Fifth Anniversary

HERE IS ANOTHER anniversary issue of the RCA ENGINEER! But this time, it is the *fifth* anniversary, marking for Bill Hadlock, as Editor, five years of planning and editing, weighing and selecting material, solving printing problems and developing imaginative colorful cover subjects, waiting for guest editorial writers to meet their deadlines. Five years of providing a better magazine each year in the face of rising costs. Five years of leadership of the Editorial Representatives and Engineering Editors who have responded enthusiastically to the task at hand—providing a professional journal to the professional engineers in the Radio Corporation of America.

Bill Hadlock and the editorial staff can look with paternal pride at their five bound volumes of the RCA ENGINEER and see five jewels on the stretched forefinger of time, sparkling forever. But they can't look long, for there is another issue coming up!

George H Brown

Dr. George H. Bro
Vice President, Engineeri
Radio Corporation of Ameri

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Editor's Note: This article is a logical follow-up to "Preparation, Approval, and Publication of Technical Papers" by R. F. Guy, which appeared in this series in Vol. 5, No. 6. It begins where most how-to-write articles end—it shows how to improve a manuscript **after** it is written. Miss McElwee presented this at the 1960 IRE National Convention in New York, where it was exceptionally well received. Because Miss McElwee—as both an engineer and an editor—has wide experience in handling professional engineering writing, the thoughts herein comprise a do-it-yourself approach of particular value to RCA ENGINEER readers in perfecting their writing efforts.

The Engineer
and the
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HOW TO EDIT YOUR OWN WRITING

by **ELEANOR M. McELWEE**

Commercial Engineering, Electron Tube Division, Harrison, N.J.

ENGINEERS HAVE a responsibility to communicate the specialized knowledge they develop in their own particular field to people working in other fields, and to do so in language that can be readily understood. Although the original writing technique is important, the difference between a good and a not-so-good paper, report, or proposal often lies in the amount of effort you are willing to expend on your material *after* you finish writing it. The first draft of a manuscript is like a sculptor's roughly blocked-out statue—it needs more work. Careful *editing* removes the excess material, smoothes out the rough spots, and clearly defines the author's intended message. Therefore, the fuction of editing is simply to make sure that the original purpose of the writing is accomplished.

Three considerations are involved in editing: the information to be transmitted, the vehicle of transmission, and the intended receiver. Of these, the last must be considered first because of its influence on the other two.

CONSIDERATION OF THE READER

Consideration of the intended reader is essential in editing because it determines both the extent of the information and the manner in which it should be presented. You certainly wouldn't describe your work in the same way to your wife as to your fellow engineers. Similarly, a report for management, an article for a professional journal, an instruction manual, or a contract proposal must each be tailored to its particular readers.

The first step in editing a manuscript, then, is to consider the probable reader: his interests, his needs, his familiarity with the subject, his language limitations.

For example, consider a new device like the thyristor. Readers of a professional journal like the *Proceedings of IRE* are interested primarily in its design principles, the adaptation of known theory to a new configuration, and the development of new materials or techniques which make it possible. Readers of commercial magazines like *Electronics* or *Electronic Design*, however, are more likely to be interested in its characteristics, its potential application to various types of circuits, and its advantages over other devices. Management people, on the other hand, are less interested in a detailed description of the device and more in its possible effect on the over-all commercial market.

You should, of course, consider your intended reader *before* you start writing; however, there is a tendency, while writing, to become completely absorbed in the message itself and to lose sight of the ultimate receiver. Before starting your editing, therefore, you should make a renewed effort to identify yourself with the reader—to read the manuscript *from his viewpoint.*

EDITING FOR CONTENT

Keeping in mind the reader's needs, then, you can edit your material, proceeding from an over-all view down to the fine details. The first questions you ask are: *What* does it say? Is this what it *should* say? Does it say *all* that it should, and nothing else?

A useful technique for evaluating content is a detailed outline prepared beforehand. Or, perhaps you have used headings and subheadings liberally throughout the manuscript and can use them as a general outline of content.

If you have used neither of these techniques, you can prepare an outline from a finished draft in any of the following three ways:

paragraph outline—from lead sentences of individual paragraphs, if the manuscript is short;

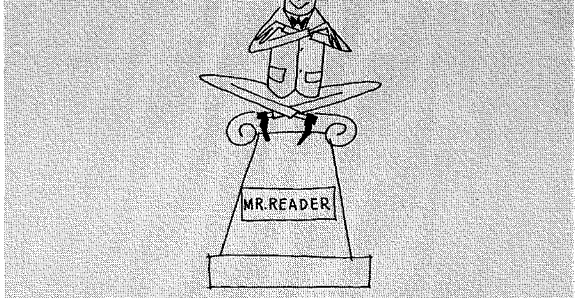
sentence outline—using the complete topic sentences for major and minor subdivisions of the manuscript, rather than from individual paragraphs, if the manuscript is longer;

topical outline—made up of series of phrases that describe the material covered; similar to the sentence outline, but easier to use for more complex manuscripts.

Using the outline, you can then quickly answer the three questions, reworking the text, or even the outline itself and then the text, until you are certain the manuscript says exactly what you originally intended and no more.

EDITING FOR ORGANIZATION

The next step in editing the manuscript is to evaluate its organization. Again, you ask a series of questions: Does the material *orient the reader* properly? Does it *follow logically* from start to finish? Does it lead the reader *smoothly* from one subject to another? Does it *neatly tie* everything up for him at the end? The outline is also useful in this step.



. . . consider your reader

Every manuscript, short or long, includes these three basic parts: *introduction, body,* and *conclusion.* In editing, you should review each part to determine whether it fulfills its particular function.

Introduction

The introduction captures the reader's interest and sets the stage. Building on *his previous knowledge,* it gives a general view of the field to be covered and defines the scope and limitations of the particular discussion. It can relate the new material to existing knowledge in the field and may summarize the important points you intend to make.

Body

Because the body comprises the detailed bulk of the text, you should be especially careful to check its organization and content. For maximum effectiveness, each manuscript should follow a consistent approach suited to its subject matter and purpose.

In general, four distinct approaches are available:

narrative—for information having chronological sequence (progress reports, historical surveys);

descriptive—proceeds from general description to an analysis of details (suited to presentations of new equipment proposals, and promotional material);

interpretive—gives new information first, then relates it to existing knowledge, and finally reasons out causes and effects (new scientific data and theories);

argumentative—well-suited for comparing various methods and recommending one; defines problem, determines governing factors, presents pertinent data, makes comparisons, and then draws conclusions and recommendations (typical of technical reports).

Such approaches can, of course, be combined to some extent. The over-all organization, however, should follow the general approach best suited to the basic purpose of the manuscript.

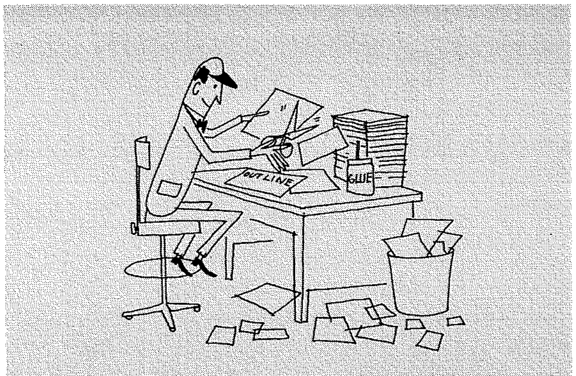
You should also make sure the body contains all of the necessary facts to tell your whole story. On the other hand, cull out all the unnecessary material—details which add no substance, irrelevant remarks, and side issues which detract from the main message. The manuscript must be complete, but also concise and direct to convey your information as clearly and briefly as possible.

Conclusion

This section wraps up the story for your reader. It briefly sums up major conclusions and relates them to previously existing knowledge. You can also make any pertinent recommendations concerning future courses of action or further avenues of investigation. Avoid merely restating theories, data, or conclusions which you have already covered in the body of the text. To be useful to the reader, the "finish" of a manuscript must interpret the text for him and leave him with a sense of completeness.

Use of Subheadings

You can also help the reader to follow the thought sequence of your paper by using headings and subheadings liberally throughout the manuscript to indicate the major and minor subdivisions. These headings are similar to the phrases used in a topical outline and map out the general content and organization.



. . . edit over-all organization and content

EDITING THE PARAGRAPH

After reviewing the over-all content and organization, you should consider the makeup of the individual paragraphs — their length, unity, substance, and development.

A good paragraph is neither too short for adequate development of its subject nor so long as to tire the reader. A good average length is between 75 and 200 words, depending on the content. The best rule is to develop the subject completely, but concisely.

The idea content of each paragraph is limited to one specific subject, clearly indicated in the lead sentence. The subject is developed logically in succeeding sentences, usually according to the same type of over-all approach selected for the whole paper, each sentence adding some new detail or facet.

In editing paragraphs, you should also review the transition from one sentence to the next, and from one paragraph to another. The reader can follow the idea content of your paper much more easily if he understands the relationship between the succeeding thoughts. You can easily point up this relationship by inserting transitional words or phrases at the beginning of your sentences and paragraphs.

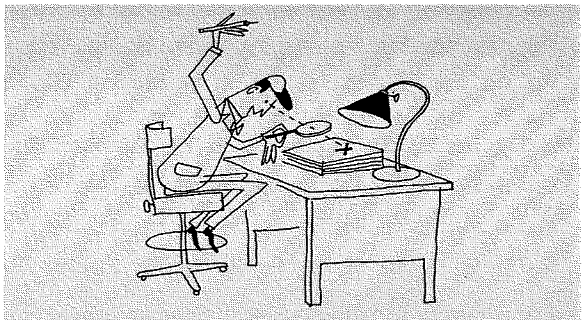
EDITING THE SENTENCE

In editing sentences, you should look for six essential characteristics: *completeness, organization, punctuation, objectivity, economy,* and *restraint.* The first three are necessary in all sentences, regardless of the type of writing involved. The others, however, are special requirements for manuscripts which deal with technical information.

Completeness means that each sentence must contain one complete thought—not just part of a thought, and not more than one thought. It may, of course, also contain modifying or qualifying words, phrases, or clauses providing they pertain to the main thought.

The *organization* of the sentence shows the relative importance of the constituent parts of its one main thought. If the thought contains two equally important parts, for example, the sentence structure must show the two parts as coordinate elements; however, if the thought contains one predominating part and one or more subordinate parts, the structure should show the degree of subordination.

The *punctuation* marks used in a sentence, like all the other organization techniques used by writers, are intended solely to help the reader understand your message. In written material they must take the place of the pauses and changes of inflection which a speaker may use to show variations of meaning. Too much punctuation is as bad as too little, however, because it may interfere with the reader's train of thought. The best practice is to punctuate only for a sound reason. Common faults and rules in this area will be discussed later.



. . . edit paragraphs and sentences for details

The characteristics of *objectivity*, *economy*, and *restraint* are special requirements in engineering writing because such writing must convey complex information as clearly and directly as possible. The use of the third-person (or *objective*) form is desirable in engineering writing because the emphasis must be placed on the facts being communicated, not on the personality or opinions of the writer. *Don't say* "We find that . . ." (first person); *do say* "It was found that . . ." or "The tests showed . . ." This emphasis on facts is maintained by an *economy* of writing which tells your story clearly and directly and avoids digressions from the central theme, and by a sense of *restraint* which avoids superlatives, broad sweeping statements, exaggerations, and personal opinions.

Besides looking for these six characteristics, you should also review the grammatical correctness of your individual sentences for practical and logical usage that will communicate your information undistorted.

To use language effectively, you must, of course, be familiar with the eight principal parts of speech and the rules which govern their usage. Fig. 1 contains a list of "don'ts" which should help you to avoid most grammatical errors and distortions of meaning.

There are many excellent reference texts on English grammar and usage. The following three are recommended for the serious engineer-writer:

G. O. Curme, *English Grammar*, Barnes and Noble, Inc., N. Y.

N. Foerster and J. M. Steadman, Jr., *Writing and Thinking*, Houghton Mifflin Co., N. Y.

C. G. Gaum, H. F. Graves, and L. S. S. Hoffman, *Report Writing*, Prentice-Hall, Inc., N. Y.

Punctuation

As mentioned earlier, you should also review the punctuation in your sentences from the standpoint of making the meaning clearer to the reader. A summary of the most important rules of punctuation is given in Fig. 2; two common violations will be discussed here.

One of the most common mistakes in punctuation is the "comma fault," i.e., the use of interfering commas between directly related sentence elements. The subject of a sentence or clause should not be separated from its verb by a comma, nor the verb from the object. Neither should restrictive elements be set off from the sentence by commas. The following examples illustrate the difference in meaning which can be introduced by the improper use of commas:

Right: Tubes which are obsolete should not be used in new equipment.

Wrong: Tubes, which are obsolete, should not be used in new equipment.

Right: Flu shots cannot be given to people who are allergic to eggs.

Wrong: Flu shots cannot be given to people, who are allergic to eggs.

Another common mistake is the omission of hyphens in compound modifiers, i.e., when two or more related

Fig. 1—Some "Don'ts" covering common grammatical errors to watch for in editing.

Don't use the nominative case of a pronoun as the object of a verb or preposition:
He is the engineer *whom* (not *who*) we talked about.

Don't use the objective case of a pronoun after *than* or *as* in clauses of comparison:
You can be as good a writer as *he* (not *him*).

Don't use the objective case of a pronoun as a predicate complement:
If you were *I* (not *me*), what would you do?

Don't use the nominative case of a pronoun as the subject or the predicate complement of an infinitive:
People often expect *her* to be *me* (not *I*).

Don't use the possessive case to name the object of an action; use an *of* phrase instead:
The *design of the equipment* (not *equipment's design*) was complex.

Don't use the nominative case of a noun or pronoun to show the subject of a gerund; use the possessive:
I object to the *lady's* (not *lady*) wearing pearls.

Don't confuse the subjunctive and indicative moods of verbs; use the subjunctive to indicate 1) a wish, 2) a supposition or very doubtful condition, and 3) a condition contrary to fact:
An engineer might change his ideas if he *were* (not *was*) a manager.

Don't use *after* with past participles:
Having made (not *after having made*) an outline, he was ready to start writing.

Don't use an adverb in place of a predicate adjective:
He went home because he felt *miserable* (not *miserably*).

Don't use the preposition *like* to connect clauses; use *as* or *as if*:
It looks *as if* (not *like*) it might rain.

Don't use words such as *this* and *it* without reference to a definite antecedent.

Don't use dangling verbals; make sure that gerunds, infinitives, and participles are connected logically and unmistakably with the words they refer to:
Wrong: Using this procedure, the problem can be solved.
Right: An engineer using this procedure can solve the problem.

Fig. 2—A summary of important rules of punctuation.

Period
1) At end of sentence.
2) After most abbreviations.
3) Use three periods (. . .) to show omission (ellipsis).

Colon
1) To show that something is to follow: a list, a series of examples, a long quotation.
2) After the salutation of a formal letter.

Semicolon
1) Between two independent clauses not connected by a conjunction.
2) Between members of a series if one or more contain commas.

Comma
1) Between independent clauses connected by a conjunction.
2) After introductory adverbial phrases or clauses.
3) Around *non*restrictive phrases or elements.
4) Around parenthetical, interrupting, or displaced expressions.
5) After all but the last item of a series.
6) Between contrasting sentence elements.
7) To separate quotations from the rest of a sentence.
8) Whenever necessary to make the meaning of the sentence more obvious.

Quotation Marks
1) Before and after direct quotations.
2) Around the name of a magazine article.
3) To enclose technical words or words used in unusual senses.

Apostrophe
1) To show possessive case.
2) To show contraction.
3) To form plural of letters, figures, etc.

Parentheses or Brackets
1) To enclose material loosely connected with main thought.
2) To set off numerals or letters indicating items of a series.
3) Around an interpolation added to quoted material.

Hyphen
1) Between all compound adjectives.
2) Between compound nouns if meaning is made more obvious.

words are used as a single modifier for a noun or pronoun. In the expression *high-frequency tubes*, for example, a hyphen is used to show that *high* modifies *frequency*, not *tubes*. The need for correct hyphenation becomes obvious when two or more compound modifiers are strung together, as in the sentence "The equipment uses *twenty-one half-inch* bolts."

Even the correct use of all punctuation marks is not a remedy for complex and involved sentence structure. If you find that your sentences require an unusual amount of punctuation, you should rework them into a simpler and more direct form rather than merely add commas and hyphens.

Other Sentence Faults

There are two other problems of which you should be aware when you edit your sentences. One is the problem of *semantics*, or word usage. Unless the words you use mean the same thing to the reader that they do to you, you have failed to communicate your ideas. The word "frequency," for example, means different things in the fields of electronics and statistics. You should be sure that the terms you use have one clear, unmistakable meaning to your reader or you should define the particular sense in which you are using them.

The other problem is variously known as *verbosity*, *circumlocution*, or *gobbledegook*. It is the problem of using too many words to say something, of talking around in circles, or of burying your meaning in a maze of unnecessarily complex terms and structures. Just as the shortest distance between two points is a straight line, so the easiest communication between you and your reader is a direct and concise statement.

In connection with this problem, use of the active voice of verbs improves the pace of the writing, and helps avoid involved sentences. The sentence "A switch S_1 controls the relay." is shorter, more direct, and no less objective than the sentence "The relay is controlled by a switch S_1."

NON-TEXT MATERIAL

Most technical papers and reports contain much illustrative and tabular material in addition to the text. You should also edit this material.

For example, *mathematical formulas* are generally used in the text only in their final form. If derivations or explanations are desirable for some readers, they may be included in an appendix. Formulas used in the text should be introduced and connected properly, so that the reader can understand their purpose even if he does not follow the detailed mathematics.

Abbreviations and *symbols* are used sparingly in the text because of the possibility that the reader may misinterpret them. When they are necessary, different and distinctive symbols are used for different parameters to avoid confusion. In the electronics field, IRE standard symbols and abbreviations should be used wherever possible. In any case, however, all symbols are defined the first time they are used. Units of measurement are given whenever they affect the validity of the relationships.

Tabular material should be simplified as much as possible so that it will help your reader rather than confuse him. Data can usually be organized so that all necessary identifying symbols and units of measurement are included in the headings and the tables themselves are kept clean and uncluttered. A useful technique for simplifying tables it to look for words or symbols which are used repeatedly in the data and then try to move them into the headings.

Graphs and *curves* should also be kept simple, but must be complete. You should check them to make sure that coordinate axes are labeled clearly, that test conditions are spelled out, and that differences between individual curves are indicated. Also, review your original data to determine whether the type of curve or graph used best displays significant trends.

Schematic diagrams, too, should be kept as simple and uncluttered as possible. The most effective circuit diagrams use a straight-forward layout with short, direct connections. Nonessential elements are omitted or shown in block form to reduce complexity. In complicated diagrams, components are identified only by part numbers, and values are given in a separate parts list. Standard symbology is used for all circuit elements, as well as for connections and terminals. Also, you should be consistent in your treatment of all diagrams.

If you are using *photographs* to illustrate a manuscript, you should make sure they help to illustrate your point. Each picture should be restricted as closely as possible to the device you are describing. Distracting background or accessory material can be cropped or airbrushed out. Call-outs are used to identify important components or features of the device.

All illustrative material must, of course, be captioned. All illustrations should be referred to in the text proper by their appropriate number. You should review your figure captions during the editing procedure to make sure that they clearly identify the illustrations and do not conflict with or only repeat the text.

IN SUMMARY: AN EDITING CHECK LIST

Because the main purpose of editing is to make sure that your message gets through to your reader, a check list is handy to help you remember the things you want to review. To be most useful, of course, the list should be your own, i.e., you determine the items which you consider most important or which you are most apt to overlook in your editing. Whatever your approach, the kind of editing described herein can make you a *better writer*, and help to establish an accurate line of communication between you and your reader.

ELEANOR M. McELWEE received the B.A. degree in English and Mathematics from Ladycliff College, Highland Falls, N. Y. in 1944. She has also taken courses at the Cooper Union Evening School of Engineering, the Technical Publications Center of Fordham University, and the Graduate School of Business Administration of New York University. From 1944 to 1947, she worked at the Western Electric Tube Shop in New York City as an assistant engineer of manufacture. From 1947 to 1951, she was employed at the Product Development Laboratories of Sylvania Electric Products, Inc. in Kew Gardens, N. Y., first as engineer in charge of the life-test program on subminiature tubes and statistical analysis of test data, and then as technical editor of engineering reports and papers. Since 1951, she has been with the Commercial Engineering activity of the RCA Electron Tube Division in Harrison, N. J., where she edits engineering publications. She is a Senior Member of IRE, and Secretary of the Professional Group on Engineering Writing and Speech. She has several papers published in the *Proceedings of the IRE*, the *Sylvania Technologist*, and the IRE Northern New Jersey *Newsletter*, and has taught "Editing Techniques for Technical Writers" at Fordham University.

THE ELECTRON MICROSCOPE—A SYMBOL OF MODERN SCIENCE

by **DR. J. H. REISNER**

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The Electron Microscope is one of modern science's most important tools. This revolutionary scientific instrument characterizes technical advances in which fundamental science and specialized technologies are crystallized into a specific new system in a relatively short time. This, the twentieth anniversary of the delivery of the first commercial electron microscope by RCA, affords an opportunity to review its development and growth.

Typical of the wide usefulness of the physical instruments developed through the medium of electronics, the electron microscope has become an invaluable aid in modern chemistry, has revolutionized biology, and is opening up new areas in metallurgy. Every branch of science has felt its influence.

To RCA, it represents leadership in the art of reducing difficult and complex scientific advances to commercial practice; for in the electron microscope, a room-full of complex optical apparatus, high-voltage supplies, electronic regulators, photographic apparatus, and vacuum systems is integrated into a conveniently small unit that can be operated reliably with no knowledge of its circuitry and components.

HISTORICAL EVOLUTION

It is only thirty-five years since it was realized that the mechanical analog of the simple physical light lens is a charged particle moving near the axis of a solenoidal magnetic field. Consequently, electron-optical instruments were soon built analogous to light optical-lens instruments. The first electron-optical microscope was completed in Germany in 1931 by Knoll and Ruska. During the next decade, electron-optical theory was extensively developed in all areas, although work on electron-microscope instrumentation was largely limited to Germany, where 1938 saw the first announced model.

Late in the thirties, active interest in the electron microscope developed in North America. At the RCA Laboratories, then located in Camden, New Jersey, Dr. V. K. Zworykin created sufficient interest in the electron microscope that a research group was set up to carry out the development under his leadership. During the same period, the Department of Physics at the University of Toronto, under the leadership of the late Professor Burton, was engaged in developing the first successful electron microscope on the American continent. Among the members of the Toronto group was Dr. James Hillier, who was invited to work on the RCA program, which he joined in January, 1940. In remarkably short time this group, of which Arthur Vance was an important member, produced the revolutionary Type EMB microscope (Fig. 1), and on December 20, 1940, the first commercial model went to American Cyanamid.

Since then, well over one-hundred man-years of research and engineering time have been invested to extend the use of the electron microscope, while constantly improving it (Fig. 2), until today almost a thousand instruments have been produced in seven basic models. The family tree of RCA microscopes (Fig. 3) shows the evolution of engineering thought, which was hastened by the rapid development of the field of electronics and of structural materials—plastics and ceramics, particularly—which continually placed new creative opportunities in the hands of the microscope engineers. Design and production of complex instrumentation such as the electron microscope is particularly suited to an industrial organization like RCA where very wide experience is actively available. Much of the success of the venture, therefore, must be attributed to the *nature of the organization* in which it grew.

It was recognized from the very beginning that it would not be sufficient to create an excellent new scientific instrument with great potentialities; it was also necessary to gain its acceptance by scientists at a sufficiently rapid rate that it could be produced in relatively large numbers and be sold at an attractively low price. In view of the radical innovation represented by the electron microscope, this task was not easy. An important step to gain the desired end was the creation of an RCA Research Fellowship of the National Research Council for the specific purpose of developing techniques of applying the electron microscope in research prob-

Fig. 1—Dr. Zworykin (standing) and Dr. Hillier at the first EMB electron microscope (1940).

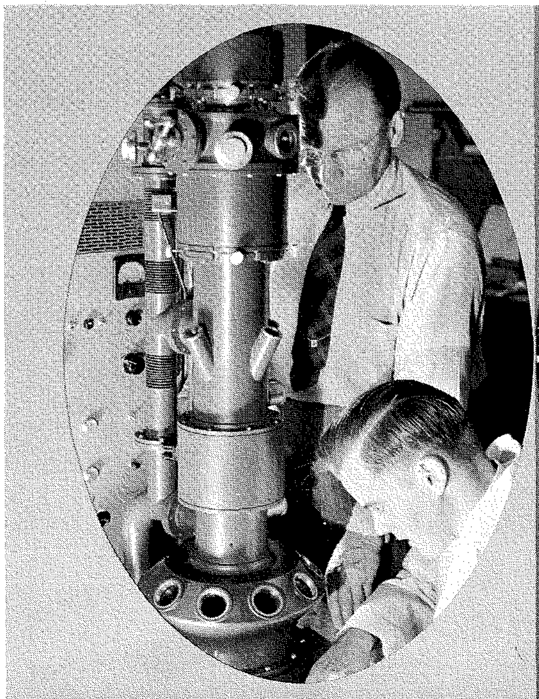
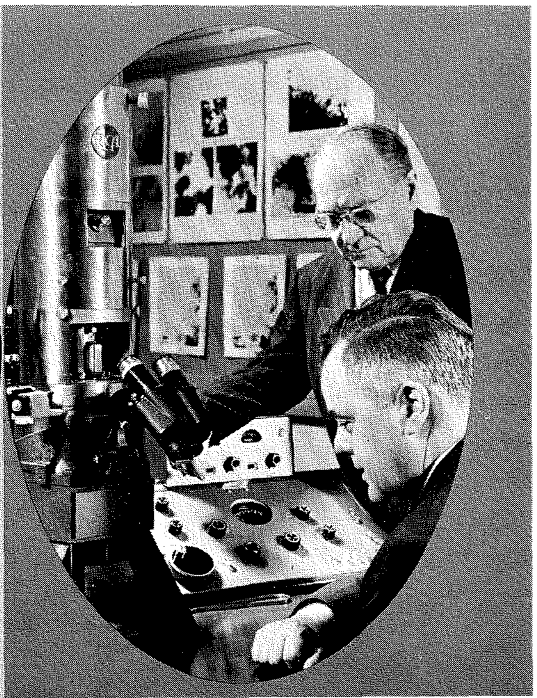


Fig. 2—Dr. Zworykin and Dr. Hillier at the EMU-3 microscope (1960).



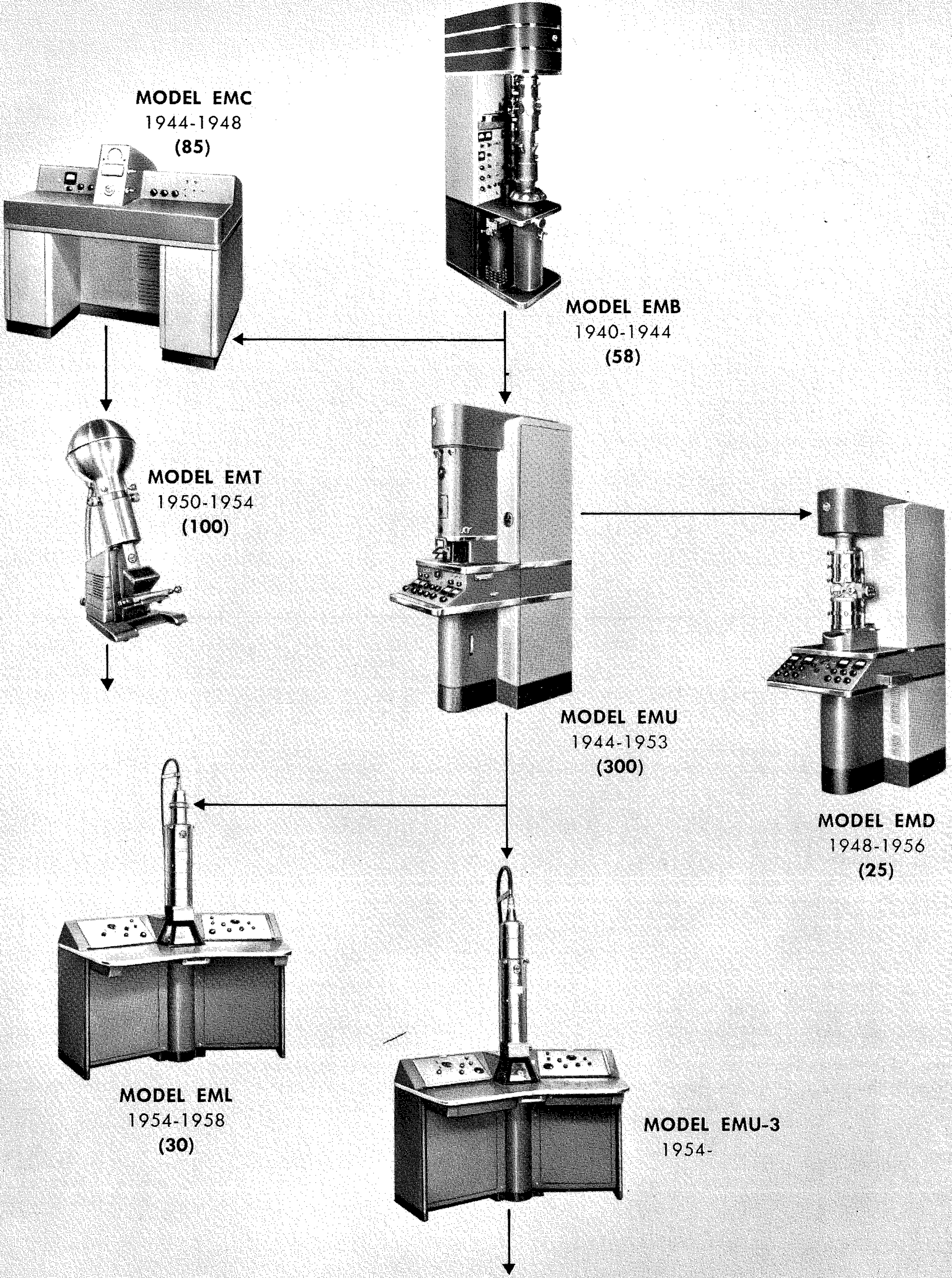


Fig. 3—The family tree of RCA electron microscopes.
(parenthetical numbers indicate units sold)

lems in the biological field. Dr. Thomas F. Anderson, as the first RCA Research Fellow, cooperating with other scientists visiting the Camden laboratory, did much to demonstrate the worth of the instrument in many different areas of research. The policy of close cooperation with research scientists was continued and extended when the research activities were transferred to Princeton and has been emphasized ever since.

A second step, which served the same objective, was the publication in 1945, of a book, *Electron Optics and the Electron Microscope*, giving a detailed account of the principles of the instrument, of techniques of operation and specimen preparation, and of results which had been obtained with it. A group effort of Zworykin, Morton, Ramberg, Hillier, and Vance, the book became the first comprehensive introduction to the new possibilities created by the electron microscope to many potential users, here and abroad.

BASIC THEORY

Two unique properties of the electron make the high magnification of the microscope useful. The best known property is that of the short effective wavelength of the high-energy electron (0.05 Angstroms at 50 kv). The second attribute is the very great brightness of high-energy electron sources. (The electron energy from a hot tungsten filament at 100 kv is 10^5 times more intense than sunlight.) Thus, there is enough energy to produce useful images at 200,000 times magnification with resolving power to require such magnifications. The theoretical resolving power of the microscope is limited to about 2 to 3 Angstroms by the necessity of using very low numerical aperture objective lenses to limit spherical aberration. That is to say, if the aperture is too large, resolution is lost because of spherical aberration; and, if too small, diffraction effects in the aperture act as a limit. A practical resolution limit of about 5 to 7 Angstroms is applied by the lack of specimen detail of sufficient mass to provide the necessary electron scattering to introduce contrast in the electronic image.

The electron microscope apparatus involves three distinct systems, *vacuum*, *electrical*, and *optical*.

VACUUM SYSTEM

As recently as the late thirties, vacuum systems were limited to the laboratory, and chemists and physicists prided themselves on their mastery of vacuum techniques, using their secret formulas of beeswax and rosin, and apparatus of blown glass. Transforming a room full of temperamental vacuum equipment into a small reliable system with simple operating controls was a major accomplishment in the Type EMB.

The electron microscope is evacuated in two steps by two very different types of pumps (Fig. 4). The initial step is carried out by a mechanical pump, which compresses the air remaining in the vacuum enclosure until it reaches atmospheric pressure where it can be released into the atmosphere. Such pumps evacuate at speeds of 1 to 2 liters/sec and operate down to pressures of about 10^{-3} mm Hg. Since operating pressures of 10^{-4} to 10^{-5} mm Hg are required, a gaseous diffusion pump is then utilized which not only operates at much lower pressures, but also at much greater speeds—hundreds of liters per second. This diffusion pump operates by trapping gas molecules which enter its throat at random. These wandering molecules are trapped in a circulating mass of oil vapor that is vaporized at the bottom of the pump, and moves to the throat where jets direct it outward and downward. At the walls, the oil vapor is condensed, and the trapped molecules are pumped out of the bottom by the mechanical pump.

Such a phenomenon can proceed only against very low pressures (e.g., 10^{-1} mm Hg). Therefore, the diffusion pump never works alone, but in conjunction with a mechanical pump. Thus, to evacuate a microscope, it is necessary first to use a mechanical pump alone and then a diffusion pump and a mechanical pump in series. RCA engineering made a real contribution to vacuum technology when it developed a reliable system of high-flow valves that could switch the two types of pumps around at will. A single-crank mechanical control system, replacing the several valve wheels of the EMB, first appeared on the EMU-1 microscope in 1944 and gave way to solenoid-actuated valves in 1947. With the EMU-3 (1954), sequencing of valves in the pump cycle was made automatic and under the control of pressure gages. This series of microscopes is pumped to 5×10^{-2}mm Hg by the mechanical pump in 70 seconds, at which pressure the valves automatically connect to the diffusion pump. Pressure then drops by two orders to 5×10^{-4}mm Hg. in 20 seconds—a total of 90 seconds from atmospheric to operating pressure.

In addition to advancement in valve systems, techniques of manufacturing vacuum enclosures, sliding seals, rotating seals, flexible couplings, and rapidly demountable vacuum-tight joints have also had revolutionary effects. While the first commercial microscopes were tested for leaks with the ether atomizer and vacuum gage, the present-day production tests for vacuum tightness are made with a helium mass-spectrometer leak locator. The heavy flanges and hex-head bolts, characteristic of early laboratory vacuum equipment (Fig. 1), have disappeared as gaskets became more accurate and reliable. Now, *O*-rings with accurate dimensions, controllable durometer, and excellent smoothness, as well as gasket grooves of carefully determined and accurately held depth and smoothness, have eliminated most joint problems.

While reliable vacuum technique made routine use of the microscope feasible, mechanized and automatic valving systems removed the necessity for any knowledge of vacuum techniques by the operator. The outstanding success of the vacuum system of the electron microscopes was one of the important influences in the rapid growth of the now large and flourishing vacuum industry. Well-known suppliers of vacuum equipment still sell gages and vacuum fittings which are close copies of those used on earlier RCA models.

THE ELECTRICAL SYSTEM

A large percentage of the engineering effort on the electron microscope since the first EMB has been expended on the unglamourous job of pushing back the decimal points. The routine attainment of voltage stabilities of 1 volt in 100,000 volts and current stabilities of 0.0005 percent are perhaps the best examples.

The focal length of a magnetic-electron lens varies directly as the electron accelerating voltage and inversely as the square of the lens-coil current. Thus, focal-length stability, on which resolving power depends, is influenced by voltage and current stability.

Much of the success of the commercial RCA microscopes can be laid to the early refusal to compromise on voltage and current stability. The difficulty of the problem of stabilizing high voltages led other pioneer workers to use electrostatic lenses, which are voltage-independent; however, this solution presents other more-fundamental problems—arc-over and insulation difficulties and, invariably, problems of focal length—which doomed the electrostatic instruments. Time has vindicated the decision of staying with the magnetic lens and solving the difficult problem of voltage stability.

From the first commercial microscope model, the high voltage has been generated by resonating an LC circuit and rectifying the high resonance voltage generated through a doubler or tripler.

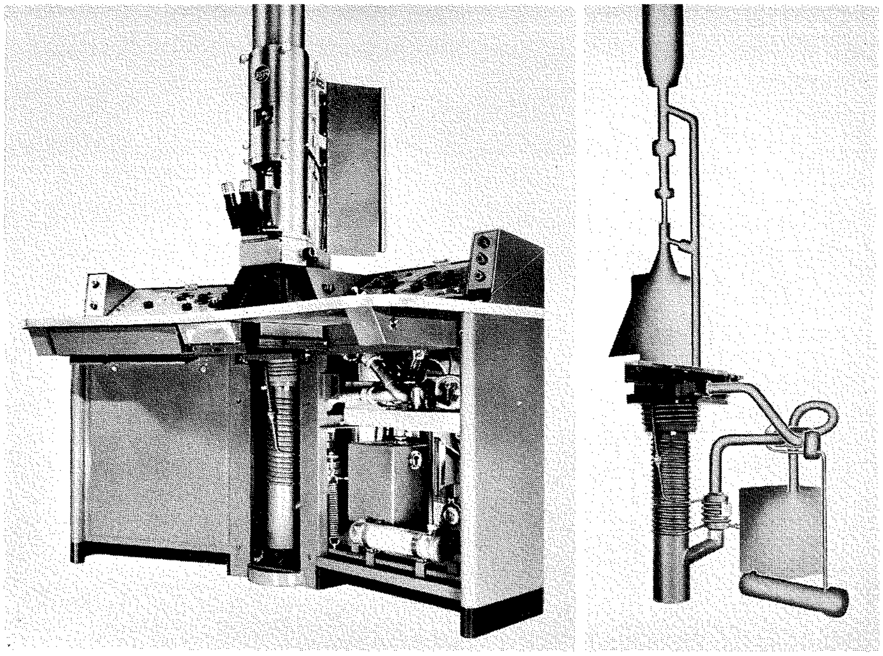


Fig. 4—EMU-3 vacuum system.

The output voltage, negative high, is regulated by referencing it through a resistive divider to a standard voltage, and amplifying the error signal so as to have it control the output of the ocsillator which excites the LC circuit. For example, a rise in voltage output will initiate a decrease in oscillator power, correcting for the original rise.

No part of the electrical system (Fig. 5) has been the source of so much engineering entertainment or technical challenge as the high-voltage unit. The principles of operation have not changed over the past twenty years, yet components have modified design philosophy.

The first design reduced the size of the high-voltage section by enclosing it in a tank of dielectric oil. To avoid the problem of a long gun-to-supply cable connection, the supply was mounted in back of the gun. Because truly compact, reliable high-voltage rectifiers did not exist, frequent failures presented serious service problems whose solutions were so elusive and amazing that the early users look back at those "pioneering" times with the nostalgia of early airplane barnstormers. The early users were not unduly dismayed for they were well aware that a minor miracle had been achieved by putting in so small a container the 60-kv supply which only a few years before constituted a room full of equipment. Difficulties with the doubler oil supply led to the design of the tripler in air, which reduced some of the strain on the rectifiers and made the supply immediately accessible for service. A real step forward, this power supply was used in over 400 commercial microscopes. Operating at atmospheric pressure, it would not work reliably at altitudes over 4,500 feet, and even when working at sea level it accumulated enough dust or humidity to cause arc-over without warning; the resounding report that followed was enough to unnerve any operator.

With the appearance of more-reliable rectifiers and capacitors, and with the requirements for 100-kv operation, the supply again became a doubler and was returned to an oil tank. This time, however, it was mounted on the floor and connected to the gun through reliable high-voltage cables and connectors. Very few of the components or materials used in the 1960, EMU-3 high-voltage supply were available when the first EMB proved to be successful.

OPTICAL SYSTEM

The long cylindrical-structure characteristic of every electron microscope is called the column. It houses the electron gun, lenses, specimen, fluorescent screen, and photographic plate, which make up the optical system (Fig. 6). It has the important function of providing the vacuum enclosure for the electron beam as it proceeds through the optical elements. The lenses are really the interaction of a solenoidal magnetic field with electrons moving close to the axis of symmetry of the field. In order to make these lenses strong, e.g., to have a 2- to 5-mm focal length, the solenoidal field is concentrated by annular magnetic pole pieces so that fields of several thousand gauss are attained.

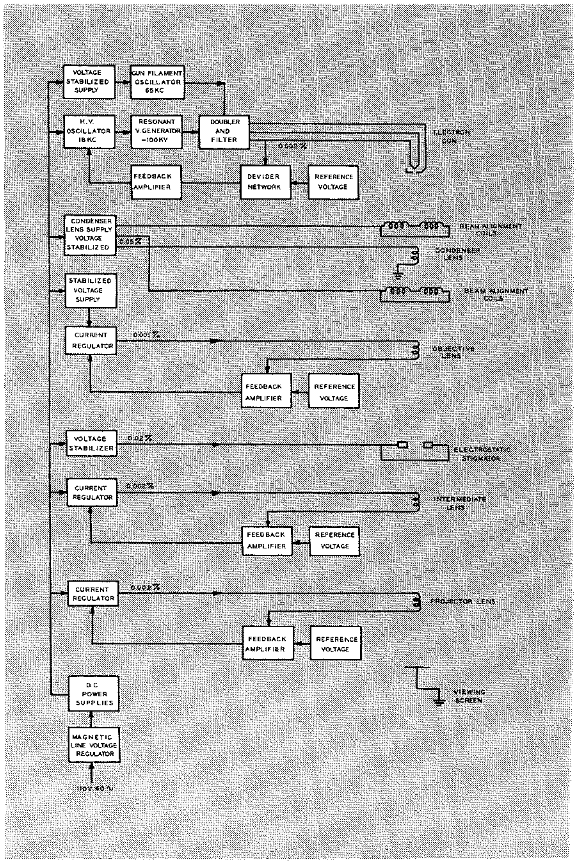
Magnetic electron lenses present the designer with several interesting properties not directly available in conventional light optical lenses. Focal length is continuously variable merely by the change of lens-energizing current. Electrostatic and magnetic electron lenses may be superimposed, since the lenses are not materials but fields. For the same reason, apertures and specimens may be positioned anywhere in the lenses. Rotation of the electron beam by a magnetic lens provides interesting properties for improving alignment of optical elements, but also provides a form of image distortion. Negative magnetic lenses are impossible, since the field term occurs as a square.

Focusing of images is easily accomplished with a potentiometer to change accelerating voltage or lens current, while the so-called Zoomar lens has been available for many years in the electron microscope to change magnification over wide ranges.

The ability to superimpose electron lenses is utilized to correct the astigmatism inherent in practical microscope objectives. This very important development in instrumentation is one of the milestones of electron microscope progress and resulted from the work of Dr. Hillier and Dr. Edward Ramberg in 1947. The anisotropy in the iron from which pole pieces are machined and the limits of mechanical precision in fabricating the pieces often cause simple magnetic lenses to be very astigmatic.

The resolving power of early instruments was severely limited by asymmetric astigmatism, so that it was unwise to guarantee better than 100-Angstrom resolving power. An asymmetric lens can be considered as the superposition of a cylindrical component on a spherical lens. Hillier and

Fig. 5—Electrical system.



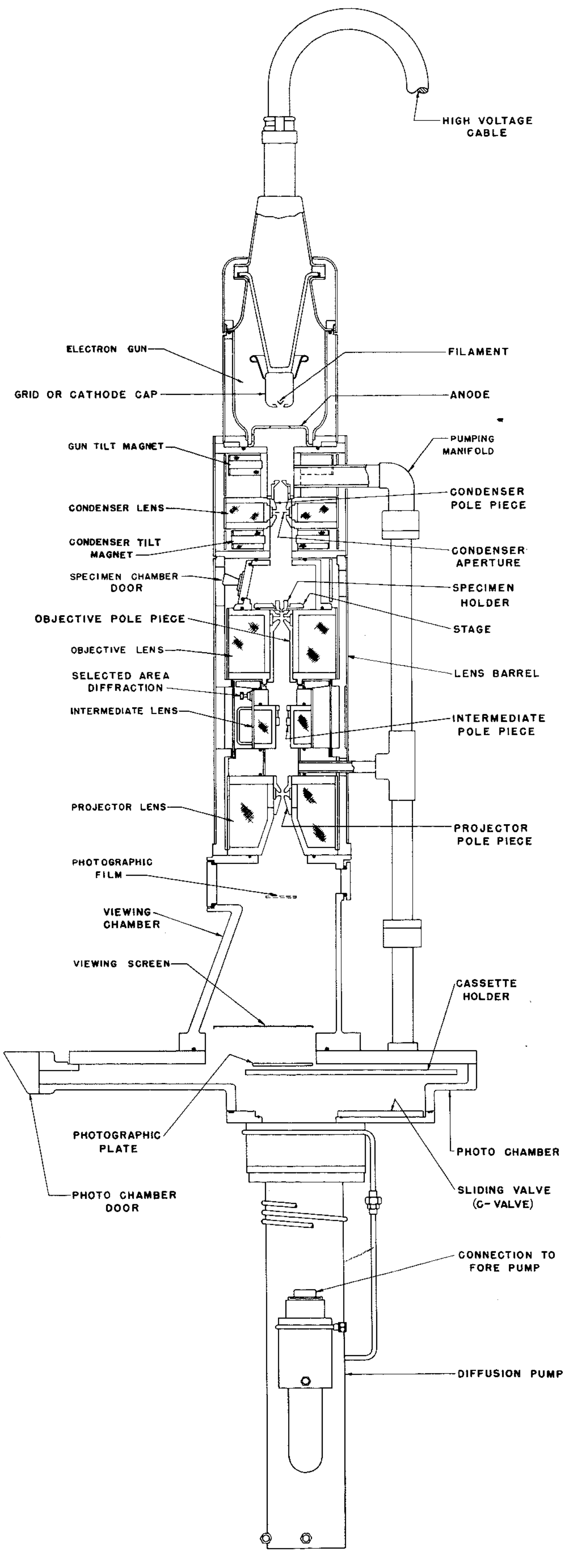


Fig. 6—Optical System.

Ramberg superimposed another cylindrical lens of equal strength, but at right angles to the unwanted component. The net result was a corrected lens, in the same manner as an ophthalmalogical correction. The first correctors were radial iron shim-screws adjusted by a succession of trials. Currently, electrostatic elements are utilized to provide the correcting cylindrical lens, a correction which can be applied while observing the image—thus avoiding the tedious series of trials of earlier days. Actually, the feature of easy adjustability was not the reason for employing the electrostatic correction as much as was the ability to apply automatically the right correction voltages when the instrument was changed from one accelerating voltage setting to another. With the electrostatic cylindrical lens, this became a simple matter of electrical switching.

The optical system, like the vacuum and electrical systems, has undergone simplification of design, but progress has still proceeded in the direction of a net complication of function. In the early instruments, alignment of optical elements was a serious problem, so that auxiliary fluorescent screens were provided at several points along the optical path to facilitate instrumental alignment; when illumination was lost at the final viewing screen, it could be located on the screens closer to the source and returned to the viewing screen. Auxiliary screens are no longer necessary because of better techniques in the design of optics and more-accurate control of mechanical tolerances. At the same time, the objective iron pole-piece has been greatly complicated (Fig. 7). The three pieces which comprised the actual objective pole-pieces of the EMB have given way to 68 pieces in the current EMU-3. The twenty-fold increase in numbers provides magnetic shims and electrodes for correction of astigmatism, as well as a complex system of inserting, or removing and centering an aperture to improve image contrast.

MICROSCOPY

The art of microscopy has changed far more than the instrument, although art and instrument have reacted strongly with one another. Most of this art is involved in specimen preparation.

Just as the specimen in the light microscope is supported on a microscope slide, so too must the specimen be supported in electron microscopy. But here, the support is an extremely thin film spread across the openings of a 200-mesh screen. The specimen screens are ⅛-inch-diameter disks punched out of electro-deposited copper mesh. The

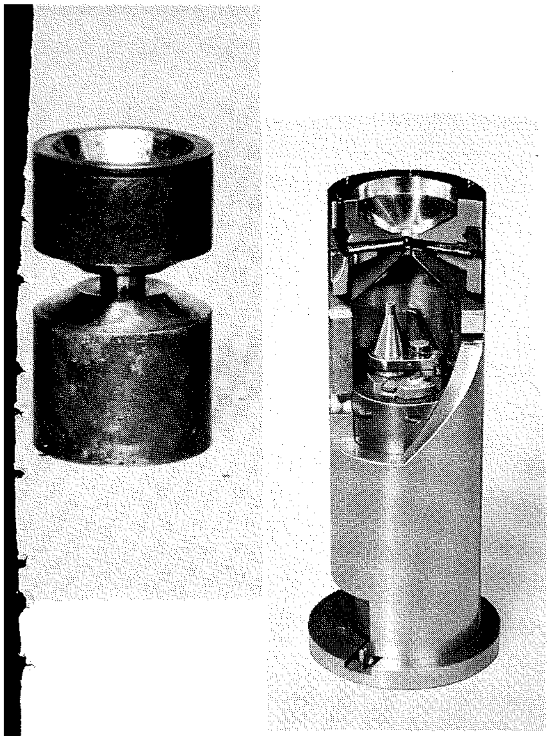


Fig. 7—Comparison of pole pieces of the EMB (left) and EMU-3.

extremely thin film (at most several hundred Angstroms thick) is placed on the specimen screen for physical support. The specimen is placed on the thin film and is effectively held suspended in the electron beam; the beam strikes the specimen only in the area of the screen openings.

When high-speed electrons strike matter, they interact with the coulomb field around the individual atoms. As a result of the encounter, they are scattered over a wide range of angles. In thin films, up to 1000 Angstroms thick, they make only one encounter on the average and are said to be *singly scattered.* Few electrons are actually stopped. In the light microscope, the illumination is absorbed differently over the area of a specimen to cause the corresponding differences in brightness which make up the image. In the electron microscope, the electrons are scattered differently over the area of a specimen. Those electrons scattered out of the optical system never return to their corresponding image points; this gives rise to brightness differences which make up the image (Fig. 8). Unfortunately, some of the scattered electrons are scattered only enough so that they cannot return to their image points, but not enough to escape the image area, so that they produce a general background illumination that lowers contrast. Therefore, specimen support membranes are made as thin as possible and apertures put in objective lenses to remove unwanted illumination.

As an example of the effect of specimen techniques on instruments, one can take the limited success of the EMC console microscope introduced in 1945. This instrument utilized a 30-kv beam and had a rather short distance from the gun to the specimen. As a result, specimens were highly heated, and unless they were extremely thin, the 30-kv beam was too scattered and not adequately penetrating. Consequently, such stringent requirements were imposed on specimen preparation that the usefulness of the instrument was limited, and the EMC was discontinued in favor of the higher-voltage EMT microscope. Yet, had the modern techniques of producing evaporated-carbon specimen support films and cutting ultrathin specimen sections been known ten years earlier, the instrument might have been in much greater demand.

The early microscopists and designers were so preoccupied with the high useful magnification of the electron microscope that the earliest instruments were limited in the low-range magnification. It was not until 1946 that the EMU microscope had its range extended downward from a minimum of 12,000 to 1,200. The preoccupation with high magnification had the unfortunate effect of alienating many biologists and metallurgists for whom the precipitous jump of 10 to 100 times in magnification was a complete separation from all the familiar shapes of cells and crystals which they needed for perspective.

Almost simultaneous with the extension of the range of the electron microscope downward to overlap light microscopy was the development of means for producing plastic-film replicas of metallurgical surfaces and, shortly thereafter, means for producing exceedingly thin sections by microtomy.

Requirements for microscopy are continually guiding the development of the instrument. Biologists soon found that the small specimen area of 0.7-mm diameter scanned in the early instruments was much smaller than that of a good microtome section; thus, the stage mechanisms (specimen transport) were redesigned to provide a 2-mm range. From the sheer complexity of their data biologists need many micrographs, and higher speed of operation became necessary. Film cameras taking up to 40 pictures at a loading were designed, and the time for evacuation of the microscope was made very short.

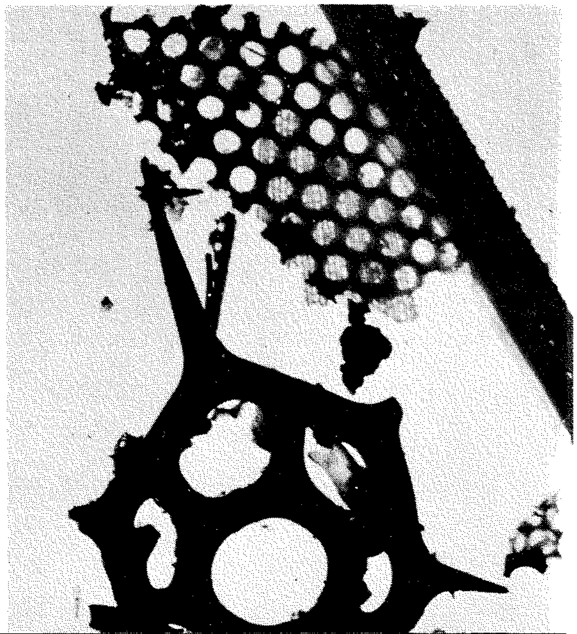
In metallurgy, the study of thin single crystals shows faults in crystal planes, the occurrence of faults under thermal stress, the patterns of growth of one crystal on another, and many other challenging phenomena. These techniques have made it necessary to extend the useful range of direct microscopic magnification upward to 200,000 times (Fig. 9). At the same time, a double-condenser system between the gun and specimen has made it possible to reduce the source of electrons illuminating the specimen to less than 2 microns, permitting optical and thermal properties valuable for the new area of research (Fig. 10). The rapid development of the microscope has not been solely due to the demands of microscopists or the creativity of the engineers, but an effective effort of both.

THE HUMAN ELEMENT

The evolution of the microscope during the past twenty years has seen scientists employing more and more complex instrumentation, with less and less knowledge of circuit details.

The relationship of the human element to the inanimate components is now a necessary and explicit concern

Fig. 8—Diatom fragments, about ×2100. Above: light micrograph, showing image defects as optical-system resolution limit is approached. Bottom: electron micrograph.



a) screened dot, ×1

b) portion of screen ×100

c) portion of screen showing imperfection, ×300

d) imperfection, ×1000

e) portion of imperfection, ×3000

f) additional magnification, ×30,000

g) additional magnification, ×300,000

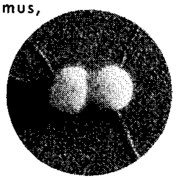
Fig. 9—Magnification of screened dot.

of all mature engineering. It is now obvious that what we call *human engineering* today was an implicit purpose and a real achievement in the first commercial microscopes. Today, one worries about fatigue and mental attitude of the human operator; in early microscopes. easy accessibility of the controls to a seated operator was the design goal to attain. Considerable success has been achieved by eliminating routine functions and controls and providing automation so that the operator has become efficient and nonfatiguing.

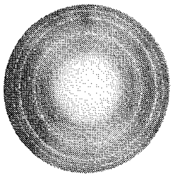
Fig. 10—Typical micrographs.

a) carbon steel, ×10,000

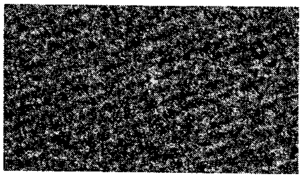
b) desoxyribose nucleic acid from calf thymus, ×112,000



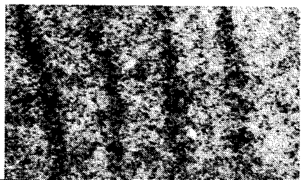
c) diffraction pattern, $Al_2O_3 \cdot H_2O$



d) Cu-phthalocynine, ×1,360,000



e) sections through myclin sheath of central nerve fibers of mouse, ×600,000



The electron microscope is inherently an instrument requiring considerable maintenance. Contaminants are introduced in the optical and vacuum systems by hot filaments, by sublimation of specimen materials, by evolution of organic vapors from photographic materials and pumping gases, by vacuum greases, and by gaskets. The vacuum system removes lubricants from mechanical systems in the pump. Pumping fluids decompose. Many of the best electrical components must still be classed as not completely reliable. Just as the equipment had to be designed to be run effectively, it had to be designed to be serviced efficiently. Actually, a voltmeter and a small oscilloscope will solve the vast majority of service problems. Built-in vacuum gages are used in vacuum maintenance. The microscope itself can be used in many ways to test itself: for example, in the measurement of 100-kv and 50-kv high-voltages, an electron diffraction pattern from a known crystal such as magnesium oxide can be used to measure voltage to 0.1 percent.

It must be emphasized that the ready availability of intelligent service personnel is one of the conditions which has made the universal use of the electron microscope possible, and an important part of the success of the microscope venture must be credited to the RCA Service Company.

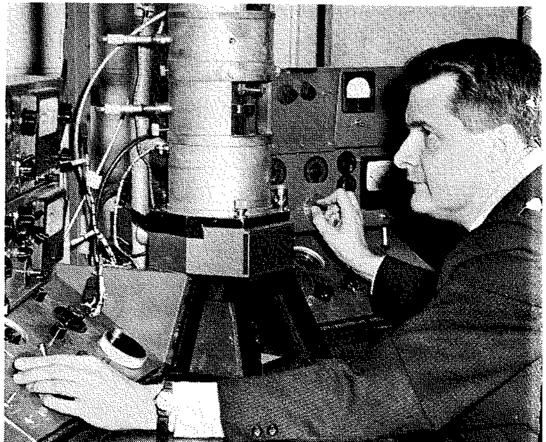
IN SUMMARY . . .

There is more than idealism behind the oft-stated thought that the engineer must interpret his work for the layman. The engineers had to come out of the laboratory and counsel the practicing microscopists. Not a few of the specimen techniques were developed by the engineers themselves. In fact, Dr. Hillier became well known as a microscopist as well as an instrument scientist. RCA engineers continue to be frequent visitors in many of the important laboratories in this country and abroad and to publish original work in journals. The microscope laboratories in Princeton and Camden have played host to hundreds of leading scientists and have trained hundreds of others in microscope techniques.

These outside activities cannot be written off as sheer promotion, although they were that at its best. An example of the personal commitment brought to science is the popular election of four RCA engineers to presidency of the Electron Microscope Society of America.

In short, the RCA Electron Microscope exemplifies the application of many technical disciplines and a broad range of auxiliary services and individual professional activities—an application fruitful to RCA, to the individuals whose work made it successful, and to the scientific community.

DR. J. H. REISNER received his BS in Mathematics from Davidson College in 1939, and a PhD in Physics in 1943 from the University of Virginia. He joined the Crystal Engineering Department of RCA Camden upon graduation, doing work in x-ray orientation techniques, instrumentation, and crystal resonators. In 1945, he transferred to the Electron Microscope Group, where he was promoted to leader in 1950. He is currently leader of the Scientific Instruments Engineering Group, which is responsible for electron microscopes, and electron and x-ray diffraction equipment. Dr. Reisner has been actively engaged in all phases of electron-microscope work, from research through design. While his main effort has been in electron optics, he has made significant contributions in vacuum technique, mechanical and electrical design, and magnetics. He is best known for his successful development of permanent magnetic lenses. He has been a frequent contributor of scientific papers and articles and a lecturer for both scientific and lay groups. He is a member of Phi Beta Kappa, Sigma Pi Sigma, Sigma Xi, and the American Physical Society, and is a fellow of the AAAS. He was president of the Electron Microscope Society of America in 1959, and previous to that, a Director. He is past-president of the Philadelphia Electron Microscope Society, a member of the New York Society of Electron Microscopists, and Associate Chairman of the International Congress of Electron Microscopy for 1962. A member of the Franklin Institute since 1946, Dr. Reisner now serves on its committee on Science and the Arts.



EIGHT RCA MEN ELECTED IRE FELLOWS

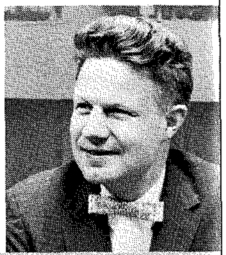
The eight outstanding RCA engineers and scientists appearing on this page have been elected *Fellows* of the Institute of Radio Engineers. This honor is bestowed, by invitation, only upon those who have made outstanding contributions to electronics. Presentation of the awards was made on March 23, 1960 during the annual IRE National Convention in New York.

. . . for contributions to radio and radar technology.

Arthur N. Curtiss (BSEE, University of Pittsburgh, 1927) joined RCA in 1930 as a design engineer. He became a supervisor in 1936, and from 1938 to 1945, was with RCA in Indianapolis, where he rose to Head of the Design Section. In 1945, he returned to Camden as Mgr., Standards Engineering. In 1951, he became Plant Mgr. of the new RCA West Coast facility, and when it grew to Department status in 1955, he was named Manager. In 1959, this became the West Coast Missile and Surface Radar Division, DEP, with Mr. Curtiss as General Manager. He is a member of several professional societies and a registered professional engineer in N. J. He received an *RCA Award of Merit* in 1955, holds four patents, and has authored papers on radar, audio, and radio.

. . . for contributions to gaseous electronics and semiconductors.

Edward O. Johnson (BSEE, Pratt Institute, 1948) joined the RCA Laboratories in 1948, where he did research on gaseous conduction and solid-state phenomena. He transferred to the Semiconductor and Materials Division in 1959 as Mgr., High Temperature Product Development. He then became Mgr., Advanced Development and is now Chief Engineer of that Division. During World War II, he served in the U. S. Navy as a radio-communications specialist in the Pacific. He holds 12 patents, has authored 20 papers, and is a member of Sigma Xi, Eta Kappa Nu, and the APS. He has received two *RCA Achievement Awards,* and is co-recipient (with Dr. W. T. Webster) of the 1952 IRE *Editor's Award.*

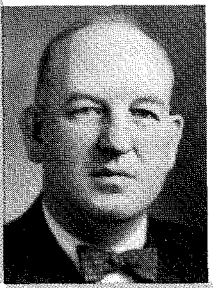


. . . for contributions to the development of electron devices.

Dr. Harwick Johnson (BSEE, Michigan College of Mining and Technology 1934; MS, 1940, and PhD, 1944, University of Wisconsin) has been associated with the RCA Laboratories since 1952. Previously, he had been a research fellow and teaching assistant in the Department of Electrical Engineering at the University of Wisconsin. Before coming to RCA, he was a Student Engineer for Phelps-Dodge Corporation in Ft. Wayne, Indiana and Engineer for Zenith Radio Corporation in Chicago. His RCA work has included FM radar, receiving tubes, noise phenomena, and semiconductor devices. After serving a year and a half as Acting Director of the Electronic Research Laboratory, he was appointed Associate Laboratory Director of that laboratory. He is a Senior Member of the IRE, a member of APS, Sigma Xi, and AAAS, and the author of many papers.

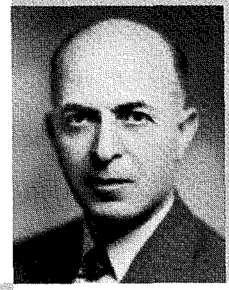
. . . for improvements in communications coding techniques.

John B. Moore (BSEE, Carnegie Institute of Technology, 1922) has been with RCA Communications, Inc. since 1922. From 1922 to 1928, he was active in the operation of commercial radio-telegraph stations. From 1928 to 1941, he was involved in research, development, and design of h-f radio-receiving systems. Since 1941, he has been engaged in plant design work and staff engineering on problems of commercial transoceanic radio-telegraph and radio-teleprinter services. His early achievements included work on the RCA foreign program reception service (1929-31) and, in 1934, proposal of the constant-ratio form of protected teleprinter code and basic system of detecting signal mutilations. He is a member of AIEE and has written on code transmission and reception.



. . . for contributions to international radio communications systems.

David S. Rau (BS, U. S. Naval Academy, 1922) was assigned to the Rocky Point high-power transmitting station as one of RCA's first student engineers. After a period as Chief Engineer of the Radio Corporation of the Philippines, a wholly owned subsidiary, he was assigned to the New York headquarters staff of RCA Communications, Inc., as a station design engineer, from which he advanced to his present position as Vice President and Chief Engineer, Engineering. During World War II, he was on active duty in Naval Communications as Head of the Shore Radio Stations Section. He was promoted to CAPT., USNR, and commended by the Secretary of the Navy. He is a member of the *RCA Review* Board of Editors and the RCA Institutes Board of Technical Advisors.



. . . for contributions to the development of high-power transmitting tubes.

Dr. Phillip T. Smith (BA, 1927, and PhD, Physics, 1931, University of Minnesota) joined the RCA Electron Tube Division in 1937 and transferred to the RCA Laboratories in 1942. Between 1931 and 1937, he was engaged in research, finally as a National Research Fellow at Princeton University, and also was an Instructor in Physics at MIT. With RCA, he has specialized in research on gas discharge, high-vacuum systems, and uhf power tubes. He has authored numerous papers, holds several patents, is a member of APS and Sigma Xi, and is listed in *American Men of Science*. He has been a Technical Director of C-Stellarator Associates since its formation in 1957, and is now on leave from the RCA Laboratories for that work in controlled thermonuclear fusion.

. . . for contributions in the field of photo-emissive surfaces.

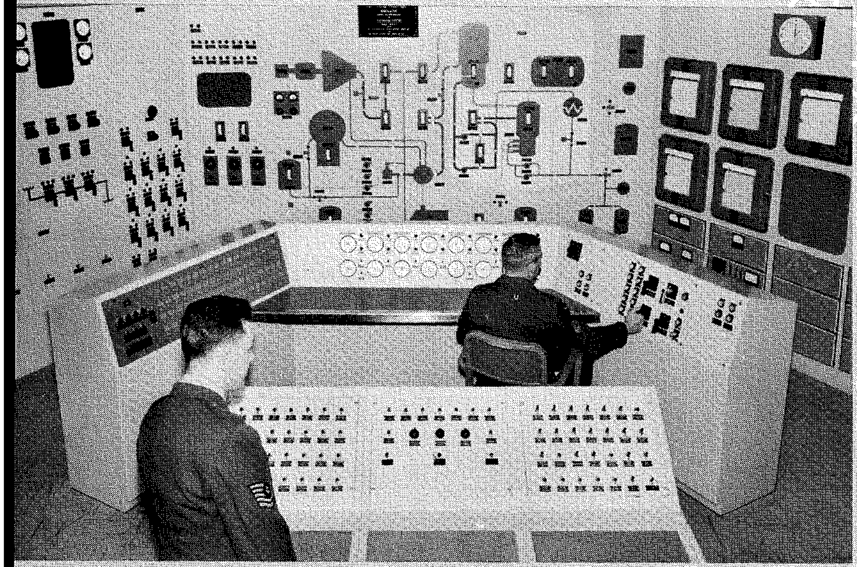
Dr. A. H. Sommer (PhD, Phys. Chem., University of Berlin) joined the RCA Laboratories in 1953 after associations with Cinema Television Co. of London, England (1936-1943) and EMI Research Laboratories, Hayes, England (1946-1953). Dr. Sommer's work has included studies of the antimony-cesium photocathode and development of photomultipler and TV pickup tubes. He invented the "panchromatic" bismuth-silver-cesium cathode and the "multi-alkali" cathode. He holds some 25 patents, mostly British. A member of APS, ACS, and Sigma Xi, he received an *RCA Achievement Award* in 1955 and is listed in *American Men of Science.*

. . . for contributions to gaseous electronic and solid-state devices.

Dr. William T. Webster, Jr. (BS, Physics, Union College, 1945; PhD, Princeton University, 1954) joined the RCA Laboratories in 1946. In 1954, he transferred to the Electron Tube Division, and then to the new Semiconductor and Materials Division as Mgr., Advanced Development. In 1959, he was named Administrative Engineer on the staff of the Vice President, RCA Laboratories, then becoming Director of the Electronic Research Laboratory. He holds numerous patents in many fields. In addition to his fundamental research leading to the understanding of gas discharge modes, he has made notable contributions to the understanding of semiconductor operation. In 1952, he was co-recipient (with E. O. Johnson) of the IRE *Editor's Award.*

ELECTRONIC SIMULATION OF A NUCLEAR REACTOR

For studies of nuclear-reactor dynamics and training of operators, a $200,000 electronic simulator is a much less expensive medium than the multimillion-dollar nuclear reactor. In addition, operating situations can be accurately simulated that would be far too hazardous with the reactor itself. The RCA Service Company has designed just such a device—the **APPR-1 Reactor Simulator**—for the U.S. Army, under a contract with the U.S. Atomic Energy Commission.



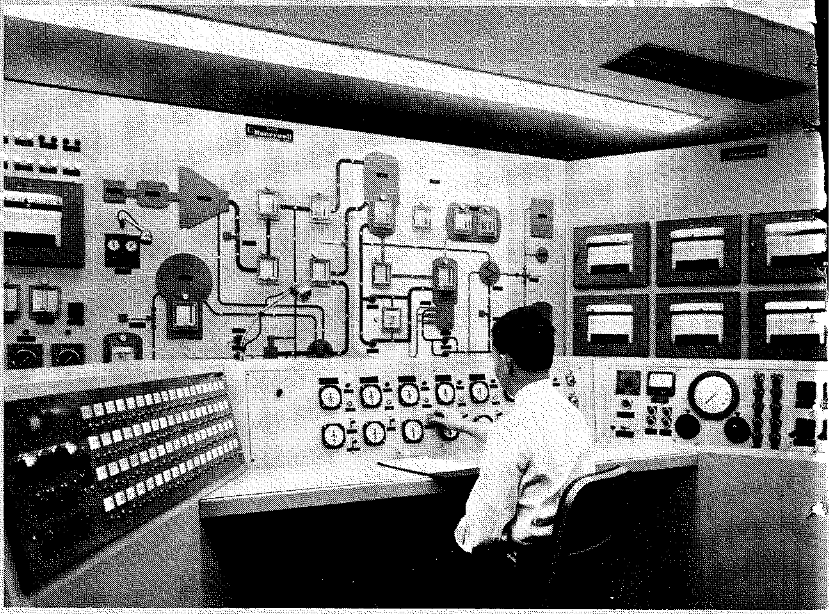


Fig. 1—Above: The APPR-1 Reactor Simulator at Ft. Belvoir, Va. (U.S. Army). Right: The control console for the actual APPR-1 nuclear reactor. Note the detail to which the simulation has been carried.

by **H. REESE, Jr., Mgr.**
Atomic Energy Services
RCA Service Company
Cherry Hill, N. J.

For certain applications, it is often more desirable to simulate the operation of a nuclear reactor rather than to build a prototype or divert an existing plant. While simulation cannot be used for experiments that require high-level neutron or gamma radiation, it is applicable for studies of reactor dynamics and operator training. In both of these, the primary reactor system is not utilized; rather, the instrumentation system is employed so that the motivating source for the instrumentation can be anything that properly simulates these signals.

REACTOR THEORY

Before describing the simulation techniques, it is illustrative to touch upon some of the basic reactor theory. (References 1, 2, and 3 present this in detail.)

Reactor operation depends on the fission process, a neutron-initiated nuclear reaction producing energy and neutrons (about 2.5 in the fission of a uranium-235 atom). A chain reaction results whose power-production rate can be raised or lowered by suitable controls. When the multiplication factor (k_{eff}) between one generation of neutrons and the next in the chain reaction equals unity, the reactor is *critical* and maintains a constant power level. If k_{eff} is less than one, the reaction dies out and is *subcritical.* If k_{eff} is more than one, it is *supercritical* and continuously increases in power level.

In most reactors, the fission process occurs when the fissionable material is struck by neutrons moderated to thermal-energy level, where the neutron cross-section is much greater. The neutrons are continually moderated, or slowed down, by inducing elastic collisions with nuclei in the reactor. It is possible to describe the diffusion of neutrons by considering them as all having one energy—thermal energy—which is equal to approximately 0.025 electron volts (ev) at room temperature. This simplification and others make it possible to write an equation describing the diffusion of neutrons in a reactor which is valid for gross time effects. For detailed design calculations, the equations are nonlinear in space, energy, and temperature.

Considering the simplified mono-energetic approach, the following neutron-balance equation can be written for an elemental volume:

Production — leakage — absorption
= rate of change of neutron density

Rearranging terms:

— leakage — absorption + production
= rate of change of neutron density

Expressing this in mathematical terms, the resulting equation for a homogeneous, bare thermal reactor, assuming a continuous (*Fermi-age*) slowing-down, is:

$$D\nabla^2\phi - \Sigma_a\phi + k\Sigma_a\phi \exp(-B^2\tau) = \frac{\delta n}{\delta t} \tag{1}$$

The term $-D\nabla^2\phi$ is simply the divergence of the neutron current vector $-D \operatorname{grad} \phi$; $\Sigma_a\phi$ is the conventional relationship for neutron absorption; $k\Sigma_a\phi \exp(-B^2\tau)$ represents those neutrons slowing down from the fission process and not leaking out; $\exp(-B^2\tau)$ represents the nonleakage probability. If this equation is solved by separation of space and time variables, the reactor period T (time to change power by a factor of e) equals l^*/k_{ex}. With a neutron life time of 100 microseconds and an excess multiplication constant of 0.01, it only requires 0.01 second to more than double reactor power. This assumes that all neutrons are promptly emitted. Fortunately, 0.7 percent of the neutrons are delayed for times ranging from a fraction of a second to many seconds. These delayed neutrons have a strong effect on the dynamics of a reactor, and even though they can be neglected in Equation 1 for space-dependent effects, they must be included for control studies. It is also necessary to include an equation for the sources of the delayed neutrons emitted from the various fission products, which will vary in concentration as a function of reactor flux and time. The two resulting equations which must be simultaneously solved are:

$$\begin{gathered} D\nabla^2\phi - \Sigma_a\phi + \\ (1-\beta)\, k\Sigma_a\phi\, [\exp(-B^2\tau)] + \\ P \exp(-B^2\tau) \sum_i \lambda_i c_i = \frac{\delta n}{\delta t} \end{gathered} \tag{2}$$

$$\frac{\delta c_i}{\delta t} = \beta_i \frac{k}{P} \xi_a \phi - \lambda_i c_i \tag{3}$$

Equation 2 can be simplified to:

$$\begin{gathered} [k_{eff}(1-\beta) - 1]\,\phi + \\ \frac{Pk_{eff}}{k\Sigma_a} \sum_i \lambda_i c_i = l^* \frac{\delta\phi}{\delta t} \end{gathered} \tag{4}$$

If it is assumed that $k_{eff} \approx 1$ and the reactor is large so that leakage can be neglected, then Equations 3 and 4 can be simplified to:

$$\frac{k_{ex}n}{l^*} - \frac{\beta n}{l^*} + \sum_i \lambda_i c_i = \frac{\delta n}{\delta t} \tag{5}$$

$$\frac{\delta c_i}{\delta t} = \frac{\beta_i n}{l^*} - \lambda_i c_i \tag{6}$$

GLOSSARY OF TERMS

ϕ	neutron flux
N	neutron density
t	time
D	neutron diffusion coefficient
B^2	buckling
τ	Fermi age
k_{ex}	excess multiplication factor
P	resonance escape probability
k_{eff}	effective multiplication factor
∇^2	laplacian operator
β	delayed neutron fraction
Σ_a	macroscopic absorption cross-section
β_i	delayed neutron fraction of i^{th} group
l^*	effective neutron lifetime
T	reactor period
λ_i	decay constant of i^{th} delayed neutron group
c_i	concentration of i^{th} group precursor
I	iodine concentration
Σ_f	macroscopic fission cross section of fuel
X_e	xenon concentration
σ_z	microscopic cross section of Xenon
K_1	fission yield of Iodine-135
K_2	fission yield of Xenon-135
Σ_u	macroscopic absorption cross section of fuel
δk_p	reactivity change due to poison
P_r	reactor power
M_f	mass of fuel elements in reactor
C_f	specific heat of fuel elements
T_f	average temperature of fuel
K_c	heat transfer coefficient between fuel and primary coolant
T_{wc}	average temperature of coolant in core
M_{wc}	mass of coolant in core
C_w	specific heat of coolant
W	flow rate of coolant
T_{oc}	coolant temperature at outlet of core
T_{ic}	coolant temperature at inlet of core
T'_{oc}	core outlet temperature anticipated a time τ_c
T_{wc}	average temperature of coolant in core
τ_c	time for coolant to pass through reactor core
T_{ix}	coolant temperature at inlet of heat exchanger
T_{ox}	coolant temperature at outlet of heat exchanger
K_b	average heat transfer coefficient in boiler
T_{wx}	average primary temperature in heat exchanger
T_s	average temperature of steam
M_s	mass of boiler secondary
C_s	specific heat of boiler secondary
K_s	constant relating heat added to each pound of feedwater
W_s	flow rate of steam
T'_{ox}	the T_{ox} anticipated by τ_b
τ_b	transit time for primary coolant in boiler
s	Laplacian operator
P_s	steam pressure
T_{sec}	average temperature of boiler secondary
k	infinite multiplication factor
δk_r	change in k due to control rods
δk	change in infinite multiplication factor
δk_t	change in k due to temperature
$\exp(n)$	notation for e^n

Physically, Equation 5 indicates that a change in neutron concentration with time is the sum of three effects: the prompt-neutron effect (which is directly proportional to excess reactivity), the delayed-neutron effect (which depends on the delayed fraction), and the concentration of delayed precursors. Equation 6 then gives a relationship for the delayed-neutron precursor concentration in terms of neutron density. Since there are six groups of delayed neutrons, Equation 6 will actually consist of six equations, and the summation term in Equation 5 will be summed over six groups.

REACTOR KINETICS COMPUTER

In principle, Equations 5 and 6 are easy to mechanize on an analog computer; however, complications arise in accurately indicating neutron concentration (proportional to the power generated in a thermal reactor) over nine decades. It is necessary to follow closely the power level of a reactor over this wide range because the control mechanism regulates the rate of power change, not the absolute level. The control-rod position is approximately the same at 1 megawatt as it is at 1 milliwatt. If the reactor is made *prompt-critical* (critical without the delayed neutrons), it is possible to have a time constant as short as that discussed earlier (0.01 second), which could result in complete destruction of the reactor. In order to monitor the reaction from start-up to full power, a fission counter is usually used during the lowest three decades of power level, and an ionization chamber is used during the upper six or more decades. The start-up counter detects the charged fission products from the individual neutron captures and puts out a pulse for each event. When the power level approaches the higher ranges, it is possible to average out the neutron events and read the d-c current from an ionization chamber. A chamber for this purpose usually utilizes the boron-10 (n,α) reaction. One of the criteria for operating a reactor is that the neutron level must be measurable at all times. In most cases, it is necessary to insert a separate source for use in the start-up range.

Two methods are currently being used in reactor simulators to achieve this wide dynamic range. One method consists of deriving Equations 5 and 6 in terms of the logarithm of the neutron density. This allows the representation of many decades with only a small change in analog voltage. The disadvantage of this method, however, is the great leverage between analog voltage and neutron density, so that the system exaggerates any errors. The second method, used by the RCA Service Company in designing the APPR-1 Reactor Simulator (Fig. 1), is a linear-voltage system that represents neutron concentration. Thus, three networks cover the entire range by having each network operate over three decades. A switching circuit interconnects the networks and allows variation of the instrumentation range. Consequently, each set of operational amplifiers can operate through a voltage range of 0.1 to 100 volts and still provide an over-all range of nine decades.

Theoretically, it should be possible to use two networks; but in a reactor system where "past history" is necessary to generate the delayed neutrons, there must be one network ready for the next highest range and one ready for the next lowest range. Therefore, at least three networks must be used.

Another complication of less importance is the fact that the excess reactivity of a reactor simulator is a nonlinear function of control-rod position, and a linear function of reactor temperature and fission-product concentration. These three functions are summed separately and fed into a reactor kinetics computer, as shown in Fig. 2. To simulate the control-rod effect on reactivity, a potentiometer with a $\sin^2\theta$ winding is mechanically connected to each control-rod drive and is used to vary a current that is summed for all rods and fed into the reactivity summer. $\mathrm{Sin}^2\theta$ is used because it approximates very well the *S*-shaped curve of reactivity versus control-rod position, where θ equals 0° to 90°.

XENON POISON

Consideration of the fission-product concentration, or *poison* as it is usually called, is important because of the high absorption cross-section of some of the products. Most notable among them is xenon-135, which is radioactive and has a half-life of 9.2 hours. In fact, it is necessary in a simulator to consider only this one isotope, since the effects from the others are comparatively negligible. Xenon-135 is a daughter of iodine-135, which has a half-life of 6.7 hours, and which in turn is a daughter product of tellurium-135, which has only a 2.7 minute half-life and can be neglected. The tellurium is produced directly from the fission process. Thus, the xenon concentration is a function of time and reactor power-level, or flux, and can be determined from:

$$\frac{\delta I}{\delta t} = K_1 \Sigma_f \phi - \lambda_I I \qquad (7)$$

$$\frac{\delta X_e}{\delta t} = \lambda_I I + K_2 \Sigma_f \phi - \lambda_{XE} X_e - \sigma_2 \phi X_e \quad (8)$$

$$\delta k_p = -\frac{X_e \sigma_2}{\Sigma_w} \qquad (9)$$

Since xenon-135 and its parent isotope, iodine-135, have fairly long half-lives, the xenon effect does not change rapidly with time and can be neglected in dynamic studies and in most training programs. Usually, however, it is put on an accelerated time scale to illustrate the build-up of xenon after shutdown. This build-up after shutdown is shown graphically in Fig. 3. It is necessary to have a small analog network to solve Equations 7 and 8 and generate the change in multiplication factor due to xenon build-up, which is fed into the reactivity summer shown in Fig. 2.

HEAT-REMOVAL CIRCUIT

The last function which is necessary to be generated to complete the simulation is the temperature effect on reactivity. In a water-moderated reactor, for example, when the temperature increases, the density of the water decreases and provides a smaller cross-section for scattering and slowing down the neutrons. This increases the chance for nonfission absorption and leakage and reduces reactivity. The reactor then has a negative temperature coefficient and tends to be stable. To generate this temperature effect, it is first necessary to solve the heat-transfer equations for the heat-removal circuit. From this, an average reactor temperature is determined. If the coefficient is calculated or measured it is then possible to determine the reactivity change due to temperature.

Fig. 4 is a block diagram of the heat-removal circuit for the APPR-1 reactor. The primary pumping rate is assumed to be constant over the full range of temperatures. The following equations represent the heat transfer in the reactor core:

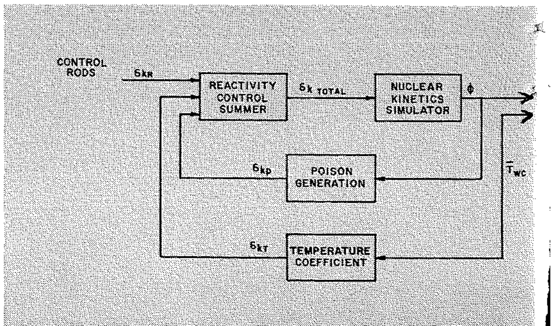
$$P_r = M_f c_f \frac{\delta \bar{T}_f}{\delta t} + K_c (\bar{T}_f - \bar{T}_{wc}) \quad (10)$$

$$K_c (\bar{T}_f - \bar{T}_{wc}) = M_{wc} c_w \frac{\delta \bar{T}_{wc}}{\delta t} + w c_w (T_{oo} - T_{ic}) \quad (11)$$

$$T'_{oo} = T_{ic} + \frac{K_c (\bar{T}_f - \bar{T}_{wc})}{M_{wc} c_w} \tau_c \quad (12)$$

$$T'_{oc} = T_{oc} + \tau_c \frac{\delta T_{oc}}{\delta \tau} \quad (13)$$

Fig. 2—Nuclear kinetics system.



The power level P_r is determined by the reactor-kinetics portion of the simulator and is proportional to neutron density.

The core and steam generator are represented on a mean temperature basis. This approximation is acceptable for an enriched reactor with small thermal capacity and the usual high transfer rates.

Equation 10 equates the power from the fuel to the heat stored in the fuel elements and the heat transferred from the fuel to the primary core. Equation 11 represents the heat passed to the primary coolant from the fuel elements, and equates that to the heat stored as a change in average reactor-core temperature plus a change in temperature of the primary coolant between the inlet and outlet of the reactor. No other losses from the reactor are considered, since they are very small compared to the heat transferred to the primary coolant. Total heat out of the reactor then shows up only as a rise in temperature of the primary coolant. This is reflected as either a ΔT across the reactor or a change in the average temperature.

Equation 12 shows that the temperature of the primary coolant at the outlet of the reactor equals the temperature of that mass of water at the inlet of the reactor plus the temperature rise due to heat transferred to it in passing through the reactor. To measure the temperatures at the correct time, it is necessary to delay measuring the outlet temperature until the inlet water has had time to pass through the core. Another way to accomplish the same thing is to anticipate the outlet temperature at a time τ_c (the time it takes the primary coolant to pass through the core) before comparing it with the inlet temperature. This is represented by Equation 13, which shows that the anticipated outlet temperature equals the present outlet temperature of the reactor plus a temperature which is proportional to the transport time through the reactor core and the rate of change of the outlet temperature. Fig. 5 shows a possible mechanization of the entire thermal simulation.

The above equations describe the heat balance in the core. The heat removed from the reactor is taken to the steam boiler through two lag networks to represent the time lag in the plenum chamber and piping. These lags are of the form:

$$\frac{T_{out}}{T_{in}} = \frac{1}{1+s} \qquad (14)$$

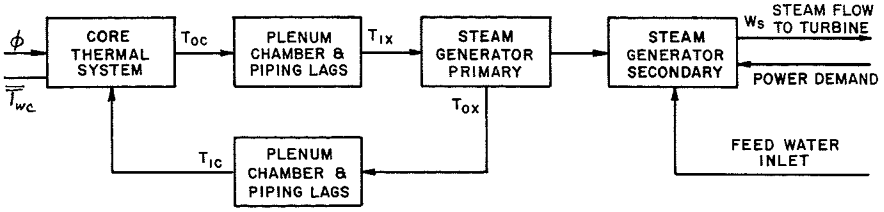


Fig. 4—Plant thermal system.

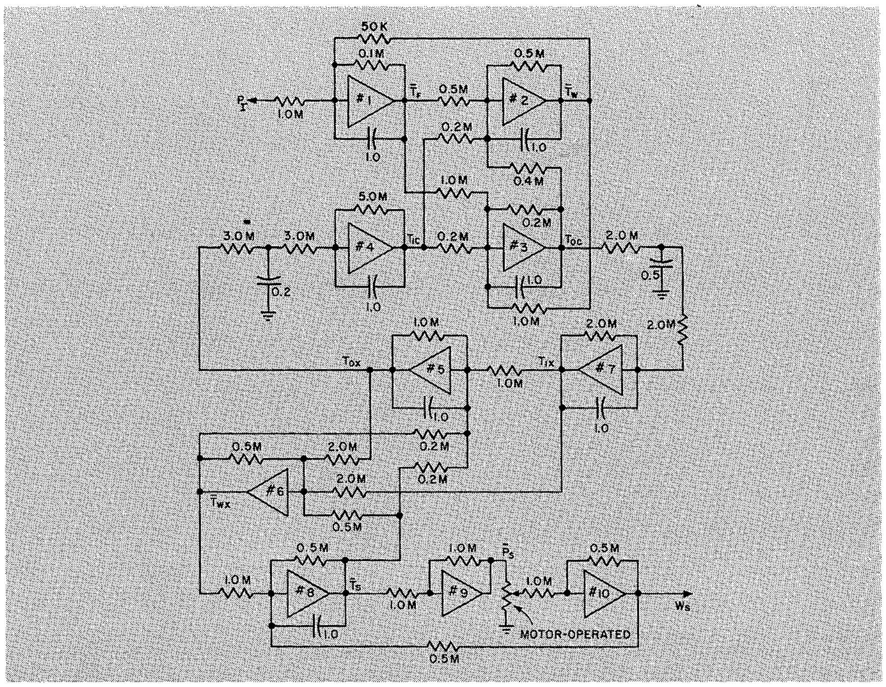
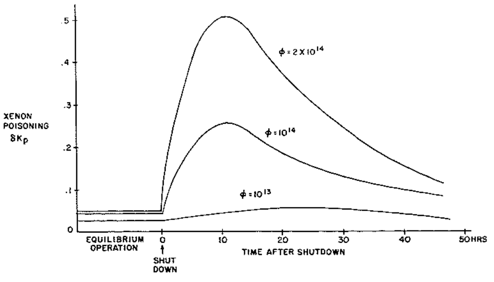


Fig. 5—Mechanization of the plant thermal system.

Fig. 3—Xenon poisoning before and after shutdown for various values of flux.



The heat contained in the primary coolant after it passes from the reactor through the pipes to the steam generator is transferred directly to a secondary system represented by a boiler partially full with water, the balance consisting of saturated steam. The transfer is represented by Equation 15:

$$wc_w\,(T_{ix} - T_{ox}) = K_b\,(\overline{T}_{wx} - \overline{T}_s) \qquad (15)$$

$$K_b\,(\overline{T}_{wx} - \overline{T}_s) = M_sC_s\frac{\delta T_s}{\delta t} + K_s w_s \qquad (16)$$

$$T'_{ox} = T_{ix} - \frac{K_b\,(\overline{T}_{wx} - \overline{T}_s)\,\tau_b}{M_{wx}c_w} \qquad (17)$$

$$T'_{ox} = T_{ox} + \tau_b\frac{\delta T_{ox}}{\delta t} \qquad (18)$$

Equation 16 assumes that all heat transferred from the primary coolant to the secondary system contributes to a change in temperature of the secondary system or is removed as steam to the steam turbine. It is assumed that:

$$\frac{\delta T_s}{\delta t} = \frac{\delta \overline{T}_{ss}}{\delta t}$$

Other losses are neglible. The third equation shows that the heat out of the heat exchanger equals the heat in at some previous time, minus the heat which is lost in going through the heat exchanger. Here again, as in the core, the temperature at the outlet is measured at some anticipated time representing the transport time through the heat exchanger, so that the temperature of the same volume of water is measured at both inlet and outlet.

Piping and plenum chamber lags are simulated in transferring the primary water back to the reactor in a manner similar to that which was used in transferring the coolant from the reactor to the boiler.

Simulation of the APPR-1 turbine-generator is accomplished by using a small motor-generator. Motor speed is regulated by a simple electronic speed control similar to industrial motor-

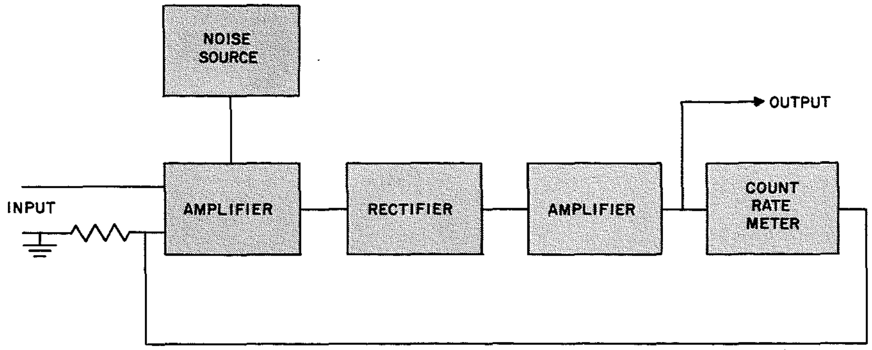


Fig. 6—Start-up random-pulse generator.

control devices. The a-c generator is driven by the motor through gearing. Since a generator with a permanent magnet field is used, the actions of the field excitation and voltage regulator controls are simulated by generator-output potentiometers. During synchronizing operation, the generator output is coupled to the line voltage through the appropriate breaker relay and synchronizing relay contacts. A synchroscope is provided for line synchronization, similar to that used on the APPR-1.

HUMAN ENGINEERING

In designing a reactor simulator it is not only important to have a computer that will satisfactorily generate signals that simulate the actual reactor, but also to have the operator in an environment much like the actual reactor. Only then is it possible to train personnel effectively. Fig. 1 shows both the actual reactor control console and the simulator. The similarity is obvious. Most of the differences were planned in order to reduce costs, but the basic operating procedures for the simulator are identical to those of the reactor.

The only other major exception is the console that appears in the foreground of the simulator photograph (Fig. 1). This is the instructor's console and permits him to simulate faults that are not possible on the actual reactor. For example, the instructor can make it appear that the primary pumps have failed in the cooling system, or he can make it appear that the power level is increasing rapidly. These operations would be too hazardous to perform on an actual reactor, but it is very helpful to provide such experience in order to train the operator to react properly in case of emergencies.

START-UP RANGE

To illustrate this point further, a discussion of the start-up range is warranted. The neutron density, or power level, of a reactor is determined during the lowest three decades by a counting device such as a fission counter or BF_3 counter. Both of these devices generate a pulse each time a neutron initiates an ionizing event. Since this is a statistical occurrence, it is possible to see a random fluctuation in counting level and period (period being the time that it takes to change power level by a factor of e). A short period then means that power level is changing rapidly. A pulse-generating device of this type could be simulated easily with a variable-frequency oscillator, a limiter, and a differentiation network. However, the pulse separation would be uniform, and for a constant power level, the period would be very steady and equal to zero. This would not be a good simulation, though, since under these circumstances, the period meter in a normal reactor facility fluctuates considerably with statistical variations in pulse rate.

In order to simulate properly the count rate and period at low-power levels it is necessary to have a randomly varying pulse generator whose average rate is proportional to reactor power level. The block diagram shown in Fig. 6 illustrates how this can be done. A d-c signal proportional to power level from the analog computer is used to bias an amplifier, into which is put wide-frequency-bandwidth noise of 3- or 4-volt amplitude. This signal is rectified, further amplified, and then put into a count-rate meter or integrator. The output of the integrator is fed back with negative polarity to the input so that the count rate automatically follows the input. The output random pulses are then taken from the input of the count-rate meter for visual display of count rate and period.

It is the consideration of details such as this that makes the difference between a true simulator and simply an analog computer. The analog computer only represents about 20 percent of the cost of the entire APPR-1 simulator. Aside from the details of the reactor kinetics, it is also necessary to simulate all of the various control circuits such as system pressurization, liquid level, and steam pressure.

OPERATING EXPERIENCE

To determine the effectiveness of training reactor operators on the APPR-1 simulator, a group of students were given a fixed number of hours of training on the simulator with no training on the reactor. A second group of students were given the same number of hours of training on the reactor with no simulator training. These two groups were then both tested for reactor operating ability on the reactor. It was found that the simulator-trained operators were much superior in operating ability and were trained at much less cost.

Actually, the optimum training course includes both simulator and reactor training, with a very large percentage of the time allocated to the simulator because of the lower operating cost, lack of hazards, and exposure of the student to more operating situations.

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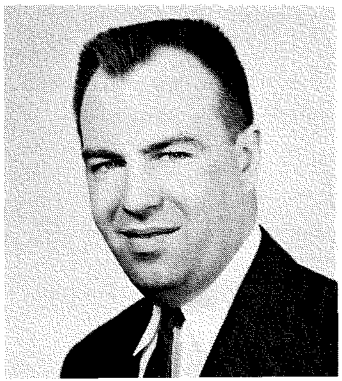
HARRY REESE, JR. received his BS in EE from Carnegie Institute of Technology in 1944 and a Master's Degree from the same school in 1948. From 1944 until 1946, he served in the U.S. Navy, with the rank of Lt. (jg), as Radar Officer on the Aircraft Carrier *Croatan*. He was employed as a development engineer for the Brown Instrument Division of Minneapolis-Honeywell from 1946 until 1949. From 1949 to 1952 he was employed as a development engineer at the Oak Ridge National Laboratory, where he worked on the Aircraft Reactor experiment and high-voltage accelerators. During this time, he was co-developer of a new-type r-f ion source. From 1952 to 1958, he was Assistant Manager, Nuclear Power Department, Curtiss-Wright Research Division, responsible for supervision of the Physics Section, including reactor physics, instrumentation, hot lab, research reactor, and health physics. In August 1958 he joined the RCA Service Company as Manager of Atomic Energy Services, where he has been responsible for all of the Service Company's atomic energy programs including C-Stellarator installation, radiation services, reactor-simulator design and construction, and radiation-instrumentation maintenance, calibration, and installation.



Electronics is basically a business of information-handling, and much of the information is visual in nature. The importance of electro-optics is evidenced by the many systems and products employing electro-optical components—photo-tubes, TV camera tubes, kinescopes, electrostatic storage tubes, flying-spot scanners, light amplifiers, photoconductors, electroluminescent materials, etc. Some new tools—**fiber optics, Electrofax,** and the **optical tunnel**—are of considerable importance in current RCA development of a number of new or improved electronic systems.

NEW USES OF ELECTRO-OPTICS

by **D. J. PARKER, Mgr.**
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Fig. 1—A fiber-optics bundle, illustrating the principle of transmission of light, element-by-element.

THE APPLICATION OF electro-optic techniques by RCA to its products dates back to the pioneer days of sound recording on motion-picture films and to the early work with electronic facsimile systems. Today, probably our most notable electro-optical products are TV broadcast equipment, live-TV cameras, film-reproducers, and closed-circuit TV systems. Even the magnetic video recorders are part of an electro-optical system, since they begin and end with electro-optical transducers.

Other important RCA electro-optical systems are bottle and ampule automatic-inspection equipment, paper- and glass-inspection machines, and high-speed facsimile systems. In addition, there are a number of RCA military systems of major importance that achieve highly sophisticated data-processing through the use of electro-optical correlators and optical-processing[1] concepts.

Complex analog computer operations made possible by these techniques contribute importantly to RCA's future in radar systems and undersea warfare.

ELECTRO-OPTICAL CAPABILITIES

Electro-optical systems or devices can be classed as those employing electrical-to-optical, and optical-to-electrical transducers. They provide a versatile, high-speed, and nearly inertialess analog of mechanical operations: for example, rotation, change in magnification, and translation. Information processing, such as addition, integration, multiplication, and correlation, can be accomplished in two dimensions. In general, these operations can be performed with much simpler equipment and at higher speed than with conventional electronics.

The outstanding characteristic of electro-optical systems is that light can be imaged, because of its short wavelength. Many parallel channels can thus be handled without providing discrete hardware for each channel.

The modern TV system, one of the simplest in function of current electro-optical systems, is illustrative of the basic ability of electro-optics. All of the scanning operations performed by the camera tube and kinescope display could be duplicated by mechanical scanners—as was indeed tried before the invention of electronic scanning tubes. But the limited speed and mechanical inertia of such devices made them impractical. Also, the provision of an additional function in the camera tube (storage and integration) yielded an enormous increase in sensitivity over photocell—mechanical-scanning systems.

NEW ELECTRO-OPTICAL TOOLS

Recently, a number of new electro-optical tools have become available to the engineer and are presently being used in the development of more-capable systems. Some of these tools which merit particular mention are *fiber optics, Electrofax,* and the *optical tunnel.*

Fiber optics, a versatile engineering principle,[2] is the technique of transferring an optical image, element-by-element, from one place to another (Fig. 1). Fiber optics are used as faceplates for camera and cathode-ray tubes, flexible bundles between objective lens and image plane, and as shape transducers. When rearranging the elements of an image, while the information is in optical form, fiber optics provide a wider latitude than when one tries to "do it with mirrors."

The Electrofax electrostatic printing process allows a permanent record or display of optical information to be made with a time lapse of only a few seconds. It is competitive with rapid-process film systems, with the difference that it results in "hard copy" rather than a transparency. In electro-optical systems, the information may be "contact-printed" onto Electrofax through fiber optics as shown in Fig. 2.

The optical tunnel has the capability of creating a multitude of identical optical images out of a single presentation or of merging many optical presentations into one (Fig. 3). This function can also be performed with multiple lenses, but not with as many optical channels or as good optical quality as is possible with the optical tunnel.

NEW SYSTEMS

Two new electro-optical systems, which use the new tools mentioned above, have been selected to illustrate the enormous capability of electro optics. Each of these systems has great potential as a new product for RCA.

Electro-Optical Memory

The extension of electro-optical techniques to new fields is well illustrated by the electro-optical memory now being constructed by DEP Applied Research. The extraordinarily high packing density obtainable on photographic emulsions and the extremely low cost per bit of the basic memory element make photographic stores particularly attractive for semi-permanent, high-capacity memories. Conventional mechanical search of this type of memory is much too slow, however, and very high light intensities are required for an adequate signal-to-noise ratio. The use of electro-optical techniques in combination with photographic storage results in a memory of unparalled performance.

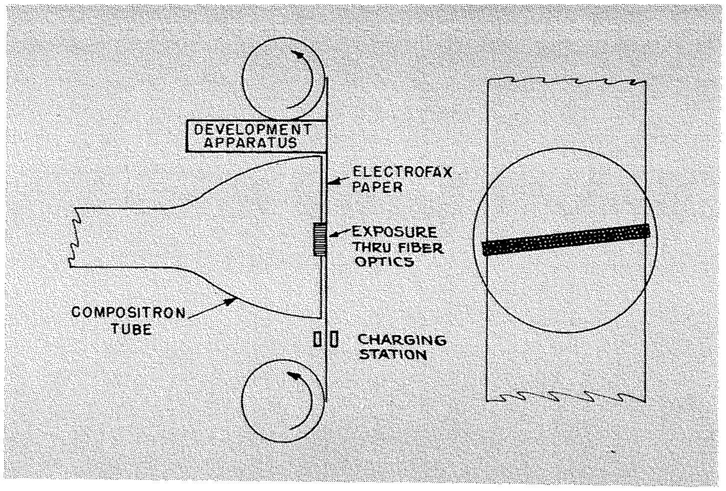


Fig. 2—Printout of an image onto Electrofax by fiber optics.

The electro-optical random-access memory consists of a number of identical parallel channels, each having a capacity of 10,000,000 total bits. The memory itself is a photographic plate. A test plate being used in the present breadboard memory is shown in Fig. 4; it contains a small proportion of the total number of binary bits in the memory channel, each bit being a minute square area which is either black or white.

The basic unit of the memory device, the channel, consists of a kinescope, photographic plate, lens, optical tunnel, and image dissector as shown in Fig. 5. The kinescope is used simply to illuminate a particular *cell* of the photographic plate. There are 1,000 such cells on each plate, and each cell contains 10,000 bits in an array of 100-by-100 bits.

The photographic plate is imaged by the lens onto the sensitive surface of an image-dissector camera tube. Between the lens and this image plane, there is an optical tunnel. All of the cells in the memory, by successive reflections from the walls of this tunnel, appear superimposed at the exit aperture of the tunnel; only the section which has been illuminated, however, is visible.

The image dissector, a nonstorage camera tube, reads out the proper bit from the 10,000 bits displayed at the exit aperture of the optical tunnel. Thus, anyone of the 10,000,000 bits in the channel can be interrogated by a combination of two pairs of x, y addresses.

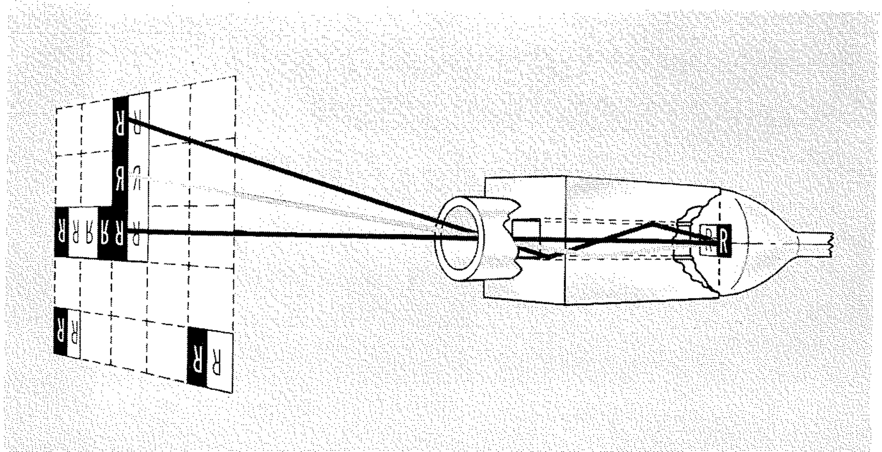
Since the address is completely electronic, the read-out rate from this memory is very high. A 38-channel memory, for example, is capable of storing the contents of 100 books, and will read out any word in one millisecond. Such memories are greatly in demand for catalogue storage, and for dictionary use in language translation.

High-Resolution Reconnaissance and Facsimile

The shape transformer properties of fiber optics can be used to great advantage at both the input and output ends of aerial reconnaissance or facsimile systems. Very-high-resolution, line-scan TV systems may be synthesized, as shown in Fig. 6, by combining a fiber-optics frame-to-line converter with camera tubes having fiber-optics faceplates. For example, 40 scanning lines on a conventionally scanned image orthicon may be transformed by a fiber-optics bundle into a single-line scan having a resolution 40 times that of the resolution of the individual scans. Thus, TV can be made to view a very-wide angle with high resolution, which is not possible with conventional TV techniques. A similar fiber-optics transducer attached to the faceplate of a cathode-ray tube would reassemble the elements into a single line image for printout onto Electrofax paper.

This type of system allows a great sensitivity increase over high-resolution film systems and a great increase in signal-to-noise ratio relative to photo-cell spot scans.

Fig. 3—Sketch showing multiple images obtained with an optical tunnel. Note that reflections occur on the interior walls of the tunnel: one is a top-wall reflection causing an image inversion; the other, a side-wall reflection causing an image reversal. The number of reflections determine the position of the image in the array.



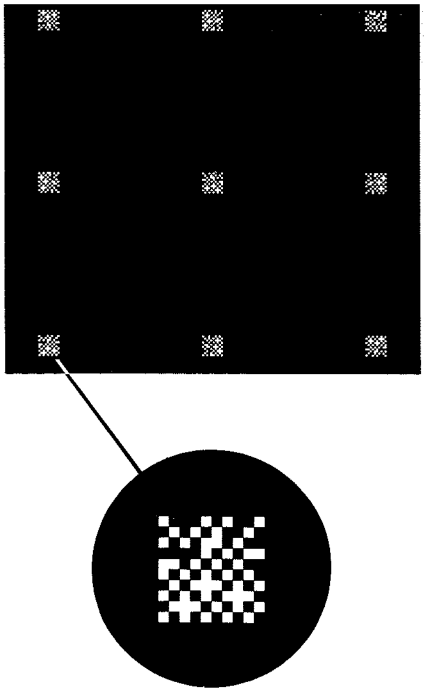


Fig. 4—Photographic storage matrix used in the present electro-optical memory model.

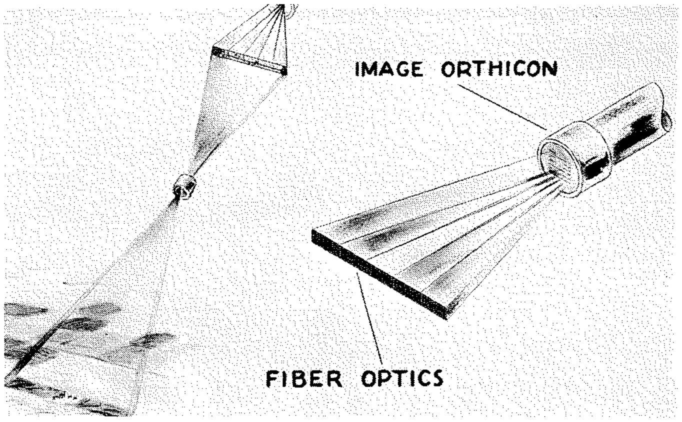


Fig. 5—Basic electro-optical memory model.

ELECTRO-OPTICS IN THE NEAR FUTURE

It is a reasonable certainty that the machine designs of the future, which inevitably will increase in required intelligence, will rely heavily on electro-optical techniques. Direct computation will, of course, take over some of the jobs as large computers become cheaper and faster, but the sophisticated performance of analog electro-optical techniques will play an important role for a long time.

For those who supply the tools used in the design of such electro-optical systems, it is already apparent that there are a few tools whose development would allow rapid growth in the performance of such systems. For example, some of these are:

1) Camera tubes and display tubes of higher resolution without any decrease in brightness.
2) Simple, fast, cheap light valves insensitive to the angle of incidence of the light they control.
3) Higher performance optical systems (Some systems are already limited by the performance of a single lens. Lenses are limited to a transfer of about 10,000,000 spatial bits of information over the field of view of the lens.)
4) A rapid writing, rapid erasing, reusable photographic transparency material.
5) Higher performance (resolution, linearity) image converter tubes, since they allow image translation and change in magnification without any raster scanning process. These tubes can replace camera-tube, kinescope combinations in many electro-optical systems and do a better job.
6) Storage display kinescopes with high resolution and sub-millisecond erase times.
7) Item No. 4 with nonlinear response for automatic contrast compression.
8) High-performance electrostatic deflection cameras and display tubes for fast asynchronous scanning.
9) Practical internally "servo-operated" camera tubes and kinescopes to solve the problem of accurate and reliable addressing.

As a concluding thought, engineering design practice in electro-optics will undergo some major revision in the near future. Some of these trends are already apparent: 1) the increased use of the Fourier transform characteristic of coherent optical systems, 2) the increased use of closed-loop deflection systems for camera tubes anad display for greater precision, and 3) integration with other major design fields—for example, the use of standard digital plug-in boards for video and deflection circuitry.

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DONALD J. PARKER graduated with a BS in Optics from the Institute of Optics, University of Rochester, in 1950 and immediately joined RCA. He has been responsible for the development and design of optical systems for a variety of commercial and military equipments. In 1954 he was named Leader of the Optics Group in General Engineering Department, DEP; and in 1957 he was appointed to his present position of Manager of Applied Physics in the Applied Research Section of the Defense Engineering Department. His group is doing applied research in atomic resonance, electrostatic printing, electro-optical systems, and magnetohydrodynamics. Mr. Parker is a member of the Optical Society of America, the Society of Motion Picture and Television Engineers, the Society of Photographic Engineers, and the IRE.

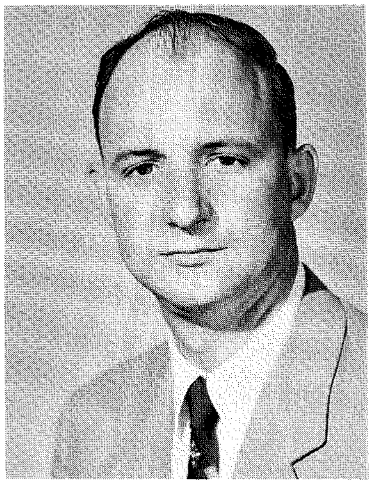
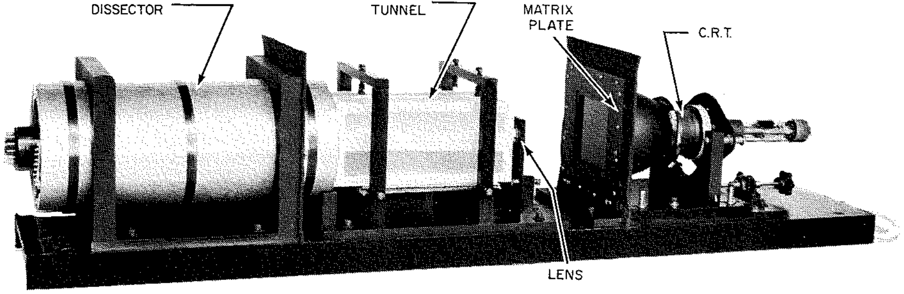


Fig. 6—Very-high-resolution, line-scan television system.



GRID MANUFACTURING—PERPETUAL DEVELOPMENT

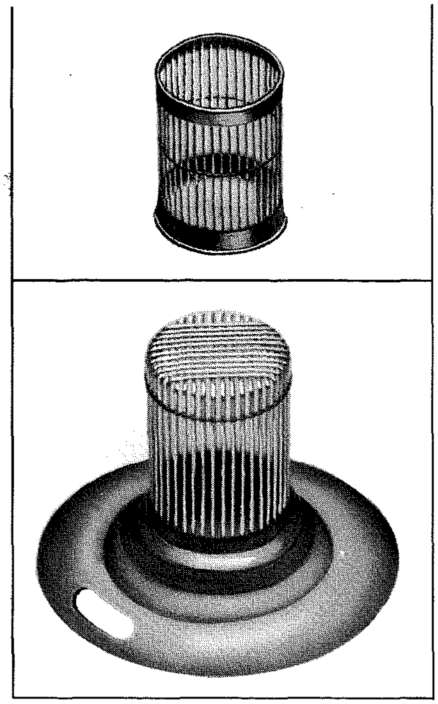


Fig. 1—Control (top) and screen grids for tube types 4X150A and 4X150D.

by **J. J. SPENCER**

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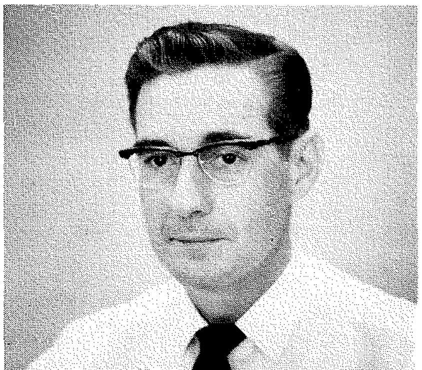
THE METHODS FOR manufacturing many tube components are selected on the basis of potential tube-type business. Stated in another way, the capital outlay for production facilities is directly proportional to the expected volume of tubes to be produced. Many of the medium- and high-power tube types are produced in relatively low volume; consequently, automatic special-purpose production facilities are not too common. However, some tube types, although not produced in large volume, have remained on schedules for several years as good steady business. The 4X150A and 4X150D have been such tube types. As a result, considerable emphasis has been placed on these tubes and their components as a means of maintaining quality and competitiveness.

JACK J. SPENCER was graduated from the University of Alabama in 1952 with a BS in Industrial Engineering. After graduation, he joined RCA as a specialized trainee assigned to the Parts Manufacturing activity. His engineering work has been primarily in the manufacturing areas of inspection, coil and heater winding, and grid fabrication. He holds memberships in AIIE, SAM, and Alpha Pi Mu.



Both the 4X150A and 4X150D are beam power tubes designed for use at frequencies up to 500 megacycles at an output rating of 140 watts. These tubes are used in radio, television, and even amateur broadcasting transmitters, as well as in both commercial and military aircraft transmitters, beacon transmitters, and instrument-landing equipment.

The control and screen grids (Fig. 1) of these tubes are discussed herein because the labor content involved is relatively high and the operator dexterity required is considerable.

GRID STRUCTURE

These grids are composed of 44 gold-plated molybdenum lateral wires held in place by nickel support rings and wrap wires. In manufacturing,

1) the grids are wound and welded,
2) cleaned by firing in hydrogen,
3) quality inspected for conformance to specifications,
4) double gold plated to reduce emission, and
5) quality inspected for plating and final dimensions.

Although several economic studies were made, it was never possible to justify the expense involved in the design and construction of completely automatic production equipment. It was therefore decided to reduce the parts cost by incorporating relatively simple and inexpensive labor-saving devices into the existing production scheme.

LATERAL WIRE

The grid of a power tube, which is located between the plate and cathode, not only receives a considerable amount of radiated heat from these electrodes but also heat generated by electron bombardment. To withstand high temperatures, the grid wires are normally made of tungsten, tantalum, or in the case of the 4X150A and 4X150D, molybdenum. The heat is dissipated by radiation from the wires and by conduction along the grid supports (Cruft Electronics Staff, *Electronic Circuits and Tubes;* McGraw-Hill Book Co., pp. 425-426, 1947).

For best manufacturing results, the straightness, surface condition, elongation, and tensile strength of the molybdenum lateral wires must be controlled. Straightness helps determine the finished grid diameter. The surface condition affects the quality of gold plating which the grid receives prior to mounting. The combination of elongation and tensile strength is maintained within limits to minimize winding and trimming difficulties.

Grids of this general construction, which are fabricated by welding techniques, require that the excess wires adjacent to the collar welds be broken off. For ease of operation, the wires should break easily and at an angle approaching ninety degrees. On the other hand, the wire should not be so brittle that excessive breaking occurs during the winding operation. Elongation and tensile-strength characteristics of the wire best describe this particular grid-making requirement. For example, the relationship of brittleness to tensile strength on the screen-grid wire is shown in Fig. 2. By means of similar techniques, the upper tensile-strength limit is also determined.

WINDING INSERTS

Fig. 3 shows the grid insert which serves the dual role of winding mandrel and welding electrode. The copper alloy inserts, which have grooves for each lateral wire, must be made to diameter tolerances of 0.0005 inch for minimum welding difficulties and maximum life.

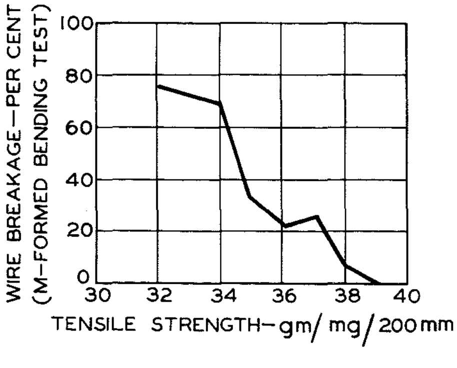
The depth of the grooves should be approximately one third of the wire diameter to provide for proper wire alignment and for proper welding. A groove which is too deep permits the wrap wire to touch the welding mandrel, as illustrated in Fig. 4, and often results in poor welds.

As the insert becomes worn, the grooves get deeper and wider; this condition causes irregularities in grid diameter and wire perpendicularity. For this reason, a constant check on insert conditions is maintained.

WINDING OPERATION

Grids are wound manually, and a two-month training period is required to develop a fully trained and efficient

Fig. 2—Brittleness vs. tensile strength.



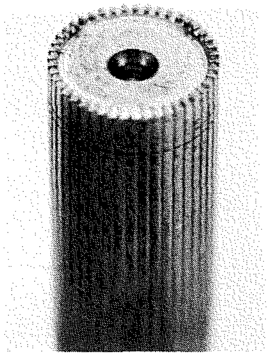


Fig. 3—Control-grid winding mandrel and welding electrode.

operator. This training is accomplished by the use of a detailed right-hand, left-hand operation chart, a training film, and instructions by experienced personnel. Even though the support rings and winding inserts are held to close tolerances, and supplementary jigs and fixtures are employed where necessary, the human element is important.

WELDING METHODS

Bonding of the molybdenum wire to the nickel support rings is primarily accomplished by flowing the molten nickel around the wire through the use of a resistance welder. Although a definite amount of molybdenum recrystalization takes place, the welding temperature does not reach a point high enough to melt the molybdenum.

The control grid is welded on a miniature sensitive welding head that utilizes an electrical-discharge power supply. The screen grid, which is made of material approximately twice as thick, is welded on a light-duty welding unit. In general, conventional welding equipment is used; however, certain features have been altered or incorporated.

Originally, the welding machines were foot-operated and the grid-holding chuck was indexed by hand for each weld. An operator both wound and welded each grid. A methods analysis showed that better utilization of time could be realized if a team approach was taken; that is, if one operator did all of the winding and a second operator performed all of the welding. At the same time, a power supply was added to the welding machine to actuate the welding head automatically. This power unit consists of an air cylinder which reciprocates by actuating microswitches. Thus, by depressing a pedal, the operator starts the welding cycle and maintains constant welding speed and uniform pressure. The yearly cost savings which resulted from the change in method and from the addition of power units amounted to $33,000. Moreover, these revisions reduced operator fatigue and improved product quality. These units were added to each of the welding stations at an over-all cost of $3000.

The next step was to reduce or eliminate nonproductive elements, such as waiting, holding, guiding, and indexing, to improve the man-machine working ratio. Accordingly, a simple levering device, connected between the reciprocating air-cylinder shaft and the indexing hand wheel, provided automatic indexing. Various stops, wire guides, and aligning fixtures were also added to reduce the chance of human error and to decrease the operational time.

These additional modifications freed the operators' hands during the welding operation to perform other elements of the work cycle, such as removing the grid from the insert and removing the excess lateral wires from the grid. Again, for a minimum outlay of money, a very favorable return was realized—capital outlay $2400, yearly saving $20,600. The reduced parts cost naturally helped to reduce tube costs and improve RCA's competitive position.

Fig. 4—How a deep groove can result in a poor weld.

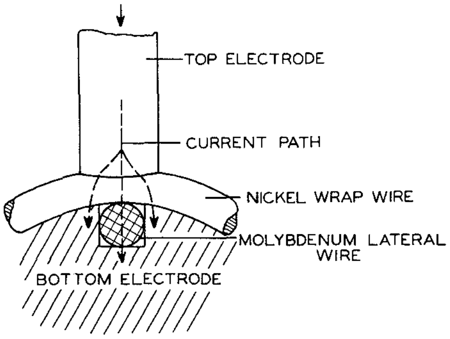
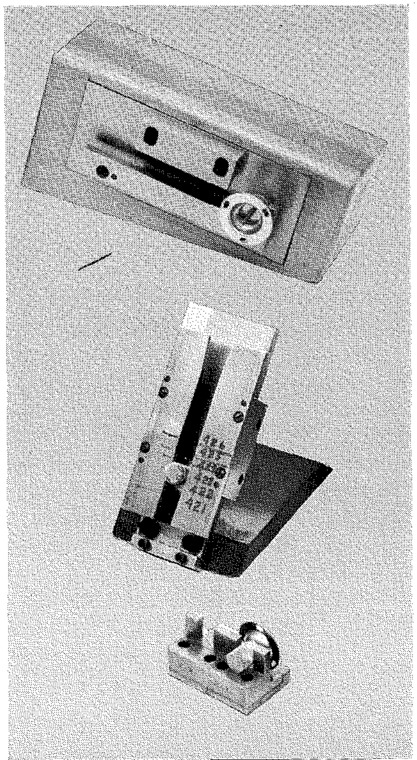


Fig. 5—Gages for screen-grid diameter.



INSPECTION TECHNIQUES

The quality level of grids is maintained by means of sampling the product during fabrication and by providing a thorough inspection after all processing is complete. The items which are rigidly controlled include inside and outside diameters, weld quality, and wire alignment and straightness.

Various devices for the inspection of certain physical characteristics have been employed over the years. For example, the grid diameter has been checked by means of the following types of gages shown in Fig. 5: 1) straight-sided "go-no-go" gage, 2) tapered-opening inclined gage, in which the part slides, and, 3) fixed-opening inclined gage in which the part rolls. The latter gage utilizes a plug which not only provides the needed mass for the rolling action, but also checks inside diameter of the part. This "rolling gage" provides the most complete diameter inspection, in that grid out-of-roundness as well as individual bent wires can readily be detected. Although both grids are well designed for strength, extreme handling precautions are observed.

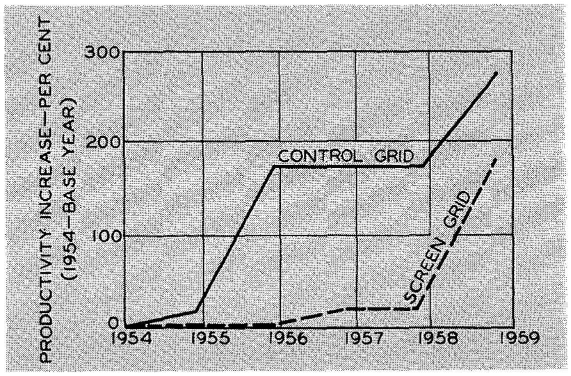


Fig. 6—Rise in productivity, 1954-59.

SUMMARY

Just as there are various types and designs of grids, there are also various procedures for fabricating these grids. The general procedure described for making the 4X150 squirrel-cage grids has been in use for several years and, as Fig. 6 indicates, a substantial increase in productivity has resulted during this period. This higher productivity has been brought about through the efforts of many people, and undoubtedly many innovations will yet be introduced before the 4X150 family becomes obsolete.

Development work on production items on the factory floor is constantly being carried out by factory personnel to reduce costs and to maintain RCA's competitive position. For today, more than ever before, it is necessary to move forward or risk being left behind.

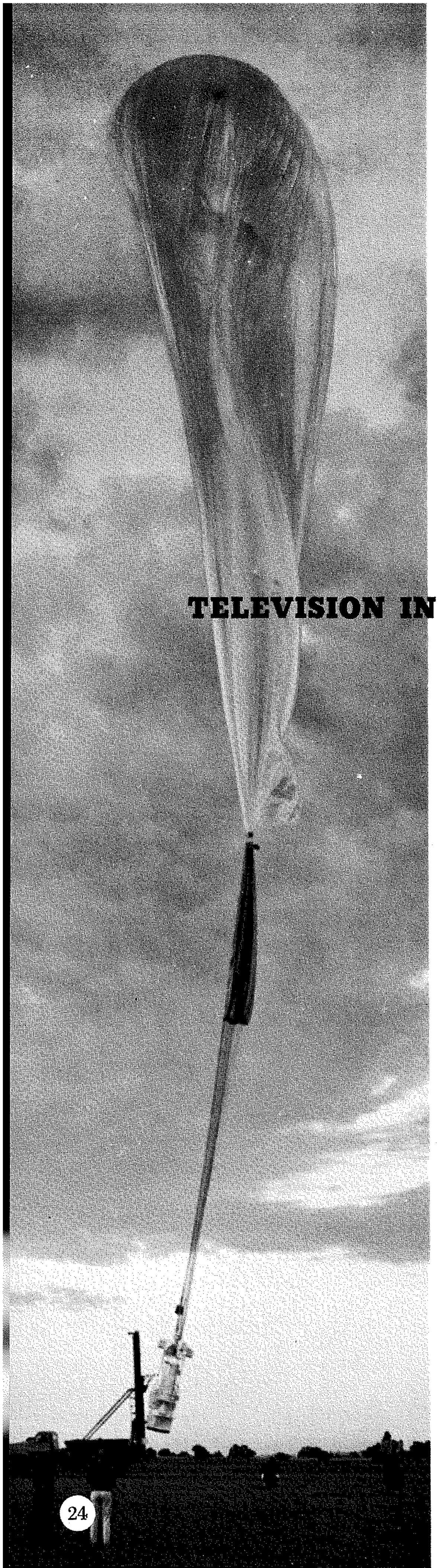


Fig. 1—The Stratoscope I just before launching.

TELEVISION IN ASTRONOMY—THE STRATOSCOPE I

by

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An astronomical problem which antedates even the day of Galileo's discovery of the telescope is the phenomenon which astronomers call *seeing*. To an astronomer the word *seeing* has a specialized meaning: it refers simply to the disturbing effects which the earth's turbulent atmosphere have on the resolution of earthbound telescopes. Indeed, it may be shown that a modest 12-inch reflecting telescope would have resolution better than Mt. Palomar's 200-inch colossus if it could somehow be removed from the atmosphere, particularly the turbulent layer called the tropopause which starts at an altitude of about 40,000 feet.

Recently, RCA Laboratories participated in a project, Project Stratoscope, which did just this. Stratoscope I is a balloon-borne telescope designed for high-altitude solar photography. RCA supplied a special TV system so that astronomers at a ground control point can see where Stratoscope I is aimed and how well it is focussed. By means of a ground transmitter, corrective commands can then be sent to the equipment aloft, permitting precise remote control of focus and aiming.

TYPICAL OPERATION

A typical flight starts before dawn with the launching of the balloon and telescope. About two hours are required to reach the operating altitude of 80,000 feet; at this altitude, the equipment is turned on by a timer. Automatic servos then orient the telescope in azimuth and elevation so that it sees the sun. After a waiting period to permit the various portions of the telescope to come to thermal equilibrium, the active part of the flight begins. An automatic film camera on the telescope starts and exposes one frame of film each second. The TV camera is also turned on, and the astronomer in charge—at the ground-control point—can aim and focus the telescope by viewing the TV screen. At the end of about three hours the film is exhausted. Automatic mechanisms now stow the telescope within the gimbal structure and then cut loose the balloon, which is not recovered. The telescope with its film and TV cameras descends to earth on a parachute so that it may be re-used. The exposed film, which constitutes the useful result of the flight is removed and developed. Fig. 1 shows a view of the telescope and balloon just after launching. The vertical distance from the top of the balloon to the bottom of the telescope is about 300 feet and the polyethylene balloon is inflated with 1,000,000 cubic feet of helium.

DESIGN PROBLEMS

As the electrical and mechanical design of the TV system had to be integrated rather carefully with the telescope itself, a number of problems arose requiring solutions and techniques quite different from those normally encountered in commercial broadcast practice. It was specified that the resolution of the TV system was to be equal to that obtained in normal studio practice and that a range of 150 miles must be attainable. At the operating altitude of 80,000 feet, the temperature is about —55°C and the pressure about 1/40 atmosphere.

Existing mechanical shutters in the telescope and film camera were arranged to expose the film once each second, the duration of each exposure being about 1.5 milliseconds. It therefore seemed logical to relate the TV frame rate directly to this system. A vertical frame rate of one frame per second was accordingly adopted. The horizontal scanning rate then followed naturally from this, 500-line resolution requiring a 500-cycle horizontal-scan frequency. Interlace was not used in order to avoid a complicated and possibly unstable sync generator aloft.

An advantage of the low frame rate is that lower bandwidth and transmitter power are required. A bandwidth of 200 kc is adequate for 500-line resolution at these scanning frequencies. Calculation showed that an FM transmitter with 200-kc deviation (modulation index = 1) and a power of 0.8 watt would be ample under ideal conditions with the receiver and antennas expected to be used. The conservative approach of providing 10 watts was adopted.

BALLOON-BORNE EQUIPMENT

A block diagram of the equipment aloft is shown in Fig. 2. Light entering the telescope is imaged at the film gate of the film camera and the faceplate of the TV pickup tube (vidicon) by an optical system comprising a primary 12-inch parabolic mirror and a number of subsidiary mirrors and lenses. Exposure duration and rate are controlled by a rotary shutter. A beam splitter following the shutter apportions the light between the TV and film cameras. After some preliminary experiments, an additional rotary shutter was installed in the path to the TV camera only. This was geared to permit only every third exposure to reach the vidicon, the two intervening ones being blanked out. This expedient was found necessary to reduce image blurring caused by the storage properties of the vidicon obtaining at the low scanning rate.

Vertical sawtooth and blanking signals for the camera were first generated electromechanically by a potentiometer and cam-operated microswitch on the 1-rps shaft of the film camera. Initial experiments with this system established that the vertical sawtooth so produced was not sufficiently free of noise, having both cyclic and random disturbances of small amplitude superimposed upon it. These produce undesired shading in the picture. An electronic vertical sweep circuit was finally substituted for the potentiometer with entirely satisfactory results. The microswitch is phased with the shutter system so that the latter illuminates the vidicon during the vertical retrace. Horizontal scanning and blanking signals are generated by circuits within the camera. Because of flashover problems associated with the high operating altitudes of the equipment, any units involving potentials over about 200 volts must be pressurized. The camera and transmitter are thus enclosed in pressure-tight housings (Fig. 4).

The video output of the camera is applied to a 2-watt commercial FM telemetry transmitter operating at 225.7 mc. This unit is used to excite a 10-watt power amplifier which feeds the antenna system.

POWER SOURCE

Power for the TV equipment aloft is supplied by lead-acid storage cells. Although there are other batteries which offer advantages in weight and efficiency, lead cells are easy to maintain, will withstand many charge-discharge cycles and are inexpensive. As weight was not a severe problem they seemed the best compromise. A disadvantage of lead-acid cells is the relatively large drop in voltage which occurs during discharge. At the battery temperatures and discharge rates involved in this system, the voltage drop is about 20 percent. As the TV system proper would not tolerate such a drop, the problem was overcome by regulating all critical voltages in the TV system with transistor regulators. Transistor dc-dc chopper converters were used to obtain the high voltages required by the vidicon and the transmitter.

GROUND EQUIPMENT

A block diagram of the ground station is shown in Fig. 3. Signals from the balloon are picked up on a pair of stacked Yagi antennas mounted on commercial antenna rotators. The antenna gain is about 15 db over an isotropic source. Motion in both azimuth and elevation may be remotely controlled from the TV operator's position. A 200-mc high-pass filter is provided at the receiver input to ensure that no spurious signals are picked up from the command and communications transmitters also located in the ground station. The command transmitter operates on 138 mc and is used to operate the airborne focussing and pointing equipment on the telescope. The communications transmitter is normally operated at about 7 mc and is used to maintain communications with the crew tracking the balloon for recovery purposes.

The incoming signal from the balloon TV system on 225.7 mc is applied to a commercial FM telemetry receiver. Its bandwidth is about 0.5 mc, and its noise figure is about 6 db. The receiver output, at a level of about 8 volts peak-to-peak, is applied to a distribution amplifier.

The latter provides three isolated outputs for the three monitors so that a defect in one will not disable the others. It also incorporates a small amount of high-frequency boost to improve the system response at the higher video frequencies. Conventional vacuum-tube circuits are used in the receiver and distribution amplifier.

Signal from the distribution amplifier is applied to three transistorized TV monitors, one of which is used by the TV operator. It is his function to continuously ride the controls of the TV system to present to the astronomer's monitor the best possible picture. The latter is the second monitor. A third monitor provides signal to a continuously-running photographic camera which records the transmitted pictures for check purposes. A photograph of one of the monitors is shown in Fig. 5.

AUXILIARY EQUIPMENT

A few auxiliary units were also supplied. A shading generator controlled by the TV operator permitted the insertion at the monitors of a small amount of additive shading. As certain features of the sun's disk which the astronomers especially wish to study were of low contrast, the shading generator proved

Fig. 2—Television system (taken aloft)

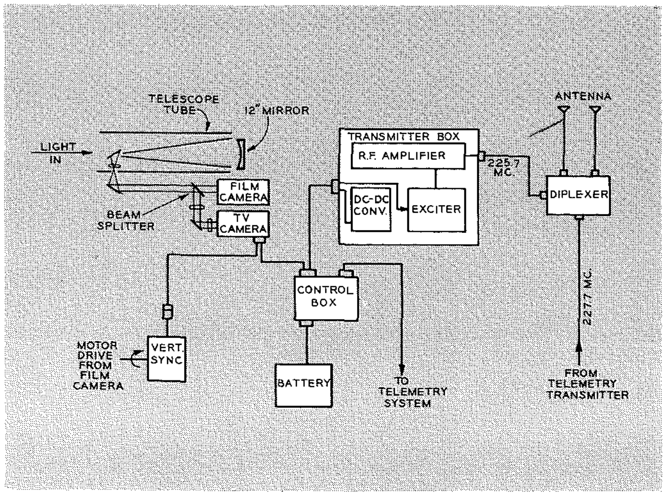
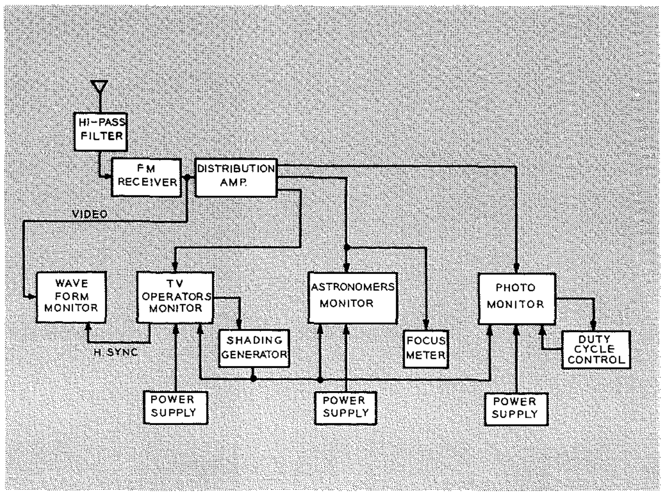


Fig. 3—Ground station.



useful in providing shading controls so that maximum flatness of field could be obtained over the surface of the vidicon target. At the astronomer's monitor, a focus meter was also made available to indicate the amount of high-frequency information in the video signal. As the latter is a maximum at best focus, the meter reading is helpful in adjusting the telescope optics. This type of system will not work with normal TV program material, but will work on certain types of images; the solar-granulation type of picture is a good example. A duty-cycle controller was also fitted to the photographic monitor to blank it out during the two frames intervening between the active frames. It will be remembered that a shutter aloft permitted only every third exposure to reach the vidicon faceplate.

CIRCUIT STABILIZATION ALOFT

As the equipment aloft is inaccessible during flight, considerable attention had to be paid to through stabilization of all balloon-borne circuitry. As mentioned earlier, a sync generator was eliminated on these grounds. Necessary operating controls were reduced to two—vidicon-target voltage and video black level. These controls were extended to the ground via the telemetry and command circuits. All other controls were preset at launch and required no further adjustment.

All circuitry aloft, with the exception of the transmitter, was fully transistorized to save weight and power; printed wiring boards were used. Fig. 6 shows the entire telescope during ground tests.

SPECIAL ANTENNA SYSTEM

RCA Laboratories also developed a special antenna system for Stratoscope I. This was needed to prevent interference from the telemetry transmitter which was separated from the TV transmitter by only 2 mc. To prevent mutual interference these two transmitters were diplexed into a common antenna via a stripline *rat-race diplexer* so that in effect, neither transmitter knew of the other's presence. The antenna itself comprised a symmetrical array of four unipoles suspended beneath a ground plane attached to the bottom of the gimbal structure. It may be considered as a sort of vertically polarized cousin of the familiar turnstile often used in TV broadcasting.

The ground-control station was mounted in a van, which may be seen in Fig. 7. In the photograph, the double Yagi antenna is the TV receiving array. The remaining antennas were for the command and telemetry systems which were the responsibility of another con-

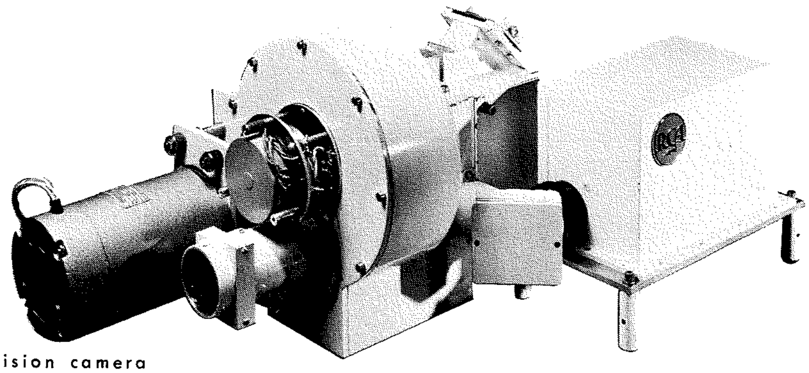


Fig. 4—Television camera (right) and film camera and driving motor (left).

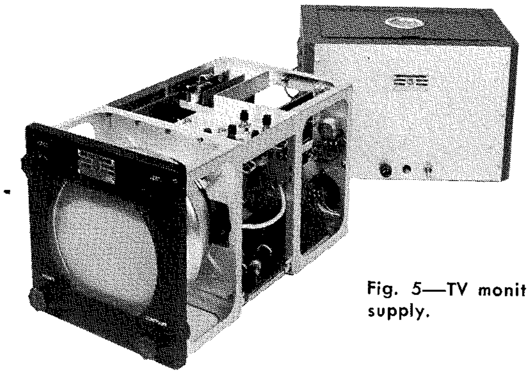
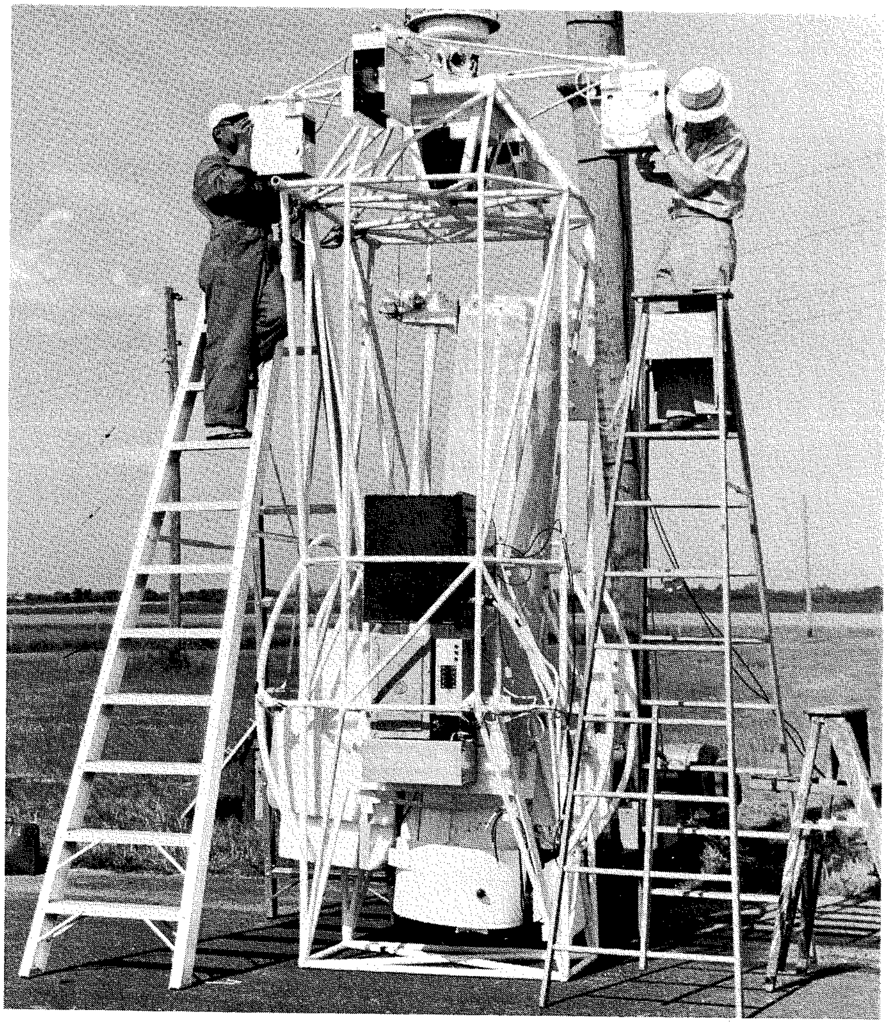


Fig. 5—TV monitor and power supply.

Fig. 6—Telescope during ground-testing.



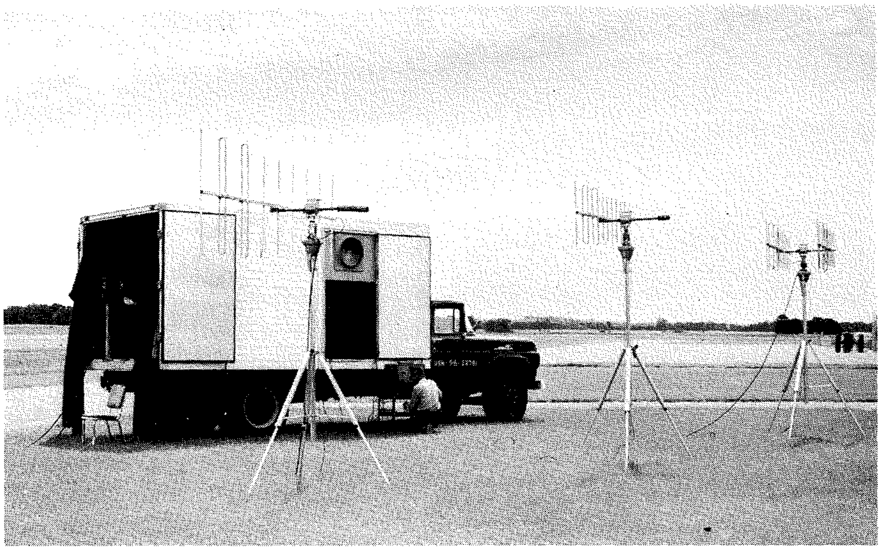


Fig. 7—Van containing ground-control station equipment.

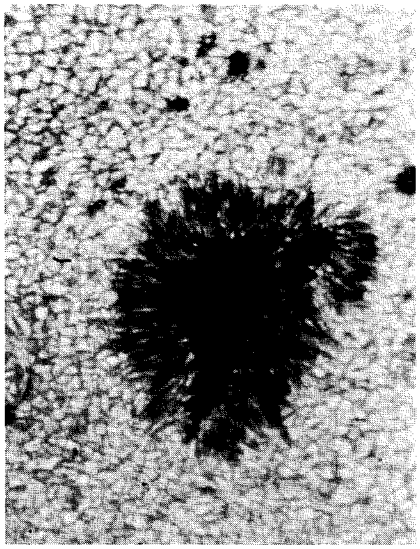


Fig. 8—A large sunspot photographed by Stratoscope I.

tractor. Power for the ground station was provided by a pair of trailer-mounted, engine-driven generators.

FLIGHT PERFORMANCE

Stratoscope I made a total of four flights during the summer of 1959. In all of them, the TV equipment functioned satisfactorily, enabling the telescope to be focused well within the theoretical focus tolerance. It also greatly assisted the astronomer in charge in finding sunspots and other areas of interest on the surface of the sun.

On the second flight, for example, the balloon camera obtained over four-hundred photographs, superior in quality to any similar photographs ever taken before by any telescope. The use of the TV system vastly increases the yield of useful pictures, one of which is shown in Fig. 9. The large sunspot visible in the photograph is about 5000 miles in diameter.

ACKNOWLEDGEMENTS

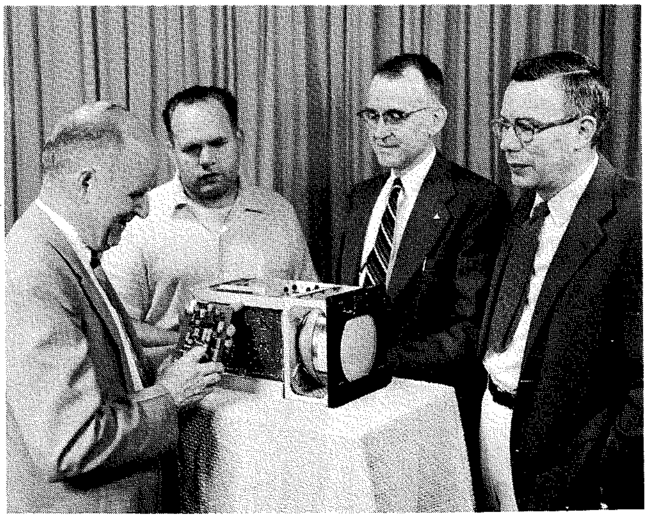
Project Stratoscope was sponsored by the Office of Naval Research and the National Science Foundation. It was under the direction of Dr. Martin Schwarzschild of Princeton University. In closing, it is a pleasure to acknowledge the interest and direction of Dr. V. K. Zworykin and the assistance of many members of the RCA Laboratories staff. Some of the basic slow-scan circuits were derived from designs of E. A. Boyd and R. Davidson (see *Slow-Scan TV: Military Applications and Commercial Potential*, RCA ENGINEER, Vol. 5 No. 3, p. 57). O. M. Woodward, J. Epstein, and W. Maxwell also rendered invaluable assistance in the design and testing of the special antenna and diplexer.

L. E. FLORY received the BSEE from the University of Kansas in 1930. He was with the research division of RCA Manufacturing Co., Camden, N. J. from 1930 to 1942, engaged in research on TV tubes and related electronic problems, particularly in the development of the iconoscope. In 1942 he was transferred to the RCA Laboratories, Princeton, N. J. From 1949 to 1954 he was in charge of work on storage tubes and since 1949 has been in charge of work on industrial TV. More recently, he has been concerned with applications of transistors to TV circuits and with medical electronics problems. He is a member of Sigma Xi and a Fellow of the IRE.

GEORGE W. GRAY attended Princeton University as a civilian and in the Navy V-12 Program until 1943 when he was assigned to active duty in the Navy. After release to inactive duty in 1946, he returned to Princeton University and received the B.A. degree in Physics. In March of 1947 he joined the technical staff of RCA Laboratories Division at Princeton, N. J. He is at present a member of the General Research Laboratory engaged in TV research. He is a member of Sigma Xi.

JEREMIAH M. MORGAN studied at Drexel Institute. In 1929 he was employed by the Victor Talking Machine Company in Camden, N. J., in the test department. With the absorption into the RCA Manufacturing Co. in 1930, he was transferred to the TV laboratory engaged in circuit design. He has continued in this line doing circuit development work on electron microscopes, TV, and special test equipment, transferring to the RCA Laboratories in Princeton, N. J. in 1942. Since 1948 he has been engaged in the development of industrial TV equipment. He is a Member of the IRE and an Associate Member of the Franklin Institute.

WINTHROP SEELEY PIKE received the B.A. degree in Physics in 1941 from Williams College. He served with U.S. Army Signal Corps during World War II as radar officer and later as project officer in charge of the Signal Corps Moon Radar project. In 1946 he joined the research staff of RCA Laboratories Division at Princeton, N. J., where he has worked on sensory aids for the blind, storage tube applications, color TV and industrial TV.



L. to R.: Flory, Gray, Morgan and Pike

INTERIOR COMMUNICATION FOR NUCLEAR SUBMARINES

by **T. E. ROLF**

Interior Communications and Speech Processing, Surface Communications Division
DEP, Camden, N. J.

This new submarine interior-communication system, conceived by SurfCom and manufactured by DEP in Camden, will be used on nuclear submarines of both the "Fleet" attack and Polaris-missile type. It represents a major advance in submarine interior communication technique. This story of its engineering describes well how such a crash program affects the design approaches.

THE RECENT COMMISSIONINGS of the Polaris-missile nuclear submarines *USS George Washington* and *USS Patrick Henry* were of vital importance to our national defense. Keeping pace with their ultramodern conception, they are equipped with a new, integrated communications system conceived and developed by the SurfCom Interior Communications Group under M. L. Graham. Fig. 1 illustrates some of the typical components of a nuclear submarine outfitted with this equipment.

Previously, a number of individual equipments were installed in a submarine to provide the variety of interior communications needed. Now, the new system, designated AN/WIC by the Navy, is designed as a completely integrated system and provides the equivalent of eight independent interphone and public-address sets, together with electronically-generated alarm signals. The amplifiers and alarm signal generators are completely transistorized, semiconductor rectifiers are used in the power supplies, and the power supply is backed up with a nickel-cadmium storage battery which will provide several hours of full-scale system operation in the event of a-c power failure.

EARLY COMMUNICATIONS STUDY

The story of the AN/WIC-1 actually began in 1952 when the Navy awarded RCA a contract for the study of contemporary submarine interior communications. The study was made by a committee composed of M. E. Hawley, W. F. Meeker, and the author. As part of the survey, they rode submarines *USS Sea Robin*, out of New London, and the *USS Bashaw*, out of San Francisco, recording and measuring ambient noise and traffic on the interior communication circuits and assaying crew-member communication needs. The committee found existing facilities inadequate by crew standards as well as by their own.

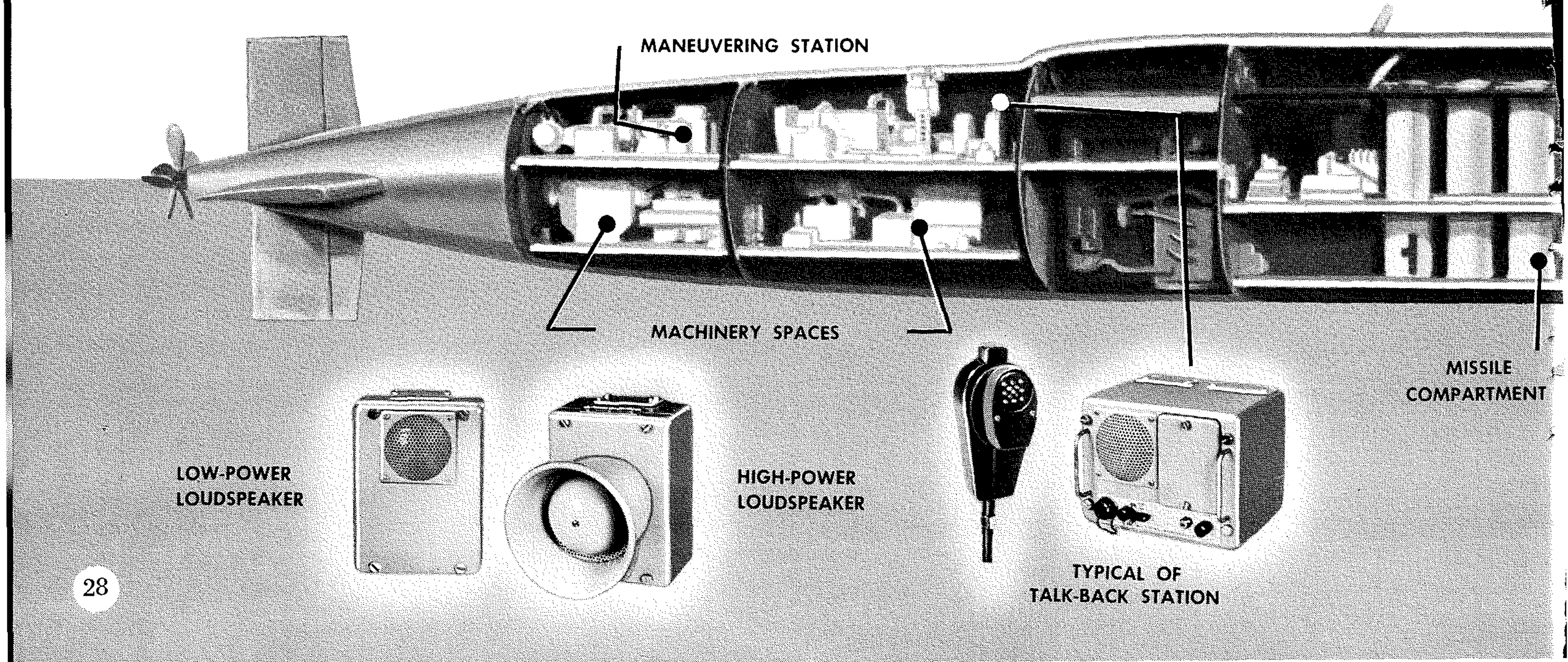
The second phase of the contract, the design and construction of an evaluative system, then began. Resulting was the IC/KXS Intercommunication System, installed aboard the *USS Croaker* in 1956 for evaluation of the system philosophies which had evolved from the study phase. It was to have been a six- to twelve-month trial, but the system performed so well that it has been retained aboard.

ORIGINAL THREE-YEAR PLAN

The favorable report by the *USS Croaker* resulted in the start of negotiations between the I.C. Section of the Bureau of Ships and SurfCom for a new program concerned with the interior communications of a guided-missile, nuclear-powered submarine. The aim of the new program, which was planned to cover a period of about three years, was first to evaluate the previous study with respect to the needs of the new vessel, make such additional studies as would be required to determine new interior communication requirements, and recommend and design a complete system. Secondly, equipment was to be designed for the system. This equipment was to be as advanced as possible using semiconductor devices for amplification, rectification and switching to the greatest possible extent. Long, maintenance-free life, extreme ruggedness and a high degree of reliability were primary criteria. The final phase required the manufacture of several complete systems which were to be installed for full scale evaluation of the project.

A "STEPPED-UP" ONE-YEAR PLAN

Obviously, this ideal program of system study, design and evaluation was too good to be true. Suddenly, in March 1958, RCA received a letter contract from the Navy to *condense the entire task into a span of 12 months* for application to three Polaris submarines. Included was a crash program to design, build, test and deliver the first system in eight months. Many long hours by SurfCom audio engineers and supporting personnel went into the effort toward making a December deadline. (Before the program was well



underway *two more* systems were added to the task, for delivery later in 1959.)

Something had to be cut from the original program. First to go was semiconductor switching; relays would be used. The leisurely system study analysis was contracted into a few informal sessions with the Department of the Navy submarine experts and with the Electric Boat Division, General Dynamics Corporation at Groton, Connecticut, where the Polaris submarine was also under a crash design-construction program. It was decided to expand the results of the original system study, apply this to the new requirements, and pick up the pieces along the way. Transistor amplifiers and tone generators would utilize the existing state-of-the-art and the know-how of the audio-engineering group. Here was a fortunate situation, for the SurfCom audio systems group had been evaluating and successfully applying transistors for about seven years. The impetus of the Polaris program consolidated this experience into a group of semiconductor devices giving every promise of meeting the stringent requirements of nuclear submarine service.

To provide sufficient equipment for the system required the design of 46 different items. These make up the 40 intercommunication stations, about 70 loudspeakers distributed throughout the vessel for general paging and transmission of orders, a central cabinet with power supplies and alarm generators, and a considerable number of junction and receptacle boxes together with headset and microphone accessories.

Concurrently with the design and fabrication of the equipment, a formidable technical manual was being written, and a set of "Navy" drawings was being prepared.

Close cooperation with the electronic design group at Electric Boat made it possible to obtain an excellent estimate of the quantity of equipment required for the five vessels and as soon as educated guesses could be made as to the electrical components required, procurement of the long term items was started. To the glory of all concerned, the accuracy of these guesses can be modestly termed phenomenal.

NEW SYSTEM REQUIREMENTS

The basic intercommunication requirements for submarines have been well established through years of operating the conventionally powered and considerably smaller vessels of the prenuclear fleet. Where the same control functions are being exercised, the same scheme of interior communication is adaptable to the newer vessels, particularly since the element of familiarity will ease the transition to newer equipment. The increase in size of the craft, of course, requires an expansion of the interior communication facilities. One of the additional considerations, for example, is the need for communication among the highly specialized engineering force handling the power plant of the vessel with its complex maze of steam turbines and auxiliary equipment. The missile-launching facilities and the organization required for the check-out and control of the missiles adds still further to the communications requirements of the Polaris type. The studies previously mentioned had indicated a considerable need for *intercom* type of communication between the various major control points in the vessel. Two communication facilities not previously found on submarines are also included in the system. One of these is an emergency reporting system whereby a report of trouble or damage may be made instantly and directly from any compartment to the control room. The second is a portable intercommunication station which may be taken "topside" when the vessel is in port or at anchor, and provides communication between the deck watch and the interior of the submarine.

Fig. 2 is a diagram of the intercommunication plan evolved for the system requirements of the Polaris type submarine. The first five circuits shown on this diagram are identified by a code which is arbitrary but has a standardized meaning in the Navy. The MC does not mean megacycles, but indicates an *amplified voice communication* circuit. The associated numerals indicate by reference the type and function of the particular circuits. Thus, for example, the Ship Control or 7 MC circuit serves the organization concerned with

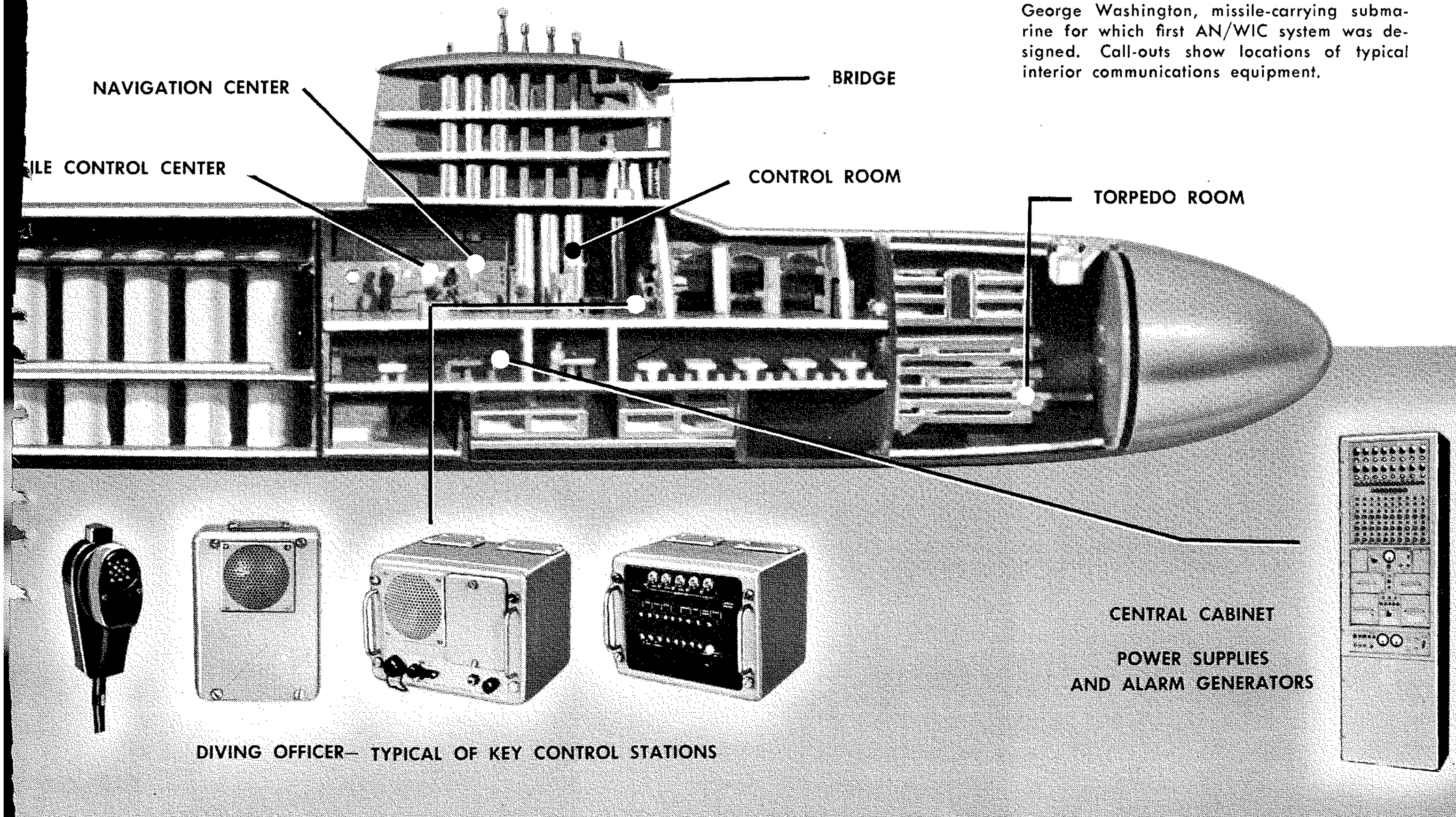


Fig. 1—Cut-away view of scale model USS George Washington, missile-carrying submarine for which first AN/WIC system was designed. Call-outs show locations of typical interior communications equipment.

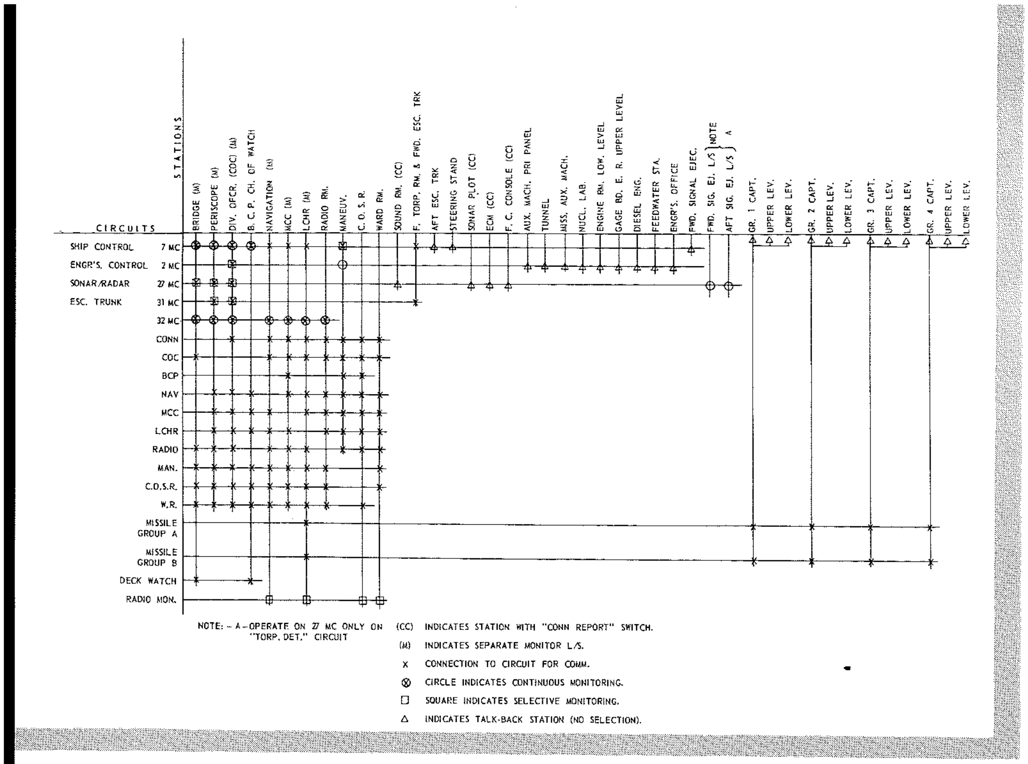


Fig. 2—Intercommunication chart showing how the AN/WIC system satisfies the Polaris-type submarine requirements.

the speed, direction and depth of the vessel and the Engineer's Control or 2 MC circuit provides service for the people in the various machinery spaces who are concerned with the propulsion plant.

Fig. 3 is a block diagram of the interior communication system designed for *USS George Washington* and its sister vessels. These two charts illustrate the system design approach based on the philosophy of providing each major operation with a party line or a loop circuit which links the personnel concerned with a particular operation. In addition, a number of key stations are provided with access to one or more of these major circuits for the purpose of obtaining or giving specialized information. It will be noted on Fig. 2 that the diving officer has access to five of the special circuits shown. This is necessary, for when the submarine is operating submerged the diving officer has a very complex function to perform and may require information from some or all of the organizations. The conning position, at the periscope station when operating submerged or on the bridge when the vessel is operating on the surface, is the master control station; this station has priority on the general announcing system and on the ship control circuits.

Not the least of the subsystems is the 1 MC, or general announcing, system. Over this system from a couple of the key points in the submarine go the important general announcements and instructions which must reach all parts of the ship; such as "pay call," the call to dinner, and "battle stations." Also over the 1 MC system are broadcast the alarm signals; the classical general alarm gong and diving alarm horn, as well as some new ones developed in the course of the job for the Polaris.

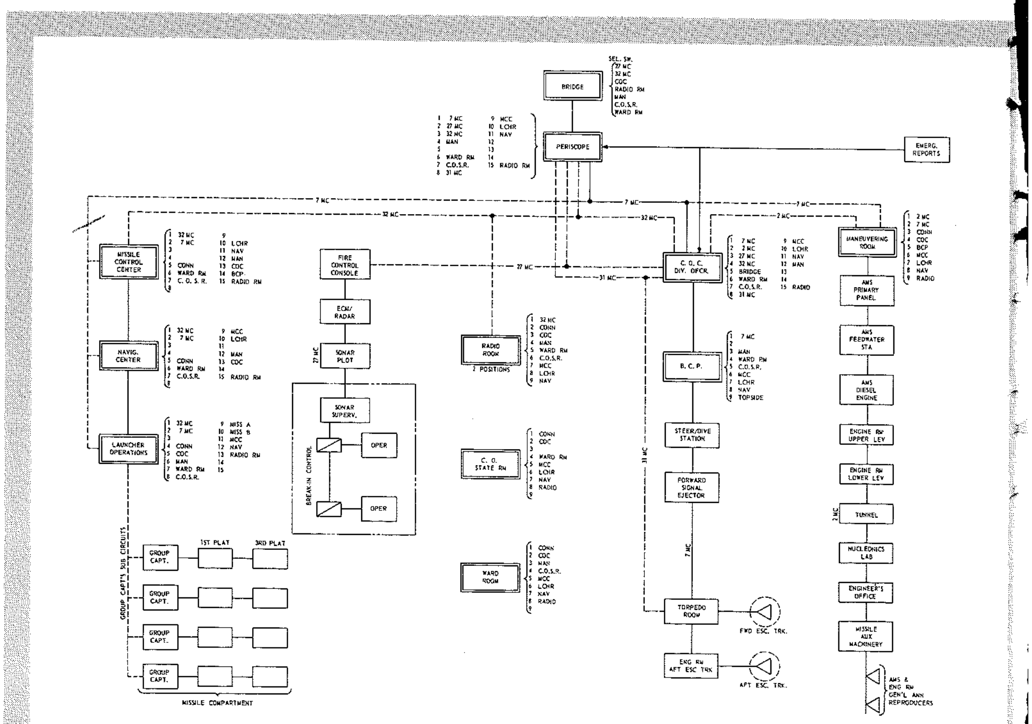
SYSTEM DESIGN CONSIDERATIONS

In order to get the design of the electronic portions of the system under way, it was necessary to formulate a few specifications concerned with the setting of the audio levels at which the system would operate, the type of transmission and receiving characteristics desired, the volume levels to be sought at receiving stations and at loudspeakers, and the type and character of such transducer accessories as the microphones, the headphones and the loudspeakers.

As already mentioned, there was no time to look for new devices; those available would have to be used. The transducer group had available the design of a comfortable headset with a noise-cancelling, boom-mounted, microphone attached. At about the same time, the transducer group was starting the development of a noise cancelling microphone for the Bureau of Ships. It appeared feasible to expect the development of a new microphone in time for use as one of the accessories with the AN/WIC system. As a hedge, it was decided to establish dual input impedances for the microphone preamplifiers; a 5-ohm input to work with the standard U.S. Air Force noise-cancelling microphone and a 150-ohm input to work with the standard Navy microphone and the new Navy microphone under development. The 5-ohm input would also be suitable for the loudspeaker-microphone of the intercom station. The microphone input level was also established with a range from —60 dbm to —33 dbm. This spread took into account the sensitivity of the microphone types under consideration and the expected output levels which would result from the way people would use an intercom or a microphone. Because of previous experience with the 4-watt loudspeaker mechanism from the LS-166/U loudspeaker, this mechanism was chosen for the basic station talk-back box and the low-power general announcing loudspeaker.

Experience had also demonstrated that an audio input up to 1-watt would provide an acoustical output suitable

Fig. 3—Block diagram of the interior communication system designed for the USS George Washington and sister vessels.



for most of the spaces in the submarine. In the noisy machinery compartments of the submarine, however, much more power would be required and because of size considerations, a loudspeaker as small as possible was desired. The small, highly efficient, re-entrant horn speaker, type LS-211/AIC, was chosen and it appeared that with up to 20 watts of audio input, these loudspeakers would satisfactorily cover the machinery spaces. The choice of nominal 1-watt and 20-watt loudspeakers established the output-power levels of the system.

In the interest of standardization of circuits as well as components, the audio amplifier requirements were divided into three areas. The first area was covered by a microphone preamplifier which incorporated a delayed agc to compensate for the different types of microphones which might be used and to compensate for the changes in speaking voice levels and distance from the microphones. The second area was covered by an audio amplifier of nominal 1-watt rating but with sufficient audio power output to supply the low-power loudspeaker unit with nearly its maximum of 4-watt input. The third area was covered by an amplifier having an output capability of 20 watts for driving the high-powered, horn-type loudspeaker. With a 1-watt amplifier available, it was decided to use 1 watt as the distribution line level so that the same amplifier could be used for this purpose. It was decided to operate the line at an impedance of 150 ohms and use a series bridging resistor of approximately 30,000 ohms for the receiving amplifier, probably for no other reason than that it had already been successfully done in the AN/AIC-10 system developed by the audio group several years previously. The attenuation provided by this combination is approximately 46 db in the worst condition.

Fig. 4 is a system level diagram prepared from the data formulated from the discussions on the transducers and transmission line levels. The line levels indicated on the chart are the maximum levels planned. In practice the loudspeakers will be operating at a level suitable for the space to be covered, by adjusting internal volume controls. Each talk-back station is also equipped with a volume control adjustable by the operator so that the volume may suit receiving conditions at the station. The transmission line level, however, is standardized and no provision is made for adjustment during operation. It will be noted from the diagram that the alarm signal modules are standardized in output to drive the 1-watt line amplifier so that the alarm signals, too, are transmitted at the standardized line level.

With these data on the input and output impedances and on the system gain requirements, the amplifier and signal generator circuit design went ahead while the equipment packaging and design plans were started.

EQUIPMENT DESIGN CONSIDERATIONS

As might be expected, the term heard most in the course of the equipment design was reliability. Considering that the vessel was expected to be away from its base on long missions and would be crammed full of complicated gear requiring the attention of the ship's electronic experts, the aim was to provide an intercommunication equipment for which the maintenance instructions could be, "as long as it works, leave it alone." The use of transistors and solid-state rectifiers was expected to provide the first long step in this direction. Contrary to the practice with the previous tube amplifiers and signal generators, there would be no need for regular checks of tube conditions nor for the regular replacement of the electron devices.

In the amplifier and generator designs, all components were used very conservatively. A stress analysis of the circuits, based on a continuous duty factor at the maximum elevated temperature, indicated a mean life expectancy of 40,000 hours, or approximately five years. When considered under more practical conditions, that is, operating under an intermittent duty cycle as would be usual with an intercommunication system, and in the pleasantly air-conditioned interior of a modern submarine, the mean life expectancy could be expected to approach ten years. There was an indication that the electronic portions of the system could be expected to equal or perhaps exceed the life of the mechanical devices such as switches and volume controls used in the equipment. Under those circumstances, it seemed ridiculous to provide means for the plug-in installation of the transistors; the sockets would be the weakest elements. Therefore, the smaller transistors are soldered directly to printed wiring boards along with the resistors and capacitors and the entire assembly is conformally coated with an epoxy resin to provide further climatic protection for the electronic circuits. The power transistors are also connected by soldered leads.

POWER SUPPLY

In order to develop a power output from the transistors under considera-

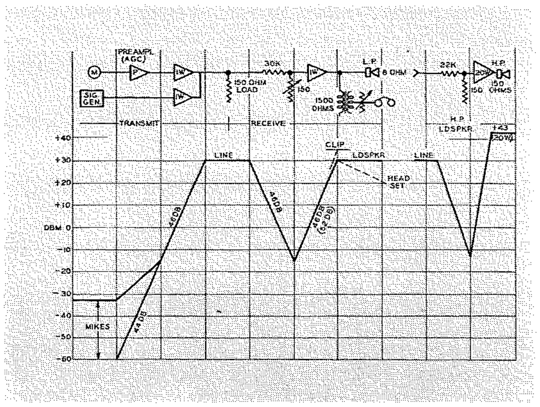


Fig. 4—System level pattern for AN/WIC.

Fig. 5—AN/WIC project meeting. Left to right: J. P. Massari, R. A. Perry, H. W. Clay, A. D. Llewellyn, S. L. Flateau and T. E. Rolf.

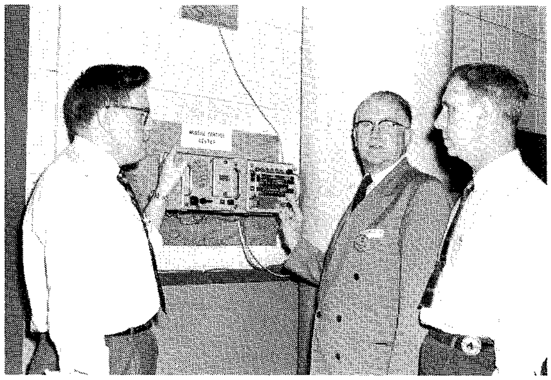


Fig. 6—Manager M. L. Graham (center), with A. D. Llewellyn (left) and T. E. Rolf, reviews the system operation.

Fig. 7—S. L. Flateau (left), Jess DiRemigio and R. B. Nelson confer on system testing setup for AN/WIC.

tion, it was determined that the most-suitable power-supply voltage would be approximately 24 volts d-c. Good relays, with reliability proved in aircraft use, were available for this voltage supply and a system working on 24 volts d-c does not offer any great hazard to personnel working on the various junction boxes and control stations of the system. This operating voltage was selected.

Another step in the direction of assuring system reliability was taken by including a storage battery in the power supply consideration. This storage battery supplies power for operating the communication system in any emergency which disrupts the primary a-c power. A nickel-cadmium type battery was chosen because it can stand in any state of charge or discharge for long periods, can withstand high rates of discharge and charging, and can float on a power supply line at slightly elevated voltages for long periods without harm. The power supply and storage battery were combined in view of the special power demands of the system. The normal current demand on the busiest circuit is not more than 5 or 6 amperes. On most of the intercom circuits, the demand is much less. As a matter of fact, the panel illumination lamps and indicator lamps in most cases draw more current than the amplifiers. The maximum current demand in the system occurs when one of the alarm signals is being transmitted over the entire general announcing system. This peak current demand approaches 25 to 30 amperes, but its duration probably does not exceed 4 or 5 seconds.

The rectifier power-supply is designed for a maximum current capacity of 16 amperes, with a regulation curve set so that when approximately 6 amperes is drained, the d-c output voltage falls to 24 volts from a normal no-load voltage of 28 volts. The battery, a nominal 24-volt unit, floats on the power-supply line at the 28-volt level. This voltage is just below the level at which cell-gassing occurs. With a light current demand, the system voltage is held essentially at 28 volts. When a system demand occurs which would normally drop the power-supply voltage to 24 volts, the storage battery tends to hold up the system voltage for demands of short duration. If the demand persists, the battery voltage will gradually fall to the 24-volt level as the load is shared between the battery and the power supply. During the short peak demands of 25 to 30 amperes, the battery again supplies the additional current, this time falling more rapidly to the 24-volt level. When the demand ceases, the battery will take as much charge as is required from the power supply until its voltage again rises to the 28-volt quiescent level.

Should the primary power source fail, the battery is already on the line and is prevented from discharging into the power supply by a blocking diode. Under normal system usage, the voltage will fall rapidly from a 28-volt to a 24-volt level and then fall more slowly until it reaches a voltage at which the main power relays can no longer be energized. With judicious use, a fully charged storage battery should permit 5 or 6 hours of full-scale intercommunication.

TESTING

To aid in "debugging" the system and to insure that the various subsystems performed as required, facilities for a complete system test were prepared in the *Listening Room* at SurfCom. Every key interior station was included, and the bridge station was simulated. Since a number of stations were to be located in the submarine control room, with relatively little physical separation, the situation was approximately duplicated in the Listening Room so that the effects of acoustical feedback could be observed. Altogether, 19 transistorized intercom stations, nearly half of those required in the submarine, were installed. With this extensive arrangement it was possible to track down the "gremlins" as well as to check control functions and observe the possible operating problems to be expected from the integration of so many subsystems.

SHIPBOARD OPERATION

The intercom systems installed in the *USS George Washington* and *USS Patrick Henry* have been performing most satisfactorily. Even before the commissioning of the ships, the systems had accumulated many hours of operation, for there is constant need of a communication system during construction for locating personnel and passing information. In earlier tube versions, the usage of intercom and paging systems prior to commissioning dictated a complete replacement of tubes whenever a new vessel joined the fleet. With the new transistorized AN/WIC system, these replacement procedures are not necessary.

ACKNOWLEDGEMENT

The author and the editors of the RCA Engineer greatfully acknowledge the invaluable assistance on this article of C. W. Fields, Leader, Engineering Publications, SurfCom.

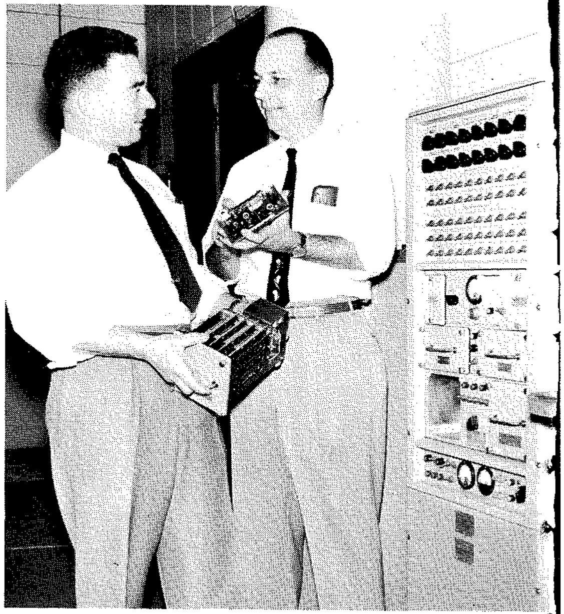


Fig. 8—H. W. Clay (left) and L. F. Boerum discuss construction features of alarm signal module. Power supply and central control cabinet are shown.

THEODORE E. ROLF has seventeen years' experience in RCA engineering with major activities in the field of Naval shipboard, audio-communication systems and equipment. Included is a seven-year background in the application of transistor and semi-conductor devices to audio-communication systems. His experience has included system studies and system design for submarine and surface-vessel interior intercommunication and loudspeaker announcing system, investigation and design of electronically-generated military alarm signals, project analyses, field contact after equipment installation, component design and product improvement. Mr. Rolf has had seven years' experience in electrical engineering outside RCA. This includes the design of electrical systems (lighting and power) for industrial and office buildings. Mr. Rolf is a member of the IRE and of the Professional Group on Audio.

Summarized here is a comprehensive evaluation of a new series of encapsulated transformers incorporating modern design and manufacturing techniques. Designed for operation at 170°C to 270°C, they have been investigated using a supply frequency of 380 cps. (See also Mr. Halpern's article, "Modern Insulation Concepts," in Vol. 5, No. 1.)

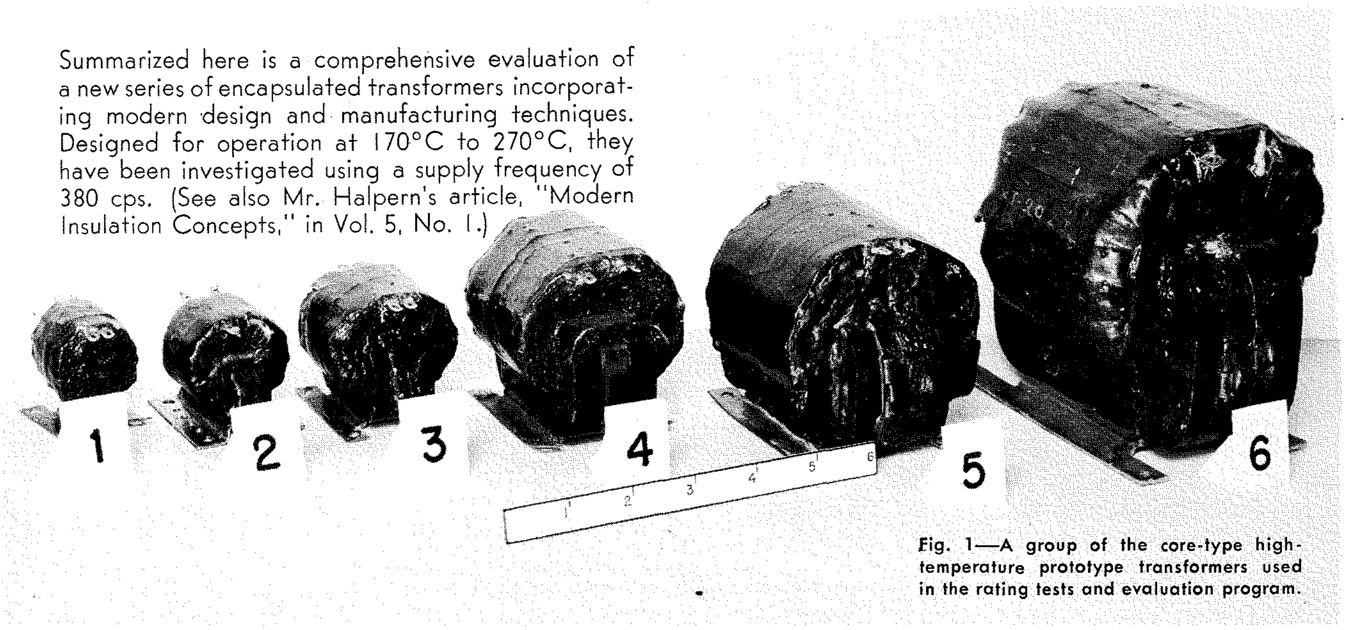


Fig. 1—A group of the core-type high-temperature prototype transformers used in the rating tests and evaluation program.

HIGH-TEMPERATURE TRANSFORMERS

by **SIEGMUND HALPERN**
Components Engineering
Airborne Systems Division
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TRANSFORMERS FOR operation at high temperatures have come into varied use in airborne applications today, with operating temperatures up to 250°C being quite commonly experienced. Experimental models of transformers have been made that are capable of operation between the temperature range of 500°C to 600°C. The use of the term *operating temperature* herein represents an ambient temperature plus a transformer temperature rise; all tests and measurements have been made in a constant ambient environment of 85°C.

COMPACTNESS WITH NEW MATERIALS

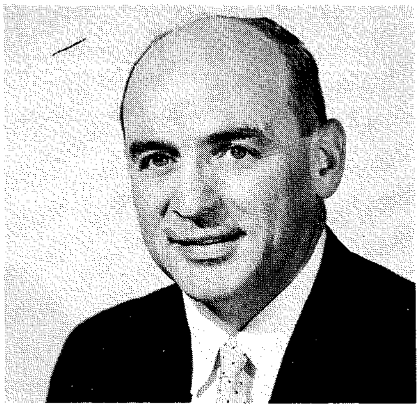
The ability of modern insulating materials to withstand higher and higher temperatures has gradually resulted in a considerable size and weight reduction of iron-core transformers, although it is not always easy to predict the extent of the possible space savings. Transformer efficiency and voltage regulation are equally difficult to ascertain because they are closely linked to the initially chosen physical size. The nature of the surrounding medium—still air or circulating air—also has a pronounced effect on the performance characteristics.

The lack of specific design data or experience very often leads to overdesign as there is not always time for the evaluation of a preliminary model; transformer operating capabilities in actual practice sometimes exceed early design expectations. An attempt to obtain the necessary data on the basis of purely theoretical considerations is not likely to succeed due to the complex nature of the thermal distribution throughout the core and coil assembly.

Similarly, uncertainty sometimes exists regarding the exact surface emissivity factor, physical deviations of a manufactured coil compared to original calculations, and the precise effect of circulating air contrasted to that of a still-air medium.

It appeared logical, therefore, to derive the desired information from a systematic design-, rating-, and performance-evaluation program on a series of typical high-temperature transformers dimensioned so as to cover the desired ranges of volt-amperes and operating temperatures.

For Mr. Halpern's biography, see p. 10, Vol. 5, No. 1.



TYPICAL CONSTRUCTION

The simple core-type construction, illustrated in Fig. 1, is distinguished by its simplicity and economy. Examination of a large number of typical high-temperature production designs proved this configuration to be the most often used.

The transformer has a tape-wound cut core made from 4-mil grain-oriented silicon steel. This thickness is suitable for the 380-to-1200-cps frequency range normally encountered in airborne applications, as it permits operation at high magnetic-flux densities with tolerable core loss and excitation current. Tape width, build-up and window area are variable, thus permitting the selection of the most suitable core size.

The coil is layer-wound and uses inorganic insulation materials such as silicone-impregnated mica-glass cloth or reconstituted mica for its tube and winding wraps. The conductor, found to combine both good conductivity and superior thermal aging characteristics, is a ceramic-coated copper-magnet wire with an overlay of Teflon. The windings are terminated on the coil periphery with silver-plated brass terminal lugs mounted on strips of silicone-bonded India-mica segment plate. Adhesive tape, when required, consists of glass-cloth tape with a thermosetting silicone adhesive, and solder is a eutectic tin-lead-silver alloy with a melting point close to 300°C.

The entire unit, after core and bracket are banded, is impregnated with a silicone resin followed by several coats of a mica-filled silicone resin. Each coat is cured separately. The total surface build-up due to the encapsulation ranges between 1/32 to 1/16 inch.

There is a great variety of encapsulating media available (such as silicone rubbers, gums, epoxies) and an even greater number of fillers. The choice and concentration of fillers will effect the thermal characteristics of the encapsulating medium. The heat dissipation of the mica-filled silicone resin compares very favorably with that of filled rubber, gum or epoxy encapsulants. High-temperature transformers using the described construction and encapsulation have excelled in life-expectancy.

A group of typical 1500-volt plate transformers have been subjected to an extended functional life test at 380 cps. The transformer test and evaluation program consisted of a periodic cycling operation. Experimental transformers operating at fully loaded conditions were alternately subjected to high-humidity and vibration environments. These weekly accelerated life tests were followed by dielectric-strength, insulation-resistance, and d-c–resistance measurements.

During the above tests, the initial operating temperature of 235°C was maintained for 2000 hours. Thereafter, the temperature was raised to 250°C for an additional 2000 hours, then to 260°C for 4000 hours, and finally to 280°C for the balance of the test. Records indicate that no failure occurred prior to 6828 hours of operation. The last unit failed after a total of 9837 hours. This performance record under the severe accelerated conditions described is very satisfactory.

TABLE II. COIL DETAILS OF PROTOTYPE DESIGNS

Unit No.	*Prim. & Sec. Wire Gage*	*Total Turns Prim. Plus Sec.*	*Copper Weight (Lbs.)*
1	29	1261	0.0896
2	26	797	0.167
3	21	473	0.377
4	16	255	0.890
5	13	225	1.765
6	8	128	4.34

RATING AND EVALUATION PROGRAM

The object of the rating- and capability-evaluation program for high-temperature transformers was to determine practical operating parameters that could be related to both weight and operating temperature. Fig. 1 illustrates a group of six specially-designed prototype transformers used for this analysis. All windings were made to pass a peak dielectric stress test of 5650 volts. Although nearly identical in their basic mechanical and electrical design, physical sizes were graduated so that Unit 2 represented an increased rating capability compared to Unit 1, Unit 3 exceeded that of Unit 2, and so on. The following parameters were evaluated for both still-air and circulating-air conditions (air circulation at a rate of approximately 75 cfm): volt-amperes delivered by secondary, copper loss, current density, efficiency, and voltage regulation. In addition, over-all volume as a function of weight was determined, a plot of which is shown in Fig. 8.

The evaluation program involved a large number of temperature-rise measurements on each of the six transformers in a constant 85°C ambient environment. Each individual test was performed twice—once for still-air, and once for circulating-air conditions. Constant input voltage and 380-cps supply frequency were maintained throughout the tests. The power delivered by the secondary of each transformer to the resistive load was varied for each test in order to cover an extended range of operating temperatures and volt-amperes. Detailed electrical measurements were made at the beginning and conclusion of each test run which permitted calculation of the desired operating parameters. Figs. 2 through 6 show the results in graphical form for a volt-ampere range of 50 to 4000 volt amperes and an operating-temperature range of 170°C to 270°C.

TABLE I. CORE DETAILS OF PROTOTYPE DESIGNS

Unit No.	*Tape Width*	*Build Up*	*Window Area*	*Core Weight (Lbs.)*
1	1/2	1/4	1/2 x 1 1/8	0.122
2	3/4	1/4	1/2 x 1 5/16	0.201
3	1	5/16	5/8 x 1 9/16	0.406
4	1 3/8	7/16	7/8 x 2 1/4	1.106
5	1 5/8	1/2	1 x 2 9/16	1.712
6	2	25/32	1 7/16 x 3 7/16	4.656

PROTOTYPE DESIGNS

Constructional details of the six prototype models (pictured in Fig. 1) generally follow the descriptions given for typical high-temperature transformers. Table I gives all the pertinent mechanical dimensions and core weights.

The magnetic-flux density chosen for each unit bears some relation to its individual weight. The plot shown in Fig. 7, derived from a large number of successful production designs, was used as a guide for the design of the prototype models.

Full utilization of the available window area was stressed in the design of the windings. For example, it appeared desirable to limit the prototype designs to two nearly identical windings. Each represented close to optimum space utilization and capability, thereby enabling de-rating should higher voltages and/or additional secondary windings be encountered. In line with the above reasoning, the same gauge wire was used for the primary and secondary winding for each particular unit. Table II gives coil details for the prototype designs, and the physical details of the prototypes are listed in Table III.

USE OF DATA

The use of the graphs should prove a valuable aid to both the designer and user of high-temperature iron-core components. Data presented should be considered as typical, and some measure of adaptation may be required if marked deviations from the described prototype models are encountered. Radically different encapsulation media will have some effect on temperature rise, although these data are believed to be within the range of tolerance normally associated with iron-core designs. The findings indicate that the power utilization capabilities of high-temperature encapsulated transformers are outstanding. Also, there is no sacrifice of efficiency and regulation as a result of high-temperature operation.

TABLE III. PHYSICAL DETAILS OF PROTOTYPE DESIGNS

Unit No.	*Over-all Size L x W x H*	*Over-all Volume (Cu. In.)*	*Total Weight (Lbs.)*	*Heat Dissipation Area of Coil ($In.^2$)*	*Ratio of Core Wt. to Complete Transformer Wt.*
1	1 7/8 x 1 3/8 x 1 13/16	4.85	0.33	6.35	0.37
2	2 1/4 x 2 1/8 x 2 1/8	8.1	0.577	8.24	0.349
3	2 7/16 x 2 1/8 x 2 3/16	11.5	1.034	10.5	0.392
4	3 5/8 x 2 15/16 x 2 15/16	31.2	2.6	20	0.425
5	3 7/8 x 3 9/16 x 3 1/2	44	4.64	28.2	0.369
6	5 5/16 x 4 1/2 x 5 1/16	126	11.3	64.7	0.413

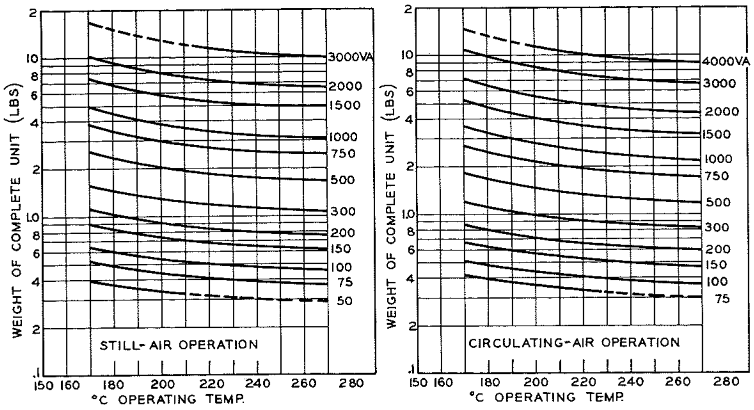


Fig. 2—380-cps volt-ampere ratings vs. weight and operating temperatures.

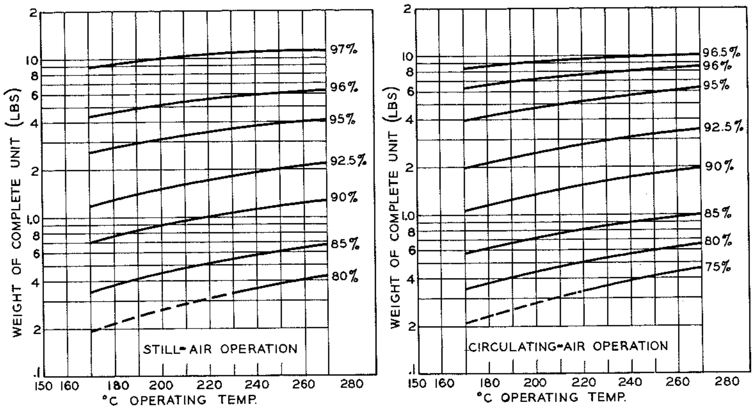


Fig. 3—Efficiency vs. weight and operating temperature.

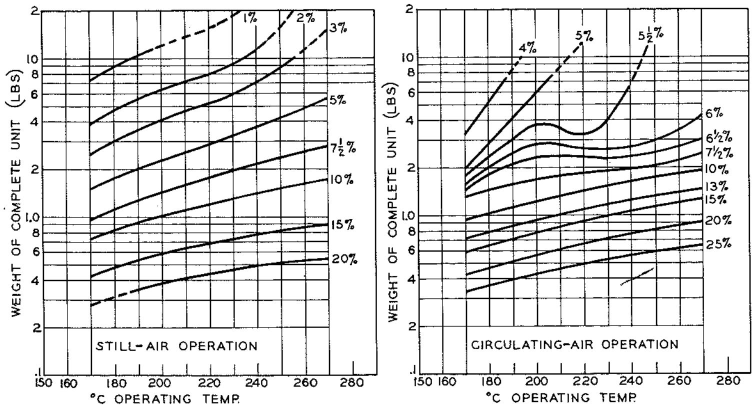


Fig. 4—Regulation vs. weight and operating temperature.

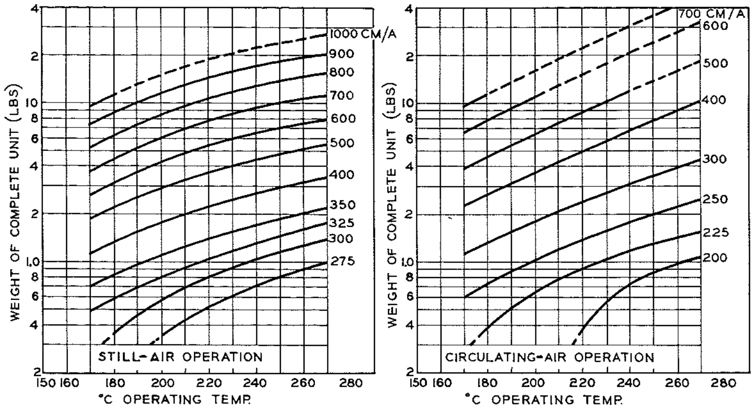


Fig. 5—Circular mils per ampere vs. weight and operating temperature.

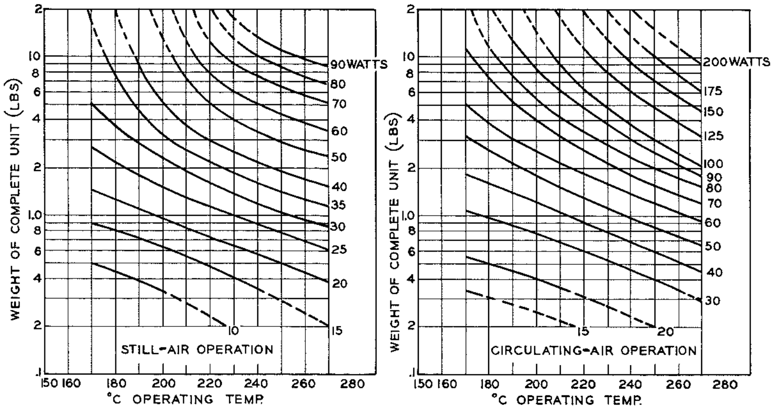


Fig. 6—Copper loss vs. weight and operating temperature.

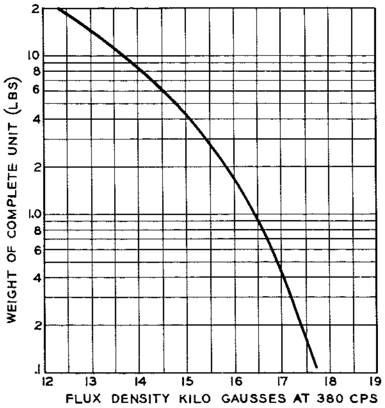


Fig. 7—Weight vs. flux density.

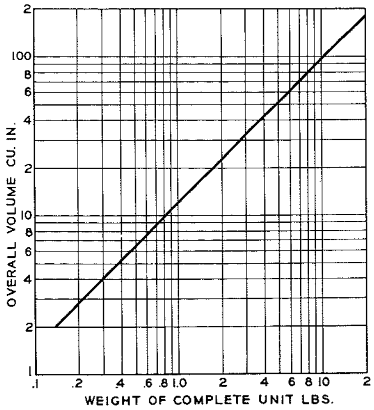
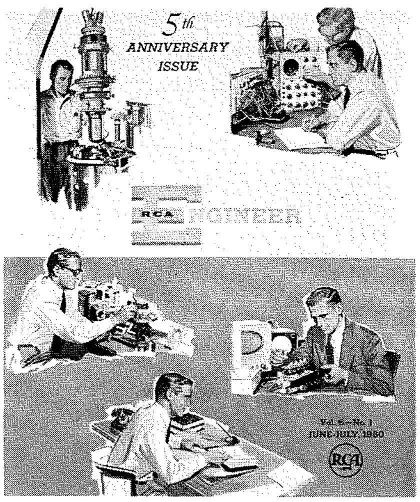


Fig. 8—Weight vs. volume.



THE RCA ENGINEER

...Its Management, Policies, and Operation

by **E. R. JENNINGS,**

Assistant Editor

FIVE YEARS AGO, 4100 copies of a new engineering journal—the RCA ENGINEER—were mailed to engineers in the Radio Corporation of America. This issue has been mailed to over 7200 RCA engineers and brings to well over 400 the number of articles published within its covers. It is appropriate, at this five-year mark, to take a look at how the RCA ENGINEER is managed, its basic editorial policies, and how its contents are planned and prepared.

MANAGING RESPONSIBILITIES

The underlying concept of the RCA ENGINEER is that it belongs exclusively to the engineering profession within RCA—a technical journal ". . . by and for the RCA engineer." The organization under which it has operated since its inception was created with this concept in mind. The *Editorial Advisory Board,* the *Engineering Editors,* and the *Editorial Representatives* listed on Page 1 and inside-back cover of every issue provide over-all management and coordination, mutually complementing the direct editorial management of the Editorial Staff (Fig.1).

Editorial Advisory Board

This policy-making group is made up of fourteen RCA management representatives closely concerned with engineering activities. Their effort ensures that the magazine reflects both the best interests of RCA and the desires of the engineering groups.

At each bimonthly Advisory Board meeting, which the Editorial Staff and Engineering Editors attend, broad plans for contents are formulated four or five issues ahead. Such basic advance planning is important to the Editorial Staff who, in subsequent work with Editorial Representatives and Engineering Editors, must make specific article selections.

Engineering Editors

These five men are relied upon for detailed critique of manuscripts, aid in gaining approvals, and suggestions for detailed improvements in the journal. They hold positions in RCA that entail regular dealing with engineering papers and reports, and might well be termed "consulting editors."

Editorial Representatives

The forty-three Editorial Representatives throughout the Corporation serve as the vital link between the engineer-authors and -readers and the Editorial Staff. In the larger RCA operating units, they work together as Editorial Boards, holding periodic meetings to plan and coordinate articles from their areas.

Because these men are both part of the RCA ENGINEER organization and close to their own engineering activities, through them the engineer-authors can work most effectively and the engineer-readers feed back comments.

BUDGETING

The operating costs of the RCA ENGINEER are paid for by the numerous RCA groups whose engineers receive it. Annually, a detailed operating budget is submitted by the Editor to engineering management. Costs are then billed on a bimonthly basis to the Corporation groups, prorated to the number of engineer "subscribers" receiving the publication in each area. These billings cover *all* operating costs—salaries, office overhead, printing, even paper and pencils—so that the journal really belongs to RCA engineering in every sense.

CIRCULATION POLICY

The RCA ENGINEER is published *for engineers at RCA.* The fact that it is not widely distributed "outside" and that subscriptions are not sold obviates selection of content based on, for example, sales-promotion criteria that although valid from a commercial standpoint, might not accurately reflect maximum worth to engineer-readers.

Close control over mailing lists is maintained. Each major engineering location has a Control Officer who *must approve the addition of anyone* in his area to the mailing list. Master mailing lists, based on the Control Officers' information, are maintained by the Editorial Secretary in Camden. The only circulation outside RCA is a few hundred copies sent through RCA Staff College Relations activity to the libraries and deans of certain engineering schools.

FROM IDEA TO ARTICLE

The majority of articles are suggested through the Editorial Representatives who, being close to the "engineering heartbeat," can most effectively reflect both current, important engineering work and reader interests. In other cases, the Editorial Staff, the Editorial Advisory Board, and the Engineering Editors may individually or collectively conceive article ideas and contact appropriate authors.

The most important phase of an article's birth is in contact and discussion with the prospective author to settle on its scope, slant, and scheduling. During this creative stage, the Editorial Representatives and Engineering Editors involved are indispensable members of the team.

With the approach decided upon, the manuscript is placed in the RCA approval cycle, *just as in any manuscript designed for "outside" publication or presentation.* Regular RCA approval procedures are followed to get the benefit of wide review for appropriateness,

Fig. 1—The RCA ENGINEER Editorial Staff. L to R: W. O. Hadlock, Editor; E. R. Jennings, Assistant Editor; and Mrs. M. A. Suckow, Editorial Secretary.

accuracy, quality of writing, and, of course, to safeguard Corporation interests.

SELECTION OF ARTICLES

The page space available is limited by a strict budget, yet a basic objective is to represent as many engineering activities as possible. With this in mind, selection of articles is based on the 1) *wide interest value* of the story, 2) *importance* of the work described, 3) *timeliness* of the story, and 4) *quality* of presentation.

The first criterion—*wide interest value*—is easily the most important. Articles are selected so that every issue contains varied material of interest to as many fields of RCA engineering as possible. In addition, selection of an individual article also depends on whether it will convey maximum information to engineers whose professional fields may be different than the author's—as well as to those who actually work within the field concerned.

The second factor — *importance* — is self evident. Articles should represent RCA's finest engineering work. But this does not mean that only very complex systems or large, glamorous equipment should be covered. On the contrary, there *can be just as much* engineering accomplishment, interest, and importance in a detailed manufacturing technique as in an immense, multimillion-dollar system. Also, because RCA engineers are important partners in management planning and administrative operations of RCA, articles in business fields are regularly published.

The third criterion — *timeliness* — is not easy to achieve in a bimonthly journal, even though it would be ideal to cover each engineering accomplishment immediately. But contents must be planned in advance, words placed on paper, approvals obtained, and the journal printed. Each consumes time. Engineers who feel they have *or will have* a story to tell should contact their Editorial Representative at the earliest possible time to ensure timely scheduling.

The last criterion—*quality*—is vital. The most important engineering story in the world is dull reading if it is not well done. It is not difficult to write a 2000-word article, but it is hard work to make it excellent and concise in order to capture and hold the reader's interest. Here, the Editors and Representatives are of particular help.

PRODUCTION AND PUBLICATION

With an approved, edited, and polished manuscript and illustrations in hand, the actual production cycle begins. First, typeset galley proofs of the text and tabular material are obtained and reviewed by the author, the Editorial Representative or Engineering Editor concerned, and the Editorial Staff.

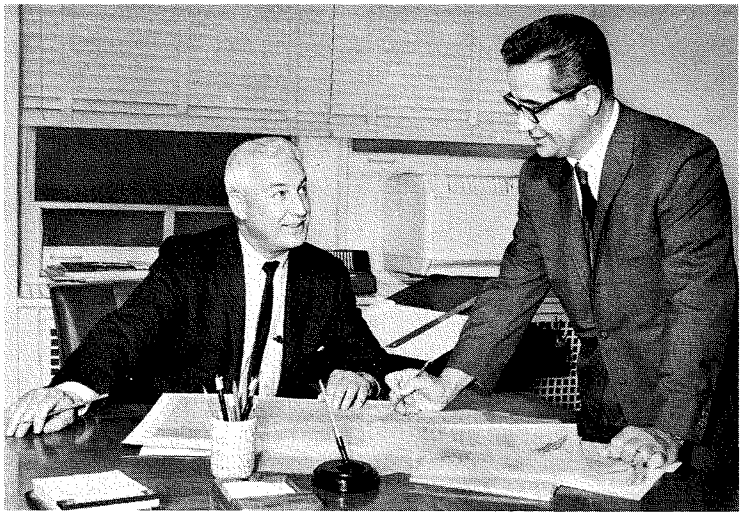


Fig. 2.—The Art and Production Department. At left, J. L. Parvin, Manager, discusses an RCA ENGINEER layout with P. F. Gallo, Jr. of the Department staff. One of this Department's important jobs has been the art direction and production of the RCA ENGINEER since its inception.

Concurrently, page layouts are created by the Art and Production Department. Attention is paid to utilizing techniques of typography and page makeup to achieve both variety and continuing identity—subtle, but very important factors. These layout and production considerations are the concern of J. L. Parvin and P. F. Gallo (Fig.2), who from the first issue on have worked miracles on making artistic, technically valid presentations of type and artwork under stringent space limitations. Mr. Parvin personally designs each color cover. Cover photos, as well as special inside photography, are taken by R. Allen, of J. O. Gaynor's DEP Photo Studio.

Approved galleys and layouts are next cast into page proofs, which are routed to the same reviewers as the galley proof. When page proofs are released, each article is a "package," ready for the printer. Before actual printing, a photographic proof, or "brownline," of the entire magazine is checked by the Editors and the Art and Production Department, and final adjustments made. With these approved, the presses can roll, and a few days later, addresses and postage are attached to the envelopes containing another issue of the RCA ENGINEER.

REPRINTS

A permanent "morgue" of all RCA ENGINEER master page negatives is maintained, to allow quick and economical reprints of articles. Many such reprints have been made since the inception of the journal, in both small and large quantities. Only the permission of the author and the Editor, and a purchase order for the printing costs involved are required for this valuable by-product.

A single article or a group of articles may be reprinted and bound either self-covering or with special cover copy. RCA ENGINEER color covers may also be used for reprints, with the journal logotype removed and appropriate copy substituted to key the reprint to the user's needs. The Editorial Staff handles all arrangements for such work as a service to the requesting group.

PUBLICATION IN OTHER JOURNALS

The RCA ENGINEER registers a copyright for each article it publishes; however, this does not mean that articles originally written for it cannot be republished in other journals. Permission of the author and the Editorial Staff is required.

Similarly, an article by an RCA man published elsewhere can be considered for the RCA ENGINEER; however, usually some revision or rewrite will be necessary to align it with the slant appropriate for the RCA ENGINEER.

Thus, although the Editorial Staff prefers original material specially written for the RCA ENGINEER, many approaches are workable—much "mileage" can be had from a given piece of writing by working with different versions. This, coupled with the possibilities inherent in the availability of reprints, gives valuable flexibility to RCA ENGINEER material.

IN SUMMARY

In describing these how's and why's of the RCA ENGINEER, it is obvious that it has been particularly successful for one principal reason: it is managed, written, and paid for exclusively by the RCA engineering groups for whom it was conceived. The Advisory Board, the Engineering Editors, the Editorial Representatives, and the engineer-authors are the ones who have assured success during the past five years. Their continued work — coupled with the comments and ideas of readers—are the keys to making it even better in the future.

A NEW MONOCHROME TV CAMERA

by **JOHN H. ROE, Mgr.**

TV Camera Engineering

Broadcast and Television Equipment Division

The TK-12 camera, described herein, was the key item in RCA's display at the annual convention of the National Association of Broadcasters held in Chicago April 3-7, 1960. Located at the point of entrance to the exhibit, the new camera was the first thing seen by every visitor. Two cameras were on display—one operating in a small studio set which included live models and a separate miniature stage with controllable lighting. The latter provided easy facility for illustrating the excellent capabilities of the new camera to reproduce a variety of lighting effects. A second, nonoperating camera was displayed to show its construction and mechanical operation. The TK-12 won "hands down" in drawing the interest of visiting station management and engineering personnel, in comparison with similar cameras made by two foreign competitors, because of its features and packaging, which were tailored to integrate readily into existing station installation.

THE NEW TK-12 monochrome TV studio camera combines a large number of new developments into a product of real importance to the telecasting industry as well as to RCA. Every aspect of today's requirements for a high-quality camera has been given consideration in planning the equipment itself and the engineering program for its development and design. Features have been carefully integrated to provide a new order of quality in performance; simplicity, stability, and economy in operation; and facility in manufacturing. The result is a product which will take its place as the backbone of the studio equipment product line, and which will be a substantial factor in maintaining RCA's leadership in the studio equipment field.

PACKAGING

The TK-12 camera chain (Figs. 1-4) consists of three main units of equipment: 1) integral camera and electronic viewfinder, 2) processing amplifier (rack-mounted), and 3) remote-control panel. The principal departure from the packaging of earlier designs lies in the integration of the camera and viewfinder into a single unit which has been styled to have a distinctive new appearance. Another difference of considerable importance is the great simplification of the control panel which has become possible because of thorough stabilization in the circuitry. In most respects, however, the camera man will find that he does not have to develop a whole gamut of new habits in operating the new equipment. Basic controls like those for focus and turret operation will have a familiar feel. New things will serve to make the operation easier and more flexible, thus fulfilling needs of which he has become conscious in using previous designs.

WHY A NEW CAMERA AT THIS TIME?

There has been no basic change in the elementary components of a TV system to account for undertaking a radical new design in cameras. Image orthicons have been used for many years in live cameras with continually diminishing competition from other types of devices such as simple orthicons and image iconoscopes, and there is no immediate prospect of a change in this trend. An important change in the technique of TV broadcasting has appeared, however, in the form of TV tape recording, which places a premium on obtaining the highest possible quality in the original picture to assure acceptable quality after several generations of recording. This demand, added to a normal growth in competitive demands for better quality and economy, and coupled with availability of continuing new developments in electronic components and circuitry, has created a situation propitious for introducing a new camera embodying a host of refinements.

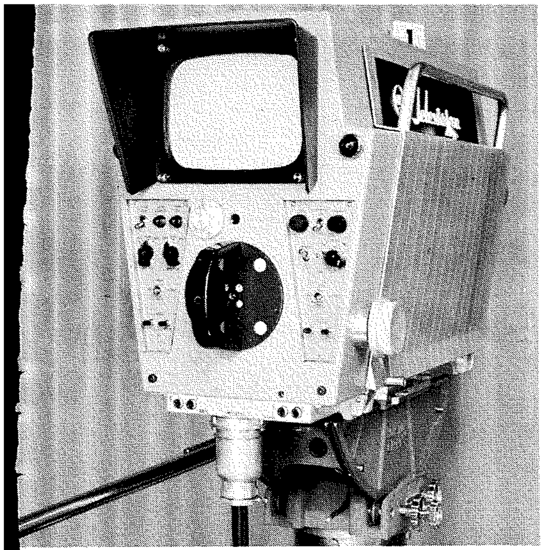


Fig. 1—The new TK-12 camera, showing the location of turret and optical-focus controls, the large (8½") rectangular view-finder, and the two groups of electrical controls used by the camera man.

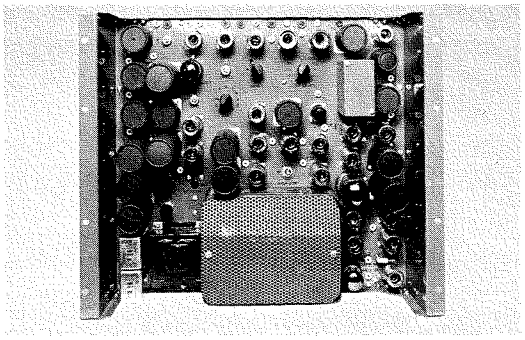


Fig. 2—Front view of TK-12 rack-mounted processing amplifier. At bottom-center is the self-regulating power transformer.

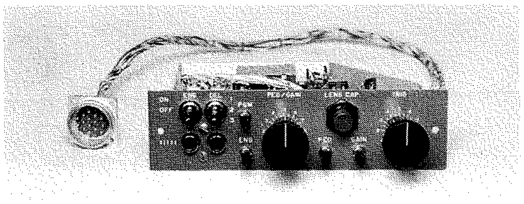


Fig. 3—Remote control panel. This panel contains the remote iris control, and a second useful control for adjusting the "mood" of the picture by changing contrast range without changing peak white level. Remote lens-capping (electronic) and intercom controls are also included. The panel is small enough to mount in a space only 8½" wide.

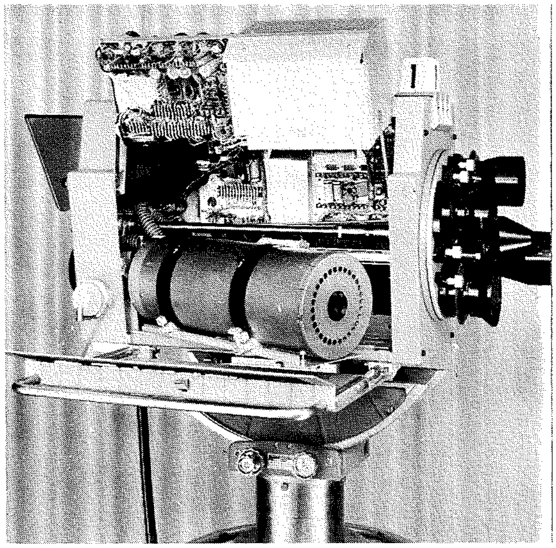


Fig. 4—How internal amplifier assemblies are opened up for access to circuits and to permit changing the image orthicon.

The general objectives of better pictures, simple and economical operation, and stability thus became the keynotes of the development and design program.

THE 4½-INCH IMAGE ORTHICON

The first objective—better picture quality—led to the choice of the RCA-7389A 4½-inch image orthicon. It is the same as its smaller 3-inch counterpart (RCA-5820, -6474, and -7513) so widely used in thousands of monochrome and color studio cameras today, with respect to basic mode of operation (Fig. 5). The work of O. H. Schade, Sr. (Electron Tube Division of RCA, Harrison, New Jersey), more than ten years ago demonstrated that the larger target area of the 4½-inch tube was capable of delivering measurably superior resolution (detail response) in both horizontal and vertical directions with maximum signal-to-noise ratio. This fact has been borne out by the experience of stations in England and Europe which have been using the larger tube in cameras for several years.

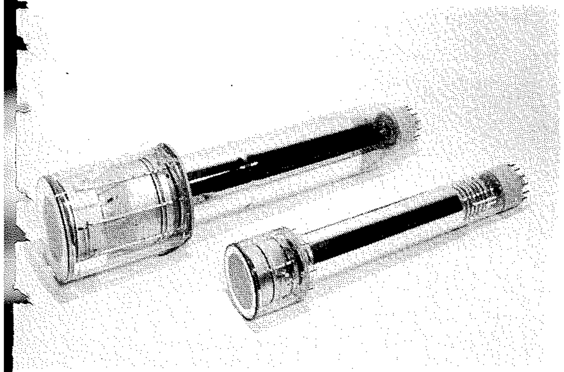


Fig. 5—The 3" and 4½" image orthicons.

As a complement to the new TK-12 camera, the RCA Electron Tube Division has developed and announced the RCA-7389A 4½-inch image orthicon. The ability of this tube to provide better picture detail is illustrated by measurements which show amplitude response at 400 TV lines of 60 percent of the response at 100 TV lines, without aperture correction. By comparison, the 3-inch tube gives only about 30-percent response at 400 lines.

Though the target of the RCA-7389A is large, the photo-cathode (i.e. the used diameter) is the same as that of the 3-inch tube, thus permitting the use of the *same lenses* for either 4½ or 3-inch tubes. Magnification of the electron image in the 4½-inch tube is brought about by suitable strengthening and shaping of the magnetic focusing field in the image section of the tube.

Another important feature built into the RCA-7389A is relatively close spacing between the glass target and the mesh. There are several desirable results. First of all, signal-to-noise ratio is increased. Then, the linear portion of the transfer characteristic is longer, permitting more accurate reproduction of the gray scale. The closer spacing also reduces broad redistribution of secondary electrons, thus reducing the characteristic overshoots and halos usually seen in pictures from the RCA-5820. In these respects, the RCA-7389A is similar to the RCA-6474 and -7513 tubes normally used in color cameras. All of these characteristics—better detail contrast, higher signal-to-noise, better gray scale, and reduced overshoots and halos—are important contributors to improved picture quality.

LIGHT CONTROL

A natural accompaniment of the capability of producing better picture quality is light control to assure maintenance of that quality at all times. The redistribution characteristics of the wide-spaced RCA-5820 permit useful pictures to be obtained under a rather wide range of illumination, but with some variation in quality with respect to gray scale and signal-to-noise ratio. It has long been recognized that even here careful control of illumination can give more uniform and pleasing results, and in the cases of the close-spaced tubes, careful control is even more desirable because of the somewhat sharper knee of the transfer characteristic. Recognition of this important fact has resulted in provision of two complementary types of illumination controls in the TK-12. One is a six-position filter disk behind the lens turret where a series of neutral filters permits control of the light falling on the photo-cathode in large steps. The second is remote control of the iris in the lens to permit vernier adjustment of the light.

Since illumination is the basic variable in the environment of any camera, light control is the corresponding basic control. Using this fact as a premise, an important objective in designing the TK-12 has been to stabilize all other factors in camera operation to an extent which would eliminate all other controls from the operating category, leaving light control as the *only* operating control.

STABILIZATION

An important key to consistent quality of performance in a TV camera, as in any electronic equipment, is stabilization. Earlier camera designs placed a large number of controls at the operating position to facilitate frequent readjustment of circuit parameters to compensate for instabilities in circuits and components. This arrangement implied that the operator would have to do frequent "tweaking" of such controls to maintain peak performance over even rather short intervals. In planning the elimination of this requirement, the first step was to explore the areas where instabilities existed and to devise methods of applying stabilizing techniques.

Two general classes of circuits are involved: amplifiers (including video amplifiers, gating and switching circuits), and power supplies.

Amplifiers

Probably the most potent approach to stabilization in this class of circuits is the use of negative feedback. Its effectiveness has been well established for many years. Earlier types of cameras have included various applications of feedback in output stages of video amplifiers and clamp circuits. In the TK-12, such circuits have been used to the fullest possible extent and in forms which have been proved by experience to be the most effective. The primary effect of such feedback is, of course, to minimize results of differences and drift in characteristics of tubes and other active devices arising from aging and changes in environment. Various types of cathode degeneration are used as well as more obvious feedback loops involving two or more stages. Two typical examples of feedback applications are described in the following.

An interesting version of cathode degeneration (for d-c only) has been found very useful in video amplifiers, or other types of Class A amplifiers, as illustrated in Fig. 6. This arrangement has the virtue of maintaining nearly constant average cathode current regardless of variations in tube characteristics, heater voltage, and aging. Since effective gain of the stage remains nearly constant if the cathode current is constant, the result is quite satisfying in terms of stabilized gain. This circuit arrangement has come to be known popularly as a *current-stabilized* amplifier.

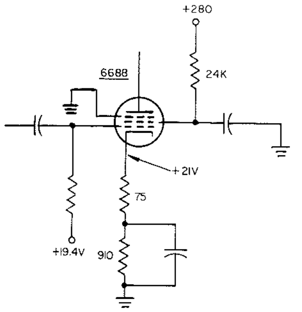


Fig. 6—Current-stabilized amplifier. A large amount of d-c cathode degeneration is provided by the large resistance in the cathode circuit, with positive bias on the grid to provide the required grid-cathode bias. Any drift in average cathode current causes a relatively large compensating change in cathode voltage, thus tending to maintain constant current. The degenerative action of the series screen resistor also aids current stabilization.

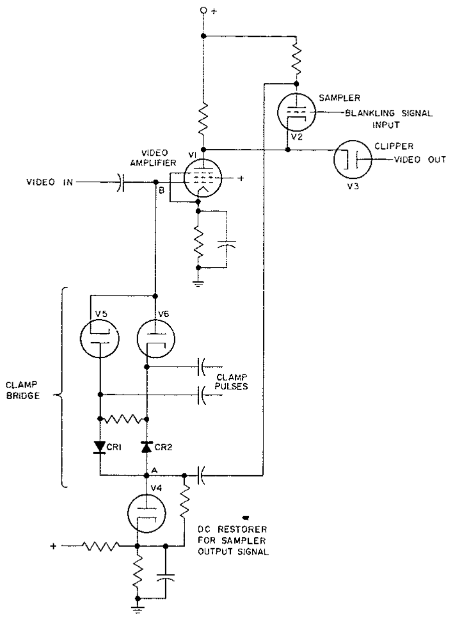
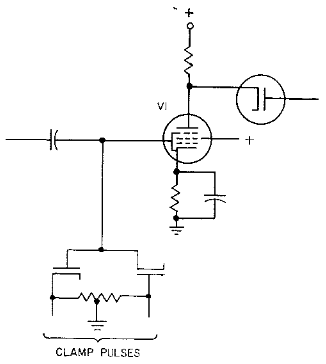


Fig. 7a—Feedback clamp. V2 samples the plate voltage of V1 during blanking periods and also adds blanking signal to the output of V1. Any drift in V1 plate voltage causes a corresponding change in voltage at A, the reference potential of the clamp, and this appears as a compensating bias change on the grid of V1, thus stabilizing the voltage at the plate of V1.

Fig. 7b—Simple clamp. In this case, the grid of V1 is clamped to ground potential, and any drift in plate voltage of V1 is not compensated.



The feedback clamp circuit is another example of the useful application of stabilization. The basic elements of this circuit are shown in Fig. 7 a. The usual driven clamp (Fig. 7 b) as it is used in TV cameras establishes blanking level accurately at a reference potential at the grid of the clamped amplifier, but the clamped amplifier itself is subject to variations from aging, drift in heater voltage, etc., so that significant errors can appear at the plate where blanking is added, thus causing corresponding errors in black level. In the feedback clamp, the plate voltage is sampled during blanking intervals with feedback to the grid so that unwanted variations in the plate voltage are largely cancelled. This circuit has been used for several years with real success in the color camera equipments and in a vidicon camera for studio work, and is now used in the TK-12 with equal success.

Power Supplies

In considering this class of circuits, it was concluded that accurate regulation of the a-c voltages associated with primary power supplies would go a long way toward eliminating a number of the variables in the system as well as toward dispensing with tap switches and voltmeters in transformer primary circuits. To accomplish this result, all power transformers in the TK-12 equipment are of the saturable-core self-regulating type. Such transformers are used in the TP-16 transistorized regulated power supply, in the processing amplifier, and in the camera itself for the local heater supply.

A simplified schematic of the power circuit for the entire camera chain is shown in Fig. 8 to illustrate the added special benefits obtained even when using very long camera cables. It can be seen that the primary power for the heater transformer in the camera must be delivered over the camera cable which may be as long as 1000 feet. The drop in voltage becomes appreciable in such long cables, but can be entirely compensated by the self-regulating transformer in the camera, thus assuring constant heater voltage on all tubes in that location.

Tests of TK-12 equipment have shown that stable operation can be achieved at any power supply input voltage from 80 to 130 volts, or with sudden changes of ±20 volts, without having to make any adjustments.

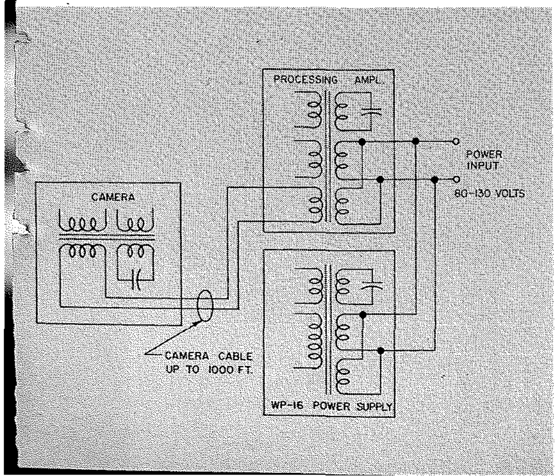
One of the principal areas of instability in many early cameras is the image orthicon itself in combination with the numerous voltages applied to it. Investigation showed that the problems lay almost entirely in the variations of operating voltages for the tube. Since some of these voltages are relatively high, with negligible currents involved, it did not seem practical to use any of the common gas-discharge or servo types of regulators. A different class of gas-discharge regulators called corona regulators has become practically available recently in voltage ranges up to 10 or 15 kv or more. They have the highly desirable characteristic of repetitive accuracy within very narrow tolerances (typically about 0.25 percent), especially under conditions of controlled temperature. By using these devices, some in a temperature-controlled oven, to stabilize all of the operating voltages for the image orthicon, it has been possible to eliminate almost completely any need for readjustment of operating parameters over long periods of time.

Equally careful attention has been given to extremely close regulation of the current in the focus coil. By using the drop across a zener diode as a reference, and comparing this voltage to the drop across a zero-temperature coefficient resistor in series with the coil, it has been possible to hold the current within a tolerance of 0.12 percent.

Beam current drift, especially during initial warm-up of the image orthicon, has also been eliminated as a serious variable by applying the current stabilizing technique previously described. A large resistance in series with the cathode provides heavy degeneration for d-c, effectively swamping out significant current changes.

It is noteworthy that the extensive use of stabilized voltages and currents in the TK-12 camera equipment permits the production of a high-quality picture within a very few minutes after the power is turned on, and production of peak performance after the 15-minute period required for temperature-controlled elements to reach equilibrium—all without readjusting previously-made correct preset adjustments. Furthermore, it means that repetitively reliable performance can be attained day-in, day-out. This is an achievement of more than casual significance to the operator, and is a tribute to the ingenuity and careful planning of the engineers who did the development work on the new system.

Fig. 8—Simplified circuit arrangement of power circuits in the TK-12. Use of self-regulating transformers permits normal operation over range of 80 to 130 volts at the input. A self-regulating transformer in the camera compensates for voltage drop in long camera cables.



NUVISTORS AND OTHER PREMIUM TUBES

In conformance with objectives for high quality in circuits, maximum use has been made of premium tube types with their more uniform and reliable characteristics. Particular notice should be taken of the use of the new, very-small RCA-7586 Nuvistor triode tube in a substantial number of circuits including the video preamplifier in the camera. These tubes are economical of both space and heat dissipation—important factors in camera design. Even more important, however, is their freedom from microphonics in the low audio frequency range where such trouble is usually encountered. Tests indicate no observable microphonic disturbances at frequencies below about 7500 cycles.

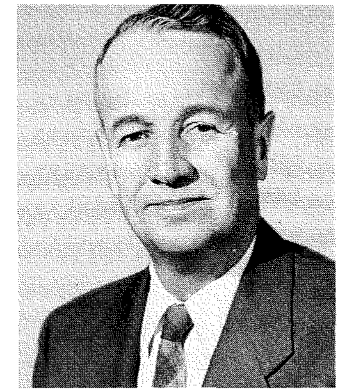
MAGNETIC SHIELDING

A feature of considerable importance when the camera must be operated in the presence of strong magnetic fields, occasionally encountered in proximity to large power equipment, is the comprehensive magnetic shielding around the image orthicon and its focus-deflection coil assembly. This shielding consists of a double layer of annealed mu-metal over the cylindrical surface of the assembly, and, equally important, single-layer shielding over the ends with openings just large enough to admit the optical image at one end and the base of the tube at the other. With such shielding, operation in 10-gauss fields is possible with insignificant distortion of the picture.

SIMPLICITY OF OPERATION

The features contributing to stability described above form the foundation for simplified operation. The effective and comprehensive accomplishments in this direction have made it practical to reduce the number of operating controls to just one, the remote iris control, as indicated previously. On this basis, it is feasible to consider that an operator at the video console should be able to handle several camera chains at one time, perhaps as many as six, thus achieving real economy in manpower.

Simplicity and economy in maintenance are equally important. Features of stabilization contribute to ease of maintenance, but in addition a number of features of special significance in this area have been included. A square-wave test signal of precisely predetermined amplitude is available in the camera for insertion at the input of the preamplifier. It is useful for making gain measurements in the system, and for presetting multiplier gain in the image orthicon. This latter function may be done by direct observation of the viewfinder without the aid of an external oscilloscope. On the basis of having this signal available, all of the preset adjustments relating to the image orthicon can be made at the camera itself using the viewfinder as an indicator. As a result, it is not necessary to have any of the preset controls at the console; all are located in the camera. This arrangement permits the addition of some new features requiring circuits in the camera cable without increasing the total number of conductors. Continued use of the standard 24-conductor camera cable, which has been used universally for many years, is a special feature.



JOHN H. ROE is a graduate of the University of Minnesota where he received a BSEE degree in 1930 and an MSEE in 1932. He began his professional employment with RCA in 1933 where he has been employed continuously since that time. He became associated with early TV studio design and installation activities in Radio City, New York, in 1936. Since then he has participated in nearly every phase of the design of TV studio equipment produced by RCA. At present, he is Mgr., TV Camera Engineering, Broadcast and Television Division, IEP, Camden, N. J.

To facilitate service testing, arrangements have been made to test performance with reduced heater voltage. This has been found to be an effective approach to anticipating failure in stabilized circuits before the failure actually occurs. Numerous pin-jacks permit easy access to circuits for measuring signal and power supply voltages without having to get at the wiring sides of chassis.

CONCLUSION

The discussion in this paper has been confined to basic features of the equipment and to the engineering approaches to the design program. Readers who may be interested in more detailed descriptions of features and packaging are referred to a paper entitled, "An All-New Monochrome Studio Camera, Type TK-12" in issue No. 107 of *Broadcast News.*

TV SURVEILLANCE FOR MISSILE LAUNCHINGS

by **J. CASTLEBERRY, JR.**
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DURING MISSILE launching operations, a critical period follows immediately after firing when spurious reflections called *ground clutter* obscure the radar information, and telemetering does not supply all the required information. Television is ideal for filling in this information void.

Television for surveillance and boresighting in missile launching operations has been previously attempted with limited success. It used industrial TV equipment modified to withstand the rigorous environment associated with the launching of a missile. Experience with a modified industrial camera, RCA ITV-6 (L. E. Anderson and R. F. Bigwood, "Closed-Circuit TV in Missile Testing," RCA ENGINEER, Vol. 3, No. 4) led to the TV system described here.

TV MISSILE SURVEILLANCE REQUIREMENTS

This TV system, the first to be specifically designed as an integral part of a missile weapons system, was carried out by RCA under a subcontract with Bell Telephone Laboratories and the Western Electric Company, under cognizance of the U. S. Air Force Ballistic Missile Division. Every aspect of the system—from the camera mounted on the radar antenna to the weapon control console monitor—is designed to provide clear, concise information about performance during the critical period immediately following the launching.

System parameters, tailored to missile launching are:

Aspect Ratios — 4:3 (greatest dimension of the rectangular kinescope along the missile axis; horizontal scan lines across the body of the missile.

Scan Rates — line (horizontal), 15,625/sec, interlaced 2:1; field (vertical), 50/sec.

Horizontal Resolution—400 TV lines.

Distortion — total from trapezoid, parallelogram-barrel, pin-cushion or "S" distortion, and nonlinearity: less than ±3 percent of picture height.

Input Power — 1200 w at 120 v, 400 cps.

THE CAMERA

The camera (Fig. 2) is designed to operate satisfactorily from −40 to +125°F, as well as under all humidity conditions, including a driving rain. Further, the camera will perform satisfactorily during and after any maneuver of the radar antenna on which it is mounted.

The camera consists of two subassemblies, the electronics section and the optical section; the electronics section contains the preamplifier, the balanced line amplifier, the blanking amplifier, the d-c filament supply for the preamplifier and the filters for the power and control voltages.

The preamplifier is constructed in a shock-mounted shielded container to eliminate any possibility of noise being introduced into the video circuits from mechanical vibration of the camera. The preamplifier uses a cascode input circuit to minimize effects of amplifier noise and input capacity; the output is 0.25 volts at 1000 ohms.

The line amplifier is designed to drive a balanced coaxial cable, such as RG130, and produces a balanced 0.3-volt output at 95 ohms. Adjustable peaking circuits compensate variable amplifier and cable characteristics.

The blanking amplifier provides the necessary pulses to blank the vidicon during the retrace interval. The vertical drive pulse is amplified and clipped to produce the vertical blanking pulse. The vidicon's horizontal-deflection retrace-pulse is clipped, amplified, and shaped to form the horizontal blanking pulse.

The optical section is contained within a sealed housing pressurized with dry nitrogen to prevent fogging of the lens. This housing contains the main lens (Baltar 152 mm, f2.7), the reticle projector, the lens-capping mechanism, the automatic-iris mechanism and the iris drive motor.

The reticle projector has a variable-intensity collimated light source, adjustable to ambient light conditions. A glass-mounted reticle-pattern transparency is focussed through a lens on the vidicon face. Reticle-base adjustments permit both transverse and rotational positioning of the pattern without depressurizing the assembly, since they are accessible from the exterior of the optical housing. The pattern is adjustable from 45 to 85 percent of picture height (measured from the bottom).

A fail-safe lens-capping arrangement, consisting of a solenoid and two capping vanes, protects the vidicon and the automatic-iris photocell from damage by the sun whenever the capping solenoid is actuated. The capping solenoid is connected so that when B+ fails, the vidicon is automatically covered. The viewing angle of the capping photocell is slightly greater than that of the main lens; therefore, the vidicon will be capped before the camera is pointed directly into the sun.

The light level that actuates the capping mechanism is determined by a neutral-density filter positioned in front of the capping photocell. This filter, available from the outside of the optical housing, may be changed without depressurizing the optical assembly.

In the automatic mode of operation, the aperture of the main lens is controlled by a mechanism utilizing an RCA 7163 photocell as a controlling element. This photocell is connected so that a variation in intensity of the light falling upon it causes a bridge circuit to become unbalanced both in magnitude and direction; the unbalance is proportional to the amount of the variation in light level. When this variation in light intensity is equivalent to an amount requiring an aperture change of one *f* number, the automatic-iris drive motor moves the iris to the required aperture. This motor also drives a special cam-shaped vane across the face of the automatic-iris photocell, which varies the light reaching the photocell and brings the bridge back into balance.

As an added reliability feature, the iris may be manually adjusted to predetermined *f* settings by operating a switch available on the monitor front panel; but the system was primarily designed for automatic control of iris and vidicon target voltage. The automatic iris controls the amount of light falling on the face of the vidicon over a range of approximately 4000:1. This combination of automatic iris and automatic target control keeps the system video output constant over an ambient light range from 2 ft-lamberts to 4×10^6 ft-lamberts of scene brightness.

TERMINAL EQUIPMENT

The terminal equipment, shown in Fig. 1, synchronizes the system, supplies power and scan currents to the camera, and processes video from the camera for distribution to the monitors. The built-in test equipment is provided for evaluation of system performance.

The sync generator supplies the 15,625-pulse/sec line-rate drive, the 50-pulse/sec field-rate drive, composite sync, and composite blanking. This generator is coupled to the 400-cycle line through an afc circuit which keeps the master oscillator locked to the line frequency during variations of ±3 percent in line frequency.

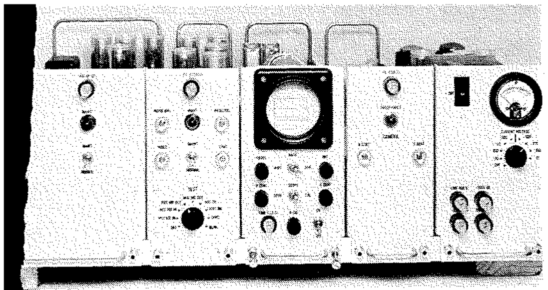

Fig. 1—Terminal equipment.

The processing amplifier accepts the balanced video from the camera, removes any extraneous noise introduced into the video along the transmission line, and processes the video for distribution to the monitors. In the processing amplifier, camera blanking is clipped off the video, black level is established, and system sync and blanking are added to the video information.

The composite video information is transformed to a balanced signal for transmission to the monitors.

The automatic target-voltage-control circuitry (also located in the processing amplifier chassis) measures the average level of the video information received from the camera and automatically adjusts the target voltage to keep the video output at a predetermined level.

The automatic target control provides a fine adjustment of system sensitivity between *f* settings of the main lens iris and extends the range of control far beyond the capabilities of the iris.

The camera deflection unit generates the horizontal and vertical scan currents required by the camera, regulates the current through the vidicon focus and alignment coils, and provides the vidicon beam centering currents. This chassis also contains protection circuitry which prevents damage to the vidicon in case of failure of one or both of the deflection generators.

The power unit furnishes the regulated d-c power required by the terminal equipment and the camera. Particular attention was given to developing a power supply with adequate reserve to accommodate the predicted supply voltage variations and hold output constant over the anticipated range of loads.

The terminal equipment has several features which greatly enhance the equipment maintainability and reliability. Test points, located so that a voltmeter or an oscilloscope cannot upset system performance, minimize the effort required to locate a fault.

The *A* scope facilitates rapid checking of the video and control waveforms, and a built-in calibrating voltage supply permits quick evaluation of the amplitude of the video or control pulses. A choice of sweep rates is provided to permit examination of the video or control wave forms at line or field rates. A rotary switch on the front of the processing amplifier allows the operator to select (for viewing on the *A* scope) the positive or negative video from the camera, the positive or negative video output from the processing amplifier, system drive, and sync or blanking pulses. Drive and blanking pulses are available at jacks on the rear of the terminal equipment frame for synchronization of special equipment.

MONITOR

The monitor (shown in Fig. 2) is designed around the RCA-8HP4 rectangular kinescope, which combines rugged construction with good resolution and high light output at relatively low anode-voltage. The monitor consists of a "mother" frame supporting the kinescope, deflecting yoke, camera-control circuitry, interconnecting wiring, and four plug-in chassis.

The monitor power supply furnishes power for the camera control, kinescope control, and plug-in monitor. The line-rate deflection chassis contains the circuitry required to generate the line-rate deflection current and the regulated 10 kv supplied to the kinescope anode. The horizontal deflection stays locked for sync frequency variations within ±3 percent. The field-rate deflection chassis contains the circuitry for generating the field-rate deflection current. The field-rate control voltage is generated by a blocking oscillator that stays locked to to the field-rate sync pulses as long as the sync pulse frequency is within ±3 percent of the nominal frequency.

The video amplifier receives a balanced video signal from the terminal equipment, amplifies it to drive the kinescope, and supplies a low-impedance video output used to operate another monitor. The differential amplifier at the video amplifier input effectively removes any noise introduced into the video during transmission from the terminal equipment.

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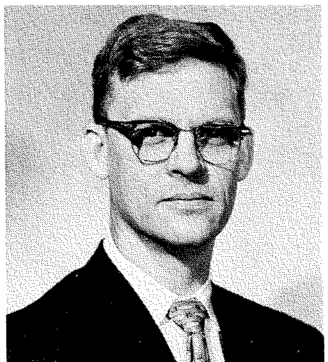

SYSTEM FEATURES

Special features such as the *A* scope, voltage and current meter on the terminal equipment power supply, test points to monitor all critical waveforms, and interchangeability of similar chassis without major system readjustment contribute to the serviceability of the system. To facilitate evaluation of system performance, a collimator (see Fig. 3), test slides, monitor overlays, and photographs of the waveforms appearing at every test point are made available.

Since the main lens is fixed-focused at a point 1000 feet from the camera, it is impractical to provide the test charts to evaluate system performance. The collimator consists of a collimated source of light, a slide holder, and a lens to bring the light projected through the test slide into focus at a point about 1000 feet from the camera. Attached to the front of the optical assembly, this arrangement facilitates rapid evaluation of system performance without requiring special orientation of the radar antenna. The slides provided are a resolution chart, a dot pattern, and a half-black, half-white slide. The resolution chart facilitates evaluation of resolution, grey scale rendition and picture shading. The dot pattern is used with a monitor overlay to determine system linearity and geometric distortion. The half-black, half-white slide is used to evaluate the system response to a transient. A light meter built into the collimator assures evaluation of the system at the specified level of 15-foot candles target illumination. A neutral density filter is provided to permit evaluation of system performance at 2 ft-candle target illumination.

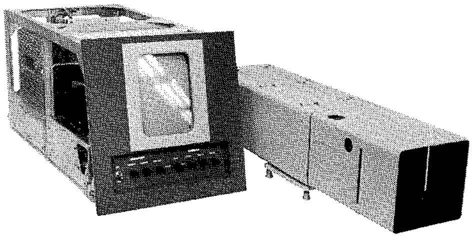

Fig. 2—Monitor and camera.

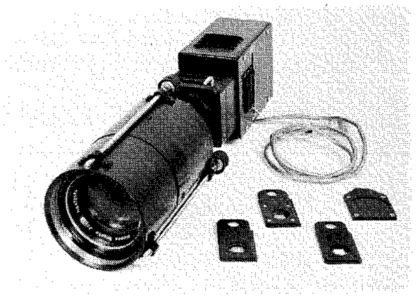

Fig. 3—Collimator, test slides and neutral density filter.

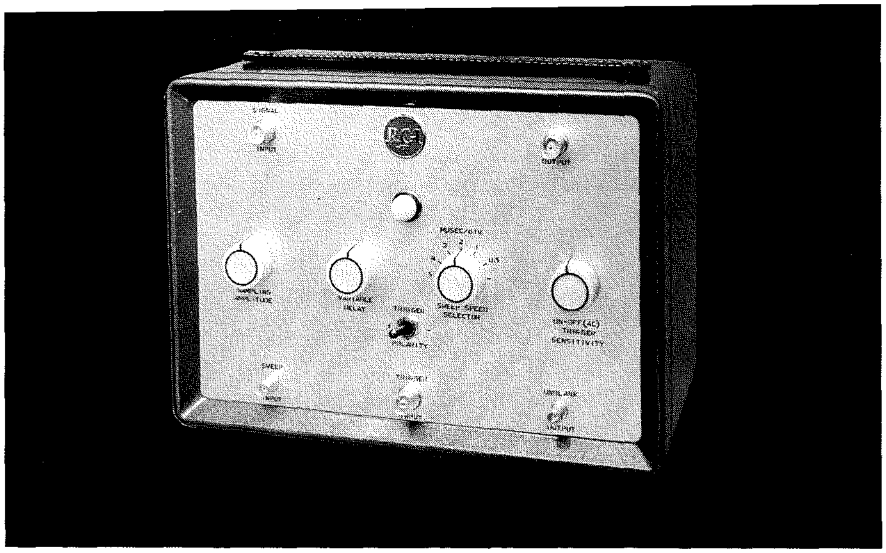

Fig. 1—Sampling oscilloscope attachment.

The increased emphasis on high-speed digital equipment, as well as the need for observation of broad spectrum phenomena, has resulted in an acute need for improvement in the art of oscilloscopic display. One approach to this problem is the unit described herein, which offers sampling techniques that effectively stretch the time scale of the signal and allow conventional oscilloscope display of repetitive waveforms. This method offers high sensitivity and relative simplicity, since available oscilloscopes can be used as part of the system.

⅓-NANOSECOND RISE-TIME SAMPLING ATTACHMENT FOR OSCILLOSCOPES

by **J. J. AMODEI***
Electronic Data Processing Division
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THE *sampling oscilloscope attachment* (Fig. 1) for conventional oscilloscopes permits the resolution of pulse rise times of one-third nanosecond ($\frac{1}{3} \times 10^{-9}$ seconds) with repetition rates up to 50 kc. The sampling circuitry is completely transistorized and contains its own power supply. The delay necessary between signal and trigger is 30 nanoseconds, while the trigger sensitivity is 1 volt at a pulse width of 2 nanoseconds. The attachment has a calibrated time scale and a usable sensitivity greater than 0.03 v/cm.

BACKGROUND

In response to the need for improved oscilloscope techniques, several new systems have been developed — each with certain advantages and disadvantages. One such system is the traveling-wave-tube oscilloscope, which features an ingenious deflection-plate structure of the traveling-wave tube type. This device reduces the effective transient time of the deflection plates by an order of magnitude. It also increases the deflection sensitivity by a similar amount, although signals of several volts amplitude are still required for useful observation.

Earlier sampling techniques for display of broad-spectrum repetitive waveforms included a type of sampling oscilloscope described and built by R. Sugarman[1]. A transistorized approach was first suggested by G. B. B. Chaplin[2], who used a transistor operated in the avalanche mode to obtain rise times of 1 nanosecond with a conventional oscilloscope.

Following lines suggested by these early techniques, work was started by G. B. Herzog[3] at the RCA Laboratories, Princeton, N.J. and the Electronic Data Processing Division, IEP, Camden, N. J. The object was to develop an even faster unit as part of the instrumentation phase of a research program for ultra-high-speed data-processing systems. The instrument described herein incorporates the best features of the Camden and Princeton models.

THEORY OF OPERATION

The performance of the sampling attachment relies on the ability of the unit to generate timed pulses of short duration, which are used to obtain almost instantaneous samples of the signal amplitude. The time and amplitude relationship of the input signal and sampling pulse can be better understood by referring to Figs. 2 through 4. The narrowness of the sampling pulse and the accuracy of its timing are factors determining the resolution obtainable with the units. Transistors operating in the avalanche mode are used together with efficient pulse-shaping networks to obtain pulse widths of the order of ⅓ nanosecond. The operation of the sampling attachment requires that the viewed waveform be repetitive and that the trigger signal be synchronous with the input waveform.

The trigger pulse occurs prior to the pulse being viewed by an interval of time fixed by the external delay lines. The trigger blocking oscillator produces a pulse which turns off diode D6 (Fig. 4). This starts the ramp that triggers the avalanche transistor, producing a voltage step which is differentiated and clipped to form the sampling pulse. The sum of the instantaneous input signal (*A* of Fig. 3) and the coincident sampling pulse (*B* of Fig. 3) is applied to the sampler diode. The output, then, is a series of pulses (*C* of Fig. 3) amplitude-modulated by the input signal on a stretched time scale. The time shift of the sampling pulse relative to the input signal is accomplished by applying a slow ramp (derived from the oscilloscope sweep sawtooth) to the emitter of the avalanche transistor. The slope of this slow ramp controls the magnitude of the interval, which in turn determines the effective sampling sweep speed. When the sawtooth wave returns to the zero level, the sampling pulse returns to its starting position and the process is repeated. The output of the sampler is amplified, stretched, and displayed on the oscilloscope.

The sampling process entails a time transformation vital to the operation of the system. This time-stretching is equivalent in a visual sense to slow-motion photography, and should be kept in mind so as not to confuse real time with sampled time; i.e., a long interval of real time may be used to display a very short portion of sampled waveform.

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* Transferred to David Sarnoff Research Center, RCA Laboratories Division, Princeton, New Jersey.

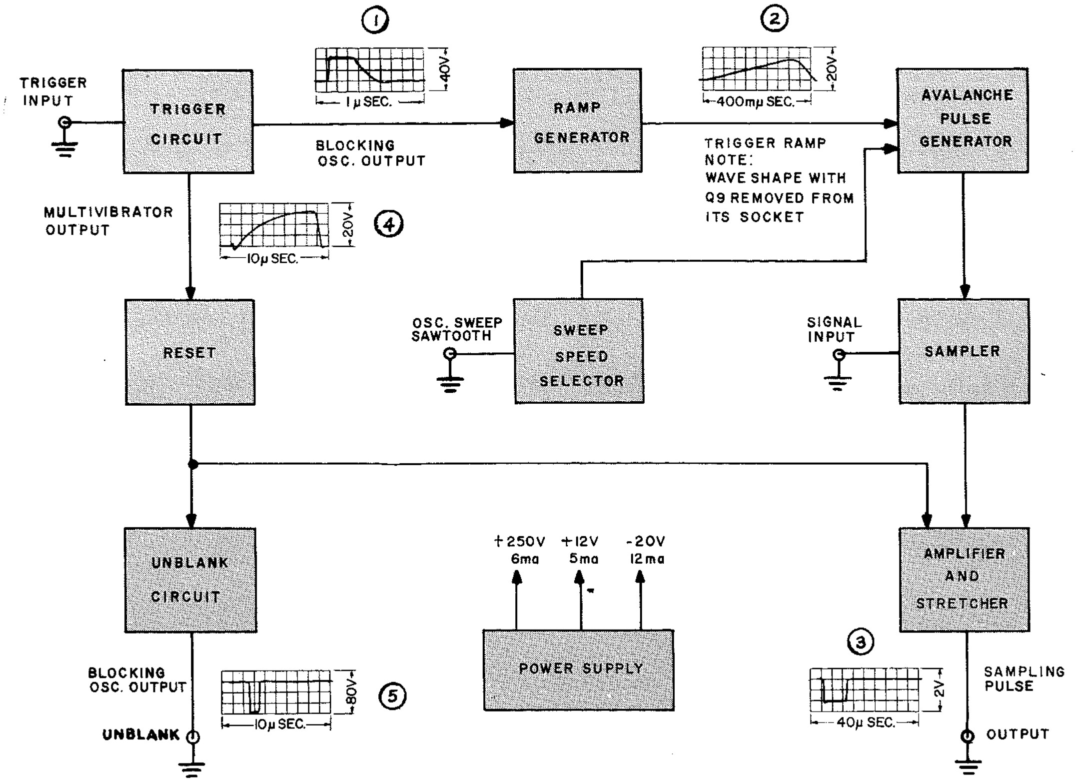


Fig. 2—Sampling circuits and waveforms.

Since the slow sawtooth wave that produced the progressive delay of the sampling pulse is derived from the oscilloscope sweep, the horizontal displacement of the spot on the cathode-ray tube and the displacement of the sampling pulse, in reference to the input signal, are linearly related.

In other words, when a certain horizontal distance, *d*, on the oscilloscope screen corresponds to a time interval, *t*, scanned by the sampling pulse, then $t = Kd$ seconds, where K is a constant determined by the slope of the fast-triggering ramp and the attenuation ratio of the sweep-speed selector; i.e., if d is measured in centimeters and t in nanoseconds, K becomes the sampling sweep speed in nanoseconds per centimeter. The oscilloscope sweep speed does not appear in the formula; this time-setting only determines the number of samples taken per unit distance on the screen.

CIRCUIT DESCRIPTION

The circuits comprising the sampling attachment are the trigger circuit, the delay mechanisms, the pulse generator, the sampling circuit, the low-frequency amplifier, the reset and unblanking circuits, and the power supply.

Trigger Circuit

The trigger circuit consists of a conventional blocking oscillator with an emitter-follower isolation stage. The blocking oscillator produces a pulse of 15-volt amplitude and 0.4-microsecond duration (waveform 1 in Fig. 2). Potentiometer R71 controls the trigger sensitivity by varying the back-bias on transistor Q11. Curves of the trigger sensitivity are shown in Fig. 5 for either transistors 2N501 or 2N695 used in the Q11 stage. The choice of transistor depends clearly on the narrowest pulse requirement.

Delay Mechanisms

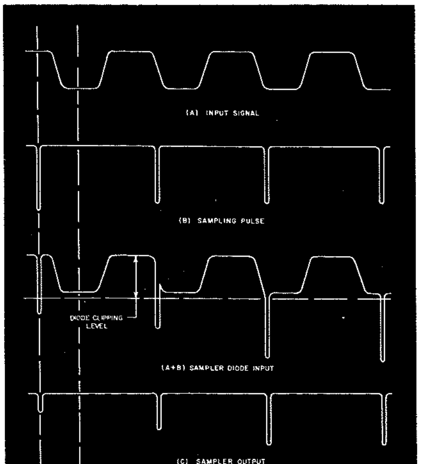
The pulse from the blocking oscillator turns off the diode D6, which clamped the base of the avalanche transistor Q9 at a negative voltage selected by the variable-delay potentiometer R68. This initiates a trigger ramp (waveform 2 in Fig. 2) as the capacitor C17 is charged through resistor R35. A very linear ramp (except for the first 10 nanoseconds) will result, since only a small portion of the total RC charge curve is used. The initial nonlinearity is due to the finite diode turn-off time and feedthrough of the leading edge from the blocking-oscillator output.

When the ramp voltage reaches the emitter voltage level, the transistor fires. (This is not necessarily true in all transistors, since the firing can occur when the base is still back-biased with respect to the emitter; however, this is not important as long as the firing point is consistent.) The time the ramp takes to reach this voltage level is determined by the RC time constant and the setting of the manual-delay selector, R68. This potentiometer simply varies the d-c ramp-starting voltage between the limits set by R69 and R70. At the minimum setting of the manual selector, the total delay necessary between the sampled signal and trigger is set at approximately 30 nanoseconds to avoid using the nonlinear portion of the ramp. The emitter-follower arrangement of the 2N247 is used as a d-c clamp. The emitter diode of the transistor has little effect on the fast leading edge of the blocking oscillator pulse, which turns off the fast-switching S555G diode.

Pulse Generator

This circuit is composed of the triggered avalanche transistor and the pulse shaping network. The point at which the avalanche step occurs is controlled by the triggering ramp, and by the delaying ramp derived from the scope sweep, fed in at the emitter of the transistor. The slope of the emitter ramp determines the progressive delay between samples and, therefore, the sampling sweep speed. This slope is easily ad-

Fig. 3—Input-signal and sampling-pulse relationship.



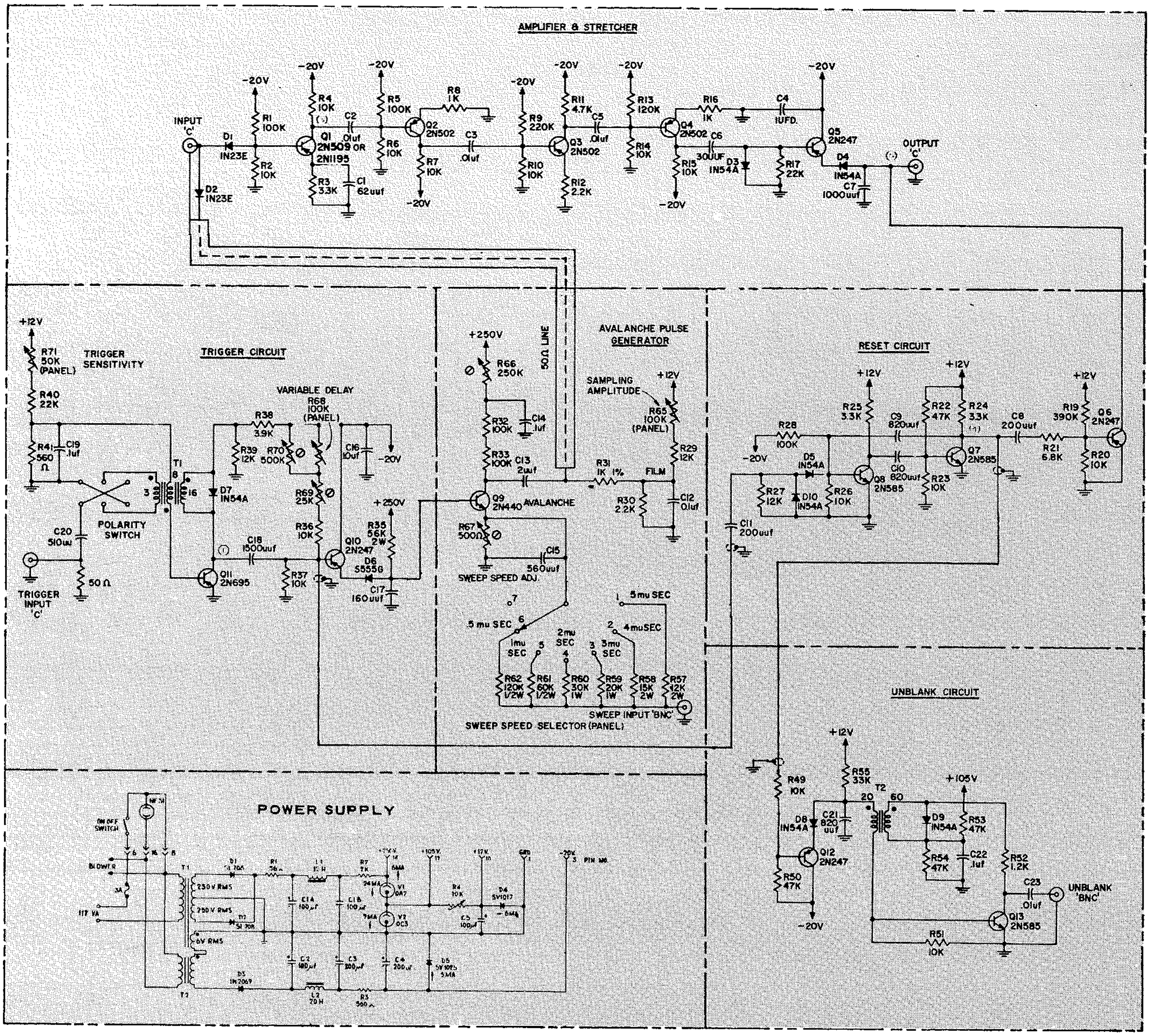


Fig. 4—Oscilloscope-attachment schematic.

justed by means of a voltage divider, composed of the emitter resistance and the adjustable sweep-selector resistance.

Sweep-speed calibration is obtained by means of the 500-ohm potentiometer in the emitter. In a typical transistor, the avalanche step would have an amplitude of 35 volts and a duration of 1.5 nanosecond. It was found that 10 percent of the commercially available 2N440 units are suitable for this usage. The yield was greater in later available types like the GT1188. If optimum rise time is not required, a larger percentage can be used. The pulse shaping of this step is done by one stage of differentiation and one stage of clipping with the 1N23E diode. The clipping level can be varied by means of potentiometer R65. Use of a small capacitor in the differentiator circuit keeps the loading on the avalanche transistor to a minimum, thus optimizing the switching time for the given unit. This makes it possible to obtain an extremely narrow pulse with just one stage of differentiation.

Sampling Circuit

The sampling circuit is composed of the back-biased diode D1 (1N23E) operating into the base of the first stage of the low-frequency amplifier. The sampling and clipping diodes are both housed in a specially made right-angle holder. The 1N23E was chosen for its better performance, although cheaper microwave or fast-switching diodes may be used where optimum rise time and signal-to-noise ratio are not required.

Low-Frequency Amplifier

The first two stages of the low-frequency amplifier use high-frequency transistors in order to gain sensitivity and signal-to-noise ratio. The narrow sampling pulse would be considerably attenuated by a lower-frequency transistor. The last three stages of the amplifier serve to stretch the pulse and amplify it (waveform 3 in Fig. 2). The clamping diode D3 sets the base line of the pulses at near zero d-c voltage. The amplifier is capable of more gain than is necessary with the present number of stages. Sufficient stabilized gain can be obtained with four stages, but transformer coupling will then be necessary to maintain the proper polarity. Capacitor C6 and resistor R17 act as a high-pass filter to avoid the additional burden of low-frequency amplifier noise.

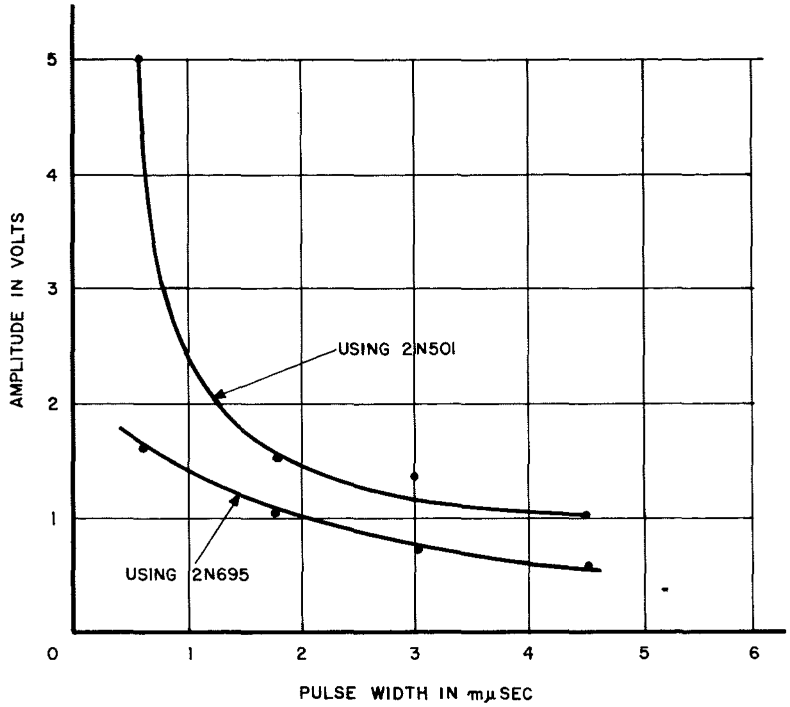


Fig. 5—Trigger-sensitivity curves.

Reset and Unblanking Circuits

A monostable multivibrator, when triggered by the pulse from the blocking oscillator in the trigger circuit, produces a pulse 8 microseconds wide (waveform 4 in Fig. 2). The pulse is differentiated and its trailing edge turns on the reset transistor so that the pulse-stretching capacitor is discharged, readying the system for another sample.

The unblanking blocking oscillator is triggered on after a 5-microsecond delay and produces a 40-volt pulse, 1.5 microseconds wide (waveform 5 in Fig. 2) to be applied to the cathode of the cathode-ray tube in the oscilloscope. This unblanks the signal after the initial transients have disappeared, thus reducing the spot smear. Also, because of the short duration of the unblank pulse, the tilt in the displayed part of the stretched pulse is negligible.

The 5-microsecond delay is obtained as follows: The positive pulse from the monostable multivibrator turns off Q12 and D8, which in turn allows C21 to charge towards the 12-volt supply voltage. When the capacitor voltage gets high enough to forward-bias the blocking oscillator base, the unblank pulse is generated. The diode in the collector prevents ringing and lengthens the recovery time so as not to obtain multiple firings. When the monostable multivibrator returns to its quiescent state, the base of Q12 becomes negative once again and quickly clamps C21 to this negative voltage. This system results in a delay which is independent of repetition rates in the range of interest. Q12 also acts as a buffer stage to prevent the large blocking oscillator signal from feeding back into the monostable multivibrator and resetting it prematurely.

Power Supply

The power supply utilized is of standard design and provides +250 volts at 6 ma, +12 volts at 5 ma, and −20 volts at 12 ma. The ripple is less than 2 mv for the low voltages and less than 10 mv at 250 volts.

PERFORMANCE

The sampling attachment is capable of resolving rise times of ⅓ nanosecond. Figs. 6 and 7 show photos of very narrow pulses, generated by a mercury relay generator, as displayed on a conventional 10-mc oscilloscope with the aid of a sampling attachment. Some of the faster units have bandwidths as high as 2 kmc and rise time capabilities which could not yet be tested because of lack of appropriate pulse-generating equipment.

The sensitivity of the units is limited only by the noise generated in the avalanche process. Usable sensitivities ranging between 10 mv/cm and 30 mv/cm have been obtained in the units constructed. Much improvement in signal-to-noise ratio can be obtained by using to advantage the frequency-transformation properties of the system by means of filter detection. A detailed treatment of this problem, however, is beyond the scope of this article. The sweep linearity is better than 5 percent and the amplitude distortion is less than 5 percent in most units, provided that the signal amplitude is kept within the proper limits.

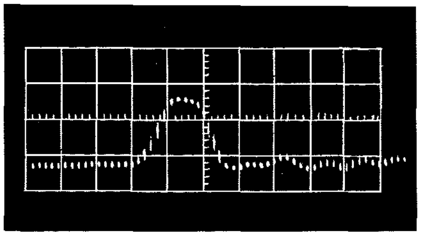


Fig. 6—1-mμsec pulse; 0.5 mμsec/div, 100 mv/div.

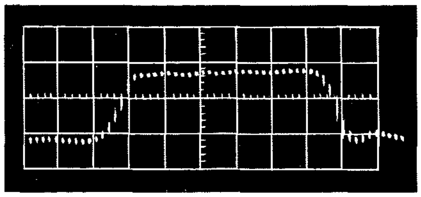


Fig. 7—3.3 mμsec pulse; 0.5 mμsec/div, 100 mv/div.

ACKNOWLEDGEMENTS

The writer wishes to thank M. D. Nelson, EDP Division, Camden, N. J. and G. B. Herzog of the Princeton Laboratories for the many fruitful discussions held during the development of the unit.

BIBLIOGRAPHY

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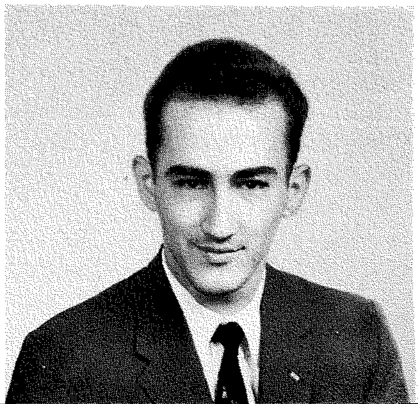
2. Chaplin, G. B. B. *A Method of Designing Transistor Avalanche Circuits with Application to a Sensitive Transistor Oscilloscope*, 1958 Transistor and Solid-State Circuits Conference.
3. Herzog, G. B. *A One Millimicrosecond Rise Time Plug-In Unit for Tektronix Oscilloscopes*, PEM-1225, October 1, 1958.
4. Goldman, S. *Information Theory*, Prentice Hall, 1953, p. 67.

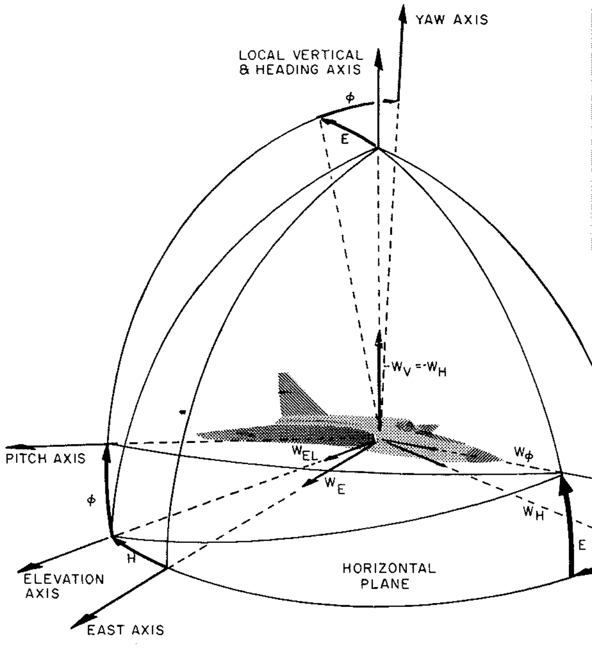
JUAN J. AMODEI graduated from Case Institute of Technology in June 1956 with a B.S. degree in Electrical Engineering, whereupon he was employed by the Philco Corporation in their transistorized radio receiver development. He joined RCA in March 1957 and spent the following three years in the EDP Advanced Development Department. His assignments consisted of the design of a highly accurate analog-to-digital converter, design of the circuitry for a medical pressure telemetering pill, and sampling oscilloscope systems. Mr. Amodei transferred to the David Sarnoff Research Laboratories at Princeton early in 1960, where he is presently working on high-speed digital circuits. Mr. Amodei is a member of IRE, Eta Kappa Nu, Phi Kappa Psi, and is presently completing thesis requirements for a Master's degree at the University of Pennsylvania.



INERTIAL NAVIGATION
PART IV—ELECTROMECHANICAL TRANSDUCERS

by **F. F. DAIGLE**
Missile Electronics and Control Division
DEP, Burlington, Mass.

The previous three articles in this author's series (Vol. 3, No. 2; Vol. 4, No. 1; and Vol. 5, No. 3) discussed the role of the gyroscope in performing its basic function of space-rotation sensing—and how this parameter (sensing) was used in conjunction with accelerometers to maintain an inertial platform dynamically level. Other electromechanical components, such as the resolver and the synchro, were discussed only in a general way without explaining the theory underlying these components. It is the purpose of Part IV to provide this basic theory on both resolvers and synchros.



ϕ AIRCRAFT ROLL
E AIRCRAFT ELEVATION
H AIRCRAFT NORTH HEADING

$W_H = W_V$
$W_{EL} = W_E \cos H - W_N \sin H$
$W_\phi = (W_E \sin H + W_N \cos H) \cos E - W_V \sin E$

Fig. 1—Platform rates

For biography of Mr. Daigle, refer to Vol. 5 No. 3, page 43.

In the process of maintaining an inertial platform dynamically level as the base travels through space and is perturbed in various ways, the gyro-sensed angular rotation of the platform (Fig. 1) must be transformed to the appropriate platform gimbals. The gyro signals arrive at the gimbal drives only after being transformed into signals generated by gyros mounted directly on the individual gimbals. The *resolver* is used to perform this series of transformations.

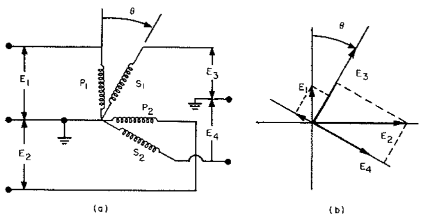
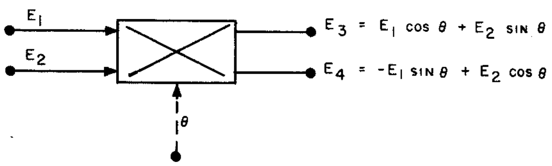


Fig. 2—Electromechanical resolver



$E_3 = E_1 \cos\theta + E_2 \sin\theta$
$E_4 = -E_1 \sin\theta + E_2 \cos\theta$

Fig. 3—Block representation of a resolver

Having stabilized the inertial platform, it is usually required to repeat the isolation gimbal angles remotely to other systems such as radar and infrared systems, which need to be inertially stabilized. It behooves the inertial designer in these instances to mount *synchros* on the gimbals so that gimbal angles can be measured and repeated remotely at locations where space is not as limited as on the platform.

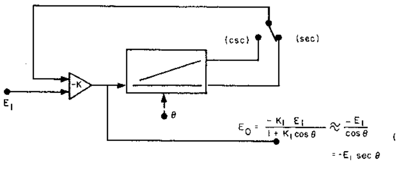
RESOLVERS

The resolver, basically a variable-coupling transformer, produces a secondary output proportional to the primary input times the cosine of the angle between primary and secondary coils.

The electromechanical resolver shown in Fig. 2 can be drawn in block form as in Fig. 3. This block representation of the resolver conveys phasing information which is acknowledged when wiring the resolver. For example, the resolver may be coupled to the main θ shaft through either an odd or even number of gears. To assure proper phasing, the resolver output windings (which may be either rotor ~~or~~ stator windings in some applications) are connected to give output voltages represented by the equations in Fig. 3 with a positive rotation of the main θ shaft.

TRIGONOMETRIC FUNCTIONS

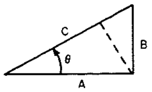
The electromechanical resolver can be used in a variety of ways, one of which is as a trigonometric function generator. Sine and cosine functions can be derived directly from the resolver with either positive or negative signs. Inverse functions such as the secant and cosecant can also be derived by a scheme similar to that outlined in Fig. 4. The resolver is used in the feedback leg of the closed-loop circuit. Therefore, care must be exercised in restricting the angle θ. For instance, with a high-gain amplifier of gain K, the secant function should be restricted to small positive and negative values of θ. The cosecant function must be restricted to a small zone centered about ±90°. Although these restrictions bar the universal applications of these techniques, there are a number of cases where these restrictions can be tolerated, and thus permit the use of these circuits.



$E_0 = \frac{-K_1 E_1}{1 + K_1 \cos\theta} \approx \frac{-E_1}{\cos\theta}$
$= -E_1 \sec\theta$

Fig. 4—Cosecant functions

Tangent and cotangent functions can also be obtained from the circuit of Fig. 4. The resolver output labelled *CSC* becomes $-E_1 \tan\theta$ with the switch position as shown. With the opposite switch position, the output labelled *SEC* becomes $-E_1 \operatorname{ctn}\theta$. The same corresponding restrictions on θ hold for the tangent and cotangent functions as they did for the secant and cosecant functions.



$$C = A\cos\theta + B\sin\theta \qquad \text{(R4)}$$

$$A\sin\theta = B\cos\theta \qquad \text{(R5)}$$

Fig. 5—Right-triangle relationships

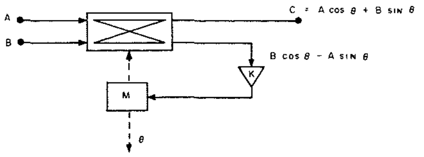


Fig. 6—Arctangent servo solution of a right triangle

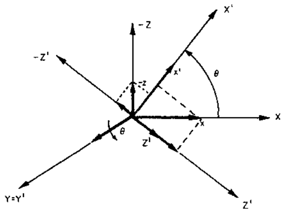


Fig. 7—Coordinate rotations

RIGHT-TRIANGLE COMPUTATIONS

One of the most useful applications of the electromechanical resolver in analog computing is in right-triangle solutions. Consider Fig. 5, which shows the right-triangle relationships. Knowing sides A and B, it is desired to compute C and mechanize the angle θ. Fig. 6 shows the mechanization of the right triangle by feeding the resolver with voltages proportional (analogs) to the sides A and B. One output is servo-nulled to produce a shaft angle θ, and the resultant side C appears as a voltage.

COORDINATE TRANSFORMATIONS

Consider Fig. 7 which shows a coordinate rotation of an XYZ system into an $X'Y'Z'$ system about the mutual $Y = Y'$ axis. The prime components can be expressed as:

$$x' = x\cos\theta - z\sin\theta$$

$$y' = y$$

$$z' = x\sin\theta + z\cos\theta$$

Expressed in matrix form, this becomes:

$$\begin{bmatrix} x' \\ y' \\ z' \end{bmatrix} = \begin{bmatrix} \cos\theta & 0 & -\sin\theta \\ 0 & 1 & 0 \\ \sin\theta & 0 & \cos\theta \end{bmatrix} \begin{bmatrix} x \\ y \\ z \end{bmatrix}$$

To mechanize the above coordinate transformation, the resolver is used as outlined in Fig. 8a. The quantity θ is defined positive clockwise when looking along the positive axis of rotation with positive *i-j-k* right-hand rotation. Figs. 8b and 8c represent coordinate rotations about the X and Z axes, respectively.

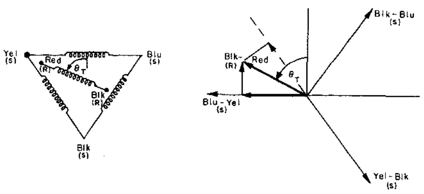


Fig. 9—Bendix synchro transmitter

RESOLVER CIRCUIT CONSIDERATIONS

In an actual coordinate transformation circuit as well as in other trigonometric circuits, the resolver must be properly matched to high-impedance circuits because of its relatively low input and output impedances. Therefore, each resolver is usually associated with isolation amplifiers, on both input and output, whose sole purpose is to provide the impedance matches required. Too, some electrical phase shift is experienced within the resolver because of its electromagnetic properties. Therefore, the amplifier also usually contains a form of lead-lag circuit to compensate for the phase shift. Sample designs of these circuits are beyond the scope of this paper.

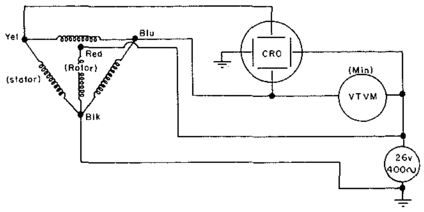


Fig. 10—Autosyn transmitter zero

SYNCHROS

A synchro, unlike the resolver, has one rotor coil and three stator coils which are delta connected. The Bendix autosyn (synchro) is used for analysis.

The *synchro transmitter* is defined as the unit whose rotor is excited with 26 volts, 400 cps. Consider Fig. 9, which shows the space picture of the synchro transmitter. Electrical zero for the transmitter (Fig. 10) is defined as the rotor position which gives a zero line voltage from stator blue-to-yellow when the line voltage from stator black-to-blue (or black-to-yellow) is in phase with the rotor excitation black-to-red.

With a 400-cycle a-c voltage on the rotor such that $e_{blk\text{-}red} = E \sin wt$, it can be seen that the three stator line voltages are as follows:

$$e_{blk\text{-}blu} = K_T\, E \cos\,(\theta_T + 30°)\,\sin wt$$

$$e_{yel\text{-}blk} = K_T\, E \cos\,(\theta_T + 150°)\,\sin wt$$

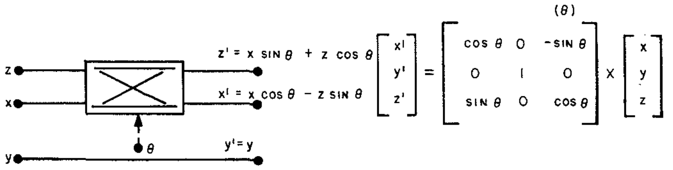
$$e_{blu\text{-}yel} = K_T\, E \cos\,(\theta_T + 270°)\,\sin wt$$

K_T is the ratio of rotor voltage to maximum line voltage, i.e.,

$$K_T = \frac{11.8 \text{ volts}}{26 \text{ volts}}$$

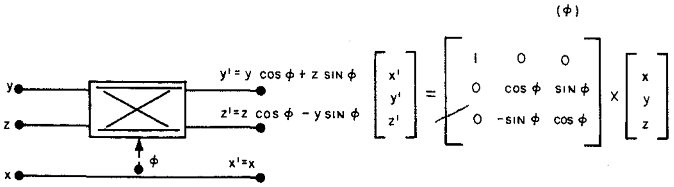
The *synchro control transformer* is defined as the unit whose stator is excited. It is also commonly referred to as an autosyn receiver and is in most cases identical in construction to the autosyn transmitter.

It is the purpose of the control transformer rotor to follow the transmitter rotor. Clockwise rotations of the rotors with respect to the stators, as viewed from end opposite the leads, gives a positive angle θ_T for the transmitter and a positive angle θ_C for the control transformer.



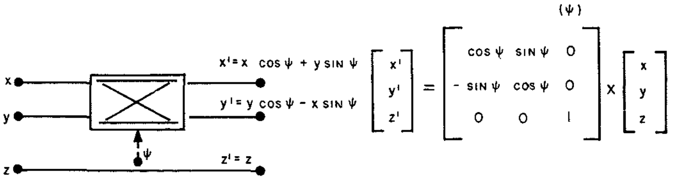
$$\begin{bmatrix} x' \\ y' \\ z' \end{bmatrix} = \begin{bmatrix} \cos\theta & 0 & -\sin\theta \\ 0 & 1 & 0 \\ \sin\theta & 0 & \cos\theta \end{bmatrix} \times \begin{bmatrix} x \\ y \\ z \end{bmatrix}$$

(a) POSITIVE CLOCKWISE ROTATION ABOUT Y



$$\begin{bmatrix} x' \\ y' \\ z' \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos\phi & \sin\phi \\ 0 & -\sin\phi & \cos\phi \end{bmatrix} \times \begin{bmatrix} x \\ y \\ z \end{bmatrix}$$

(b) POSITIVE CLOCKWISE ROTATION ABOUT X



$$\begin{bmatrix} x' \\ y' \\ z' \end{bmatrix} = \begin{bmatrix} \cos\psi & \sin\psi & 0 \\ -\sin\psi & \cos\psi & 0 \\ 0 & 0 & 1 \end{bmatrix} \times \begin{bmatrix} x \\ y \\ z \end{bmatrix}$$

(c) POSITIVE CLOCKWISE ROTATION ABOUT Z

Fig. 8—Mechanized coordinate transformations

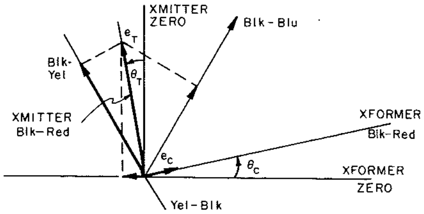


Fig. 11—Control transformer relationships

In a repeater hook-up, the transmitter stator leads are connected to the controller-transformer stator leads, color for color, when the rotations for both units are to be in the same sense. Thus, the line voltages appearing at the control-transformer stator are the same as the line voltages at the transmitter stator.

In repeater applications, the voltage appearing across the transformer rotor is used to actuate a servomechanism which rotates the transformer rotor until the rotor voltage is zero.

Fig. 11 is similar to Fig. 9b and shows the stator voltages applied from the transmitter to the control transformer. The angles θ_T and θ_C are equal in magnitude and sense; however, the control transformer electrical zero lags the transmitter zero by 90°. This can be shown mathematically by summing the projections of the above three equations for stator line voltage upon a vector lagging the transmitter rotor vector by 90°.

Electrical zero for the control transformer (Fig. 12) is defined as the rotor position which gives a zero rotor red-to-black voltage when both stator blue-to-black and yellow-to-black are excited. Since there are two such orientations, the true null appears when the rotor red-to-black voltage is in phase with the blue-to-black stator when that stator winding alone is excited.

A typical servo application of synchro transmitters and control transformers is shown in Fig. 13. Interchanging the blue and yellow connections allows for a reversal of transformer rotor direction. A reversal of transformer rotor rotation is also brought about by interchanging the red and black inputs to the servo amplifier.

MULTIPLE-SPEED SYNCHRO SYSTEMS

Where high repeating accuracies are required, a two-speed synchro system may be used. Two transmitters and two control transformers are used. One transmitter-transformer pair is used as *coarse* and the second pair as *fine*. The coarse set is directly coupled to the input-command member whereas the fine set rotates n times the coarse angle. A two-speed limiter circuit (switch) allows the coarse signal to be acted upon by the servo until the output member is within 360°/n of null, whereupon the fine is switched on and the remainder of the electrical null is controlled by the fine input.

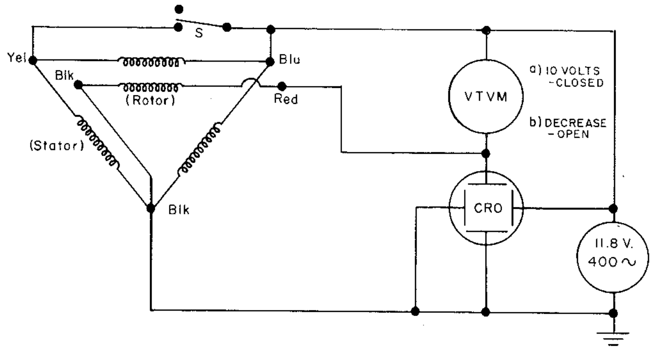


Fig. 12—Synchro control transformer zero

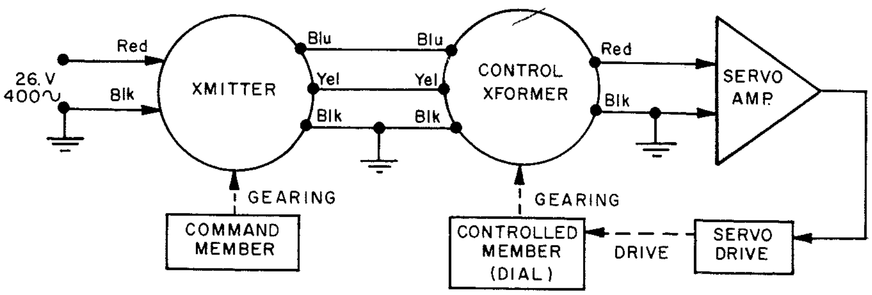


Fig. 13—Servo application of synchro transmitter and control transformer

SYNCHRO DIFFERENTIAL

A third member of the synchro family is the *differential* which has three stator coils and three rotor coils. The stator coils are excited from a transmitter stator which represents the electrical equivalent of a command input angle, θ_T. The second input to the differential is the mechanical angle θ_D itself.

Since the differential stator is excited by the transmitter stator, the differential stator corresponds electrically to the transmitter rotor rotation θ_T. This in turn induces into the differential rotor a voltage which is a function of the differential rotor rotation θ_D. By exciting a control transformer stator with the voltages induced in the differential rotor, a control transformer null is found at a rotation $\theta_T + \theta_D$ away from the control transformer electrical zero.

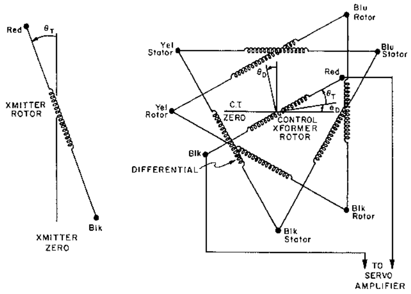


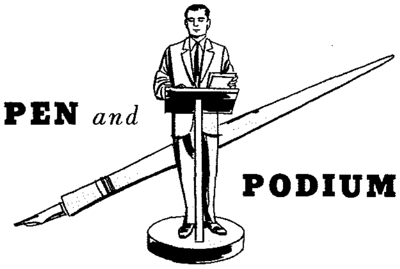
Fig. 14—Synchro differential relationships

The electrical zero for the differential is defined as the rotor position which gives a zero rotor blue-yellow voltage when the stator yellow-black and blue-black are excited with the same voltage. Since there are two such nulls which are 180° apart, the true null exists when the rotor blue-black voltage is in phase with the stator blue-black excitation.

SYNCHRO PHASING

In systems where a large number of synchros are used, standardization of phasing becomes an important requisite. Because of the various gear trains or couplings involved between synchros and controlled members, the phasing becomes particular to the application itself. However, to eliminate confusion in replacing and zeroing synchros, the synchro transmitters should all be identically *pig-tailed* to male connectors. This also applies to the synchro control transformers, resolvers and differentials. Thus, phasing of the equipment becomes a part of the circuitry between synchros; the synchro is regarded as containing the standardized pig-tailed connection.

The phasing circuitry can then be worked out by blue-yellow and red-black interchanges where they apply.



PEN and PODIUM

Based On Reports Received Over a Period of About Two Months

DEFENSE ELECTRONIC PRODUCTS

Camden, N. J.

Reliability Prediction

H. L. Wuerffel. Local Chapter of PGRQC Mtg., Philadelphia, Pa., March 8, 1960. Sources of parts data suitable for use in the various prediction techniques.

New Tools for Micro-Recording and Reproduction

D. J. Parker. National Microfilm Assn., New York City, April 20th. The characteristics and advantages of the "Video File."

An Electrostatic Color Map Printer

D. J. Parker. Society of Motion Picture and Television Engineers. Los Angeles, May 2; presented by L. J. Krolak. The Electrofax Color Map Printer constructed for the U. S. Army.

Printed Circuit Standardization

M. Arbogast. Standards Engineers Society, Philadelphia, April 25, 1960. The relationship between the lack of standards and the spectacular growth of the printed circuit industry.

Developments in Thermoelectric Devices

E. C. Farmer. MIT Chapter of AIEE-IRE, April 14. Principles of thermoelectrics, with design considerations.

Fiber Optics—A New Tool in Electronics

L. J. Krolak. Society of Motion Picture and Television Engineers, Los Angeles, May 2nd. The use and RCA application of fiber optics.

Films for Defense

L. A. Shaffer. May, 1960, issue of "American Cinematographer." RCA solves photographic problems involved in documenting the construction of the tracking radar to produce motion picture progress report and training films.

Military Television Surveillance for Missile Launchings

J. Castleberry, Jr. IRE Symposium on Military Communications. Rome, N. Y. June 25, 1960. A television system developed as part of the Titan launching instrumentation.

Reliability Analysis of Resistor Drift Characteristics

B. R. Schwartz. Electronic Components Symposium, May 12th. A Method for synthesizing resistor test data into an estimated drift characteristic for multi-environments.

An Automatic Air Traffic Control Communications System

A. W. Muoio. Univ. of Penna. March 29, 1960. Present voice communications system in air traffic control.

Moorestown, N. J.

New Uses for Microwaves

Dr. E. W. Matthews. Villanova Univ.—IRE-AIEE Student Branch April 6, 1960. Two interesting microwave applications: linear accelerators, utilizing microwave fields to produce megavolt electron beams; and radio astronomy, probing the secrets of the universe at microwave frequencies.

Recent Developments in Parametric Amplifiers

Dr. E. W. Matthews. Univ. of Pa., Moore School Colloquium, March 15th. Included background and historical review; summary of varactor diode characteristics; theory of parametric amplification and description of various modes of operation; and summary of best results obtained to date.

Practical Applications of Queuing Theory

E. Rawdin. Engineers Club, Philadelphia, April 5th. Basic concepts and practical applications of queuing theory.

The Development of Management Personnel From Engineering Talent

F. W. Anderson. March 16th, Engineers' Club, Philadelphia. Objectives and results of a recently completed engineering supervisory training program at RCA.

Pulse Radar for Trajectory Instrumentation

D. K. Barton and S. M. Sherman. 6th Nat'l Flight Test Instrumentation Symposium, San Diego, California, May 3, 1960. Status of surface-based pulse radar for trajectory instrumentation; performance figures; factors determining accuracy, as well as recent advances.

Intabs—Instantaneous Target Backscatter System

L. J. Cantafio. Master's Thesis, Moore School of Electrical Engineering. June, 1960. Radar cross section and method of incorporating its automatic and instantaneous measurement into a typical radar system.

The Technical Consultant in Electronics

H. R. Ketcham. American Management Assn. Seminars on Research Laboratory Administration (used as reference material for conferees). Utilization of consultants; proper contractual and working relationship.

Van Nuys, California

Circuit Engineering with RCA Micromodules

J. Porter. IRE Cedar Rapids Section Mtg., April 20th. A three-axis solid state missile autopilot, largely amenable to RCA micromodule packaging techniques, including a transformerless power supply.

The Air Traffic Control Radar Beacon System

J. H. Pratt. Aviation Electronics Assn. Convention, San Francisco, April 20th. History of the Air Traffic Control Radar Beacon System and the problems that have delayed its implementation.

Origination of Venture Research

Dr. G. V. Nolde. IBM Research Laboratories, San Jose, California, April 20th. Engineering methods in manufacturing.

A Novel, High-Performance, Solid-State Autopilot

J. Porter and R. Moses. 1960 Winter Convention on Military Electronics, Los Angeles, Feb. 3-5th. Development and design of a general-purpose, solid-state, three-axis, programmed autopilot.

INDUSTRIAL ELECTRONIC PRODUCTS

Improving Picture Quality Through Phase Equalization

R. S. Jose. 38th Nat'l Assn. of Broadcasters Convention, Chicago, April 4th. The factors, effects, and remedy of time delay involved in vestigal sideband TV transmission.

TV Automation

F. R. McNicol. 38th Nat'l Assn. of Broadcasters, Chicago, April 6th. Automation of the program assembly function as one of the most promising approaches to cost reduction in operation of a TV station.

Techniques of Supervision in a Multi-Level Group

H. M. Elliott. Engineering Adm. Seminar, Cornell University, June 14-17, 1960. As a supervisor develops and advances in the company, administration and direction of projects absorb more and more of his time and he finds himself a participant in a multi-part game.

New Concepts in TV Cameras

S. L. Bendell and H. N. Kozanowski. 87th SMPTE Convention, Los Angeles, May 8, 1960. The development of television cameras, electrically stabilized to produce optimum picture quality with a minimum of operator attention.

A Tunnel Diode Tenth Microsecond Memory

M. M. Kaufman. IRE International Convention, New York City, March 24th. The packaging techniques developed for, and the description of a tunnel diode memory cell practical for a large (approx. 10^5 bits) cell.

A Precise Timer for Control of the Thermofusion Experiment at Princeton

P. Slavin. 1960 AIEE District 5 Mtg., Milwaukee, Wisc. April 27th. Behavior and characteristics of the Timer used by experimental physicists to select precise timing pulses placed in a period of 100 seconds.

A Video Head Assembly for Recording Primary Standard TV Tapes

A. H. Lind and H. G. Wright. SMPTE Convention, Los Angeles, Calif. May, 1960. The need for standard reference recorded tape for alignment of TV tape recorders is recognized by all TV Tape Recorder users.

The Measurement of FM Deviation in TV Tape Recordings

A. H. Lind and A. C. Luther. SMPTE Convention, Los Angeles, May, 1960. The basic limiting parameters in the tape recording system and several methods of measurement, including a new technique that offers greater operational convenience.

RCA VICTOR HOME INSTRUMENTS

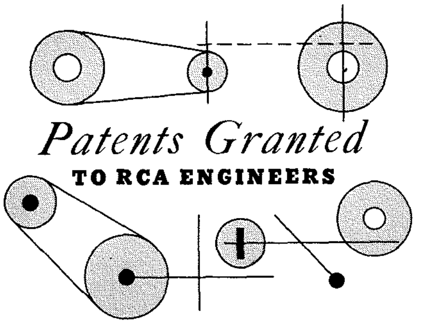
Cherry Hill, N. J.

A High Performance Transistor Output Circuit

R. C. Graham. IRE, Chicago, June 20, 1960. The design considerations and performance of the output circuit currently used by RCA Victor in their transistor radio line incorporates the use of a high impedance, center-tapped speaker, replacing the output transformer-speaker combination conventionally used.

A Low Noise VHF Tuner Using a Nuvistor Triode RF Amplifier

G. C. Hermeling, Jr. IRE, Chicago, June 20, 1960. The pertinent parameters and measurement methods of the RCA nuvistor triode high frequency RF amplifier.



Patents Granted

TO RCA ENGINEERS

BASED ON SUMMARIES RECEIVED OVER A PERIOD OF ABOUT TWO MONTHS

DEFENSE ELECTRONIC PRODUCTS

Frequency Modulation Limiter Which Does Not Detune Associated Tuned Circuit
2,932,734—April 12, 1960; C. A. Rosencrans

Multi-Beam Convergence Apparatus
2,928,981—March 15, 1960; M. Kolesnik and C. Small

Receiving System for Suppressed or Reduced Carrier Waves with Phased-Locked Synchronous Detector.
2,930,891—March 29, 1960; L. L. Lakatos

Modulator for Color Television Transmitters
2,935,555—May 3, 1960; M. Feryszka

Gravitational or Accelerational Responsive Device
2,928,667—March 15, 1960; R. H. Peterson

Phonograph Record
2,932,522—April 12, 1960; C. C. DeWitt

Frequency Variation Response Circuit
2,935,607—May 3, 1960; W. R. Koch

Electromechanical Filter Assemblage
2,935,706—May 3, 1960; D. L. Lundgren and J. J. Murphy

INDUSTRIAL ELECTRONIC PRODUCTS

Reeling System
2,928,620—March 15, 1960; A. V. Stavrakis, and C. J. Kennedy (no longer with RCA)

Composite Signal Transmitting Systems
2,929,867—March 22, 1960; R. C. Dennison

Oscillator
2,930,002—March 22, 1960; N. E. Edwards and A. W. Muoio

Television Transmission
2,930,846—March 29, 1960; R. S. Jose

Frequency Shift Oscillator
2,930,991—March 29, 1960; N. E. Edwards

Television Signal Separator Circuits
2,932,689—April 12, 1960; R. W. Sonnenfeldt

Frequency Modulator
2,932,803—April 12, 1960; S. S. Spiegel and L. E. Thompson

Reduction of Reflection in a Transmitting System
2,934,640—April 26, 1960; W. Darling

RCA LABORATORIES

Electrical Display Device
2,928,894—March 15, 1960; J. A. Rajchman

Phase Comparison Circuits
2,928,955—March 15, 1960; G. B. Herzog

Method of Making Surface Alloy Junctions in Semiconductor Bodies
2,932,594—April 12, 1960; C. W. Mueller

Transistor Frequency Converter Circuits
2,932,735—April 12, 1960; E. W. Herold

Semiconductor Devices
2,932,748—April 12, 1960; H. Johnson

Miller Effect Control of Bandpass in Vicinity of Subcarrier Frequency
2,934,599—April 26, 1960; D. D. Holmes

D-C Stabilized Amplifiers
2,935,556—May 3, 1960; A. A. Barco

Underwater Object Locator
2,935,728—May 3, 1960; A. R. Morgan

ELECTRON TUBE DIVISION

Getter Structure
2,928,925—March 15, 1960; E. S. Thall, and H. J. Miller (no longer with RCA)

High Transconductance Electron Tube
2,932,757—April 12, 1960; W. J. Helwig

Electron Beam Tube
2,932,758—April 12, 1960; O. H. Schade, Jr.

Tip-Off Apparatus for Electron Tubes
2,934,860—May 3, 1960; J. L. Gallup

Electron Tube Fault Detection
2,928,026—March 8, 1960; M. V. Hoover

RCA VICTOR HOME INSTRUMENTS

Color Television Matrix Amplifier System
2,927,957—March 9, 1960; A. J. Torre

Transistor Deflection Circuit for Television Receivers
2,933,641—April 19, 1960; H. C. Goodrich

Pen and Podium, Continued

RCA VICTOR RECORD DIVISION

Indianapolis, Ind.

Pressure and Temperature Measurements Within the Molding Cavity During the Compression Molding of a Phonograph Record

R. G. Fox, Jr. Society of Plastics Engineers, Central Indiana Section Meeting, Indianapolis, Jan. 26, 1960. The reasons for pressure and temperature measurements in the molding cavity, as well as the problems involved in the design and fabrication of the sensors and solutions obtained.

Contributions of Electroplating to Phonograph Records

Dr. A. M. Max. Houston Branch of the American Electroplaters Society on Jan. 19th and the Dallas-Forth Worth Branch of the AES on Jan. 20th.

Temperature and Pressure Measurements In the Molding Cavity During Molding

Ralph G. Fox, Jr. Central Indiana Section of the Society of Plastics Engineers Feb. 9th.

Stereophonic Recording and Reproduction

R. C. Moyer. New York Section of the American Institute of Electrical Engineers, March 16th.

Stereophonic Records

H. E. Roys and R. C. Moyer. Bell Telephone Managers' Club, Indianapolis, March 7th.

ELECTRON TUBE DIVISION

Harrison, N. J.

An X-Band Periodic-Focused Traveling-Wave Limiter Chain

R. McMurrough, W. J. Caton, and G. Novak. AIEE Winter Gen'l Mtg., New York City, Feb. 1-5th. Operation of two RCA developmental traveling wave tubes in limiter applications over the 8000- to 12,000-megacycle band.

Suppression and Limiting of Undesired Signals in Traveling-Wave-Tube Amplifiers

H. J. Wolkstein. AIEE Winter Gen'l Mtg., New York City, Feb. 1-5th. Performance of traveling-wave tubes in the presence of multiple signals of various frequencies and strengths within the passband, and the progress obtained in the use of traveling-wave tubes as limiters to provide nearly constant power output over a wide range of signal power level and frequency.

Lancaster, Pa.

Multiplier Phototube Development Program At RCA-Lancaster

R. W. Engstrom and R. M. Matheson. 7th Scintillation Counter Symposium, Philadelphia, Feb. 25-26th. The many-phased development program carried on in Lancaster to provide special and improved multiplier phototubes for a variety of applications, emphasizing improved pulse-height-resolution tests and ruggedization techniques.

Image Intensifiers for Nuclear Track Imaging

R. G. Stoudenheimer, J. C. Moor, and H. L. Palmer. 7th Scintillation Counter Symposium, Philadelphia, Feb. 25-26th. The development of two- and three-stage cascaded image converter tubes having sufficiently high gain and low threshold detectivity to permit the photographing of the tracks of nuclear particles in scintillation chambers.

Princeton, N. J.

A Modulation-Demodulation Scheme for Ultra-High-Speed Computing and Wide-Band Amplification

F. Sterzer and W. Eckhardt. Solid-State Circuits Conf., Philadelphia, Feb. 10-12th. Method for modulation of rf power by means of variable-impedance modulators.

SEMICONDUCTOR AND MATERIALS DIVISION

Somerville, N. J.

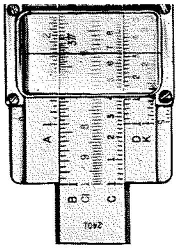
The Effects of Transformer Parameters on Surge-Voltage Transients in Rectifier Circuits

P. E. Kolk. AIEE Winter Gen'l Mtg., New York City, Feb. 1-5th. Transformer surge-voltage transients in rectifier circuits and corrective networks when critical damping criteria are applied.

The Tunnel Diode—A Promising New Semiconductor Device

E. O. Johnson. IRE/AIEE Student Branch Mtg., Pratt Institute, Feb. 4th. Theory of operation of tunnel diodes as well as selection of materials, manufacturing considerations, and possible applications.

Engineering NEWS *and* HIGHLIGHTS



FIRST ANNUAL SC&M ENGINEERING ACHIEVEMENT AWARDS

The Semiconductor and Materials Division has announced the winners (right) of their first annual *Engineering Achievement Awards.* The awards will be presented annually to as many as five engineers engaged in a technical phase of the Company's business. It is planned that the announcement of future awards will be made during *National Engineers' Week.*

Candidates for the awards are nominated by their managers, using such criteria as technical innovations, process improvement, cost reduction, customer acceptance, quality assurance, and "bottleneck-breaking." All engineering personnel within the Division are eligible to participate if engaged in a technical phase of the Company's business for at least nine months during that year in a nonsupervisory capacity.

David H. Wells, Findlay, Ohio, a Production Engineer at the Findlay plant. He is a graduate of Tufts College and joined RCA in 1952.

Martin H. Dempsey, New Brunswick, New Jersey, is an Associate Engineer at the Somerville plant. He is a graduate of Newark College of Engineering and joined RCA in 1958.

Richard A. Santilli, Somerville, New Jersey, is an Engineering Leader at the Somerville plant. He is a graduate of Penn State and joined RCA in 1957.

Frederick B. Smith, Berkeley Heights, New Jersey, is a Field Engineer at Somerville. He is a graduate of Hofstra College and joined RCA in 1952.

Nelson H. Savoie, Tewksbury, Massachusetts, is a member of the Technical Staff at the Needham plant. He is a graduate of Northeastern University and joined RCA in 1957.

RCA MANUFACTURING MAGNETIC TAPE

RCA has entered the magnetic-tape manufacturing field and is producing tape for commercial, professional and home recording use at a new Indianapolis plant of the RCA Victor Record Division. Already in operation, the Indianapolis plant will produce two billion feet of tape during its first year, according to **A. L. McClay,** General Plant Manager, Manufacturing, for the Division. Magnetic tape previously was purchased from outside sources for producing both RCA Victor records and prerecorded tape, and for sale in blank form.

Blank tapes for professional, broadcasting, industrial and home use are marketed by the Distributor Products organization of the RCA Electron Tube Division. Sales of these products currently are made through electronics and photographic distributors. Prerecorded tape is marketed by the RCA Victor Record Division.

Initially, the Indianapolis plant will concentrate on the manufacture of audio tape. Later, it will turn out magnetic tape for use in electronic data processing systems and television tape recorders.

NEW RCA SERVICE CO. EDP TRAINING CENTER

Construction of a modern two-story building has been started at Cherry Hill, N. J., especially designed for the training of engineers, technicians, programmers, sales, and other personnel in RCA electronic data processing systems. The Electronic Data Processing Services Dept. of the RCA Service Company will utilize the 70,000 sq. ft. structure, planned for late-1960 completion.

Personnel trained there will join RCA Service Company administrative and technical personnel currently responsible for installing and maintaining EDP equipment, and for services at RCA Data Processing Centers in various cities.

The Electronic Data Processing Services Dept. was established in 1959, with **Leonard S. Holstad** as Vice President in charge of the activity. In addition to installation and maintenance work, the department is responsible for the marketing of data processing services available at the RCA centers.

239 GRADUATED BY RCA INSTITUTES

A class of 239 students was graduated by RCA Institutes on May 19, 1960. The graduates, 34 percent of whom are war veterans, include students from Greece, Germany, India, British West Indies, Italy, Canada, Brazil and Vietnam.

LEAS NAMED OUTSTANDING OHIO ST. ALUMNUS OF 1960; DR. BROWN KEYNOTES CEREMONY

J. Wesley Leas, Chief Engineer of RCA's Electronic Data Processing Division, has been selected as the recipient of the "Texnikoi Outstanding Alumnus Award," designating him as the outstanding Ohio State University Engineering alumnus of the year. This award was made to Mr. Leas for his *outstanding achievements in the field of engineering as well as his general civic activities,* by Texnikoi, an honorary scholastic fraternity in the College of Engineering at Ohio State University. This took place in ceremonies at the University on May 6, at which **Dr. George H. Brown,** Vice President, Engineering, (whose son is a senior engineering student there), delivered the keynote address entitled, "The Bare Bones of Science."

Mr. Leas' distinguished career began when he graduated from Ohio State University in 1938 with a BSEE degree. After some sales-engineering work, he entered the military service in 1941 and was a Staff Member of the Tele-communications Research Establishment (the RAF Radar Laboratory) in England. Returning to the United States, Mr. Leas became Assistant Head for Engineering of the Combined Research Group at the Naval Research Laboratory in Washington, D. C.

He left active duty as a Lt. Colonel and was appointed Airborne Radar Chief of the Airborne Instruments Laboratory in Nineola, New York. While there, and later as a member of the Technical Staff of the Air Navigation Department Board in Washington, D. C., he served as Technical Advisor to numerous federal agencies concerned with air navigation and traffic control.

Since coming to RCA in 1951, Mr. Leas has organized the Electronic Data Processing Engineering Activity, developing it from a small nucleus to a present group of over 500 engineers and scientists. Currently an Advisor to the Department of Defense on Electronic Data Processing, he has served on a four-man Advisory Group on Computers to the Assistant Secretary of Defense, Research and Development.

Mr. Leas has also participated in many professional activities, is a Senior Member of the IRE, and has recently been elected to a 3-year term on the Administrative Committee of the IRE Professional Group on Engineering Management. He is a member of Eta Kappa Nu, Kappa Kappa Psi, and Sphinx (senior men's honorary of Ohio State).

NATION'S FIRST ADVANCED STYLING AND ENGINEERING CENTERS FOR HOME INSTRUMENTS

The nation's first advanced styling and engineering centers for TV sets, stereophonic phonographs, and other home instruments are being set up by RCA to develop new concepts for models as far ahead as 1970. The RCA Advanced Styling Center will be established late this year, while the Advanced Engineering Center is already operating at the RCA Laboratories in Princeton, N. J.

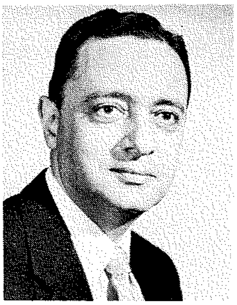
The purpose of the Advanced Styling Center will be radical experimentation which can eventually be incorporated into the whole range of home instruments. In developing the program, a small group of front-rank industrial designers have been brought together to oversee and evaluate developments in the world of art, interior decorating, fashion, and furniture.

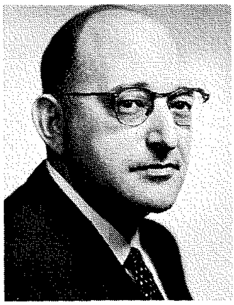
Just as the Styling Center will concentrate on improving the outside of home instruments, the Engineering Center is focusing on improving the inside. It is working on technological advances that can be incorporated into products three or more years in the future.

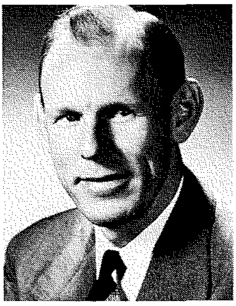
J. W. Leas


C. H. Colledge


J. J. Graham


B. Kreuzer


S. N. Lev


C. E. Burnett


J. B. Farese


R. L. Yorke

SEVEN DIVISION VICE PRESIDENTS APPOINTED

In announcing seven new Division Vice Presidents, John L. Burns, President of RCA, stated, "In the past few years, the expansion of the electronics industry into new fields has brought about a steady growth of many of RCA's activities. With this growth, there has been active interest in giving proper recognition and status to persons holding the increasing number of responsible positions in RCA. As a result, we have adopted a policy which provides for the appointment of Division Vice Presidents in RCA's operating organizations. . .".

Those named to the new posts are: **Charles H. Colledge,** Division Vice President and General Manager, Broadcast and Television Equipment Division, IEP, Camden, N. J.; **J. J. Graham,** Division Vice President and General Manager, Communications and Industrial Electronic Products Operations Division, IEP, Camden, N. J.; **Barton Kreuzer,** Division Vice President and General Manager, Astro-Electronics Products Division, Princeton, N. J.; **S. N. Lev,** Division Vice President and General Manager, Missile and Surface Radar Division, DEP, Moorestown, N. J.; **C. E. Burnett,** Division Vice President, Industrial Tube Products Department, Electron Tube Division, Lancaster, Pa.; **J. B. Farese,** Division Vice President, Entertainment Tube Products Department, Electron Tube Division, Harrison, N. J.; **Robert L. Yorke,** Division Vice President, Commercial Records Creation Department, RCA Victor Record Division, New York City.

Mr. Colledge joined the National Broadcasting Company in 1933. He held positions of increasing responsibility in production and engineering, and in 1956 became Vice President, Facilities Operations. Two years later, he was appointed General Manager of the IEP Broadcast and Television Equipment Division. He was educated at Columbia University, Newark College of Engineering, and Massachusetts Institute of Technology. During World War II, he served as a Lieutenant Commander in the United States Navy.

Mr. Graham held the positions of Manager, Manufacturing Engineering Administration, Controller of RCA's former Commercial Electronic Products Unit, and Manager, Operations Administration, before being appointed in December, 1958, to the position of General Manager, Communications and Industrial Electronic Products Operations Division. He attended the University of Pennsylvania and later completed the Advanced Management Program at Harvard.

Mr. Kreuzer became associated with RCA in 1928, following his graduation as an electrical engineer from the Polytechnic Institute of Brooklyn. He entered sales activities in the motion-picture equipment field in 1935, and was named in 1941 National Sales Manager for RCA's motion picture equipment. From 1946 to 1954, he served successively as Manager, RCA Theatre Equipment, and Marketing Manager, RCA Theatre and Industrial Equipment Department. From 1954 to 1958, he was Director, Product Planning, and since 1958 he has been Manager, Marketing, of the Astro-Electronic Products Division.

Mr. Lev holds a Master of Science degree in Electrical Engineering from the University of Pennsylvania. He joined RCA in 1934, and has had wide experience in the plant management, production and administrative fields. In 1948, he won the *RCA Victor Award of Merit* for establishment of the first mass-production television receiver plant in the United States. Since October, 1959, he has served as General Manager of the Moorestown Missile and Surface Radar Division.

Mr. Burnett has been active in tube production at RCA since 1933, when he became an engineer on cathode-ray circuits. He was advanced to Engineering Supervisor in 1940, and later held important positions in tube manufacturing and sales. Since 1957, he has been Manager of Industrial Tube Products. Mr. Burnett received a B.S. Degree in Electrical Engineering from Southern Methodist University, and a Master of Science degree from Massachusetts Institute of Technology.

Mr. Farese joined RCA in 1930 as Office Manager of Accounting for Engineering, and in 1935 he became Supervisor of General Accounting. In 1947, he was named Assistant to the Controller; in 1953, Manager of Manufacturing of the Electron Tube Division; in 1956, Manager of Personnel, and in 1957, Manager, Entertainment Tube Products Department. Mr. Farese completed the Advanced Management Program conducted by the Harvard Business School.

Mr. Yorke, a graduate of the University of Michigan, joined RCA in 1947. He has held positions of increasing responsibility in many phases of the RCA Victor Record Divisions' operation, including field sales, planning and promotion, artist and repertoire, and establishment of RCA Victor's present West Coast activity. Since January of this year, he has been in charge of the Commercial Records Creation Department.

ELECTRONICS PROGRAM INITIATED IN ITALY

An international development program has been launched for the creation in Southern Italy of an electronics manufacturing complex.

In an agreement of unprecedented scope between a European state agency and private industry of another nation, the Istituto per la Ricostruzione Industriale (I.R.I.) has secured the assistance of RCA International, Ltd., of Montreal, to direct the project, drawing on the services and facilities of the various subsidiaries and affiliated companies of RCA.

The initial phase is expected to involve the gradual investment in several projects by the Italian group of some $25,000,000, which will be utilized to expand existing facilities and build new ones in the manufacture of tube, semiconductors and other components. Subsequently the program is intended to encompass other fields of electronics. Italian personnel will be trained in electronics in RCA schools to be established. The creation of a research laboratory and establishment of training facilities similar to RCA Institutes are also contemplated.

IEP FORMS NEW ELECTRONIC RECORDING DEPARTMENT

A new Electronic Recording Products Department has been formed to meet the growing needs for magnetic-tape-recording devices in TV broadcasting, business-data processing, remote-control telemetering, and the space program.

The new unit, falling under IEP's Broadcast and TV Equipment Division, will be headed by **M. A. Trainer,** who joined RCA in 1930 and has played an important role in the development leading to all-electronic television.

Heading the Department's engineering activity is **A. H. Lind,** who has specialized in studio TV and audio equipment since coming to RCA in 1946.

J. R. BEJARANO ELECTED PRESIDENT OF RCA INTERNATIONAL, LTD.

Jose R. Bejarano, for many years an executive and leader in the electrical equipment industry in Brazil, has been elected President of RCA International, Ltd., of Montreal. Born in Mexico, he is a United States citizen and a graduate of Columbia University, holding a BSEE and MSEE-Phys.

MONTREAL ENGINEERING FACILITIES EXPAND

Expanded Research Facilities, a new Environmental Laboratory, and Transistor Plant were the subject of an exposition held at the RCA Victor plant in Montreal on April 22nd.

REGISTERED PROFESSIONAL ENGINEERS

Richard W. Cox, Electron Tube Division	Prof. Eng., 6212-E, Pa.
David O. Price, Electron Tube Division	Prof. Eng., 6203-E, Pa.
Frederick W. Brill, Electron Tube Division	Prof. Eng., 6673-E, Pa.
James S. Class, Electron Tube Division	Prof. Eng., 6583-E, Pa.
Frank T. Kay, Home Instruments	Prof. Eng., 11053, N. J.

ELECTRON TUBE DIVISION HOLDS ENGINEERING MANAGEMENT SEMINARS

Over 240 members of Engineering Management in the RCA Electron Tube Division have just completed a series of three Engineering Management Seminars organized by the Division's Organization Development and Training functions, the Chief Engineer, and local Personnel and Engineering representatives. All levels of Engineering Management, from Leaders up, in the Division's Product Development, Equipment Development, Quality Control, and Manufacturing Engineering activities participated.

Engineering Management Seminar I dealt with *Economic Aspects of RCA's Role in the Electronics Industry*. The Seminar further pinpointed the extensive responsibility of Engineers and Engineering Managers in the realization of the Company's over-all objectives. Prominent roles were played in this Seminar by **C. R. Johnston,** Manager, Marketing Research, RCA Staff; **H. W. Leverenz,** Director, Research, RCA Laboratories; **Dr. G. R. Shaw,** Chief Engineer, Electron Tube Division; and **D. Y. Smith,** Vice President and General Manager, Electron Tube Division.

Leadership was the subject of Seminar II, which was devoted to the recognition and application of leadership skills. Through lectures, discussion groups, and role-playing demonstrations, the participants gained insight into individual and group behavior, motivation, and other important aspects of the human relations complex. Stress was placed on the basic managerial responsibilities of developing and motivating subordinates toward greater achievement to insure the accomplishment of Company goals. Some of the principal speakers from the RCA staff for this program were: **J. M. Cook,** Administrator, Personnel Research; **P. C. Farbo,** Manager, Professional Personnel Programs; **R. F. Maddocks,** Administrator, Training; **J. L. Mastran,** Manager, Organization Planning and Management Development; and **D. F. Schmit,** Vice President, Product Engineering.

Engineering Management Seminar III was devoted to *Professional Employee Relations*. This program gave a comprehensive coverage of compensation and evaluation policies at the local, divisional, corporate, and industry levels. Various aspects of Professional Employee Relations were discussed by **G. H. Brown,** Vice President, Engineering; **D. H. Ewing,** Vice President, Research and Engineering; and **C. M. Sinnett,** Director, Product Engineering Professional Development —all of RCA Staff; and **L. A. Kameen,** Manager, Personnel, Electron Tube Division.

B. J. Haley, Manager, Organization Development and Training for the Electron Tube Division, developed and coordinated the program. Others assisting from the Division were **Dr. G. R. Shaw,** Chief Engineer; all Product Operations Engineering Managers; and **J. F. Hirlinger,** Administrator, Technical Personnel Programs.

COMMITTEE APPOINTMENTS

LANCASTER, PA.

Harry B. Walton, Tube Parts Manufacturing, was recently made Secretary to the Boys' Work Committee of the Lancaster YMCA. **H. J. Werntz,** Life Test and Data Engineer, has been elected vice-president of the Franklin & Marshall College Chapter of Sigma Pi Sigma, National Physics Honor Society.—*H. S. Lovatt*

MARION, OHIO

T. J. Morris, B & W Kinescope Engineering, was recently elected as President of the Industrial Management Club. Leo Whitcomb, Manager Electrical design, Equipment development group appointed as 2nd Vice-President. The Marion branch has 260 members and sponsors plant tours, educational programs, industrial expositions, and is active in setting up Purdue Management Conferences.

The Marion Plant Engineering Education Committee has recently appointed **J. C. Dobie,** Manager of Parts Plant Engineering as Committee Chairman. The committee for the next year includes **C. T. Lattimer, C. W. Thierfelder, L. F. Hopen, J. F. Stewart, A. N. Brooks, B. F. Miller, J. A. Collins, R. J. Conrad,** and **D. J. Ransom.** Monthly seminars are being planned for presentation to the engineering group, as well as several plant tours.—*J. DeGraad*

ENGINEERS IN NEW POSTS

In the RCA Service Co., **H. Reese, Jr.,** has been appointed to the newly created position of Mgr., Nuclear and Scientific Services. At Cape Canaveral, Fla., **G. D. Clark** has been named Mgr., RCA Missile Test Project.

In the M and SR Div., DEP, Moorestown, **L. J. Ortino** has been named Mgr., Mechanical Development and Design. Also for that Division, **R. H. Baker** has been named Mgr. for BMEWS in the United Kingdom, for implementation of the third BMEWS site at Flyingdale Moor, Yorkshire, England.

In the SC and M Division, **W. H. Wright** has been named Plant Mgr. of the new transistor and rectifier plant being erected at Mountaintop, Pa. **L. H. Urdang** has been named Mgr., Quality Control, for that plant. For the entire SC and M Division, **A. M. Okun** has been named Mgr., Product Assurance.

In Microwave Production Engineering, Electron Tube Division, **E. Goldman** will head production engineering on traveling wave tubes, **B. Halpern** will head production engineering on magnetrons, and **G. Suminski** will head production engineering on parts and materials.

Within IEP, **J. P. Taylor** has been appointed to the new post of Mgr., Marketing Administration, for the Broadcast and TV Equipment Division.

MEETINGS, COURSES AND SEMINARS

Electron Microscope Demonstration

The latest model EMU-3F RCA Electron Microscope was recently installed and demonstrated for the International Congress of Anatomists Convention held in New York City, April 11 to 14. Messrs. **H. W. Taylor, A. R. Klotzbach,** and **A. P. Vees,** RCA Service Company Electron Microscope specialists, made the installation.—*E. Stanko*

Microwave Refresher Course

A mobile microwave refresher course was recently made available to the field service representatives of the RCA Service Company by **R. M. Dombrosky,** Administrator for the Mobile-Microwave Activity of Technical Products Division. This information was developed especially to bring up the standard of service methods and procedures and to assist new employees in learning the best service methods.

—*E. Stanko*

TV Activities at SMPTE

At the SMPTE Convention in Los Angeles, May 1-7, RCA exhibited TV Tape equipment, the new TK-12 Camera, the TK-15 vidicon camera, the TS40 transistorized switching equip. special effects equipment, TV tape editing equip., and audio and film recording. A number of papers were also given (see *Pen and Podium*, this issue and next issue).—*J. H. Roe.*

Video Tape Editing

As representative from the West Coast Closed Circuit Television Systems Engineering and Film Recording, **J. J. Askins** is attending an 18 week course in Video Tape Editing at the University of Southern California. The course is being given under joint sponsorship of SMPTE and the Motion Picture Film Editors Local #776 IATSE.—*C. E. Hittle*

Engineering Courses at Indianapolis

"Fundamental Theory and Application of Semi-Conductors" is being taught by **Eugene Montoya,** Test Design Engineer for the Indianapolis Television-Components Plant. It is sponsored by the Training Group and attended by Engineers and Engineering Assistants of the Indianapolis Tube and Record Plants.

Norbert Drilling and **James Osman** are studying for their master's degree by attending evening courses given by the Purdue Graduate School.—*J. Osman.*

DEGREES GRANTED

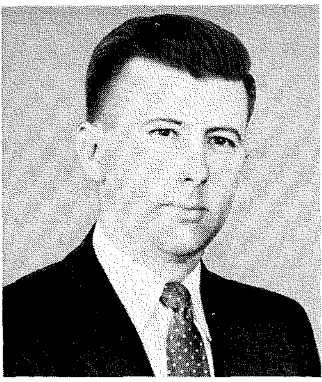
In Home Instruments, Cherry Hill, **L. A. Harwood** has received his MSEE from the University of Pennsylvania. In the Airborne Systems Division, DEP, Camden, **D. Roda** has received his MBA from Temple University and **M. Koenig** his MSEE from the University of Pennsylvania.

LANCASTER EMPLOYEES HONORED

P. O. Damon (right) of Camera, Oscillograph, and Storage Tube Engineering, a member of the Franklin and Marshall Chapter of Sigma Pi Sigma, Honorary Physics Society, congratulates four newly elected members: (left to right): H. J. Werntz of Engineering Services, J. K. Peifer of Phototube Engineering, P. P. Hatzikyriakos of Silicon Rectifier Engineering, and J. A. Eshleman of Super Power Tube Engineering. All are taking evening work at the College, under the RCA Tuition Loan and Refund Plan. Eshleman is studying for a Bachelor's Degree, while the other three are working for a Master's, all in Physics.


E. I. Small


The Ass't Editor and H. J. Russell (right)


J. J. Lawler


M. C. Kidd

FOUR NEW ED REPS NAMED FOR MONTREAL, NEEDHAM, NATICK, AND CHERRY HILL

At the Needham Materials Operation of the Semiconductor and Materials Division, **Edward I. Small** has replaced **L. A. Wood** as RCA Engineer Editorial Representative. The other three appointments are new additions to RCA Engineer activities. **H. John Russell** will represent RCA Victor, Ltd. in Montreal, Canada, where RCA engineers and scientists will now receive the RCA Engineer. **John J. Lawler** has been named Editorial Representative for the new Electronic Data Processing Service Dept. of the RCA Service Co. in Cherry Hill, N. J. **Marshall C. Kidd** has been named Editorial Representative for the new Industrial Computer Systems Dept., Electronic Data Processing Division, IEP, Natick, Mass.

Edward I. Small received his BSME Degree from the University of Maryland in 1948. His first work after graduation was in research and development with the Anthracite Institute of Wilkes Barre, Pennsylvania. While there, he developed and obtained patents for several devices in the fields of ash removal and stoker feed systems, and continuous extrusion processes. After four years with the Institute and before coming to RCA, Mr. Small was employed with other companies, with responsibilities in the mechanical engineering field, among which were two years as Chief Mechanical Engineer with the Motor Division, Holtzer Cabot-National Pneumatic Co. in Boston.

In May, 1959, he joined the Materials Engineering activity of the Needham Materials Operation, Semiconductor and Materials Division, responsible for the mechanical design of magnetic assemblies.

H. J. Russell studied electrical engineering at Battersea Polytechnic, London, afterwards joining Marconi's Wireless Telegraph Co., Ltd., where he spent eight years in the design and development of ground and airborne communication equipment. He was then transferred to the Research Department where he worked on facsimile transmission over long HF circuits and the development of equipment for recording on steel wire and tape.

His next appointment in the Marconi Company was to plan and develop the technical organization and equipment of Egyptian State Broadcasting in Cairo, Egypt, later becoming Engineer-in-Chief of this organization, a post he held until 1944. During the war years he planned and carried out a number of technical projects for the British Middle East Forces, being awarded a mention in dispatches for distinguished service. The last two years of the war were spent in South East Asia as Technical Advisor to South East Asia Command on secondment to the British Foreign Office, where the work consisted of planning and supervising the build-up of tele-communication systems in liberated countries.

After the war, Mr. Russell was sent to Egypt to organize a Middle East office for the Marconi Company and act as technical representative. On completion of this assignment in 1949, he was appointed technical consultant to the Brazilian Marconi Company in Rio de Janeiro where he reorganized the technical facilities. In 1952, he was seconded by Marconi's Wireless Telegraph Co. Ltd. to the British Commonwealth Relations Office for three years to act as Chief Technical Advisor to the Ceylon Government in reorganizing and re-equipping Radio Ceylon. He was transferred to the Canadian Marconi Company in Montreal in 1955 to organize and build up international export of their products.

He joined RCA Victor, Ltd. in 1957 as Manager of Administration, Defense Systems Division. Mr. Russell is an Associate of the Institute of Electrical Engineers and the Engineering Institute of Canada.

John J. Lawler received the BS in EE degree from the University of Massachusetts in 1950 at which time he joined the RCA Service Company as a Field Engineer. He was engaged in part time graduate work at Syracuse University in 1952 and returned to the University of Massachusetts in 1953 receiving the MS in EE in 1954. He then returned to the RCA Service Company's Computing System Service Section where he worked as an engineer and as Manager of Engineering and Training. Mr. Lawler is now Manager of Engineering in the Electronic Data Processing Service Department. He is a member of IRE and a Registered Professional Engineer.

Marshall C. Kidd received the B.Ch.E. degree from Ohio State University in 1944. From 1944 to 1945 he was associated with Bakelite Corporation in Bound Brook, New Jersey. In 1945 he joined the Allen B. DuMont Laboratories in Passaic, N. J., where he worked with cathode-ray tubes. In 1946 he returned to Ohio State University and received the B.E.E. degree in 1948. He joined the Advanced Development Section of the RCA Victor Television Division in 1948.

He has developed transistor circuits, including digital circuits, and precision measuring equipment for transients and phase in the audio-video range. His experience includes transducer development and design of magnetic recording equipment. He also developed a subscription television system using digital coding for security and has worked on digital communications equipment. He is now Leader, Design and Development Engineering, in the new Industrial Computer Systems Dept., Electronic Data Processing Division, IEP, Natick, Mass.

Mr. Kidd is the author of a number of technical papers on transistors and digital circuits. He holds six U. S. Patents and is a senior members of the IRE.

ENGINEERING MEETINGS AND CONVENTIONS

JULY 28-29
7th Annual Symposium on Computers and Data Processing, Denver Research Institute, Stanley Hotel, Estes Park, Colo.

AUGUST 1-3
4th Global Communications Symposium (PGCS: U. S. SIGNAL CORPS), Statler Hotel, Washington, D.C.

AUGUST 6-9
National Audio-Visual Convention, Morrison Hotel, Chicago.

AUGUST 8-12
1960 Pacific General Mtg. (AIEE), El Cortes Hotel, San Diego, Calif.

AUGUST 23-26
WESCON, Ambassador Hotel, Memorial Sports Arena, Los Angeles, Calif.

AUGUST 29-SEPTEMBER 3
International Information Theory Meeting (PGIT-IEE), London, England

SEPTEMBER 1-3
Society for Industrial and Applied Mathematics, Summer Meeting, East Lansing, Michigan

SEPTEMBER 6-8
Joint Automatic Control Conf. (IRE-PGAC: ASME: ISA: AIEE: AIChE), M.I.T., Cambridge, Mass.

SEPTEMBER 15-16
8th Annual Engineering Management Conf. (PGEM: AIChE: ASME: ASCE: AIEE: AIIE), Morrison Hotel, Chicago

SEPTEMBER 10
American Society for Quality Control, Rutgers Conf., New Brunswick, N. J.

SEPTEMBER 19-22
National Symposium on Space Electronics & Telemetry (PGSET), Shoreham Hotel, Washington, D.C.

SEPTEMBER 21-22
Industrial Electronics Symposium (PGIE: AIEE), Sheraton-Cleveland, Cleveland, Ohio.

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