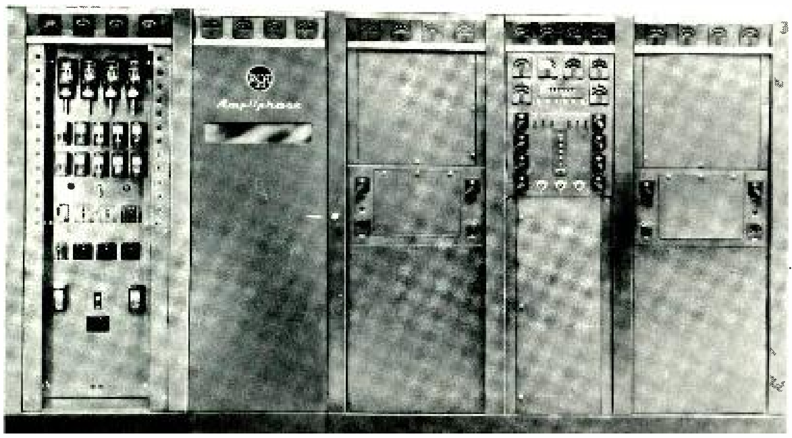

Fig. 1—(Top photo): The BHF-100A 100-KW Shortwave Transmitter, front view.

BHF-100A SHORTWAVE TRANSMITTER . . . 100 kw for International Broadcasting

The growth of international broadcasting in the past 15 years reflects both the rapid emergence of new nations and the technical advances made in receiving and transmitting equipment. During this period, RCA has supplied more than twenty-five 50-kw shortwave broadcast transmitters to eight different countries. Now, RCA is installing seven 100-kw shortwave complexes in three more countries for 3.6- to 26.1-Mc operation. This 100-kw BHF-100A equipment utilizes "ampliphase" modulation and a number of design innovations.

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In addition to the normal requirements for a good broadcast transmitter such as high fidelity, low operating cost, and easy maintenance, the good shortwave transmitter must possess certain other requisites. Most important among these is that frequency of operation be changed as many as six times a day with a minimum of *off air* time. The transmitter must also operate into an antenna, or antenna system, having standing-wave ratios as high as 1.5:1 and impedances from 300 to 600 ohms.

Other requirements, such as high over-all efficiency, simple and reliable cooling methods, a minimum of different types of electronic components, lightweight materials, and easy-to-service mechanical components are all dictated by the remote areas where most of these transmitters will be located.

The BHF-100A shortwave transmitter (Fig. 1) utilizes the RCA-developed outphasing system of modulation, *ampliphase*,[1] to achieve excellent performance and meet the stringent requirements imposed on shortwave transmitters. The basic ampliphase system is well-accepted in medium-wave standard broadcast transmitters—over 40 of these, from 10- to 250-kw, are now operating in the field.

As Fig. 2 illustrates, the 100-kw BHF-100A occupies significantly *less* floor space than older 50-kw shortwave transmitters — a compactness achieved by the ampliphase system.

The heart of the BHF-100A is the exciter-modulator, drive-regulator unit (Fig. 2). On each side of this central area, the two RF power-amplifier chains extend toward the rear of the transmitter and are fixed to the "combining-point" balun where the AM, balanced output is produced. The over-all arrangement forms an approximately square transmitter area with complete accessibility to all components in a minimum amount of space.

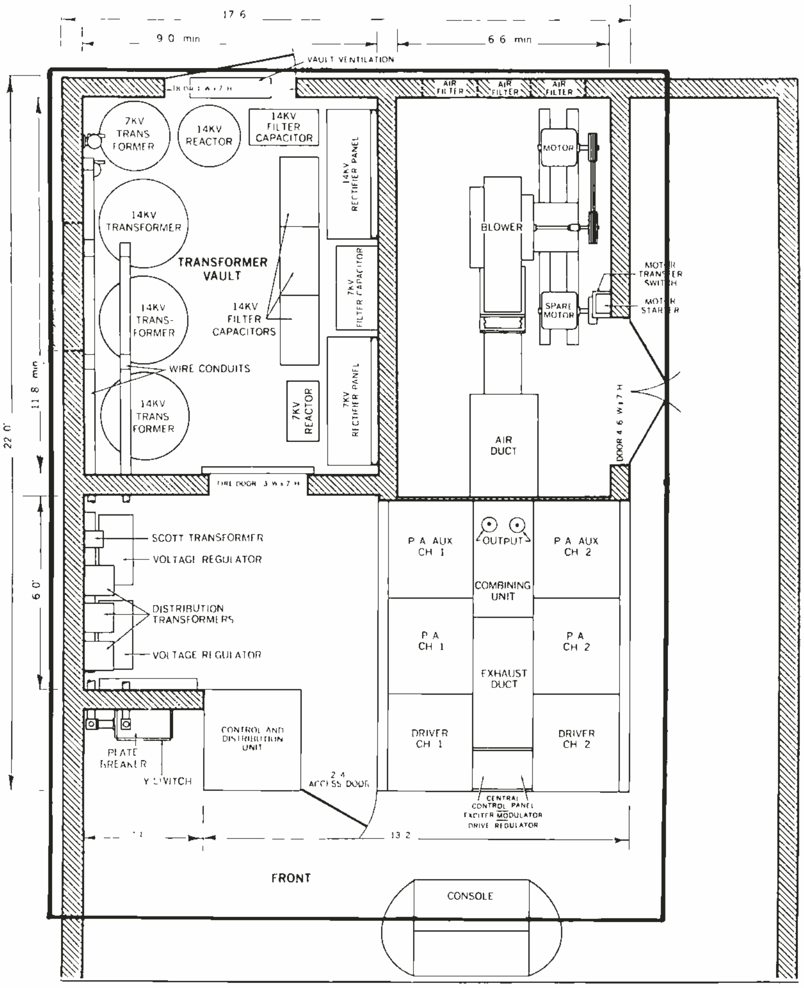

Fig. 2—Typical floor plan for the BHF-100A. The "old" 50-kw shortwave transmitter had a floor area, shown by heavy lines, approximately 25% greater than the "new" BHF-100A.

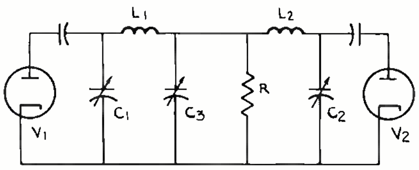

Fig. 3—Simplified PA output circuit.

AMPLIPHASE MODULATION

Ampliphase, or outphasing, modulation (originally proposed by H. Chiriex[2]) produces an AM signal by synthesis of two RF signals, each containing linear phase modulation of the intelligence to be transmitted.

Basically, AM is obtained in the transmitter as follows: A single low-level RF source is split into two separate channels having a fixed angle of separation less than 180°. These two sources are then phase-modulated by antiphase audio signals containing the information to be transmitted, amplified in separate channels to the output power level required of the transmitter, and then combined in a common impedance to produce the AM signal.

With two constant and equal current generators of phase difference θ feeding a common resistive load R, the real power P_R will be:

$$P_R = \left(2I \cos \frac{\theta}{2}\right)^2 R$$

The load impedances, Z_1 and Z_2, that the two generators see are:

$$Z_1 = 2R \cos^2 \frac{\theta}{2} + jR \sin \theta$$

$$Z_2 = 2R \cos^2 \frac{\theta}{2} - jR \sin \theta$$

This, in effect, means that unless compensation of the circuit is made, the generators will be feeding complex loads. Since the generators in question are high-power vacuum tubes in the BHF-100A transmitter, there must be compensation of the circuitry in order to procure maximum efficiency of tube operation.

The practical circuit to get AM from two differentially phase-modulated, high-power sources is shown in Fig. 3. The plate tank circuit of tube V_1 consists of a 90° network C_1, L_1, and ½ C_3. The plate tank circuit of tube V_2 consists of a 90° network C_2, L_2, and ½ C_3. The 90° networks provide:

1) correct impedance transformation between load and each tube;
2) a high-Q tank circuit for proper operation of a Class C high-efficiency amplifier; and
3) a constant-current output source when a constant voltage is supplied to the input.

Capacitors C_1 and C_2 are also used to compensate for the reactive component of the load seen by each tube. An increase in capacitance on one side and a decrease on the other allows each tube to look at a unity power-factor load and achieve maximum efficiency at one particular phase angle between the two signals. In this particular transmitter, the compensation offset is done at a phase angle θ of 135°, the angle at which carrier level is achieved. Deviations from 135° to produce modulation detunes each tank circuit slightly; however, the power factor does not vary too widely even at 100-percent modulation, as evidenced by a minor loss in power-amplifier efficiency (80-percent at carrier and 77-percent at 100-percent modulation).

AMPLIPHASE FEATURES

Ampliphase modulation is particularly suitable for high-power transmitters. Lower fabrication cost and economy in operation and in utilization of tubes and components are the principal advantages. In the BHF-100A power-amplifier stage, two air-cooled tubes are used in each channel to supply an equal amount of power to the load. Each tube has the same dissipation requirement and the same RF plate swing, never exceeding the swing at carrier level.

In addition to balanced tube operation, there is a balance in plate-circuit configuration. All like elements of the final tank circuit are of equal value, except for the input capacitor to the network. The same equality of the two RF amplifiers is carried through the transmitter to the input stage where the original unmodulated signal is divided.

From the users' standpoint, identical channels mean fewer different spare parts and tubes to be carried in inventory, and the convenient checking of suspect components by side-to-side interchange between channels. Other features are the compact size (no large modulation transformers and reactors are required), the ease with which a complete new modulator can be installed or switched in, and high over-all transmitter efficiency.

The power output and performance of the ampliphase transmitter is dependent upon having: 1) a known load resistance, 2) a fixed carrier angle, 3) a method of tuning for unity power factor instead of resonance, and 4) capability of quick frequency changes in the shortwave band. Therefore, amplitude modulation demands a new set of tuning rules.

By the judicious use of a built-in reflectometer to indicate proper load, an oscilloscope to indicate unity power factor of the final amplifiers, and oscilloscope and delay lines to indicate the proper carrier angle, the system can be adjusted to a new frequency in a rapid and logical manner.

CIRCUIT DESCRIPTION

Fig. 4 indicates that a circuit description of one phase-modulated channel readily applies to the other. This should be so visualized in discussing the circuitry. The RF excitation of approximately 5 watts at any frequency between 1.0 and 9.0 Mc is supplied to a broadband transformer at the input to the transmitter. Output of this transformer is push-pull, with a grounded center providing two RF voltages of 180° phase relationship for the two transmitter channels. These 180° voltages are then fed to two 600-ohm variable delay lines ganged to one control; rotation of this control delays one signal and advances the other until 135° phase separation is achieved.

Output of the delay line is fed to a modified Belaskis Phase Modulator having the triode section of a 6EA8 as the modulator and the pentode section as a tripler to achieve sufficient linear phase modulation in one tube. The Belaskis phase modulator does not require tuning and is most compatible with shortwave requirements in that respect. It is however, difficult to cascade this type of

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WILLIAM S. DAY received his BSME from Purdue University in 1959. He joined RCA as a Design and Development Trainee and upon completion of the training program was assigned to the High Power Broadcast Transmitter Group of the Broadcast and Communications Products Division. He has worked on the mechanical design of the BTA-10J transmitter and presently he is working on refinements in the design of the BHF-100A.

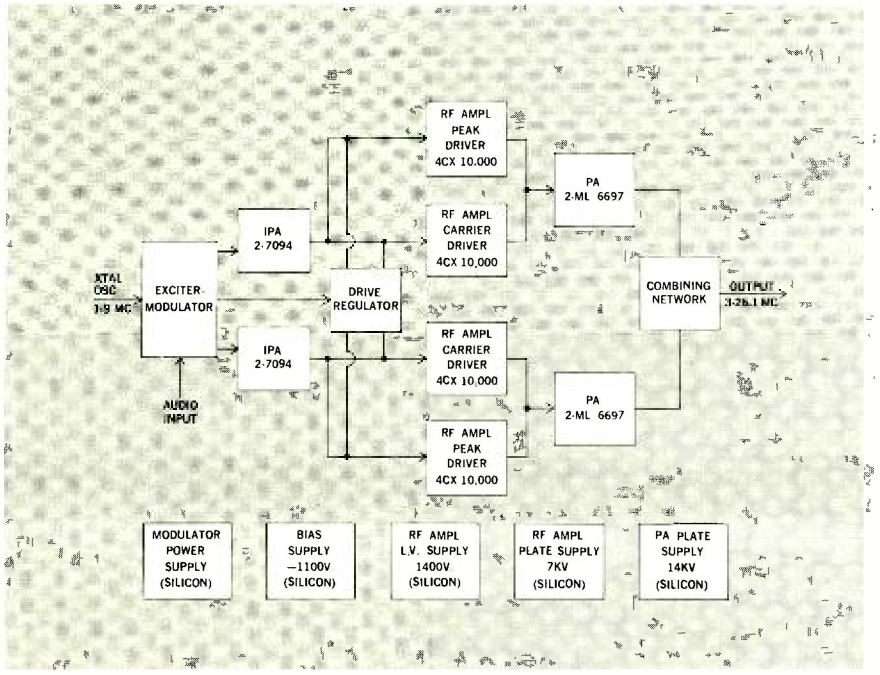


Fig. 4—BHF-100A block diagram.

modulator—thus, the 6EA8 tripler requirement.

The output of the tripler, a phase-modulated signal at the transmitter operating frequency, is fed to a high-gain RF amplifier. A 12BV7 tube is used as a limiter to remove incidental AM and ⅓-carrier-frequency modulation from the signal. The output of the 12BV7 is then fed to the final amplifier of the exciter modulator, a Class C power amplifier having approximately a 7-watt output at 75-ohm impedance.

It is interesting that the full range of 3 to 27 Mc is covered in four bands. A frequency change can be made by moving one band selector switch to the proper position and adjusting only one control, which drives six inductor tuning slugs to a calibrated point. This rapid phase-modulator tuning is of sufficient accuracy to permit the transmitter to be set up and operated without utilizing the fine trimmers of each circuit. The fine-tuning controls provided can, however, be adjusted while programming to optimize performance.

The exciter-modulator output is fed through a 75-ohm cable to a broadband transformer driving the intermediate power amplifier — a straightforward Class C amplifier utilizing a parallel pair of 7094 tetrodes to provide approximately 100 watts to the driver stage. Although the input circuitry to this stage is very broad, it is necessary to compensate the circuit by switching four shunt indicators to cover the band.

The intermediate power amplifier output is tuned by a variable coil in parallel with a capacity divider formed by blocking condensers and the input capacitance of the driver tubes. The two driver tubes are grid-modulated amplifiers, providing proper drive for the final stage under all modulation conditions. Because of the widely varying drive requirements and load impedances, the two tubes of this stage are biased at different levels. Thus, at carrier and below, one tube is supplying power; above carrier level, both tubes are supplying power to drive the final stage. To match the low input impedance of the grounded-grid power amplifier to the relatively high impedance of the driver stage, a 180° network plate-tank circuit is used. This network meets the special requirements of feeding a load of a varying nature. Load impedance at the peak of modulation is low and at the trough of modulation is high. The network accomplishes the correct transformation ratios and precludes incidental phase modulation (usually resulting from variable loads). There are other satisfactory methods, such as transformer coupling; however, in the BHF-100A the 180° network provides greater tuning simplicity.

Each final power amplifier utilizes two ML-6697 air-cooled triodes in a grounded-grid configuration to produce 50 kw of carrier power and 200 kw of peak modulation power. The input of this stage consists of the output portion of the special 180° network with its output capacitance located directly between the two tubes. In addition to this capacitance, a shunt inductance is required at the high-frequency end of the spectrum to compensate for the high input capacitance of the tubes. This shunt inductance is also one arm of a neutralizing bridge which prevents incidental phase modulation.

A 90° network transforms the final output circuit from a constant-voltage source to a constant-current source, it is then combined in the common load with current from the other channel amplifier to produce AM. The combined output is fed through a section of the line containing a reflectometer to the balun for transformation from a single-ended 15-ohm output to a balanced output of 300 ohms. Electrically, the balun consists of a series-tuned, resonant-primary circuit inductively coupled to a balanced parallel-resonant secondary circuit. In addition to serving as an impedance matching device, the balun also provides RF harmonic attenuation.

The remaining components of the transmitter such as power supplies, control circuits, protective devices and metering circuits are conventional and compatible with the high design criteria used throughout.

SPECIAL ELECTRICAL-MECHANICAL COMPONENT DESIGN

Because of the wide frequency range of the transmitter and the high power level involved, many of the electrical components had to be designed and fabricated rather than purchased. Close cooperation between electrical and mechanical design engineers resulted in the use of new materials and ideas that have given good electrical performance and minimum product cost.

A major problem area in high-power transmitter design is to provide an economical trouble-free variable inductor. The approach used in the power amplifier and the balun of the BHF-100A has proven highly successful under actual operation. Basically, the line inductor consists of two sets of parallel 1½-inch-diameter hard copper tubing (Fig. 5), ranging in separation from 10 to 12 inches: the adjustable (sliding) shorting bar is made from 1½-inch-square hard-brass tubing of 0.060-inch wall thickness. By notching and slotting the contact area of the square tubing, fingers are shaped to provide good line contact along the entire path of travel. These fingers tend to have a leaf-spring action, creating a direct positive pressure on the copper line and reducing the possibility of joint-heating and resultant failure. With this configuration, five mechanical joints of the rotary-type inductor are reduced to two. Contacts are mounted in pairs on a melamine cross-bar which is driven by a pair of chain-connected lead screws.

In addition to these contacts, a series-parallel switching arrangement in the

Table I—Transmitter Harmonic Distortion at 3.6 Mc

Hum & noise, 56 db; modulation capability, 100%.

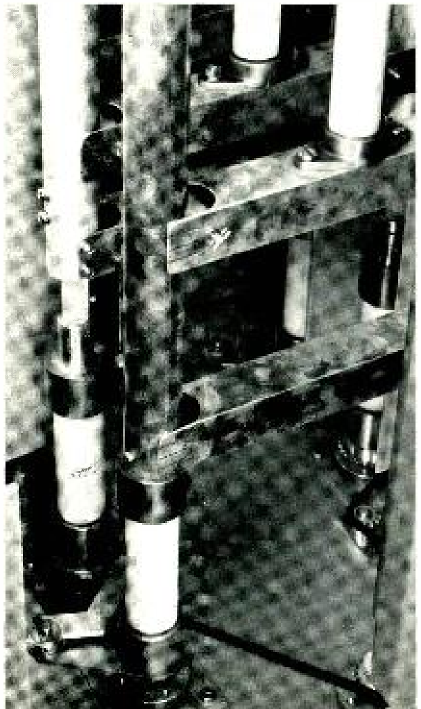
% of Full Modulation	*% Harmonic Distortion at Test Frequencies*						*Carrier Shift, %, @ 400 cps*
	50 cps	*100 cps*	*400 cps*	*1 kc*	*5 kc*	*7.5 kc*	
25	1.4	1.2	1.2	1.3	1.5	1.7	0
50	1.4	1.1	1.2	1.4	1.8	1.9	0
85	3.0	2.2	2.3	2.4	3.2	3.4	0
95	2.0	2.0	2.0	2.0	2.5	3.1	0

lines allows a greater range of inductance. With this, the operator may change the set of four 1½-inch lines arranged on the corners of a 10-by-12-inch rectangle from series to parallel configuration. The mechanism is operated by a motor drive interlocked by limit switches and an overriding slip clutch.

The balun is situated between the two RF cabinets in an area 22 by 40 inches (Fig. 2). This system consists of three lines. The center one serves as a primary coil, and the two outer lines, either in series or parallel, serve as the secondary coil. Since the primary coil is completely surrounded by an electrostatic shield and shunt capacitance to ground is high, it is necessary to "trombone" this line (Fig. 5). By linking drives of the three movable shorts to a pair of lead screws inside the primary lines, the bottom of the primary line is allowed to slide over its upper portion. Thus, at the high-frequency end of the band, the volume of the coil is half that of the low end.

Since the only way to drive this collapsing line and derive maximum capacitance reduction is by having lead screws operating directly on the line, an insulating material with the correct properties had to be found. The lead-screw material chosen was polypropylene, which has electrical properties very similar to teflon, mechanical properties similar to nylon, and a cost about a third that of teflon.

Fig. 5—Partial side view of balun with electrostatic shield removed showing sliding contacts and "trombone" section.



Several other mechanical features were incorporated into the RF units. In mounting the power-amplifier tubes (ML-6697) in each channel, a Rexolite shelf was used as the tube support. The mechanical strength of Rexolite (a crossed-linked styrene co-polymer) is sufficient to support the 82-pound weight of the tubes. Rexolite has many other advantages in this application including its low dielectric-constant, low loss-factor and relatively high imperveance to tracking.

As is usual in most transmitters, the cooling problem in the BHF-100A proved to be the power-amplifier tube anode glass-metal seal. The solution was to notch the plenum portion of the ML-6697 air distributor at its point of contact with the cooling fins of the tube. Thus, sufficient cooling air is channeled over the seal surface. The area between the two RF channels and the front of the combining network forms an air exhaust duct for the driver and power-amplifier tubes and houses the various tuning drives which terminate at the central control panel.

CENTRAL CONTROL PANEL

From the standpoint of the transmitter operator, the most important area of the transmitter is the central control panel (Fig. 6). The upper portion of the panel is devoted to the final-tube current meters and the read out indicators of the motor-driven inductors. Directly above the indicators is a roll chart containing tuning data for six precalibrated frequencies. Directly below the indicators are the motor operating switches for the inductor driving motors. Along either side of this panel are all the variable-capacitor tuning controls with their roll chart located directly in the center.

On either side of the vertical roll chart is a plate-to-cathode monitoring oscilloscope which indicates unity power factor or maximum efficiency of the final-amplifier tubes, and also the phase and loading status of the double-π network driving the final amplifiers. These oscilloscopes are direct-reading and so designed and constructed that from 3.0 to 26.0 Mc there is less than 3° differential between the vertical and horizontal deflection circuits. The deflection circuits also contain low-pass filter networks so that the straight-line fundamental indication on the scope will not be misread because of harmonic distortion.

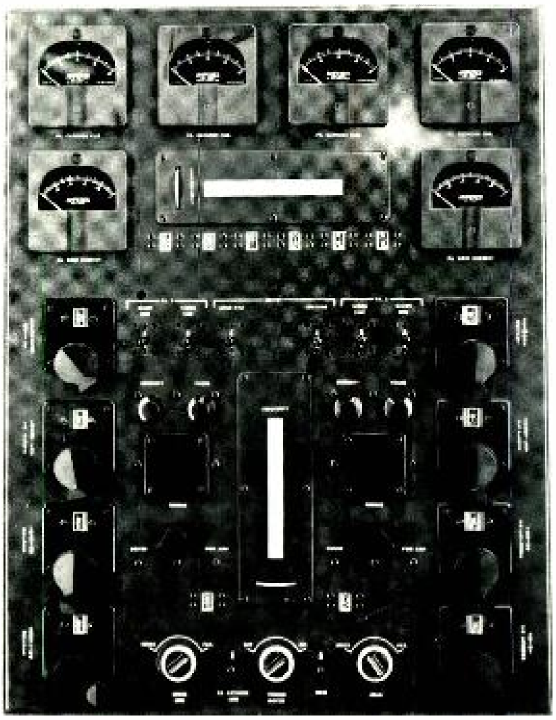


Fig. 6—Central control panel.

TRANSMITTER PERFORMANCE

Seven of the type BHF-100A transmitters have been shipped to the international market and an eighth is presently set up in Camden for further testing and demonstration. A typical set of data taken at 3.6 Mc is given in Table I, indicating the excellence of performance.

As with any new development—whether a 100-kw transmitter or a 1-watt resistor—public acceptance is the true criteria of an outstanding design; however, since everyone does not buy a 100-kw transmitter every day, it will be years before a complete evaluation can be made. However, problem areas in previous shortwave transmitters have received special attention, and the over-all performance of the BHF-100A can be expected to exceed that of its predecessors.

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NEW TECHNIQUES FOR FERRITE NANOSECOND MEMORIES

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A major trend in development of future computers is toward extremely high speed—in fact, operating cycles on the order of a nanosecond (10^{-9} second). The attainment of such speeds necessitates development of new and faster memory devices, and a fabrication technique for them that is both technically and economically feasible. This paper describes the important development of a new ferrite high-speed memory core and the establishment of a practical assembly technique for it. Both goals were attained through a program of integrated RCA research and development.

FOR SEVERAL YEARS ferrite cores[1,2] have constituted the mainstay of computer storage memories. The typical computer today[3] has a transistor-driven core memory which operates in a coincident-current mode[4,1] with a 5-to-10-μsec cycle time. Although a coincident-current storage unit with a cycle time approaching 2 μsec has been built, higher speeds have been attained by exploiting so-called *partial-switching* modes of operation. Word-address memory systems[5] with cycle times less than 1 μsec and as low as 0.7 μsec have been reported.[6,7] To attain these speeds with conventional 50/30 cores (that is, cores of 0.050-inch outer diameter, 0.030-inch inner diameter) drive requirements are necessarily high (approximately 1 ampere-turn), and particular attention must be given to the physical arrangements of conductors, sense windings, and storage elements.

Actually, short cycle times have been realized by the development of fast-switching storage elements which operate in impulse switching modes using high drives, and by minimizing such factors as propagation time, field transients, and mutual-coupling effects to reduce the duration of the unproductive phases of the memory cycle. The reduction of these phases has assumed increasing importance as the operating speeds of memories have increased. Array geometry, timing operation, and the relative positioning of components have become prime factors in the determination of the minimum access time of a memory.

The use of permalloy thin films as high-speed storage elements has recently received a great deal of attention.[8,9,10] A small memory with a cycle time of less than 0.5 μsec has been operated,[11] and speeds of better than 1 Mc appear feasible.[12] In addition to their high-speed potentialities, thin-film memories can be fabricated in large sheet arrays at relatively low cost. (This fabrication technique has not been fully developed at the present time.) Disadvantages of thin-film memories include high drive-current requirements (0.5 to 1 ampere) and low bit outputs (less than 5 mv).[9] Large arrays operating at high speeds may, in fact, be impracticable, because the discrimination between the low output signal and the stack noise becomes increasingly difficult as memory capacity is increased.

Early in 1959, the RCA Laboratories, Princeton, N. J., undertook a research program to establish the feasibility of ferrites for high-speed memories. The approach adapted differs fundamentally from that of the magnetic films in that it uses closed magnetic paths of miniature dimensions. Although this method offers fundamental system advantages (low drive-current requirements, high output voltages), it requires advances in fabrication technology before application.

Under applied-research support from the RCA Laboratories, the project was then undertaken at the SC&M Memory Products Operation, Needham, Mass., to develop ferrite memories operating at 2 Mc. Ferrite cores inherently provide high output (about 50 mv). In addition, by reducing the size of the core aperture, drive currents may be decreased and fast switching maintained. The program was set up with the primary goal being a memory of several thousand bits and a cycle time of 0.3 μsec or less. In addition, this memory was to offer bit costs competitive with those of slower, more conventional arrays. These goals require the solution of two associated problems: first, the development of low-drive, fast switching memory cells; and second, the development of methods for the assembly of these cells into arrays. This paper describes approaches taken at Needham to solve these problems.

FERRITE-PIECE FABRICATION

For several months, Needham has been using conventional dry-pressing techniques to prepare ferrite pieces with 5-

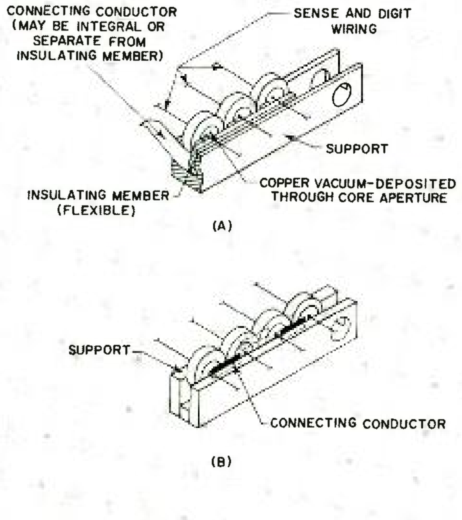


Fig. 1—Word-strip assemblies.

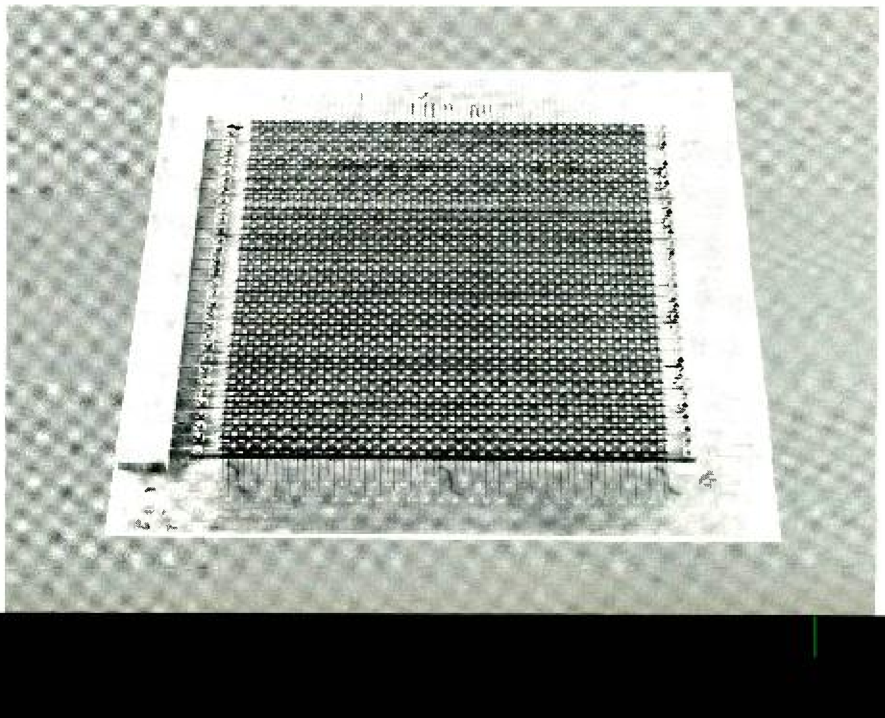


Fig. 2—Completed assembly plane of 16 words, 12 bits per word.

DR. HENRY P. LEMAIRE received the Ph.D. degree in Physical Chemistry from Purdue University in 1950. His previous studies were conducted at the University of Manitoba, where he received the B.Sc. and M.Sc. degrees. After graduation, he was appointed to the staff of St. Michael's College in Vermont, where he taught chemistry. Dr. Lemaire came to the Memory Products Operation in 1959. He is presently in charge of Advanced Development, having general supervision of the development of ferrites for new applications, high-temperature ferrites, and high-speed memories.

to 10-mil apertures. These pieces serve as building blocks for the strip assemblies that will be described later. Although a certain element of care and craftsmanship must be exercised in making pressed pieces with such small holes, fabrication on a production level is quite feasible.

The possibility of using one continuous ferrite strip instead of isolated pieces is appealing because it obviates the need for joining the platelets mechanically and electrically. As mentioned before, this method could also result in high bit densities, because such strips laminated with insulation spacers would comprise a very compact design.

ASSEMBLY METHOD

The method of assembling the memory stack is based upon a two-core-per-bit word-address system. A new printed-winding technique was developed that permits the assembly of ferrite cores with 5- to 10-mil apertures into complete word strips. With this technique, the read-write is printed, while conventional hand-threading techniques are used for the digit-sense wire. Fig. 1 shows two ways of assembling the ferrite pieces into strips.

Strip Assembly

The assembly of platelets into word-strips is essentially a three-step operation:

1) Metallization of individual ferrite pieces by vacuum deposition.
2) Mechanical assembly of ferrite pieces into strips; at the same time the conductive path between pieces is completed.
3) Electroplating of the strip as a unit to improve contact between platelets and to lower the over-all resistivity of the conductive path.

The first step is a relatively simple operation and involves the vacuum metallization of the appropriate pattern on the individual ferrite pieces. The aperture wall is also metallized at the same time. Toroids (0.050-inch outer diameter, 0.010-inch inner diameter, 0.010-inch thick), have been generally used but in a few cases the pieces have been rectilinear.

Metallized cores, or platelets, have been assembled into strips in a variety of ways, but assembly is generally similar to the methods shown in Fig. 1. In Fig. 1a, the cores are held in a plastic member in which a photo-etched conductor connects the far side of one core to the near side of the adjoining core. These core connections complete the electrical path along the length of the strip. The plastic member rests in an aluminum support to facilitate handling and assembly.

Fig. 1b shows another mode of "wiring" the platelets and supporting them. Fig. 2 shows a plane of 16 words, 12 bits each, which was assembled by this technique. The electrical connection between platelets is simpler, and the plastic piece is self-supporting. The copper connector between platelets may be an integral part of the plastic-support member. The return conductor is printed on the underside of the structural support and can be brought close to the actual core winding. This arrangement is of particular importance because it minimizes mutual inductances and coupling effects between word lines.

Stack Assembly

As indicated previously, each strip constitutes one word of the memory stack, and the printed conductor is a common read-write winding. The strips, stacked side by side and wired as shown in Fig. 2, constitute a plane. The planes may then be stacked vertically as shown schematically in Fig 3. Although the sense-digit wire is hand-threaded with comparative ease, one of the obvious advantages of the strip concept is that it is easily adaptable to a mechanized threading.

The finished stack is a compact unit (packing density may vary between 1000 and 2000 bits/in.^{3}) and is particulary well suited to high-speed operation. Depending on the thickness of the plastic strip support, the sense-digit wire can be made very short and thereby reduce sense delays and stray noise pick-up.

ELECTRICAL EVALUATION

Material evaluation and optimum drive-pulse characteristics were determined by the use of two general methods which both involve two-core-per-bit operation. One mode of testing was aimed at *amplitude sensing*, the other at *bipolar sensing*. The core wiring and pulse programming for each method of operation are shown in Fig. 4.

Fig. 3—Typical plane and stack assembled from individual strips.

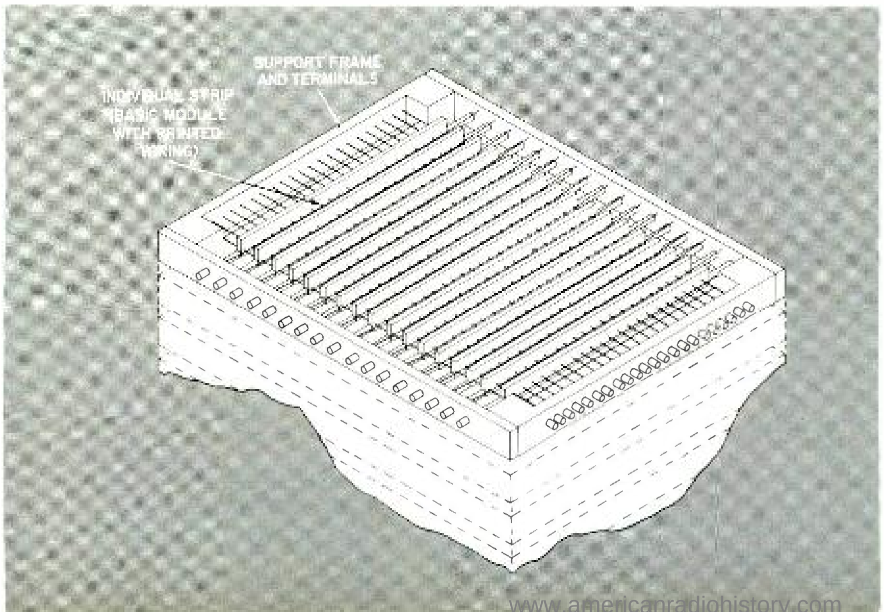
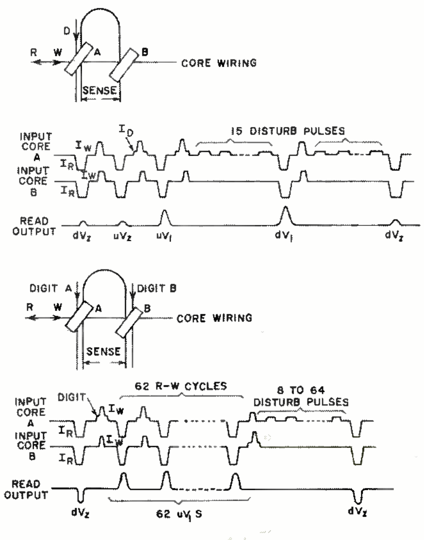


Fig. 4—Core wiring and pulse programming for amplitude-sensing and bipolar-sensing methods.



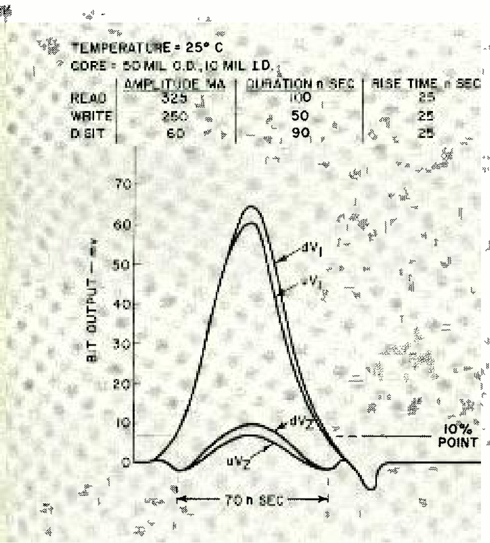


Fig. 5—Output signals for amplitude-sensing method.

The essential difference between the two methods is that in bipolar sensing, either core of the bit may receive a digit pulse; in amplitude sensing, only one core receives the digit pulse. In either case, digit pulses and partial-write pulses are always in the same direction. Unipolar bit drives were used when it became evident that bidirectional digiting led to an increase in digit-disturb sensitivity. This effect was particulary evident when individual cores were wired on a two-core-per-bit scheme. Test results showed that a core which received a digit pulse opposite in direction to the partial-write pulse had a lower digit-disturb threshold than a core for which write and digit pulses were in the same direction. This effect and similar phenomena have been reported elsewhere.[8]

Amplitude Sensing

Cores which were tested with the amplitude-sensing mode were subjected to the series of input pulses as shown in Fig. 4a. The four read outputs obtained during the pulse sequences are shown in the bottom part of the figure. This sequence was chosen to produce the worst signal-to-noise ratio; in this case, this ratio is the ratio of the amplitude of the undisturbed *1* to the amplitude of the disturbed *0* $(uV_1{:}dV_z)$. The particular order of the sequence—undisturbed *0* voltage (uV_z), undisturbed *1* voltage (uV_1), disturbed *1* voltage (dV_1), disturbed *0* voltage (dV_z), was intended to bring out instability in the remanent state on readout, if instability existed. If readout were incomplete the dV_z which follows a dV_1 would have its highest value, and a uV_1 following a uV_z would have its lowest value.

The four read outputs were superimposed to obtain a simultaneous oscilloscope display of the type shown in Fig. 5. The switching time, taken at the 10-percent points. is about 70 nsec. The relatively small difference between disturbed and undisturbed signals is an indication that the digit-disturb pulse has minimum disturbing effect on the core.

Fig. 6a shows the effects of variations in the digit and partial-write current amplitudes for fixed read-current conditions. The *1* and *0* outputs are actually undisturbed *1*'s (uV_1) and disturbed *0*'s (dV_z), respectively. Fig. 6b shows the signal-to-noise ratios which serve as a guide in the determination of optimum drive-pulse characteristics. For the particular durations and rise times used in this case, a range of workable digit and partial-write current levels is available. In Fig. 6a, for example, it is apparent that a digit current in the 60- to 70-ma range and a partial-write current of 200 to 220 ma would give a *1* output of 40 to 65 mv. at signal-to-noise ratios of 9 or 10 to 1. Switching times in this case are in the order of 80 nsec.

Bipolar Sensing

In the bipolar-sensing method (Fig. 4b), core A is digited to write a *1*, core B to write a *0*. Thus, in the test program shown, the first series of read outputs are undisturbed *1*'s. The last readout on the right is a disturbed *0* which is termed the "lowest *0*." In this case, although core B is raised to the higher flux state by superimposing digit and partial-write pulses, the disturb pulses are applied to core A. (If the pulse patterns in the two cores were reversed, the initial series of readouts would be undisturbed *0*'s and the last readout a disturbed *1*.)

Actually, the pulse sequence is a variation of that used for amplitude sensing and was chosen to give the worst-case conditions (i.e., by promoting the lowest *0* or the lowest *1*). As before, the reasoning was that if the read-pulse amplitude or duration was insufficient to bring the core back to a stable remanent state, a *0* would have its lowest value if it followed a series of *1*'s. A disturbed *0* obtained under these conditions, then, should be the lowest *0*.

This particular pulse sequence also aggravates the worst-case condition by the increase in core temperature caused by the high pulse repetition rate (2 Mc). In one of the materials examined, both cores become heated to about 20°C above room temperature. Core A, however, undergoes more flux reversals per cycle than core B, and becomes slightly warmer than core B. The temperature difference between the two cores was found to be in the order of 5 to 7°C. This temperature difference tends to increase the *1* output and decrease the *0* output. Because core A is warmer, it not only has an increased output, but also a reduced coercivity which tends to lower the digit-disturb threshold.

The temperature effect was easily observed by switching from the program shown to one producing a series of undisturbed *0*'s followed by a disturbed *1*. For about 3 seconds after the program change, the output amplitudes are unstable. Immediately after the program change, the undisturbed *0* is low and gradually increases to a higher stable value. Initially, the disturbed *1* is relatively high and stabilizes at a lower value. If the pulse program is again reversed, the undisturbed *1* is low initially, and gradually increases; the disturbed *0* is high initially and gradually decreases.

Fig. 7 shows the effect of digit-current amplitude on output for a given material and for a given set of partial-write and read conditions. The upper curve is a plot of undisturbed *1* (or undisturbed *0*) outputs as a function of digit-current

Fig. 6a—Bit output vs. digit current with variations in digit and partial-write current.

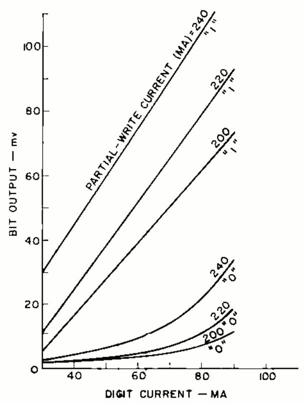
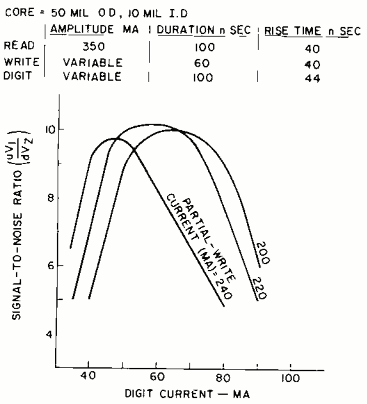


Fig. 6b—Signal-to-noise ratio vs. digit current with variations in digit and partial-write current.



amplitudes. The lower curve shows the effect of digit amplitude on a disturbed *0* or disturbed *1*. As expected, the undisturbed output gradually increases as the digit current level is increased. The disturbed output, on the other hand, goes through a maximum (in this case at about 90 ma). The decrease in *0* output beyond this point occurs because the disturb threshold of the core has been grossly exceeded at this digit-current level. This decrease is also caused by the fact that the disturbed curve is now "split", depending upon whether 8 or 62 disturb pulses were in the pulse program. Point E in Fig. 7 is the current level at which a difference is first detectable between the effects of 8 and 64 disturb pulses. In practice, an operating digit level would have to be below 80 ma to be "safe". At current levels below point E, the disturbed outputs are generally significantly lower than the undisturbed outputs because of the heating effect described earlier. Evidently, the core is quite usable at these frequencies (2 Mc) in spite of this effect.

Core Uniformity

One of the more important considerations in this program has been core and bit uniformity. Core uniformity, or lack of uniformity, ultimately determines the time and cost of testing quantities of cores. Several small sample batches of cores were examined using a test jig and a straightforward read-write program without digits. Output distribution in a batch of 200 cores is shown in Fig. 8. The distribution is normal and falls within a fairly narrow range. The test was repeated for two other core firings and similar results were obtained. In each case, the extremes were within about 8 percent of the mean. These same cores, when tested in a two-core-per-bit method that also used a simple read-write pulse pattern, showed a *0*-output spread essentially the same as in the one-core-per-bit test.

A plane of 16 words, 12 bits per word, was assembled from this batch of cores. Outputs from each of the 192 bits were measured by the use of the bipolar program shown in Fig. 4b. The average disturbed output was 35 mv with an average deviation of 4 mv. Bit outputs in two of the 16 words were also measured at 4 kc and 2 Mc by use of the amplitude-sensing method described in Fig. 4a. Average signal-to-noise ratio (uV_1:dV_z) at 2 kc was 6:1; at 2 Mc it was 5:1. The worst-case signal-to-noise ratio (lowest uV_1: highest dV_z) in the 24 bits examined was 3.3:1 at 2 kc and 2.5:1 at 2 Mc. Here again, the effect of pulse repetition rate is apparent, but at worst it is only slightly detrimental to discrimination.

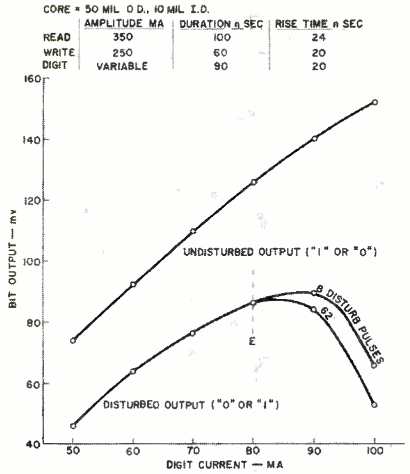


Fig. 7—Digit current vs. bit output for bipolar-sensing method.

Because the 16-by-12 plane is assembled essentially from unselected cores, the results described present an optimistic picture. It appears possible that core selection before stack assembly might not be necessary. Although "bad" bits will evidently show up in a finished plane, this type of detection should present a simpler problem than a 100-percent core testing. In any case, there is always a certain amount of core breakage in assembly, so that plane repair is necessary.

SUMMARY

The fabrication of microferrite memories having one printed winding and one wound winding, and having cycle times of 250 nsec and drive current levels of 350 ma has been found to be both feasible and practical. Such memory cells have been successfully operated at pulse repetition rates of 2 Mc. The future shows promise of attaining even faster speeds with the development of cores having smaller apertures and by further refinement of assembly methods.

ACKNOWLEDGMENT

The author acknowledges the active roles played by several co-workers on this project. Special credit is due to the following members of the Memory Products Operation: J. J. Sacco, J. J. Cosgrove, H. DiLuca, A. Erickson, B. Doolittle, B. Frackiewicz, R. Gravel, D. Kadish, P. Lawrence, and H. Lessoff.

Additional acknowledgement is due to RCA Semiconductor and Materials Division, Somerville, for aid in developing the assembly techniques; to RCA Electron Tube Division, Harrison, for help in developing vacuum-deposition methods; and to RCA Electronic Data Processing, Pennsauken, for their cooperation in he electrical evaluation phases of the work. Special acknowledgement is made to the RCA Laboratories at Princeton for their applied-research support. A great deal of this development is a result of work in high-speed ferrites previously undertaken at the laboratories.

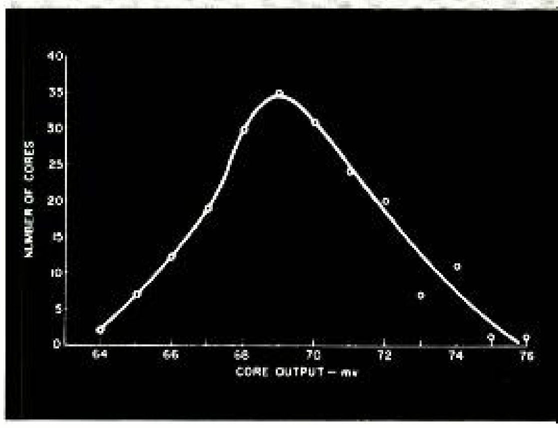


Fig. 8—Core-output distribution for 200-core sampling.

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Engineering and Research NOTES

BRIEF TECHNICAL PAPERS OF CURRENT INTEREST

Resolution of Electrostatic Patterns

by I. M. Krittman, *Physical Research, Astro-Electronics Division, DEP, Princeton, N. J.*

The scope and progress of electrostatic recording efforts at AED were reported in the RCA Engineer by Hutter, et al.[1] Further studies of the detailed operation of electron beam devices have revealed an effect which may significantly limit their performance. The effect apppears to apply to the photo-dielectric tape camera, the (electrostatic) analog signal recorder, and also the image orthicon.

In each of these storage devices, a reading electron beam senses the potential distribution rather than the written charge distribution on a target. The potential distribution differs from the charge distribution because of "fringing" of the electrostatic field at the target surface. The transformation of a charge pattern into a potential pattern on the surface of a dielectric can be considered an imaging process.[2] The theoretical sinewave response of an aperture defined by this process was derived by the author. The deleterious effects of field-fringing are more pronounced with thicker dielectric targets. While it can be made small in a photo-dielectric tape camera, the fringe-field seriously limits electrostatic signal recorder performance. Improved performance can result, however, from better electron guns (i.e., higher beam-current densities).

If one uses standard estimates of recorder signal-to-noise ratio and packing density are greatly reduced from earlier calculations. Thus, a recorder comprising a standard image orthicon gun and a 2-micron-thick insulating target (calculations indicate that recorder performance may be near-optimum for this thickness of polystyrene) is expected to exhibit a 20-db signal-to-noise ratio at a bandwidth frequency of 10 Mc and a packing density of 150,000 bits/cm^2. Earlier calculations yielded corresponding values of 30 db, 20 Mc and 1,000,000 bits/cm^2.

In cycled or transient modes of operation, image orthicons are also subject to fringe-field effects. Normally, these tubes are operated as steady-state devices; i.e., a charge flow equilibrium is established across the target. This equilibrium process may partially compensate for the field-fringing.

Experiments to demonstrate the existence of electrostatic field-fringing were conducted at AED by A. D. Cope and E. Luedicke. A 5820 image orthicon was operated at low illumination and high mesh potential to reduce secondary redistribution effects. Sinewave responses were obtained for the first, third and fifth readout scans.

Only preliminary conclusions can be made at this time. First field response coincided almost exactly with the predicted response due to field-fringing alone. This may indicate that the low-velocity beam in the 5820 image orthicon is not a limiting element. Multiple-field camera response as definitely improved over first-scan response. However, there is evidence of a fringe-field even after many scans. Continuing experiments are aimed towards obtaining data for other mesh-to-target spacings and different target materials. The lateral resistivity of the target probably affects the charge flow equilibrium process. These results may lead to a better understanding of this process in image orthicon targets.

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Neutron Spectrometer to be Available for Studies of Crystal Structure

by D. A. Ross and J. G. White, *RCA Laboratories, Princeton, N. J.*

A neutron spectrometer has been constructed in RCA Laboratories for use at the Industrial Reactor Laboratories. As soon as operating experience has been obtained, the spectrometer will be made available for the solution of crystal-structure problems arising in the product divisions. This instrument will permit studies of crystal structure by neutron diffraction and will provide information that we have not been able to obtain by use of x-rays. The results should aid in the preparation of improved materials.

Neutrons are superior to x-rays in two respects. First, x-rays, which are diffracted only by the orbital electrons of an atom, cannot accurrately locate the positions of light elements in a crystal or differentiate between atoms with nearly equal numbers of electrons. Neutrons are scattered by the nuclei and can therefore identify almost all atoms for which x-rays fail, and show their positions in the crystal. Second, x-rays have no magnetic properties and therefore cannot differentiate between magnetic and nonmagnetic atoms. Neutrons, on the other hand, have magnetic moments and can interact with magnetic atoms to show not only their positions but the changes in their magnetic orientation for various positions in the crystal lattice, a property which controls the magnetic characteristics of the material.

In the neutron spectrometer, a narrow tube through the nuclear reactor shield permits a beam of neutrons to enter an external drum that contains 5000 pounds of shielding to protect the operators, and yet can be rotated on bearings. Within this drum the neutrons strike a crystal of known structure that acts like a prism to spread the neutrons into a spectrum. This known crystal and the drum are rotated to choose a beam of neutrons of the desired wavelength (between 0.5 and 5 angstroms) which is then made to strike the crystal to be studied. This unknown crystal, in turn, diffracts the neutrons into a pattern that is detected by electronic counters to provide the data from which the crystal structure can be calculated.

Magnetic materials will be the first to be studied; the results should permit us to determine the magnetic structure of complex magnetic crystals in the hope that their magnetic properties can be better understood. The first nonmagnetic material to be studied with the neutron spectrometer will probably be a superconductor with a structure that is still unknown because the positions of the all-important hydrogen atoms cannot be determined with x-rays.

How Shared Loading in Decode Matrices Reduces Driver Requirements

by P. J. Anzalone and E. L. Schlain, *Surface Communications Division, DEP, Camden, N. J.*

The principle of *shared loading*, when properly applied to decode matrices, can result in a considerable reduction in driver requirements. This saving reduces the cost of the device, and also can result in higher operating speed because of the reduced loading.

Logic: In Fig. 1, each of the decode-matrix *and* gates contain *N* inputs, or one per input bit. In such a decode-matrix, each input is connected to $2^N/2$ gates. If it were not for shared loading, each of these inputs would be loaded to the extent of $2^N/2$ gates; with shared loading, the loading on the driving gates can be considered as being considerably less. Each gate is considered one load on a driver if only that input is logical *1* (*O* for p-n-p logic circuits). If one other input to the gate is *1*, then each of the *1* inputs can be considered as "sharing" the load, so that the load on each of the high inputs is only ½. Similarly, if three inputs to a gate are *1*, the

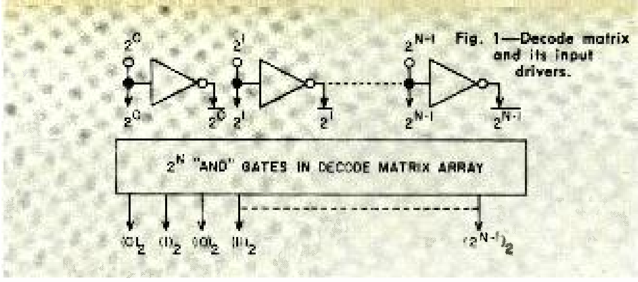


Fig. 1—Decode matrix and its input drivers.

load on the driver is ⅓ unit, and so on. Since decode matrices are widely used, the exact loading on the driving gates will be calculated for a full matrix.

When the output of the driver under consideration is *0*, the load on it is defined as being zero. When the output of the driver is *1*, it will be loaded by the individual gate in accordance with how many other inputs to this gate are *1*. The total maximum load on the driver, L_d, is the summation of the loading of all the individual gates to which it is connected. Since there are 2^N,N-input decoding gates and $2N$ input wires (the N bits and their complements), then each input wire is connected to 2^{N-1} gates. To obtain all of the possible decode combinations, the other inputs to the gates must, therefore, be represented by the binary numbers from 0 to $(2^{N-1} - 1)$ inclusively. Thus, the maximum loading on a given driver is:

$$L_d = \sum_{X_2 = 0}^{2^{N-1}-1} \frac{1}{1 + \Sigma \text{ of } 1 \text{ inputs in } X_2} \qquad (1)$$

Where: X_2 is the code pattern of *1*'s and *0*'s into any gate, and the *1* in the denominator represents the load on the driver due to its connection to each gate.

Eq. 1 can be expressed in terms of combinations:

$$L_D = 1 + \frac{1}{2}C(N\text{-}1, 1) + \frac{1}{3}C(N\text{-}1, 2) + \ldots + \frac{1}{N}C(N\text{-}1, N\text{-}1)$$

This can be rewritten as:

$$L_D = \frac{1}{N}[C(N, 1) + C(N, 2) + \ldots + C(N, N)]$$

The bracketed quantities are the coefficients of the binomial expansion of $(1 + 1)^N$, except for the first term of the expansion, $C(N, 0)$, which equals 1. Therefore, $L_D = 1/N\ [2^N - 1]$.

Circuitry. The above analysis is valid, in general, only where each driver is capable, with respect to power dissipation only (not fan-out), of supplying all of the current required by all of the gates to which the driver is connected. This is so because the current required by the decoding gates is not likely to divide equally between each of the drivers connected to it, and in the worst case, all current will flow to one driver. This is not as restricting as it may first appear to be, because when the driver is called upon to deliver this current, its transistor is in saturation and the power dissipation in the transistor will, therefore, be low because of the low V_{CE} existing at this time. Additional care must be used when the frequency of operation is so high that the switching time becomes comparable to the cycle period, because the power dissipation of the driving transistor goes up accordingly.

Another potential type of failure (other than excessive power dissipation) which may occur when drivers are connected effectively in parallel, is that the β of the transistor driver receiving all of the load current may not be high enough to supply all of this current. In this case, the transistor will come out of saturation and the V_{CE} will rise slightly. The V_{CE} cannot rise above the point at which the circuit will fail, because the other drivers connected to the load will assume that part of the current that the former transistor could not supply, and the parallel driving circuit will function properly (assuming the circuits were properly designed for normal non-parallel operation).

Packaging. When this method is used, there may be one restriction on the packaging: namely, that all of the drivers should be mounted on the same plug-in board, so that it is impossible to disconnect some of the drivers while the others are still operating. This condition must be imposed because the presence of all the drivers is required to stay within the rated load specifications when the shared loading principle is used to the fullest extent. When the shared-loading principle is used to a lesser than fullest extent, it may be possible to separate some of the drivers. If a rule of operation is established that power to the equipment is turned off before disconnecting one or more of the drivers, then there are no restrictions on their location.

Example For a Six-bit Decode Matrix: The inputs to the matrix are the six bits and their complements (twelve wires). Since there are 2^6 possible combinations, there will be 2^6 six-input decoding gates to be driven. Each input wire is, therefore, connected to $(2^6 \times 6) \div 12 = 32$ gates. The loading on each input is $(2^N - 1/N = (2^6 - 1) \div 6 = 10.5$. Thus, each input need be capable of driving only 10.5 instead of 32 loads — a saving of 67 percent.

Locked-Train Gears Reduce Backlash in Instrument Applications

by H. K. Weis, *Surface Communications Division, DEP, Camden, N. J.*

Locked-train gearing (often found in heavy-duty gearing) can be very useful in reducing backlash in instrument gearing, which usually has small power loads, yet needs precision to maintain smooth velocity relationships. Low backlash is often required to keep phase shift between shafts to an acceptable low value.

A *locked train* is a group of gears with two or more power "circuits" between input and output. The number of meshes must allow each successive gear to drive its mating gear in the proper direction. Referring to Fig. 1, each path has its own share of the total load depending on the elastic constants of the several paths. By displacing the two gears on shaft 2, for example, with respect to each other while they are still in mesh, a torque will be generated for *all* the gears, while either stationary or in motion. When in motion, this torque will cause a *circulating power* that will be equal to the input power when the gear set has no output load. In practice, the circulating power will be approximately the same over the operating load range of the gear set. Variation in gear loading due to external load variations and tooth error appear as a variation on a constant load; the total load is always positive, never passing through zero.

Low angular backlash can be achieved by several methods: 1) more precise construction; 2) larger-diameter gears, so that a given dimensional backlash between teeth will cause a smaller angular backlash; 3) loading gears so that they always run against one face of each tooth. Locked train gearing and the so-called "split gears" or scissors gears are of this third type; however, the locked train, while of higher initial cost, is more efficient, longer wearing, and easier to lubricate than the scissors gear.

Typical Instrument Application: Assume an instrument servo found to have too much backlash. Other important considerations are: 1) redesigned assembly should be driven by the same motor and amplifier, and it should fit into the same space previously used; 2) moment of inertia reflected to the motor shaft should be about the same as the original condition: 3) phase relationships are critical between eight output shafts running at four different speeds; five of the eight shafts have the same relative speed; two additional outputs, not so precise, are also required; and 4) the gearing runs continuously in two modes: constantly in one direction, and periodically reversing.

Preliminary investigation would indicate use of an antibacklash device; however, with eight synchro outputs running at several speeds, the usual spring-loaded gears would generate too much friction load and do not wear well. Therefore, a locked train gear drive is chosen with the gears selected to give the proper relative shaft velocity at each synchro (Fig. 2). The constant load on the gears can be adjusted while the gears are running by a spring-loaded shaft to a bevel gear differential. This shaft, although mounted in bearings, rotates only enough to take up backlash in the gear train plus a slight elastic deflection. This construction allows adjustment of the preload while the gears are operating (Other methods of setting up this preload could be used.)

This mechanism meets all the requirements listed above and is

Fig. 1—Principle of locked-train gearing.

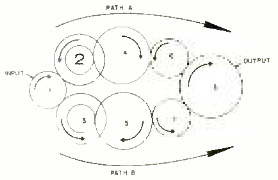
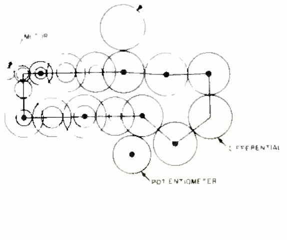


Fig. 2—An instrument servo application. Solid circles are rotating component shafts.



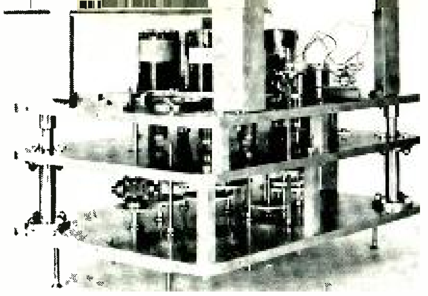


Fig. 3—Equipment diagrammed in Fig. 2.

easy to manufacture with stock gears (Fig. 3). Efficiency is about 95%. The circulating load is adjusted to keep the gears in constant contact during the dynamic load cycle. The frequency response of the gear train and amplifier together is −3 db (71%) at 30-cycle sinusoidal input.

The Flexode—An Adaptive Semiconductor Device

by Dr. J. O. Kessler, *RCA Laboratories, Princeton, N. J.*

Applied electric fields may cause drift of semiconductor dopants exhibiting high diffusivity at relatively low temperatures. Such drifts are employed in the construction of a new family of semiconductor devices called *flexodes*.

Consider a two-contact flexode, which is normally a resistor. Application of DC sufficient to heat the device (200 to 400 ma are typical) converts it to a rectifier whose forward direction corresponds to easy flow of the applied current. Continued application of the current improves the rectification characteristic until a steady state is reached. If at any time thereafter, a reverse DC of sufficient magnitude is applied, the device reverts to a resistive state and subsequently becomes a rectifier in the opposite direction. The cycle is repeatable. Signals normally processed, i.e. signals well below the breakdown region, do not effect such switching. The back resistance of flexode rectifiers generally exhibits a spontaneous decrease which may be halted either by the intermittent application of current in the appropriate direction or by cooling the device. Flexode rectifiers with widely varying back-resistance decay rates have been made (from no change during one month at room temperature to a decrease of 50% in a few minutes).

Germanium base material with lithium as the mobile dopant is being used in making these devices at present. Flexode formation is different from the production of p-i-n junctions. The latter process starts with a p-n junction in which the lithium is drifted in the back direction by the electric field, thus widening the depletion layer. In the floods, previously nonexistant or latent junctions are formed by forward drift, while reverse-drift first degrades and then destroys the action of junctions initially present. Furthermore, the process is reversible.

The flexode holds promise either as a circuit element whose characteristics may be tailored to a particular job by electrical processing, or as an adaptive device whose function may be changed by externally applied signals long after installation in a circuit. It is also a device whose characteristic depends on appropriate elements of operational history, and whose rate of adaption to operating condition depends on externally adjustable gross variables, such as the temperature.

Thus, one may visualize information handling machines containing flexode sections which "learn" at elevated temperatures, and which may be made to maintain their organization at low temperatures. Since flexode characteristics arise from bulk conditions near the contacts, the device is likely to be suitable for the construction of multicontact monolithic circuit elements.

Fig. 1—The change with time of a typical flexode diode I-V characteristic due to passage of direct current. The junction with characteristic 1-1 disappears, and a new junction, with characteristic 5-7 is formed. Numbers indicate corresponding arms of the I-V characteristics, taken successively after equal time increments. The figure is schematic only.

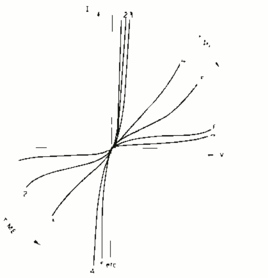
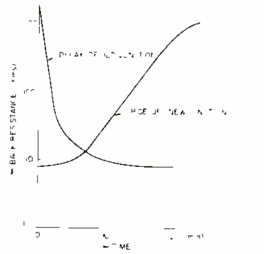


Fig. 2—Back resistance of flexode junctions as a function of time, at constant temperature and D. C. The current is in the forward direction of the new junction." The time and resistance scales are typical; in some cases they may differ, independently, by as much as a factor of 10.



New GaAs Power Varactor Diodes, VD310

by H. Kressel and L. H. Gibbons, Jr., *Semiconductor and Materials Division*, Somerville, N. J.

For some time, GaAs varactor diodes (VD110, VD210 series) have have been available on a sampling basis for use as parametric amplifiers. These devices are useful when very high cutoff frequencies and low noise are required, but reverse breakdown voltage requirements are modest (up to 6 volts). However, because of increasing interest in solid-state microwave power sources, need has arisen for varactors with both higher breakdown voltages and high cutoff frequencies—for efficient harmonic generation at frequencies in excess of 2 Gc. These requirements have been met by a new series of GaAs varactor diodes, VD310, with minimum breakdown voltage of 30 volts and cutoff frequencies up to 220 Gc at breakdown.

Because of the inherent high electron mobility of GaAs, these diodes have a lower series resistance than silicon diodes with comparable breakdown voltages. The package used (Fig. 1) can be easily mounted in waveguides, and offers low capacitance (about 0.35 pf) and low inductance (0.35 nh).

The efficiency of a nonlinear-capacitance device as a harmonic generator is determined by: 1) The value of n in $C = K/(\phi - V)^n$, where C = junction capacitance, ϕ = built-in potential, and V = applied bias; 2) series resistance R of the diode, and hence the cutoff frequency given by $f_{co} = ½\pi RC$; and 3) the order of the harmonic.

For example, if the cutoff frequency for a diode which operates as a frequency doubler is ten times the fundamental frequency, the theoretical conversion efficiency is about 20 percent. If the cutoff frequency is increased by a factor of five, the conversion efficiency rises to about 70 percent for the same fundamental frequency. The higher cutoff-frequency characteristics of the new VD310 series permit high-efficiency harmonic generation at fundamental frequencies which were previously limited by the diodes.

The series resistance of a diode with a given area and thickness is proportional to the resistivity of the lightly doped side of the junction. The resistivity required (Fig. 2) to achieve a given breakdown voltage is much lower for GaAs than for silicon devices. As a result, devices with higher cutoff frequencies can be fabricated.

The maximum power input which a varactor harmonic generator can handle is given by $P_{in} \alpha 2\pi f C_{min} V_B^2$, where V_B = diode breakdown voltage, C_{min} = capacitance at breakdown, and f = input frequency. Thus, higher breakdown voltages are required for harmonic generation at lower frequencies.

The power dissipation of the new VD310 series is 300 to 500 mw, depending upon the size of the junction capacitance. When a suitable heat sink is used with the new VD310 case, output power levels in excess of 1 watt can be achieved with efficient conversion.

At the present time, high-cutoff GaAs diodes which have breakdown voltages up to 50 volts can be fabricated. Higher-breakdown epitaxial diodes with voltages comparable to those achieved with silicon are under development. It should be noted, however, that RCA silicon varactor diodes (with lower cut-off limits) are available with breakdown voltages up to 200 volts.

Reference 1) L. H. Gibbons, A. E. Widmer, and M. F. Lamorte, "GaAs Varactor Diodes," RCA Engineer, April-May, 1962.

Fig. 1—Package for GaAs power varactors, VD310 series.

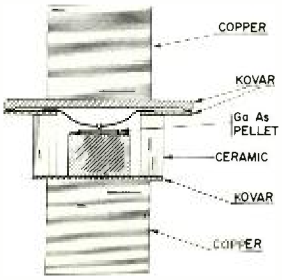
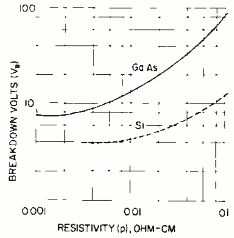
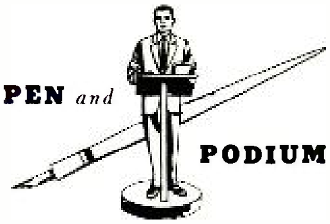


Fig. 2—Breakdown voltage for GaAs near-abrupt p-n junctions vs. resistivity of N-type lightly doped side of the junction.





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ELECTRON TUBE DIVISION

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DATES and DEADLINES

Professional Meetings and Calls for Papers

Meetings

Aug. 29-Sept. 1, 1962: 2nd Intl. Conf. on Information Processing, IFIPS, IRE, ACM, AIEE, AFIPS; Munich, Germany. Exhibits. *Prog. Info.:* Dr. E. L. Harder, Westinghouse Electric Corp., E. Pittsburgh, Pa.

Aug. 29-Sept. 5, 1962: 5th Intl. Cong. for Electron Microscopy, Electron Microscope Soc. of America, Natl. Inst. of Health, RSF, ONR, AEC, OOR, AFOSR; Sheraton Hotel, Phila., Pa. *Prog. Info.:* Electron Microscope Soc. of America, 7701 Burholme Ave., Phila. 11, Pa.

Sept. 3-7, 1962: Natl. Adv. Technology Management Conf., IRE-PGEM, AIEE, ASCE, AIChE, et al.; Opera House Worlds Fair Grounds, Seattle, Wash. Exhibits. *Prog. Info.:* Georges Brigham, 805 Logan Bldg., Seattle 1, Wash.

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Sept. 4-7, 1962: Assn. for Computing Machinery (ACM) Natl. Conf. & Inter. Data Processing Exhibit, Hotel Syracuse and War Memorial Aud., Syracuse, N.Y. *Prog. Info.:* R. W. Beckwith, 7614 Hunt Lane, Fayetteville, N.Y.

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Sept. 13-14, 1962: Natl. Symp. on Engineering Writing & Speech, IRE-PGEWS, Mayflower Hotel, Washington, D.C. *Prog. Info.:* J. E. Durkovic, % ARINC, 1700 K St., N.W., Washington 6, D.C.

Sept. 16-20, 1962: 1962 Fall Mtg. Electrochemical Soc., Statler-Hilton Hotel, Boston, Mass. *Prog. Info.:* Electrochemical Soc., 1860 Broadway, New York 23, N.Y.

Sept. 19-20, 1962: 11th Ann. Industrial Electronics Symp., IRE-PGIE, AIEE, ISA; Hotel Sheraton, Chicago, Ill. *Prog. Info.:* J. A. Granath, Armour Res. Found., 10 W. 35 St., Chicago 16, Ill.

Sept. 28-29, 1962: 12th Ann. Broadcast Symp., IRE-PGB; Willard Hotel, Washington, D.C. *Prog. Info.:* Dr. Wm. Hughes, E.E. Dept. Okla. State Univ., Stillwater, Okla.

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Oct. 2-4, 1962: Natl. Symp. on Space Elec. & Telemetry, IRE-PGSET; Fontainebleau Hotel, Miami Beach, Fla. Exhibits. *Prog. Info.:* O. A. Hoberg, Marshall Space Flt. Center, M-ASTR-I, Bldg. 4487-B, Huntsville, Ala.

Oct. 8-10, 1962: Natl. Electronics Conf., IRE, AIEE, et al; McCormick Pl., Chicago, Ill. Exhibits. *Prog. Info.:* Dr. T. W. Butler, Jr., E.E. Dept., Univ. of Michigan, Ann Arbor, Mich.

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Oct. 22-24, 1962: ECCANE (East Coast Conf. on Aerospace & Navigational Elec.) IRE-PGANE: Baltimore Sect.: Emerson Hotel, Baltimore, Md. *Prog. Info.:* Wm. C. Vergara, Dept. 466-2, Bendix Radio, Towson, Md.

Oct. 25-27, 1962: 1962 Electron Devices Mtg., IRE-PGED: Sheraton Park Hotel, Washington, D.C. *Prog. Info.:* J. E. Thomas, Jr., IBM Corp., Components Lab., Dept. 677, P.O. Box 110, Poughkeepsie, N.Y.

Oct. 30-31, 1963: Spaceborne Computer Engineering Conf., IRE-PGEC; Disneyland Hotel, Anaheim, Calif. *Prog. Info.:* Dr. R. A. Kudlich, AC Spark Plug Div., General Motors Corp., 950 N. Sepulveda Blvd., El Segundo, Calif.

Nov. 1-2, 1962: 6th Natl. Conf. on Product Engr. & Production, IRE-PGPEP; Jack Tar Hotel, San Francisco, Calif. Exhibits. *Prog. Info.:* G. F. Reyling, Varian Associates, 611 Hansen Way, Palo Alto, Calif.

Nov. 4-7, 1962: 15th Ann. Conf. on Engineering in Biology and Medicine, IRE, AIEE, ISA; Conrad Hilton Hotel, Chicago, Ill. Exhibits. *Prog. Info.:* D. A. Holaday, P.O. Box 1475, Evanston, Ill.

Nov. 5-7, 1962: NEREM (Northeast Electronics Research & Engineering Mtg.), IRE; Commonwealth Armory & Somerset Hotel, Boston, Mass. *Prog. Info.:* I. Goldstein, Raytheon Co., Box 555, Hartwell Rd., Bedford, Mass.

Nov. 7-9, 1962: 22nd Natl. Mtg. Operations Research Soc. of America (ORSA), Sheraton Hotel, Phila., Pa. *Prog. Info.:* J. D. Kettelle, Jr., Kettelle & Wagner, 1770 Lancaster Ave., Paoli, Penna.

Calls for Papers

Jan. 24-28, 1963: 69th Ann. Mtg. American Mathematical Soc. and the Mathematical Assn. of America, Berkeley, Calif. *DEADLINE:* Abstracts, **11/23/62,** to American Mathematical Soc., 190 Hope St., Providence 6, R.I.

Feb. 11-15, 1963: 3rd Intl. Quantum Electronics Symp., IRE, SFER, ONR; Unesco Bldg. & Parc de Exposition, Paris, France. (Exhibition of working experiments & advanced devices Feb. 8-15). *DEADLINE:* Resume, **10/1/62** to Madame Cauchy, 3eme Congres d'Electronique Quantique, 7, rue de Madrid, Paris 8eme, France.

Feb. 20-22, 1963: Intl. Solid State Circuits Conf., IRE-PGCT, AIEE, Univ. of Penn., Sheraton Hotel & Univ. of Penn., Phila., Pa. *DEADLINE:* 300-500 wd summary and 35-wd abstract, **11/1/62,** to A. K. Rapp, Philco Scientific Lab, Blue Bell, Pa.

March 25-28, 1963: IRE Intl. Conv., Coliseum and Waldorf-Astoria Hotel, New York. Exhibits. *DEADLINE:* **10/19/62,** to Dr. D. B. Sinclair, IRE Headquarters, 1 E. 79 St., New York 21, N.Y.

April 17-19, 1963: Intl. Special Tech. Conf. on Non-Linear Magnetics (INTERMAG), IRE-PGEC, PGIE, AIEE; Shoreham Hotel, Washington, D.C. *DEADLINE:* 200-wd abstracts, **11/5/62,** to J. J. Suozzi, BTL Labs, Whippany, N.J.

April 17-19, 1963: SWIRECO (Southwestern IRE Conf. & Elec. Show), Dallas Memorial Aud., Dallas, Tex. Exhibits. *DEADLINE:* Approx. **10/1/62.** For info.: Prof. A. E. Salis, E.E. Dept., Arlington State College, Arlington, Tex.

May 13-15, 1963: NAECON (Natl. Aerospace Electronics Conf.), IRE-PGANE, Dayton Sect.: Dayton, O. Exhibits. *DEADLINE:* Approx. **12/15/62.** For info.: IRE Dayton Office, 1414 E. 3 St., Dayton, O.

May 20-22, 1963: Natl. Symp. on Microwave Theory & Techniques, IRE-PGMTT; Miramar Hotel, Santa Monica, Calif. *DEADLINE:* 100-wd abstract, 1000-wd summary, in duplicate, with title, **1/5/63,** to Dr. Irving Kaufman, Space Tech. Labs, Inc., 1 Space Pk., Redondo Beach, Calif.

May 21-23, 1963: Spring Joint Computer Conf., AFIPS (PGEC, AIEE, AIM); Cobo Hall, Detroit, Mich. Exhibits. *DEADLINE:* Approx. **11/10/62.** For info.: E. C. Johnson, Bendix Corp., Res. Labs Div., Southfield, Mich.

June 11-13, 1963: Natl. Symp. on Space Electronics & Telemetry, IRE-PGSET: Los Angeles, Calif. Exhibits. *DEADLINE:* Approx. **12/15/62.** For info.: J. R. Kauke, Kauke & Co., 1632 Euclid St., Santa Monica, Calif.

June 19-21, 1963: Joint Automatic Control Conf., IRE-PGAC, AIEE, ISA, ASME, AICHE: Univ. of Texas, Austin, Tex. *DEADLINE:* Abstracts, **9/30/62,** manuscripts, **11/1/62,** to O. L. Updike, Univ. of Va., Charlottesville, Va.

Aug. 20-23, 1963: WESCON (Western Elec. Show & Conf.), IRE, WEMA: Cow Palace, San Francisco, Calif. *DEADLINE:* Approx. **4/15/63.** For info.: WESCON, 1435 La Cienega Blvd., Los Angeles, Calif.

Oct. 15-18, 1963: Intl. Symp. on Space Phenomena & Measurement, IRE: Statler-Hilton, Detroit, Mich. *DEADLINE:* 300-500 wd. summary, 35 wd. abstract, **11/1/62,** to A. K Rapp, Philco Scientific Laboratory, Blue Bell, Pa.

Jan. 8-10, 1963: Millimeter and Submillimeter Conf., IRE; Orlando, Fla. *DEADLINE:* 3 cps. 500-wd abstracts, **9/15/62,** to J. J. Gallagher, Tech. Prog., Millimeter & Submillimeter Conf., MP-172—Box 5837, Martin Company, Orlando, Fla.

Be sure DEADLINES are met — consult your Technical Publications Administrator for lead time needed to obtain required RCA approvals.

Symmetry of Transition Metal Impurity Sites in Crystals as Inferred from Optical Spectra—W. A. Weakliem and D. S. McClure: *Journal of Applied Physics*, Jan. 1962

Theory of Cyclotron Resonance Absorption by Negative-Mass Holes in Germanium—R. C. Duncan and B. Rosenblum: *Physical Review*, Jan. 1962

New Ferroelectrics of Tetramethylammonium-Trihalo-Mercurate Family—E. Fatuzzo, R. Nitsche, H. Roetschi and S. Zingg: *Physical Review*, Jan. 1962

Measuring the Value of Information Services—J. Hillier: *Journal of Chemical Documentation*, Jan. 1962

Thermal Conductivity of Ge-Si Alloys at High Temperatures—B. Abeles, D. S. Beers, G. D. Cody and J. P. Dismukes: *Physical Review*. Jan. 1962

Double Injection in Insulators—M. A. Lampert: *Physical Review*, Jan. 1962

Recent Developments in Maser Devices and Materials—H. J. Gerritsen: *Applied Optics*, Jan. 1962

Injection Luminescence from Gallium Arsenide--J. I. Pankove and Mr. M. J. Massoulie: American Physical Society, N.Y.C., Jan. 26, 1962

Photoemission and Band Structure of the Semiconducting Compound CsAu—W. E. Spicer: *Physical Review*. Feb. 15, 1962

Reflectivity of Gray Tin Single Crystals in the Fundamental Absorption Region—M. Cardona and D. L. Greenaway: *Physical Review*, Feb. 15, 1962

A Print-Out System for the Automatic Recording of the Spectral Recording of the Spoken Syllables—H. F. Olson and H. Belar: *Journal of the Acoustical Society of America*, Feb. 1962

Excitions at the L Absorption Edge in Zinc Blende-Type Semiconductors — M. Cardona and G. Harbeke: *Physical Review Letter*, Feb. 1962

Dielectric Breakdown in Cadmium Sulfide—R. Williams: *Physical Review*, Feb. 1962

The Stabilization of Germanium Surfaces by Ethylation. I. Chemical Treatment, II. Chemical Analysis, III. Electrical Measurements—J. A. Amick, G. W. Cullen and D. Gerlich: *Journal of Electrochemical Society*, Feb. 1962

Tunnel Diode Balanced Pair Switching Characteristics J. J. Gibson, G. R. Herzog, H. S. Miiller, R. A. Powlus: International Solid-State Circuits Conference, Feb. 13, 1962

Hot Electrons in Thin Films—J. J. Quinn, Synposium, Philco Research Labs., Bluebell, Pa., Feb. 28, 1962

Medical Electronics -V. K. Zworykin: American Technion Society, Feb. 1962

High Temperature Susceptibility of Garnets: Exchange Interactions in YIG and LuIG—P. J. Wojtowicz: *Journal of Applied Physics*, March, 1962

The Nature of One-ion Models of the Ferrimagnetic Anisotropy—P. J. Wojtowicz: *Journal of Applied Physics*, March, 1962

Flux Reversal in Ferrite Cores Under the Effect of a Transverse Field—Kam Li: *Journal of Applied Physics*, March, 1962

Permalloy-Sheet Transfluxor-Array Memory--G. R. Briggs and J. W. Tuska: *Journal of Applied Physics*. March. 1962

Minimum Size and Maximum Packing Density of Nonredundant Semiconductor Devices—J. T. Wallmark and S. M. Marcus: *Proceedings of the IRE*, March, 1962

The Sputtering of Silicon Carbide by Positive Ion Bombardment—R. E. Honig: *Proceedings Fifth Inter. Conference on Ionization Phenomena in Gases*, Munich, Germany, 1961

Crystal Growth by Chemical Transport Reactions-1 Binary, Ternary, and Mixed-Crystal Chalcogenides R. Nitche, H. U. Bolsterli and M. Lichtensteiger: *Journal Physics and Chemistry Solid*, Pergamon Press, 1961

The Unit Cell Dimensions and Crystal Structure of KBaPO4- C. W. Struck and J. G. White: *Acta Crystallographica*, March, 1962

Distribution of Electron Bombardment Induced Radiation Defects with Depth in Silicon—H. Flicker: American Physical Society, March 26, 1962

The Effect of Ag on Impact Ionization in Cs_3Bi—W. Spicer: American Physical Society, Baltimore, Md., March 24, 1962

Electron Paramagnetic Resonance of Manganese in Gallium Arsenide—N. Almeleh, B. Goldstein: American Physical Society, Baltimore, Md., March 26, 1962

Radiation Damage in Silicon I: Photovoltaic Response—B. W. Faughnan and J. A. Baicker: American Physical Society, Baltimore, Md., March 26, 1962

Radiation Damage in Silicon II: Lifetimes—J. A. Baicker and B. W. Faughnan: *American Physical Society*, Baltimore, Md., March 26, 1962

Theory Formation by Machine—S. Amarel: Seminar at Computation Labs., MIT, March 20, 1962

Computer Memories—Remarks on Possible Future Developments—J. A. Rajchman: Symp. on Application of Switching Theory in Space Technology, Sunnyvale, Calif., Feb. 27 to March 1, 1962

New Research Developments in Television That will contribute to Medical Education—V. K. Zworykin: CIT-MIFED Conf. Present Status & Future Prospects of T.V., Milan, Italy, April 23, 1962

Small Particles Measurement Techniques—M. D. Coutts: Coulter Counter User's Meeting, Phila., Pa., April 26, 1962

Review of Semiconductor Analysis in U.S.A.—S. J. Adler: Semiconductor Analytical Group, 1962 Spring Meeting, New York City, April 20, 1962

Behavior of Chromium in the System $M_2Al_2O_4$-Al_2O_3—R. H. Arlett: American Ceramic Society Annual Meeting, New York City, April 29, May 3, 1962 and *ACS Journal*

Energy Levels of Divalent Thulium in CaF_2—Z. J. Kiss: American Physical Society, Washington, D. C., April 23-26, 1962

Uranium-Doped Calcium Fluoride as a Laser Material--Z. J. Kiss and J. P. Wittke: SADTC-NATO Symp. on Technical & Military Application of Laser Techniques, April 3-5, 1962, Hague, Netherland

Derivation of the Electron Affinity from Slow Electron Reflection--H. Heil: American Physical Society, Washington, D.C., April 23, 1962

Dielectric Constant of a Degenerate Electron Gas in a Magnetic Field—J. J. Quinn: American Physical Society, Washington, D.C., April 24-27, 1962 and *Bulletin of APS*

On the Control of Electroluminescent Cells by Unipolar Transistors—T. N. Chin: *Journal of Electronics and Control*, April, 1962

Sources of Contamination in GaAs Crystal Growth—L. Ekstrom and L. R. Weisberg: *Journal of the Electrochemiual Society*, April, 1962

Recombination Radiation in a Gallium Arsenide P-N Junction—J. I. Pankove: Electrochemical Society Meeting, Symposium on Luminescence, Los Angeles, Calif., May 6-10, 1962

On the Automatic Formation of a Program which Represents a Theory—S. Amarel: Symposium on Self-Organizing Systems Sponsored by ONR, Chicago, Ill., May 22, 1962

Electronics Fifty Years Later—J. Hillier: *IRE Student Quarterly*, May, 1962

Luminescence and Phase Relationships in the ZnS, ZnSe, ZnTe Ternary Systems—P. N. Yocom: Electrochemical Society Meeting, Los Angeles, Calif., May 1962

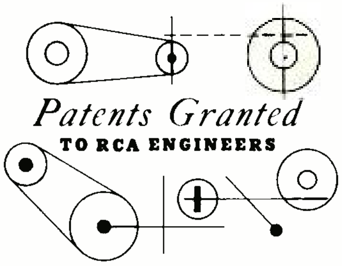
Correlations Between Electrical Characteristics & Light-Emission for Powder-Electroluminescence—R. E. Shrader: Electrochemical Society Meeting, Los Angeles, Calif., May, 1962

The Preparation, Single Crystal Growth Emission and Excitation Spectra of Alkaline Earth Halides and Halofluorides Doped with Divalent Rare Earths—G. J. Goldsmith, M. Kestigian and P. N. Yocom, Electrochemical Society Meeting, Los Angeles, Calif., May, 1962

BROADCAST AND COMMUNICATIONS PRODUCTS DIVISION

The Technology of Television Program Production and Recording— J. W. Wentworth: *Proceedings of the IRE* (Anniversary Issue) May 1962

Two Speed Operation of Television Tape Recorders for Tape Economy—A. H. Lind: 91st SMPTE Convention, California, May 1, 1962



Patents Granted

TO RCA ENGINEERS

As Reported By RCA Domestic Patents, Princeton

DEFENSE ELECTRONIC PRODUCTS

3,032,284—Web Reeling System, May 1, 1962; J. M. Uritis

3,033,923—Locating Objects Viewed by Remote Television Camera, May 8, 1962; A. C. Stocker

3,033,995—Circuit for Producing an Output Voltage Indicative of the Absolute Value of the Difference Between Two Input Voltages, May 8, 1962; F. L. Putzrath

3,034,712—Record Member, May 15, 1962; T. H. Mead

3,035,179—Condenser Optical Systems for Flying Spot Scanners, May 15, 1962; D. J. Parker

3,036,272—Pulse Width Discriminator, May 22, 1962; C. G. LeVezu

3,037,089—Angled Transducer Heads to Minimize Magnetic Coupling, May 29, 1962; H. R. Warren

3,037,093—Magnetic Recording and Reproducing Apparatus, May 29, 1962; M. J. Nowlan

3,037,151—Voltage Monitoring Apparatus, May 29, 1962; I. Cimerman and W. Saeger

3,037,190—Information Transmission System, May 29, 1962; P. J. Herbst

3,037,203—Electrical Information Conversion System, May 29, 1962; W. E. Woods

RCA LABORATORIES

3,032,009—Electrophotographic Developing Apparatus, May 1, 1962; K. J. Magnusson

3,032,674—Electron Gun Structure for Cathode Ray Tube, May 1, 1962; J. W. Schwartz

3,033,989—Radiant Energy Sensitive Device, May 8, 1962; B. Kazan

3,034,987—Magnetic Cores, May 15, 1962; P. K. Baltzer

3,037,064—Method and Materials for Obtaining Low Resistance Bonds to Thermoelectric Bodies, May 29, 1962; F. D. Rosi and R. A. Bernoff

3,037,065—Method and Materials for Thermoelectric Bodies, May 29, 1962; E. F. Hockings

3,037,071—Automatic Chroma Control of Viedo Amplifier with Effect Limited to Chroma Components, May 29, 1962; L. F. Schaefer and A. Mocovski

BROADCAST AND COMMUNICATIONS PRODUCTS DIVISION

3,032,749—Memory Systems, May 1, 1962; V. L. Newhouse

3,037,090—System for Duplicating Magnetic Tape Records, May 29, 1962; A. Bouzenburg

HOME INSTRUMENTS DIVISION

3,032,615—Acoustic Devices, May 1, 1962; R. E. Hamson

3,034,477—Wire Coating Apparatus, May 15, 1962; H. D. Williams

ELECTRON TUBE DIVISION

3,036,674—Compression Seal and Sealing Material Therefor, May 29, 1962; T. G. Branin

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The Quadruplex Video Tape Recorder and Its Three Sampled Data Feed-Back Control Systems with Special Emphasis on the Vacuum-Guide Servo—G. V. Rao: Moore School, University of Pennsylvania, May 8, 1962

An All-Transistor Switchable Standards Television Tape Recorder--R. N. Hurst and R. G. Thomas: Second International Television Symposium, Switzerland

The Transfer Function Slide Rule as an Aid to the Approximation Problem in Network Synthesis—F. M. Brock: Moore School, University of Pennsylvania and Moore School Library

DEFENSE ELECTRONIC PRODUCTS

An Error Detection and Correction Technique for the RCA Modified Diphase Modem—C. Atzenbeck: *MSEE Thesis*, Brooklyn Polytechnic Institute

Broadband Parametric Amplifiers by Simple Experimental Techniques—Bossard and Pettai: IRE PGMT Symposium, Boulder, Colorado, May 24, 1962

Some Characteristics of Tunnel Diode UHF Mixers—J. Klapper, A. Newton and B. Rabinovici: *IRE Proceedings*, April, 1962

Self-Biased Low-Noise Tunnel Diode Downconverters—J. Klapper, A. Newton and B. Rabinovici: SWIRECO, Houston, Texas, April, 1962

Microminiature Crystal Oscillator Using Wafer Modules—M. Lysobey: Electronics, April 31, 1962

Missile Launch Locater—R. M. Carrell and R. Richter: *Ground Support Equipment*, February/March 1962

Tunnel Diode Shift Register—B. Rabinovici: *IRE Proceedings*, April, 1962

Tunnel Diode Full Binary Adder—B. Rabinovici and C. A. Renton: *IRE PGEC Transactions*, April, 1962

Instantaneous Measurement of Tape Flutter—A. Schulbach: *Electronics*, May 11, 1962

Generating a Worst-Case Noise Pattern in Coincident Current Memories—Ying Luh Yao: *Electronic Design*, May 10, 1962

Analog-to-Digital Converter Uses Transfluxors—N. Aron and C. Granger: *Electronics*, May 18, 1962

Micromodules in Avionics and Space—B. J. O'Kane: Symposium of the Society of American Military Engineers, Wash.. D.C., May 21, 22, 1962

Dynamic Analysis and Simulation of Management Control Functions—R. B. Wilcox: *AIEE Transactions*, and AIEE North Eastern District Meeting, Northeastern University, Boston, May 9, 1962

Satellite and Missile Instrumentation—Dr. R. C. Gunter, Jr.: Student AIEE/IRE Section, University of Conn., Storrs, Conn., April 10, 1962

Extreme Value Theory Applied to False Alarm Probabilities—T. L. Fine and M. J. Levin: IRE Professional Group on Information Theory, April, 1962

Three Types of Satellite Communications Systems—H. R. Mathwich: Joint AIEE District 7 & District 15 Mtg., St. Louis, Mo., May 1, 1962

Satellite-Star Occulations for Geodetic Determinations—G. D. Gordon: COSPAR & IAG Symposim, Washington, D.C., April 26, 1962

RCA-AED—P. C. Murray: Peddie Schol Cum Laude Society, Hightstown, N.J., May 4, 1962

Astro Projects—S. Sternberg: ARS, Princeton Section, Hightstown, N.J., May 15, 1962

Space Communications—S. Sternberg: Bendix Symposium, Detroit, Michigan, May 25, 1962

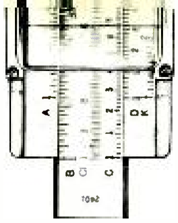
Satellite Communications—R. B. Marsten: IRE/AIEE Joint Meeting, Stevens Institute, Hoboken, N.J., May 9, 1962

STAFF RESEARCH AND ENGINEERING

Writing: Open Channel to Professionalism—W. O. Hadlock: *Electronic Design*, May 24, 1962.

Better Writing for Engineers: W. O. Hadlock: *Standards Engineering*, Feb. 1962

BMEWS—G. W. K. King: Rotary Club, Havertown, Pa., June 18, 1962; Civil Defense, Springfield, Pa., May 14, 1962; Tom Carlisle Club, Springfield, Pa.

Engineering  NEWS *and* HIGHLIGHTS

ARE YOU REGISTERED?

In the June-July 1962 RCA Engineer the editorial by J. C. Walter, "Registered Professional Engineers in Industry" included a list of some 230 RCA engineers who were known to possess state licenses. The Editors realized the list was incomplete, and asked that readers who were licensed (and not included in that list) send that information in. The following additions to the roster have been received in the past few weeks. *If you are licensed and have not yet informed the* RCA Engineer, *send that information to*: RCA Engineer, 2-8, Camden, N.J.

Dr. E. W. Engstrom, President, RCA, PE-33755, *N. Y.*
Dr. C. B. Jolliffe, Vice President & Technical Director, PE-32455-E, *N. Y.*
H. W. Phillips, DEP, PE-25336, *N. Y.;* PE-8428, *N. J.*
R. R. Hoefle, DEP, PE-24639, *Ohio*
I. W. Lovell, DEP, PE-5522, *Mass.*
W. F. Lanterman, NBC, PE-62-773, *Ill.*
W. E. Theile, RCAC, PE-2756, *Calif.*
W. I. Matthews, RCAC, PE-3455, *Calif.*
S. H. Herman, DEP, PE-1855-E, *Pa.*
W. A. Dailey, DEP, PE-11319, *N. J.*
S. M. Solomon, DEP, PE-38663, *N. Y.*
J. J. Logan, DEP, PE-15458, *Texas*
A. O. Bergholm, PE-19717, *N. Y.;* PE-7033, *Pa.*
J. E. Parker, DEP, PE-9272, *N. J.*
G. A. Lucchi, DEP, PE-5690, *Calif.*
M. Weiss, DEP, PE-04796E, *Pa.*
G. Hyde, DEP, PE, *Ontario, Canada*
J. T. Coleman, DEP, EE-875, *Ark.*
J. M. Fanale, ETD, PE-7009E, *Pa.*
J. W. Smith, ETD, PE-15928, *Ohio;* PE-31611, *N. Y.*
E. G. Otto, DEP, PE-7778, *N. J.;* PE-409, *N. H.;* PE-542, *VT.;* PE-5801, *Mass.;* PE-1930, *Md.;* PE-220, *Va.;* PE-28, *Dist. of Col.;* PE-1481, *N. C.;* PE-2574, *Ga.*
T. J. Boerner, DEP, PE-12164, *N. J.*
H. L. Watts, DEP, EIT-125, *Miss.*
W. G. Henderson, ETD, ME-5323, *Pa.*
D. W. Palmquist, ETD, PE-7925-E, *Pa.*
J. B. Buckley, DEP, PE-27938, *Ohio*
N. Schwarz, DEP, PE-1278, *Vt.*
T. E. Nash, ETD, PE-6951-E, *Pa.*
R. S. Fow, BCP, PE-4391-E, *Pa.*
E. de Haas, DEP, PE-10803, *N. J.;* PE, *Ontario, Ca.*
H. N. Livingston, DEP, EE-1505-E, *Pa.*
H. Natalis, ETD, PE-9669, *N. J.*
J. R. Sarver, DEP, PE-2821, *Ga.*
R. B. Resek, DEP, PE-18180, *Ohio*
C. C. Osgood, DEP, PE-09279, *N. J.*
H. A. Taylor, RCAC, PE-26872, *N. Y.*
J. S. Furnstahl, DEP, PE-11029, *N. J.*
R. A. Alleman, ETD, PE-2750-E, *Pa.*
S. L. Abbott, DEP, PE-10084, *Pa.*
R. S. Shultz, DEP, PE-2060, *Wash., D. C.*
S. V. Zinn, Jr., DEP, PE-7876-E, *Pa.*
H. W. Abrams, DEP, PE-2538-E, *Pa.*
J. Stumpf, DEP, PE-21677, *Ohio*
R. B. Ayer, ETD, PE-11731, *Pa.*
J. F. Bohn, DEP, PE-1599, *Maine*
E. O. Deaver, DEP, PE-9870, *Pa.*
Y. H. Dong, DEP, PE-24180, *N. Y.;* PE-7192, *N. J.*
A. J. Eliopoulos, DEP, PE-23709, *Ohio*
H. H. Franke, DEP, PE-2777, *Conn.;* PE-34559, *N. Y.*
A. R. Freedman, DEP, PE-2814E, *Pa.*
J. Gorman, DEP, PE-8825, *N. J.*
S. I. Harris, DEP, PE-2611, *Del.;* PE-4691, *Ala.*
M. B. Herscher, DEP, PE-1539E, *Pa.*
M. M. Ruffman, DEP, PE-5904, *Ind.*
J. C. Kohr, DEP, PE-2520E, *Pa.*
R. D. Moncher, DEP, PE-35248, *N. Y.*
M. McCord, DEP, PE-20813, *Ohio*
R. J. McKnight, DEP, PE-5762E, *Pa.*
J. J. O'Brien, DEP, PE-11739, *N. J.;* PE-36461, *N. Y.*
F. A. O'Grady, DEP, PE-9799, *N. J.*
J. F. Petri, DEP, PE-11793, *N. J.*
W. W. Pleasants, DEP, PE-232-01-0205800, *Wash.*
N. M. Rizzo, DEP, PE-4583E, *Pa.*
S. Stimler, PE-04864E, *Pa.*
C. C. Wright, DEP, PE-816, *Tennessee*
R. A. Risse, DEP, PE-37050, *N. Y.*

BURLINGTON AUTHORS HONORED

The paper "Navigation for Rendezvous in Space" by **A. M. Schneider, E. B. Capen, E. P. Walner, Jr.,** and **C. M. King** has been selected as the outstanding paper on the subject of navigation or space guidance published during 1961 in *Navigation*, the journal of the Institute of Navigation. The authors have been given the *Samuel M. Burka Award* of the Institute, consisting of $200.00 and a certificate, presented at the 1962 annual meeting of the Institute in San Diego, Calif. (A condensed version of this major paper appeared in the RCA Engineer, June-July 1962.)—*R. E. Glendon*

G. W. CRAWFORD OF ETD HONORED

G. Wallace Crawford, a veteran of 44 years in the electron tube industry (and RCA Engineer author of "Toughmindedness and Tomorrow," Vol. 4, No. 4) was honored recently by more than 500 business executives and RCA employees at a testimonial dinner, held just before he left for Italy to be Tube Project Manager for ATES, an electronics company owned by the Italian government. RCA is providing management for this company.

Believed to have had one of the longest careers in the electron tube manufacturing field, Mr. Crawford was Plant Manager of the Harrison facility from 1953 to 1959. He was also responsible for establishing tube manufacturing plants in several foreign countries. More recently, he served as Manager, Operations Planning for ETD.

MTP ENGINEER HONORED FOR IMPROVING RADAR TRACKING

A. E. Hoffmann-Heyden of Systems Analysis, Missile Test Project, RCA Service Co., Florida, was honored recently for his important contributions to improved radar tracking. The commendation was for his work in achieving a reduction in the time lost between target acquisition and radar "lock-on," which resulted in improved tracking of Mercury spacecraft. During the past eight years as an RCA engineer, he has been responsible for radar evaluation at the Atlantic Missile Range.

C. E. BURNETT SELECTED FOR WHO'S WHO IN AMERICA

C. E. Burnett, Division Vice President, Industrial Tube Products, ETD, Lancaster, has been named to *Who's Who in America* and will have his biographical sketch included in the next printing of that famous reference volume. The editorial board of *Who's Who*, in order to choose persons for inclusion, uses advisors and is guided by standards which have been tested by fifty years of use in selecting those persons whose achievements merit inclusion.

SLOAN FELLOWSHIP GRANTED TO MENDELSOHN, DEP-DSD

A *Sloan Fellowship* award has been granted to **R. Mendelsohn,** Leader, Data Processing Projects, DEP-DSD, Van Nuys. He will attend the Stanford Graduate School of Business from September 1962 to June 1963. Mr. Mendelsohn received the BSEE from the University of Wisconsin, and has 12 years of engineering management experience. He is currently the project leader of ground recording and display equipment for the Ranger tv system.—*D. J. Oda*

SIGNAL CORPS PRESENTS HIGHEST QUALITY AWARD TO ETD PLANT AT WOODBRIDGE, N. J.

The Army Signal Corps recently presented its highest quality award to the Woodbridge plant of ETD for "*consistent production of high quality receiving tubes over a long term period.*" Designated Riqap, the award identifies the Army Signal Corps' Reduced Inspection Quality Assurance Plan. The ETD plant at Harrison, N. J., received this same award in 1961. Participation in Riqap is by mutual agreement between the contractor and the Signal Corps. Through Riqap, both realize mutual benefits in reduced costs and improved relationships.

THERMOELECTRIC COMPONENTS FOR OUTER SPACE NUCLEAR REACTOR TO BE SUPPLIED BY ETD

The Atomics International Division of North American Aviation, Inc. award a $2 million contract earlier this year to the Electron Tube Division, Harrison, to develop and produce thermoelectric modules for what is expected to be the world's first nuclear reactor sent into outer space. The six-month contract covers the development and fabrication of thermoelectric units utilizing a new RCA-developed material that will permit, at higher temperatures, more reliable electricity generation from the heat of nuclear fuel in space environments than would be possible with other thermoelectric materials. The thermoelectric module is one of the key components for the Snap 10A project (Systems for Nuclear Auxiliary Power). Snap 10A reactors are scheduled for flight testing in 1963.

This thermoelectric work is one of the projects of the ETD New Business Development group headed by **L. R. Day. P. P. Roudakoff** is Project Manager of the thermoelectric materials and devices activities. (*See article by James and Chace,* RCA Engineer, *April-May, 1962*).

The thermoelectric engineering team includes: **R. L. Klem,** Engineering Project Manager; **N. S. Freedman,** Manager, Research and Development; **L. J. Caprarola,** Manager, Fabrication and Processing, and **P. L. Farina,** Manager, Equipment Design and Development.

Special air-conditioned laboratories have been equipped with new processing and manufacturing facilities for this critical program.

STAFF ANNOUNCEMENTS

ETD Industrial Tube Products Dept., Harrison: **D. W. Epstein,** Mgr., Conversion Tube Operations, has announced his staff as follows: **R. W. Engstrom,** Mgr., Advanced Development Engineering-Conversion Tube; **W. G. Fahnestock,** Mgr., Operations Planning and Controls-Conversion Tube; **L. W. Grove,** Mgr., Display Tube Operation; **J. K. Johnson,** Mgr., Photo Cell Operation-Mountaintop; **J. A. Molzahn,** Mgr., Quality Control-Conversion Tube Operations; **G. A. Morton,** Director, Conversion Devices Laboratory-Princeton; **M. Petrisek,** Mgr., Camera Tube Operation; **R. C. Pontz,** Mgr., Photo and Image Tube Operation; and **F. S. Veith,** Staff Engineer.

Electronic Data Processing: **A. L. Malcarney,** (Group Executive Vice President, DEP and EDP) Acting General Manager, Electronic Data Processing, announces the EDP organization as: **E. D. Foster,** Division Vice President, Plans and Programs; **J. W. Leas,** Manager, Data Communications and Custom Projects; **E. S. McCollister,** Division Vice President, Marketing; **M. W. Poppei,** Manager, Business Analysis; **J. H. Walker,** Controller, Finance; **A. K. Weber,** Division Vice President, Operations.

Also in EDP, **A. D. Beard** is appointed Chief Engineer, Engineering, reporting to **A. K. Weber,** Division Vice President, Operations. Mr. Beard had previously been Mgr. Electronic Engineering, DEP-DSD, Van Nuys. **J. W. Leas,** Mgr., Data Communications and Custom Projects, EDP, has named his staff to include: **J. K. Mulligan,** Mgr., Communications Equipment Engineering; **J. L. Owings,** Mgr., Data Communications Engineering; and **R. E. Wallace,** Mgr., Custom Projects Marketing.

DEP-ACCD, Camden and Burlington: **I. K. Kessler,** Division Vice President and General Manager, DEP-ACCD, announces the technical organization of the DEP Aerospace Communications and Controls Division as follows: **D. C. Arnold,** Mgr., Operations-Burlington; **J. P. Barkow,** Plant Mgr., Camden Defense Plant; **R. B. Barnhill,** Mgr., MTE Program; **R. E. Davis,** Mgr., TSQ-47 Program; **W. W. Kauffman,** Mgr., Product Assurance; **C. K. Law,** Mgr., Programs Management; **R. Trachtenberg,** Chief Engineer, Engineering Department-Camden; and **J. D. Woodward,** Technical Consultant. Mr. Arnold's staff includes: **J. F. O'Connell,** Mgr., Administration and Controls; **S. L. Simon,** Chief Engineer, Engineering Department-Burlington; and **T. S. Weeks,** Plant Mgr., Burlington Plant.

DEP-ACCD, Camden: **R. Trachtenberg,** Chief Engineer, DEP-ACCD Engr. Department Camden, announces his staff as: **A. H. Benner,** Mgr., Advanced Systems and Techniques; **J. S. Furnstahl,** Mgr., Design Controls and Product Assurance Engineering; **L. M. Grant,** Mgr., Technical Services; **J. T. Molieri,** Mgr., Operations Programming and Analysis; **R. B. Moses,** Mgr., Administration and Controls; **J. R. Rippere,** Staff Engineer; **H. Ruben,** Mgr., Communications Engineering; and **R. Trachtenberg,** Acting Mgr., Preliminary Design.

DEP Data Systems Division, Van Nuys, Calif.: **G. F. Breitwieser,** Chief Engineer and Projects Manager, announces the organization of the Engineering Department and Projects Management as follows: **L. Voorhees,** Administrator, Eng. Administrative Planning; **H. M. Watts,** Mgr. Systems Engineering; **W. M. McCord,** Mgr., Missile and Space Projects; **P. A. Scholz,** Mgr., Defense Projects; **R. H. Lesser,** Mgr., Development and Design Engineering; **A. P. Davies,** Mgr., Engineering Support and Services; **L. Jacobs,** Mgr., Design Support Engineering; and **D. J. Pizzicara,** Mgr., Systems Projects.

Technical Programs, DEP, EDP: **C. A. Gunther,** Division Vice President, Technical Programs, has announced his staff as: **N. I. Korman,** Director, Advanced Military Systems, and **J. N. Marshall,** Mgr., EDP Advanced Development Engineering.

DEP Astro-Electronics Division, Princeton: **S. Sternberg,** Chief Engineer, Engineering Department, announces his staff as: **N. M. Brooks,** Mgr., Engineering Administration and Product Assurance; **M. S. Cohen,** Mgr., Advanced Systems and Operations Analysis; **E. A. Goldberg,** Mgr., Spacecraft Design and Test; **E. C. Hutter,** Mgr., Physical Research; **V. D. Landon,** Mgr., Technical Advisory Staff; **J. Lehmann,** Mgr., Space Observation Systems; **W. P. Manger,** Mgr., Spacecraft Systems; and **R. B. Marsten,** Mgr., Space Communication Systems.

DEP Defense Engineering (Staff), Camden: **H. M. Elliott** has been named Staff Engineer to **W. G. Bain,** (Vice President, DEP) Acting Chief Defense Engineer, Defense Engineering. In this capacity, Mr. Elliott is responsible for technical coordination of military data processing techniques and memories.

ETD, Harrison: **L. R. Day,** Mgr., New Business Development, announces his staff as: **R. Avigdor,** Administrator, New Business Development Project; **L. P. Garner,** Administrator, New Business Research; **W. M. James,** Administrator, Advanced Product Development; **P. P. Roudakoff,** Administrator, New Business Development Project; and **H. F. Scott,** Administrator, New Business Development Project. *(For general information on this activity, see article by James and Chace in* RCA ENGINEER, *April-May 1962)*

ETD Entertainment Tube Products Dep., Harrison: **J. Cimorelli,** Mgr., Engineering, announces the organization of Engineering as follows: **K. G. Bucklin,** Administrator, Tubes and Semiconductor Liaison; **J. J. Carrona,** Mgr., Chemical and Physical Laboratory; **G. Wolf,** Mgr., Engineering Methods and Standards; **P. L. Farina,** Mgr., Engineering Administration; **N. S. Freedman,** Mgr., Superconductor Materials and Devices Laboratory; **E. C. Hughes, Jr.,** Administrator, Technical Committee Liaison; **R. L. Klem,** Mgr., New Products Engineering; **W. H. Warren,** Mgr., Receiving Tube Development, and **R. A. Wissolik,** Mgr., Commercial Engineering.

RCA Victor Home Instruments Div., Indianapolis: **E. I. Anderson,** Chief Engineer, Engineering Department, announces his staff as follows: **K. A. Chittick,** Mgr., Engineering Administration; **D. H. Cunningham,** Mgr., Electro-Magnetic Product Engineering; **C. W. Hoyt,** Staff Engineer; **L. R. Kirkwood,** Mgr., Product Engineering—TV; **L. M. Krugman,** Mgr., Product Engineering—R/V, and **W. Y. Pan,** Mgr., Advanced Development Engineering, Princeton.

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34 ENGINEERS EARN MS IN RCA GRADUATE STUDY PROGRAM

The engineers listed below have been awarded Masters Degrees through their participation in the RCA Graduate Study Program. In addition to their formal degree, all are honored at a special RCA dinner, and by presentation of a distinctive certificate. For a description of this program, which is sponsored by the operating Divisions and administered by the College Relations Activity, RCA Staff, Camden, see Vol. 5, No. 5, RCA ENGINEER *The Engineer and the Corporation: RCA Graduate Study Program.*

W. Allen, DEP, Camden	MSEE,	University of Pennsylvania
V. Andreone, EDP, Pensauken	MSEE,	University of Pennsylvania
J. Assour, RCA Labs., Princeton	MSEE,	Polytechnic Inst. of Brooklyn
T. Bullock, DEP, Moorestown	MSEE,	University of Pennsylvania
R. Burack, DEP, Moorestown	MSME,	University of Pennsylvania
G. Chamberlin, EDP, Pennsauken	MSEE,	University of Pennsylvania
R. Cohen, RCA Labs., Princeton	MS/Physics,	Rutgers, State University
J. Daniel, DEP, Camden	MSEE,	University of Pennsylvania
J. Fort, DSD, Van Nuys, Calif.	MS/Physics,	Univ. California at Los Angeles
G. Frippel, DEP, Princeton	MSEE,	Rutgers, State University
H. Gnuse, DSD, Van, Nuys, Calif.	MSEE,	Univ. California at Los Angeles
S. Gotkis, DEP, Moorestown	MSEE,	University of Pennsylvania
C. Greenman, DEP, Camden	MSEE,	University of Pennsylvania
S. Gygi, DEP, Camden	MSEE,	University of Pennsylvania
R. Hansen, DEP, Camden	MSME,	University of Pennsylvania
A. Haraburda, DEP, Moorestown	MS/Physics,	University of Pennsylvania
C. Kurys, DEP, Moorestown	MSEE,	University of Pennsylvania
W. Lile, EDP, Pennsauken	MSEE,	University of Pennsylvania
J. McEvoy, DEP, Camden	MS/Physics,	University of Pennsylvania
W. Mehuron, DEP-Moorestown	MSEE,	University of Pennsylvania
L. Miamidian, DEP, Camden	MSEE,	University of Pennsylvania
K. Morris, DEP, Camden	MSEE,	University of Pennsylvania
D. Murray, EDP, Pennsauken	MSEE,	University of Pennsylvania
J. O'Hara, DEP, Camden	MSEE,	University of Pennsylvania
T. Olson, DEP, Camden	MSEE,	University of Pennsylvania
P. Palosky, DEP, Moorestown	MSEE,	University of Pennsylvania
A. Rauchwerk, DEP, Moorestown	MSEE,	University of Pennsylvania
P. Riedinger, DEP, Moorestown	MS/Physics,	University of Pennsylvania
S. Ruben, DEP, Camden	MSEE,	University of Pennsylvania
D. Snider, DEP, Camden	MSEE,	University of Pennsylvania
A. Smith, DEP, Moorestown	MSEE,	University of Pennsylvania
W. Summers, DEP, Camden	MSEE,	University of Pennsylvania
H. Weinstein, RCA Labs., Princeton	MSEE,	Polytechnic Inst. Brooklyn
D. Wing, DEP, Moorestown	MS/Physics,	University of Pennsylvania

...PROMOTIONS...

to Engineering Leader and Manager

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

Surface Communications Division, DEP

J. B. Potts: from engr. to *Ldr., Engineering Systems Projects* (J. R. Holshouser; Camden)

R. D. Houck: from engr. to *Ldr., Engineering Systems Projects* (D. R. Marsh, Camden)

J. D. Bradley: from member tech. staff to *Ldr., D&D Engrs.* (P. J. Riley; Reliability Design and Analysis)

D. E. Jack: from engr. to *Ldr., D&D Engrs.* (M. Howell, Mgr., Military Data Link Engineering, Camden)

Major Systems Division, DEP

W. A. Schreiner: from engr. to *Mgr., Relay System Integration and Test* (R. M. Wilmotte, Princeton)

J. M. Osborne: from Sloan Fellowship to *Mgr., Minuteman Program* (J. H. Sidebottom, V.P. and Gen. Mgr., Moorestown)

P. Gyllenhaal: from engr. to *Ldr. Systems Engrg.* (R. J. Renfrow, Moorestown)

Astro-Electronics Division, DEP

F. S. Sakate: from engr. to *Ldr., Engrs.* (R. B. Marsten, Princeton)

J. Baumunk: from engr. to *Ldr., Engrs.* (R. B. Marsten, Princeton)

C. T. Cole: from engr. to *Mgr., Program 35* (R. E. Hogan, Princeton)

Defense Engineering, DEP (Staff)

M. J. Kozak: from engr. to *Ldr., D&D Engrg.* (A. J. Schwartz, Camden)

Aerospace Communications and Controls Division, DEP

C. H. Hart: from engr. to *Ldr., Tech. Staff* (H. H. Knubbe, Burlington)

E. E. Corey: from engr. to *Ldr., Tech. Staff* (E. B. Galton, Burlington)

A. Lubin: from engr. to *Ldr., Tech. Staff* (E. B. Galton, Burlington)

S. S. Kolodkin: from Ldr., Tech. Staff to *Mgr., Guidance Equipment* (W. M. Pease, Burlington)

T. P. Speas: from Ldr., D&D Engrs. to *Mgr., Engrg. Product Assurance Projects* (J. S. Furnstahl, Mgr., Design Controls and Product Assurance Engrg., Camden)

Data Systems Division, DEP

D. Halpern: from Publ. Engr. to *Mgr. Pub. Services* (A. Davies, Van Nuys)

M. Siskel: from Mgr. Electronic D&D Engineering to *Mgr., Electronic Engineering* (R. H. Lesser, Mgr. High Frequency D&D, Van Nuys)

Broadcast and Communications Products Division

J. J. Clarke: from engr. to *Leader, D&D Engrs.* (N. L. Hobson, Broadcast and TV Studio Equipment, Camden)

D. M. Taylor: from engr. to *Ldr., D&D Engrs.* (N. L. Hobson, Broadcast and TV Studio Equipment, Camden)

Semiconductor & Materials Division

W. N. Lewis: from engr. to *Ldr., Manufacturing Engineering* (H. Goshgarian, Somerville)

N. M. Goun: from engr. to *Ldr., Manufacturing Engineering* (H. Goshgarian, Somerville)

RCA Service Company

R. E. Shannon: from Ldr., Senior Engrs., to *Mgr., System Integr. and Inf. Handling* (R. G. Tracy, BMEWS—Site III, England)

J. M. Soich: from Sr. Engr. to *Ldr., Engrs.* (J. T. Shields, BMEWS—Home Office)

J. M. Davis: from engr. to *Ldr., Engrs.* (W. M. Stobbe, BMEWS—Site I Thule, Greenland)

D. L. Lyndon: from Ldr., Engrs. to *Mgr., Checkout and Monitoring* (J. D. Callaghan, BMEWS—Home Office)

R. Y. MacQuade: from BMEWS Application Engr. to *Ldr., Engrs.* (H. Sanders, BMEWS—Home Office)

R. H. Flamm: from Ldr., Range Station Electronics to *Engineering Coord.* (J. P. Sharkey, Missile Test Project, Space Instru. Systems, Florida)

GUNTHER AND MILLER APPOINTED DIVISION VICE PRESIDENTS

Appointment of **Clarence A. Gunther** as Division Vice President, Technical Programs, and **N. Richard Miller** as Division Vice President, Business Planning, Radio Corporation of America, was announced today by **Arthur L. Malcarney,** Group Executive Vice President. Both executives will report directly to Mr. Malcarney, who is responsible for defense and electronic data processing operations.

Mr. Gunther (formerly Chief Defense Engineer, Defense Electronic Products) will coordinate the engineering and technical activities of DEP and EDP. Mr. Miller (who joined RCA in 1957 as a Director on the Corporation's Product Planning Staff) will assist Mr. Malcarney in business and product planning for the Corporation's data processing and related defense activities.

SURFCOM—TUCSON EXPANDS

The DEP Surface Communications Division Systems Lab in Tucson, Arizona is expanding its facilities by 6000 sq. ft. to take care of long-term firm work load. Construction is expected to take approximately 10 weeks.

—*J. F. Gibbings*

DEGREES GRANTED

In addition to the Graduate Study Program degrees listed on the opposite page, the following RCA engineers and scientists received degrees in recent graduating ceremonies:

D. M. Y. Chang, DEP-MSR, Moorestown	MSEE	Villanova Univ.
M. Boltan, DEP-MSR, Moorestown	BSEE	Drexel Institute of Technology
F. L. Walker, DEP-MSR, Moorestown	BSEE	LaSalle Univ.
L. R. Andros, DEP-MSR, Moorestown	MSEE	Drexel Institute of Technology
G. E. DeLong, DEP-MSR, Moorestown	MSEE	Drexel Institute of Technology
J. P. Dougherty, DEP-MSR, Moorestown	MSEE	University of Pennsylvania
J. F. Fleming, DEP-MSR, Moorestown	BSEE	Drexel Institute of Technology
B. Peskin, DEP-MSR, Moorestown	BS, Physics	Temple University
P. T. Scully, DEP-MSR, Moorestown	BSEE	Drexel Institute of Technology
J. Stepchew, DEP-MSR, Moorestown	MSEE	Drexel Institute of Technology
D. Loev, DEP-MSR, Moorestown	MSEE	University of Pennsylvania
R. W. Ottinger, DEP-MSR, Moorestown	MSEE	Drexel Institute of Technology
W. A. Dischert, DEP-MSR, Moorestown	BSME	Drexel Institute of Technology
E. H. Locklin, DEP-MSR, Moorestown	MSEE	Drexel Institute of Technology
G. Rullo, DEP-MSR, Moorestown	MSME	Villanova University
M. E. Sisle, DEP-MSR, Moorestown	MSEE	Drexel Institute of Technology
F. Wezner, DEP-MSR, Moorestown	MBA	Drexel Institute of Technology
J. J. Wonderlich, DEP-MSR, Moorestown	MSEE	University of Pennsylvania
E. R. Adams, DEP-MSR, Moorestown	BSEE	Drexel Institute of Technology
R. A. Bennett, DEP-MSR, Moorestown	BSME	Drexel Institute of Technology
G. J. Goldberg, DEP-MSR, Moorestown	BSME	Drexel Institute of Technology
A. J. Leone, DEP-MSR, Moorestown	BSME	Drexel Institute of Technology
R. E. Matchett, DEP-MSR, Moorestown	BSEE	Drexel Institute of Technology
L. L. Steele, DEP-MSR, Moorestown	BS, Electronic Phys.	LaSalle University
V. A. Gerardi, DEP-MSR, Moorestown	MSEE	Villanova University
A. Golden, DEP-MSR, Moorestown	MSEE	Drexel Institute of Technology
B. H. Mosher, DEP-MSR, Moorestown	MSEE	Drexel Institute of Technology
R. A. Peterson, DEP-MSR, Moorestown	MSEE	Drexel Institute of Technology
J. J. Ratkevic, DEP-MSR, Moorestown	MSEE	Drexel Institute of Technology
R. D. Rippey, DEP-MSR, Moorestown	MSEE	Drexel Institute of Technology
M. C. Timken, DEP-MSR, Moorestown	MSEE	Drexel Institute of Technology
A. Marshall, DEP-MSR, Moorestown	MA, Physics	Brown University
G. H. Heilmeier, RCA Labs., Princeton	Ph.D., Engrg. Phys.	Princeton University
J. C. Miller, RCA Labs., Princeton	Ph.D., E. Engrg.	Yale University
R. O. Winder, RCA Labs., Princeton	Ph.D., Math.	Princeton University
J. F. Allison, RCA Labs., Princeton	MSE	Princeton University
J. Burns, RCA Labs., Princeton	MSE	Princeton University
L. S. Cosentino, RCA Labs., Princeton	MSE	Princeton University
J. A. Goodman, RCA Labs., Princeton	MSEE	Columbia University
F. P. Heiman, RCA Labs., Princeton	MSE	Princeton University
J. P. Robinson, RCA Labs., Princeton	MSE	Princeton University
D. A. Walters, RCA Labs., Princeton	MSE	Princeton University
W. E. Arrowood, DEP-Appl. Res., Camden	MSEE	University of Pennsylvania
B. Shelpuk, DEP-Appl. Res., Camden	MSEE	Drexel Institute of Technology
J. Breckman, DEP-MSD, Moorestown	MSEE	University of Pennsylvania
J. C. Bry, DEP-MSD, Moorestown	MSSE & OR	University of Pennsylvania
A. D. Korbin, DEP-MSD, Moorestown	MSEE	University of Pennsylvania
S. Yates, DEP-MSD, Moorestown	MS	University of Pennsylvania
H. L. Saks, DEP-MSD, Moorestown	MSEE	Polytechnic Institute of Brooklyn
J. G. Ottos, ETD, Lancaster	MS, Physics	Franklin & Marshall College
A. M. Krause, DEP-Surf Com, N. Y.	MEE	New York University

DEP GETS $35.5 MILLION CONTRACT FOR MINUTEMAN ELECTRONIC COMMAND EQUIPMENT

The Boeing Company has awarded a $35.5 million contract to DEP for the manufacture of the electronic command network equipment for the first wing of MINUTEMAN ICBM's. The equipment includes electronic monitoring and launch-control systems to be operated from remote control-centers. Messages to and from the missile are sent in code via buried cables; part of the coding and decoding equipment for the systems also will be constructed by RCA. The system is self-monitoring, and gives warning signals if any malfunction or tampering occurs. *(See* **Kishi, Cohen** *and* **Rosenthal,** *this issue, for a discussion of "Self-Verification.")* Under a separate contract, RCA is manufacturing a voice communication network for the same system.

DR. A. N. GOLDSMITH ELECTED HONORARY VICE PRESIDENT

The RCA Board of Directors has elected noted scientist, engineer, and inventor, **Dr. Alfred N. Goldsmith,** an Honorary Vice President. Dr. Goldsmith is the second person in the history of RCA to be elevated to his position, the first being **Dr. Vladimir K. Zworykin.**

Dr. Goldsmith, who has made many inventions in the fields of radio, motion pictures, and television, was Director of Research and later Vice President of RCA from 1919 to 1933. He has since served as Senior Technical Consultant to RCA. Dr. Goldsmith, at the age of 31, joined RCA as Director of Research in 1919. In 1920, his work made possible the first commercial radio with only two control knobs and a built-in speaker. He also made vital contributions to the development of the first color-television tube to find commercial use. Dr. Goldsmith, who is the author of several books, is a Co-founder, Fellow, and Life Member of the IRE. In addition Dr. Goldsmith, has held office and/or been active in every other major professional society concerned with electronics. He holds the high grade of *Fellow* in many of these, and is an *Eminent Member* of Eta Kappa Nu.

NEW DETROIT FACILITIES FOR THE BCP INDUSTRIAL AND AUTOMATION DEPARTMENT

Suburban Plymouth Township, near Detroit, Mich., is the location of a new structure of 40,000 square feet to house the Industrial and Automation Products Department of the Broadcast and Communications Products Division. This Department produces electronic systems used in automatic inspection, gaging, and other industrial operations.

Scheduled for completion by early fall 1962, the expansion program was dictated by a higher level of RCA participation in the inspection and gaging systems market and by the future sales potential for such equipment, particularly in the automotive and metal-working industries. **N. R. Amberg** is Manager of the Detroit facility.

ALPHONSE AND ASSOUR RECEIVE RCA LABS DOCTORAL STUDY AWARDS

Gerard A. Alphonse, Member of the Technical Staff of the Computer Research Laboratory, has been granted an *RCA Laboratories Doctoral Study Award* for the academic year 1962-1963. Mr. Alphonse will attend Brooklyn Polytechnic Institute full-time to complete his Ph.D. in E.E.

Jacques M. Assour, Member of the Technical Staff of the Electronic Research Laboratory, has received an *RCA Laboratories Doctoral Study Award* for the 1962-63 academic year to complete, full-time, requirements for his Ph.D. in Electro-Physics at the Brooklyn Polytechnic Institute.

DATA PROCESSING SEMINAR AT BETHESDA

The Data Systems Center hosted an RCA Seminar in *EDP Concepts* for four afternoons recently. Instructors from the RCA Education Section of Government Marketing Services in Washington lectured to a large group of Center personnel on the philosophies of EDP and other aspects of the computer program at RCA. Also, nearly fifty personnel from the Data Systems Center and the Washington and Southern Regional Marketing Office attended the "A.R.&D. Road Show" recently. Attendees from DSC represented the ACSI-MATIC and 466L Programs, marketing, and various study groups of the Center.—*J. Carter*

J. B. Coleman, Broadcast Pioneer

The passing of **John B. Coleman** on July 12, 1962 brings closer the end of an era whose scientists fathered present-day radio broadcasting. Those of us who were part of this period in the early 1920's still marvel at each new development which has improved the art of transmission. It was men like **Coleman, Dr. Frank Conrad, H. P. Davis** and many others who pioneered the art of broadcast transmission. Originally, the equipment for transmitting was built in the engineering department of Westinghouse and installed in Dr. Conrad's garage. It was here that Coleman transmitted music from Victrola Records and later was sponsored by a department store in Pittsburgh. This installation was the forerunner of Station *KDKA*, whose call letters still symbolize today the early beginnings of a tremendous industry.—*J. C. Stangert*

Broadcast stations in the formative years were crude by present standards.

John B. Coleman inspecting a transmitter in Camden, ca. 1936.

D. R. Crosby

G. Lieberman

THREE NEW ED-REPS: CROSBY IN EDP, LIEBERMAN AND MORSELL IN DEP-ACCD.

David R. Crosby has been named RCA ENGINEER Editorial Representative for Advanced Development Engineering, Electronic Data Processing, Pennsauken, N. J., replacing **John Sweer.**

In the DEP Aerospace Communications and Controls Division, **Gil Liebermann** has replaced **Joe Connors** as Editorial Representative for Systems Engineering, Camden, and **W. M. Morsell** has replaced **Dick Crawford** as Ed Rep for D&D engineering, Camden. Both Lieberman and Morsell will serve on Frank Whitmore's DEP Editorial Board.

David R. Crosby received his EE degree from Rensselaer Polytechnic Institute in 1934 and his MS from Harvard University in 1935. From 1935 to 1941 he was employed by IT&T. He joined RCA in Camden in 1941, and since has worked on high-power transmitters, RF transmission lines, antennas, microwave filters, and modulation theory. Since 1958 he has been associated with a group in EDP Advanced Development Engineering developing high speed computer technology, and is now a group Leader with responsibility for developing fabrication techniques for nanosecond computers. He is a Registered Professional Engineer, a Member of the AIEE, the IRE, and the Mathematical Association of America. He has been active in committee work, and was program chairman for one of the national conventions. For six years he was a member of the evening faculty of Rutgers University. In addition to authoring several conference papers and U. S. patents, he has published five papers in the Proc. IRE, and other papers in AIEE journals and the RCA Review.

G. Lieberman received a BA in Mathematics at New York University in 1948, and an MA in Mathematical Statistics at Columbia University in 1949. Since then, he has done graduate work in Mathematics and Electrical Engineering at University of Maryland, American University, and the University of Pennsylvania. From 1950 to 1955, he was with the U. S. Naval Research Laboratory, where he worked on sonar, acoustic signal analysis, and on aural and visual pattern recognition. From 1955 to 1959, he was with the U. S. Naval Ordnance Laboratory, where he also worked on navigation and guidance systems. During this period, he taught courses in Probability and Statistics at the University of Maryland. He joined RCA in March 1959 in the DEP Airborne Systems Division's Communications Systems Group. In January, 1962, he was promoted to his present position of Staff Scientist for the DEP-ACCD Advanced Systems and Techniques Group. His work has involved analysis of digital communication systems, performance evaluation of a spread spectrum system in a fading medium, effects of hard limiting on spread spectrum signals, and research on adaptive communication techniques. Mr. Lieberman is a Member of the IRE, the Institute of Mathematical Association of America.

Because of the volume of degrees and other special news to include in this issue, the regular column *Professional Activities* was postponed to the next issue, where we will "catch up" on all previously submitted items—*The Editors.*

Editorial Representatives

The Editorial Representative in your group is the one you should contact in scheduling technical papers and announcements of your professional activities.

DEFENSE ELECTRONIC PRODUCTS

F. D. Whitmore *Chairman, Editorial Board, Camden, N. J.*

Editorial Representatives

J. B. Rippere *Aerospace Comm. & Contr. Div., Camden, N. J.*

W. M. Morsell *Design-Devel. Eng., Aerospace Comm. & Contr. Div., Camden, N. J.*

D. B. Dobson *Systems Support Eng., Aerospace Comm. & Contr. Div., Burlington, Mass. and Camden, N. J.*

G. Lieberman *Systems Eng., Aerospace Comm. & Contr. Div., Camden, N. J.*

R. Glendon *Aerospace Comm. & Contr. Div., Burlington, Mass.*

I. N. Brown *Major Systems Div., Moorestown, N. J.*

T. G. Greene *Missile & Surf. Radar Div., Moorestown, N. J.*

D. J. Oda *Data Systems Div., Van Nuys, Calif.*

H. J. Carter *Data Systems Center, Data Systems Div., Bethesda, Md.*

C. W. Fields *Surf. Comm. Div., Camden, N. J.*

M. P. Rosenthal *Surf. Comm. Div., New York, N. Y.*

J. F. Gibbings *Surf. Comm. Div., Tucson, Ariz.*

P. J. Riley *Surf. Comm. Div., Cambridge, Ohio*

L. A. Thomas *Astro-Elec. Div., Princeton, N. J.*

M. G. Pietz *Applied Research, Def. Eng., Camden, N. J.*

R. P. Dunphy *Central Eng., Def. Eng., Camden, N. J.*

BROADCAST AND COMMUNICATIONS PRODUCTS DIVISION

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